Archaeometallurgy in Sardinia

Monographies *instrumentum*
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Collection dirigée par
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Archaeometallurgy in Sardinia

from the origins to the beginning of the Early Iron Age

edited by

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Presentation

This volume is a revised and corrected version of the Italian and English prototypes edited by Ulrico Sanna, Roberto Valera and Fulvia Lo Schiavo, originally set up by CUEC Editrice, Cagliari, (maquette by Tatiana Cossu) and presented at the Workshop "ARCHAEOMETALLURGY IN SARDINIA: from the origins to the beginning of Early Iron Age", September 9th-10th, 2004. The original project was financed by Consiglio Nazionale delle Ricerche, Progetto Finalizzato Beni Culturali.

The workshop was organized by the Prof. U. Sanna, Department of Chemical and Materials Engineering - University of Cagliari, Prof. R.Valera, Department of Geoengineering and Environmental Technologies - University of Cagliari, and Fulvia Lo Schiavo, Institut of Studies on Aegean and Near Eastern Civilisations - National Council of Research, with the contribution of the Associazione Italiana di Metallurgia, the Associazione per l'Università del Sulcis – Iglesiente, and Prof. M. Cavallini, University "La Sapienza" Roma, Prof. G.L. Garagnani, University of Ferrara, A. Giumlia-Mair, AGM Archeoanalisi, Merano (BZ), O. Lecis, President of AIM, Prof. W. Nicodemi, University (Politecnico) of Milan, and past-president of AIM.

The prototype and the attached CD-ROM, were also presented in Milan, at the International Workshop "*Archaeometallurgy in Europe*", September 24th-26th, 2003.

The volume was critically commented by the specialists invited to the workshop and was revised and corrected by authors and editors, after discussing the different aspects of prehistoric metallurgy on Sardinia over a time span of 3000 years, and the interconnections Sardinia had during this period with other European and Mediterranean cultures.

The Italian version is going to be published in the near future in Cagliari.

The Editors of the present English edition are Fulvia Lo Schiavo, Alessandra Giumlia-Mair, Ulrico Sanna and Roberto Valera. The papers reflect the Authors' ideas. The editors do not always share their opinions and are not responsible for the translations into English.

Fulvia Lo Schiavo,
Alessandra Giumlia-Mair,
Ulrico Sanna, Roberto Valera.

Foreword

This work represents one step along the research path on archaeometallurgy in Sardinia which commenced more than fifteen years ago. It contains the results obtained during the five-year Cultural Heritage project funded by the Italian Research Council (CNR), specifically concerned with the provenance of raw materials and the metal working techniques in Sardinia in pre- and protohistoric ages.

This multidisciplinary research effort has involved a team of experts who contributed to this book and to the multimedia CD-Rom edition, combining their expertise in a variety of fields. Thus, archaeologists, geologists and materials scientists joined forces in this unusual experience which provided a forum for a fruitful and spirited exchange of ideas and information.

A study of a small number of finds housed in the Villanovaforru Museum laid the cornerstone for archaeometallurgical studies in Sardinia. A grant awarded by the Credito Industriale Sardo to the then fresh graduate Cirillo Atzeni (who authored the chapter on ancient metallurgy and co-authored the one on archaeometric investigations), and the invaluable collaboration of the museum curator Ubaldo Badas, made it possible to carry out this first research project.

This study has been an opportunity for our research team to apply the knowledge and the methods developed for other kinds of materials in the investigation of archaeological finds.

On this occasion were also laid the foundations for a cooperation with experts of profoundly different disciplines and for perfecting a common working method and ultimately produce better results.

The CNR Target Project cultural heritage (1996-2001) provided the opportunity to carry out a systematic investigation and to address new issues, especially those concerned with the interrelations of pre-nuragic and nuragic Sardinia with the contemporary civilizations of the Eastern and Western Mediterranean.

The investigation of such a large number of archaeological finds was made possible by the helpfulness and always fruitful cooperation of the two Archaeological Services operating in Sardinia.

Given the roughly three thousand year time span considered and the evolution of metal working during this period, a wide variety of archaeological finds had to be examined, ranging from copper to arsenical copper to the more common tin-copper alloys to lead, silver and gold, not forgetting the minerals, the different ceramic artefacts, associated with metal working techniques, and fragments of the very few pieces of slag found. Particular attention was focused on objects recovered from hypothetical smelting sites.

As already mentioned, this work is only the beginning of a certainly long research, and, hopefully, it will be useful for experts working in this field. The research results have elucidated certain aspects of archaeometallurgy in Sardinia, however very many significant problems remain unsolved. For the moment the lack of essential information renders impossible any exhaustive answer to these questions, one example being the scant information about mining and smelting activities in the pre-nuragic and nuragic ages.

Concerning the editorial format, it was decided to dare and take advantage of the variety of communication tools available today, which meant paying special attention to the new forms of communication.

The attached CD-Rom is in fact produced so as to be consulted by means of the well-established navigation system borrowed from the web.

In the hard copy, which is available in both Italian and English, the topics are introduced in logical sequence, the first part describing the fundamentals of ancient metal working, the second devoted to aspects of Sardinian geology and mineral deposits. The third part concerns the investigations on more than 260 finds, divided into different groups, while the fourth and last part systematically presents the archaeological frame.

The fourth part, followed by the conclusions, documents all finds inventoried to date and demonstrates both the variety and large numbers of artefacts and technologies, these civilizations passed down through the ages.

If we compare the number of finds analyzed up to day with the actual number of finds, we can get an idea of how much work still needs to be done. Nevertheless we are confident, that the general outline of Sardinian archaeometallurgy has now been defined and, on this basis, we are able to give a priority to future research projects, while, of course, the basic premise of our archaeometallurgical research, will remain the interdisciplinary approach.

Ulrico Sanna

PART I

ASPECTS OF ANCIENT METALLURGY

1.

ASPECTS OF ANCIENT METALLURGY

Cirillo Atzeni

Metallurgy of the early civilizations is not a gift from the gods, but the daughter of fire, of man curiosity, of that experimental technique which, long before it was recognized and identified by the savants as being basic to an understanding of nature, was being practised by free or slave craftsmen.

It was the use of minor quantities of metals such as copper, gold and silver occurring in their native form that enabled the first rudimentary experiments to be carried out on metallic substances. The distinctive properties of these materials certainly differed from those of stone, terracotta or materials of plant origin, such as wood, reeds and rushes, or of animal origin such as bones and hides. Presumably heating the metals to extremely high temperatures produced a sufficient quantity of molten metal to be cast and worked into simple shapes, which were then hammered to improve the shape and performance of cutting utensils, such as blades.

In those early days, melting furnaces probably did not differ substantially from the primitive pottery kilns where temperatures of 700-900 °C often proved sufficient. The melting point of silver is 961 °C (of silver alloyed with 10 % copper around 890 °C), gold on the other hand melts at 1063 °C (but gold alloyed with 10 % copper at 940 °C) and copper at 1083 °C (but a copper alloy containing 5 % As melts at 1040 °C, one containing 10 % Sn at 1010 °C). The melting points of lead and tin are far lower, just 327 °C and 232 °C. Anyone who was familiar with pottery firing processes would certainly have been able to attain such temperatures and the materials available at the time – more or less clayey soils and/or stones, would have been suitable for fabricating crucibles and moulds. Presumably the first alloys were discovered in this context of empirical experiments on the metals available at the time, some of which often occurred as alloys in nature. For example, the different colours which can be obtained with the three metals gold, copper and silver may well have lead to the production of the first intentional alloys.

However, the process of extracting metal from ores is conceptually very different from melting or alloying. In general metal extraction required some of the basic components used for melting such as furnaces, charcoal and forced draught. The raw material was no longer native metal but a special kind of "stone", the metal-bearing mineral which bore no resemblance to the metal itself… but in the case of copper-bearing oxidized ores for instance, the ore was associated with the native metal and corrosion of the surface of copper artefacts produced a similar appearance, an attractive green-blue patina. Curiosity and experiments (try, reasoning and try again) did the rest.

The evolution of metallurgy can in general be thought of as the accomplishment of actions and production of artefacts which required increasing energy and complexity and thus spans successive ages. As will be seen in Part III, despite the many gaps, the evolution of metallurgy can be documented throughout its different stages by the prehistoric finds of Sardinia, although only partially documented as a local development. In this chapter we provide a general description, without referring to thermodynamic data (Ellingham 1944) of some elements in order to provide a more comprehensible framework for the archaeometric results presented herein.

1. Native copper

Metals are chemical elements which compared to the other materials available to primitive peoples (stone, wood, bone, terracotta, etc.) had distinctive symbolic (colour, lustre, immutability of gold) and functional/practical features (possibility of large plastic deformation, tenacity, shapeability, etc.). Few metals occur uncombined in nature, the great majority being combined with other chemical elements such as oxygen (oxides) sulphur (sulphides, sulphates) or carbon (carbonates, hydrated carbonates) and their extraction requires high temperature processes in the presence of reducing chemical agents. However, in rare cases metals are found in the pure or native form and of one such metals is copper.

Native copper generally occurs near the earth's surface, in the upper portions of ore veins and is associated with the products of alteration and enrichment of these ores resulting from weathering by atmospheric agents including water, oxygen, carbon dioxide, chlorides, etc. These products are usually carbonates, bright green and blue in colour, which were probably as long ago appreciated as pigments.

Native copper occurs in two forms: as thin, at the most centimetre-sized, arborescent/dendritic forms and as pebbles/nuggets which can easily be distinguished from common stones because of their much higher specific gravity (about 8 g/cm^3 against 2÷3 g/cm^3). These copper nuggets with greenish, bluish or reddish patinas on the surface do not chip or break into pieces when struck with a hammer like other pebbles, but undergo plastic deformation. They can reach remarkable sizes. The Smithsonian Institution's collection in Washington houses a gigantic 99.98 % pure copper nugget weighing some 3 tons. Historically, the natives of North America mined the major occurrences of native copper in the Great Lakes region and in Europe as late as 1862 nuggets weighing as much 15 kg were still being collected in Transsylvania (Tylecote 1987, Crivelli 1953, Selmi 1876).

Native copper was not generally available worldwide, but certain ore bodies presumably contained significant amounts.

Compared to metal extracted from ores by means of metallurgical processes, the metallographic section of native copper reveals grains of fairly large size (in the order of millimetres against a few tens of micrometres), lower porosity, twinned crystals and inclusions, the latter often consisting of fragments of accompanying rocks, for example quartz, and a lower oxygen/oxide content.

Regarding the presence of any other metals as impurities, though it is not easy to generalize, native copper usually contains smaller proportions of arsenic, selenium, antimony, nickel, gold and silver than smelted copper. On the other hand, they contain comparable concentrations of cobalt, zinc, tin and mercury, thus these features are not as distinctive (Tylecote 1987).

It is not easy to establish whether an artefact has been made using the native metal. Working can alter the original microstructural properties of copper, for example cold hammering which may have been followed by heating (annealing) to shape the object and/or to improve hardness for instance for fashioning cutting utensils or the edge of a blade, or even re-melting.

The age, rarity and state of preservation – mineralization of the thinner or outermost portions – of ancient finds believed to be made of native copper constitute further impediments to the removal of adequate samples for conducting complete archaeometric investigations.

2. Copper extracted from oxide ores

Copper oxide ores such as malachite and azurite were known and used in antiquity, because of their bright green and blue colour and their occurrence in near-surface deposits, certainly before the advent of extractive metallurgy. Their association with native copper could not pass unobserved or be considered accidental. The weathered surface of the nodules and arborescent forms and the patinas which formed on artefacts made from these were clearly the same.

In modern terms (Davenport 1986) the following minerals are defined as "oxides":

malachite	$CuCO_3·Cu(OH)_2$	57.5 % Cu
azurite	$2\ CuCO_3·Cu(OH)_2$	55.3 % Cu
cuprite	Cu_2O	88.8 % Cu
tenorite	CuO	79.9 % Cu
chrysocolla	$CuSiO_3·2H_2O$	36.2 % Cu
antlerite	$Cu_3SO_4·(OH)_4$	53.7 % Cu

Upon heating to the relatively low temperatures which can be obtained with a wood fire relying on natural draught (400-500 °C) malachite and azurite are converted into oxide CuO, for example:

$$CuCO_3·Cu(OH)_2(s) \rightarrow 2\ CuO(s) + CO_2(g) + H_2O(g)$$

(s, l and g denote the physical state of chemical species; respectively : solid, liquid or gaseous).

The reduction of the oxides to metal can thus be accomplished in a furnace where the combustion of carbon in forced draught generates, on the one hand, the high temperatures necessary for the process to take place (copper melts at 1083 °C) and on the other, it provides the main reducing agent, carbon monoxide CO (Yazawa 1974):

$$C(s) + 1/2\ O_2(g) \rightarrow CO(g)$$

$$C(s) + O_2(g) \rightarrow CO_2(g)$$

$$CO_2\ (g) + C(s) \rightarrow 2\ CO(g)$$

$$CuO(s) + CO\ (g) \rightarrow Cu\ (l) + CO_2\ (g)$$

It would also be possible to trigger the reduction reaction at relatively low temperatures, lower than the melting point of copper, but in these conditions the efficiency of the entire extraction process, in terms of the ratio between the amount of metal recovered and the amount of copper contained in the furnace charge, would be unsatisfactory. In fact, even though it is reasonable to presume that early metalworkers used copper rich ores, which could be carefully selected given the small amounts involved, the ore inevitably contained some quantities of other material, known as the gangue minerals, which became separated during the process, forming the major constituent of the slag. In order to maximize separation efficiency both the copper and the gangue minerals would have had to be molten so that the metal, which has higher specific gravity and low viscosity than the slag (7÷8 g/cm^3 vs. 3÷4 g/cm^3 and 3÷4 cPoise vs. 500÷2000 cPoise, respectively; water viscosity is around 1 cPoise) could descend by gravity to the lower part of the furnace. This process also requires a suitable residence time to enable the separation process to be completed. More details on slagging operations are provided in the next paragraph.

3. Copper extracted from sulphide ores

The most common copper ores are sulphides. Oxide ores are the result of weathering by atmospheric agents of sulphide veins exposed at the surface. Thus oxide and sulphide ores are usually bordering of the same orebodies and consequently also consecutive terms in the metallurgical development. The most common minerals of this class are:

chalcocite	Cu_2S	79.9 % Cu
covellite	CuS	66.4 % Cu
bornite	Cu_5FeS_4	63.3 % Cu
chalcopyrite	$CuFeS_2$	34.6 % Cu

The most common of these is without doubt chalcopyrite, easily recognizable because of its golden colour. The copper occurring in chalcopyrite is accompanied by significant amounts of iron (30.5 %) and sulphur (34.9 %), which complicates the extraction process. Generally copper sulphides are also accompanied by other sulphides including that of lead, zinc and arsenic and the enclosing rock forms the gangue.

Some archaeo-metallurgical scholars (Sperl 1980, Zwicker 1985) believe that the metallurgical treatment of chalcopyrite was carried out in two stages:

1. ore roasting, during which the sulphides were converted to oxides;

2. smelting of the oxides, similarly to the oxidized ores processing discussed in the previous paragraph.

Numerous experimental reproductions have demonstrated the above process to be feasible. Nowadays the flowsheet for metallurgical processing of chalcopyrite differs substantially, yielding an intermediate product known as "matte", a Cu-rich copper-iron sulphide. The need for this intermediate stage depends on the fact that the copper ores available today are extremely lean. Some researchers also discuss matte processing in an archaeological context.

Once chalcopyrite has been heated to ignition temperature, around 400 °C, in a charcoal or wood furnace, it too starts to burn, because of the sulphur contained therein, generating significant quantities of heat. The main reactions taking place in the roasting process can be schematized as follows:

$$CuFeS_2(s) + 3\ O_2\ (g) \rightarrow CuO(s) + FeO\ (s) + 2\ SO_2(g)$$

$$6\ CuFeS_2(s) + 19\ O2(g) \rightarrow 6\ CuO(s) + 2\ Fe_3O_4(s) + 12\ SO_2(g)$$

$$4\ CuFeS_2(s) + 13\ O_2(g) \rightarrow 4\ CuO(s) + 2\ Fe_2O_3(s) + 8\ SO_2(g)$$

$$4\ CuFeS_2(s) + 7\ O_2(g) \rightarrow 4\ CuS(s) + 2\ Fe_2O_3(s) + 4\ SO_2(g)$$

$$CuFeS_2(s) + 4\ O_2(g) \rightarrow CuSO_4(s) + FeSO_4(s)$$

The sulphates which form during roasting in turn decompose to oxides at around 800÷900 °C.

Roasting can be carried out in open fires in pits or surrounded by low stone walls with natural circulation of air. During this process the mineral loses its original colour, turning reddish or blackish due to the presence of oxides. The sulphur dioxide, SO_2, emitted in the fumes with its suffocating smell, is no doubt the most inconvenient and dangerous result of the roasting operation not only for the metalworkers but also in terms of environmental contamination.

The product of the roasting process can then be fed to the smelting furnace where the iron oxides combine preferably with the silica, to form the main constituents of the slag, the remaining copper sulphide may react with the copper oxide, producing metallic copper and sulphur dioxide and the copper oxide can also directly be reduced to copper metal by the action of the carbon monoxide (Yazawa 1974).

Needless to say the reactions described above do not account for the other numerous chemical, mineralogical and physical transformations that the ore charge undergoes during roasting and smelting. As mentioned before, despite careful hand sorting of the ore to be treated and its high Cu content, the ore charge placed in the furnace inevitably contained other metallic minerals as well as gangue. The amount of gangue minerals contained in the ore was likely to have increased over time once the Cu-rich deposits had been depleted and ancient miners traced the copper veins underground. In order to separate the gangue from the metal, this waste material needs to be combined so as to form a sufficiently fluid molten slag. This can be achieved by adding flux to the furnace in amounts which could also be empirically determined. Fluxes such as iron or manganese ores and quartz rocks were all readily available in antiquity but primitive metalworkers might also have used bones (which supply phosporous), limestone (calcium) or ash (potassium, sodium). Iron-calcic slag generally tends to be more fusible and fluid than slag containing iron alone.

If the slagging process is incomplete, then the metal produced will not separate entirely from the gangue with which it is genetically associated, resulting in poor metal recoveries.

The slag produced by metallurgical processing of copper is composed primarily of silicates, *i.e.* silica, SiO_2, combined with metallic oxides like for example FeO, Fe_2O_3, CaO. Fortunately, the copper oxides show a low chemical affinity for silica. Any copper oxides or metallic copper reporting in the slag are usually physically trapped or enclosed therein. The ("acid") silica-to- ("basic") metallic oxides ratio varies, and for this reason the composition of ancient slag cannot always be fully determined in stoichiometric terms nor is its mineralogy easy to characterize (Stiavelli, 1937-a). The major crystalline component is often fayalite $(FeO)_2{\cdot}SiO_2$.

Slag is often very heterogeneous and appears to have solidified from the pasty state rather than from a molten mass. The material is blackish in colour, shiny and, when exposed, the interior shows a bubbly texture. Specific gravity is relatively high due to the presence of iron. Along with the crystalline and amorphous silicates, the slag may also contain macroscopic copper inclusions, charcoal fragments, remains of the minerals contained in the ore charge, iron oxides and even globules of metallic iron or cast-iron (iron/carbon alloy), if the furnace was operated locally or temporarily under strongly reducing conditions.

It is reasonable to assume that the efficiency of the process for extracting copper from chalcopyrite, which relied simply on roasting followed by smelting, deteriorated significantly when the charge contained low grade copper ore. When processing lean ores, the amounts of iron and sulphur to be separated are so large that smelting ultimately produces only minor quantities of metallic copper and large amounts of copper-iron sulphides, which do however have higher Cu content than the crude ore. This smelting product is the so-called copper matte. The copper is eventually extracted through a series of roasting and reduction smelting stages, obtaining a successively higher grade copper matte and ultimately metallic copper.

Nowadays metallurgical processes for the production of copper from chalcopyrite involve a preliminary roasting stage for concentrating the copper, producing a matte with a 40-70 % Cu content, which is joined by slagging of part of the iron to obtain fayalite. It is only in the second stage, performed in another equipment, that the iron is completely slagged and the copper sulphides reduced to metallic copper:

$$1/2\ Cu_2S(l) + O_2(g) \rightarrow Cu(l) + 1/2\ SO_2\ (g)$$

The metallurgical process design takes into account the chemical affinities of the elements to be separated: copper shows a greater affinity to sulphur than iron: iron in turn has a greater affinity for oxygen than copper; sulphur has a greater affinity for oxygen than for copper.

Some researchers suggest that these processes were already being carried out deliberately as early as the Bronze Age. Certainly historical evidence indicates that successive roasting/smelting processes, comprising up to 6÷8 stages, were being performed at least from the 1500's onwards (Agricola 1556).

The discovery and study of ancient smelting furnaces is of primary importance both because of their archaeological significance and for gaining an understanding of how metallurgy developed over the ages. Today there is general consensus that smelting operations in ancient times were carried out in the vicinity of the ore deposits. This would have enabled small quantities of material to be transported for trading (the metal rather than the more bulky ores, fluxes and fuels). Furthermore, significant amounts of sulphur dioxide were emitted during roasting and smelting, a gas with extremely irritating effects even at low concentrations in air, which could be perceived at a distance of a few hundred metres. Other emissions included metal oxides, volatile arsenic, zinc and lead, especially hazardous in the immediate vicinity of the roasting/smelting site.

Generally speaking the smelting furnaces used in prehistoric times were of small capacity, with a truncated conical or cylindrical shape, or pear-shaped, with a diameter ranging from 30 to 50 cm and a height roughly twice the diameter (Tylecote 1967, 1976, Wagner 1985, Rehder 1985). They were partially dug or sunk completely into the ground and the pit was lined with thick stones bound together and coated with layers of clay or slag, to ensure good heat insulation. This enabled the high temperatures required for smelting to be attained in a relatively short time and maintained for several hours. The furnace would have had a forced draught system consisting of 1÷3 nozzles (*tuyères*) a few centimetres in diameter attached to a primitive form of hand or foot bellows through which air was blown. It has actually been suggested that in some sites stone walls were made as funnels for conducting the winds into the furnace. Once the pit had been dried out and the lining fired by burning charcoal or wood, the ore charge, charcoal, and any slagging agents or flux were placed inside it in alternate layers or just mixed together. The ore pieces needed to be suitably sized to facilitate air circulation. The creation of forced draught and heat insulation allowed to raise the temperature to around 1200 °C in the vicinity of the *tuyères*.

A number of experimental replica trials have convincingly demonstrated the possibilities and limitations of ancient metallurgical techniques.

Doonan (1994) for example in a paper appropriately entitled "Sweat, fire and brimstone", describes his attempts to mechanically prepare, hand sort and roast a chalcopyrite ore. Using a rectangular pit piled up with wood and ore he succeeded fairly easily in reaching temperatures of 700÷900 °C. The sulphur dioxide fumes could be perceived at a distance of 200 m. He observed that some of the roasted nodules contained small amounts of copper in metallic form.

Rostoker & Sadowski (1980) conducted experiments on a 71 % concentrate of chalcopyrite. The first stage of the experiment consisted in roasting the mineral, reaching temperatures of 800 °C. The main products obtained after 15 hours roasting were CuO, iron oxides and $CuO{\cdot}Fe_2O_3$ spinels. The resulting "oxidized" material was then smelted adding a flux consisting of silica and tricalcic phosphate (contained in bones). They succeeded in recovering 80 % of the copper. The slag, readily fusible at 1130-1200 °C, blackish in colour and heavy due to the iron content was composed chiefly of fayalite. Some of the slags were ferromagnetic due to the presence of magnetite.

Tylecote (1980) also conducted a number of experiments, some using Sardinian ores. He built a replica of furnace unearthed in the famous Chalcolithic archaeological site at Timna in Palestine. A typical heating cycle for smelting oxidized minerals consisted in preheating for six hours, smelting for an hour and a half (ore charge and charcoal) followed by another hour and a half at high temperature to promote separation of the metal from the molten slag by gravity. The Sardinian ore, collected from Calabona, Alghero (Merkel 1984) was composed of cuprite Cu_2O, tenorite CuO and minor amounts of malachite, with a total copper assay of 30 %. Hematite, Fe_2O_3 was used as slagging agent. After six hours they obtained a separation efficiency of 73 %, burning a total of 57 kg of coal to treat 2.5 kg of mineral.

4. Copper refining

The copper extracted using the metallurgical processes discussed above, today called “blister” or “black” copper because of its appearance, is never pure, though it is not unusual to obtain products assaying 95÷97 % Cu. However, if, depending on its use, the copper was required to be malleable and ductile or was required to exhibit stable properties when alloyed with other metals, generally to produce bronzes, then the primary metal had to be refined in order to eliminate to the greatest extent possible the other metals present as impurities, along with other elements such as oxygen and sulphur.

Needless to say, primitive civilizations were unable to reason or express themselves in these terms. Nonetheless, the series of operations which we will call “fire refining” produced a “red” metal (pure copper actually has a pinkish tinge, the reddish colour of the surface is due to an inevitable thin oxidation layer) which responded very differently to hammering, melting and casting and cutting.

Chalcopyrite itself has a fairly variable composition, as the copper and iron may be isomorphously replaced by Ag, Au, Pb, Co, Ni, Sn, Zn and other metals, while the sulphur may be partly replaced by arsenic. In any case, chalcopyrite is often accompanied by a variety of other metal sulphides such as Pb, Fe, As, Sb and Bi. Many of these sulphides can be reduced to their metallic form under conditions which do not differ substantially from those for reducing copper sulphides/oxides. In particular, iron sulphide can be partly reduced to metal under locally or temporarily strongly reducing conditions, and passes into the molten mass, being soluble up to 6 %, seriously jeopardizing the mechanical performance of the copper, once it has solidified.

Prehistoric metalworkers certainly had the available means for conducting fire refining (“fire” in the sense of “non electrolytic”, today by far the most commonly used technique), perhaps managing to produce 98÷99 % pure copper. The main impurities in the copper were not so much other metals but rather oxygen and sulphur, chiefly in the form of copper oxides and sulphides.

It would also have been fairly easy to visually control the fire refining operations. Appearance of the surface of the molten mass, bubbling, colour and appearance of the fracture surface of the solidified metal were all important diagnostic features for experienced craftsmen (Altmayer 1925, Stiavelli, 1937).

In practice, copper refining was carried out as follows:

- the raw copper was placed in a clay or stone crucible and heated to melting point;
- the molten copper was stirred and air blown onto the surface and a silica granulate was added; its specific gravity is far lower than that of the molten metal and so it floats on the surface; the slag forming on the surface was skimmed off until the surface remained clear and mirror-like;
- the copper melt was then covered with a layer of charcoal and stirred with a branch of fresh wood: the fracture surface of the metal passes from reddish to pinkish as the oxide content decreases and tenacity increases.

Simply remelting the raw copper in air produces a certain degree of refining.

Essentially, the refining technique relies on oxidation of the foreign metals initially dissolved in the copper bath. These combine with the silica to form slag which is then removed from the surface. Some relatively volatile metals and oxides are also emitted in the fumes from the copper melt. Part of the copper becomes oxidised during the process but is reduced once again to metal in the final phase by charcoal additions and due to the reducing effect of the wood used for mixing.

Elements such as Fe, Mn, Co and Sn oxidize quickly and rapidly form slag, while Zn, Pb, As, Bi and Sb are susceptible to partial volatilisation. Zinc oxide combines with the silica to form slag. Pb, on the other hands starts to oxidise mainly once most of the iron has been oxidised. Moreover, because of its high specific gravity (at the process temperatures around 10 g/cm^3, compared to around 8 g/cm^3 of the copper bath) the lead tends to segregate on the bottom of the crucible. Arsenic forms a toxic, volatile oxide but is difficult to completely eliminate because of the formation of copper arsenates which are fairly stable. Sb also combines with copper to form antimoniates and in terms of moving away, is probably the most recalcitrant metal.

Oxidation of Ni only begins in earnest once most of the Fe and Co have been eliminated. The Ni oxide can then pass into the slag in the form of a silicate. However, when both Sn and As are present they can form antimoniates and arsenates and the stability of these compounds hinders their efficient removal.

Se and Te do not enter in the slag. The noble metals Au, Ag and Pt do not oxidise and tend to remain in the refined copper. The precious metals, and in particular silver, could be recovered from the raw copper exploiting their higher affinity for lead. The technique of adding lead and removing it from the copper bath by gravity separation enabled the majority of noble metals to be selected, where it was considered convenient. Silver and gold were then recovered by means of cupellation.

The slag generated during refining is generally very fluid and forms a sort of opaque film on the surface of the copper melt. Once the first refining stage has been completed, the surface of the copper bath should have a mirror-like sheen. Unlike smelting slag, one distinctive feature of this kind of slag, apart from its physical appearance and the small quantities produced, is that compared to other metals it contains relatively little iron.

Part of the copper also oxidises: this reaction actually plays an important role in the refining process as a whole, aided by the fact that copper has little affinity for silica and for this reason does not form slag.

Copper oxide promotes oxygen transfer and reactions in the molten mass. First of all there is the formation of CuO which is then rapidly converted into Cu_2O. As the bath becomes saturated with Cu_2O, there is an increase in the concentration of CuO, which is unstable at high temperatures and tends to decompose, generating oxygen in the atomic form ($2CuO = Cu_2O + O$). Atomic oxygen readily binds to the atoms of the impurities contained in the molten copper.

Another impurity usually present in the copper melt is sulphur, S, chiefly in the form of copper sulphide. The elimination of most of the metallic impurities creates suitable conditions for the reaction $2Cu_2O + Cu_2S = 6\ Cu + SO_2$ to take place. As the sulphur dioxide is released, the molten copper begins to bubble. Once the bubbling has ceased, this stage of the process is considered complete and the copper satisfactorily refined.

The final (though never complete) reduction of the copper oxides is accomplished by covering the bath with a layer of charcoal and stirring it with a fresh wood stick. When this is placed in the bath, the heat evaporates the wood moisture and the organic molecular complexes break down into light hydrocarbons, carbon monoxide, carbon and hydrogen. The generation of all these gases and vapours cause the molten metal to effervesce and they react with the copper oxides converting them into copper metal – they are all chemically reducing – producing carbon dioxide CO_2 and water vapour.

5. Copper-arsenic alloy

Copper alloyed with arsenic is certainly one of the oldest and most important alloys in terms of widespread use and variety of applications. The presence of arsenic, generally in concentrations by weight of no more than 7-8% (As is volatile), has a pronounced effect on both the mechanical and aesthetical properties of copper artefacts. Today when we talk about alloys it is obvious that we mean "derived from…by addition of…" but in primitive times this alloy was likely regarded simply as "another" metal which was different from/alternative to copper, but offered plain advantages over the latter.

One of the readily apparent advantages of arsenic presence is that it reduces blistering of the cast copper artefacts because of its deoxidising effect.

But the main advantage of arsenical copper compared to pure copper is its superior hardness. This is already appreciable in the cast form but is further enhanced when the cast metal is worked, for example, by cold hammering required to beat a blade into shape. The mechanical performance of arsenical copper (which of course could not be "measured" in the modern sense of the word but that ancient metalworkers would certainly have been aware of) is only slightly poorer than that of bronze alloys containing the same amount of tin (Maréchal 1962).

The presence of arsenic also could give a silvery sheen to the surface of copper artefacts. For example metallographic observation of a sword recovered from the Los Millares site in Spain, dated to the local first Copper Age of the 3rd millennium B.C. showed a completely "silvered" surface, found to be rich in Cu_3As (containing around 29 % As) whereas the As content of the bulk was around 5 % (Meeks 1993, La Niece 1989). This surface enrichment process is believed to be attributable to a phenomenon today known as "inverse segregation". A multicomponent system made up, for example, of copper and arsenic, copper and tin and so forth, which is perfectly homogeneous in the molten form will solidify in a non-homogeneous manner. The first phase to solidify will be enriched in the element having the highest melting point, in the specific case copper, while the molten phase will correspondingly become enriched in the component with low melting point (tin or arsenic; pure arsenic does not actually melt but sublimes). As solidification usually begins from the walls of the container, which are cool, the last part to solidify will be the nucleus which will ultimately be enriched in the component with the lowest solidification temperature. This process is known as "segregation". In inverse segregation, on the other hand, it is the surface, not the core, which becomes enriched with the element having the lowest melting point. This process has been described for arsenical copper and it is believed to be caused by the molten metal seeping into the interdendritic spaces created between the grains which solidify first, for example as a result of shrinkage when the metal passes from the molten to the solid state and to which the remaining melt is squeezed in certain casting conditions.

Native arsenic, *i.e.* arsenic in its elemental state, is rare but occurs in some deposits, including lead-bearing orebodies. It has a grey metallic appearance but is brittle, not ductile; the fresh fracture is shiny but tarnishes rapidly upon exposure to air. Arsenic is usually combined with other elements and associated with the commonest copper, lead and iron minerals. The red and yellow arsenic sulphides, realgar As_2S_2 and orpiment As_2S_3 were known in antiquity and used as pigments.

Metallic arsenic can be produced with the simplest of metal extraction processes, namely through decomposition by heating minerals such as arsenopyrite/mispickel FeS_2FeAs_2 or leucopyrite/lollingite $FeAs_2$. The arsenic is separated in the form of vapour and upon contact with cool walls will condense enabling the metal to be collected. The minerals never decompose completely and to minimize oxidation of the metal produced in this way, care needs to be taken to avoid an oxidizing environment in the furnace due to excess combustion air.

Arsenic oxide can be obtained from the other minerals by roasting. Once this volatile compound is recovered from the fumes it can be reduced to metal using charcoal-carbon monoxide.

However, there is a deceptive simplicity in these processes. The volatility of arsenic and its compounds probably prevented it from being recognized as such in antiquity long before it was being used.

Numerous researchers argue that arsenical copper was accidentally discovered during the smelting of copper minerals associated with arsenic minerals. Should this be the case then the production of the alloy postdates both its recognition and the practice of extracting copper from its ores. As previously mentioned, the upper portions of copper orebody are often composed largely of oxides and carbonates of different stoichiometries, the weathered products of the original sulphides. Once the easily mineable surface deposits have been depleted, the veins are worked underground. These are the so called “enrichment” zones where some elements dissolved from the more exposed parts by atmospheric water, have deposited. These deposits contain copper- and arsenic-enriched minerals. Thus the generally accepted hypothesis as to the evolutionary sequence of prehistoric metallurgy, from copper to copper+arsenic, was dictated by the very nature of the mineral deposits themselves. The dwindling supplies of arsenic rich ores and the health hazards associated with their extraction (perhaps it is no coincidence that the Greek god of metalwork *Hephaestus* was depicted as a cripple, and one of the pathology of prolonged arsenic exposure is in fact skeletal crippling) were the driving forces which led to arsenical copper being supplanted by copper alloyed with tin.

Presumably copper arsenic alloys were also obtained by adding arsenic bearing minerals to the copper melt. As already mentioned, arsenic can be liberated simply by thermal decomposition. This operation does however presuppose a depth understanding of the metallurgical process. Besides, even the “silvering” of the surfaces mentioned above could be done by cementation, whereby the arsenic was diffused out at high temperatures from minerals placed on the surfaces of artifacts for a sufficiently long period of time.

6. Further remarks on metal working

Beside the extraction of the metal from its ores, its refining or the recovery of precious metals, discussed in the previous paragraphs, the actual fabrication of metal artefacts required additional operations such as melting, alloying, casting the molten metal into appropriately prepared moulds, shaping the objects by hammering and sometimes also perforating holes, riveting, brazing, polishing and so forth.

Molten copper tends to absorb gases; ten grams of molten copper are able to dissolve 4 Ncm^3 of nitrogen, 12 Ncm^3 of hydrogen and as much as 26 Ncm^3 of CO. When moisture is present, in the air or in the moulds, particularly those made of terracotta, significant quantities of hydrogen, in the form of gas, and oxygen, in the form of oxides (generated by the decomposition of water: $2Cu + H_2O \rightarrow Cu_2O + 2H$) are trapped in the melt.

During solidification gaseous hydrogen tends to develop while the copper oxides which remain trapped between grains, embrittle the metallic structure. The combined presence of both, oxides and sulphides, generates sulphur dioxide which is emitted into the atmosphere ($2\ Cu_2O + CuS \rightarrow 5\ Cu + SO_2$).

The emission of gases causes porosity in the upper layers of the cast metal, which being the first to cool, solidify into a pasty consistency, producing a pitted surface.

Good melting practice requires the molten metal bath to be protected from the atmosphere by means of a layer of carbon and the metal to be cast preferably into closed moulds, for example two-piece moulds, even when fabricating two-dimensional objects such as blades.

Details of Sardinian archaeological moulds are reported in Part III and IV of this volume.

Metals such as arsenic and tin deoxidise the copper. Lead also acts as a deoxidant, exhibiting higher affinity for the oxygen than the “red metal”. However only minor quantities of lead should be added to the melt as, being insoluble, it tends to segregate at the grain boundaries, embrittling the structure and diminishing mechanical performance. Adding larger proportions of lead is only of advantage in statue-making for improving the fluidity of the melt so as to facilitate its passage into the more intricate casting paths. Note that lead is not an alloying element as arsenic and tin which when combined with copper give a true solid solution.

As the molten metal solidifies shrinkage occurs which can produce cracks or voids within the cast metal. This frequently happens, especially when the passages conveying the melt to the different parts of the mould are not properly shaped and the melt level is insufficient. As a result the ultimate density of the cast copper may be less than 95 % of the theoretical one.

7. Tin and bronzes

Metallic tin exhibits inferior mechanical properties and therefore it is not surprising that there are few direct applications. Tensile strength of the pure cast metal is just 15 N/mm^2, compared to around 220 N/mm^2 for copper. Cold hammering does little to strengthening and may actually produce the opposite effect.

The few prehistoric tin finds which have survived to date in the Mediterranean area consist largely of small containers, ornaments or decorations/coatings on vases, sometimes with added lead. The durability of these objects is in theory threatened by the so-called “tin pest”. This is the effect produced by the allotropic transformation which the metal undergoes at about 13 °C which substantially changes its specific volume. However, this phenomenon is strongly inhibited by the presence of certain common impurities. It is difficult to judge to what extent this "disease", which reduces the tin to dust, has lead to underestimate the use of pure tin in objects manufacturing.

By contrast, substantial benefits derives from the tin as alloying metal for producing bronze. In antiquity there was practically no substitute for tin for "strengthening" copper. The tensile strength of cast bronze containing 10% tin can be as much as 260 N/mm^2 and increases significantly after strain hardening. The hardness of this alloy increases accordingly and can attain values which compare favourably with early steels.

The most reliable method for the production of bronze consists in adding metallic tin to the copper melt. Bronze might also have been produced by using what today is the main, and probably the only major tin bearing ore – namely cassiterite (tin dioxide). This process, known historically as cementation, was probably accomplished by spreading a layer of cassiterite mixed with carbon on top of the copper bath. Blowing air *i.e.* oxygen into the melt generates carbon monoxide, creating a reducing atmosphere which transforms the tin oxide into the metallic state. Part of the tin is thus incorporated into the melt. Using this technique it was perhaps more difficult to control the composition of the bronze, *i.e.* the resulting metal was likely to be more variable, than by adding a weighed quantity or a known volume of metal. Some researchers maintain that cementing copper with cassiterite actually predated tin metal additing. Besides, the alloying technique probably did not differ from the ones previously employed for producing arsenical copper, as there is no evidence to suggest that As has ever been isolated in its elemental form in prehistoric times. Later civilizations resorted to cementation for the production of brass as well as copper and zinc alloys: given the thermodynamical and metallurgical properties of zinc, it was unthinkable that early man would have succeeded in isolating this metal (see Part III, L: Fake bronze figurines).

As already mentioned, cassiterite, prevalently SnO_2, is probably the only tin-bearing mineral to have been used by early civilizations. This mineral still plays a fundamental role in mining and metallurgical industry.

Cassiterite has such an unusually high specific gravity (6.8÷7.1 g/cm^3 against 2÷3 g/cm^3 of common rocks) that on the one hand it has concentrated preferentially in alluvial deposits while on the other it is easy to recognize and upgrade by hand sorting. For the above reasons, cassiterite and gold mining have some features in common and sometimes gold have been known to be associated with alluvial cassiterite. Cassiterite occasionally occurs in the readily identifiable form of "wood tin", which exhibits a fibrous structure resembling wood. Ancient civilizations were unlikely to have had sufficient technical know-how to extract cassiterite from primary deposits, where it usually occurs in veins hosted by granite.

As cassiterite is an oxide, it can be metallurgically processed as-received without the need for the preliminary treatment required by say sulphide metal-bearing ores. The chemistry of the extraction process can be summarized by the simple overall reaction:

$$SnO_2(s) + 2\ CO(g) \rightarrow Sn(l) + 2\ CO_2\ (g)$$

Carbon monoxide CO is generated by charcoal reacting at a glowing red heat with the oxygen air blown into the furnace.

The operating temperature for cassiterite smelting depends on two factors. The first concerns the different thermodynamic stability of the oxides, which defines a threshold level below which the oxygen will preferentially bind to the carbon as CO_2 rather than to the metal. In our case, the complete chemical reaction is accomplished from around 900 °C upwards. The direct reaction of cassiterite with the carbon of the charcoal, in the solid form, has little influence especially for temperatures of below 1000°C.

The above chemical reaction does not however complete the process. In fact, the cassiterite is accompanied by other minerals, which, as mentioned previously, constitute the gangue. In order to achieve an efficient performance, the gangue minerals must be molten, and constitute the slag with part of the material used for the crucibles and to line the furnace (usually clayey soil) or slag from previous smelting operations.

To achieve efficient metal production the metal must be separated by gravity from the molten slag with which it was originally associated. If the slag is sufficiently fluid, and its viscosity depends on both composition and temperature, the metal will become physically trapped in the slag, in the form of prills which are unable to coalesce and collect at the bottom of the crucible where it is recovered. This process requires a minimum operating temperature of 1000-1100 °C, which ancient metalworkers would have had no difficulty in attaining in forced draught (bellows operated) furnaces of small capacity, say a few litres.

Unfortunately, part of the tin dioxide (which has a melting point of 1127 °C) tends to bind to the silica, a common gangue constituent, and goes into the slag in the form of silicate. When smelting cassiterite ores containing only minor proportions of silica, stannates tend to form which also end up in the slags. This has a negative affect on separation efficiency unless the slag is reprocessed/recirculated slag, as was the custom in historic times.

If necessary, the tin can be refined adopting the following procedure:

- the metals with higher melting point than the tin (in particular copper and iron or carbon iron alloys) remain on the bottom of the metal bath heated to temperatures slightly above the melting point of tin and the metallic tin, efficiently separated from them, is then tapped from the top of the crucible;

• the metals with low melting point (in particular lead and bismuth) can be oxidized and their oxides transformed into slag by blowing air on to the molten bath and stirring or spooning out the molten metal.

In both cases a certain amount of tin ends up in the slag, though the slag could actually be resmelted. Because it is relative volatile, some of the tin may be emitted in the fumes, also in the form of oxides.

Several researchers have attempted to reproduce the ancient tin extraction process. Earl, for example (1985, 1996) working with small quantities of ores, succeeded in reaching temperatures of between 1100 and 1200 °C simply by blowing air into the furnace and was able to obtain metallic tin in the form of millimetre sized prills for lean ores (40 % cassiterite, recovery efficiency 33 %). Actual separation of the metal, the so-called button which remains at the bottom of the crucible was achieved using 65-70 % cassiterite concentrates and in this case recovery efficiency increased to 56 %.

The superior performance of bronzes has long been recognized. The mechanical properties of the alloys at 8÷1 0 % Sn compare very favourably with the early steels (iron-carbon alloys) and in fact actually exhibit greater durability. Why steels largely supplanted bronzes in tools and weapons is a complex issue and one of major interest, in that the answer is not simply to be sought in the technical aspects but involves the whole question of “raw materials geopolitics” in the centuries spanning the Ist millennium B.C.

Here we will address only certain aspects which are within the scope of the present work, namely those directly associated with the interpretation of the archaeometric data presented in Part III of this volume.

Sn can, within certain compositional limits, form a substitutional solid solution with the copper, the so-called α phase. The atomic (and monovalent ion) size of tin is fairly similar to that of copper, the difference being around +15%. Thus the tin can replace the copper in definite position in the crystal lattice (matching other physical conditions). The distortion introduced into the crystal structure of copper creates a barrier hindering dislocation mobility. Dislocations are linear lattice defects which determine the deformability of metals. Their movement under tension is hindered by the interaction with other structural defects which interrupt the regular pattern of the crystal lattice, for example grain boundaries, precipitates/inclusions and of course the stress fields generated by the presence of substitutional solute atoms of a different size compared to the atoms they have replaced. Hence the addition of tin, within certain limits, actually strengthens the crystal structure of copper: bronze is harder and more mechanically resistant than pure copper.

A similar mechanism comes into play when arsenic or zinc are added to copper. In this latter case the difference in atomic size is only +4% and in fact the α phase of brass is far wider than that of bronze. The atomic size of other chemical elements such as Pb for example is very different from the copper atom (37 % larger) rendering them im-miscible and hence unsuitable for alloying. When added to the melt the Pb segregates forming inclusions along the grain boundaries and does not strengthen the crystal structure but on the contrary it weakens the metal at the microstructural level. To present day the addition of lead to bronzes and brasses improves their workability precisely because the lead inclusions result in a weaker microstructure. The presence of lead in bronze is actually justified for a number of other reasons – it is a deoxidant, improves melt fluidity and is cheaper.

Adding tin to the copper also alters the colour of the alloys. With additions of around 3÷4 % the typical reddish colour of copper predominates, 5÷10 % tin produces a golden yellow bronze, 10÷25 % a pale yellow and a tin content of 25 % produces a white alloy. The colour of the cut bronze or bronze shavings is strongly indicative of the amount of tin contained in the alloy.

The mechanical properties of alloys containing up to 2÷3 % tin are fairly similar to technically pure copper, whereas copper alloyed with 8÷10 % tin exhibits superior hardness and mechanical strength but can be still cold-hammered. The alloy in this case has an a phase structure, while with higher proportions of tin (the limit depends not only on the quantity but also on the cooling conditions) a new phase appears in the microstructure, the so-called δ phase. This phase, which corresponds to the formula Cu_4Sn, is extremely hard and brittle (the structural component is the α+δ eutectoid). Thus, with tin additions exceeding 12÷13 % the alloy becomes increasingly brittle and difficult to cold work. Further increasing the alloying content produces bronzes which are used for mirrors and bells and which are only suitable for casting. In addition to being sonorous, these bronzes are extremely hard and polishable to a “mirror” finish but also extremely brittle. Ancient peoples quickly recognized that an optimum tin content of around 8÷10 % was adequate for maximizing mechanical performance for example in the fabrication of weapons, though the practice of remelting could produce a certain variability in alloy composition.

One last point of interest is associated with the broad solidification range of bronzes; “normal” and “inverse” segregation have been briefly discussed in the previous paragraph dealing with copper arsenic alloys.

In addition, the specific gravities of the metals present in the molten metal can differ substantially; for example at 1120 °C the specific gravity of copper is 7.9 g/cm^3 compared to 9.8 g/cm^3 for lead, 9.1 g/cm^3 for silver and as much as 17.2 g/cm^3 for gold. If the melt is left to stand then the metals will partially separate by virtue of their different specific gravity; clearly this effect has profound implications for the archaeometric study and for data interpretation.

8. Lead

The mechanical properties of lead are notoriously rather poor. This soft and malleable low melting metal (327.4 °C) has relatively high specific gravity (11.3 g/cm^3) and good overall durability. The principal ore of lead is galena, PbS. Quite frequently galena occurs in well crystallized shiny black faceted form in outcrops too.

In some outcrops, galena may be altered and so transformed into other mineral species, because of the action of atmospheric agents. One of the most common alteration products is the carbonate $PbCO_3$, the major constituent of the mineral cerussite. It is relatively simple to process ores composed chiefly of cerussite. The carbonate decomposes at low temperatures, between 300 and 400 °C depending upon its state of hydration, and produces first of all oxides which are in turn reduced to metallic lead by carbon/carbon monoxide.

$PbCO_3(s) \rightarrow PbO(s) + CO_2\ (g)$

$PbO\ (s) + CO\ (g) \rightarrow Pb\ (l) + CO_2\ (g)$

$PbO\ (s) + C\ (s) \rightarrow Pb\ (l) + CO\ (g)$

The extraction of lead from galena is generally regarded to be a fairly straightforward operation (or at least easier than extracting copper from chalcopyrite) and some scholars actually maintain that this metal was the first ever smelted. According to Krysko (1979) the ancient Egyptians believed all metals to be “fathered by lead”.

It is possible to extract lead from galena rich ores at temperatures probably no higher than 900 °C, thereby lowering fuel-reducing agent consumption obtaining at the same time a high purity metal. However, this process has two disadvantages, namely the noxious fumes generated by smelting creating an unhealthy environment and poor lead recoveries.

By heating to moderately high temperatures galena reduced to millimetre sized fragments, the sulphur is partly transformed into oxide and partly into sulphate according to complex reactions which can be schematized as follows (Kellogg 1960, Yazawa 1967, Willis 1980):

$2\ PbS\ (s) + 3\ O_2\ (g) \rightarrow 2\ PbO\ (s) + 2\ SO_2\ (g)$

temperature < 400 °C

$PbS\ (s) + 2\ O_2\ (g) \rightarrow PbSO_4\ (s)$

temperature < 450 °C

The smelting charge is often stirred to enable atmospheric air to thoroughly penetrate the ore in the furnace. This process leads to the formation of stuff including sulphates and oxides with different stoichiometries:

$PbSO_4 \cdot (1 \div 4)PbO$.

When this phase of the operation is judged to have developed to a sufficient degree, the temperature of the furnace is increased, for instance by forcing air into the fuel bed, to allow the newly formed oxide and sulphate to efficiently react with the remaining sulphur. It is during this stage of the process that metallic lead is produced according to the reaction:

$PbS\ (s) + 2\ PbO\ (s) \rightarrow 3\ Pb(l) + SO_2\ (g)$

temperature 600÷700 °C

$PbS\ (s) + PbSO_4\ (s) \rightarrow 2\ Pb(l) + 2\ SO_2\ (g)$

Other reactions contributing to the lead extraction process are the so-called “direct” reactions:

$PbS\ (s) + O_2\ (g) \rightarrow Pb(l) + SO_2\ (g)$

and those taking place between carbon and carbon monoxide, from temperatures of 200 and 400 °C upwards respectively, though much higher temperatures (800÷900 °C) accelerate the reaction significantly.

For the process to perform satisfactorily, the gangue should contain no more than a few percent of silica as this element tends to readily combine with the lead to form silicates. As lead silicate has a low melting point (766 °C) it tends to stick the smoldering mass together preventing oxygen from penetrating and thus the lead from reacting. Several other reactions are involved in this process which result in the re-formation of sulphide; though PbS melts at 1120 °C, at the operating temperature of the furnace it is in a plastic and cohesive state.

In modern lead smelting processes – low shaft furnace smelting was still being employed in the 20th Century – the addition of lime promotes the decomposition of lead sulphates and silicates, releasing the lead and hence triggering reactivity. Lime was certainly known in antiquity and some researchers claim to have found evidence of the production and use of lime in constructions as early as Preceramic contexts of the Near East (Kingery 1987, Garfinkel 1987). However it is difficult to judge whether lime was used by early metalworkers for lead smelting. The limestone decomposes into lime at 850÷950 °C and consequently adding it directly to lead smelting furnaces operating at lower temperatures would have served little purpose.

9. Silver

Silver occurs as native metal or combined with other chemical elements in a variety of minerals and ores. For the purposes of the archaeometallurgical study a distinction needs to be made between two cases. Ancient lead and copper are always found to contain a minor amount of silver. In the case of silver contents exceeding several hundred ppm its recovery using suitable extraction techniques, could be considered both technically feasible and economically justified. But it can be also reasonably assumed that both native silver and true silver ores played an important role in ancient metalworking. In Sardinia silver was reportedly collected as late as the second half of the 1800’s in outcrops or near-surface deposits in the lenses/pockets form of small dimension but high concentrations (Traverso 1909, Selmi 1874, Roswag 1885).

Today no more than one third of silver production is extracted from what can be definited as true silver bearing ore deposits. The most common minerals are probably argentite Ag_2S, pyrargyrite Ag_3SbS_3 (or Ag_3AsS_3) and cerargyrite AgCl. Silver concentrations in this ores are generally low and recovering the precious metal - though today, economically speaking, silver is by far the least valuable of the precious metals - involves flotation and adding the resulting concentrates to lead and copper smelters. The remainder of silver production is recovered as by-products from the processing of other metals such as lead (in the 1980's around 35 %), copper (around 14 %) and zinc (around 13 %), gold, nickel, cobalt, uranium, manganese and others (Schlain 1986, Proctor 1986).

It is easy to assume that man's first encounter with silver was with the native form, before early civilizations realized that this metal could be extracted from other metals, for instance from lead. Native silver often occurs in silver ore deposits frequently in the form of intertwined coiled wires. The native metal is ductile, malleable and sectile and is "silver white" within. Sometimes in modern day mines we can retrive also nuggets of native silver which can weigh tens of kilograms, and in some rare cases more than a hundred.

Native silver is often associated with minor amounts of other metals for example Sb, As, Cu, Au, Hg.

To obtain a small ingot from a bundle of native silver wires to make it easier to shape the metal into some form of object, the pieces had to be molten in a crucible. Pure silver melts at 960.5 °C a temperature which is relatively easy to attain, even though with the aid of forced draught. At these temperatures certain compounds such as bromide, carbonate and oxide would decompose to form additional metal. However, of these substances the only one commonly present in nature is bromide. Silver carbonate and silver oxide tend to decompose spontaneously at the extent that they are seldom found in nature. At 200 °C silver carbonate is transformed almost entirely into oxide which in turn decomposes, releasing oxygen and depositing the metal. In presence of CO/C, the silver oxide yields metal already at 40÷50 °C. This is extractive metallurgy in its simplest form, which could well have paved the way to roasting and smelting of lead and copper ores, but no evidence has been produced to uphold this hypothesis.

In antiquity silver and lead metallurgy are strictly related. In fact, not only a minor amounts of silver is often observed in lead artifacts but the molten lead is able to recover silver from the silver ores (sulphide, chloride, bromide). Lastly, silver as well as gold can be recovered by means of a cupellation which though fuel-intensive is fairly simple to perform. This process relies on the fact that lead oxidizes more readily than silver and gold (which are noble metals in terms of chemical-corrosion). In practice lead is molten in a shallow, wide crucible, called "cupel" and the temperature is then raised to 900÷1000 °C and air is blown onto the surface of the lead bath. Of course ancient metalworkers judged the temperature by eye, by the colour of the furnace and by the effects produced. The first elements to form are the oxides of the impurities contained in the melt, for instance copper and iron which have a powdery appearance. These float to the surface and are skimmed off. This is followed by the formation lead oxide mostly in the form of litharge, which at these operating temperatures is molten but floats on the metal bath and can be gradually removed. Lead oxidation is an exothermic process, *i.e.* it generates heat not unlike a normal combustion process and this helps to maintain the melt hot and boiling. As the lead oxidizes, the level of the melt in the crucible diminishes and more "raw" lead or even ores rich in silver chloride can be added. Lastly, when most of the lead has been removed, the remaining oxide appears as a thin iridescent film, the shaking ceases, the fumes subside and the surface of the bath remains white with a mirror-like sheen. The so-called silver "button" settles at the bottom of the crucible.

From 10 kg of cupelled lead containing 1000 pm Ag (0.1%) one obtains just 10 g of the precious metal. That part of the lead oxide recovered (the remainder is released in the fumes or absorbed by the crucible or furnace walls) can then be readily reconverted into metal by smelting at relatively low temperatures with charcoal/carbon monoxide as no gangue material is present. The lead oxide could also be used as a yellow pigment which turns red after further heating or simply on rubbing against a surface.

At least a couple of advances, which are now part of the history of cupellation, could have been achieved in antiquity in that both derive from essentially empirical evidence, though current findings do not enable to determine their origin. The first concerns the use of bone ash for cupel fabrication and more generally the use of natural materials with low silica content, as molten lead tends to bind with silica. The second development might have stemmed from the observation that upon cooling, molten lead containing silver separates into two liquids of different specific gravity, the liquid with the higher silver content floating over the poorer one. The fraction richer in silver is then poured off for further processing by means of cupellation, a process today known as "Pattinson's process" (Laatsch 1930).

It is highly unlikely that the mercury amalgamation process was already used in the prehistoric period discussed here. Mercury, unique amongst the metals in that it occurs as a liquid at room temperature, would have had to have been extracted by what is a relatively simple process, namely heating in air the most common mercury ore cinnabar (HgS), sometimes used in antiquity as a red pigment. However, the toxic fumes given off by mercury, which has a boiling point of 356.6 °C, would have had to be channeled elsewhere and condensed by cooling.

As far as working silver is concerned, it should be pointed out that the molten metal has an extraordinary ability to absorb atmospheric oxygen. One volume of silver can absorb as much as 10 volumes of oxygen. As silver solidifies, in a range of temperatures just a few tens of degrees below its melting point, this enormous quantity of gas is released from the metal in the form of bubbles which on reaching the partly solidified or pasty/semi-solid surface create a puckered, pitted effect. Some voids may also form inside the ingot (Vitiello

1995). If silver is alloyed with copper then part of the oxygen is converted into copper oxides which remain trapped between the grains and can impair the properties of the metal such as ductility and malleability (embrittlement). For satisfactory results silver should therefore be molten in a crucible covered with a layer of charcoal so as to avoid contact with atmospheric oxygen.

Copper was often added to silver to improve the hardness and hence wear resistance of artefacts. However compared to silver, copper is far more chemically unstable and a greenish patina may form also on predominantly silver-rich archaeological finds. By treating the surface with natural corrosive substances the uppermost layer of artefacts made of silver-copper alloys could be enriched in silver.

Because of its chemical stability and negligible solubility in natural water, silver chloride is the most common alteration product of silver artefacts unearthed in archaeological sites. It often forms a several millimetres thick layer and in some artefacts, rings for example, it can affect the entire section. Silver bromide and sulphide are often associated with silver chloride whereas oxide and carbonate content is negligible, the corrosion process reflecting the same order of chemical stability occurring in the ore outcrops.

10. Gold

One of the distinguishing features of gold is its chemical stability. It is usually found in nature uncombined with other elements, an exception with the other metals but the general rule for gold. Consequently early metalworkers did not have to tackle the problem of smelting gold.

Compared to other metallic elements such as copper, tin or lead, gold is relatively common but it seldom occurs in such large quantities as to make its presence manifest and its recovery feasible with ancient technologys. Primitive man's first encounter with gold was necessarily in alluvial placers. The natural disintegration of rocks containing gold in the form of specks, flakes and tiny nuggets, released the metal. Because of its high specific gravity, 19.3 g/cm^3 compared to barely 2÷3 g/cm^3 of the other rock fragments, the gold separated from the other sediment clasts during transport and deposition, accumulating locally for example in easily distinguishable concentrations in stream and riverbeds. It is well known that placer gold also occurs as nuggets forming by virtue of the thermodynamic stability of this metal which prevents the grain surfaces from oxidizing. As a result the grains weld together when subjected to slight pressure. In fact a nugget is usually the agglomeration of tiny gold grains, sometimes containing different amounts of impurities, such as silver and in some cases non-metallic clasts, such as quartz.

Silver is commonly found in native gold. In fact the two metals have practically identical atomic radius and as a result solid substitutional solutions can occur at almost any concentration. Metallic gold usually contains also minor amounts of copper and sometimes also platinum and the metals of the platinum group, ruthenium, rhodium, palladium, osmium and iridium. In spite of their different supply source these metals sometimes end up in the same sediment transport and depositional environment (*placers*). Notwithstanding its high melting point, platinum usually combines with gold whereas the other elements of the same group and particularly Os, Ru and Ir form globules a few tens of mm in size. Osmium isotopes are currently under test as a tool for the provenancing of gold artefacts (Junk 2003).

The less noble elements could be readily removed by melting the gold, blowing air onto the melt and then skimming off the oxides floating on the surface. However, with this technique it was not possible to separate the silver. This was done by treating the finely divided alloy with common salt, sodium chloride, leaving it to stand for long periods at high temperatures in sealed terracotta crucibles. Being less noble than the gold, the silver was converted into chloride.

Many ancient gold artefacts have been fashioned from thin sheets. This is another distinctive feature of the metal, *i.e.* it can be hammered into sheets or drawn into extremely thin wires without breaking. A few grams of gold are sufficient to obtain large sheets. In antiquity the metal was hammered between parchment/animal skins.

The three metals Au, Ag and Cu impart a variety of colours to their alloys. The colour of gold alloy was probably an important factor in ancient times and a recognized test of purity. It is well known that increasing the silver content of gold alloys makes the colour paler, while the presence of copper imparts a reddish hue to the metal. Clearly the colour is related to the amount of gold contained in the alloy, but the preference for one colour over another is also a question of taste.

The surfaces of artefacts made of gold alloy which were buried for centuries or millennia are often found to be Au-enriched, as the less noble elements tend to dissolve in corrosion. Probably, this phenomenon was observed and known in antiquity and the process was accelerated using natural mineral or plant substances which were known to corrode the metals.

Lastly, a few comments on the archaeometric characterization of gold finds. Their rarity and value and their usually good state of preservation have often posed an insurmountable impediment to archaeometric investigations, which traditionally rely on removing samples, albeit minute, from the finds themselves. Over the last few years however, non destructive or minimally destructive techniques have been developed that resolve the most important issues such as provenancing and dating.

Of these, the Laser Ablation ICP-MS technique, developed by South African gold producers for provenancing the metal has enabled to determine chemical composition and lead isotope on the artefact itself, focussing a laser on surfaces of diameter ranging from 0.2 mm to 20 μm. Comparison of the chemical-isotope “fingerprints” collected for a number of ore deposits in South Africa is usually regarded as resolutive (Grigorova 1998). Recent determinations of osmium isotope ratios 186/188 and 187/188 (“187” and “186” are the result of the decay of rhenium “187” and platinum “190”) on single inclusions using Laser Ablation ICP-MS with multiple collector, provided promising pointers as to their source (Junk 2003).

Lastly, another innovative technique consists in determining the amount of helium contained in a sample weighing just a few tens of milligrams. Helium is produced by the radioactive decay of U and Th, traces of which are present in gold and it remains trapped in the crystal lattice until heated to melting point when almost all of it is released. This method allows to distinguish whether the gold concerned is native ore or gold molten in antiquity or in recent times (Eugster 1996).

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PART II

GEOLOGY

FOREWORD ON GEOLOGY AND MINERAL DEPOSITS

R. G. Valera

Strong ties weld the history of the Sardinian people to the geology of their land. It is an extremely rich and varied geology, sharing events rooted before the deepest Paleozoic. The rough rock structures witness its complex evolutionary vicissitudes, offering multifarious lithological types even in narrow environments. In fact volcanic, igneous, metamorphic, and sedimentary products may occur in close contact and in a short space, showing such a wide choice of physical characteristics, that it offers the most immediate means for the simple vital needs of ancient man.

Nevertheless, it is not only the highly complex, differentiated rocky massifs, with their peculiar morphology, that recall the attention of whoever is immersed in Sardinian nature. The abundance of mineralogic species, usually rare or inconspicuous in common lithologies, have always created an extraordinary aesthetic anomaly in Sardinia, arousing the curiosity and interest of whosoever might be travelling across the countryside with such various multiform landscapes. Minerals at times heavy and often with uncommon lively colours, or shining characterized by the presence of perfect crystals, alone or in association, cannot pass unnoticed. Still today they are a remarkable feature in the experience, and simple culture of those that spend most of their time in close contact with nature, as has always been with shepherds, hunters, and farmers.

The greater or lesser abundance, and the variety of minerals and lithologies have certainly always and everywhere conditioned the relationship of the people with their life environment, affecting their character, and guiding their choices and life styles. A clay gully landscape could not have helped the development of a megalithic culture, and no matter how original and highly specialised, as in the plains of Mesopotamia, metallurgy could only have occurred as an activity of pure transformation of imported materials in a country of barren rocks of lead, silver, copper, and iron. This is the reason why Sardinian cultures show a clear imprint of the nature they were born and evolved in. This is why still today not only geologists, but also shepherds and common people feel the same sensation of ancient wonder, and an instinctive wish to beneficiate the discovery, as soon as they meet outcrops of brilliant heavy minerals such as galena, or vitreous coloured ones such as fluorite.

Certainly the modern explorer is driven by evaluation criteria related to economic concepts unimagined in the Bronze age. Therefore these mineralisations, including the poorest, must be regarded with the eyes of the first "miners" today, if an adequate evaluation to primitive requirements is to be given. "Important" in those eyes may have been an orebody of small size, as long as poor in barren material and made up of easily treatable ores. However, even in this case, there was a minimum limit given by the true and not "apparent" quantity of useful ore that the mineralisation was capable of supplying. Sardinia actually overflows with mineral occurrences and small indications. Iron sulfides (pyrite, pyrrhotite) can be found ubiquitous, and frequently accompanied by more or less conspicuous sulfide traces of other metals like lead, zinc, and copper. The very common pyrite itself is cupriferous at times, although not even slightly reaching the condition of true chalcopyrite; but, it is still sufficient to release enough copper for the weathering processes to supply raw material for extended or fragmentary coatings, nothing more than a deceiving call. Experience teaches very soon actually that a few green malachite coatings do not commonly hide large mineral treasures, while a ferruginous gossan with many-coloured streakings and brown-reddish mineral nodules may offer the surprise of copper compounds valuable in grade, though not in quantity.

In any case two things are certain. First, that every gossan owes its existence to a primary orebody that establishes its quality and size characteristics: no matter how exploited the gossan may be, the primary original orebody must remain, or at least its roots and traces of its environment. Second, that exogenous dynamics command a continuous weathering-removal process of outcropping substances, such that it cannot be admitted that ore deposits existed whose weathering products were not directly proportional in the past to the primary orebodies they derived from. Supposing that these weathering products provided the ancients with matter for metallurgy, no matter how reduced, they must still have left traces and testimony of the parent bodies, which are always manifest to the geologist of today, though they may seem weak to a less careful or skilled observation.

It is therefore possible to outline the panorama of ore deposits accessible to the ancient Sardinian people, first of all within the framework of a schematic reconstruction of the geological history that originated them. With the help of the knowledge contributed by more than three millennia of exploitation in Sardinia, we shall see schematically the order of magnitude of the actual primeval georesources available, from which the “apparent” mineralisations have been filtered off and reconstructed on the basis of the paragenetic and environmental characteristics, the primary parent orebodies, as well as the information reported by ancient authors.

1.
OUTLINE OF GEOLOGY AND MINERAL DEPOSITS OF SARDINIA

Paolo G. Valera,
Roberto G. Valera

1. Introduction

Mineral resources are so called because of their availability to be exploited through mining activity, stimulated by the need of raw materials typical of the civilisation level of a given historical time. Mineral resources are therefore identified by the "mineral deposits" which are, in turn, geological bodies characterised by the economic interest due to their shape, size, and forming substances. Such bodies can be made up entirely by useful raw materials, that can be totally exploited (e.g. coal seams), or they can be either the "mother" or the "reservoir rock" of the substances of interest (e.g. a gold-bearing quartz vein, where gold is the interesting ore). In this case exploitation will be followed by a dressing process for the recovery of the interesting ore that leaves dumps of barren material.

The wide variety of geologic bodies involved in today's mining activity is a consequence of the economic significance of the concept of "mineral deposit", as sources of all the mineral raw materials necessary for the various industrial fields: metallic and industrial minerals, fossil fuels, dimension stones, geothermal energy, ground waters. Since the very beginning mankind has learned to identify and handle the mineral commodities offered by nature, leaving several witnesses of such an activity. It is easy to trace a broad outline of their appearance according to a chronological scale, which should start from flintstones and obsidians, clays for pottery, colouring minerals (ochre, copper salts etc.), gold and copper, semiprecious minerals (e.g. cornelian, lapislazuli, nephrite), ornamental stones (marbles, porphyries, diorites etc.), down to later metals such as silver, lead, tin, iron.

Thanks to its long-lasting, complex, and varied geological history, Sardinia can offer examples of almost all types of mineralization, many of which are of great importance in the very old mining tradition of the island. Still today mining is an essential part of the Sardinian industry, which is particularly developed as regards industrial minerals (feldspars, clays, and quartz sands) and ornamental stones (granite), the classic lead-zinc branch being practically depleted. The tradition is well and alive so far, minerals are explored continuously, and at times satisfactory results are reached: today's boom of the gold compartment is the best example.

2. Geology of Sardinia

As it is clearly outlined in the Geologic Map of Sardinia (Carmignani ed. 1996) the geology of the island bears the imprint of events that developed in a time span of almost 600 MA, starting from the late Precambrian (Fig. 1).

The oldest levels are seen in the southernmost part of the island, where micaschists occur, followed by phyllites, metasandstones, and marbles of the Bithia formation, at the boundaries between the Precambrian and the Lower Cambrian. Subsequently the true Cambrian sequence develops, and gives rise to the regional frame of SW Sardinia, with the Nebida formation (or "Sandstones formation"), and the Metalliferous carbonatic sequence (Gonnesa formation, with limestones and dolomites) which terminates with the nodular limestones and shales of the Cabitza formation, passing on to the Lower Ordovician (pl. I, 1). On the other hand, the detrital formations of San Vito and Solanas occur in the corresponding eastern regions.

The "Sardic Phase" of the Caledonian orogenesis induces the first tectonic movements of Sardinian geological history. Folding processes are responsible for uplift, then a short continentality and the subsequent transgression of the Ordovician sea follow, accompanied by an even intense volcanic activity in the eastern region. The Capo Spartivento orthogneisses, the Sarrabus grey porphyries, and the Gerrei porphyroids are assigned to this phase, together with the associated metadetrital and metavolcanoclastic rocks, which belong to the Barbagia's Serra Tonnai, Manixeddu, and Monte Corte Cerbo formations. The sedimentary sequences are characterised by metaconglomerates and metasandstones, by silts with interbedded alkaline and basic metavolcanics, and by metatufites with metamorphic limestones, often silicified ("Sarrabus Quartzites").

New environmental conditions take place at the end of the Ordovician events, ranging from the Lower Silurian to the Lower Carboniferous. In an open to epicontinental sea sedimentation processes give rise to sequences of nodular limestones; thin bedded limestones; limestones with cephalopods, crinoids, graptolites; cherts, siltites, and black carbonaceous pelites with graptolites.

Hercynian orogeny brought about the complete re-arrangement of the Paleozoic litho-geostructural fabric. A regional metamorphism developed, ranging from green-schist *facies* to amphibolite *facies*, taking part in complex overthrusts: “internal nappes” (Gennargentu, southern Nurra) and “external nappes” (Goceano, Sarcidano, Quirra, Gerrei, Sarrabus, Arburese, Iglesiente-Sulcis p.p.) develop, but the thrusted and folded south-western Cambrian district is not involved. The emplacement of the Sardinian-Corsican composite batholith is the result of a broad, strong magmatic activity, with varied plutons from late-tectonic to post-tectonic phases: tonalites, granodiorites, monzogranites, leucogranites, accompanied by aplites, pegmatites, and a wide swarm of quartz porphyries and calc-alkalic basaltic dikes. A metamorphic aureole of variable size borders the igneous complex, giving rise at times to notable migmatites (Gallura, Baronie, Asinara).

A regional emersion follows the Hercynian cycle, underlined by rhyolite, rhyodacite, and andesite volcanics. The regional environment, lasting from the Upper Carboniferous to the Middle Trias, is marked by conglomerates, sandstones, siltites, with vegetable fossil remainders, anthracite lenses, and shales and cherty limestones.

The Mesozoic evolves from the continental-marine environment to a frankly marine environment. The Trias appears in “German” *facies*: dolomites, marly dolomites, marls, dolomitic limestones, and sandy limestones, with interbedded gypsum. The continental levels consist of important deposits of clays of limnic environment, and ferriferous laterites, followed by thick Jurassic-Cretaceous deposits of the carbonatic shelf, limestones, dolomitic limestones, oolitic limestones, marly limestones, and siliceous limestones; rich in fossils with littoral to bentonic fauna. In Nurra a wide bauxitic horizon corresponds to a sedimentation pause with a short emersion during the Upper Cretaceous.

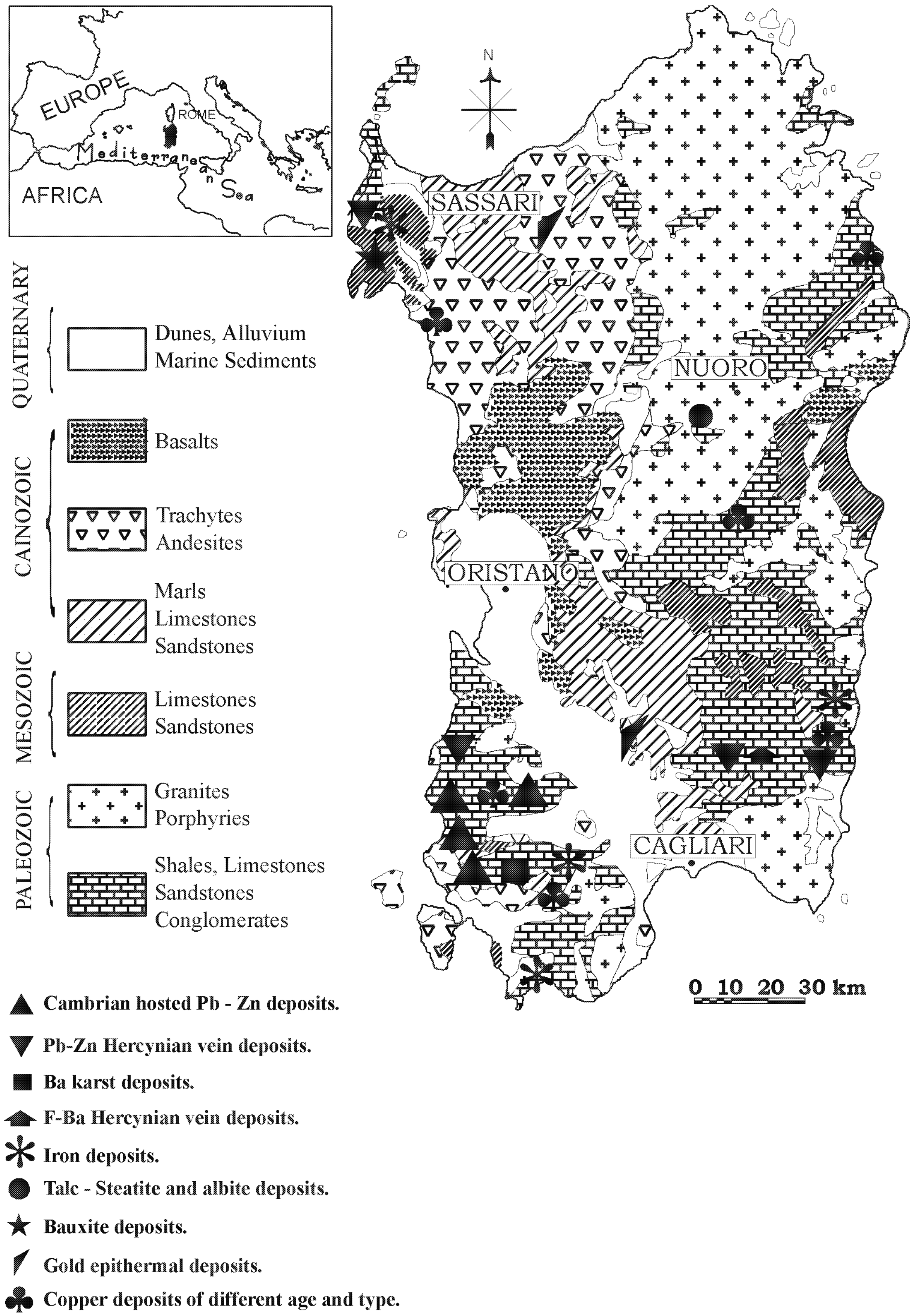

Fig. 1 - Schematic geologic outline and main ore deposits of Sardinia

The Cainozoic starts with sandstones and conglomerates, at once changing to limestones, marly limestones, marls, and clays. In Sulcis the sequence hosts the big lignite deposit. While the Sardinian Rift takes shape, as an easternmost arm of the complex rift system affecting the European plate in the Oligocene-Miocene, the Oligo-Miocene calc-alkaline volcanic cycle develops, accompanied by an intense hydrothermalism, with andesites, basaltic andesites, and rare basalts. Then rhyolites, rhyodacites, and minor comendites are emplaced. Overlying the volcanics continental deposits occur, represented by conglomerates, sandstones, siltites passing to littoral deposits (Ussana and Cixerri formations). Furthermore cherty limestones, argillaceous marls, sandstones; with interbedded tuffites.

The sedimentary Miocene is testified by marine deposits of medium-low depth, with marly sandstones, siltites, calcarenites; marls, arenaceous marls, sandstones, and sands; limestones, sheeted limestones, and microcristalline limestones of an evaporitic environment.

In the Pliocene-Pleistocene the remote repercussions of the Alpine tectonics are revealed by strong disruptive effects; among the major structures we mention the setting out of the Campidano trough, oblique to the Tertiary Rift, while volcanism resumes, with alkaline, transitional, and subalkaline affinity, with specialised displays: rhyolites and rhyodacites, rich in vitreous obsidian-perlitic *facies*; trachites, fonolites, tefrites; alkaline and transitional basalts, basanites, and trachibasalts overlying fluvial-lacustrine deposits.

We can conclude this brief outline recalling the detrital deposits of the alluvial, eolian, and beach systems, discontinuously covering all the oldest deposits.

3. The mineral deposits

Formations and geologic bodies, representing a great wealth of mineral resources that have been progressively recognized and exploited since the most ancient times, occur in the above historical frame. The reconstruction and interpretation of the events that caused and accompanied their beneficiation are an essential part of the Sardinian culture and mining tradition, that is always bound to a particular sensitivity for the natural environment hosting the mineralisation, whose position in the general geologic frame is both clarified and well documented today.

3.1. The Sardinian metallogenic province

The Sardinian metallogenic province is characterised by the predominance of lead-zinc-(silver) mineralisations, generally accompanied by quartz, barite, and fluorite in variable settings, and in bodies of different size and shape in the rocks of all types and ages from the Paleozoic to the Cainozoic. The constancy and persistence of these concentrations, which are genetically referable to different kinds of processes and phenomenologies, witness a continuous evolution, progressively inheriting and sometimes storing the characters of previous manifestations, starting from a *proto-ore* often difficult to interpret. Other elements may accompany the above substances, characterising the different metallogenic epochs, wich each time may take on important value locally. According to the framework outlined by Pretti *et al.* (1990), seven distinct metallogenic epochs are identified:

I) The *first metallogenic epoch* is characterised by the occurrence of mineralisations partially or totally bound genetically to the Cambrian sequence. They are residual (Fe) concentrations; evaporitic episodes (Ba); strictly *strata-bound* polymetallic (Pb-Zn-Fe; minor Cu) sulfides, with typical associations corresponding to specific stratigraphic levels, as it is demonstrated by the occurrence of massive pyrite-sphalerite concentrations at the footwall of the "Metalliferous" sequence (Campo Pisano, Antas), by the prevalence of sphalerite in the intermediate *facies* ("sphaleritic limestone": Monteponi, San Giovanni), and by the galena-sphalerite association in the upper horizons. A substantial witness of the effects of this precocious metallogenic epoch is given by the occurrence of limestone pebbles, with galena and pyrite spots in the footwall conglomerate of the Ordovician (Benz 1964, 1965), supplied by the erosion of the underlying Cambrian levels. Actually, the present attitude of the mineralised bodies should be related mainly to mobilisation and reconcentration phenomena, following the set up of the *protore*. The importance of this first epoch has been questioned recently on the ground of isotopic analyses, whose results could be interpreted in favour of rejuvenating the origin of at least part of the metals (Caron *et al.* 1997).

II) The *second metallogenic epoch* coincides with the phenomenologies promoted by the Sardinian Phase of the Caledonian orogenesis. Particular importance is given to this epoch as regards the origin of the Pb-Zn *protore*, according to recent isotopic interpretations (Caron *et al.* 1997), which would point out the Cabitza slates and the Ordovician conglomerates as probable major lead suppliers of Cambrian hosted mineralisations. It is indeed an epoch of great importance, also marking the arrival of fluorine, which appears for the first time with the fluorite in the mineral paragenesis of the paleokarsts in the Cambrian carbonatic rocks, just at the footwall of the Cambro-Ordovician unconformity, in agreement with the transcurrent *rifting* phase development proposed by Vai (1982) (Punta Nebidedda type).

III) The third metallogenic epoch can be placed between the Upper Ordovician and the Lower Devonian. At the origin of the present mineral bodies, the proto-ores referable to this epoch are represented by sedimentary and volcano-sedimentary mineralisations:

i) Pb-Zn-Ag-F-Ba paragenesis: the Sarrabus "silver lode", strictly *strata-bound* within the horizons of the "Serra S'Ilixi Group". Ni,Co,Sb,As sulfides and sulfosalts participate in the paragenesis, and locally gold may also be present;

ii) Sb-W-(Au): Silurian of Villasalto (Su Suergiu and Martalai), Ballao (Corti Rosas);

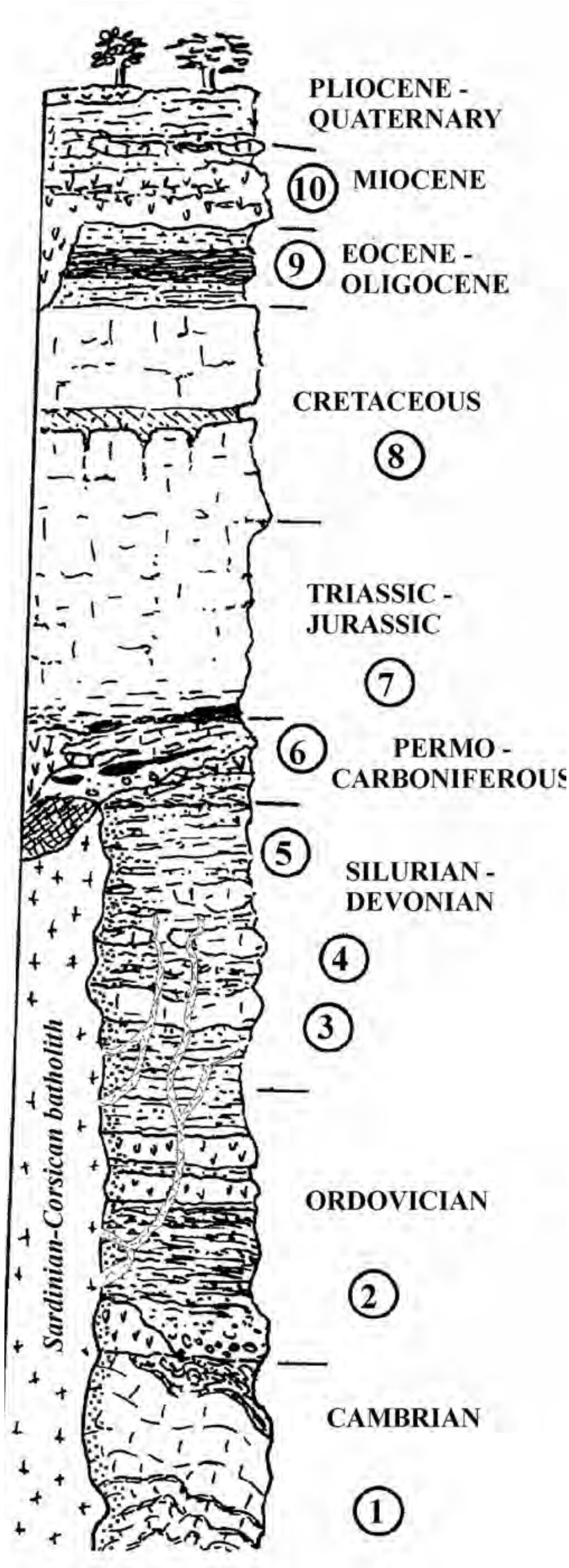

Fig. 2 - Schematic outline of the Sardinian ore deposit distribution.
1 : Pb-Zn-(AG); Ba; Fe; in variable attitude in the Cambrian levels. 2 : Ba-F-(Pb, Zn, Ag) karst fillings in the Cambrian limestone at the Ordovician footwall.Pb-Zn-Ag-Ba-F vein deposits. 3 : Pb-Zn-Ag-Ba-F; Ni-Co; Sn, As; Mo, W; Sb,W, (Au); Sb; As-Pb-Zn-Cu-Au vein deposits. Fe-Zn-Pb-Cu-(Au) mixed sulfides in skarn and lenses. 4 : Magnetite, with garnets, fluorite, scheelite deposits. Nurra oolitic iron. 5 : Talc, albitites; pegmatites. 6 : Anthracite. 7 : Limnic continental deposits at the footwall of the “tacchi” (remains of the Mesozoic carbonatic shelf) : lateritic Fe, refractory clays. 8 : Bauxite. 9 : Subbituminous coal. 10 : Hydrothermal products of the calc-alkaline volcanism : epithermal gold deposits; bentonites; kaolin. Siliceous-feldspathic sands.

iii) Fe: Nurra oolithic iron;

iv) polymetallic sulfides: a great number of lens-shaped, stratiform, and concordant deposits with massive Fe-Zn-Pb-(Cu) sulfides often gold-bearing (low grade, Correboi type).

IV) The *fourth metallogenic* epoch coincides with the Hercynian orogenesis, and it is linked to its conspicuous magmatic activity and to the related regional and thermal metamorphic processes. It was the engine of a number of processes, giving rise to several types of mineral deposits. We may list the mobilisation and reconcentration processes within the pre-existing *protores*, producing the mineral bodies as they occur at present (Monteponi type), according to the new tectonic fabric; the emplacement of hydrothermal mineralisations of different thermal level in the wide vein swarm, everywhere crossing the crystalline basement; and the products of thermometamorphic activity related to the intrusion of the different plutons that belong to the composite Sardinian-Corsican batholith. Therefore this epoch comprises:

i) the massive ore-bodies hosted by the Cambrian "Metalliferous" carbonatic sequence (Monteponi type), whose *protore* should still be referred to as originating in the 1st metallogenic epoch, while at least a part of the mobilisation and reconcentration processes must be assigned to the subsequent 5th metallogenic epoch;

ii) the hydrothermal vein deposits with base metals and industrial minerals. Some of these gave the greatest contribution to the Sardinian mining industry: such as Montevecchio and Ingurtosu, which offered an aggregate amount of 50-60 Mt of crude ore @ 10-11% Pb+Zn, with 500-1000 g/t Ag/Pb and 1000 g/t Cd/Zn. Still active and of great importance is the Genna Tres Montis (Silius) deposit, whose original reserves were 30 Mt of CaF_2 + 15 Mt $BaSO_4$ + 1.5 Mt PbS. Sulfide parageneses with major arsenopyrite, and gold are typical of some vein deposits, the most important being part of the Baccu Locci (Villaputzu) deposit;

iii) polymetallic (Fe-Zn-Pb-Cu) sulfides (Funtana Raminosa type), and iron oxides (magnetite, locally with fluorite, scheelite, wollastonite: San Leone type, today depleted) in skarns;

iv) *greisen* type deposits, with molibdenite, chalcopyrite, wolframite, (cassiterite);

v) talc-steatite deposits (Orani type) still exploited, which were the former suppliers of soapstone for metallurgical moulds, and the nearby sodic feldspar deposits (albitites) nowadays the producers of raw materials for ceramics;

vi) aplo-pegmatite and pegmatite dikes, lenses, and stockworks, normally belonging to the muscovite class, sometimes to the miarolitic class, exceptionally to the rare elements class (LCT family), showing a paragenesis with tantalite, lepidolite, and phosphates of the alluaudite series (Pani, Valera 1993). Their size is generally small, except the big Asinara (Sassari) aplo-pegmatite bodies;

vii) dikes of pegmatitic-pneumatolithic to transitional pneumatolithic environment, with As, Ni-Co, W, Sn, Mo mineralisation. In the past these small deposits were open to some exploitation activity, e.g. Perda Majori (Villaputzu), Punta Santa Vittoria (Fluminimaggiore) and Perd'e Pibera (Gonnosfanadiga);

viii) mineralised bodies of various shape and size, due to intense mobilisation and reconcentration processes of the *proto-ores* or of original concentrations of less importance. As an example we may mention the Sarrabus "silver lode", strictly *strata-bound* in the "Serra S'Ilixi Group" horizon, cropping out for a length of more than 30 Km. This lode occurs as a sequence of well conformable, E-W striking vein-shaped bodies, cutting across the big Hercynian quartz porphyry dikes that strike NNW-SSE, which in turn cross the mineralised belt (Valera 1974).

Actually, in some cases (e.g. i) the tie between ore bodies and granitoids is not so sharp. It is particularly evident in the case of the hydrothermal fluorite-bearing mineralisations and the leucogranitic *facies*.

V) The *fifth metallogenic epoch* can be considered a consequence of the processes started by the post-Hercynian peneplain development, which promoted weathering, mobilisation, and reconcentration processes of the pre-existing mineralisations hosted in the crystalline basement. We can distinguish:

i) iron ores in residual deposits, still surviving below the protection of the remains of Mesozoic sedimentary cover ("Ferro dei Tacchi", "Tacchi Iron" as they are called locally) in the Ogliastra area, and/or clays for refractories of limnic environment (Laconi type), and quartz-only conglomerates. Iron was exploited during the war times, whereas clays are still produced in several mining units;

ii) Fe, Pb, Zn oxidized ores and barite in karst accumulation;

iii) repeated and strong supergene mobilisation in the already formed Pb-Zn-Ag ore deposits, particularly clear in the Sarrabus "silver lode".

VI) The *sixth metallogenic epoch* is responsible for the big Nurra bauxite deposit formation, of Upper Cretaceous age, tonnage 70-80 Mt, grading up to 60-62 % Al_2O_3. A stimulating hypothesis (Rizzo 1994) suggests that marine waters overlying the region for a long time during the Mesozoic era could be involved in the hydrothermal fluids that originate the Orani albitites (type iv) of the 4th metallogenic epoch). According to this hypothesis the Orani albitites could therefore be genetically assigned to the 6th metallogenic epoch.

VII) The *seventh metallogenic epoch* terminates the schematic history of the Sardinian ore deposits, with the events that accompany Alpine tectono-magmatic activity. The following stages can be assigned to these events:

i) porphyry copper deposits. The best known is that of Calabona (Alghero) related to a grano-diorite cupola;

ii) gold deposits associated with epithermal systems, recently discovered and under exploitation today, bound to Miocene volcanics (Furtei type);

iii) sulfide and oxidized ores scattered in the Miocene pyroclastics, without any economic interest not even in the most ancient times;

iv) ochers and manganese ores, frequently enriched by supergene processes, bound to Oligocene-Miocene volcanics in the island of San Pietro and in NW Sardinia;

v) kaolin, bentonites, and alunite, derived from different alteration processes developed in the same Cainozoic volcanics, and occurring all over Tertiary Sardinia, feeding frequent open pit mining activities especially in the Romana-Cossoine district (Sassari);

vi) fluorite mineralisation, hosted by the fractures of the Sardinian Tertiary rift systems, particularly evident in the Grighini district (Oristano), at times sites of mining activity in the past (Monreale and Perda Lai, Sardara), witnessing the importance of hydrothermal circulation developed by Alpine tectonics. Fluorite linked to Miocene volcanics was explored at nuraghe Onigu (Masullas), whereas simple indications occur in the fractures cutting across the Monte Cardiga Eocene sandstones, that belong to the Alpine system affecting the western coastal fabric of the island.

3.2. Industrial minerals and rocks

The importance of the mining activity in industrial minerals and rocks calls for a few comments on these georesources. Many minerals already appear in the history of metallogenic epochs above, and some, such as barite and fluorite, participate directly in the events that characterise the development and evolution of lead-zinc mineralisations. Some remarkable georesources, which deserve proper consideration, have not been mentioned. It is particularly interesting to recall the sources of intense mining activity represented by the perlites of Monte Arci (Oristano), corresponding to the same lava levels that host the obsidian, whose industry long characterized the prehistory of Sardinia. Moreover, siliceous-feldspathic sands are exploited at Florinas (Sassari) today, and ornamental building stones are produced from granites and from Mesozoic limestones in the northern part of the island, while Paleozoic marbles do not have any economic interest.

3.3. Fossil fuels

In the geologic history of Sardinia two periods favoured the necessary conditions for the formation of fossil fuels: the Lower Permian, with the little anthracite basin of Seui, and the Eocene, with the large basin of subbituminous coal in SW Sardinia. The former was rapidly depleted during the war time, whereas the latter is still being studied for problems related to the economy of its exploitation. It is of enormous size (500 Mt), but it is polluted by a high sulphur grade, with the result that it cannot be exploited due to its environmental impact.

3.4. Geothermal energy and waters

The fracture system responsible for the opening of the Sardinian Tertiary Rift, which has been mentioned above as a site of recent hydrothermal circuits, and is in turn responsible for the emplacement of some fluorite mineralisation, is still followed by a flow of thermal waters. Such a flow is clearly fed by the same sources, at least as a long final tail, so that it often shows very anomalous fluorine contents. Thermal waters, known and appreciated since the ancient times, still supply some spas today.

We complete our scenario by quoting the oligomineral water springs, which can at least partly be referred to as being supplied by the same circuits. The mineral waters industry is well and thriving, and covers a good deal of the island's needs.

4. Conclusions

Sardinian geological history, and its fall-out on the occurrence of the many different types of mineral deposits as summarized above may be used as background for the interpretation of the Sardinian mining history from the very beginning. Actually the island's range of georesources can be considered sufficient to have satisfied its requirements almost completely as they appeared with the development of civilization. Cherts and obsidian, clays and soapstone, copper, lead, and silver, were found and exploited by the locals, who immediately used the minerals, and exchanged them within the country, and overseas. Only few substances had to be brought from abroad, chiefly gold and tin, which though existing on the island, could not be recovered because of lack of technology, which only today is available.

The seven metallogenic epochs left traces of various shapes and sizes. Some of them can be considered true mineral deposits, while a multitude of indications occur everywhere, not only in the crystalline basement. The main ore deposits have been exploited until recent times, and most of them are totally depleted today. Nevertheless, the Sardinian mining history and tradition are still alive, and it is quite common to find their imprint in the natural environment: traces of the first approach to the first digging of the georesource, next to the last works for its large exploitation.

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2.
SARDINIAN ORE DEPOSITS AND METALS IN THE BRONZE AGE

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Alessandro Rivoldini

1. Introduction

A geological outline of Sardinia (see Part II, chapter 1) shows a wide choice of georesources, both metalliferous and non, which were certainly well known to the inhabitants from remote times. The archaeological finds witness the fast attainment of a remarkable improvement in the recognition and in the experimentation of various mineral species. Lithoid materials: flintstones, obsidian, alabaster, soapstone, clays for pottery etc. were soon appreciated and used according to their physical-petrological properties (hardness, plasticity, compactness, homogeneity, polishing etc.), and it is clear that the metalliferous ores were soon beneficiated, both on account of their peculiar properties (weight, colour, brightness), and because they were abundant. The lead sulfide, brilliant heavy galena, so widespread in the crystalline basement of the island, is the best example.

Mineral resources, representing important exchange commodities, probably shared in the establishment of a primitive economic system, well outside the original districts of occurrence. Obsidian artefacts from the extinct volcano of *Monte Arci* (Oristano), which perhaps supported the island in the primitive Mediterranean network, occur all over Sardinia and in various Mediterranean sites. We may imagine that the managers of such a network, skilled and expert in the evaluation of mineral raw materials, soon became aware of the importance of the jewel-case that was the Paleozoic igneous-metamorphic complex of Sardinia, attracting towards the island the attention of metal diggers.

The appearance of the first metal objects (copper, silver), and traces of their local treatment are attributed to the Ozieri culture (second half of IV millennium B.C.) (Ugas in Lo Schiavo 2000). The origin of the metal is unsolved, it is reasonable however to imagine that metal objects at least initially were treated as samples, a kind of “business cards”, by voyagers and explorers, perhaps themselves “itinerant smiths” (Braudel 1998). We may assume that the evolution of the use of metal in Sardinia started with the arrival of news accompanying these peculiar goods on the island (e.g. the Beaker torques of *Gonnostramatza*: Lo Schiavo 1996; Cincotti 1998), which rapidly enhanced the exploitation of local minerals, soon recognized and reported. Based on the lead isotope ratios of lead scraps from archaeological sites of certain origin testifying to their Sardinian origin (see *infra*), this can be stated with certainty about lead, while tin, gold, and largely copper were still imported.

The history of silver is less documented. On account of its characteristics, however, it probably followed the same fate as lead, only perhaps a little later. It is a fact that the competition for the control of resources, culminating in the war between Rome and Carthage, is likely to have developed not only for the possession of lead, but also for other commodities (e.g. the wood of the large forests), and it is not inappropriate to suppose that it was precisely for silver, which was certainly already known as wealth of the island at that time.

2. Historical notes on Sardinian mineral raw materials

The main lines of the history of mineral use in Sardinia have already been outlined (Lilliu 1986, 1988; Lo Schiavo 2000). The starting point is given by the flint artefact finds at *Perfugas* (more than 150.000 years ago; Lower Paleolithic, Clacton, Riss). The first pottery is assigned to the Lower Neolithic (VII millennium B.C.). Various lithologies follow: limestone, sandstone, crystalline schists, marble, trachite, granite, alabaster, and steatite are the most widely used types. The highest point of the lithic industry is reached with the *Monte Arc*i obsidian mentioned above. Wherever one walks about in Sardinia, one very frequently meets obsidian splinters and tool fragments (pl. I, 2) also in completely foreign contexts, such as the geological environments far from the Monte Arci, shaped in the Paleozoic christalline basement, in witness of one of the most ancient human industries. This precious volcanic glass supplied a rich network of commerce, leaving certain evidence in a number of sites overseas, from the Po Valley to Catalonia.

For an appraisal of the knowledge of the Sardinian wealth of mineral raw materials in ancient times, we must refer to the testimony of the authors that first collected data and documents on this subject. Three among these are important: Baldracco (1854), Marchese (1862), and Goüin (1867). Baldracco in particular compiled a detailed and reasoned inventory of the known mineralisations, which he visited, analysed, and appraised personally, including also those that were more difficult to reach. It is important to point out preliminarly a fact that emerged from these writings: *i.e.* that by very old tradition, the mine and the site where the ore was dressed were one and the same place. Only in the case of lack of fuel (e.g. a region without vegetation) or of water, could the dressing plant be located away from the place of exploitation. This could justify the fact that slags or crude ore were very rarely found in or around the settlements, where the metals were still worked to produce weapons, tools etc., starting from ingots or precious scraps. Therefore going back to the nuragic age, though remote, we may recognize the roots of the above mining tradition, which was certainly handed down in time without any significant changes. This can be also seen comparing remains from ancient mining sites such as Laurion, or descriptions recorded by "intermediate" authors such as Pliny and George Agricola: cupellation is the best example.

As stated above, the Ozieri culture is assumed to be the starting point of the first perception and exploitation of Sardinian lead and copper ores, silver being limited by the mastery of the technology of cupellation. Actually, argentiferous galena was the only available silver ore, since the *stricto sensu* silver minerals were not accessible in ancient times (see *infra*). As regards tin we shall demonstrate that it is unlikely to have been obtained from any mineralisation on the island. We are therefore forced to refer to the trade routes for its supply from the rare, far away deposits already known from ancient times. Tin was considered a precious metal (Valera, Valera 2003) (see Part IV, chapter 6.1), and its value depended, largely, precisely on the distance between known deposits and users. The closest tin districts to Sardinia geographically correspond to the area of Monte Valerio (Tuscany), and to the region of Castilla y León (Spain).

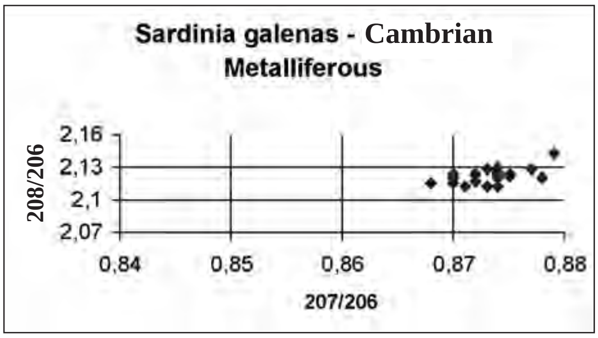
Gold also was unavailable in Sardinia, as its very low-grade ore deposits, discovered recently, can only be beneficiated with cianidation technology. As we shall see later, it is only recently that Sardinia proved to be a metallogenic province also for gold. In fact gold is so finely dispersed in its host rock, that is often called "invisible gold". The provisions issued in the constitutions of Valentinian, Valens, and Gratian (369-378 A.D.) (Lilliu 1986) against the so called "*metallari aurileguli*" (gold diggers) seem to deal with problems of general security, and imperial competence or monopoly, rather than with the illegal acquisition of the precious metal, which could not even be seen, or recovered at that time in those conditions. Nor should it be underestimated that no stories or traditions referring to gold in Sardinia actually exist: this fact would have been very strange, if there had been any mention of it at all, even in ancient times. Only De Vargas-Bedemar (1806) supports a thesis in favour of the existence of gold in Sardinia, when he quotes the placename "*Logudoro*" (logu-d-oro = site-of-gold) a province in the north of the island, a supposed analogy with the gold mineralisations in Piedmont (northern Italy), and the existence of a Sardinian goldsmith's art that is kept alive by local mines, "which have never been disclosed". In these conditions it can be excluded that the few known very ancient gold objects were produced locally, e.g. the mentioned torques of Beaker culture from Gonnostramatza, and the Su Benatzu sheet dated Final Bronze – Early Iron age (Lo Schiavo, Usai 1995).

The nuragic culture flourished in the Bronze age with an intense development of mining and metallurgic activity. Copper and bronze objects, salvage scraps, oxhide and bun ingots, and working tools witness the mastery, and the diffusion of technologies for the treatment of metals. The exploitation of Sardinian ores is proved by the large amount of lead scraps from several different uses found everywhere: pottery repairs, clamps connecting stone blocks in particular buildings, and casts to fix bronze figurines and sword blades to the "Tables of Offerings" (Valera *et al.* 2002). Lead is also contained in variable grades, often remarkable, both in copper and tin alloy pieces. The Sardinian origin of this lead is demonstrated by isotopic ratio fingerprints, which are typical of the island's Pb ore deposits, and cannot be mistaken for any other reasonably accessible deposit in the Mediterranean region. The fact that lead comes from many sources in this area has been clear since the first studies on this subject (Dayton 1984). It is worth mentioning the case of the ingots belonging to the wreck of the island of Mal di Ventre (first half of the 1st century A.D.) (Alessandrello *et al.* 1991), mostly bearing the *PONTILIENI* mark. Pinarelli *et al.* (1995) quote the lead isotopic ratios measured in these ingots, and compare them with the ratios obtained analysing both finds from south Sardinia, and an ingot from *Villasimius* (Cagliari), bearing the *M. PONTILIENUS* mark. According to the results the authors ascribe the origin of the Mal di Ventre and *Villasimius* ingots to the Miocene galenas from south-western Spain, whereas the other finds are characterised by the isotopic ratios typical of the Iglesiente (SW Sardinia) Cambrian galenas (see *infra*).

3. The lead isotopic ratios in Sardinian ores and metals

The reliability of the method based upon the lead isotope ratios is widely verified and accepted (Budd *et al.* 1995; Stos-Gale *et al.* 1995). An extensive scientific literature has long confirmed their use solving problems related to dating and the characterisation of ores and metals. On account of the wealth and abundance of lead bearing mineralisations in Sardinia, which are clearly evident everywhere in the striking aspect of the galena, the ubiquitous lead sulfide (pl. II, 1 and 2), and the comparative frequency of cupriferous occurrences (often inappropriately called "ore deposits" by the non-specialised literature), a great deal of data has been collected and published, and are now available for critical analysis and comparison. Thanks to a careful assessment, processing, and comparison with the results of analyses carried out on new, well-planned sampling sets, the above data were used to identify two lead-bearing families, whose isotope ratios fall into well-differentiated fields. We propose (Valera *et al.* 2002) a simple classification: Cambrian deposits (fig.1, tab.1), and Hercynian vein-type (fig. 2, tab. 2), while a third family, consisting of *strata-bound* polymetallic mixed sulfides (fig. 3, tab. 3), genetically complex, and chronologically arranged in a long time span, shows extremely variable lead isotopic ratios. This time span covers the genetic-evolutionary history of most of the metals exploited in Sardinia, from the oldest levels (Cambrian) up to the end of the Hercynian metallogenic processes (Permian-Triassic) (fig. 4, tab. 4).

Representativeness of our ore samples is guaranteed by our severe observance of the basic sampling principles and methods, supported by a multidecennial experience on the studied mineral deposits, and strengthened by the meaningful checks available in the by now vast literature.



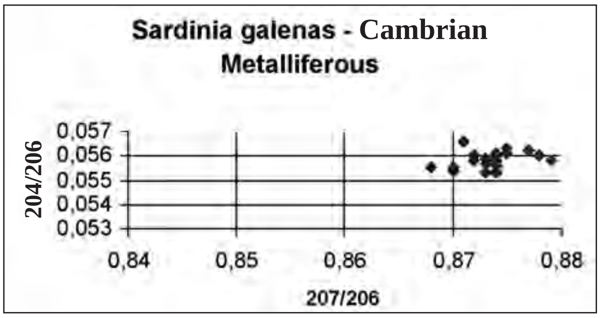


Fig. 1 – Lead isotopic ratios of galena from Cambrian sulfide mineralisations. The shifting towards the Hercynian vein field is due to the "Silver Rich" ores of the S. Giovanni mine, whose evolution accounts for mobilisation processes with later contributions compared to the early emplacement phases.

Tab. 1 - Lead isotopic ratios of the Cambrian "Metalliferous" Complex galenas.

Sample	Pb 208/206	Pb 207/206	Pb 204/206
S. Giovanni, Ag-Rich - A	2.116	0.868	0.0555
S. Giovanni, Ag-Rich - B	2.112	0.871	0.0566
S. Giovanni, Ag-Rich - C/1	2.128	0.873	0.0553
S. Giovanni, Ag-Rich - C/2	2.124	0.87	0.0555
S. Giovanni, Ag-Rich - D	2.116	0.87	0.0554
S. Giovanni, Ag-Rich - E	2.12	0.87	0.0554
Monteponi, Cungiaus open pit - 1	2.121	0.874	0.0558
Monteponi, Cungiaus open pit - 2	2.118	0.872	0.056
Monteponi -200, Monsignore stope	2.123	0.875	0.0563

Monteponi, main gate outcrop	2.123	0.872	0.0558
Acquaresi –10 lev.	2.128	0.877	0.0562
Masua,"Massa Marx"	2.125	0.874	0.0558
Tiny (cerussite)	2.12	0.878	0.056
S.Giorgio, Pisan excavation, border	2.112	0.874	0.0556
S.Giovanni, "Massa Pozzo 2", from +6 to +30	2.13	0.874	0.0553
S.Giovanni, West Contact, -42	2.129	0.873	0.0557
Gutturu Pala, base level exploitation	2.143	0.879	0.0558
Gutturu Pala, base level adit	2.13	0.874	0.0561
Su Corovau, lower level	2.124	0.874	0.056
S.Benedetto, Coremò IV	2.122	0.875	0.0561
Reigraxius, base level dump	2.113	0.873	0.0559

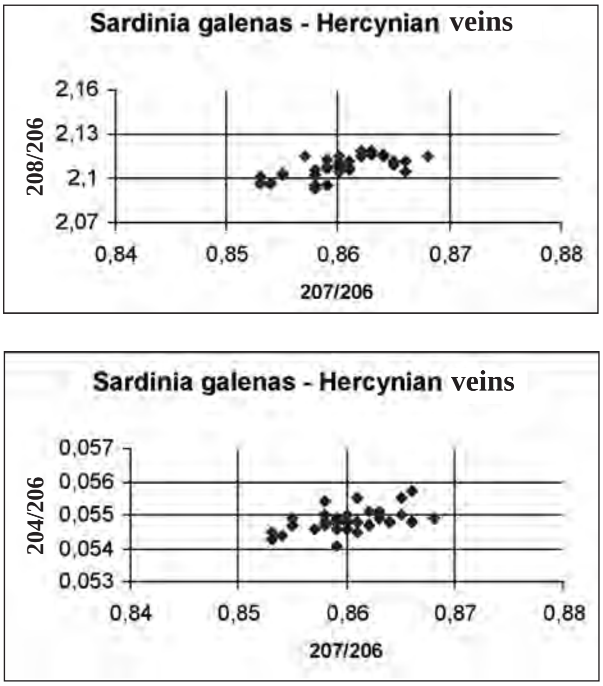


Fig. 2 – Lead isotopic ratios in galenas from post-Cambrian vein mineralisations, with typical quartz-fluorite-barite-carbonates-base metal sulfide parageneses. The hydrothermal metallogeny bound to the Hercynian magmatism is prevailing, with early and late contributions mirrored by the distribution of the values.

Tab. 2 - Lead isotopic ratios of the Hercynian vein galenas.

Sample	Pb 208/206	Pb 207/206	Pb 204/206
Silius, 230 lev.	2.107	0.859	0.0541
Silius, 230 lev., 20 m more to the West	2.115	0.862	0.0547
Silius outcrop	2.11	0.86	0.0546
Silius, 150 lev., rise 7 W	2.111	0.866	0.0548
Silius, 200 lev., I sublev.	2.103	0.855	0.0549
Filone Palazzo outcrop	2.118	0.862	0.0551

Filone Palazzo, I lev.	2.115	0.868	0.0549
Correboi outcrop	2.093	0.858	0.055
Correboi, Upper lev.	2.095	0.859	0.0549
Correboi, middle dump	2.102	0.855	0.0547
Correboi, base dump	2.102	0.858	0.0547
Serra S'Ilixi, easternmost adit	2.101	0.853	0.0545
Serra S'Ilixi, adit near the deck	2.096	0.854	0.0544
Tuviois	2.097	0.853	0.0543
Baccu Locci, outcrop	2.115	0.864	0.0548
Baccu Locci, S. Riccardo	2.106	0.861	0.0545
S'Ortu Becciu	2.106	0.861	0.0548
Sos Enattos, Tuppeddu	2.108	0.859	0.0546
Argentiera	2.115	0.857	0.0546
Montevecchio, S.Antonio, outcrop	2.105	0.866	0.0557
Montevecchio, Piccalina 1, outcrop	2.107	0.861	0.0555
Montevecchio, Piccalina 2, outcrop	2.106	0.858	0.0548
Montevecchio, Piccalina 3, outcrop	2.105	0.86	0.055
Montevecchio, Sanna, S.Barbara lev.	2.116	0.863	0.0549
Montevecchio, Sanna 1 (DIGITA)	2.116	0.864	0.0548
Montevecchio, Sanna 2, outcrop	2.115	0.86	0.055
Montevecchio, Sanna 3, outcrop	2.105	0.86	0.0548
Montevecchio, Sanna 4, outcrop	2.119	0.863	0.0551
Montevecchio, Sanna 5, outcrop	2.119	0.863	0.0549
Montevecchio, Sanna 6, gossan	2.112	0.865	0.055
Montevecchio, Sanna 7, outcrop. W	2.109	0.865	0.0555
Montevecchio, Sanna 8, outcrop. W	2.095	0.858	0.0554
Canali Serci, Madama lev.	2.111	0.861	0.0545
Canali Serci, S.Sisinio S lev.	2.108	0.86	0.0546
Canali Serci, S. Sisinio N lev.	2.113	0.859	0.0548

Regarding a classification of the Sardinian mineral deposits, Pinarelli *et al*. (1995) differentiated Cambrian and Ordovician mineralisations, while Ludwig *et al.* (1989) differentiated further among Cambrian "*stratabound*" deposits, Ordovician deposits, "Funtana Raminosa" deposits, vein deposits, Hercynian contact-metamorphic deposits, and "karst-fill" deposits. However this classification could become even more detailed in its metallogenic phases (see Part II, chapter 1), in order to allow greater precision in the picture of ore deposits, and supply criteria for a sistematic distinction with which to search for a genetic fingerprint in ancient lead finds. To this purpose and relying on the experience acquired analysing the collected data, we believe our proposed subdivision sufficiently satisfys the requirement of an adequate method for the recognition of the origin of nuragic leads, and needs no further distinction.

As a matter of fact, the comparison of the data classified here with those obtained from an analysis of Pb scraps from nuragic sites from different parts of Sardinia (fig. 5 – 14, tab. 5 - 14)[1], shows a clear preference for minerals originating in the Cambrian hosted ore deposits. Also in this case based on the following considerations we point out the representativeness of the analysed samples:

- population homogeneity: the samples only refer to metal lead;

- random sampling: the fragments are never selected or characterized by place of origin according to the single sites, where in certain cases (e.g. nuraghe Arrubiu) they were found stored in hoards under collapse;

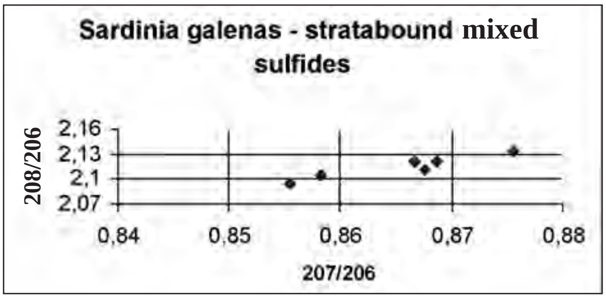
- Sardinian population of ore deposits. They do not cause anomalous distributions, and highlight and clearly circumscribe dissimilar or foreign elements;

1- All measurements were made by quadropole ICP-MS on sample solutions, obtained by ultrapure nitric acid digestion. Uncertainties (RSD %) for individual measurements are <0.5 %, and accuracy <1 %. The values are based on the NBS "Common Lead Isotopic Standard" (NIST SRM-981).

- the samples come from 11 different sites mostly located in the middle of the island, except for a few, which were provided by the Archaeological Museum of Cagliari. The number of samples varies from site to site, and only in 2 cases (S'Arcu 'e is Forros; Villasor) they were so few that they can only be considered simply as a record. These cases however are not very different from the above general picture, which is dominated by the leads marked "Cambrian";

- the relatively homogeneous silver content of the leads in each of the sites, even with marked differences from site to site, shows that the sampling fully represents situations characterized by homogeneous supply. Nevertheless the same sampling (the case of Abini) also shows the coexistence of leads that underwent at least 2 different grades (processes) of desilveration, which means that they could derive from at least 2 different supply phases.

The above confirms that the method is valid, and that the results are correct, though it cannot be considered an ultimate exhaustive answer to the many unsolved problems. Only by analysing a greater number of populations and sites, will it be possible to strengthen this documentation and increase its reliability, while for the time being, it should be considered at a preliminary stage, though concrete.



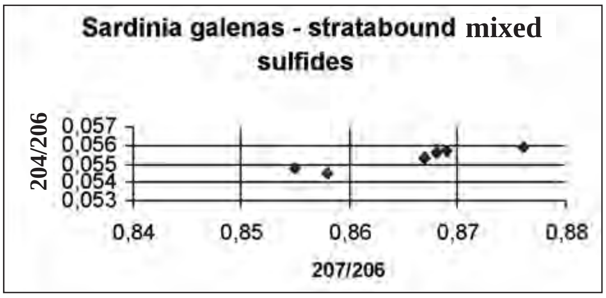
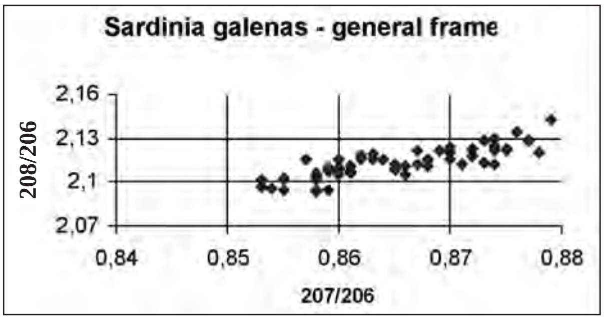


Fig. 3 – Lead isotopic ratios in galenas from some "stratabound" mineralisations occurring in levels ascribable to the Silurian (III metallogenic epoch).

Tab. 3 - Lead isotopic ratios, and silver grade of the stratabound polimetallic mixed sulfides.

Sample	Pb 208/206	Pb 207/206	Pb 204/206	Ag ppm
Torpè, Canale Barisone	2.111	0.868	0.0556	
Correboi, mixed sulfides (below road)	2.134	0.876	0.0559	170
B.Locci, stratabound mixed sulf., hand sample	2.104	0.858	0.0545	
Rio su Poru (Gremanu), mixed sulfides	2.121	0.867	0.0553	
Correboi, mixed sulfides lens, along road	2.094	0.855	0.0548	
Funtana Raminosa (DIGITA)	2.122	0.869	0.0557	



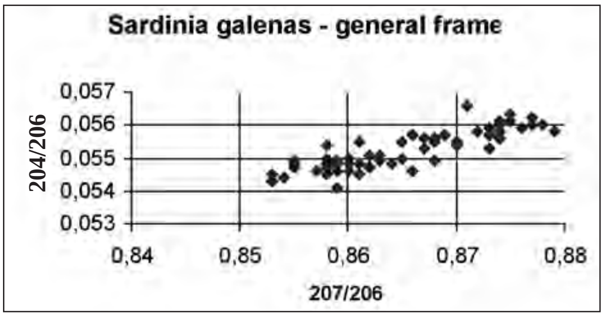


Fig. 4 – General frame of lead isotopic ratios in Sardinian galenas. Their attitude underlines the progressive evolution of the settlements, from the most ancient levels (Cambrian) to the end processes of the Hercynian metallogenesis, with the contribution of the different metallogenic epochs.

Tab. 4 - Overall list of the isotopic ratios in galenas from the different Sardinian ore deposit types.

Sample	Pb 208/206	Pb 207/206	Pb 204/206
Silius, 230 lev., S.Giuseppe ?	2.107	0.859	0.0541
Silius, idem, 20 m more to the West, S.Giuseppe ?	2.115	0.862	0.0547
Silius outcrop (office gate; S.Giuseppe ?)	2.11	0.86	0.0546
Silius, 150 lev., rise 7 West	2.111	0.866	0.0548
Silius - 200 lev., I sublevel	2.103	0.855	0.0549
Acquaresi -10 lev.	2.128	0.877	0.0562
Monteponi -200, Monsignore stope	2.123	0.875	0.0563
M.Poni, main gate outcrop	2.123	0.872	0.0558
Masua, Massa Marx	2.125	0.874	0.0558
Filone Palazzo, I lev.	2.115	0.868	0.0549
Filone Palazzo outcrop	2.118	0.862	0.0551
Tiny, cerussite	2.12	0.878	0.056
Correboi, middle dump	2.102	0.855	0.0547
Correboi, base dump (pebble)	2.102	0.858	0.0547
Correboi outcrop, ex Correboi 1	2.093	0.858	0.055
Correboi Upper lev. ex Correboi 2	2.095	0.859	0.0549
Serra s'Ilixi, easternmost adit, sorting	2.101	0.853	0.0545
Serra s'Ilixi, adit near the bridge, sorting	2.096	0.854	0.0544
Tuviois, near the houses, sorting?	2.097	0.853	0.0543

S S.Giorgio, Pisan excavation, border	2.112	0.874	0.0556
S.Giovanni, “Massa Pozzo 2”, from +6 to +30	2.129	0.877	0.056
S.Giovanni, West Contact -42	2.129	0.873	0.0557
B.Locci, S.Riccardo (sample 1SR)	2.106	0.861	0.0545
B.Locci, outcrop	2.115	0.864	0.0548
Gutturu Pala, base lev. exploitation	2.143	0.879	0.0558
Gutturu Pala, Base lev. adit	2.13	0.874	0.0561
Su Corovau, lower lev.	2.124	0.874	0.056
Reigraxius, Base lev. dump	2.113	0.873	0.0559
Reigraxius, Silver Vein	2.112	0.867	0.0556
S. Benedetto, Coremò IV	2.122	0.875	0.0561
S'OrtuBecciu, 60 m below outcrop (DIGITA)	2.106	0.861	0.0548
Sos Enattos, Tuppeddu vein	2.108	0.859	0.0546
Argentiera	2.115	0.857	0.0546
S. Giovanni. Ag-Rich - A	2.116	0.868	0.0555
S. Giovanni, Ag-Rich - B	2.112	0.871	0.0566
S. Giovanni, Ag-Rich - C/1	2.128	0.873	0.0553
S. Giovanni, Ag-Rich - C/2	2.124	0.87	0.0555
S. Giovanni, Ag-Rich - D	2.116	0.87	0.0554
S. Giovanni, Ag-Rich - E	2.12	0.87	0.0554
Cungiaus open pit - c.1	2.121	0.874	0.0558
Cungiaus open pit - c.2	2.118	0.872	0.0558
Canali Serci Madama lev.	2.111	0.861	0.0545
Canali Serci S.Sisinio South lev.	2.108	0.86	0.0546
Canali Serci S. Sisinio North lev.	2.11	0.859	0.0548
Montevecchio, S. Antonio vein, outcrop	2.105	0.866	0.0557
Montevecchio, Piccalina 1 vein, outcrop	2.107	0.861	0.0555
Montevecchio, Piccalina 2 vein, outcrop	2.106	0.858	0.0548
Montevecchio, Piccalina 3 vein, outcrop	2.105	0.86	0.055
Montevecchio, Sanna vein, S.Barbara lev.	2.116	0.863	0.0549
Montevecchio, Sanna1 vein (DIGITA)	2.116	0.864	0.0548
Montevecchio, Sanna 2 vein, outcrop	2.115	0.86	0.055
Montevecchio, Sanna 3 vein, outcrop	2.105	0.86	0.0548
Montevecchio, Sanna 4 vein, galena+barite	2.119	0.863	0.0551
Montevecchio, Sanna 5 vein, outcrop	2.119	0.863	0.0549
Montevecchio, Sanna 6 vein, gossan	2.112	0.865	0.055
Montevecchio, Sanna 7 vein, West outcrop	2.109	0.865	0.0555
Montevecchio, Sanna 8 vein, West outcrop	2.095	0.858	0.0554
Torpè, Canale Barisone	2.111	0.868	0.0556
Correboi, mixed sulfides (below road)	2.134	0.876	0.0559
B.Locci, stratabound sulfides, hand sample	2.104	0.858	0.0545
Rio su Poru (Gremanu), mixed sulfides	2.121	0.867	0.0553
Correboi, mixed sulfide lens, along road	2.094	0.855	0.0548
Funtana Raminosa (DIGITA)	2.122	0.869	0.0557

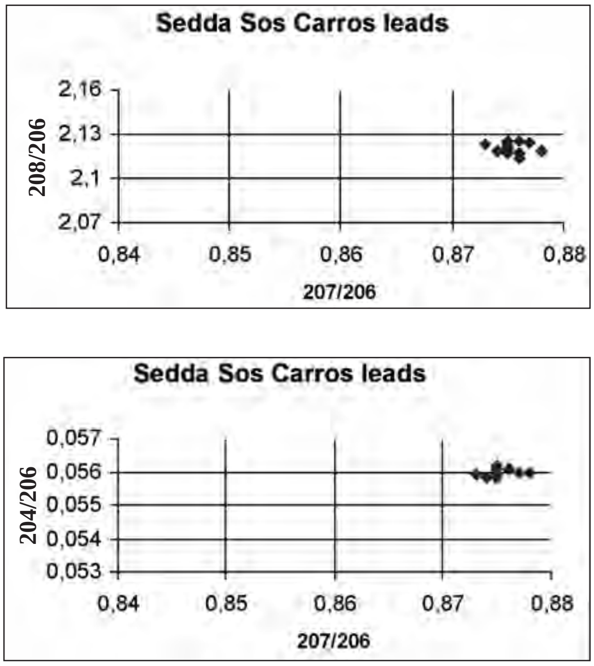
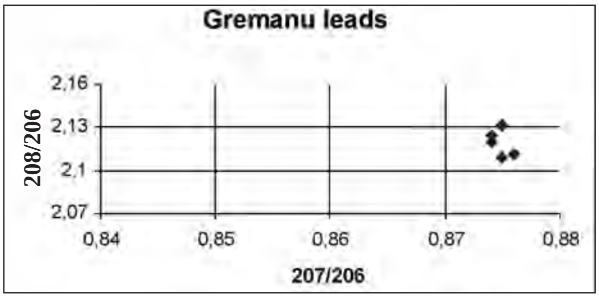


Fig. 5 – Lead isotopic ratios of leads from the Sedda Sos Carros excavations, Oliena (Nuoro). The values fall within the leads from Cambrian galenas.

Tab. 5 - Lead isotopic ratios, and silver grades of the Sedda sos Carros lead finds.

Sample	Pb 208/206	Pb 207/206	Pb 204/206	Ag ppm
Sos Carros vano "i", Pb fragment	2.118	0.875	0.0558	225
Sos Carros, Pb, filling in stone	2.119	0.878	0.056	223
Sos Carros 1, Pb fragment	2.117	0.875	0.0561	197
Sos Carros 2, Pb fragment	2.117	0.876	0.0561	393
Sos Carros 3, Pb fragment	2.124	0.877	0.056	290
Sos Carros 4, Pb fragment	2.114	0.876	0.0561	432
Sos Carros 5, Pb fragment	2.123	0.873	0.0559	405
Sos Carros 6, Pb fragment	2.121	0.875	0.0559	300
Sos Carros 7, Pb fragment	2.125	0.875	0.0559	142
Sos Carros 8, Pb fragment	2.123	0.875	0.0561	392
Sos Carros 9, Pb fragment	2.118	0.874	0.0558	n.d.
Sos Carros 10a, Pb fragment	2.123	0.875	0.0562	301
Sos Carros 10b, Pb fragment	2.125	0.876	0.0561	393



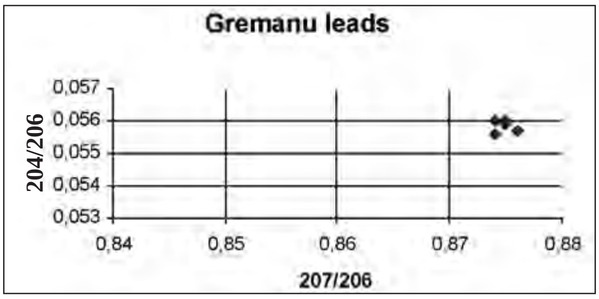


Fig. 6 – Lead isotopic ratios of leads from the Gremanu excavations (Fonni, Nuoro). The values fall within the leads from Cambrian galenas.

Tab. 6 - Lead isotopic ratios, and silver grades of the Gremanu finds.

Sample	Pb 208/206	Pb 207/206	Pb 204/206	Ag Ppm
Gremanu, Pb connection between stones	2.125	0.874	0.056	270
Gremanu, Pb filling in stone	2.12	0.874	0.0556	200
Gremanu, Pb fragment 1	2.109	0.875	0.056	
Gremanu, Pb fragment 2	2.112	0.876	0.0557	
Gremanu, Pb in quartz with sword	2.132	0.875	0.0559	

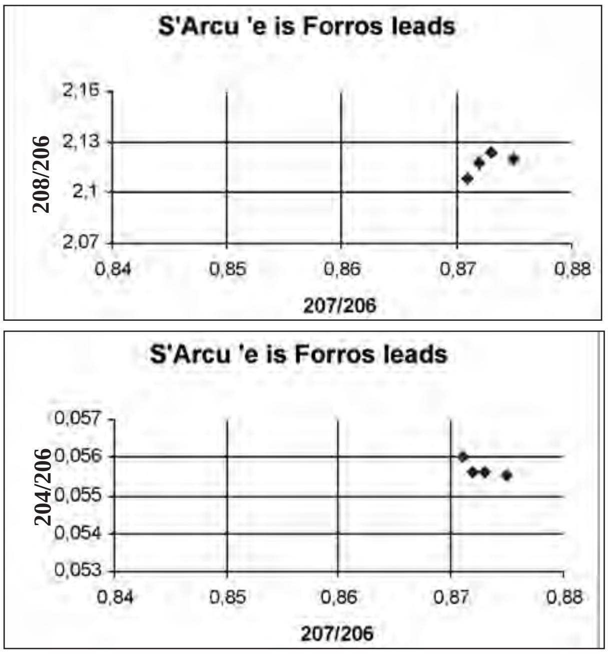
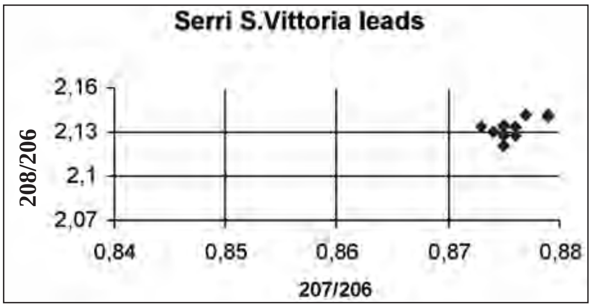


Fig. 7 – Lead isotopic ratios of samples from a large lead disk, and from a lead slice from the S'Arcu 'e is Forros excavations (Villagrande Strisaili, Nuoro). The values fall within the leads from Cambrian galenas.

Tab. 7 - Lead isotopic ratios, and silver grades of S'Arcu 'e is Forros finds.

Sample	Pb 208/206	Pb 207/206	Pb 204/206	Ag ppm
Pb Disc - border	2.12	0.875	0.0555	40
Pb Disc - centre	2.124	0.873	0.0556	n.d.
Pb Disc - middle	2.118	0.872	0.0556	48
Pb ingot strip	2.108	0.871	0.056	n.d.



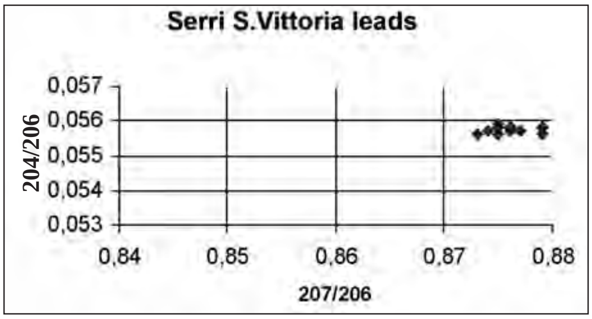
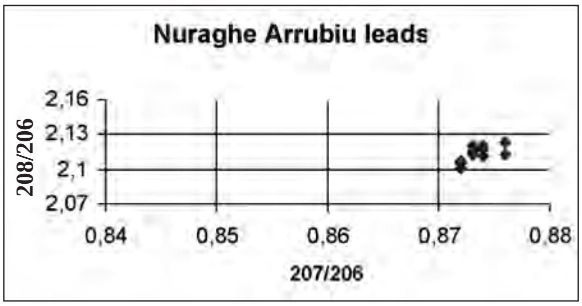


Fig. 8 – Lead isotopic ratios of leads from the Serri Santa Vittoria excavations (Nuoro). The values fall within the leads from Cambrian galenas.

Tab. 8 - Lead isotopic ratios, and silver grades of Serri S. Vittoria lead finds.

Sample	Pb 207/206	Pb 208/206	Pb 204/206	Weight gr	Ag ppm
Serri S. Vittoria (S.S.V.) - inv. 43219	0.876	2.133	0.0557	510.9	50
S.S.V., lead clamping 1	0.875	2.121	0.0558	216.6	20
S.S.V., lead clamping 2	0.879	2.141	0.0558	275.8	80
S.S.V., lead clamping 3	0.875	2.135	0.0556	253.4	15
S.S.V., decorated lead clamp 1	0.875	2.134	0.0556	474.4	160
S.S.V., decorated lead clamp 2	0.874	2.13	0.0557	430	25
S.S.V., two holes piece	0.876	2.128	0.0558	318	30
S.S.V., small decorated lead clamp	0.875	2.133	0.0559	307	58
S.S.V., large decorated lead clamp	0.879	2.14	0.0556	1627.2	48
S.S.V., herringbone decorated lead clamp 1	0.875	2.134	0.0559	824.7	28
S.S.V., herringbone decorated lead clamp 2	0.875	2.128	0.0558	422. 5	28
S.S.V., hemispheric section prism	0.873	2.133	0.0556	306.8	85
S.S.V., lead fixing for sword	0.877	2.141	0.0557	271.7	88



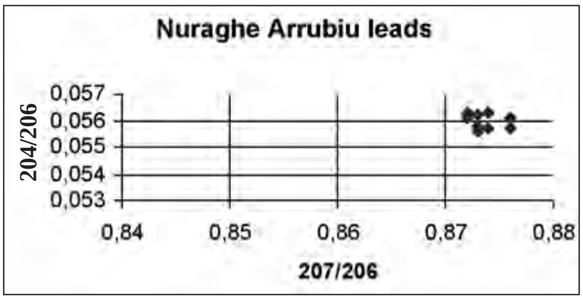


Fig. 9 – Lead isotopic ratios of lead fragments collected at different points of the nuraghe Arrubiu (Orroli, Nuoro). The population is clearly contained within the cluster of the leads of the Cambrian “Metalliferous”.

Tab. 9 - Lead isotopic ratios, and silver grades of the nuraghe Arrubiu lead finds.

Sample	Pb 208/206	Pb 207/206	Pb 204/206	Ag ppm
nuraghe Arrubiu 1	2.117	0.874	0.0557	30
nuraghe Arrubiu 2	2.113	0.876	0.0557	43
nuraghe Arrubiu 3	2.12	0.873	0.0556	53
nuraghe Arrubiu 4	2.12	0.874	0.0557	50
nuraghe Arrubiu 5	2.116	0.873	0.0558	20
nuraghe Arrubiu 6	2.113	0.873	0.0562	30
nuraghe Arrubiu 7	2.107	0.872	0.0563	60
nuraghe Arrubiu 8	2.105	0.872	0.0561	75
nuraghe Arrubiu 9	2.111	0.874	0.0563	92
nuraghe Arrubiu 10	2.107	0.872	0.0562	85
nuraghe Arrubiu 11	2.101	0.872	0.0563	93
nuraghe Arrubiu 12	2.123	0.876	0.0561	

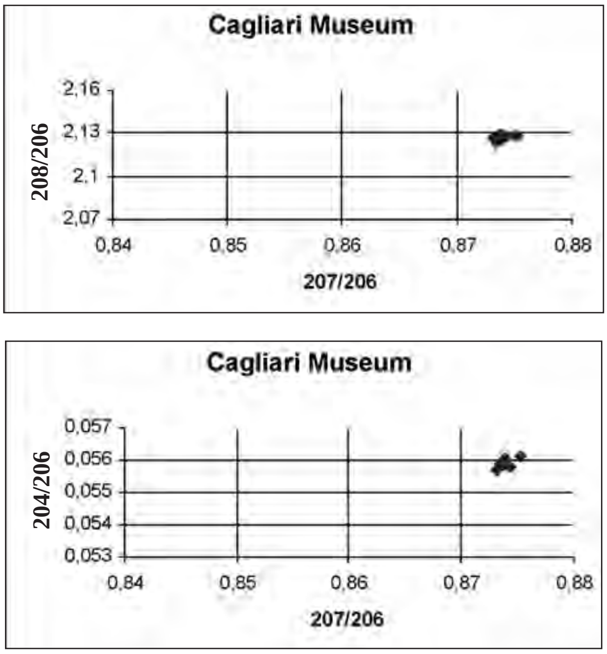


Fig. 10 – Lead isotopic ratios in different lead samples from finds exposed in the Cagliari Archaeological Musem. The values fall within the leads from Cambrian galenas.

Tab. 10 - Lead isotopic ratios, and silver grades of lead finds guarded in the Cagliari Archaeological Museum.

Sample	Pb 207/206	Pb 208/206	Pb 204/206	Ag ppm
Inv. Museo Ca 1281 (S. Anastasia ingot)	0.875	2.128	0.0561	430
Museo Ca, oval ingot	0.873	2.124	0.0559	360
Inv. Museo Ca 171311, Lead clamp Barumini	0.874	2.128	0.0558	370
Museo Ca, stalked piece	0.873	2.127	0.0557	350
Museo Ca, piece cut in two	0.874	2.13	0.0558	350
Museo Ca, Sinnai, Bruncu Mogumu, No. 634	0.874	2.126	0.0561	380

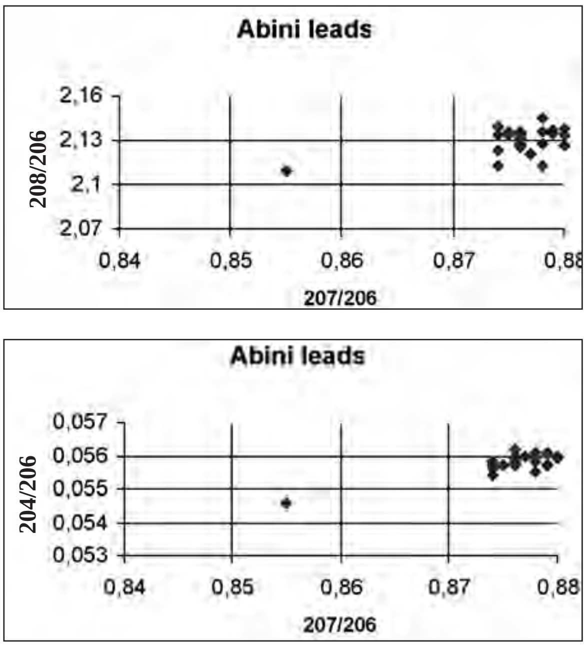


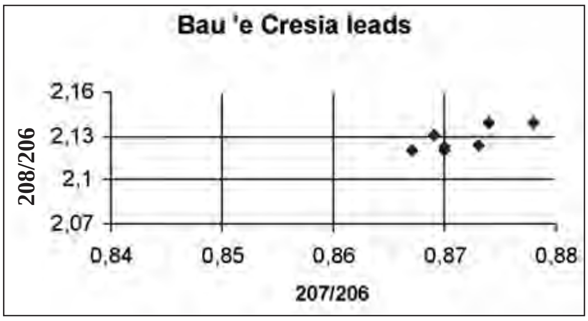
Fig. 11 – Lead isotopic ratios of lead samples from the Abini excavations (Teti, Nuoro), kept in the Archaeological Museum of Cagliari. The values fall within the leads from Cambrian galenas, with the exception of one that could come either from a Hercynian vein or a strata-bound polymetallic mixed sulfide orebody (this type of mineralization is not frequent in the area but in the neighbouring areas).

Tab. 11 - Lead isotopic ratios and silver grades of the Abini lead finds.

Sample	Pb 207/206	Pb 208/206	Pb 204/206	weight gr	Ag ppm
Abini, box 2346, lead no. 1	0.875	2.136	0.0557	76.3	38
Idem, c. 2	0.876	2.131	0.0562	91.3	113
Idem, c. 3	0.876	2.127	0.056	122	130
Idem, c. 4	0.88	2.138	0.056	112.2	55
Idem, c. 5	0.88	2.127	0.056	51.8	23
Idem, c. 6	0.877	2.121	0.056	20.3	55
Idem, c. 7	0.878	2.136	0.0559	18.7	40
Idem, c. 8	0.88	2.133	0.0559	20	46
Idem, c. 9	0.876	2.125	0.056	45.1	138
Idem, c. 10	0.878	2.113	0.0561	19	170
Idem, c. 11	0.879	2.137	0.0561	37.6	68
Abini, lead fixing no. 12	0.876	2.128	0.0558	196.1	14
Idem no. 13	0.876	2.133	0.0557	13	25
Idem no. 14	0.875	2.133	0.0557	47.6	230
Idem no. 15	0.876	2.135	0.0557	29.3	68
Idem no. 16	0.878	2.128	0.0558	58.9	25
Idem no. 17	0.874	2.139	0.0557	6.5	88
Abini, box 2346, lead no. 18	0.876	2.136	0.0558	116.9	38
Idem, c. 19	0.874	2.113	0.0556	104.4	60
Idem, c. 20	0.874	2.123	0.0556	45.1	58
Idem, c. 21	0.874	2.113	0.0558	26.6	88
Idem, c. 22	0.879	2.135	0.0557	18.1	28
Idem, c. 23	0.855	2.109	0.0546	38.7	155
Abini, lead clamp, no. 24	0.878	2.145	0.0555	11.5	15
Idem, no. 25	0.876	2.128	0.0559	12.2	163
Idem, no. 26	0.874	2.134	0.0554	8.4	45

Nevertheless, an interesting observation already emerges from the mass of data analyses, *i.e.* the occurrence in some instances of "non-Cambrian" values, as though, for some unexpected reason, the ancient metallurgists were forced to replace the normal supply of lead with a substitute from other Sardinian deposits (Hercynian vein-type or stratabound polimetallic sulfides). This is certainly the case of a lead scrap from Abini, Teti (Nuoro, fig 11, tab. 11), of a few from Bau 'e Cresia, Villagrande Strisaili (Nuoro, fig 12, tab. 12), Solarussa (Oristano, fig. 13, tab. 13), and nuraghe Adoni, Villanovatulo (Nuoro, fig. 14, tab. 14). It should be noted, incidentally, that of the above sites "non-Cambrian" mineralisations would only have been available to Bau 'e Cresia and to S'Arcu 'e is Forros (Correboi, see below). The metallurgists of the other sites must have searched far away, and accepted uncertain "gleanings" from small mineralisations that occurred in the Paleozoic basement.

The lead contained in tin scraps of S'Arcu 'is Forros (fig.7, tab. 7) on the contrary is seemingly of foreign origin. Nevertheless, a Sardinian origin can certainly be assumed for the nuragic metal lead, and at least for part of the copper, which was however an important item on the imports list, as is demonstrated by the widespread findings of Cyprian oxhide fragments and ingots in Sardinia.



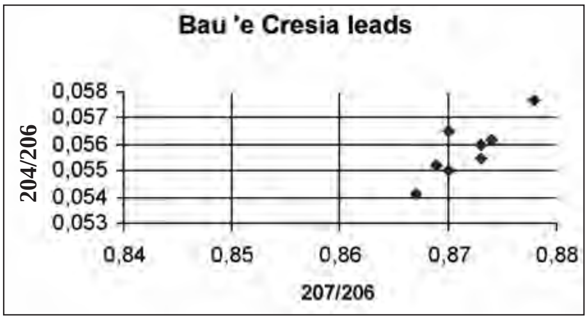
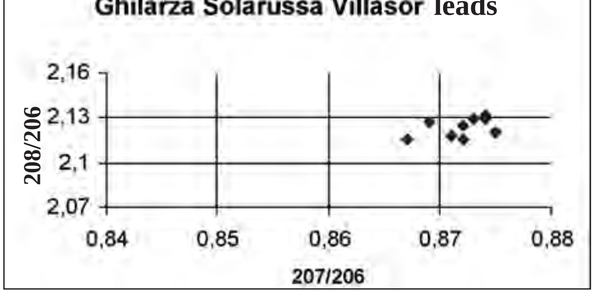


Fig. 12 – Bau ‘e Cresia, Villagrande Strisaili (Nuoro – Traces of a valley bottom settlement, unpublished, a few km north of S’Arcu ‘e is Forros). Lead isotopic ratios of lead fragments scattered on the surface of the site. The trend of the dispersion of values points towards the field of the leads from Cambrian galenas, with the exception of the bottom of the crucible that occupies an unusual extreme position due to the 204/206 ratio.

Tab. 12 - Lead isotopic ratios, and silver grades of the Bau ‘e Cresia lead finds.

Sample	Pb 207/206	Pb 208/206	Pb 204/206	Ag ppm
Bau 'e Cresia, fragment Pb 1	0.87	2.12	0.055	135
Bau 'e Cresia, fragment Pb 2	0.873	2.124	0.0555	121
Bau 'e Cresia, fragment Pb 3	0.867	2.12	0.0541	132
Bau 'e Cresia, fragment Pb 4	0.874	2.139	0.0562	116
Bau 'e Cresia, fragment Pb 5	0.869	2.131	0.0552	122
Bau 'e Cresia, crucible bottom	0.878	2.139	0.0577	140
Bau 'e Cresia, Pb lead scrap 1	0.873	2.124	0.056	112
Bau 'e Cresia, Pb lead scrap 2	0.87	2.123	0.0565	121



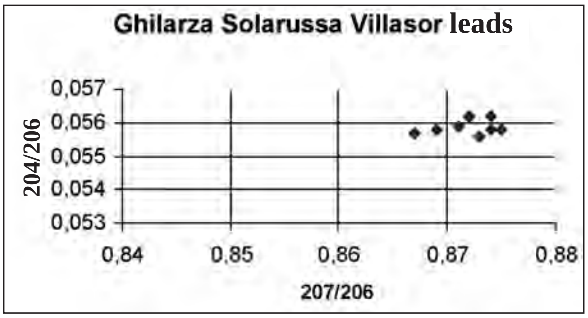


Fig. 13 – Lead isotopic ratios of lead fragments from nuraghe Orgono (Ghilarza), from Solarussa, and from nuraghe Su Sonadori (Villasor). The values fall within the leads from Cambrian galenas, with the exception of two from Solarussa which could originate from mineralisations of the Hercynian vein.

Tab. 13 - Lead isotopic ratios, and silver grades of the nuraghe Orgono (Ghilarza), the Solarussa, and the nuraghe Su Sonadori (Villasor) lead finds.

Sample	Pb 208/206	Pb 207/206	Pb 204/206	Ag ppm
Ghilarza Pb fragment sect. 1	2.116	0.872	0.0562	
Ghilarza Pb fragment sect. 2	2.131	0.874	0.0558	
Ghilarza lead clamp 1	2.129	0.873	0.0556	
Ghilarza lead clamp 2	2.12	0.875	0.0558	
Solarussa US 8 Pb fragment	2.118	0.871	0.0559	
Solarussa US 61 B Pb fragment	2.127	0.869	0.0558	37
Solarussa US 13 D I Pb fragment	2.115	0.867	0.0557	283
Solarussa US 58 E Pb fragment	2.125	0.872	0.0562	
Villasor Pb fragment	2.129	0.874	0.0562	

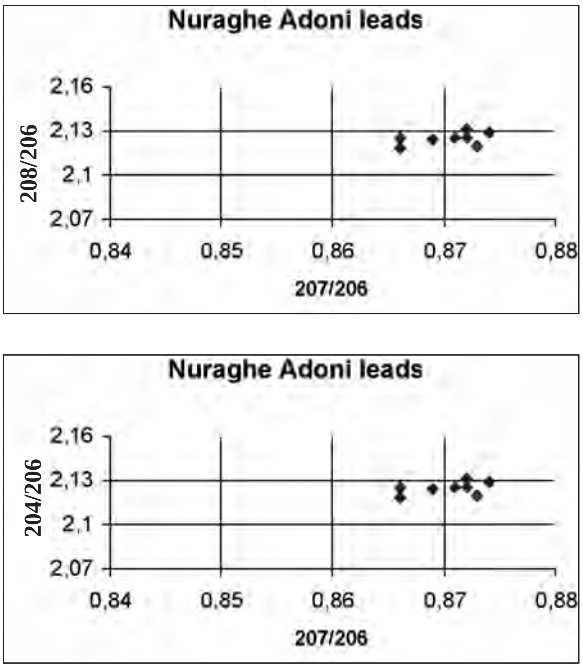


Fig. 14 – Lead isotopic ratios of leads, and of one silver piece collected in the nuraghe Adoni area (Villanovatulo, Nuoro). The fact that the site was occupied by Vandals, as known from other silver finds, could justify an anomalous source of samples nos. 8 (silver leaf), and 5 (lead fragment from the surface) (see tab. 14), which are more consistent with an origin close to the Hercynian vein type, since for silver purposes, polymetallic mixed sulfide orebodies can be overlooked.

Tab. 14 - Lead isotopic ratios, and silver grades of the nuraghe Adoni lead and silver finds.

Sample	Pb 208/206	Pb 207/206	Pb 204/206	Ag ppm
1. N. Adoni, wall X, 20.10.99, lead clamp 1a	2.125	0.871	0.0559	288
2. N. Adoni, lead clamp 1b	2.125	0.872	0.0561	258
3. N. Adoni, sample 2	2.131	0.872	0.056	308
4. N. Adoni, 11.10.99, sample 3	2.12	0.873	0.0557	220
5. N. Adoni, 25.10.99, sample 4	2.124	0.869	0.056	293
6. N. Adoni, Tower C, surface, sample 5	2.125	0.866	0.055	260
7. N. Adoni, 11.11.99, lead clamp, sample 6	2.129	0.874	0.0563	225
8. N. Adoni, wall B-C, collapsed level q. 803.66, Ag	2.119	0.866	0.056	Ag

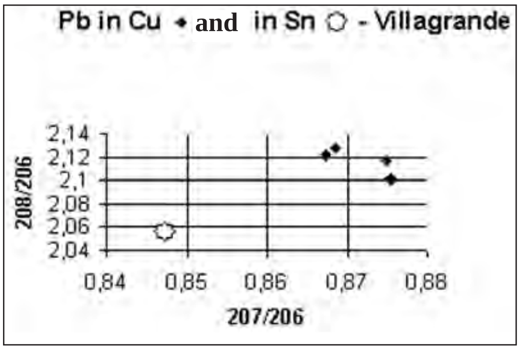


Fig. 15 – Lead isotopic ratios in copper scraps, and in the metal tin of S'Arcu'e is Forros, Villagrande Strisaili (Nuoro). The lead values in the metal tin stray considerably from the Sardinian fields. Therefore they can be proposed as an element in favour of an external origin (modified from Valera, Valera 2003).

Tab. 15 - S'Arcu`e is Forros, lead content in copper fragments.

Sample	Pb %
AVR 116	41.00
AVR 123	2.5
AVR 124	0.17
AVR 125	5.4
AVR 126	3.5

Tab. 16 - S'Arcu`e is Forros. Lead isotopic ratios in copper and tin fragments (after Valera, Valera 2003).

Sample	Pb 207/206	Pb 208/206
AVR 123	0.868	2.127
AVR 124	0.867	2.122
AVR 125	0.875	2.116
AVR 126	0.875	2.101
Tin	0.847	2.057

4. The problem of silver

Silver requires a separate discussion, because the beneficiation of local resources depends on the importation of knowledge and technology (cupellation) from countries that had already developed metallurgy. Actually (see *infra*) we can exclude the exploitation of local silver ore minerals *stricto sensu*, whose occurrence was only discovered in the island after the XVII century (the “Sarrabus silver lode”, see *infra*). Therefore only argentiferous galena can be considered available to the ancient metallurgists as a silver-bearing ore. The data suitable for a reliable reconstruction of the Sardinian silver history can be recovered from the following sources:

- chronological position of the to date analysed archaeological silver finds;
- information about mining productions. The data from the beginning of the modern mining industry are particularly important to outline a reference picture of the Ag/Pb ratios, however generally dealing with unattainable stopes in nuragic age;
- analyses of the Ag grades and of the Pb isotope ratios in the nuragic leads;
- analyses of the Pb isotope ratios in the Sardinian galenas, which are always argentiferous.

As regards the Ag grades, nuragic Pb analyses show contradictory elements (see tab. 5-14). Taking into consideration the difficulties due to the irregular distribution of this silver in its alloys, the only data available for their interpretation is referred to deposits exploited for lead in the industrial age, *i.e.* since the exploitation trend in lead-zinc mines has been known from official documents. The useful data for evaluation can be summarized as follows:

- as mentioned above, most of the analysed nuragic leads bear the isotopic fingerprint of the Cambrian galenas;
- our nuragic Pb analyses range between 13 g/t and 432 g/t Ag/Pb. These values are in good agreement with the recent literature (Atzeni *et al.* 1988; Atzeni *et al.* 1992);
- according to Rolandi (1971) the Ag/Pb ratios of the Sardinian Cambrian galenas, exploited in Pisan times (XIII century) range between 500 g/t and 4000 g/t;
- according to Zoppi (1888) the galena of the Cambrian “Metalliferous Ring” massive orebodies had very variable Ag grades, rather low on the average (see tab. 17).

Dealing with the 1879/1882 production of Monteponi, Zoppi gives 511 g/t and 250 g/t as average values, referring to them as 1st and 2nd quality ore. Zoppi says: “*In the same block of ore made up of a solid core of pure galena, and galena scattered in the calcareous matrix, it was always found that the inner pure galena analised proved of a lower silver grade than that contained both in the scattered ore and in the lead extracted from the ore itself*”. The distinction between 1st and 2nd quality ore is therefore justified (see tab. 18);

Tab. 17 (Zoppi, 1888, 92) - Lead and silver grades of samples from different stopes of the Cambrian massive deposits.

Tenore °/₀ in piombo	Grammi d'argento per tonnellata di minerale	Grammi d'argento per tonnellata di piombo
	Miniera di Monteponi.	
Livello Vesme (Cantiere Keller)		
80,00	100	125
47,50	111	233
Livello Etere	»	»
70,45	150	211
60,00	275	458
San Marco	»	»
44,33	180	406
35,57	200	562
	Miniera di Masua.	
75,40	400	530
46,00	466	1 014
	Miniera di Nebida (*cantiere S. Luigi*).	
78,00	200	256
31,00	333	1 075
	Miniera Punta Mezzodi.	
80,00	125	157
42,50	150	353
	Miniera S. Benedetto.	
80,20	125	156
54,00	200	370

Tab. 18 (Zoppi, 1888, 93) – Lead and silver grades in the 1st and 2nd quality ores from the massive deposits sold between 1979 and 1882.

		Quantità in tonnellate	Tenore in	
			Piombo	Argento Grammi per quintale
		Anno 1879-1880.		
Galena . . .	1ª Qualità . . .	2 743	82,239	21,115
	2ª Qualità . . .	7 254	62,199	30,707
		Anno 1880-1881.		
Galena . . .	1ª Qualità . . .	2 903	82,584	21,420
	2ª Qualità . . .	8 471	64,486	32,120
		Anno 1881-1882.		
Galena . . .	1ª Qualità . . .	1 242	82,980	19,090
	2ª Qualità . . .	11 074	62,700	34,030

• furthermore, Zoppi reports a fundamental observation: "*the ore matrix is rarely siliceous, but it is almost always ferrouginous, a little bit argillaceous, and sometimes baritic*": according to the present knowledge of the geological frame, we are in a position to deduce, without the shadow of a doubt, that the ore only came from the outcrops, *i.e.* from the only sites accessible in ancient times;

• Zoppi's data partially disagree with the data published by Monteponi (1950) on the 1896/1950 production, which give richer values. This is clearly due to the fact that the Monteponi data mostly refer to underground exploitations (very different from those of the ancient weathered outcrops), initially stopes between the surface and the "sea-level".

This interpretation is supported by the proportionally inverse trend of the silver grades vs. the depth of exploitation (see tab. 19). The grades on the average decrease with in the years, *i.e.* they change from the particularly high valiues of the "cementation zone" (high levels, enriched by deposition of the leached silver from the weathered superficial zone) to the lower valuies of the more recent productions, therefore deeper, exploited from the primary deposit, not reached by the enrichment of the cementation zone;

Tab. 19 - Monteponi. Silver yield in lead productions between 1895 and 1950 (Monteponi, 1950).

YEAR	g/t	YEAR	g/t
1895/96	1185		
1896/97	892	1923	447
1897/98	642	1924	665
1898/99	1110	1925	863
1899/1900	878	1926	633
		1927	793
1900/01	770	1928	866
1901/02	852	1929	569
1902/03	1001	1930	625
1903/04	945	1931	600
1904/05	926	1932	623
1905/06	957	1933	648
1906/07	886	1934	627
1907/08	745	1935	449
1908/09	806	1936	684
1909/10	747	1937	685
1910/11	589	1938	511
1911/12	740	1939	476
1912/13	597	1940	617
1914	954	1941	729
1915	926	1942	552
1916	965	1943	184
1917	928	...	
1918	765	1946	294
1919	594	1947	805
1920	831	1948	424
1921	679	1949	648
1922	756	1950	650
		average	693

Tab. 20 - Montevecchio. Silver yield in lead productions 1933/1947 (Montevecchio 1948).

YEAR	g/t
1933	528
34	575
35	391
36	854
37	655
38	468
39	526
40	635
41	622
42	823
43	425
…	…
45	8,5
46	406
47	538

• the data from the Montevecchio ore deposit (see tab. 20) (Montevecchio 1948) are less easy to interpret, because the mineralisation is complex. In any case the isotopic ratios of this deposit place its influence on the nuragic leads in a border position compared to the prevailing weight of the isotope ratios belonging to the Cambrian related ore deposits of the Iglesias district.

Consequently, nuragic leads lend themselves to different interpretations as regards silver content. Three scenarios can be outlined:

1. *The nuragic leads did not undergo desilveration* : therefore the grades of our analyses should correspond to the Ag grade of the original galenas. The middle-high values being consistent only with the data of Zoppi (1888) (tab. 17, 18) we can rule out that this approach may be applied to all the analised leads.

2. *The nuragic leads underwent good desilveration*, starting from well sorted Ag rich galenas (Ag/Pb>>500 g/t), practically corresponding to those later exploited by the Pisans (Rolandi 1971). Any high residual Ag values in some leads should be ascribed to the primitive cupellation stage. However a certain discrepancy seems to appear between sorting skill of the ore to be processed (actually to be demonstrated, because it is extremely difficult even for an expert today to distinguish macroscopically among more or less argentiferous galenas, unless they contain clearly recognizable silver sulfides and/or sulphosalts), and incomplete beneficiation. In this connection we quote Alessandrello *et al.* (1991) on the silver content of certainly desilvered Roman leads (1st century B.C.): the silver there rarely exceeds 100 ppm.

3. *Not always the nuragic leads underwent desilveration* : some lots could have been supplied as produced from the first stage of the galena metallurgy (see Sedda sos Carros, tab. 5). However they would be episodic events, justified only by the original treatment of relatively silver-poor galenas.

Actually, the clear lack of interest in silver in nuragic times should not contradict its production, obtained by more or less advanced desilveration of galena. It could be simply due to the choice of the producers, who were more interested in using it as a precious item of exchange (with the rare and precious tin ?) in the Mediterranean traffic network, active since the obsidian times. In this case lead could be considered a worthwhile by-product of silver metallurgy, anticipating what was practically the rule in Classical and Roman times.

5. The mineral deposits of Sardinia

Neglecting the indications of exclusive mineralogical interest, we shall list the mineralisations which could have attracted the attention and stimulated the enterpreneurial spirit of the ancients, outlining the features suitable for an estimation of their former economic weight. In this view the “gossan”, *i.e.* the whole formed by the weathering products characterizing the base-metal sulfide mineralisations from the outcrops to some metres in depth, is greatly important, it being a possible source of useful ores, *i.e.* primary sulfide remains, regenerated sulfides, native metals, oxides, carbonates etc. E.g. in copper deposits malachite can be particularly abundant, and certainly it drew the attention first as colouring matter, then as a source of the metal. However it must be mentioned that the gossan size is directly proportional to the original orebody size, and that it is settled, maintained, and controlled by weathering processes, that drain away a good deal of their own products. Taking into account these considerations, and referring to as the general Sardinian mineral deposit frame (see chapter 1), with the help of the documents recovered from early modern mining activity it is possible to trace the primitive outline of the most interesting orebodies, as well as the size and composition features of the originally cropping out parts of each deposit, as they must have appeared to the first users.

COPPER (fig. 16)

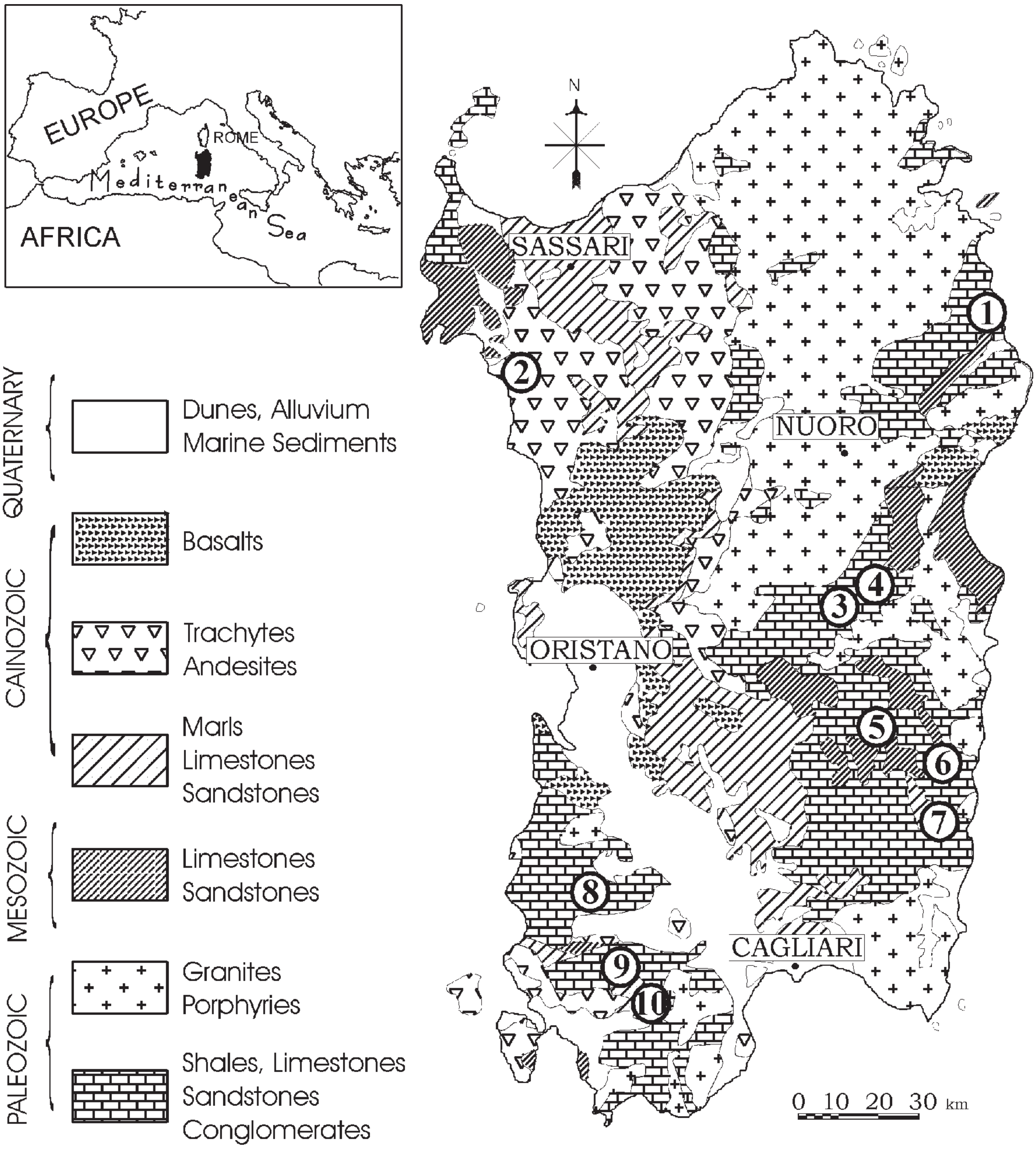


Fig. 16 - Copper mineralisations
1: Val Barisone. 2: Calabona. 3: Funtana Raminosa. 4: Correboi.
5: Monte Nieddu. 6: Talentino. 7: Baccu Locci.
8: Sa Duchessa. 9: Rosas - Sa Marchesa.
10: Barisonis.

Val Barisone (Torpè, Nuoro). Multiple lens-shaped orebody, quartz-carbonates-base metal sulfides (major chalcopyrite, pyrite : pl. III, 1), known for a length of about 300 metres (Valera 1965). IV metallogenic epoch. Few tens of metres in outcrop, scarce gossan, crusts of alteration products (mainly malachite). Perhaps initially some kg of oxidized minerals. Little or no native copper.

Calabona (Alghero, Sassari). Porphyry copper orebody, VII metallogenic epoch. Rich gossan with Fe and Cu oxidized minerals, with cores of pyrite, chalcopyrite, and regenerated Cu sulfides. Covellite, cuprite, bornite, and chalcocite were abundant. Probable outcrop of some hundred square metres, some tons of Cu oxidized minerals and regenerated sulfides, perhaps substantial (tens of kg) native copper.

Funtana Raminosa (Gadoni, Nuoro). Base metal sulfides with major pyrite-chalcopyrite in several lens-shaped orebodies (IV metallogenic epoch, isotopic ratios tab. 3). Scarce oxidized minerals, some regenerated sulfides. Native copper frequent, but not abundant. A few tons of outcropping weathered ore, formerly processed with difficulty (primitive know-how). Recorded as the major source of Sardinian Cu in the earliest times. Actually its true size, rather scanty, can be deducted from the documents of the last mining exploitation, run by a private enterprise (Società Cuprifera Sarda, 1971-1975). The following data are reported : average annual production of crude ore 44,304 metric tons, with average grades: Zn 3.31%, Pb 1.45 %, Cu 1.09 %. From the flotation plant the chalcopyrite concentrate was about 1.500 t/year, corresponding to an average content of about 430 metric tons of metal copper, with a concentration biased by a pollution of barren stuff, taking into account that the copper content in the chalcopyrite is 34%. This concentrate was sold in Spain to the Rio Tinto Patino Inc. for the electrolytic process in the Huelva plant, only outlet for copper metallurgy. It is therefore proved that in modern times the size of the ore deposit, and especially its copper grade level allowed not much more than a rudimentary exploitation, certainly with very selective working methods, witnessing dimensions very different from those of the Cyprus ore deposits. Unfortunately these data are a serious limitation to the interpretation of Funtana Raminosa as an important Sardinian copper supply source in the Bronze age. In fact:

- the metal contents in the last exploitations certainly correspond to the order of magnitude of the primeval grades, given the characteristics of the ore deposits. We can only accept the presence of some oxides, though not in great quantities because of easy superficial leaching, facilitated by local climatic and morphological characteristics;
- the ore exploitation had to be concluded necessarily with careful hand sorting, in order to separate the chalcopyrite, to be followed by the metallurgical process for the copper production. Excluding the losses that a process in primitive conditions would certainly suffer, we have to take into account also discards and slags accumulated in the two working phases. Actually, for each kg of produced metal we would expect at least 90 kg of sorting discards, and 5/10 kg of slags. The remains, on the contrary, also from what is known from the literature, are proportional to the small size of the ore deposit, and to its low grades.

On the other hand, quoting Goüin (1867) *verbatim*: "*Dans le centre de l'île, à Gadoni, il y a des recherches anciennes nombreuses, pour ce métal : mais malgré une étude approfondie je n'ai pu rien constater de bien sérieux.* ". We must remember that access to this area was difficult until the Central State Sardinian Road was built, which was only active in the Monastir – Laconi tract in 1840, while its continuation north (Meana-Atzara-Sorgono-Gavoi-Orani-Nuoro) had only been planned, but not completed. La Marmora (1860) nevertheless describes the Genna Entu Pass near Aritzo, where "*the old road from Cagliari crossed to the north of the island*", testifying to the existence of a communication and trade ridge-line for people and commodities between the different provinces of the island.

Correboi (Villagrande, Nuoro). Several small mixed polymetallic sulfide lenses, commonly Cu-poor, crop out in a big area (pl. III, 2), with gold traces (III metallogenic epoch, isotopic ratios tab. 3). Improbable former occurrence of Cu oxidized minerals in sensible concentrations.

Monte Nieddu and surroundings (Esterzili-Orroli, Nuoro). Several mixed polymetallic base metal sulfide (frequent chalcopyrite) lenses, difficult to process. III metallogenic epoch. Oxidized minerals give rise to a gossan some dm thick, with scarce concentrations of Cu alteration products. Some kg to some tens of kg on the whole for each orebody.

Talentino (Tertenia, Nuoro). Some lenses of Cu-bearing mixed polymetallic sulfides (III metallogenic epoch). Gossan few dm thick. Some kg of Cu oxidized minerals. Native Cu absent. Exploited 1854-1857, total production 500 t of crude ore.

Baccu Locci (Villaputzu, Cagliari). Some mixed polymetallic sulfide lenses, with sensible chalcopyrite (pl. IV, 1) (III metallogenic epoch, isotopic ratios tab. 3). Abundant oxidized minerals (chiefly malachite and azurite – pl. IV, 2): formerly probably some hundred kg. Well represented native Cu (originally perhaps several tens of kg).

Sa Duchessa (Domusnovas, Cagliari). Notable skarn massive body, at the granite-Cambrian complex contact, with important transformation products of the primary Cu-bearing sulfides. IV metallogenic epoch. The most abundant ore minerals were chrysocolla (copper silicate) with primary and regenerated sulfides (chalcopyrite, bornite, chalcocite, covellite), oxides, carbonates, sulphates (cuprite, azurite, malachite, chalcantite, brochantite, linarite, etc.). It is reasonable to suppose that the first outcrops offered a few tons of Cu oxidized minerals, of a high grade. The original existence of native copper is also certain, though in a limited amount, proportionally to the size of the weathering products. Galena is also present: the data relating to the lead isotope ratios in four samples are mentioned by

Stos-Gale *et al.* (1995 - tab.1), and, as expected, the values are consistent with the Cambrian attitude. Therefore any copper that might have been produced from Sa Duchessa ore should bear the Cambrian isotopic marker, making it practically impossible to differentiate between alloys containing copper from this deposit, and alloys with copper of other origin but supplemented with the lead of galenas from the Iglesias Cambrian district.

Rosas / Sa Marchesa (Narcao, Cagliari). Several skarn lenses embedded in the Cambrian sequence, with Pb, Zn, and sensible Cu mineralization (IV metallogenic epoch). Exploited underground in the XX century. The traces of these mineralisations are not clear in outcrop, while old testimonies mention the presence of frequent Cu oxidized minerals, among them the “rosasite”, a Cu-Zn carbonate which was found here and described for the first time. The rather high galena silver grade is to be recorded: 800 g/t (Pruna 1965).

Barisonis (Narcao, Cagliari). Today disappeared, probably it was a mineralisation similar to that of Rosas / Sa Marchesa, occurring in the same region. Baldracco (1854) there mentions “*old diggings*” which are ascribed by Goüin (1867) to the exploitation of “*metalliferous earths*” associated to the sulfide mineralisation, silver exceeding 4.3 kg/t. Mentioned also by Marchese (1862), a single production of 12.5 “quintals” of Cu-bearing pyrites is recorded in the year 1856. In that time Barisonis and Talentino were the only active exploitations for copper in Sardinia.

LEAD (and SILVER) (fig. 17)

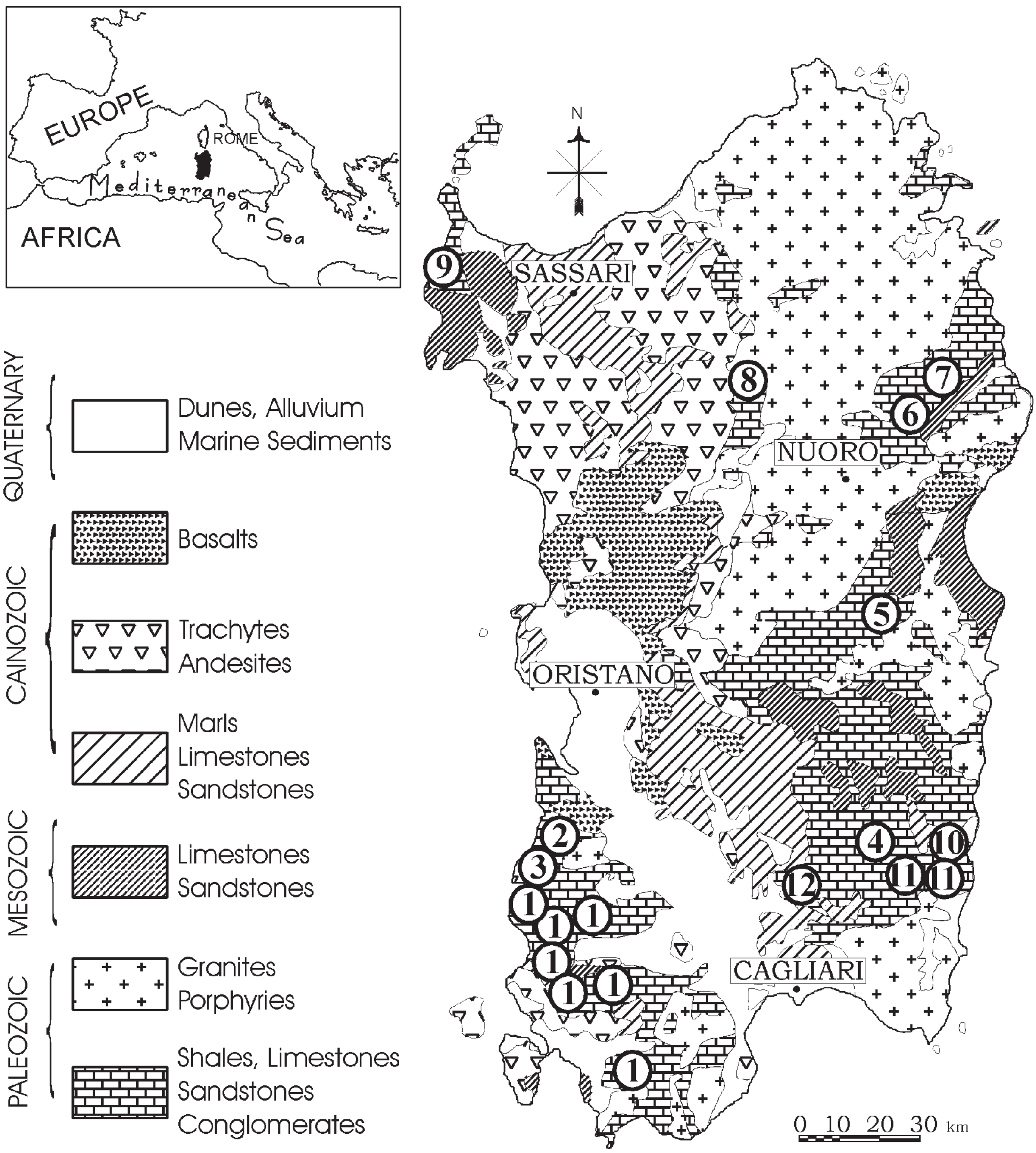
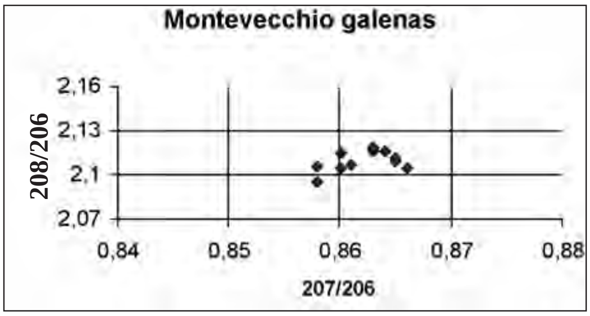


Fig. 17 - Lead-Silver mineralisations
1: Iglesias district "Metalliferous". 2: Montevecchio.
3: S'Oreri/Filone Palazzo. 4: Genna Tres Montis. 5: Correboi.
6: Sos Enattos. 7: Guzzurra. 8: Su Elzu. 9: Argentiera.
10: Baccu Locci. 11: "Sarrabus siver lode". 12: S'Ortu Becciu.

"Metalliferous Ring" (this is the name given by the mining tradition to the mineralised formation, giving rise to a chain in the shape of "ring"; Iglesias area, Cagliari). Massive deposits confined within the Cambrian carbonatic sequence, controlled by the tectonic fabric from Buggerru (north) to Narcao (south). Genetically starting in the I metallogenic epoch, mostly developed and emplaced in the IV metallogenic epoch. Particularly important is the large Monteponi deposit, which probably had a gossan of tens of thousands of cubic metres, consisting mainly of Pb carbonates and sulphates, associated with abundant remains of galena and calamine, corresponding to the present great open pit known as "Scavi Cungiaus" (pl. V, 1 and 2). The Ag/Pb ratio of the galena was variable, reaching up to 8 kg/t ("Silver-rich ore" of San Giovanni, Iglesias), and was the effect of conditions reached through a complex evolution. The Pb isotopic ratios of the Cambrian galenas form a cluster (fig. 1, tab. 1) with some variance due precisely to the "Silver-rich ore" of the San Giovanni mine.

Montevecchio (Guspini, Cagliari). Important lode 8 km long, and several tens of metres thick, cropping out as an almost continuous big wall, consisting of prevailing quartz, with carbonates, Fe oxides, and especially Pb-Zn oxidized minerals. IV metallogenic epoch. Still today in sheltered outcrops it is possible to notice the massive galena as it commonly occurred on surface in former times. The Pb isotopic ratios fall in the area of the "Hercynian veins" (fig. 18, tab. 21). The Ag content of the surface ore was up to 1 kg/t.



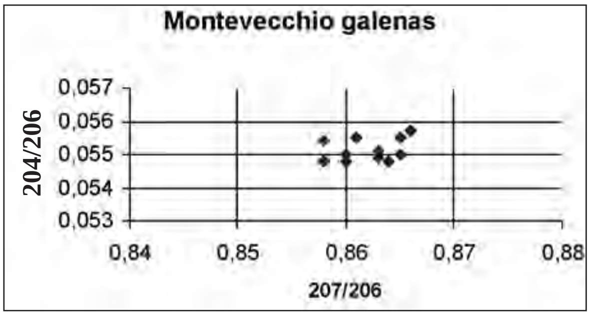


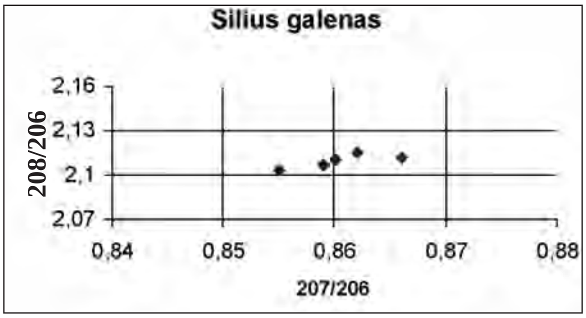
Fig. 18 – Lead isotopic ratios in galena samples from different points of the three main vein orebodies at Montevecchio (Guspini, Cagliari). The dispersion of the values reflects the long and complex genetic history of the ore deposit.

Tab. 21 - Lead isotopic ratios in galenas of the different orebodies of Montevecchio.

Sample	Pb 208/206	Pb 207/206	Pb 204/206
Montevecchio, S. Antonio vein, outcrop	2.105	0.866	0.0557
Montevecchio, Piccalina 1 vein, outcrop	2.107	0.861	0.0555
Montevecchio, Piccalina 2 vein, outcrop	2.106	0.858	0.0548
Montevecchio, Piccalina 3 vein, outcrop	2.105	0.86	0.055
Montevecchio, Sanna vein, S.Barbara lev.	2.116	0.863	0.0549
Montevecchio, Sanna1 vein (DIGITA, coll. room)	2.116	0.864	0.0548
Montevecchio, Sanna 2 vein, outcrop	2.115	0.86	0.055
Montevecchio, Sanna 3 vein, outcrop	2.105	0.86	0.0548
Montevecchio, Sanna 4 vein, galena+barite	2.119	0.863	0.0551
Montevecchio, Sanna 5 vein, outcrop	2.119	0.863	0.0549
Montevecchio, Sanna 6 vein, gossan	2.112	0.865	0.055
Montevecchio, Sanna 7 vein, West outcrop.	2.109	0.865	0.0555
Montevecchio, Sanna 8 vein, West outcrop.	2.095	0.858	0.0554

S'Oreri/Filone Palazzo (Fluminimaggiore, Cagliari). This was essentially a barite-fluorite vein (today depleted) with scarce galena, which increased only in depth (IV metallogenic epoch). The position of the lead isotopic ratios of the galena from this deposit (tab. 4), partially trending towards the area of the Cambrian galenas, can be interpreted easily, because it occurs close to the mineralised Cambrian itself (S'Oreri barite-fluorite-galena mineralisations in the Metalliferous reefs, cropping out in the near west), which supplies the Hercynian hydrothermal fluids.

Genna Tres Montis / Muscadroxiu (Silius, Cagliari). The same genetic type, though not bound to the Cambrian. Fluorite-barite-galena lode, IV metallogenic epoch. Its outcrop was of little interest, just a barite-fluorite vein with scarce galena, but it was different in depth and turned out to be the most important producer in Europe of fluorite-galena (after 1960). Without any interest to Bronze age metallurgists, who could find several orebodies of this type in outcrop devoid of any metal interest everywhere in Sarrabus-Gerrei (SW Sardinia) (fig.19, tab. 22).



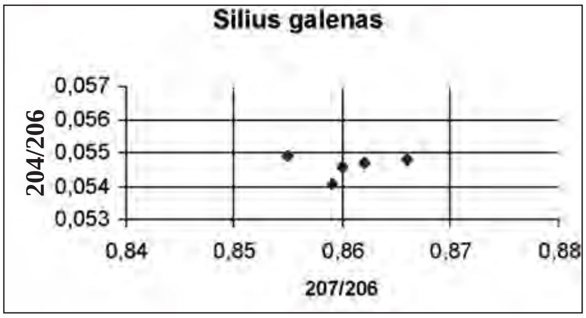


Fig. 19 – Lead isotopic grades in the galena samples from different underground sites of the Genna Tres Montis ore deposit (Silius, Cagliari) (only one sample collected in one of the rare outcrops). The composition of the vein orebody, formed by several emplacements in a long span of time, is reflected in the scattering of the values.

Tab. 22 - Lead isotopic ratios in galenas of the Genna Tres Montis – Muscadroxiu ore deposit.

Sample	Pb 208/206	Pb 207/206	Pb 204/206
Silius, 230 lev., S.Giuseppe ?	2.107	0.859	0.0541
Silius, idem, 20 m more to the W, S.Giuseppe ?	2.115	0.862	0.0547
Silius outcrop (office gate; S.Giuseppe ?)	2.11	0.86	0.0546
Silius, 150 lev., rise 7 West	2.111	0.866	0.0548
Silius – 200 lev., 1st sublevel	2.103	0.855	0.0549

Correboi (Fonni, Nuoro). Hercynian hydrothermal fluorite-barite vein, a couple of hundred metres long, with abundant galena in outcrop, still visible today on the surface in scattered pebbles covered and masked by a black plattnerite crust. The Ag grade was high, because of the presence of specific minerals of the metal (sulfides and sulphosalts). IV metallogenic epoch. Modern exploitations started in 1854. However at the time of La Marmora (1860) only lead was exploited, allowing the assumption that the local silver potentiality was unknown, or forgotten, until the beginning of the beneficiation which started at the end of the XIX century.

Sos Enattos (Lula, Nuoro). Vein outcrop of quartz, and Pb-Zn sulfides, IV metallogenic epoch (pl. VI, 1). Minor gossan. The modern exploitation started in 1861, however Rolandi (1971) mentions a local tradition about a Roman pit.

Guzzurra (Lula, Nuoro). Fluorite-quartz-galena-sphalerite vein system, less interesting than Sos Enattos. IV metallogenic epoch. Exploitation started in 1863.

Su Elzu (Ozieri, Sassari). Pb-Zn-Cu vein deposit (IV metallogenic epoch), explored and exploited undergound in the last century. No outcrops are visible today, therefore it is reasonable to suppose that the gossan was very poor.

Argentiera (Nurra, Sassari). Quartz-carbonates, with argentiferous galena and sphalerite in a large vein deposit. IV metallogenic epoch. Gossan completely leached. Baldracco (1854) quotes ancient works carried out without blasting, referring to the Pisan epoch. Certainly interesting for the Bronze age know-how. Silver grades of galena similar to those of Montevecchio, probably higher in outcrop.

Baccu Locci (Villaputzu, Cagliari). Hercynian quartz-arsenopyrite-galena-sphalerite-(chacopyrite, sulphosalts, gold) vein orebody, IV metallogenic epoch. Outcropping discontinuously for some hundred metres, 1-3 metres thick. Occurs close to the above polymetallic sulfide lenses. In prehistoric times the gossan should have been rather visible due to the arsenopyrite and its weathering products. The nearby copper oxidized mineral outcrops of the *strata-bound* mixed sulfides strongly suggest local availability of raw materials for arsenical copper production. Any existing testimony of ancient works have obviously been cancelled out completely by recent exploitation.

"The Sarrabus Silver Lode" (SE Sardinia). An E-W trending lode from the sea to the Campidano (Cagliari). Though rather complex genetically, starting from the III metallogenic epoch, its present outline is mostly due to the Hercynian hydrothermalism (IV metallogenic epoch). The vein swarm lies trending E-W from the sea to the Campidano for 30 km (first east deposit "Baccu Arrodas" near Muravera, the westernmost "Terra Mala" near Soleminis, Cagliari). The mineral association is barite-fluorite-calcite-quartz in outcrop. Galena, native silver, and Ag minerals (native silver, sulfides, sulphosalts: pl. VI, 2) start occurring some metres in depth. On the surface silver only occurred as cerargyrite (chloride), a mineral difficult to recognize. No gossan in the past was evident on account of the brittle ore association and the weak consistence of the hosting shales, so that the first discovery of some indications is recorded (Baldracco, 1854) only in the XVII century, and its true discovery and beneficiation started (and ended) at the end of the XIX century.

S'Ortu Becciu (Donori, Cagliari). Barite Hercynian vein (IV metallogenic epoch) with few sulfide alteration products in scarce outcrops. Abundant galena appeared only in depth, after underground research that led to its exploitation in the XX century (fig. 20, tab. 23). Without interest for the ancients, because of lack of silver, and sulfide-poor surface composition.

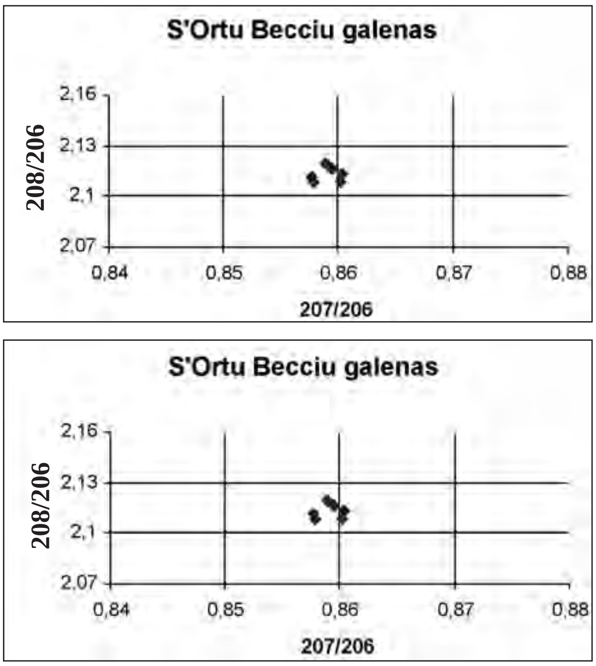


Fig. 20 – Lead isotopic ratios in galena samples from different dumps of the S'Ortu Becciu ore deposit (Donori, Cagliari). The narrow field of values reflects the simplicity of the barite-galena mineralising event, restricted in a relatively short time span.

Tab. 23 - Lead isotopic ratios of the S'Ortu Becciu galenas.

Sample	Pb 208/206	Pb 207/206	Pb 204/206
S'Ortu Becciu 1	2.11355	0.86033	0.0547
S'Ortu Becciu 3	2.10839	0.86027	0.0547
S'Ortu Becciu 5	2.10879	0.85787	0.0546
S'Ortu Becciu 7	2.11603	0.85941	0.0545
S'Ortu Becciu 9	2.11998	0.85895	0.0547
S'Ortu Becciu 11	2.11097	0.85772	0.0547

Hercynian vein orebodies in general. Small size hydrothermal veins, lenses and stock-works commonly consisting of barite-fluorite-calcite-quartz, with traces of galena are scattered in the Sardinian crystalline basement and, less frequently, in the Sardinian-Corsican batholith. IV metallogenic epoch (fig. 2, tab. 2). They are medium-small size orebodies, commonly made up of a mineral association of barite, fluorite, quartz, calcite with other carbonates, in variable ratios, always accompanied by traces of galena. Most of them underwent some exploration in the past (especially at the end of XIX – beginning of XX century), and still show the marks of this activity: small excavations, short adits, and shallow pits. Galena was the main object of these works, it being collected by private entrepreneurs, and sold to the large enterprises of the mining industry. However the large enterprises themselves organized survey programmes aimed at finding new resources to supplement exploited ore deposits. The explored occurrences were actually identified with certainty based on memories and traditions handed down from very ancient times, and at times recorded in the form of tales in written documents, as in the case of the "*living toads in the limestone*" mentioned by Baldracco (1854). They could have supplied some small quantities of Pb sulfide for limited needs.

Polymetallic mixed sulfide orebodies in general. Already mentioned in relation to a number of Cu-bearing mineralisations. *Strata-bound* base metal sulfide lenses (III metallogenic epoch, fig. 3, tab. 3), generally of low tonnage (not more than some thousand tons each) with major pyrite-pyrrhotite-galena-ferriferous sphalerite-(minor or absent chalcopyrite), accompanied by magnetite, quartz, and Ca-silicates (garnets, wollastonite), often forming the base mineral association later giving rise to true skarns (IV metallogenic epoch). They are frequent all over the crystalline Paleozoic basement, perfectly conformable with the host rock structures, which usually belong to the Ordovician-Silurian-Devonian volcano-sedimentary sequence. As noted elsewhere (Valera *et al*. 2002) they must have been of very difficult use with Bronze age technology. Since the gossans were poor, their alteration products were also quite poor.

GOLD (Fig. 21)

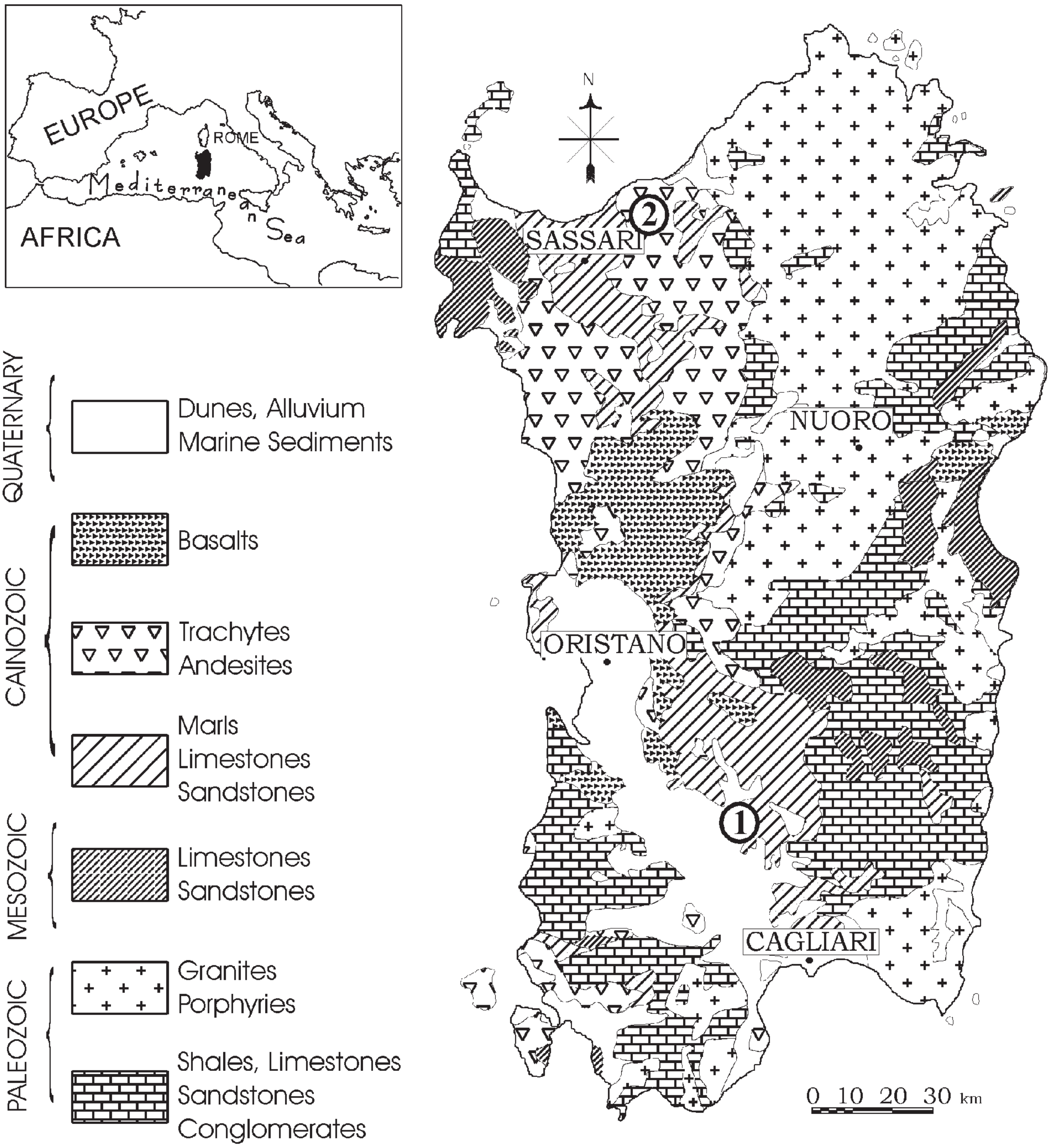


Fig. 21 - Epithermal gold mineralisations
1: Furtei. 2: Osilo.

Gold. It is only in recent years that the epithermal gold model has revealed Sardinia as a gold metallogenic province. Actually, no gold of economic interest had ever been reported before in the long mining history of Sardinia, though a few legends have been handed down through the centuries. Former studies detected the presence of gold at times in pretty good concentrations, but in any case bound to mineralisations hosted in the Paleozoic chrystalline basement, which were already known for sulfide parageneses (typical and frequent the association pyrrhotite-pyrite-arsenopyrite-marmatite) often accompanied by scheelite, or even for antimonite-scheelite paragenesis. The above vein mineralisation of Baccu Locci, and the deposits of Villasalto – Ballao (Cagliari; see *infra*), that were exploited in past times, belong to this large family: however the gold there (pl. VII, 1) was never considered recoverable, not even as a by-product.

The application of the relatively recent epithermal ore deposit model (Garbarino *et al.* 1991), which has already been tested world-wide, has made it possible to discover a deposit of economic value, which is being exploited at present (Furtei, Cagliari), while other indications (Osilo, Sassari) are explored. This model is based on the low-temperature hydrothermal processes bound to volcanic activity in particular crustal sections, that also developed in the Sardinian Cainozoic. The importance of the hydrothermal process is testified by the intensity of alteration phenomena (silicification, sericitisation, caolinisation etc.) in the volcanic sequence, where sulfide, sulphosalt, and native gold mineralisations are emplaced in suitable structures. They are low grade gold mineralisations (2-3 g/t) that can be exploited economically in large open pits, as long as the well milled ore is processed in cianidation plants for the best possible recovery of the finely dispersed gold, often hidden in minerals from which it cannot be separated by other means.

The attitude conditions and especially the gold liberation rate (the metal is never visible to the naked eye) of the Sardinian epithermal deposits induce us to rule out that they may have ever been known or even presumed in ancient times. Referring to the above conditions it should also be noted that a favourable state did not occur for the formation of placers. This could have been the only possibility for indications of the existence of gold, themselves being useful economic deposits. We therefore rule out any possibility of beneficiation of gold by ancient miners in Sardinia.

IRON (fig. 22)

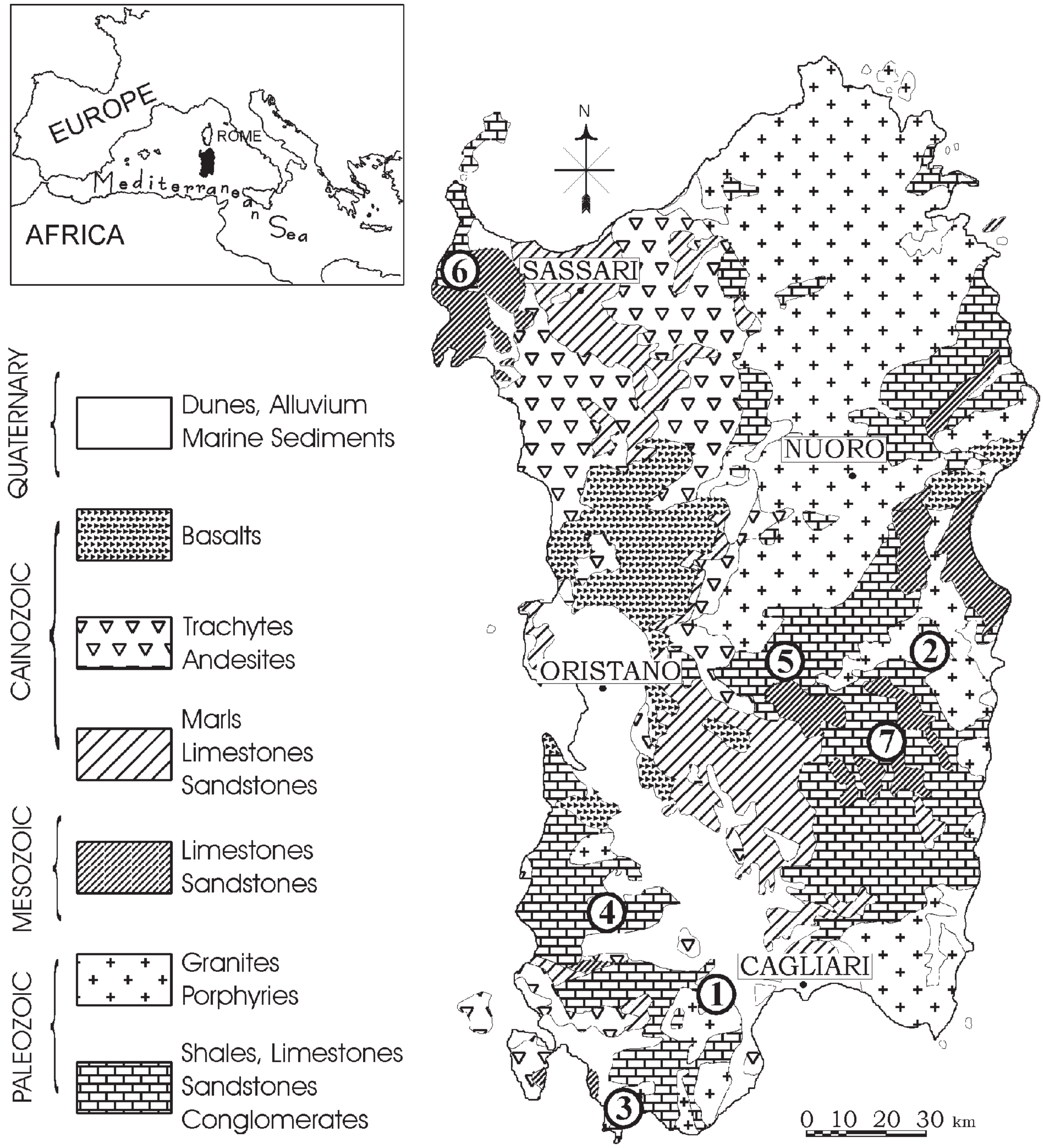


Fig. 22 - Iron mineralisations
1: San Leone. 2: Monte Idolo. 3: Monte Lapanu. 4: Perda Niedda.
5: Giacurru, Perdabila, Bruncu Mela. 6: Canaglia. 7: “Ferro dei Tacchi”.

Iron mineralisation (see map p. 74) of different types and ages occur in Sardinia as deposits of modest size. Some were the subject of documented mining activity in recent times, though they have been completely abandoned today. However the interest shown in 1767 (Rolandi 1971) in a Sardinian iron metallurgy deserves some attention. As a matter of fact an iron foundry was planned near Tortolì (Cagliari) as part of the mining activity supported by the duchy of Savoia. The project was considered more than once though it was never followed up in practice, but it clearly demonstrates the existence of an ancient tradition confirmed by one of the placenames in the territory of Arzana (Nuoro): Cava Calamita ("Magnet Quarry").

San Leone (Capoterra, Cagliari). Major magnetite accompanied by quartz, calcic silicates, fluorite, scheelite, and minor sulfides in thick skarn lenses. IV metallogenic epoch. Today depleted after a long exploitation, this was the only true iron mine in Sardinia. Unimportant gossan.

Monte Idolo (Arzana, Nuoro). This is the magnetite-bearing skarn mentioned above (IV metallogenic epoch) object of interest of a first iron initiative, probably inspired by an ancient tradition that preferred this district even compared to the larger San Leone deposit. The initiative was abandoned probably on account of its small size.

Monte Lapanu (Teulada, Cagliari). Genetically similar to San Leone, but strictly linked to limestones. The ore association is given by magnetite, siderite, ematite, and pyrite. Today under military restraint.

Perda Niedda (Domusnovas, Cagliari). Orebody from thermometamorphism of granite on Cambrian limestones. Magnetite, ematite, Pb-Zn-Fe sulfides, accompanied by fluorite, quartz, and calcic silicates. IV metallogenic epoch. A conspicuous gossan, derived from deep seated weathering (several tens of metres), made up by abundant iron oxides. It occupies a surface of about two hectares.

Giacurru, Perdabila, Bruncu Mela (Meana Sardo-Gadoni-Aritzo, Nuoro). Lens-shaped skarns with major magnetite, explored in the past with some exploitation, genetically like the adjacent Funtana Raminosa deposit (see above), but without copper. Poor gossans.

Canaglia (Nurra, Sassari). Layers and lenses of "oolithic" iron (structure given by magnetite, leptochlorite, chamosite, and siderite concentric shells) in layers and lenses interbedded within the Silurian metamorphic complex. III metallogenic epoch. Poor gossan, some recent exploitation only for a short period.

"Ferro dei Tacchi" ("Iron of the Tacchi", Ogliastra, E Sardinia). Hematite – limonite lenses, derived from continental laterites, deposited on the post-Hercynian peneplain, and later covered by Mesozoic carbonatic sediments. V metallogenic epoch. The erosion remains of this Mesozoic cover are the so-called "*tacchi*", sheltering the iron crust at the footwall. There was some exploitation just before the Second World War, but no clues of any ancient works were found.

TIN (see map p. 75):

Perdu Cara (or Sedda Planuceddu, or Monte Linas: Fluminimaggiore, Cagliari). A NE-SW trending vein mineralisation (Zuffardi 1958; Valera, Valera 2003), 10-100 cm thick, 1500 m in length, consisting of quartz-cassiterite-(magnetite) in the northern section, changing to quartz-arsenopyrite in the southern part (pl. VII, 2). IV metallogenic epoch. One of the authors of this paper (R. G. Valera) was a member of a group of prospectors in 1958 in charge of evaluating a possible exploitation of the tin deposit; the survey gave negative results. In that time the arsenopyrite section had been completely depleted for many years, and the tin section showed traces of small diggings with a few shallow pits no more than 1 metre deep. These works had been carried out by the miners of the arsenopyrite section perhaps towards the end of their activity, of course by blasting. Later in the '60's the tin section was explored by another mining enterprise that also exploited some thousand of tons of ore from underground. Finally in the '70's *Ente Minerario Sardo* (the Regional Mining Authority) carried out a new exploration campaign, both at the surface and underground, which was unfortunately marked by a terrible accident, concluding that the deposit was too small and of no economic interest. The presence of surface occurrences of quartz pebbles with some cassiterite (pl. VIII, 1) is due to the above works, while initially the cassiterite was only visible in the outcrops scattered as specks and patches in the massive quartz, and at times finely dispersed in the country rock for few centimetres near the selvages. The debris left by the last works have certainly misled a few authors, who were clearly unaware of the study of mineral deposits or local mining history, and made an enthusiastic estimation (Ingo *et al.* 1996) of the extent of the tin mineralisation. This mineralisation can be considered little more than a mineralogical rarity (for Sardinia). The only hypothesis that can be proposed is that it could have been a source of a few cassiterite to form some small placers (but no more than few kg of ore) along the creeks downstream from the ridge, along which the quartz vein outcrops. There are no traces, however, of such an imaginary placer, and its discovery by hypothetical skilled experts in the Bronze age could well be a primeval example of serendipity. In any case, any miniplacer that could have been discovered was certainly completely depleted until the last drop of cassiterite, as no traces of it are visible today.

Nevertheless, we have analysed the trace elements in some of the samples of the Perdu Cara cassiterite, and compared them with the results of analyses carried out on some metal tin fragments collected at S'Arcu 'e is Forros (Valera, Valera 2003) (figg. 24 and 25, tab. 24 and 25). As regards copper, zinc, and especially tungsten, some substantial differences stand out, that cannot be ascribed only to metallurgical transformation.

TIN (fig. 23)

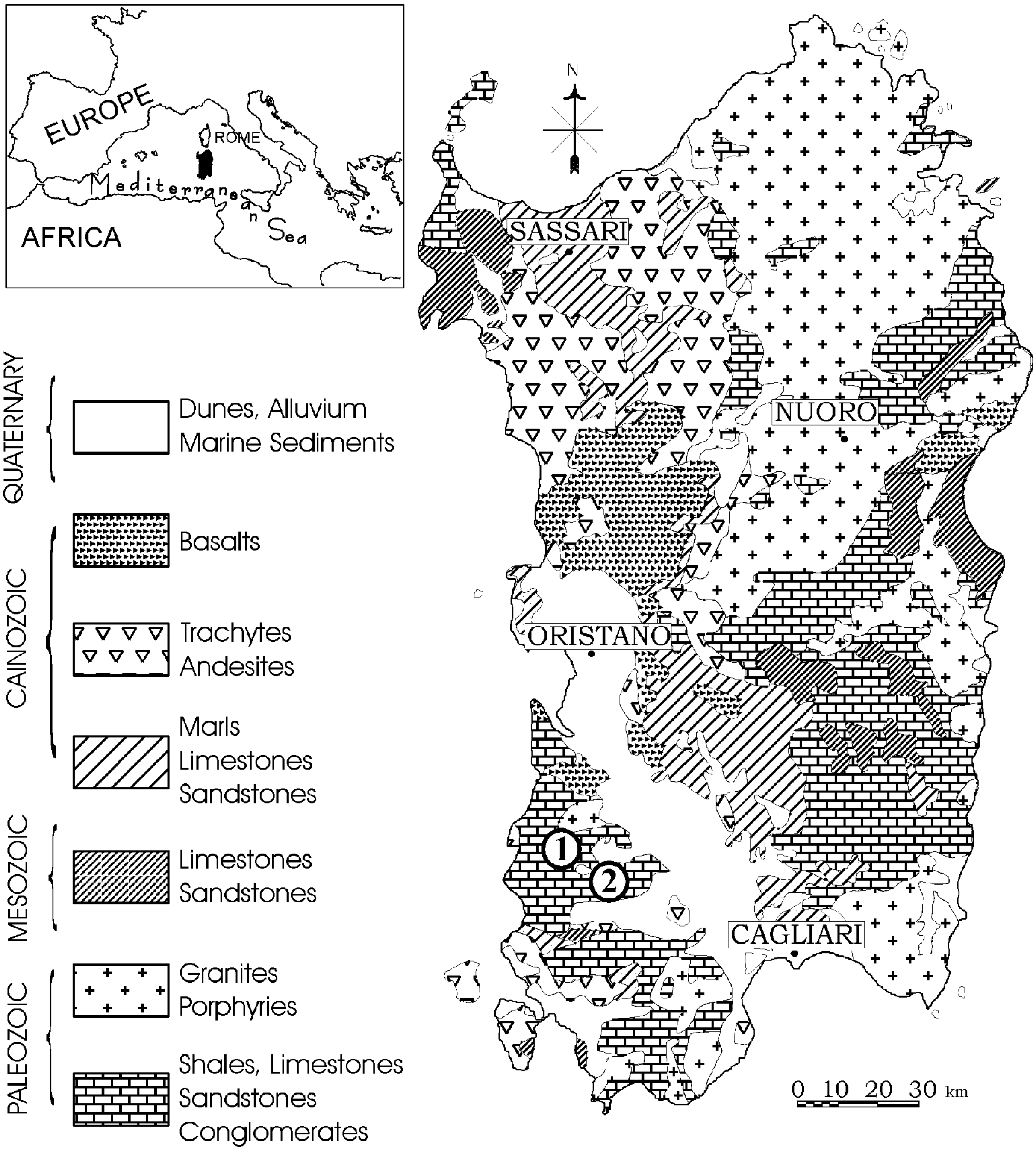


Fig. 23 - Tin mineralisations
1: Perdu Cara. 2: Canali Serci.

Canali Serci (Villacidro, Cagliari) (Piepoli, Collari 1936; Valera, Valera 2003): this is a quartz-siderite lode of Hercynian age (IV metallogenic epoch) with sphalerite, galena, pyrite, marcasite, pyrrhotite, cassiterite, and rare stannite and tetrahedrite. It is a classic example of a misunderstanding about ore deposits. As a matter of fact in the past century the tin mineralisation was what attracted the organisation of the mining unit that was responsible for the intense beneficiation of the deposit. Beneficiation was only made possible by the flotation process, because the minor tin ores (cassiterite and stannite, visible only under microscope) are finely dispersed and intergrown with major zinc, lead and iron sulfides. Of course placer concentrations produced by a natural hydrogravimetric sorting could not be expected in such a paragenetic and liberation conditions, while it cannot be excluded that a tin increase could have been possible as a geochemical anomaly in the related alluvial deposits. In any case it cannot be assumed that the modest capacitiy of this mineralisation could have been known before the modern age, and it is equally unlikely that it may have been beneficiated in ancient times (fig. 26 and tab. 26).

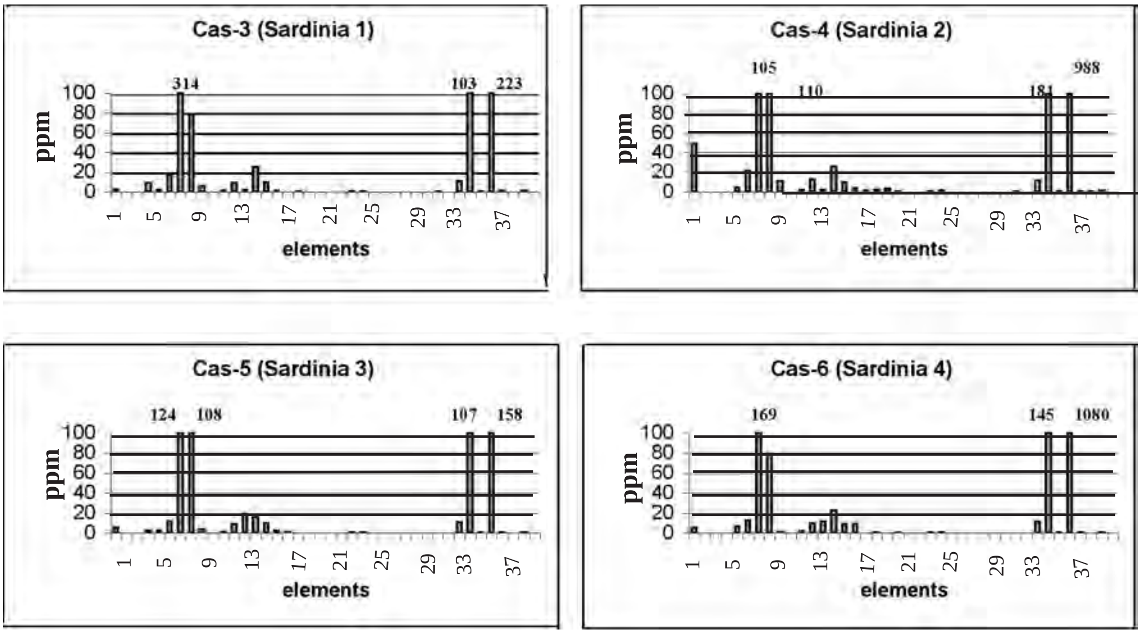


Fig. 24 – Trace element distribution in the Perdu Cara cassiterite. The elements and their respective value are marked by numbers corresponding to the lists in tab. 24.

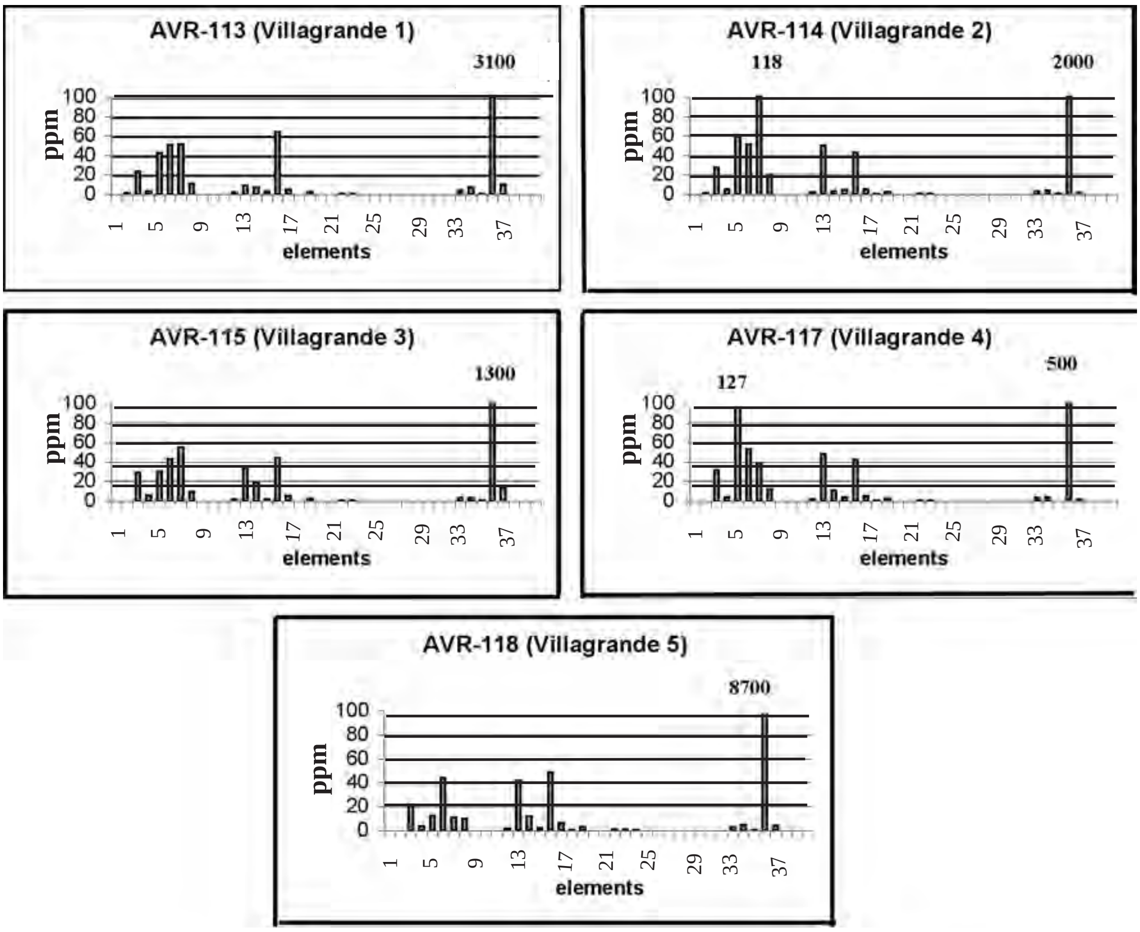


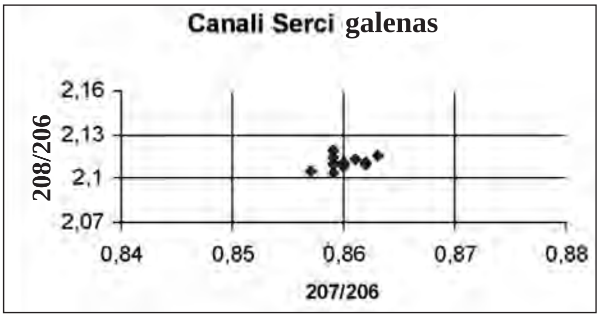
Fig. 25 – Trace element distribution in five tin fragments from S'Arcu 'e is Forros. The elements and their respective value are marked by numbers corresponding to the lists of tab. 25.

Tab. 24 - Trace elements (ppm) in four cassiterite samples of Perdu Cara.

	Cas-3	Cas-4	Cas-5	Cas-6
1 - Li	2.8	49	5.7	5.7
2 - Sc	nd	nd	nd	nd
3 - V	nd	nd	nd	nd
4 - Cr	8.5	nd	2.5	nd
5 - Co	2	4.2	2.3	6.5
6 - Ni	16.7	21.4	11.5	12.2
7 - Cu	314	105	124	169
8 - Zn	79	110	108	78.2
9 - Ga	6.1	10.4	3.8	1.3
10 - Y	nd	nd	nd	nd
11 - Zr	1.5	2.2	1	1.6
12 - Nb	8.5	12.5	8.9	9.4
13 - Cd	2	2	19	11
14 - In	25	26	16	22
15 - Mo	9.5	9.3	9	8.7
16 - Sb	1	3.7	2.7	8.5
17 - Cs	nd	1.5	1	nd
18 - La	0.5	1.6	nd	0.5
19 - Ce	0	3.4	nd	0.2
20 - Pr	0.3	0.7	0.3	0.4
21 - Nd	nd	nd	nd	nd
22 - Sm	nd	0.3	nd	nd
23 - Eu	0.8	0.9	0.7	0.7
24 - Gd	0.8	1.3	0.8	0.9
25 - Tb	nd	0.1	nd	nd
26 - Dy	nd	nd	nd	nd
27 - Ho	nd	nd	nd	nd
28 - Er	nd	0.2	nd	nd
29 - Tm	nd	nd	nd	nd
30 - Yb	nd	nd	nd	nd
31 - Lu	0.4	0.4	0.3	0.3
32 - Hf	nd	nd	nd	nd
33 - Ta	10.9	11.4	10.4	10.9
34 - W	103	181	107	145
35 - Tl	0.6	0.8	0.5	0.6
36 - Pb	223	988	158	1080
37 - Bi	1	0.8	0.8	0.7
38 - Th	nd	0.4	nd	nd
39 - U	1.2	1.3	0.6	0.5

Tab. 25 - Trace elements (ppm) in tin fragments of S'Arcu 'e is Forros.

	AVR-113	AVR-114	AVR-115	AVR-117	AVR-118
1 - Li	nd	nd	nd	Nd	Nd
2 - Sc	1.2	1	nd	Nd	Nd
3 - V	23.6	27.1	28.4	31	20.9
4 - Cr	3.4	5.2	5.4	4	3.5
5 - Co	42.7	58.9	29.6	127	12.5
6 - Ni	50.6	51.1	43.3	53.3	43.6
7 - Cu	51.3	118	55	38.3	10.9
8 - Zn	10.6	19.5	9.6	11.8	10
9 - Ga	0.1	0.2	0.2	0.3	0.2
10 - Y	nd	nd	nd	Nd	nd
11 - Zr	nd	nd	nd	Nd	nd
12 - Nb	2	1.6	1.6	2.1	1.8
13 - Cd	9	50	33	48	42
14 - In	7	3	19	11	12
15 - Mo	3.3	4.5	2.2	3.6	1.9
16 - Sb	63.7	43.1	44	42.2	48.4
17 - Cs	4.8	4.9	5.2	5.2	6.2
18 - La	0.3	0.5	0.3	0.4	0.5
19 - Ce	2.3	2.6	2.5	2.6	3.1
20 - Pr	nd	nd	nd	Nd	0.2
21 - Nd	nd	nd	nd	Nd	nd
22 - Sm	0.7	0.8	0.9	0.9	0.9
23 - Eu	0.5	0.7	0.8	0.8	0.9
24 - Gd	0.3	0.3	0.2	0.3	0.3
25 - Tb	nd	nd	nd	nd	nd
26 - Dy	nd	nd	nd	nd	nd
27 - Ho	nd	nd	nd	nd	nd
28 - Er	nd	nd	nd	nd	nd
29 - Tm	nd	nd	nd	nd	nd
30 - Yb	nd	nd	nd	nd	nd
31 - Lu	nd	nd	nd	nd	nd
32 - Hf	nd	nd	nd	nd	nd
33 - Ta	3.8	3.1	3	3.1	3
34 - W	6.8	4	3.4	3.8	4.6
35 - Tl	0.5	0.4	0.4	0.3	0.3
36 - Pb	3100	2000	1300	500	8700
37 - Bi	10.4	1.4	14.6	1	4
38 - Th	nd	nd	nd	nd	nd
39 - U	nd	nd	nd	nd	nd



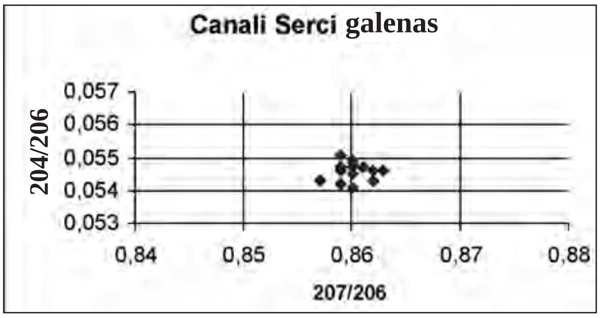


Fig. 26 – Canali Serci, Villacidro (Cagliari) - Lead Isotopic ratios in galena, from different dumps. The complex paragenesis, which shows cassiterite associated with sulphides, exhibits a rather restricted scattering of values.

Tab. 26 - Canali Serci - Isotopic ratios in galena sorted from sulphides.

Sample	Pb 208/206	Pb 207/206	Pb 204/206
Canali Serci 1/1, lower dump	2.113	0.861	0.0547
Canali Serci 1/2, lower dump	2.105	0.857	0.0543
Canali Serci 1/3, lower dump	2.11	0.862	0.0543
Canali Serci 1/4, lower dump	2.111	0.86	0.0548
Canali Serci 1/5, lower dump	2.111	0.862	0.0546
Canali Serci 1/6, lower dump	2	0.863	0.0546
Canali Serci 2/1, middle dump	2.11	0.859	0.0542
Canali Serci 2/2, middle dump	2.108	0.86	0.0541
Canali Serci 2/3, middle dump	2.109	0.86	0.0545
Canali Serci 2/4, middle dump	2.104	0.859	0.0546
Canali Serci 3/1, upper dump	2.114	0.859	0.0547
Canali Serci 3/2, upper dump	2.111	0.86	0.0547
Canali Serci 3/3, upper dump	2.119	0.859	0.0551
Canali Serci 3/4, upper dump	2.11	0.86	0.0549

ALUNITE (fig. 27)

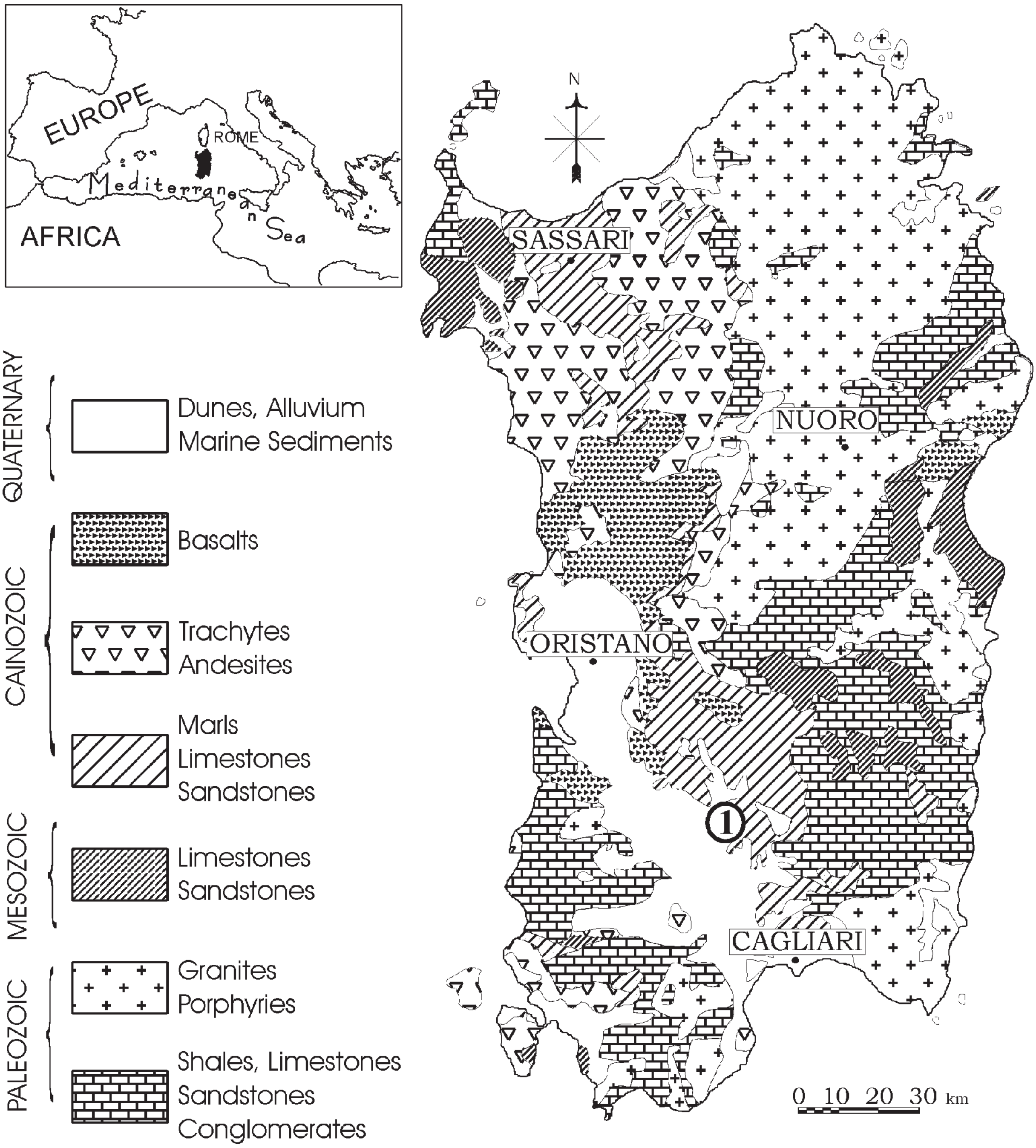


Fig. 27 - Alunite mineralisations
1. Furtei.

Alunite is the base ore for the production of alum. Its presence in Sardinia is due to the high sulfidation processes which gave rise especially to the gold mineralisation of Furtei (see above). Its was evaluated as a result of studies carried out on this mineralisation (Garbarino *et al.* 1991), which also pointed out its conspicuous frequence as veinlets, small lenses, and nodules together with its close bond with jarosite, of which it is often a minor component. Jarosite has a similar composition, but it is particularly rich in iron. For this reason it is usually assimilated to iron oxides, that are extremely frequent weathering products in the gossan on account of its earthy and yellowish appearance.

ANTIMONY (Fig. 28)

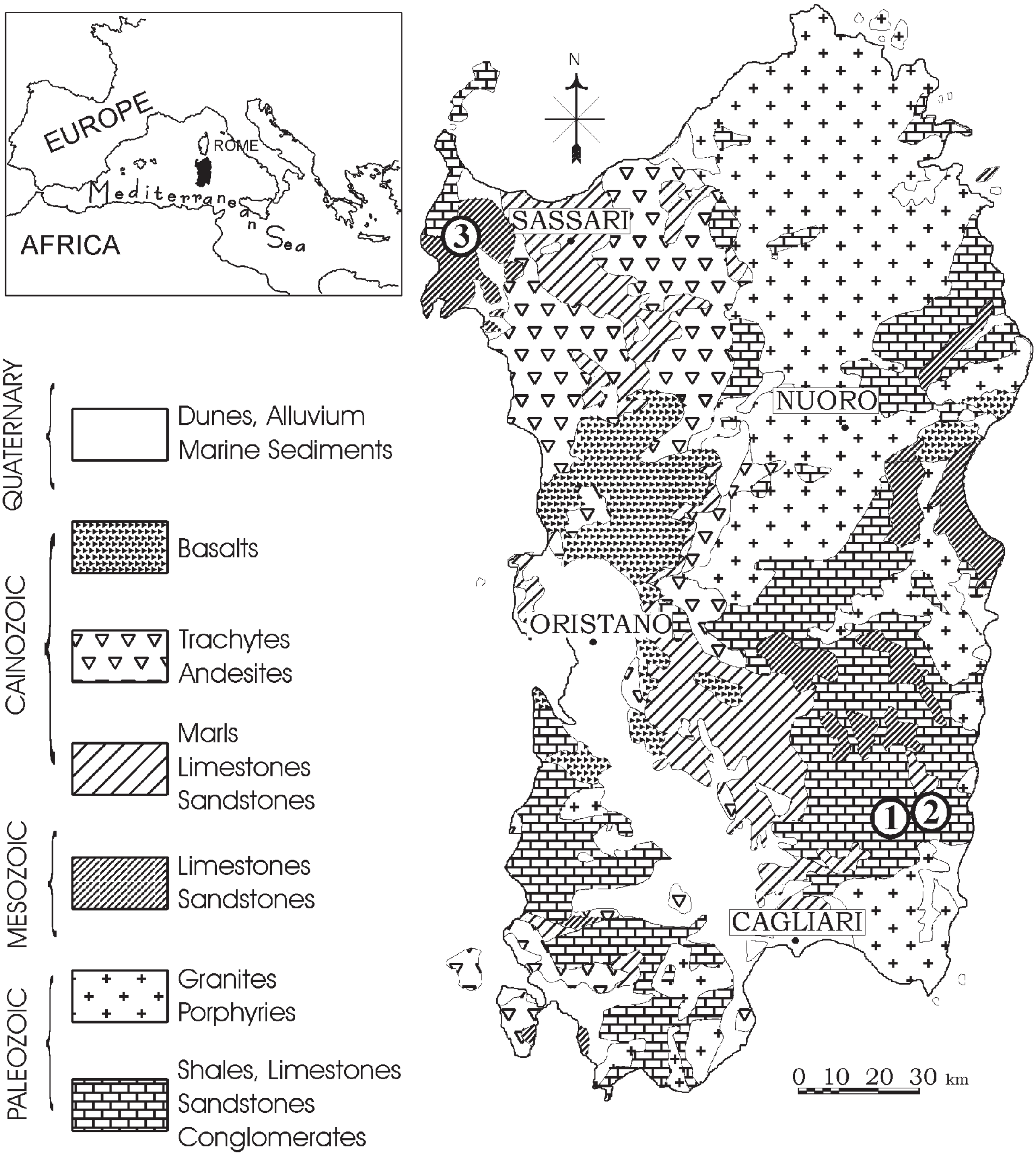


Fig. 28 - Antimony mineralisations
1: Su Suergiu - Martalai. 2: Corti Rosas.
3: Sa Bumbarda.

Su Suergiu – Martalai (Villasalto, Cagliari): stibnite lenses (with scheelite) enveloped into a shale sequence, very loose and incompetent, difficult to exploit in ancient times. Gold traces. III metallogenic epoch.

Corti Rosas (Ballao, Cagliari): same situation, mineralisation of scarce importance.

Sa Bumbarda (Alghero, Sassari): stibnite vein mineralisation, in quartz. Very small size, IV metallogenic epoch.

TALC-STEATITE (Fig. 29)

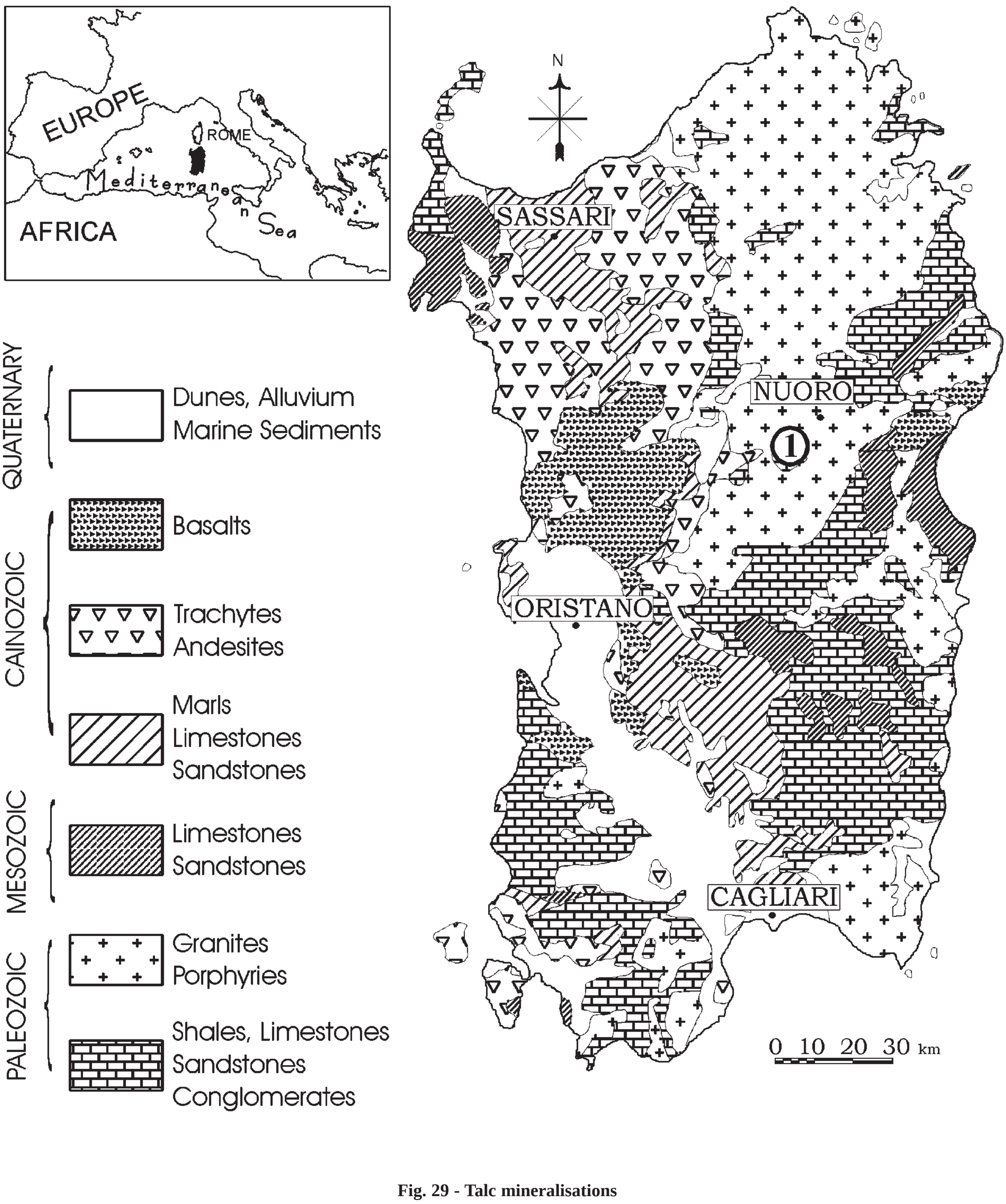


Fig. 29 - Talc mineralisations
1: Orani.

Sa Matta (Orani, Nuoro): the only deposit of a large size in Sardinia known since primeval times, that is still in production today. IV metallogenic epoch.

CLAY (Fig. 30)

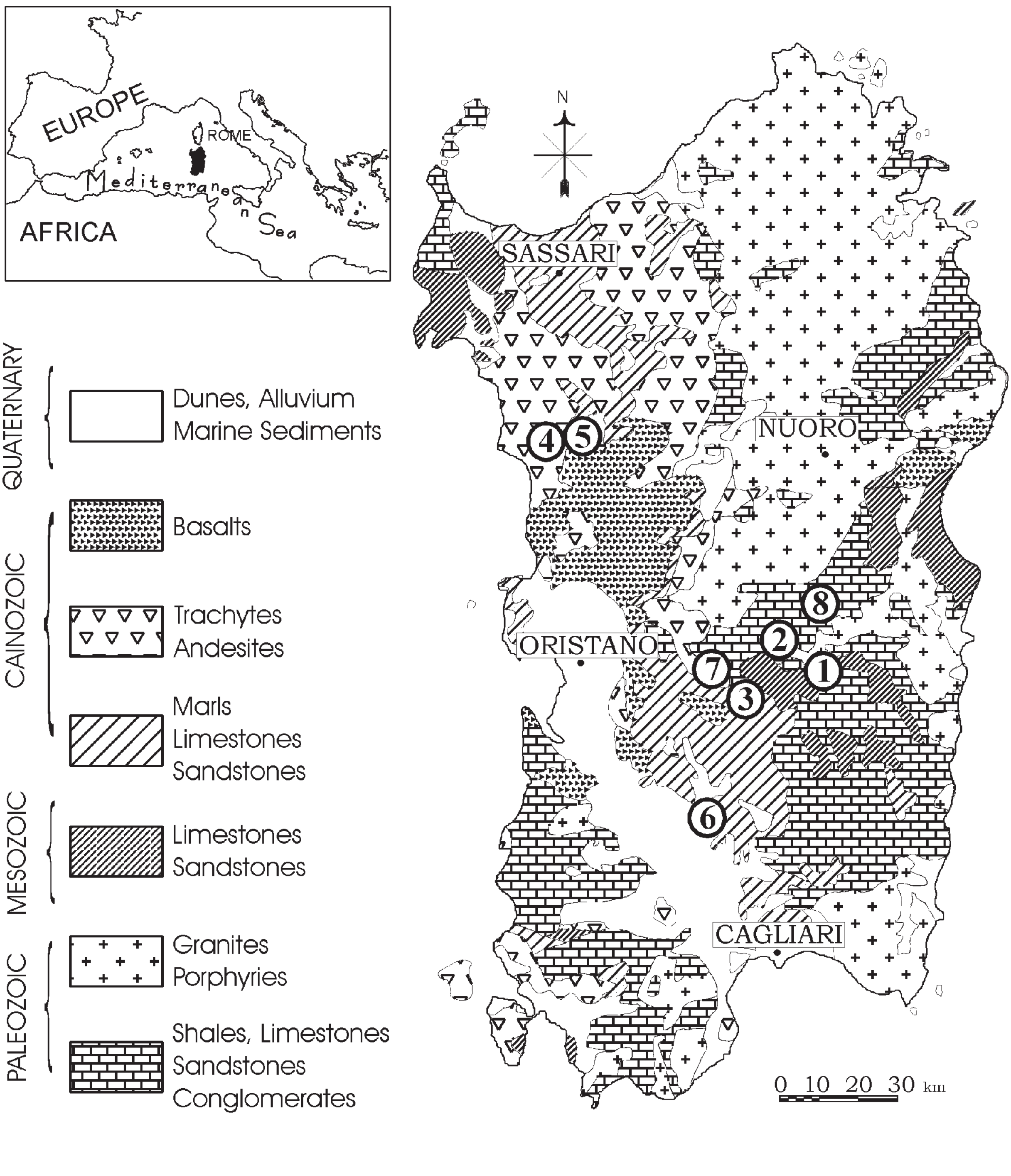


Fig. 30 - Clay mineralisations
1: Sadali. 2: Ortuabis. 3: Funtanamela.
4: Mara. 5: Cossoine. 6: Serrenti. 7: Su Lau.
8: Flumendosa.

For refractories : at the footwall of the Mesozoic carbonatic sequences (“Tacchi”: Sadali, Ortuabis, Funtanamela etc.). V metallogenic epoch.

For ceramics: associated with the Tertiary volcanics in several zones: Mara, Cossoine, Serrenti etc., and in recent alluvial or limnic deposits. VII metallogenic epoch.

For fulling-mills: associated with the Tertiary volcanics or in reworked deposits. Typical deposits: Su Lau (Nurallao), and near the bed of the Flumendosa river (Gadoni). VII metallogenic epoch.

6. Conclusions

Though limited to those clearly useful to the ancients, the mineralisations reviewed here abundantly justify the fame always assigned to Sardinia. The arrival of competences and suggestions, certainly accompanying the Mediterranean exchange and trade routes, should only be considered a starting point of the beneficiation and exploitation of the mineral georesources, where lead, copper, and silver excel since the very beginning. Tin also, and the benefits of its use share an advanced metallurgical culture, which was acquired where tin was known and available, according to a long tradition of use. This was soon conveyed to Sardinia and quickly acquired by the island’s metallurgists.

The lack of tin mineralisations in the Mediterranean world, exploitable in the Bronze Age, suggests the existence of a few privileged trade routes, capable of supplying the unusual, precious metal – maybe in monopoly conditions. If we add the data of the nuragic lead isotopic ratios, that point to the supremacy of the Cambrian mineral sources in Sardinia, and therefore of its south-western metalliferous district, we may propose the following scenario:

1. At the beginning of history the Cambrian “Metalliferous Ring”, which hosts a great number of Pb-Zn-Ag mineralisations, presented the enormous outcrop of the Monteponi deposit, and many minor occurrences. Several tens of thousands of cubic metres of oxidation products and sulfides, easily processed for the production of lead and silver. Nowadays the “Scavi Cungiaus” (pl. V, 1) is a large open pit testifying to millennia of digging, where a few empty profiles (pl. V, 2) left by ancient adits of indeciferable age can be seen almost at the surface. It is impossible to find testimony of ancient metallurgical activity today: the hundreds of thousands of tons of slag, still rich in lead and silver, that had been piled up progressively (especially in Roman and medieval times, but certainly stratified on older remains and more ancient testimonies), were exploited completely and processed between 1858 and 1872 (Rolandi 1971) under the capable management and guidance of Enrico Serpieri, a central figure in the early years of recent Sardinian metallurgic history. After smelting tests were carried out in Marseille on a 949 t technological sample, the slag was treated in an adequate metallurgic process developed in foundries purposely built in Domusnovas and Fluminimaggiore (Cagliari), or reconditioned for the purpose (Villacidro, Cagliari). The results of the recovery were so good that a similar process was promoted in identical conditions in Greece, for the exploitation of the ancient slag stored in Attica, in front of the Makronesos island (Ergastiria plant, 1865). Nowadays nothing can remain of the ancient exploitations in the Cambrian-hosted ore deposits. Nor was anything left after the repeated renewals of mining with progressively improved open pit methods until the today’s final depletion. Perhaps a last witness is still visible in certain heaps at Perda S’Oliu, east of Fluminimaggiore, however of indeciferable age.

2. The conspicuous huge deposits of the Cambrian district, and particularly of Monteponi, were identified and started being exploited very early, by Sardinians and/or by searchers that landed following the trail of the trade exchange, which had been active from very ancient times (the obsidian testimony). The island of San Antioco, *i.e.* Ptolemy’s Molibodes Nesos, Plumbaria Insula par excellence, could have inherited and maintained the function of epicentre of trade, from its deep-rooted, strengthened tradition, which was asserted by distributing all over the island both the locally produced lead and the imported tin, especially since it was the starting point for the export of silver and lead, which in this frame were certainly produced not only for internal needs.

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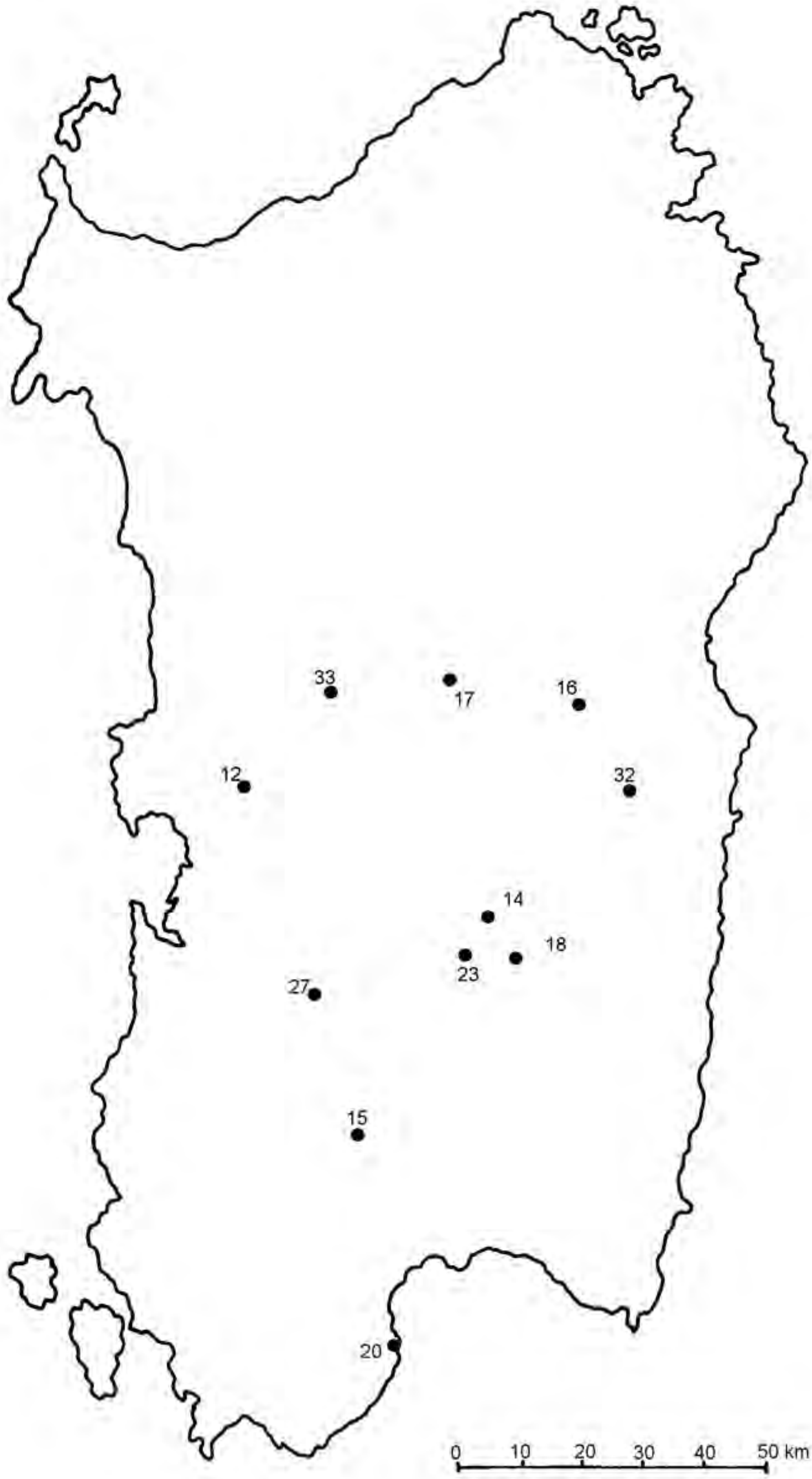
ARCHAEOLOGICAL FILES

The file numbers indicate the chronological sequence of the finds and their contexts (index p. 411).



Archaeological file 12

Solarussa (Oristano), nuragic spring “Mitza Pidighi”.
(Alessandro Usai)

The nuragic spring of Solarussa lies next to the settlement surrounding nuraghe Pidighi, at the border between the Campidano Maggiore plain and the Paulilatino basalt *plateau*.

Some obsidian tanged arrow-heads and a pottery fragment decorated in the Ozieri style show that the spring was already known in pre-nuragic ages (Late Neolithic: IV mill. B.C.). The monument was built some time after the construction of the complex nuraghe Pidighi, perhaps together with the setting up of the permanent adjacent settlement.

During the longer part of its life, the spring was formed only by a horseshoe-shaped body, built with raw or partly dressed polyedric stones. It includes a roughly trapezoidal room with the back wall constructed with squared stones. Still today the water flows from a little cell drawn in the middle of the back wall; the base of the cell is constituted by a great slab with settling hollow, which connects to a channel at least 21 meters long, formed by stones soldered with lead castings. The first part of the channel fits the cobbled paving of the internal room, which is covered by a seat on the right side; in front of the spring, the open space on the left side of the channel received a pebble pavement, while platforms made of larger stones were settled on both sides of the horseshoe-shaped body.

Only during the last part of its life, the spring was enlarged on the left front side with the construction of a semicircular wall defining a small enclosure; within it, partly on the old pebble pavement and partly on a platform made of polyedric stones, was settled a structure formed by some small irregular slabs and covered by a large elliptical slab, probably serving as an altar. In the same time, a new slab floor was built in the internal room, which covered the channel and the old floor.

The collapse stratum of the semicircular wall goes down almost to the same level of its base; therefore it must have stood for a rather short time. The enclosure wall and the horseshoe-shaped body collapsed at the same time, marking together the abandonment of the spring and of the whole nuragic settlement.

As the layer inside the room has been repeatedly disrupted, the chronological data are offered by the finds recovered in the rich stratified deposits, excavated in the enclosure and outside the spring, especially on the left side. The potteries found just on the platform flanking the external wall (stratum 61, layers 3-4) belong to the terminal phase of the Middle Bronze Age or to the initial phase of the Late Bronze Age; above there is a deposit of the Late Bronze Age (stratum 58; stratum 61, layers 1-2), also preserved in the northern part of the space later occupied by the enclosure; above there is the deposit of the Final Bronze Age, extended all over the excavation area and subdivided into an initial (stratum 13, layers 2-3) and an advanced or terminal phase (stratum 13, layers 1-2); on top there are the collapse deposit (stratum 11) and the surface layer with medieval and modern materials (stratum 0).

The spring of Solarussa delivered a great amount of pottery finds, plenty of obsidian flakes and instruments and very few metallic elements. The only bronze element is constituted by a small double wheel with junction rod.

For the scientific analyses some lead pieces have been selected, as well as a fragment of clay crucible probably used for lead casting. Moreover, a probable iron find has been added, recovered in a layer (stratum 33) uncovered by the collapse deposit; one may suggest for it the same chronology assigned to the pottery finds, yet without excluding the possibility of infiltration from the surface. (Usai A. 1996; Usai A. 2000; Usai A. 2004)

List of the selected metallic finds

1) Lead casting, found between two stones of the water channel; it should belong to the building phase of the nuragic spring.

2) Shapeless lead fragment (stratum 61, layer 1).

3) Pottery fragment with lead repairing plug (stratum 58, layer 1).

4) Pottery fragment with lead repairing plug (stratum 13, layer 1).

5) Pottery fragment with lead repairing plug (stratum 13, layer 1).

6) Iron element (stratum 33).

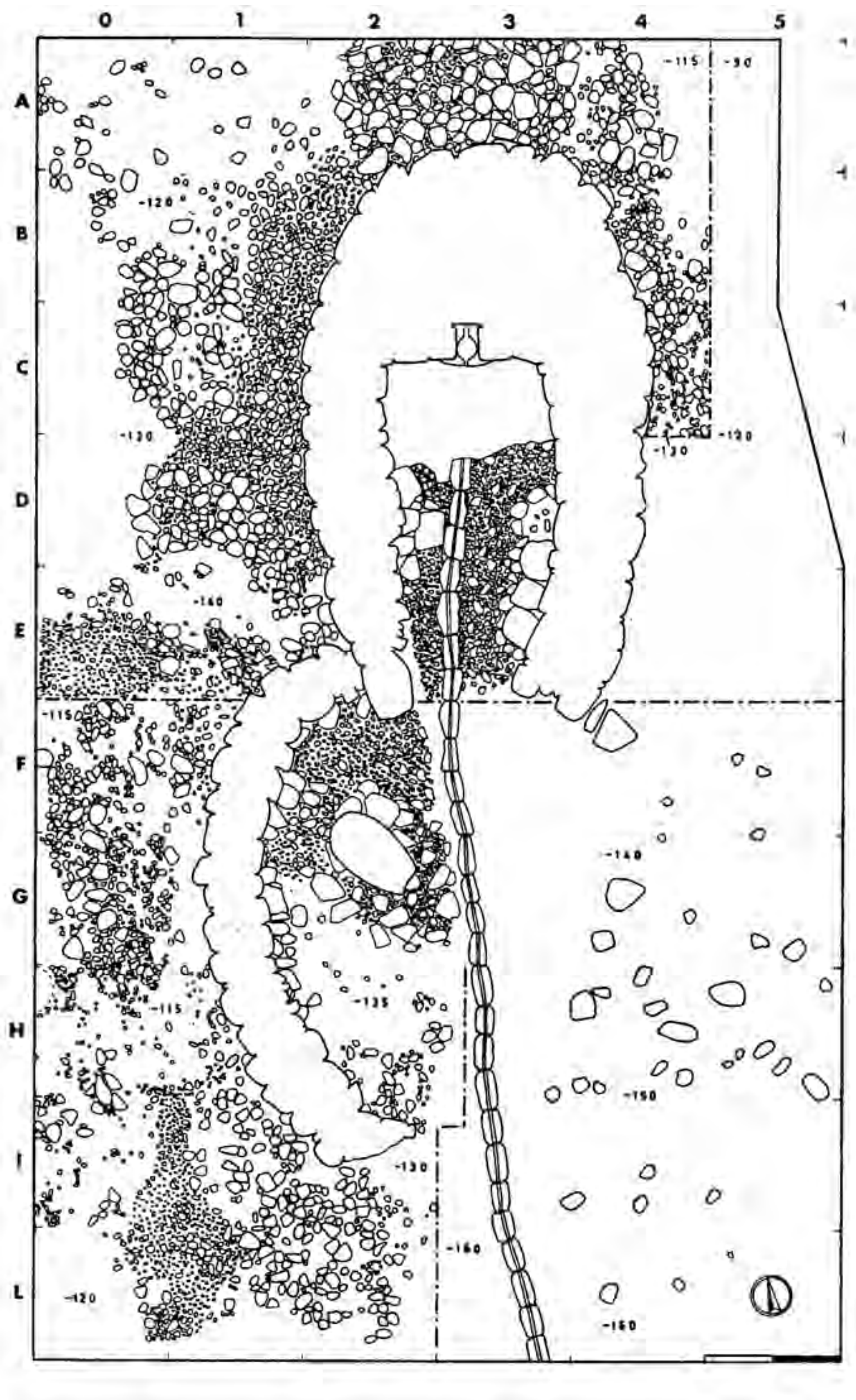


Fig. 1 – Solarussa, Mitza Pidighi: plan of the nuragic spring. *(after Usai A. 2000)*.

Archaeological file 14

Villanovatulo (Nuoro), nuraghe Adoni.

(Fulvia Lo Schiavo)

The nuraghe Adoni of Villanovatulo is a real stratigraphic and chronological stronghold for the area, which goes from the high Flumendosa towards the territory of Isili. It is a nuraghe with an anomalous ground-plan, situated at 811 m above sea-level, on the top of the high point of a *plateau* with steep precipices; naturally defended and isolated from the other nuraghi, it enjoys quite exceptional visibility over an extremely large territory, in visual contact with numerous nuraghi of the zone.

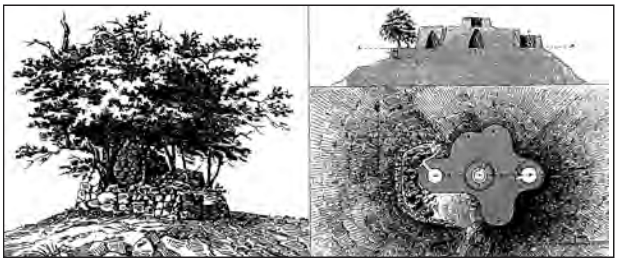


Fig. 1 – Villanovatulo (NU), nuraghe Adoni: ground plan, prospect and cross-section published by La Marmora in 1840 *(after Sanges 2000, 196).*

The monument consists of many towers erected on different levels and linked together by various stretches of wall. It is constructed of blocks of organogenic limestone and built onto limestone beds, which is a not particularly suitable material for either foundations or construction. However it is evident, in spite of this difficulty, that the positioning was deliberate, probably designed to control a vast territory from which the monument in its turn could be clearly seen over a very wide radius.

Long known – the central tower, crowned with oaks, was reproduced in a print by La Marmora in his *Voyage en Sardaigne* (1840) – it was only in 1997-2000 that the monument and part of the village which surrounds it were excavated and restored, producing stratigraphies and associations of great interest. Subsequent phases of construction and occupation were distinguished, and numerous indications show that use continued, even if sporadically, into historical time and the Middle Age, without doubt on account of its strategic position (Sanges 2000).

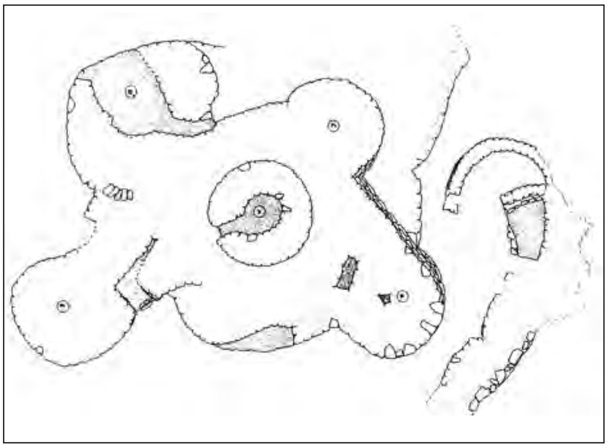


Fig. 2 – Villanovatulo (NU), nuraghe Adoni: general plan *(after Sanges 2000, 194).*

The collapse of the great brackets and the stone-hammered ashlars, which crowned the central tower, sealed the stratum of the raised courtyard X, from which exclusively material attributable to the Recent Bronze Age was recovered; a small awl in bronze with bone handle, a certain quantity of ceramic material, as well as a large quantity of bones.

In the collapse of the ashlars were found various clamps and lead castings, which served to “bind” the numerous square blocks (Campus 2000; Campus, Leonelli 2003; Campus, Leonelli 2004; Campus *et al.* 2004).

Archaeological file 15

Villasor (Cagliari), nuraghe Su Sonadori.
(Alessandro Usai)

Nuraghe Su Sonadori lies at the western border of the territory of Villasor, at the boundary between the Campidano plain and the lowest slopes of the Linas massif. The region, called “S’Aqua Cotta” (that means “Warm water”), is crowded with nuragic settlements.

The monument, currently under excavation, is an unusual complex nuraghe derived from the fusion of an originally single tower (A) with some adjacent round huts (C, D, H) and with true perimetric towers (E, F, G), connected by walls which include also the front courtyard (B) and the side entrance corridor (I, L). Despite the attempt of creating a coherent building following an organic project, the small volume of the added bodies does not balance the overwhelming bulk of the central tower: therefore the building looks paradoxically like a simple group of dwellings disposed around a courtyard, where the original tower looks disproportionate and almost out of place. The central tower with raised entrance looks rather archaic; the corridor and the round chamber have no niches; no remains of the staircase can be seen. The central tower is flanked by six independent round buildings, connected by short and thin straight walls; five of them have a round chamber, but only two (E, G) are thick enough to support a stone vault; on the contrary, the buildings C, D and H, smaller and thinner, seem to be huts provided with perishable ceilings. Of the tower F only the solid base is preserved, where one can see part of an earlier straight wall; a vaulted chamber must have existed on the base, with entrance from above.

Two occupation layers have been detected in the chamber of the central tower. The lower one (stratum 53) delivered a hearth, animal bones and remains of a bench; that indicates a primary habitation function. In the upper layer (strata 43-51) was found plenty of pottery and particularly small and medium size jars, besides some millstones and pestles; that shows a prevailing utilization as storehouse for foodstuffs and other perishable goods. This function is symbolically underlined by a large jar with thickened rim, buried intact in a pit (feature 51A) dug under the yellowish dirt level (feature 52) which constitutes the floor of the second phase, and belongs to it; the jar contained a miniature collared jar in grey clay. The courtyard B and the rooms C and H seem characterized by activities of food preparing, cooking and consumption.

The scanty finds from the lower layer of the central tower chamber can be attributed to a late moment of the Middle Bronze Age or to a passage phase between the Middle and Late Bronze Ages; all the other materials so far recovered in the monument belong to the southern aspect of the Sardinian Late Bronze Age. The development of a more complex social and economic function in the central tower probably coincided with its transformation into the main core of the complex nuraghe; on the contrary, the general reorganization did not change the domestic functions of the peripheral rooms and of the common open space. The available data suggest a predominant connection of the monument with the intensification of the mixed farming economy, probably through the functions of an authority appointed to food concentration and redistribution for the whole community.

Nuraghe Su Sonadori is next to the lead deposit of Monte Zippiri, exploited till the beginning of the 20th century. Although the excavation has not yet delivered meaningful remains of metallurgical activity, some little bronze and lead elements or fragments have been recovered, as well as some fragments of indeterminate metallic ore. (Usai, Marras 2004; 2005)

List of the selected metallic finds:

1) Tiny copper or bronze fragment (stratum 53: lower occupation layer of the central tower chamber).

2) Small copper or bronze fragment (stratum 43: upper occupation layer of the central tower chamber).

3) Lead repairing plug (stratum 71: occupation layer of the southeast chamber).

4) Group of small copper or bronze fragments (stratum 62: occupation layer of the courtyard).

5) Fragment of indeterminate metallic ore (stratum 67: occupation layer of the southeast chamber).

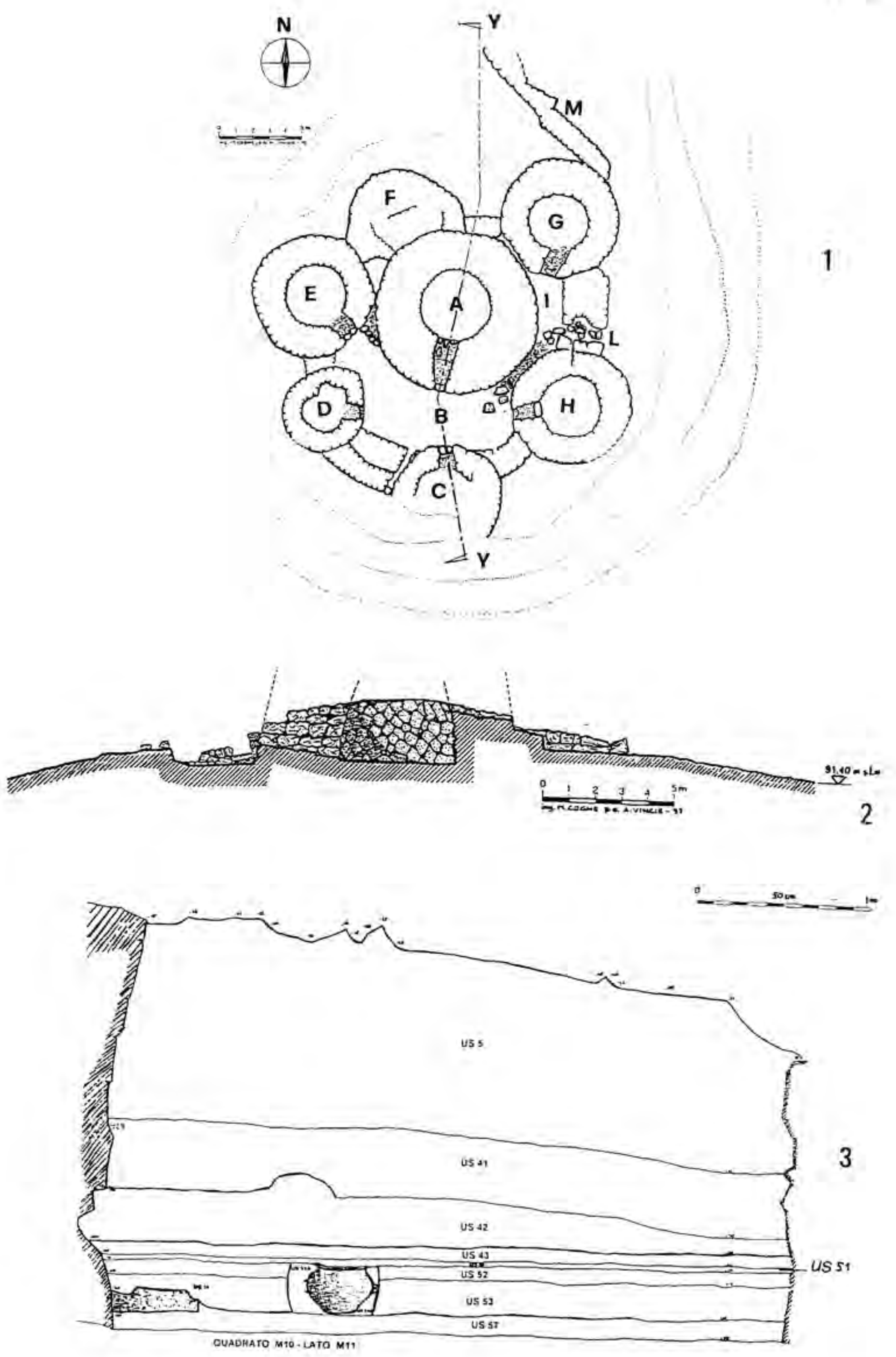


Fig. 1 – Villasor, Su Sonadori: 1-2) plan and section of the nuragic building;
3) stratigraphic section of the central tower chamber *(after Usai A., Marras 2004)*.

Archaeological file 16

Fonni (Nuoro), Gremanu.

(Fulvia Lo Schiavo)

The area of Madau or Gremanu, in the territory of Fonni, at the feet of the pass of Correboi, has long been known, starting from the zone most frequently mentioned as "Madau", where there is a *necropolis* consisting of five giant's tombs, partially excavated and restored in the 1980s (tomb 2 by G. Lilliu).

Later, in 1989, on a wooded hill called "Gremanu", some two kilometres south of the previous locality, in the area of the Caravai pass, a Sanctuary of the Springs was explored, where two small basins, constructed with extraordinary refinement using blocks in even courses, catch the spring rising from the side of the mountain and channel it from one to the other and towards other structures by way of small channels, these too made of finely jointed basalt blocks. To the right of the springs there is a perfectly paved basin, rectangular in shape with the short side facing out over the valley, next to another paved space, covered in the tholos fashion, in which a third well opens, containing material attributable to the final phases of the Bronze Age (Fadda 1993, 177).

At the foot of the Sanctuary of the Springs, many structures were identified during the work, all unfortunately damaged and suffering from illegal excavation; for this reason, on account of its size and masonry structure, it seemed at the beginning that the monument was a small one-tower nuraghe.

However, it turned out that the building had been completely restructured inside and transformed into a highly refined place of cult, known thereafter as the "Round Temple". In fact a very finely paved floor came to light and a bench along the walls, but above all an internal "ceremonial" wall. The wall was constructed with blocks in equal courses placed in rows one on the other, smooth, with protomes of rams sculpted in relief, with dentils and with moulding decorated in zigzags, ending up with a row of votive swords. These were fixed with their points upwards, sunk into lead poured into holes, made in the topmost surface of the stones.

The Round Temple turned out to be external and touching a *temenos*, elongated in ground plan and more than 70 metres long, with a width of 13 m to the north and 22 m to the south. In the north zone in front adjacent to the Round Temple is enclosed a small and perfect "*megaron*" temple, arranged in two internal rooms, the bigger of which is in its turn divided by a short isodomic wall; in front of this and leaning against the east wall of the *temenos* is another apsidal paved building of worship.

The southern zone of the *temenos* suggests that it was used for collective rituals: a monumental entrance to the south between two structures which curve inwards, a bench along the walls, a further, curvilinear ma-sonry structure to the east and a delimitation to the north consisting of two large huts which face each other and linked by an east-west wall with a passage at the centre.

The whole complex, which occupies about seven hectares and is in turn surrounded by an extensive village, has been excavated and restored many times, alternating with just as many acts of vandalism and destruction; preliminary reports put it in the Recent and Final Bronze Age period, but it is possible that the first phase of settlement may date back to the Middle Bronze Age (Fadda 1997; 1998; Fadda, Posi 2003).

In the 1996 excavation season, between the "*megaron*" temple and the nearby Tempio Rotondo within the *temenos*, were found five fragments of oxhide ingots and one planoconvex one, many votive swords, the fragment of an Allerona-type sword, fragments of dirks and small daggers, a *stiletto*, pins and fragments of bronze figurines (see oxhide file 10).

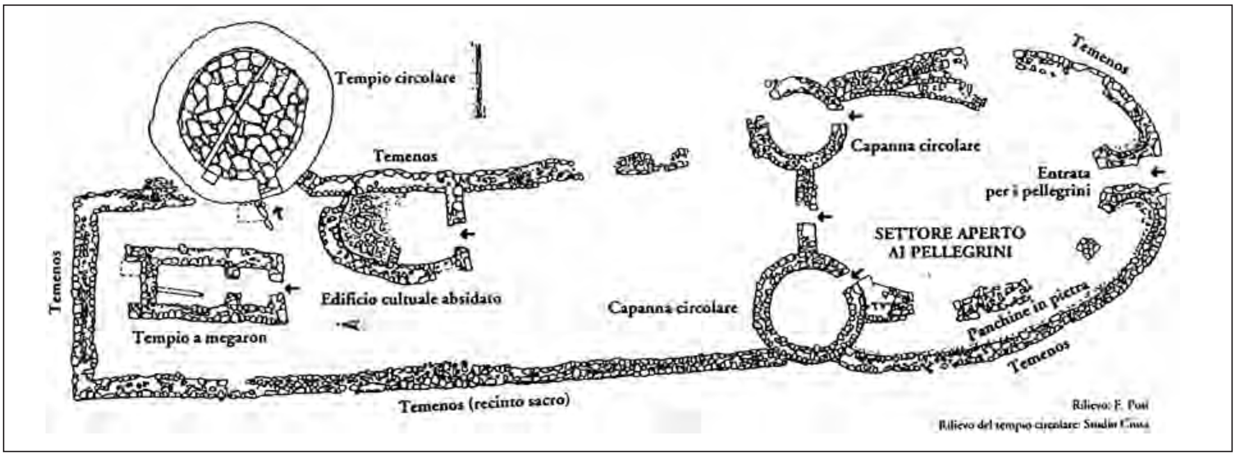


Fig. 1 – Fonni (NU), Gremanu: plan of the cerimonial area *(after Fadda 1999, 76)*.

Archaeological file 17

Teti (Nuoro), nuragic sanctuary of Abini.
(Fulvia Lo Schiavo)

From the middle of XIX century it has been known that, in the locality of Abini, there is a vast sanctuary consisting of various structures encircled by an enclosure, including a sacred well, and of an adjacent nuragic village ("*Interrojas*"). It still happens that the complex of Abini is defined as a "hoard". This begun with Pais himself, who was responsible for the first edition (Pais 1884). From the descriptions of the first authors and also on the basis of the recent excavations, there is no doubt that this is in fact a "typical" nuragic sanctuary, that is to say a Well Temple or Sacred Spring within an enclosure, next to a complex of structures and buildings which are also "sacred", *i.e.* characterized by the "isodomic " masonry style, all enclosed in a vast *temenos*.

Many «hoards» of bronzes were found and excavated from 1865 onwards within the sanctuary area.

Ransacked and devastated several times, the site of Abini has produced an enormous mass of bronzes, mainly votive and of figurines (see Part III, List of analysed finds: I2-7; I9-10), at present in the Museo di Cagliari, assembled in three collections: Timon (1865), Vivanet (1878) and Gouin (1882); there is also the material from Taramelli's excavation of 1929-30 (Spano 1865, 7; Fiorelli 1978; 1882; Nissardi 1884; Pais 1884; Pinza 1901, 163; Taramelli 1931).

At the moment and until the publication of the recent excavations (Fadda, Tuveri, Murru 1992, 250-251; Fadda 2000), it is not possible to reconstruct the original situation, but it is probable that more than one hoard were deposited, displayed or buried in the sanctuary, and there were also offerings spread about. It must be remembered too that the nuragic village of "*Interrojos*" (or "*Interrogas*"), next to the sanctuary, has also hardly been explored.

The sanctuary's chronology is also made complex by the presence of vases of the Early Bronze Age (Ferrarese (Ferrarese Ceruti 1978, 240, no 52, fig. 229) amongst the material; however, overall, it can be assumed that the chronological span is the same as that of other nuragic sanctuaries, between the Recent and the Final Bronze Age, not excluding a more ancient settlement and later occupation.

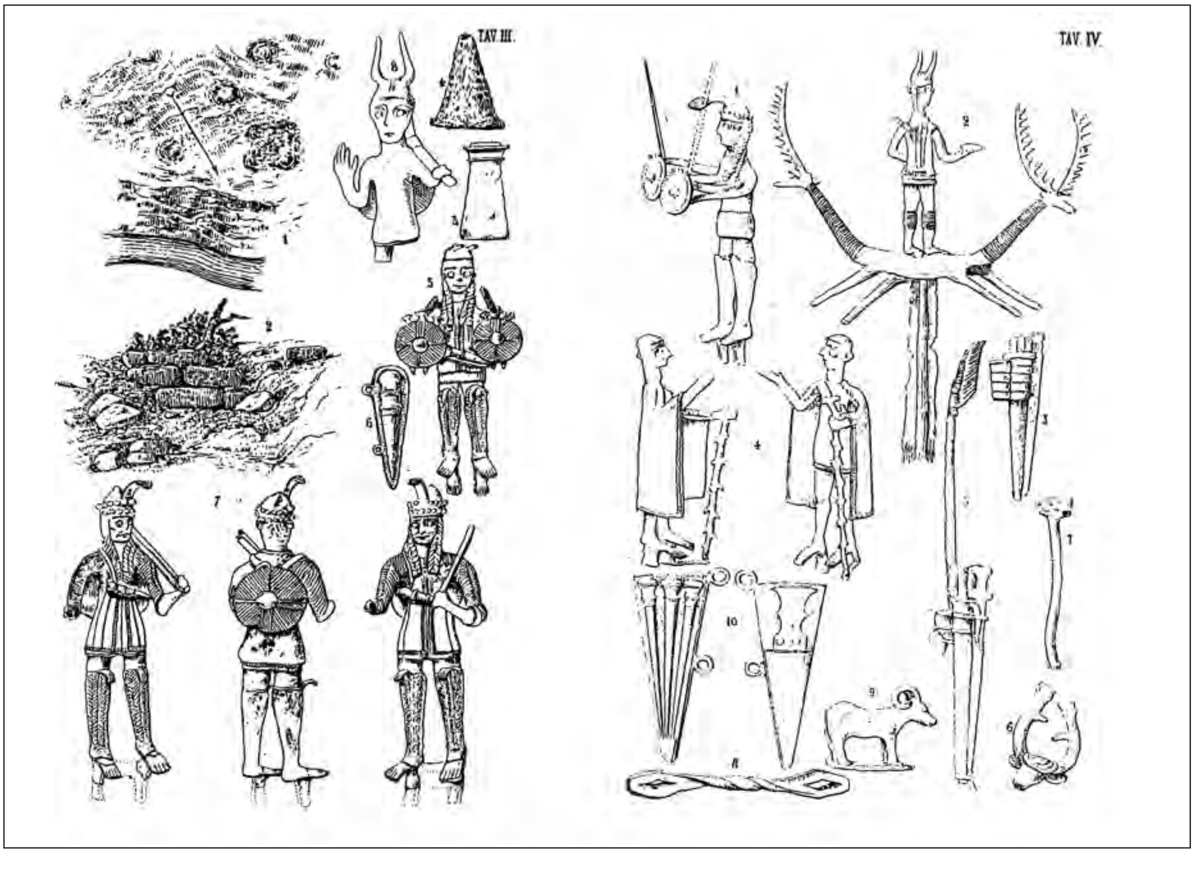


Fig. 1 – Teti (NU), Abini: planimetric sketch of the site, partial prospect of a structure and representations of bronze figurines and other artefacts *(after Spano 1865)*.

On account of ransacking and wild and uncontrolled excavations, caused by the very abundance of bronzes and bronze figurines present in the sanctuary and scattered everywhere, and also placed in vases and in holes in the ground, it is not possible to identify exactly the provenance of the fragment of oxhide ingot which Pigorini in 1904 noted as not belonging to the ingots from Serra Ilixi; the fragment remained on display in the Museo di Cagliari until its restructuring, together with the material from Teti. Many other oxhide ingot fragments in the storeroom of the Museo di Cagliari carry a label with the inscription “Teti (?)”: since there is no inventory number, it is not possible to confirm or to deny this indication (see oxhide file 12).

Equally contradictory and difficult to interpret is the information concerning the presence of pieces of raw metal, including tin (see Part IV, chapter 6 with bibliography).

Archaeological file 18

Orroli (Nuoro), nuraghe Arrubiu.

(Fulvia Lo Schiavo)

The nuraghe Arrubiu at Orroli is to be found in the heart of the wild part of the province of Nuoro, the high Sarcidano, and dominates the ford of the middle course of the Flumendosa river.

This is the only five-tower nuraghe and the largest known from archaeological literature. Around the central tower (A on the plan, present height ca. 15 m) there are another five towers (C-G) linked to each other by mighty, straight walls, with an irregularly pentagonal courtyard in the middle (B). In the chamber of the central tower, the false cupola (*tholos*) is still whole, ca. 11 m high and 5 m in diameter; three niches open at the two sides and in front of the entrance. The one on the left is elbow-shaped in ground plan, deeply set into the thickness of the wall of the tower. In the central courtyard there is a bench along the whole east side, a well, a zone designed for a hearth and a niche; seven accesses join the central courtyard to the other corridors and towers of the complex.

The five-tower structure is surrounded by a further masonry structure, the outer defence, with seven towers (H-P) and three courtyards (K-X-Y), while along the southern side arises a second added structure with four or five towers (Q-U). In the east zone, there are two circular huts.

The results of the excavations, begun in 1981, are still being analysed, but it is still possible to make some preliminary observations.

The monument was built over a limited span of time, approximately between the XIV-XIII centuries BC; the construction of the central tower in particular, contemporary to the five-tower bastion, is to be dated within the XIV century BC, and its abandonment between the end of the Final Bronze Age and the beginning of the Early Iron Age (ca. IX century BC).

What allowed the certain dating of the layout of the complex and of its first phase of existence was the fortunate discovery of a small Mycenaean vase, an alabastron of MycIIIA2 date (1400-1340), the fragments of which ended up in the lowest levels of both the courtyard and the chamber, under the most ancient beaten floor. That demonstrates, in addition to the other details of construction, emerging from the excavation and from the study of the monument, that the construction of the central tower and of the five-lobed bastion happened simultaneously.

The structure of the five-lobed complex collapsed before or at the beginning of the so-called “geometric” period, filling the central courtyard with ca 500 cubic metres of rubble, including finely worked stones from the coping of the terrace of the central tower; these last total many hundreds of blocks of various forms, and were all catalogued during the excavation and fed into a computerized programme, which elaborated, on a photogrammetric basis, a graphical reconstruction of the monument. Some of the stones are still fastened to one another with lead clamps poured into expressly made cavities.

It would appear that the whole superstructure collapsed at the same time and it is possible that the suddenness and the extent of the collapse – due to causes still unknown – prevented the continuation of life on the site: in fact it has been established that the monument was totally abandoned from the First Iron Age up to Roman times.

The Romans settled in the site (from ca. II-I century BC to IV century AD) without removing the ruins and without using the rooms and the internal passages; on the contrary, they established themselves above the rubble, smoothing it down particularly in the space of the central courtyard (B) at a level of about 12 m, and in the southern courtyard (K) in front of the entrance to the five-lobed complex. Here were found two extraordinary plants for the production of wine, with rectangular and circular basins in sandstone and limestone, with spouts and holes, winepress bases, grindstones etc.

The Roman works thus came to seal the nuragic strata, the archaeological examination of which has revealed an undisturbed sequence.

In 1987 work began on the excavation of the central courtyard, beginning from the top of the imposing mass of the collapsed tower, after removing the Roman stratum which had “sealed” it. A group of lead items was thus discovered. This is a hoard which must have been buried under the floor or in the masonry of the chamber of the first floor, and after the collapse of this, slipped down the walls of the tower. There are three planoconvex ingots of lead, two large lumps of crumbled lead sheet, perhaps the remains of vessels, and more than one hundred lead clamps for the repair of vases, some still with fragments of pottery incorporated.

Some bronze objects were also found together with the lead material : two fragments of votive swords, a small spear head, a small cylindrical, ribbed bead like the one from the nuraghe Albucciu at Arzachena, a small axe with orthogonal cutting edges (“axe-adze” or “*maleppeggio*”) and a small dagger with a solid handle with half-moon hilt, all forms characteristic of nuragic production.

Other fragments of bronze and lead artefacts were found in various zones of the excavation. A fragment of an indeterminate type of ingot was found in the corridor linking the central courtyard and tower F, which in part uses the wall of the central tower A, and goes around it. (Lo Schiavo, Sanges 1994; Lo Schiavo 2000; Cossu *et al.* 2003, with bibliography).

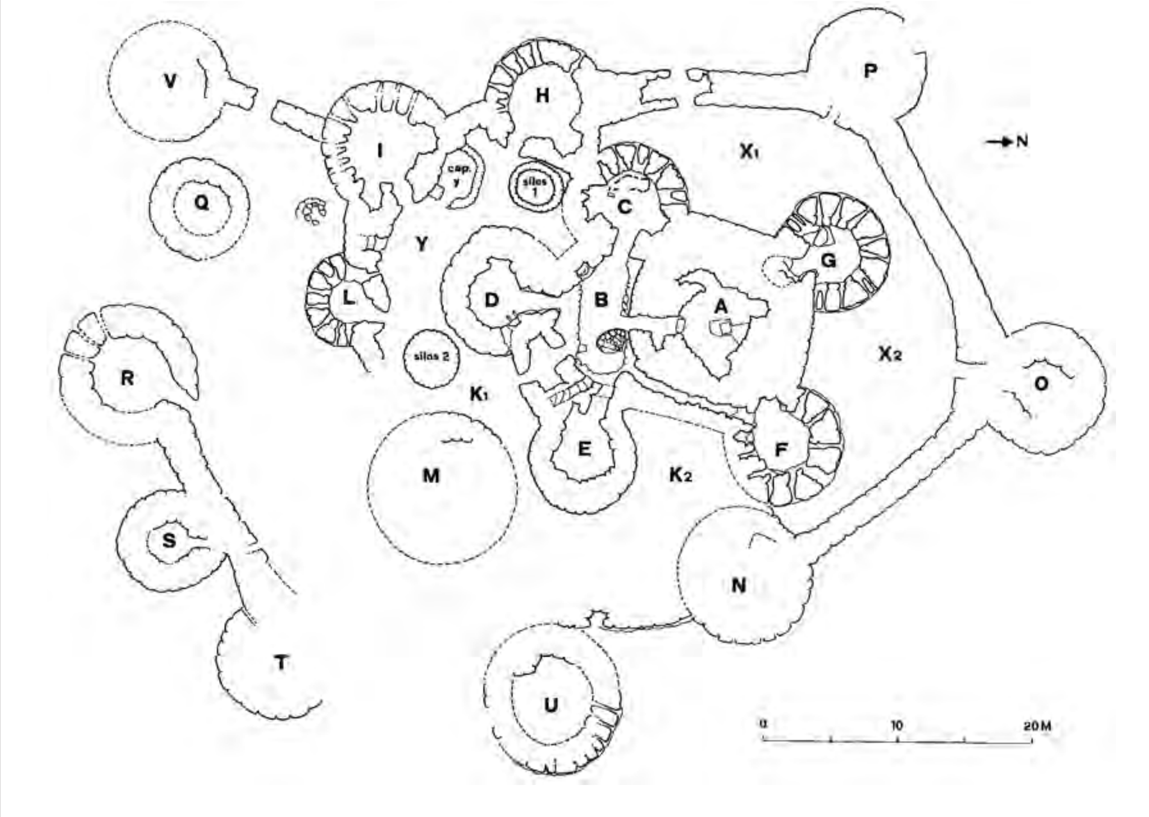


Fig. 1 – Orroli (NU), nuraghe Arrubiu: general plan
(mapping by Roberta Pitzalis and Giorgio Pisano; drawing by R. Pitzalis).

Archaeological file 20

Sarroch (Cagliari), nuraghe Antigori.
(Fulvia Lo Schiavo)

The nuragic fortress of Antigori is situated on a hill at the west end of the gulf of Cagliari. A massive fortification surrounds the summit, blending in with the natural rock, incorporating towers and including, at the centre, the structures of various huts.

The differences in building technique of the fortress, which includes both a polyhedric structure in small stones and blocks of great size arranged in courses, show that construction and use developed in various phases; the huts on the summit date to various periods too. The complete publication of all excavations is under way, under the editorship of L. Vagnetti and by the pupils of Maria Luisa Ferrarese Ceruti, who directed the excavations and the studies on the site.

Access "*i*" opens to the south and leads into a corridor which goes to the summit, with ramps and steps.

Room "*a*", square in plan and with north and south walls constructed and leaning on the rock, produced a stratigraphic succession, with nuragic pottery, documenting the first layout of the fortress at the base. It is later associated with Mycenaean pottery of the Late Mycenaean IIIB and C, and with forms which are locally produced imitations.

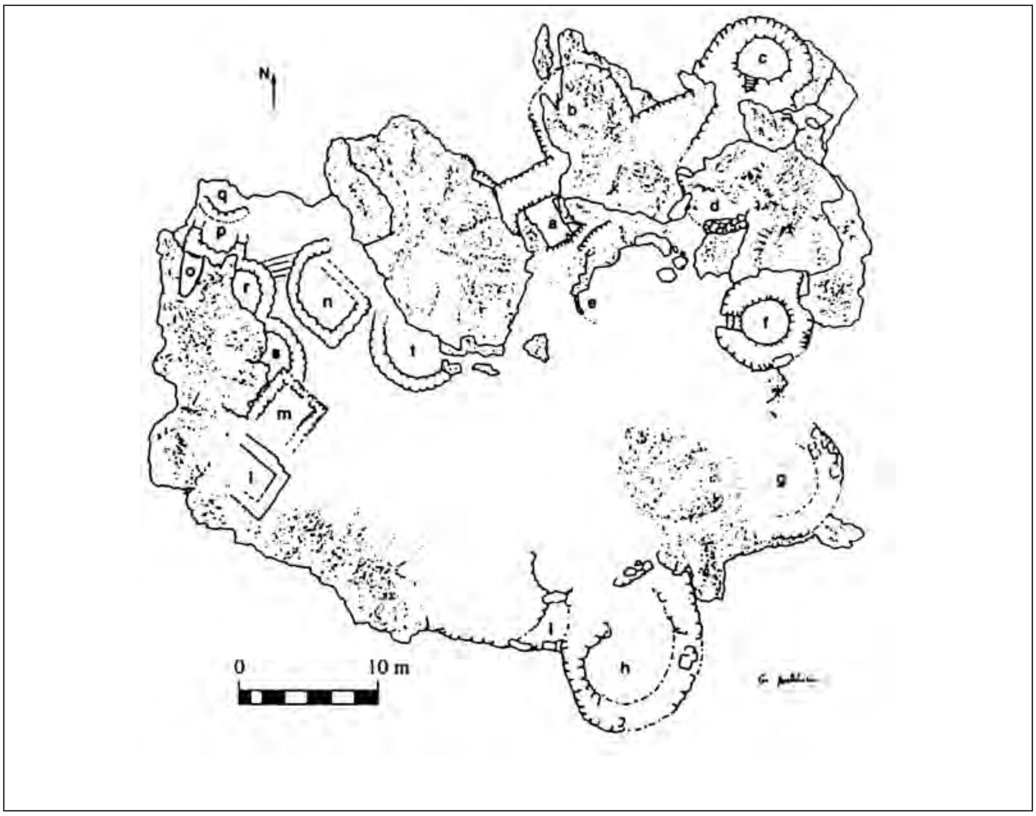


Fig. 2 – Sarroch (CA), Antigori: general plan *(after Ferrarese Ceruti 1986, fig. 1).*

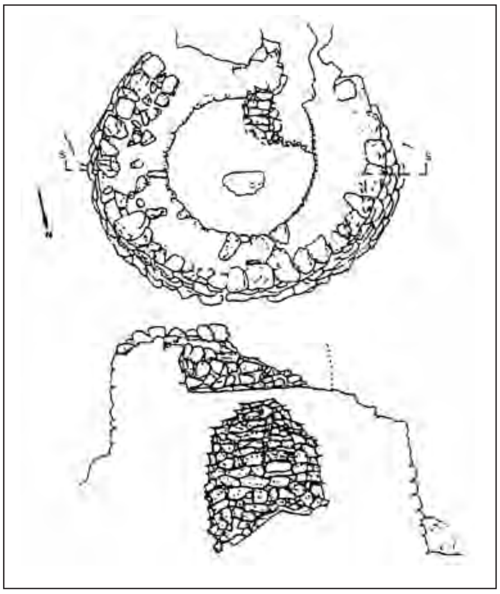


Fig. 2 - Sarroch (CA), Antigori: plan and section of tower *“c” (after Ferrarese Ceruti 1986, fig. 3).*

Tower *“c”*, the highest and best preserved, consists of two floors one above the other, circular in plan and *tholos* covered. The stratigraphy of the upper floor, in five levels, has produced artefacts of extraordinary importance: from stratum 4, a fragment of worked iron about 3 cm long, corroded and rusted, perhaps belonging to the blade of a knife or dagger (see Part IV, chapter 7), associated with a “wishbone handle” classified by L. Vagnetti as “Base-ring II ware”, certainly attributable to Cypriot manufacture of Late Cypriot II and below a level containing other fragments of Mycenaean pottery (Ferrarese Ceruti 1986, 10; Lo Schiavo, Macnamara, Vagnetti 1985, 5 fig. 2,5; Relli 1994; Forci, Relli 1995). From stratum 3a of the same room, a fragment of votive sword (Ferrarese Ceruti 1986, 184-5; Lo Schiavo 2004, fig. 4, 1), see Part IV, chapter 2 and 7.

Tower *“f”*, which is on the south-west side, is circular in ground plan and has access from the central *plateau* by way of a short staircase. In this too was found a rich stratigraphy with little Mycenaean material, almost as if its erection were to be attributed to the terminal phase of Mycenaean occupation of the site (Ferrarese Ceruti 1982; 1983).

The Mycenaean pottery includes both shapes of Mycenaean mainland production, of good quality, and of peripherical workshops, Cypriot and Cretan, including large containers for foodstuffs and vases for transport; most of the material is of local imitation production. Here for the first time Ferrarese Ceruti identified and described a new type of nuragic pottery, the so-called “grey slate”, which, being found in association with the Mycenaean ceramic of the Late Mycenaean III B, has become indicative of levels datable to the Recent Bronze Age and it also shows Mycenaean technical influence on the local production of *impasto*, as it is more polished and baked at higher temperatures.

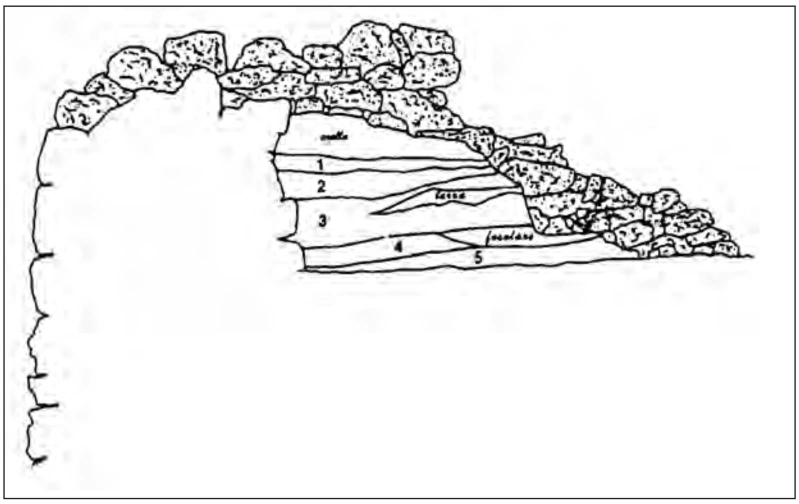


Fig. 3 - Sarroch (CA), Antigori, tower *“c”*: section and stratigraphy of the upper room *(after Ferrarese Ceruti 1986, fig. 4).*

Lead clamps for the repair of vases (Nb1-Nb17) were found over the whole site, while in shelter *“o”*, a little natural cave at the north end of the complex, was discovered a small lead object, interpreted either as a small double axe (Ferrarese Ceruti 1981) or as a miniature ship (Lo Schiavo 1986).

Archaeological file 23

Serri (Nuoro), federal nuragic sanctuary of S. Vittoria.
(Fulvia Lo Schiavo)

On the south-west extremity of the Giara (*plateau*) of Serri, right above the perpendicular slope which looks out onto the town of Gergei, rises now the little country church of S. Vittoria, which gives the name to the splendid nuragic complex next to it, and which dominates a great stretch of the horizon all around. Towards the south-east, it narrows into a saddle about 30 m wide near the ruins of the church of S. Sebastiano. Beyond, it widens again, taking in the urban centre of Serri, the only one which still occupies one of the *giare* which, in nuragic times, were by preference used for settling along the slooping sides.

The excavations conducted by Taramelli from 1907 to 1929 brought to light a vast complex of buildings, spread over an area of almost four hectares. The archaeologist gave them names based on structural characteristics or particular finds (Taramelli 1909; 1911; 1914; 1922; 1931b). Further explorations were carried out from 1986 to 1991, under M.G. Puddu (1986, 1987, 1989, 1990, 1991; see Puddu 1992, 1995). Furthermore, for reasons of safe-guarding, the zones outside the nuragic sanctuary were examined; it was ascertained that in Byzantine times the occupation of the site was very wide-spread, not only with burials, but also with buildings, wells and cisterns. There are no reports of the results of other, recent excavations, carried out in the course of works to arrange the site for tourism (excavations M. Sanges 1998; Sanges 2002).

The “Head’s House” (“*Casa del Capo*”) rises on the north side, flanked by a wall; it is a large circular hut, its *atrium* is floored with slabs and it has benches at the sides. To the east of this and almost at the centre of the complex is the great “Enclosure of the Feasts” (“*Recinto delle Feste”*), a vast elliptical enclosure (73 x 50 m), on which open various rooms, beginning with the entrance to the east: the “House of the Hearth” (“*Casa del Focolare*”), the “Enclosure with the Seat” (“*Recinto con Sedile*”), the “Enclosure of the Axe” (“*Recinto dell'Ascia*”); on the north follows a zone divided into small square rooms, open on one side towards the centre, as far as the Foundry; on the south side is the portico, which goes as far as the Kitchen. As we can see, the interpretation of Taramelli was that of a great *cumbessìa*, *i.e.* a complex which served to receive pilgrims gathering for the feasts in the sanctuary.

In the group of buildings around the small church of S. Vittoria various sequential building phases, not easy to understand, followed each other. Where now rises the so-called “Tower with Embrasures” (“*Torre con Feritoie*”) there was a corridor nuraghe which, on the basis of the materials found in the excavations carried out here by M.G. Puddu (fragments of pottery with “*metopale*” decoration) dates to the Middle Bronze Age (BM3). From this point were built stone walls, now incorporated into other structures. The defensive wall extending as far as the “Head’s House” was part of these structures.

In this group of buildings on the south-west spur of the *plateau*, are also the “*Ipetrale*” Temple, a square and isodomic structure, the “Hut of the Priest” (“*Capanna del Sacerdote*”), the “Circular Enclosure with Seat” (“*Recinto Circolare con Sedile*”), the “Sacred Path” (“*Via Sacra*”), the “Boundary Wall with the Entrance Hut” (“*Muro di Cinta con la Capanna dell'Ingresso*”).

The fulcrum of this part of the sanctuary is the Well Temple, surrounded by an elliptical enclosure (19 x 13 m), carefully constructed with an “isodomic” structure with well-shaped ashlars, of basalt and also of limestone, used to give a polychrome and decorative effect, as in similar sacred buildings. It is circular in ground plan, 2,10 m in internal diameter and 3 m in height, and becomes slightly conical in construction, because of the slight jutting of each row. It is reached by way of a 13 steps staircase, preceded by a rectangular *atrium* with lateral benches and limestone paving, with a table or altar with a hole for libations at the centre, connected to a small channel which runs side-ways and discharges on the outside.

Other constructions are found grouped on the south-east, to the east, to the north-east sides. Among these there are the “Enclosure of the Tortures, or of Justice” (“*Recinto dei Supplizi o della Giustizia*”), the “Enclosure of the Meetings”, or the “Curia” (“*Recinto delle Riunioni*” o “Curia”), the “Block of the Double Baetylum” (“*Isolato del Doppio Betilo*”), the “Enclosure of the Table” (“*Recinto della Mensa*”), etc.

Many of these rooms, as the previous ones, suggest a non-domestic use of common habitation; the canons of construction are undoubtedly those usual in the nuragic period, mostly dating to the Recent and Final Bronze Age periods (ca. XIII-X/IX centuries BC). The complex suggests the hypothesis that a large federal village-sanctuary collected the surrounding peoples around the place of worship, in a naturally defended site already frequented from the Middle Bronze Age onwards.

Hundreds of bronze items and figurines, tools, weapons, ornaments etc, were found over the whole area of the Sanctuary, with particular density around the Well Temple; these are now housed in the Museo Nazionale in Cagliari. Important also are the lead clamps for repairing vases and fixing bronze figurines to the “Table of the Offerings” (Taramelli 1914; 1922; 1931a; Puddu 1992; 1995; Lo Schiavo 2000a).

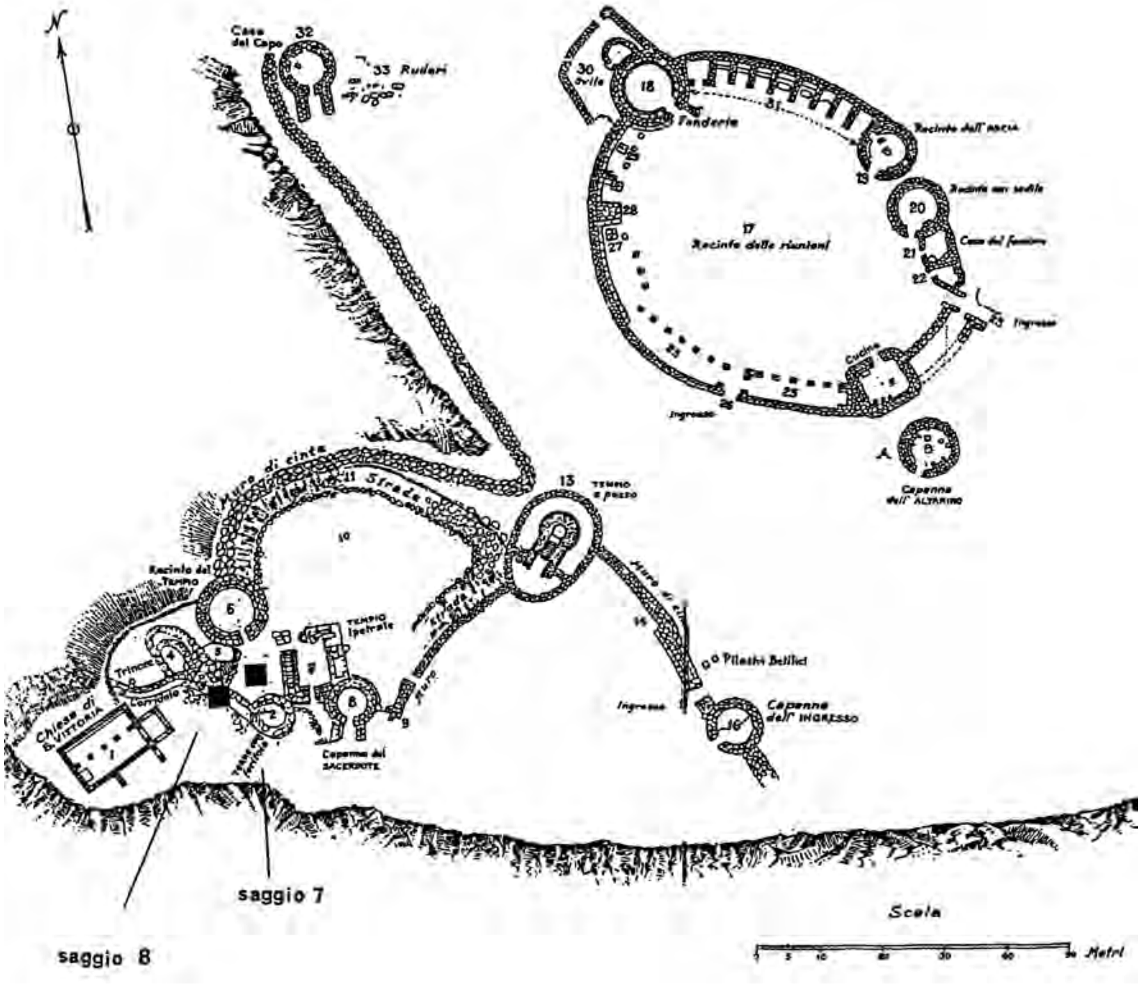


Fig. 1 – Serri (NU), S. Vittoria: general plan of the western zone of the sanctuary *(after Puddu 1992, fig. 36)*.

Archaeological file 27

Sardara (Cagliari), S. Anastasìa.

(Fulvia Lo Schiavo)

The town of Sardara is at the centre of a zone of the Guspini region, densely dotted by settlements from every epoch, prehistoric, nuragic, Phoenician and Roman. Many of the nuragic sites were mentioned by Antonio Taramelli in the first part of the report on the excavation of the site of Sant'Anastasia, which received its name from the nearby church, in the north part of today's town.

It is a nuragic village, in which Taramelli excavated a well temple with a paved *atrium*, a covered tholos chamber, with flat base about 3 m in diameter, and an access staircase, covered with flat stones with a staircase "in nega-tive". Following the stretch of wall which bounds the temple, a second, much deeper and narrower well came to light to the west. It was full of richly decorated vases with plastic motifs, impressed and very polished, evidently for ritual use (Taramelli 1918). A third sacred well was identified during the works in the 1980s at around ten meters to the south of the previous one.

Other rooms were explored, including the "Hut of the Small Channels" (no. 1 – "*Capanna delle Canalette*"), the "Hut of the Council" (no. 5 – "*Capanna del Consiglio*"), and others, partially preserved and not excavated (nos 2, 3, 6).

Structures and material of the greatest importance were brought to light: under the beaten floor of the entrance of Hut 1 (*Capanna delle Canalette*), a buried hoard of fragments of oxhide ingots inside a large bowl with a fragment of another as a lid (see oxhide file 26).

In the Hut of the Council (no. 5), named on account of its larger size and because of the presence of benches along the walls, there was a small column and two round stone discs. One of these had the remains of ten lead supports on which were fixed ten bronze objects (pins, bronze figurines or votive swords), and the upper part of a small model of a nuragic tower with battlement: G. Ugas hypothesized that it is an altar composed of various superimposed elements.

Buried in front of a stretch of the wall near the entrance, a second hoard, inside a jar, contained a series of weapons and bronze tools; 3 chisels with trunnion handle, 6 awls of various sorts, 6 large pins, 4 needles, 5 daggers, one with bone handle, 3 dirks, 1 spit, 2 handles from *situlae* or basins, one belt with small hooks, 1 ladle and one pair of foundry tongs. Next to this hoard were buried three basins, one inside the other. Two of them had two-lobed handles (and one was also topped with a lotus flower) and the third had triple-spiral attachments.

In addition, twelve lead ingots were found in the rubble of the stone wall. Evidently they were originally hidden in the wall, and another three were buried on top of the hoard (Ugas 1987).

Hut 4 was identified at the north-east edge of the area of the village, and was only partially excavated because it is covered by a modern construction. The entrance faces north-west, and there is a threshold with raised step and a paved floor, slightly downwards sloping. It seems that another access communicated with a second room.

Inside the hut 4 B (livello 3), in secondary deposit, were found the remains of casting moulds in terracotta, certainly used for the manufacture of objects by the lost-wax technique. As at S. Barbara of Bauladu (see Archaeological file 29), the casting button ("*bottoni di versamento*") has been found and the distribution channels ("*canali di adduzione*") were still sunk in the clay of the mould (Usai L. 1987, 201-204; Ugas 1988, fig. 4).

Although the area explored is limited and the quantity of material recovered not great, the identification of the site as "metal workshop", *i.e.* a site for the production, finishing and repair of objects, does not seem to be doubious.

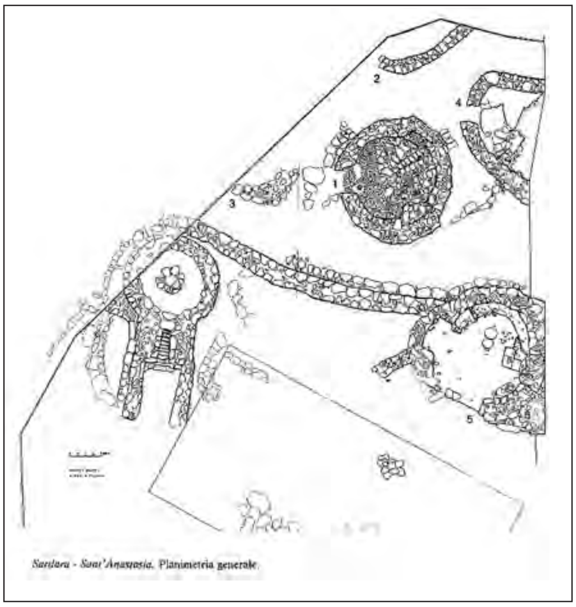


Fig. 1 - Sardara (CA), S. Anastasia: general plan *(after Ugas, Usai 1987).*

Archaeological file 32

Villagrande Strisaili (Nuoro), S'Arcu 'e is Forros.
(Fulvia Lo Schiavo)

In 1985-86 illegal excavations were reported in a nuragic complex of enormous size, arranged around a three-tower nuraghe and a large "*megaron*" temple. Research has continued, since then and until today, aimed at the exploration of the zone, the repair of the monuments and the recovery of material.

However, the number and complexity of the structures meant that only the principal nucleus, which has at its centre the large "*megaron*" temple, has been investigated. The temple was several times excavated and restored, and was shown to be a mighty construction of schist and poor-quality granite blocks sloping for 17 m in length and 5.50/6.50 m in width, rectangular in ground plan and doubly *in antis*. It is delimited by a sockle along the long sides, subdivided by dividing walls into four internal rooms (A-D), fairly big, and covered ogivally with slabs of schist, found inside during the excavation. Although not linked to any well or spring, lustral rites have been hypothesized, because of a long channel covered with small slabs which passes through the masonry from room B and continues sloping to the outside and also because of the *ollae* found buried at the corners of the rooms (Fadda 1996, 80).

The entrance of the temple opens onto a vast *temenos*, elliptical in shape, with a bench along the walls. This enclosure has an access on the right, and communicates on the left with a circular room, preceded by a short *atrium*. Of particular importance for the understanding of the phases of construction and occupation of the complex is the fact that the enclosure is over a pre-existing hut A, at its centre, which has produced material of the Middle Bronze Age period (Fadda 1996, 82). Outside the enclosure a very small, rectangular structure has also been identified and explored, probably a second "*megaron*" temple, the structure of which rests on older levels of the Middle Bronze Age period, to which the earliest phase of use of the sanctuary certainly dates. The period of its maximum flourishing and evolution can be dated to the Recent and Final Bronze Age, on the basis of the pottery and bronze artefacts found.

Four of the huts around the temple were also excavated, and produced, protected by the collapse of the upper part of the structures, the internal furnishings, such as the clay flooring, the hearths, the sectors of it delimited by small walls, niches and small niches, etc, and much material which confirms the continuity of use of the site from the Middle to the Recent and Final Bronze Ages.

During the first surveys and explorations, great quantity of raw metal, of fragments of ingots, both oxhide and planoconvex (see oxhide file 12), together with a huge amount of bronze artefacts, was gathered from the huts, from the area outside the temple and from a structure similar to a nuraghe, much damaged by the illegal excavators. The artefacts included flanged axes, fragments of Cypriot-type tripods, a bronze figurine representing a crouching lion of an oriental-type, a basin of bronze sheet, a large circular ingot of lead with two holes (11.7 kg), and other fragments of lead and scraps. Many other whole and fragmentary artefacts were found during the excavations: votive swords, daggers, pins, pendants, sheet vessels, bronze figures, in addition to a casting mould for a dagger.

The hypothesis was immediately put forward that it was a large settlement with an extensive sanctuary, to which belong the many offerings and the small nuragic model used as a base for fastening votive bronzes with molten lead (Fadda 1996, fig. on p. 82), and that in the locality was situated a metal workshop (see Part IV, chapter 6 with bibliography).

The numerous excavations which followed, concentrated chiefly on the "*megaron*" temple and on the adjacent structures, and confirmed these theories, most recently (Oct.1999) supported by the discovery of various shapeless fragments of metallic tin. It is still arguable where exactly were the furnaces, and what form they had had (see Part IV, chapter 6; Fadda 1989; 1989a; 1991; 1995, 112-116; 2003; in press 2; Vagnetti, Lo Schiavo 1989, 227, fig. 28.4; Lo Schiavo 1990, 26-27, no 11b; Lo Schiavo, Valera R., Valera P. 2003).

Archaeological file 33

Ghilarza (Oristano), nuraghe Orgono.
(Alessandro Usai)

Fig. 1 – Ghilarza (OR), nuraghe Orgono *(phot. Usai A.)*.

Nuraghe Orgono lies about 2 kilometres northeast of Ghilarza, on the edge of the basalt *plateau* which overlooks the Tirso River valley (Manca Demurtas, Demurtas 1992).

The nuraghe is formed by three building bodies constructed in successive moments. The earliest part consists of an elongated central core with main entrance from southeast, which contains an elliptical longitudinal chamber, shaped like an overturned boat with two large side niches. At the back of the chamber is the entrance of the internal staircase which originally led to the top terrace, and which is also directly connected with the outside through a raised secondary northeast entrance. Subsequently was built the powerful annular sheathing wall, which allowed the widening of the top terrace. Both entrances were kept in use and provided with niches drawn in the thickness of the added wall. In the last phase, a round tower with domed circular chamber was built on the top of the monument, leaving on the front and on the back two small terraces accessible through the large window of the upper room. This caused the deviation of the upper stretch of the staircase, which was opened orthogonally in the solid structure and most probably prolonged up to the new top terrace. The narrow passage on the edge of the sheathing wall at the right side of the upper tower was widened with a balcony supported by four overhanging corbels, still preserved, just over the secondary entrance which (maybe at the same time) was obstructed and formed a simple side niche.

Because of these original solutions, the monument can be attributed to the evolutionary stages of the nuragic architecture which mark the transition from the class of the corridor nuraghi to that of the nuraghi with elliptical or boat-shaped vaulted chamber and finally with round domed chamber. This evolutionary process developed most probably during the long span of the Middle Bronze Age. Some comb-decorated pottery fragments recovered outside are evidence for the life of the monument at least during a late moment of the Middle Bronze Age or in the Late Bronze Age. The excavation of the upper chamber delivered a nuragic habitation layer of the Final Bronze Age or beginning of the Iron Age, scant remains of punic occupation and a notable context of reutilization at the time of the Roman Empire.

Very few metal pieces (all of lead) were recovered in the nuragic layer of the upper chamber: two of them are plugs for repairing pottery; the last two (the smaller one is cone-shaped, the larger one has the shape of a truncated cone) are of uncertain identification.

List of the selected metallic finds:

1) Lead, trunco-conical element (height: cm 6,1).
2) Lead conical element (base diameter: cm 2,1).
3) Larger pottery fragment with lead repair.
4) Small pottery fragment with lead repair.

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PART III

ARCHAEOMETRIC DATA

ARCHAEOMETRIC PREFACE

Cirillo Atzeni,
Luigi Massidda, Ulrico Sanna

To introduce the next chapter, which will present and discuss most of the archaeometric results illustrated in this volume, a schematic description is provided of the metallurgical activity, the traces that remain and how to recognize and use these traces for reconstructing ancient metal production processes (Mannoni 1996, Harris 1990).

The three columns below show which materials are involved in the different stages of the process and what remains once the process has been completed. The archaeologist and archaeometrist conduct investigations on the remains, which the passing of time altered to varying extents (Gilchrist 1989, Tylecote 1977, 1987).

Input	Process	Remains
Materials used as quarrying tools (stone, bone, metals) and for transport Ores Stone material for pestles and mortars	**Mining** **&** **beneficiation of metalliferous ores**	Waste minerals Remains of quarrying and crushing tools Galleries/quarry faces/pits
Mineral concentrates Fluxing/slagging agents Stone material, ceramis material and clay earth for furnaces, crucibles and *tuyères* Wood/Charcoal Air	**Roasting** **&** **Smelting**	Slags Fumes (powders) Pieces of furnace and remains of crucibles and *tuyères*
Metals (ingots and fragments) Stone material, ceramic material and clay/earth for furnaces, crucibles and *tuyères* Wood/Charcoal Tongs,crucible handles Air	**Melting** **&** **Casting**	Pieces of furnace and remains of crucibles, moulds and *tuyères* Metalworking debris

Ingots Semifinished objects Hammers and anvils Files, cutters, abrasives, etc. Tongs	**Cold** **&** **hot** **forming**	Metal scraps, remains of tools
Finished objects	**Usage**	Objects or fragments from broken objects
Objects or fragments from broken objects	**Burial** **&** **Corrosion**	Metal finds, encrustations/impregnations also on non-metallic finds
Unearthed finds	**Excavations** **&** **Museum display**	Objects that have undergone, interaction with modern materials during treatment for restoration/reconstruction and preservation

As can be seen there exists a very wide variety of objects, traces or “evidences” of the various aspects of metalworking. It should be said that even the fumes emitted during smelting, and to a lesser extent during other thermal treatment, leave usable traces. For example, analysis of the soil or of bones may well provide useful indications for delimiting the site and gleaning information about an ancient community of miners and metalworkers.

The archaeometric approach to studying ancient mining and metalworking embraces an extremely diverse range of disciplines: from geomineral and geophysical prospection to palaeoecology, from osteology to chemical, isotope and metallographic characterization of the metal finds and petrographic characterization of the ores and slags. Some of the main analytical techniques used in archaeometallurgy are discussed in Ciliberto (2000) and Scott (1991).

1.

INVESTIGATIONS AND RESULTS

Cirillo Atzeni,
Luigi Massidda, Ulrico Sanna

A – Copper artefacts

(Archaeological files 3, 7 and 13)

The development of metalworking in Sardinia can be traced right from the use of copper, to copper alloyed with arsenic through the entire development of bronze metallurgy and perhaps, even to the beginnings of iron-working. Finds made of gold and above all of silver were also discovered on the island.

The earliest metal artefacts found in Sardinia include a series of daggers, swords and spearheads. Analyses performed in the framework of this project showed them to be composed of unalloyed copper. This is the first time that pure copper artefacts are reported (Demurtas 1999).

The finds examined are described below:

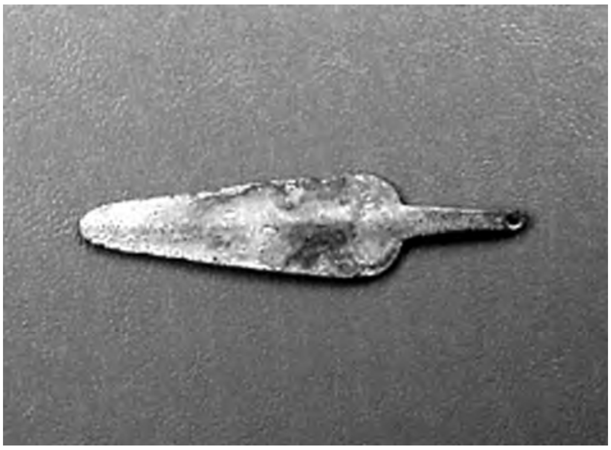


Fig.1 – A small blade from Su Monti, Orroli (NU); A1.

- a small blade (A1), with pronounced midrib and almost rectangular tang, perforated at the end, length 12 cm, from Su Monti, Orroli (NU), Figure 1;

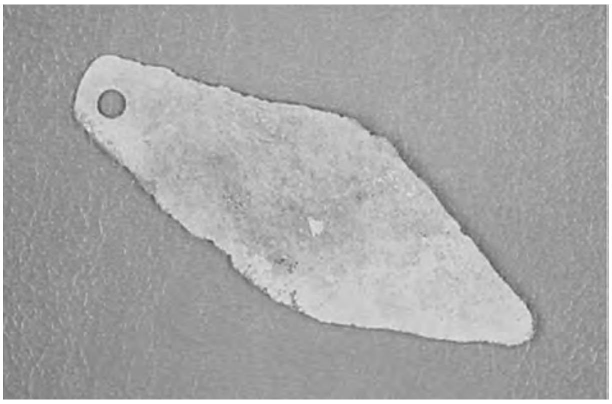


Fig. 2 – Two small daggers from Murisiddi, Isili (NU); above A2, below A3.

- two small daggers with thin triangular blade from Murisiddi, Isili (NU), one rhomboid-shaped with a hole at the end for the handle (A2, 7.4 cm long) the other with a triangular blade and short tongue-like tang with two small holes at the shoulder, one on either side for attaching the handle (A3, 7.5 cm long), Figure 2;

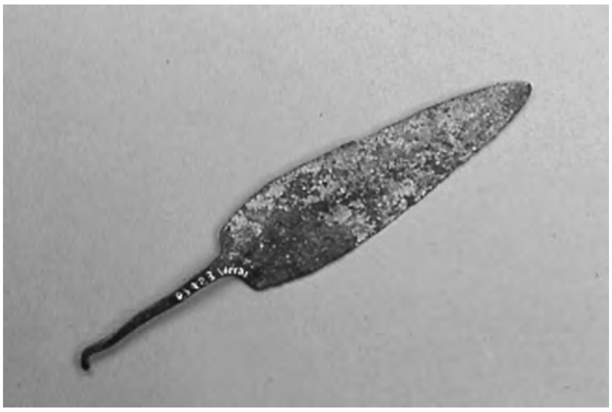


Fig. 3 – Dagger A5 from Ottana (NU).

- a large dagger 31.7 cm long (A4) and a dagger (A5) 19 cm long, both with hooked terminal tang, from a judiciary seizure in Ottana (NU), Figure 3 and plate IX.1;

Fig. 4 – Spearbutt A6 from Ottana (NU).

- again (from the cited hoard confiscated in Ottana (NU)) a socketed spearhead (A6) (length 27.7 cm), Figure 4.

Preliminary stereomicroscopic examination and gentle scraping with a lancet showed all these finds to be highly mineralized. X-ray diffraction (XRD) analysis revealed that most of the original metal was transformed into oxides and carbonates. The most badly affected were the thinner parts of the artefacts, like the blade edges, which unfortunately are also the parts which better allow the removal of samples for archaeometric investigations.

For this reason it was decided to perform preliminary non-destructive semi-quantitative analyses on the artefacts by means of scanning electron microscopy combined with energy dispersion spectroscopy (SEM+EDS) on areas of a few millimetres, cleaned with a lancet.

All finds were found to be made of simple copper.

Because of the difficulties in removing samples, additional compositional data for the trace elements were only determined for the large dagger A4 and for the spearhead A6. A sample was shaved from the dagger near the tang by using a 1 mm drill bit, small enough to avoid any damage. A minute fragment was cut from the spearhead tip which was already cracked.

The results of the atomic absorption spectrometry analysis (AAS) are shown in Table 1.

Table 1
Trace metal analysis (AAS; ppm; 1%=10000 ppm) of finds A4 and A6 (Sn < 2 ppm, Cd < 0.03 ppm, As < 0.5 ppm).

	Fe	Pb	Zn	Ag	Sb
Dagger (A4)	2500	800	30	1600	800
Spearbutt (A6)	600	700	10	100	< 0.2

We were also able to determine the lead isotope ratios on the spearhead A6 by means of inductively coupled plasma mass spectrometry (ICP-MS). The values obtained, 2.081 (for 208/206 isotopes), 0.842 (207/206) and 18.473 (206/204) appear to match more closely the "Cypriot type" than "Sardinian type" ore deposits (Gale 1997, Stos-Gale 1995, 1996, 1997).

Because of the limitations encountered in performing determinations on these deeply corroded, albeit in appearance intact, artefacts, we simply classified the type of metal used in the fabrication of this first series of finds. In fact, the lack of other data such as complete trace element and isotope analyses, means that it is not possible, at least for the time being, to advance any hypotheses on the provenance of the metal or to distinguish whether native copper or smelted copper was used (Barraclough 1986, Arribas 1989, Wayman 1985).

B – Arsenical copper artefacts

(Archaeological files 2, 10, 6, 8 and 9)

The next stage in the development of metallurgy was the production of copper alloyed with arsenic. Arsenic minerals occur frequently in copper ores and they were probably “inadvertently” smelted jointly. However, the superior hardness of blades made of arsenical copper could not have passed unnoticed.

Again, this is the first time that Sardinian archaeological finds made from arsenical copper have been identified and metallurgically characterized.

Two series of finds have been examined: a group of small blades of different origin and a group of swords, one unearthed by chance in the Maracalagonis (CA) countryside and six discovered during archaeological excavations which brought to light the “*Tomba dei guerrieri*” in Sant’Iroxi-Decimoputzu (CA) (Atzeni 1997a, Demurtas 1999).

Fig. 5 – Dagger B2 from Janna Ventosa (NU).

The first group consists of the following weapons:

- a large dagger blade, leaf-shaped from Janna Ventosa, Nuoro (B2), 26 cm long, with pronounced ribbing, and one hole at the end of the near-rectangular tang, Figure 5;

- three small dagger blades: one (B3), 7.5 cm has a triangular blade with rounded base perforated with two holes found at Sa Turricula, Muros (SS), Figure 6, the other two recovered from Cave 1 at Frommosa, Villanovatulo (NU), a tanged dagger 10 cm long (B4) and the other with single holed trapezoidal base 7.9 cm long (B5), Figure 7.

Fig. 6 – Small blade B3 from Sa Turricula, Muros (SS).

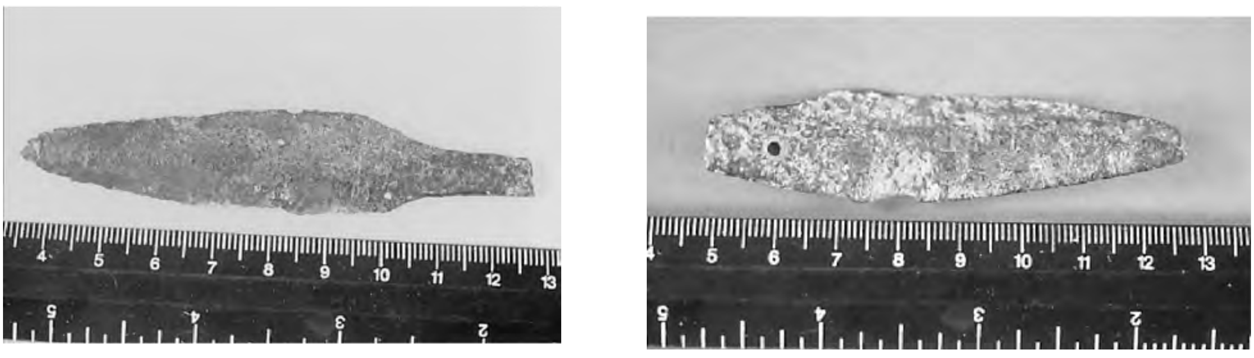


Fig. 7 – Small daggers from Frommosa, Villanovatulo (NU); left B4, right B5.

Non-destructive tests were first carried out on all finds by using SEM+EDS technique, on the surface and after scraping it with a lancet to expose an unmineralized portion a few millimetres in size, generally close to the longitudinal axis of the blade. The three small daggers were found to contain no more than 3 % arsenic, while the Janna Ventosa dagger contains As up to 7 % and on the patina as much as 20 %.

A sliver of metal was also shaved off the Janna Ventosa dagger at the join between blade and tang, while for the Frommosa dagger a minute piece of metal was cut from the cracked end of the tang. AAS analysis was performed to determine trace elements in these samples. The results are shown in Table 2.

Table 2
Chemical analysis (AAS, ppm) of finds B2 and B4 (two samples) (Sn < 2 ppm, Sb < 0.2 ppm, Cd < 0.03 ppm).

	Fe	Pb	Zn	Ag	Bi	Ni
Dagger from Janna Ventosa (B2)	330	100	80	900	440	80
Small dagger from Frommosa (B4)	1500 360	530 700	20 70	2000 300	< 0.2 < 0.2	< 0.1 < 0.1

The alloys were found to be of high purity. Interestingly, the Frommosa dagger did not contain appreciable Bi and Sb, though these two metals commonly occur in Sardinian ore deposits and are frequently observed in archaeological finds dated to later ages. The differences detected in the two samples are not surprising for trace element determinations on intrinsically heterogeneous artefacts.

SEM+EDS observations on the metallographic section of the Frommosa dagger revealed the presence of inclusions in which sulphur is associated with copper, likely the residues of the sulphurous ores from which the base metal was extracted. Vickers microhardness measured under a load of 20 g was 128 kg/mm^2 (1255 N/mm^2 in SI units). This value certainly indicates a good quality blade, at the limits of the possibilities of a blade made from copper alone even if it had undergone strong cold-hardening (Marechal 1962).

The second groups of finds consists of six swords unearthed in the "*Tomba dei guerrieri*" at the S. Iroxi site in Decimoputzu (CA) (Figure 8). Another similarly fashioned broad-bladed sword with rounded base with seven rivet holes (B1) was discovered in an unknown location in the municipality of Maracalagonis (CA) and has a presumed original length of 60 cm, (Figure 9 and pl. IX.2).

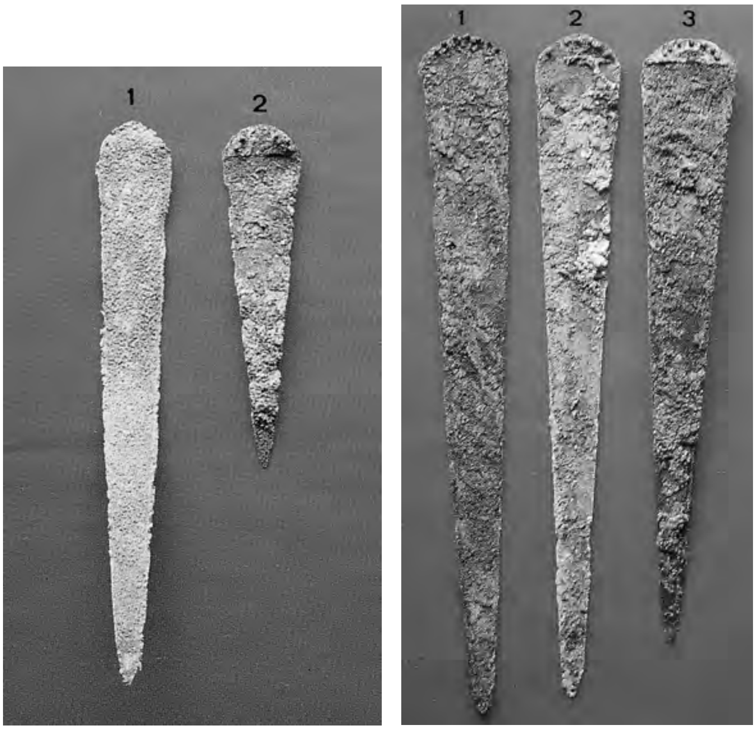


Fig. 8 – Weapons from the "*Tomba dei guerrieri*" in Sant'Iroxi site, Decimoputzu (CA).

Fig. 9 – Sword B1 from Maracalagonis (CA). Sample collected near rectangular tear.

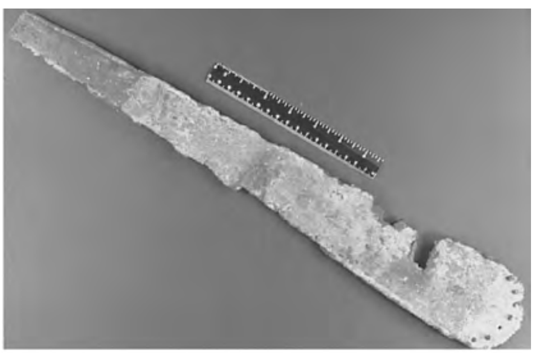


Figure 10 shows the points where the samples were removed from the S. Iroxi swords.

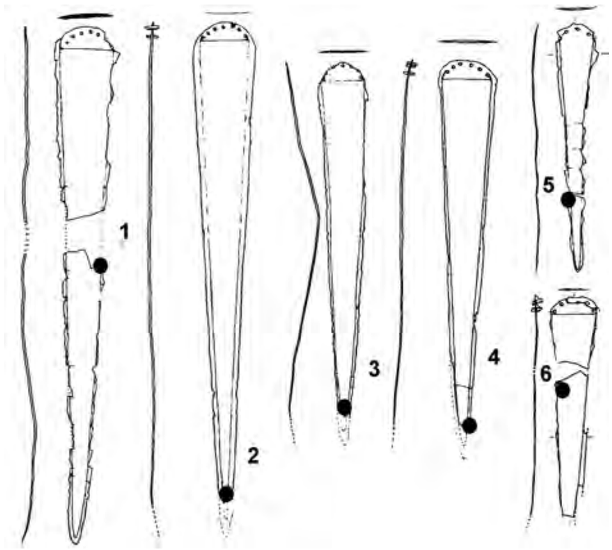


Fig. 10 – Sampling points on Sant'Iroxi swords.1 "497"(B7), 2 "498" (B8), 3 "408" (B6), 4 "499" (B9), 5 "501" (B10), 6 "502" (B11).

Figure 11 shows a detail of the sample removed from B7, which was sufficiently large to permit fuller metallographic, chemical and isotopic investigations.

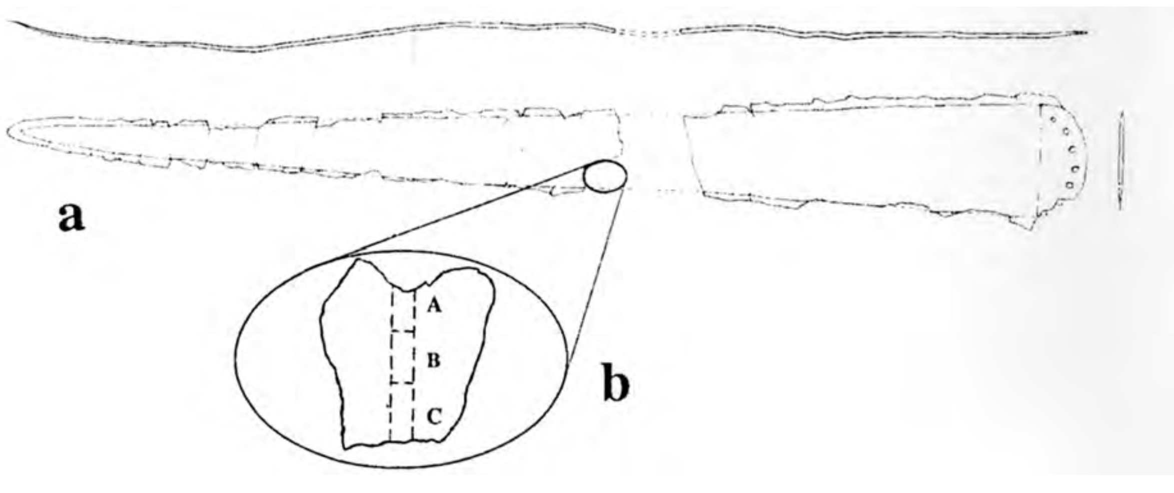


Fig. 11 – Detail of the sample collected from B7 sword.

EDS analysis revealed arsenic to be the principal alloy constituent while the tin content was negligible.

The result of the AAS analyses for trace elements are reported in Table 3.

Table 3
Chemical analysis (AAS, ppm) of samples removed from finds B7 and B1 (Sn < 2 ppm).

	Fe	Pb	Zn	Ag	Sb	Bi	Ni
Sant'Iroxi 497 (B7)							
Sample A	100	4800	40	< 0.05	330	110	25
Sample B	10	4700	40	10	280	90	10
Sample C	30	4700	40	4	330	140	30
Maracalagonis (B1)							
Sample 1	60	5600	60	20	1100	170	< 0.1
Sample 2	600	4300	30	< 0.05	1000	170	< 0.1

The most common trace element is lead, and similar amounts are found in the two swords. However, this cannot be considered an indication for a local source for the ores, as finds discovered elsewhere in the Mediterranean contain even higher lead content, for example artefacts from the Cyclades (Gale 1989b, Eaton 1976, Craddock 1976).

Only minor traces of iron have been detected. This probably means that the copper ores contained only small amounts of this element and/or no slagging with the aid of iron oxides was necessary. Note that the copper oxhide ingots produced during the later Bronze Age, almost certainly obtained by smelting and slagging chalcopyrite minerals, and of good quality, contained several hundred ppm of iron (Atzeni 1998, Gale 1992, Lo Schiavo 1990, Hauptmann 2002, Craddock 1987).

Relatively high concentrations of bismuth and especially antimony have been observed, far higher for example than in oxhide ingots. Thus it may be assumed that the copper was extracted from minerals such as covellite (CuS), chalcocite (Cu_2S), tennantite ($Cu_3(As,Sb)S_3$), enargite (Cu_3AsS_4) and, where present, with their weathered products (carbonates and/or oxides) (Barraclough 1986, Tylecote 1976). The samples contained only minor amounts of Ag; the same considerations apply to Zn. The Maracalagonis sword was not made of brass, *i.e.* of a copper+zinc alloy, as originally reported in Vodret (1959).

Metallographic analyses have been performed on sections of finds B7, B8 and B11. A more detailed investigation was carried out on the sword B7, for which, as already mentioned, a reasonable size sample was available.

Two kinds of inclusions have been observed in the metallographic sections of B7, both elongated in what is presumably the direction of hammering. The first (Figure 13) of these was found to contain far higher arsenic concentrations than the surrounding matrix and the edges had been eaten away by selective corrosion. The second (Figure 12), light-coloured inclusion contains sulphur associated both with the copper and with the arsenic (Atzeni 1997a, Demurtas 1999, LaNice 1989, Meeks 1993).

The co-presence of Cu, As and S in the inclusions suggests that they are "residues" of the copper ore smelted such as enargite or tennantite (see above). Likewise the presence of Sb in some cases in amounts to as much as a few percent. Some lead inclusions have also been observed.

The tests carried out do not enable to establish whether the swords had been "silvered", as is the case of the Los Millares sword (Meeks 1993).

The surface of the artefacts was highly mineralized. Signs of corrosion around the edges of the samples, characterized by abundance of chlorides and hydrated carbonates were clearly visible, and were confirmed by the XRD determinations.

The samples taken from finds B6, B9 and B10 were almost completely mineralized. The remaining metal occurs in the form of minute metal islands surrounded by a sea of corrosion compounds. SEM+EDS and XRD analyses again showed the corrosion products to include chlorides.

Metallographic examination of the Maracalagonis sword (B1) revealed inclusions elongated in the direction of hammering and the presence of sulphur (30-65%) associated with both the copper (15-50 %) and the arsenic (15-30 %). No arsenical copper inclusions of almost eutectic alloy composition with corroded edges of the kind observed in B7 were detected. The corrosion products were found to contain again significant amounts of chloride (Demurtas 1999).

Vickers microhardness determined under a 20 g load on sword B7 from the Sant'Iroxi site showed hardness to increase outwards towards the blade edge: 137, 147 and 179 kg/mm^2 (1343, 1442 and 1755 N/mm^2 in SI units). Microhardness measurements on the Maracalagonis sword yielded a mean value of 137 kg/mm^2 (SI equivalent 1343 N/mm^2). These values are comparable with those reported in the literature, for example, by Maréchal (1962), for similar Cu-As alloy compositions. The microhardness of the finds suggests the swords could be used efficiently both for cutting and stabbing (Atzeni 1997, Demurtas 1999).

Table 4 shows the results of lead isotope analysis on three fragments of B7 and on the Maracalagonis sword B1.

The isotopic signature of the sword B7 unearthed at the Sant'Iroxi site matches that of "Sardinian type" ore deposits (Gale 1997, Stos-Gale 1995, 1996, 1997), presuming of course that most of the significant amount of lead present was not derived directly from the smelting but was afterwards added to the melt. The isotopic data obtained for the Maracalagonis swords are internally inconsistent.

Table 4.
Lead isotope ratios (ICP-MS) of samples of B7 and B1.

	$^{208}Pb/^{206}Pb$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{204}Pb$
S. Iroxi (B7) : sample A	2.110	0.864	18.066
S. Iroxi (B7) : sample B	2.108	0.864	18.123
S. Iroxi (B7) : sample C	2.102	0.867	18.071
Maracalagonis (B1)	2.098	0.872	17.917

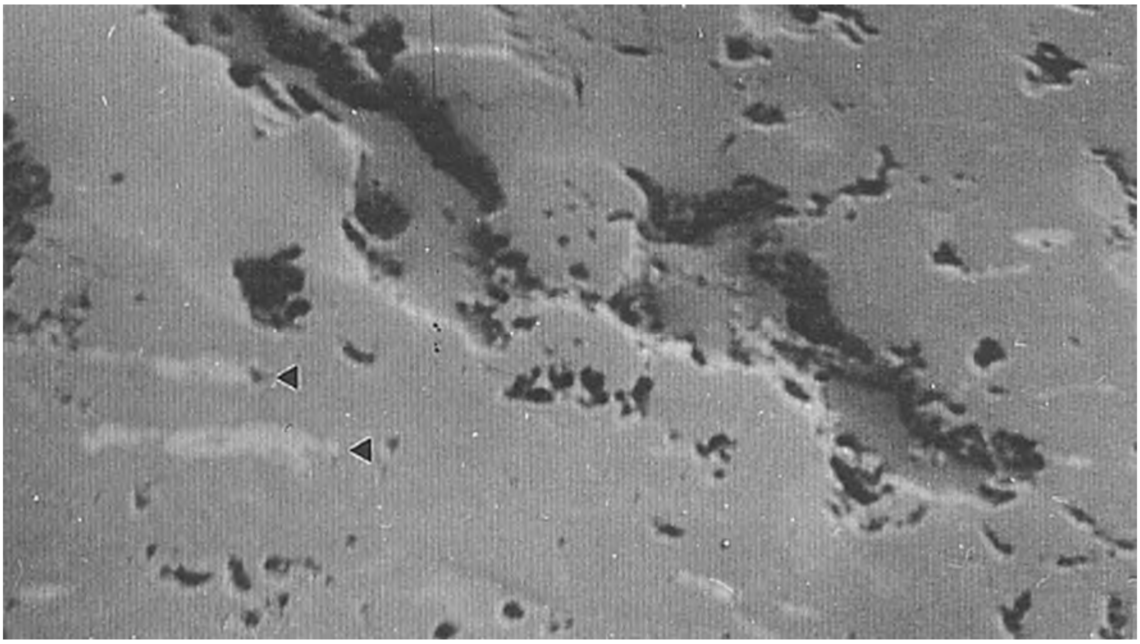


Fig. 12 – Some inclusions containing S, from B7 sword (the longer is 50 μm).

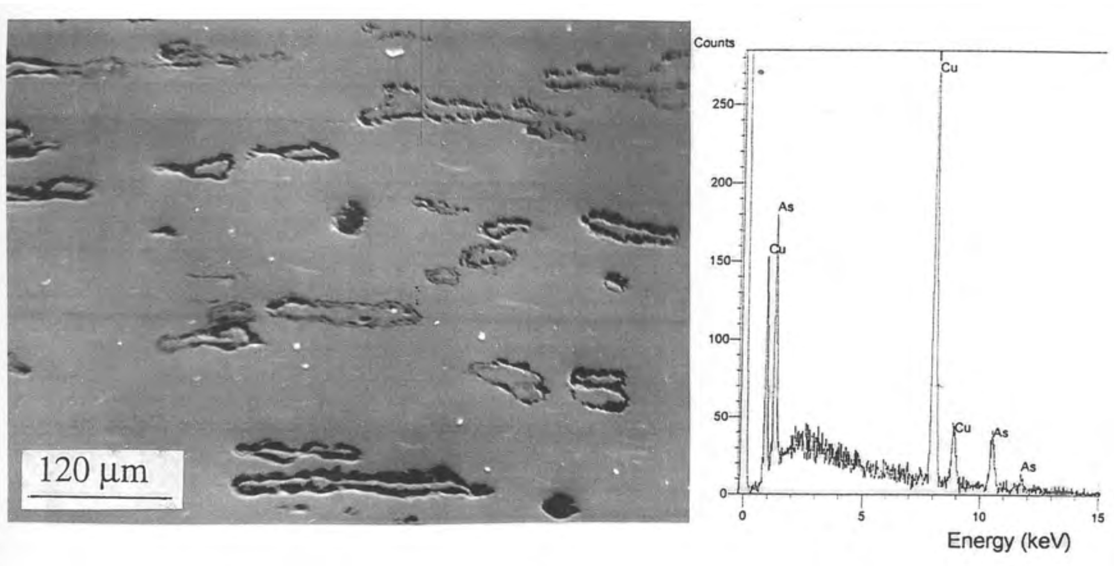


Fig. 13 – Some inclusions (the bar is 120 μm) rich in As, from B7 sword; right, a related EDS spectrum.

C – The earliest bronze artefacts

(Archaeological files 13 and 4)

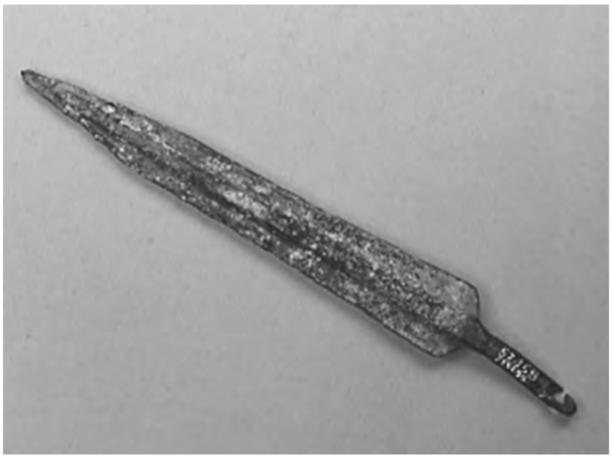


Fig. 14 – Dagger C3 from Ottana (?) (NU)

The depletion of arsenic-bearing copper ores (though arsenic remained one of the chief traces in copper finds, for example in oxhide ingots), the health hazards associated with smelting operations along with the discovery of the new metal tin, in itself a low utility one but which, when added to copper, significantly increased its strength, laid the technical foundations for the beginnings of the age of bronze metallurgy.

The finds discussed in this paragraph, were all made of tin bronze. Hence they might (here we use the conditional as they cannot be set into a clear archaeological context) rank among the finds attesting the early use in Sardinia of objects made from this alloy and would so represent an important step in the transition to the next age, which saw a true boom in the availability of bronzes.

The geology of tin bearing ores in Sardinia and the archaeometric data for the tin bronze artefacts are discussed in chapter 2, Part II of this volume.

The following archaeological finds have been examined:

from Monte Baranta site in Olmedo (SS):

- N. 8 (C1) *spatula*, or blade with rounded tip, single hole, length 13 cm;

and from a judiciary seizure at Ottana (NU):

- N. 15 (C2) tanged dagger with single rivet hole, length 24.1 cm (Pl. IX, 3);
- N. 16 (C3) tanged dagger with single rivet hole, length 24.4 cm (Figure 14);
- N. 17 (C4) tanged dagger with single rivet hole, length 21.5 cm;
- N. 18 (C5) tanged dagger with single rivet hole, length 19.1 cm.

Considering their thinness and the highly mineralized state of the blade edge, the artefacts are relatively well preserved. Fragments of material were removed from the *spatula* C1 near the rivet hole, from the dagger C2 at the end of the tang and near to the shoulder of C4; shavings were drilled using a 1 mm bit proceeding lengthwise from the shoulder of daggers C3 and C5.

Table 5 shows the chemical composition of the alloys used for the five artefacts. In all cases, the material was tin bronze: the amount of arsenic contained in the alloy is below the detectability limit.

The two main impurities were found to be Fe and Pb, in some artefacts in concentrations of more than 1%. These elements were probably contained in the copper ores, perhaps in the form of sulphides. The fact that these two metals are present in high level indicates that the copper refining process was not particularly efficient.

SEM+EDS observation of the metallographic sections of samples taken from C2 and C4 revealed the microstructure to be typical of metals subjected to cold working/hammering. Some inclusions contain both sulphur and copper. Lead has also been detected, typically segregated to the grain boundaries. The average concentration of tin contained in the matrix, determined by SEM+EDS, was, in both cases, in excellent agreement with the values obtained by means of AAS (8.1 vs 8.5 % and 10.7 vs 9.7 %).

Table 5

Chemical analysis (AAS, %, or ppm were indicated) of bronze finds C1-C5 (Cd < 0.03 ppm; As < 0.5 pp; Bi < 0.2 ppm).

	Sn	Fe	Pb	Zn	Ag	Sb	Ni
C1	4.2	0.02	1.50	0.015	0.23	0.09	< 0.1 ppm
C2	8.1	1.2	0.96	0.052	0.05	0.10	0.057
C3	3.1	0.28	0.07	0.003	0.06	0.07	0.048
C4	10.7	1.7	0.74	0.250	0.25	0.70	< 0.1 ppm
C5	5.6	0.26	0.27	0.004	0.10	0.04	0.073

D – Hoards of copper fragments

Of major interest are the numerous deposits of copper fragments discovered in Sardinia. The fact that these deposits also contain pieces of oxhide ingots (so-called because their shape resembles a stretched, dried oxhide) make these “little treasures” all the more fascinating. The oxhide ingots were in fact perhaps the most characteristic commodities traded in the Mediterranean during the Bronze Age (Bass 1967, 1985, 1986, Hauptmann 2002).

During this project, the two deposits at Baccus Simeone (previously investigated by numerous researchers) and Baradili, which was discovered in 1937 but practically ignored until recently, have been analysed, at least partially.

Da – Baccus Simeone, Villanovaforru

(Archaeological file 26)

The deposit of Baccus Simeone (Figure 15 and pl. X,1) contains an assortment of copper fragments and was discovered in the early 1980’s, near the village of Villanovaforru (CA).

Among the finds studied here (Atzeni 1987, 1998) BS2 (Da1) and BS3 (Da2) are unmistakably pieces of oxhide ingots. BS24 (Da3), BS26 (Da4) and BS30 (Da5) are believed to be bits of so-called “bun ingots”.

However, the deposit includes other finds, which bear no resemblance to copper ingot parts. For example BS54 (Da7) looks like molten copper spread on the ground, while BS60/20 (Da10), BS35 (Da6), BS60/12 (Da8), BS60/15 (Da9) and BS60/32 (Da11) can only be identified in general terms as nodules or scraps.

Some of the finds were fragments of objects and have been classified as “sheet metal”, see the lower part of Figure 15. We studied finds Da 12, 13 and 14 (the latter obviously a fragment of a socalled “votive sword”) and Da 15, 16 and 17.

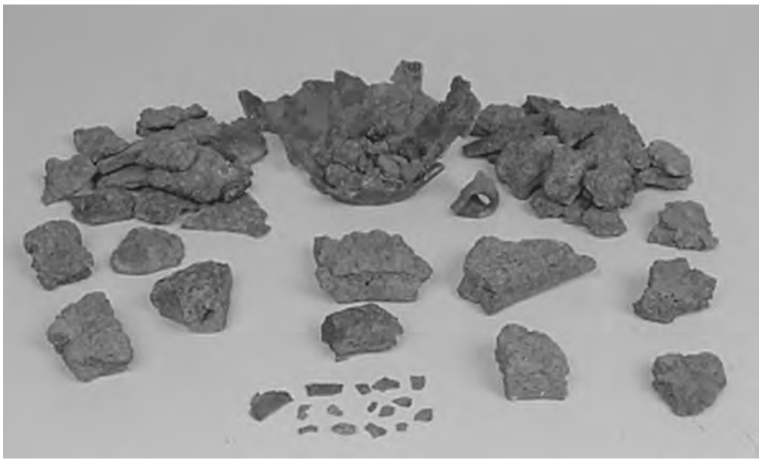


Fig. 15 – The copper fragments of the Baccus Simeone deposit, Villanovaforru (CA).

Several samples were taken from some of the finds to determine the homogeneity of the constituent material. Two or three samples were collected from different points of BS2 and BS26. The sections and drill shavings from identified as pieces of oxhide or bun ingots had the distinctive pinkish red colour of technically pure copper.

Table 6 shows our chemical analysis data of the trace elements, along with data determined by other researchers.

Table 6

Chemical analyses of Baccus Simeone finds, in ppm (*: AAS (Atzeni 1998); +:, neutron activation INAA (Gale 1992); “: AAS (Lo Schiavo 1990); type: oxh = oxhide, bun = bun ingot; Pb n.r.< 0.1 ppm, Co n.r. < 0.005 ppm, Ag n.r. < 1 ppm; Zn n.r. < 0.3 ppm).

	Fe	Pb	Zn	Ag	Ni	Co	Type	from
BS1	0.0600	0.0100	0.0070	0.4500	0.031	0.0170	oxh	“
BS2	0.015	0.0061	0.0017	0.001	0.026	0.019	oxh	*
“ “	0.017	0.0022	0.003	0.0015	0.025	n.r.	oxh	*
“ “	0.06	0.013	0.003	0.002	0.03	n.r.	oxh	*
“ “	0.0540	0.0200	0.0005	n.r.	0.036	0.0190	oxh	“
BS3	0.035	0.016	0.0051	0.0031	0.038	0.14	oxh	*
“ “	0.1500	n.r.	0.0140	0.0130	0.044	0.0540	oxh	“
“ “	0.1245	-	0.0046	0.0088	-	0.1250	oxh	+
BS4	0.0470	n.r.	0.0100	0.0050	0.005	0.0050	oxh	“
BS5	0.0770	0.0260	0.0100	n.r.	0.110	0.0300	oxh	“
“ “	0.0406	-	0.0034	0.0030	-	0.0761	oxh	+

	Fe	Pb	Zn	Ag	Ni	Co	Type	from
BS7	0.0270	0.0100	n.r.	n.r.	0.027	0.0050	oxh	“
BS9	0.4600	n.r.	0.0050	n.r.	0.023	0.0080	oxh	“
BS10	0.0760	0.0190	0.0130	0.0080	0.051	0.0390	oxh	“
BS13	0.0380	n.r.	0.0060	n.r.	0.029	0.0090	oxh	“
BS45	0.0310	0.0110	0.0050	n.r.	0.026	0.0210	oxh	“
B6	1.38	0.52	0.087	n.r.	0.037	0.042	bun	“
“ “	1.6	-	0.0588	0.0002	-	0.0823	bun	+
BS11	0.2600	n.r.	n.r.	0.6700	0.046	0.0090	bun	“
“ “	-	-	-	0.0098	-	0.0224	bun ?	+
BS19	0.09	0.396	0.0082	0.001	0.0228	0.0071	scrap	*
BS24	5.2	0.7185	0.0734	0.0089	0.0294	0.015	?	*
BS26	0.17	0.048	0.016	n.r.	0.039	0.026	bun	*
“ “	0.2	0.47	0.015	0.001	0.022	n.r.	bun	*
BS27	0.9200	0.5100	0.0540	n.r.	0.044	0.0130	bun	“
“ “	2.100	-	0.0378	0.0001	-	0.0331	bun ?	+
BS30	0.0065	0.055	0.0008	n.r.	0.02	0.0007	bun	*
BS34	0.0120	n.r.	n.r.	n.r.	0.010	n.r.	bun	“
“ “	0.00602	-	-	0.0007	-	0.0006	bun ?	+
BS35	7.6	0.644	0.333	0.0066	0.0297	0.0203	scrap	*
BS53	0.1500	0.2000	0.0150	n.r.	0.031	n.r.	bun	“
“ “	-	-	0.0058	0.0006	-	0.00752	bun ?	+
BS54	0.8	2.3	0.052	0.001	0.048	n.r.	scrap	*
BS59	0.1800	0.0210	0.0053	0.0860	0.010	n.r.	bun	“
“ “	0.0875	-	0.0024	0.0868	-	0.0003	bun ?	+
BS60/12	4.6	n.r.	0.0195	0.0102	0.0418	0.0131	scrap	*
BS60/15	2.75	0.33	0.31	0.0011	0.071	0.032	scrap	*
BS60/18	0.04	n.r.	0.0046	0.0045	0.0255	0.043	scrap	*
BS60/20	20	0.5813	0.0453	0.0135	0.0366	0.0172	scrap	*
BS60/32	1.22	0.38	0.058	0.0004	0.055	0.037	scrap	*

The results obtained for the ten finds, sampled at different points, indicate variations in trace element composition which, in some cases, may be considered significant. The greatest differences were observed for Fe and Pb. In particular, Fe concentrations in the oxhide fragment BS2 ranged from 60 to 170 ppm while the Pb content of the piece of panel BS26 varied from 480 to 4700 ppm. However, these variations generally do not alter the order of magnitude and consequently do not preclude reliable evaluation of the metal quality, presumably even when determinations are performed on a single sample.

Fe is one of the most commonly observed impurities in the samples taken from the oxhide ingot fragments. Pb and Zn concentrations remain around < 0.02 %. Only very minor amounts of Ag have been detected while Ni contents of less than 0.05 % and Co of less than 0.14 % have been determined (Atzeni 1987, 1998, Lo Schiavo 1990, Begemann 2001).

The samples removed from pieces of non-oxhide ingots generally contained larger quantities of metallic impurities than the oxhide ingots. Again Fe is the most abundant impurity, some samples containing significant proportions (5.2 % and 7.6 % in BS24 and BS35), indicative for inefficient refining. Pb content is also usually higher, with percentages of as much as 2.3 % in the sample removed from BS54. Only very minor amounts of Zn have been detected, with the exception of BS35 which was found to contain 0.33 %. Ni concentrations of less than 0.05 %, and Co concentrations of less than 0.0 3 % were determined. Nevertheless, analysis of samples of fragments thought to come from bun ingots showed some of them to be fairly pure, like the one from BS30.

The finds generically classified as scrap because of their appearance, were found to be heterogeneous (the only exception being BS60/18). The sample taken from BS60/15 contained significant amounts of Pb and Zn and especially of Fe.

Table 7

Chemical analysis (AAS, ppm or % where indicated) of the "sheet" fragments retrieved at Baccus Simeone (for all samples: Bi < 0.2 ppm, Sn < 2 ppm left out Da14: Sn=3.0 %).

	Fe	Pb	Ag	Sb
Da 12 (BSa)	200	300	500	1500
Da 13 (BSb)	3400	800	600	900
Da 14 (BSc)	2200	< 0.1	500	50
Da 15 (BSd)	2300	2300	600	400
Da 16 (BSg)	1400	100	10	200
Da 17 (BSl)	5000	1.5 %	100	600

Considerable proportions of Pb and Fe were observed in BS60/32, of Fe in BS60/12 and of Pb and Fe (as much as 20 %) in BS60/20. Ag content was always found to below 0.01 %, Ni below 0.07 % and Co less than 0.0 4 %.

Regarding the "sheet" fragments examined (Table 7), they were significantly composed of practically pure copper, except for the fragment of votive dagger (Da14) which contained a minor amount of tin (Sn 3 %).

In addition to the chemical composition, valuable indications about the quality of the metal can also be drawn from characterization of the inclusions present in the microstructure. The samples examined exhibited the typical metallographic microstructure of the as-cast product. The most common inclusions are copper oxides. X-ray diffraction analysis (XRD) showed all the samples to contain Cu_2O. This type of inclusion is associated primarily with the fact that while oxygen dissolves readily in molten copper, it is barely soluble in the solid metal, and leads to the formation of eutectic Cu/Cu_2O. An example of this is shown in the photograph of Figure 16 (AMS 1972, Leoni 1984, Scott 1991, Sperl 1980, Hauptmann 2002). These inclusions embrittle the metal structure, but in the case of ingots the embrittlement is actually an advantage, because they can be readily broken into pieces of manageable size for transport, trade and hoarding and of course for melting in crucibles for the preparation of alloys.

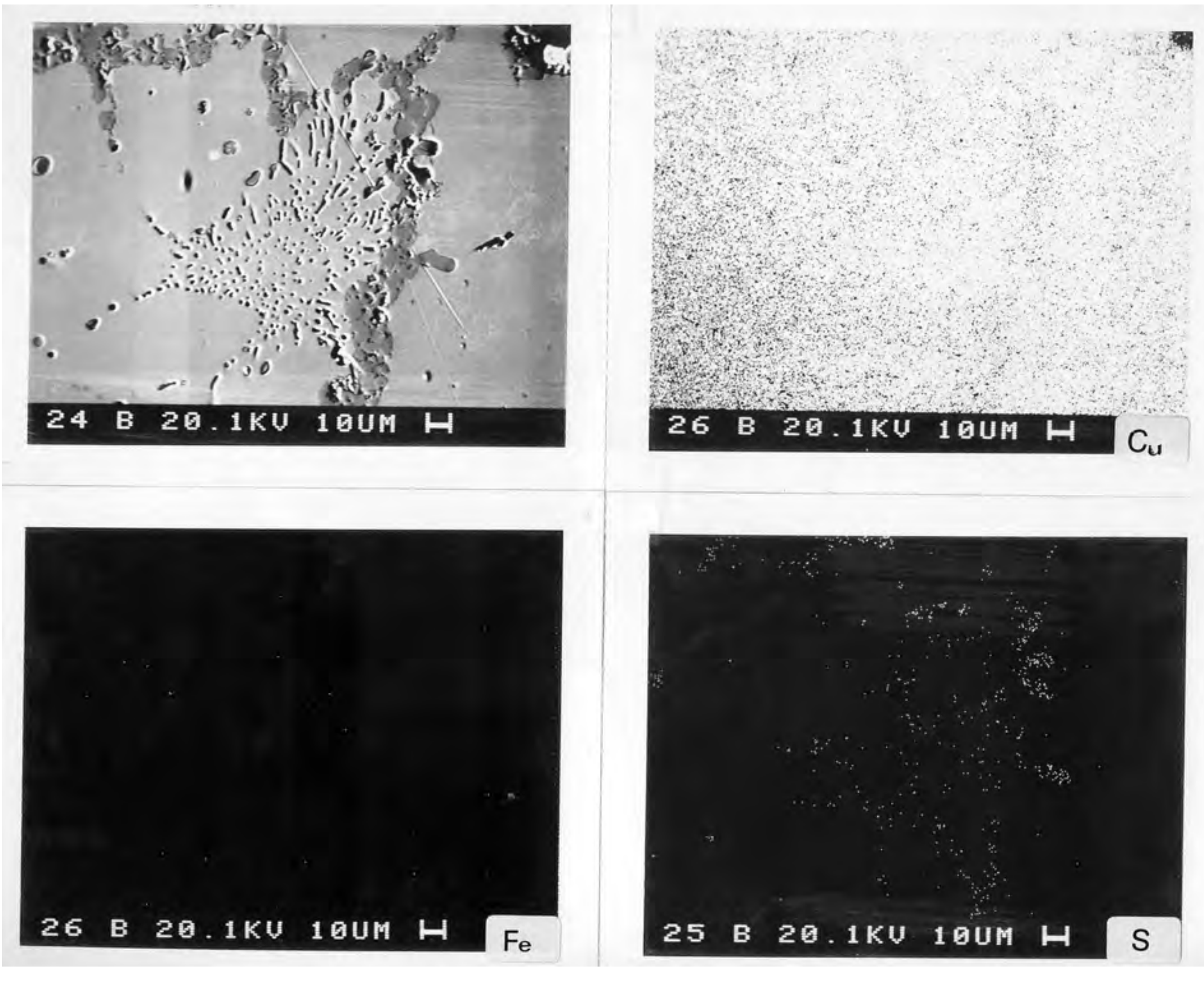


Fig. 16 – Electron Probe Micro-Analysis (EPMA) maps from BS26 (bar is = 10 μm).

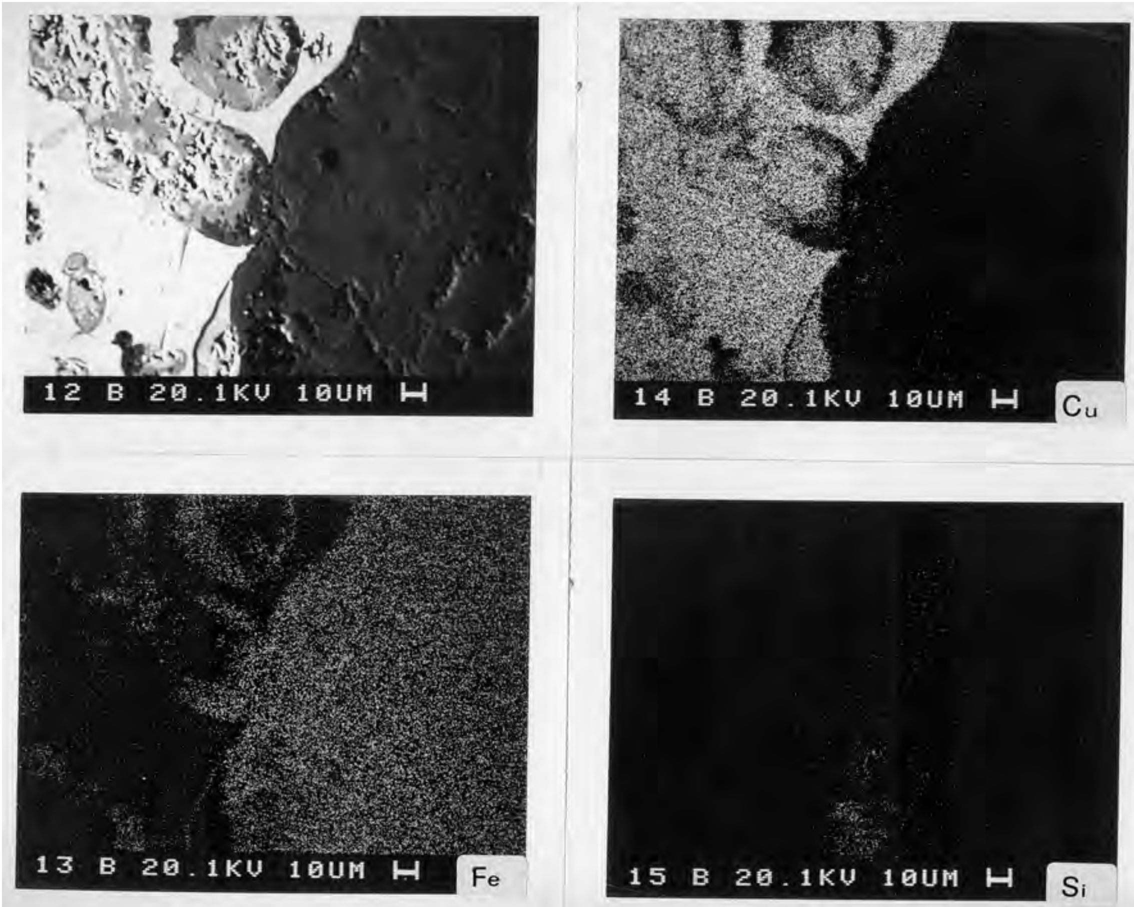


Fig. 17 – Electron Probe Micro-Analysis (EPMA) maps from BS60/20-a (bar is = 10 μm).

Compositional mapping of metallographic sections by means of EPMA enabled to identify inclusions whose composition is probably related to the kind of ore used for extracting the copper. In some of these inclusions the copper signal is clearly associated with the S signal (copper sulphides), in others the S signal is associated with both the Cu and the Fe signals, while others still are characterized by the Fe signal alone (iron oxides). The segregation of copper, iron and lead compounds to the grain boundaries is clearly visible. Observation of the inclusions also showed in general the purity of the fragments of oxhide ingots to differ from the other types of ingots. In fact, practically all the inclusions present in the oxhide ingots are copper oxides, with very few iron oxides and sulphide inclusions, while lead is rarely segregated to the grain boundaries.

Copper sulphide inclusions have been observed in BS26, 54 and 60/20, iron oxide inclusions are also present in BS35, while in BS24 Fe also occurs in the form of sulphide. This variety of inclusions was observed to be particularly abundant in finds such as BS60/12 and especially BS60/20 (Figures 17 and 18) which can be regarded as intermediate copper extraction stages from chalcopyrite type ores.

Table 8 shows the lead isotope ratios determined both by Gale, using thermal ionization mass spectrometry (TI-MS) and by the workers involved in the current research project (ICP-MS) (Atzeni 1998, Gale 1987, 1992, Stos-Gale 1997). Of all the metallic finds, the pure metal ingots are the most reliable for advancing reasonable hypotheses on the possible sources of the copper ores. It is unlikely that an ingot was produced from a mixture of ores of different origin, as commonly happens, in the preparation of alloys and it is for this reason that the determination of lead isotopes is of little use for studying bronze artefacts.

Examination of the data in Table 8 shows first of all that the oxhide samples probably belong to the same series, even allowing for the discrepancies in the two independent analyses performed on BS2.

Furthermore, the bun ingots cannot be grouped with the oxhide ingots, neither can they be regarded as belonging to any other single family. In particular, it can be ruled out that the oxhide ingots examined here were obtained by refining the metal used in the other types of ingots. Such an operation would make sense if the production had to be tailored to an internationally recognized standard, to improve the trade of the ingots.

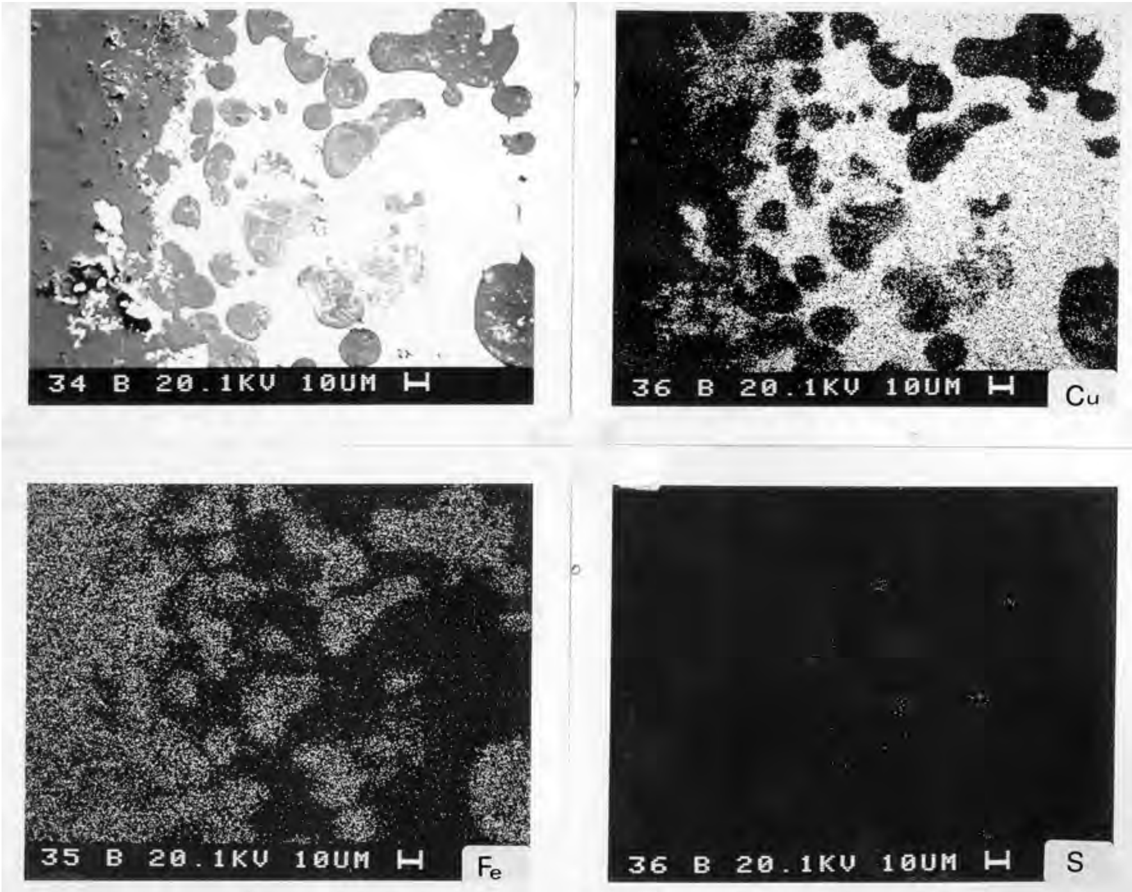


Fig. 18 – Electron Probe Micro-Analysis (EPMA) maps from BS60/20-b (bar is = 10 μm).

In fact, prolonged thermal refining of copper would only diminish the lead content of the lighter isotopes, and result in higher 208/206 and 207/206 ratios and a lower 206/204 ratio, differentiating further the metal of the bun ingots from the group of oxhide ingots.

The oxhide ingots examined here were fabricated from copper-bearing minerals extracted from deposits whose lead isotope ratios match "Cypriot type" ores. On the other hand, for five samples of bun ingots, a "Sardinian type" ore is suggested as a possible provenance. Mention might be made, purely indicatively, of the Sa Duchessa and Arenas ore deposits (Gale 1997; Stos-Gale 1995,1996, 1997). This consideration suggests that a multitude of supply sources existed at the time, justified perhaps by the different quality/cost of the copper available in the Mediterranea area.

As far as the lead isotope ratios of the "sheet" finds are concerned, the data cannot be correlated with any mining regions for which comparable data are available.

Table 8
Lead isotopic ratios (* :ours data by ICP-MS; + : Gale data by TI-MS).

	$^{208}Pb/^{206}Pb$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{204}Pb$	From	Type
BS1	2.07138	0.84114	18.489	+	oxhide
BS2	2.079	0.849	17.957	*	oxhide
" "	2.07258	0.84134	18.491	+	oxhide
BS3	2.07395	0.84329	18.438	+	oxhide
BS4	2.07858	0.84583	18.387	+	oxhide
BS5	2.07025	0.84048	18.510	+	oxhide
BS7	2.07526	0.84282	18.486	+	oxhide
BS9	2.07686	0.84504	18.404	+	oxhide
BS10	2.07408	0.84335	18.430	+	oxhide
BS11	2.07169	0.84141	18.489	+	oxhide
BS6	2.11849	0.86933	17.953	+	bun-ingot
BS13	2.10231	0.85961	18.151	+	bun-ingot
BS24	2.148	0.908	16.818	*	scrap
BS27	2.11106	0.86578	18.020	+	bun-ingot
BS35	2.123	0.875	17.587	*	scrap
BS53	2.11560	0.86961	17.915	+	bun-ingot
BS59	1.76992	0.74462	21.168	+	bun-ingot
a	2.049	0.852	18.520	*	laminar
b	2.009	0.827	18.838	*	laminar
d	2.039	0.842	18.500	*	laminar
l	2.084	0.859	18.013	*	laminar

Db – Baradili

(Archaeological file 21)

Fig. 19 – The 14 copper fragments from Baradili (CA) hoard.

Fourteen of the 150-200 or so pieces of coppery material retrieved from a hoard in the municipality of Baradili (CA) were analysed (Figure 19 and pl. X,2). All finds can be classified as pieces of ingots, some clearly of oxhide ingots type. They varied in weight from a little more than 200 g to over 1500 g.

The greenish/bluish patina is typical of copper. Fracture surfaces are clearly visible on each piece, with porous, in some cases even "cavernous" cross-section. The upper surface of the ingot, which is exposed to the air during casting, could be recognized in most cases by its blistered appearance, with pits up to 5 mm in size. These pits are created by the gases escaping during solidification to the outermost surfaces which become pasty as they start to cool. No such pits are found on the lower surface, which is usually rough, almost as if the copper had been cast on fairly uncompacted ground, or in any case on a rough surface.

Some of these fragments can be clearly considered pieces of oxhide ingots (finds denoted Bar1 (Db1, Figure 20), Bar2 (Db2, Figure 21), and Bar6 (Db6); with a thickness of 3.5÷4.0 cm. Judging by their thickness, other fragments could also be classified in this same group, for example Bar5 (Db5), Bar10 (Db10) and Bar12 (Db12). Other pieces are on the other hand thinner than these (2÷3 cm).

Fig. 20 – Close-up view of find Db1 from Baradili (CA) hoard.

Fig. 21 – Close-up view of find Db2 from Baradili (CA) hoard.

Metallographic sections were prepared for the three pieces, Bar2 (top and bottom ends, the top end being the blistered surface), Bar5 (again at the two ends) and Bar4 (Figures 22-24). All sections were found to contain oxide inclusions, usually surrounding the grain. These were particularly numerous in the upper parts of Bar2 (Figure 22) and Bar4 (Figure 23).

The microstructure is substantially similar to that of the fragments of oxhide ingots unearthed at Baccus Simeone.

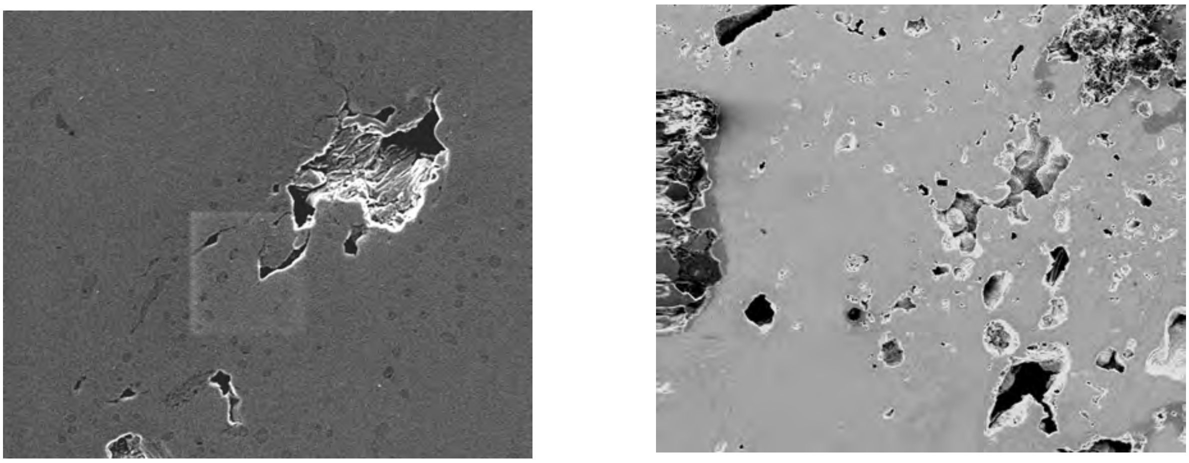


Fig. 22 – Metallographic view from Db2 (100 X).

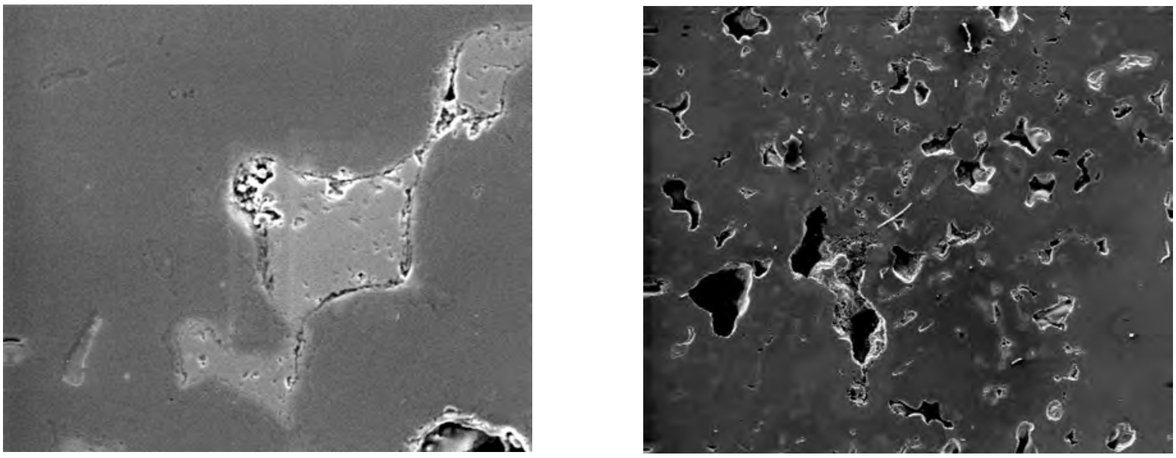


Fig. 23 – Metallographic view from Db4 (100 X).

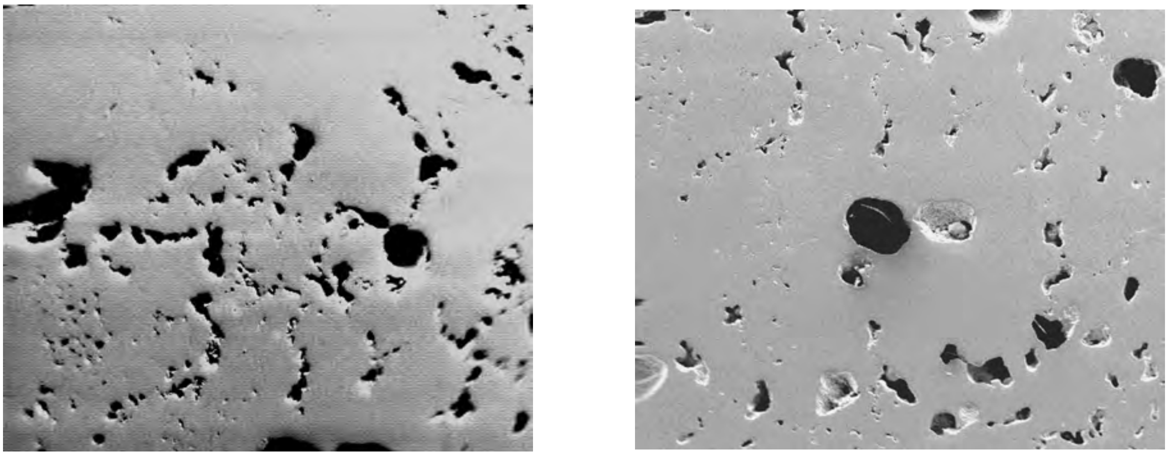


Fig. 24 – Metallographic view from Db5 (100 X).

Chemical composition and lead isotope ratios were determined on samples shaved from the top and bottom ends of the ingot pieces using a 2 mm drill.

The results of chemical analyses (Atzeni 2003b) are shown in Tables 9 and 10.

Table 9

Chemical composition of the Baradili finds (Sn, As, Pb, Zn, Ag, Au, Sb e Bi: ICP-MS, ppm; Fe: AAS, ppm; QDL: detectability limit;ND: not determined, lack of analytical solution).

Db/Bar	Sn	As	Fe	Pb	Zn	Ag	Au	Sb	Bi
1 down	32	4329	410	63	43	44	9.4	55	5.6
1 up	21	1470	410	67	69	33	5.9	37	5.4
2 down	18	1331	940	118	41	49	10.4	45	8.9
2 up	16	1468	300	116	64	49	10.0	42	6.4
3 a	18	2471	860	110	46	80	13.2	104	4.6
3 b	12	1701	500	201	27	49	14.7	54	6.2
4 a	18	2794	1140	120	49	78	15.6	87	5.5
4 b	14	2333	1910	92	50	66	13.7	69	4.5
5 a	22	2024	260	114	49	67	15.9	61	6.7
5 b	20	1675	440	101	87	53	14.6	50	5.6
6 down	22	3317	5400	118	55	130	24.9	118	9.7
6 up	35	2614	7600	94	35	121	23.8	106	6.1
7 a	45	3008	ND	109	38	89	ND	104	4.5
7 b	27	2549	ND	94	49	68	ND	83	2.8
8 down	22	1660	ND	81	76	41	ND	46	6.2
8 up	19	1185	490	47	70	33	8.3	29	3.2
9	9	778	230	29	35	16	3.9	24	4.4
10 down	18	1876	ND	88	80	54	ND	65	6.4
10 up	15	1277	2100	77	87	15	9.8	38	4.6
11 down	11	1224	ND	38	76	22	ND	33	3.1
11 up	11	1345	260	37	36	24	5.3	36	3.8
12 down	23	2710	9800	115	71	97	23.0	74	8.8
12 up	13	3154	ND	127	155	103	ND	94	4.5
13 down	13	6394	250	112	54	33	7.6	48	4.1
13 up	13	2105	520	83	43	49	8.9	74	6.6
14 down	13	1416	1210	43	58	27	7.2	41	3.9
14 up	14	4735	ND	58	61	32	ND	50	5.5
QDL	0.2	0.5	10	0.5	0.5	0.2	0.2	0.2	0.1
Mean and	19	2331	1751	88	60	58	12.6	60	5.5
Stand. Dev.	8	1254	2672	38	26	31	6.1	25	1.7

Table 10
Chemical composition (ICP-MS, ppm) of the Baradili finds (* - also considering the figure in brackets: 227/156; other elements determined: Mo < 15, W < 5, Ga < 1 and Ta < 0.5 ppm).

Db/Bar	Co	Ni	Cr	V	Al	In	Tl
1 down	124	169	261	109	5.4	0.8	0.9
1 up	466	184	480	192	1.7	0.6	0.6
2 down	86	239	314	126	21.5	1.0	1.9
2 up	266	304	458	190	16.0	1.0	1.0
3 a	168	231	308	124	31.5	0.6	0.7
3 b	344	167	288	113	15.0	0.4	1.6
4 a	181	259	563	219	1.9	0.8	0.8
4 b	478	283	463	189	4.0	0.8	0.8
5 a	806	261	456	185	7.0	0.8	0.8
5 b	396	359	501	215	1.5	1.0	1.0
6 down	279	287	619	265	31.0	1.3	1.3
6 up	405	378	683	(681)	29.8	1.2	0.6
7 a	166	335	443	178	2.5	0.6	0.6
7 b	444	244	494	197	5.7	0.6	0.6
8 down	436	175	471	198	3.5	0.6	0.6
8 up	287	182	493	201	2.5	0.4	0.4
9	155	239	454	198	2.8	0.5	0.5
10 down	135	325	370	200	8.9	1.1	1.1
10 up	299	292	483	203	6.1	0.9	0.9
11 down	665	189	520	209	2.5	0.4	0.4
11 up	275	172	498	157	9.5	0.4	0.4
12 down	164	338	424	(822)	67.0	1.0	1.2
12 up	491	357	450	189	29.0	0.8	0.8
13 down	262	236	543	211	6.9	0.6	0.6
13 up	141	212	456	190	20.0	0.5	0.5
14 down	222	183	454	189	4.4	0.6	0.6
14 up	362	201	492	189	11.1	0.6	1.1
QDL	0.5	0.5	0.5	0.5	1.0	0.1	0.1
Mean and	314	252	461	185 *	13	0.7	0.8
Standard dev.	178	66	93	35	15	0.3	0.4

Comparison of the two samples removed from different points in the direction of thickness shows that in some cases the differences are statistically significant, for instance for As, which is a fairly volatile element.

However, considering the order of magnitude of the trace constituent concentrations, the hoard can be regarded as homogeneous in metallurgical terms. The most abundant trace element, (leaving aside O and S) is arsenic (thousands of ppm), followed by iron (several hundred ppm), Co, Cr, Ni and V (hundreds of ppm), Sb, Pb and Ag (tens of ppm) and lastly Bi (a few ppm). The Ag/Au ratio is around 5÷6, similarly to the value reported in (Stos-Gale 1997).

The lead isotope ratios are shown in Table 11.

Table 11
Lead isotope ratios (ICP-MS) of the Baradili (CA) finds.

Db/Bar	Pb, ppm	$^{208}Pb/^{206}Pb$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{204}Pb$
1 down	63	2.089	0.844	18.531
1 up	67	2.079	0.850	18.005
2 down	118	2.079	0.844	18.414
2 up	116	2.075	0.838	18.529
3 a	110	2.078	0.844	18.462
3 b	201	2.080	0.846	18.574
4 a	120	2.098	0.854	18.505
4 b	92	2.076	0.839	18.068
5 a	114	2.078	0.843	18.592
5 b	101	2.077	0.840	18.567
6 down	118	2.084	0.842	18.417
6 up	94	2.069	0.842	18.482
7 a	109	2.078	0.841	18.552
7 b	94	2.080	0.845	18.494
8 down	81	2.059	0.845	19.484
8 up	47	2.063	0.841	18.439
9	29	2.038	0.835	(17.649)
10 down	88	2.072	0.841	18.088
10 up	77	2.066	0.837	(25.548)
11 down	38	2.079	0.842	18.632
11 up	37	2.052	0.843	18.191
12 down	115	2.083	0.846	18.337
12 up	127	2.081	0.844	18.569
13 down	112	2.068	0.840	18.223
13 up	83	2.089	0.849	19.353
14 down	43	2.086	0.841	18.682
14 up	58	2.079	0.843	18.486
Mean and	88	2.075	0.843	18.531
Standard dev.	38	0.012	0.004	0.314

As a whole, the finds are substantially homogeneous. None of the samples examined matched the lead isotope fingerprint of "Sardinian type" deposits, even allowing for the anomalies, while the closest match once again proved to be with "Cypriot type" deposits (Gale 1997, Stos-Gale 1995, 1996, 1997).

E – Copper slags and metalworking scraps

(Archaeological files 34 and 24)

It is reasonable to assume that during the periods considered here, transmediterranean trade or exchange concerned metal artefacts or ingots, rather than the ores themselves which were presumably worked on site or in the vicinity of the mining field. Thus, in general, the presence of slag from smelting, cupellation or forging, etc. or of metalworking debris such as drips, splashes and fragments in an archaeological site is almost certain evidence of local metalworking or in some way related activities.

The slag is usually blackish, glassy and frothy, a clear indication that it has solidified from a semi-fluid, pasty state. Some of the slag "weighed" far more than a common stone. Often composition and microstructure are strongly heterogeneous and vary from one sample to another. The different compounds formed and coexisted in non-equilibrium (in thermodynamic terms) conditions (see Part I, chapter 1) (Tylecote 1977, Zwicker 1972).

It is estimated that to produce 30 kg of copper as much as 300 kg of slag were generated (Muhly 1980). Added to this is the semi-fused, vitrified terracotta for lining the furnace and the crucibles. An archaeological site where ingots were produced should be associated with slag heaps perfectly recognizable in the landscape. And millions of tons of prehistoric slag are estimated to exist in Cyprus, Huelva-RioTinto-Spain and in Etruria-Italy (Zwicker 1972, Costantinou 1992, Craddock 1985a, Rothenberg 1989). Similarly, enormous quantities of wood and charcoal were burned, and this altered dramatically the vegetation in and around metallurgical sites, for example again in Cyprus (Costantinou 1992). Melting of pieces of ingot, preparation of alloys and casting of artefacts certainly generates a far smaller amount of slag and slag of different composition (see Part I, chapter 1).

Up to now relatively little slag has been found in Sardinia, and there are only a few samples from Forraxi Nioi (Tylecote 1984) and Nurallao (Zwicker 1980) which are studied. Some of the less pure pieces from Baccus Simeone-Villanovaforru mentioned above might well represent intermediate smelting stages of chalcopyrite.

However, there is still no sign of the "copper slag heaps" which would prove unequivocably that early copper metallurgical activity flourished on the island. There may be many reasons why these slag heaps have never been discovered, but it cannot be denied that one possible explanation is that primary copper production did not go on for very long and was carried out to a lesser extent than hitherto believed, given the very numerous bronze objects retrieved in the Late Bronze/Early Iron Age contests.

One thing is certain: very few copper deposits were historically mined in Sardinia (Carta defines the industry history as episodic (1948)), far fewer than lead-zinc and even iron ore deposits. The data reported by Carta (1948) concern marketable ore production in the period from 1851 to 1948. Obviously this period is in no way comparable with the prehistoric ages but over those hundred years Sardinia's mining and metallurgical industries flourished as never before. This period spans two world wars and Italian autarchy, episodes during which no stones were left unturned in terms of mineable deposits. Some 7,584,000 tons of zinc, 3,147, 000 tons of Pb, 1,532,000 tons of iron but barely 75,000 tons of copper [and even 430 (!) tons of tin] were produced during this time. Therefore it is unlikely that the remains of ancient copper workings, slag and furnaces would have been reworked or destroyed in the course of subsequent industrial scale operations, as by contrast can be documented for lead (see Carta 1948 and Part II of this volume). The question remains to be solved and warrants a major research effort.

A number of fragments of undefined shape have been unearthed from the Genna Maria nuragic complex at Villanovaforru. Some are slag, while other fragments are probably pieces of ingots or smelting remains.

One fragment weighing around 110 g (E1) was found jammed in a wall near the NW corridor of the nucleous. It has high specific gravity, is heterogeneous, rough and jagged, grey in colour tending to reddish in places, with greenish patches. Bulk chemical composition showed the main metal constituents to be Fe (25 %), Pb (21 %) and Cu (16 %), with Ag (19 ppm), Bi (110 ppm), Sb (240 ppm), Zn (110 ppm) and Ni (1500 ppm) as secondary components.

X-ray diffraction analysis clearly indicated metallic copper, the oxide Cu_2O, fayalite and lead oxide and carbonate signals. EPMA mapping shown in Figure 25 (sample E1) clearly illustrates the microstructure's heterogeneity.

Other fragments of high specific gravity with cupric encrustations (E2 and E3), were retrieved from hut No.12 in the village encircling the towers. Chemical determinations performed on one of these fragments (E2) showed it to be composed chiefly of lead (64%) and copper (23 %). Other constituents included Ag (80 ppm), Bi (85 ppm), Sb (110 ppm), Ni (220 ppm), Zn (18 ppm) and lastly Fe (290 ppm).

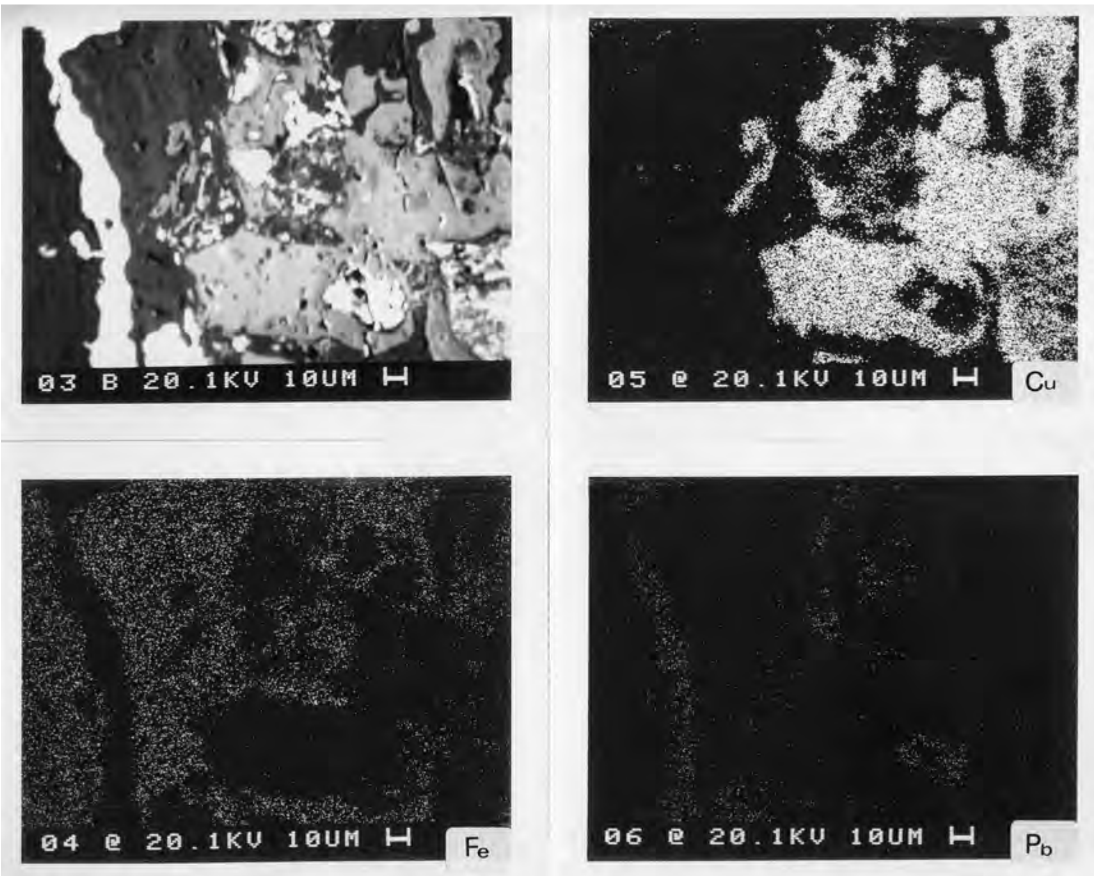
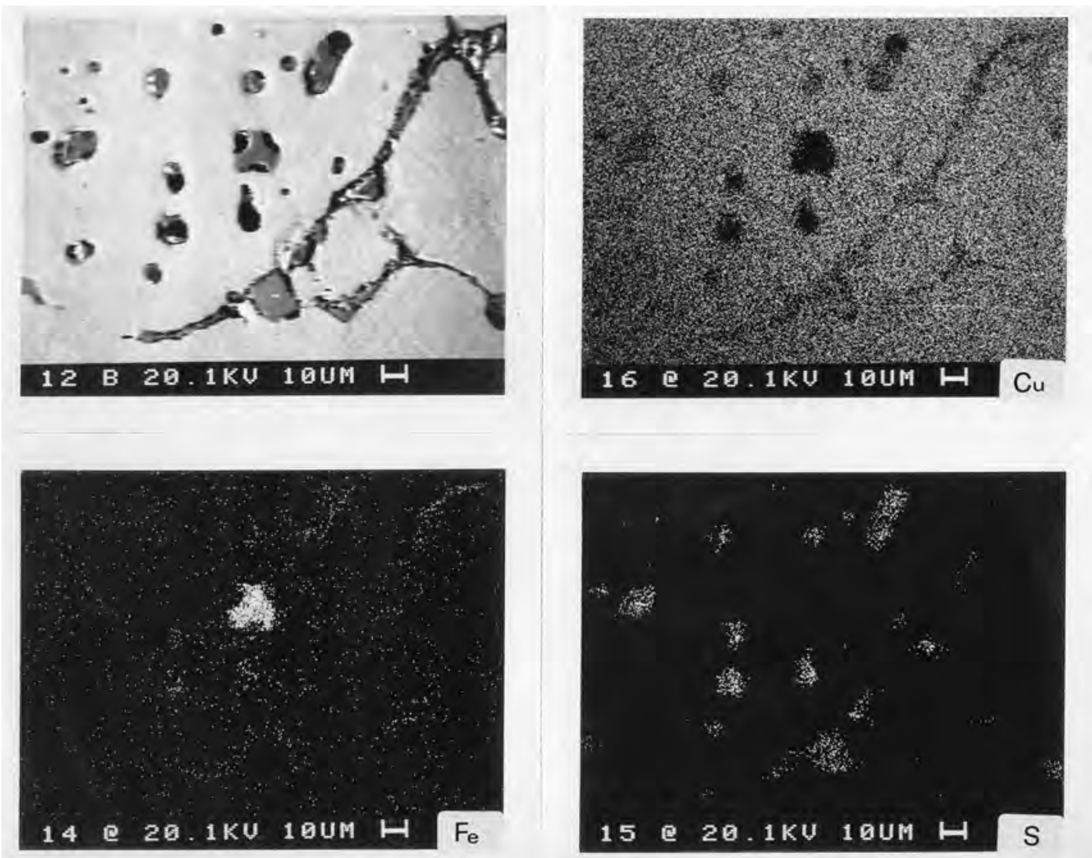


Fig. 25 – Electron Probe Micro-Analysis (EPMA) maps from E1 (bar is 10 μm).

Fig. 26 - Electron Probe Micro-Analysis (EPMA) maps from E2 (bar is = 10 μm).



The XRD spectrum shows various crystalline components including copper in its metallic form, quartz and lead in metallic form and as oxides and carbonates. EPMA mapping (Figure 26) indicates the presence of sulphur in the copper areas, copper sulphides and combined iron inclusions. With respect to the copper “islands”, the lead is intergranular. This fragment is probably simply the remains at the bottom of a crucible in which lead or tin containing lead was added to the copper.

The heavier metal separates out as unusable waste. The low iron content and the metallic lead contained in these finds distinguish them from the slag retrieved in the central tower. Given the minor percentage of silver, it is unlikely that this fragment can be associated with the practice of “washing” the copper with lead for extracting the precious metal, reported in the literature (see for example the discussion between Halleux and Gale in Rothenberg (1989, page 70).

The outer surface of sample E3 had a rusty appearance, but actually turned out to be composed of copper. Chemical analysis indicated Cu >94 %, with 1.41 % Pb and 3.69 % Fe, 1200 ppm Zn, 500 ppm Ni and 100 ppm Cr. Figure 27 shows an area with inclusions and in particular segregated lead.

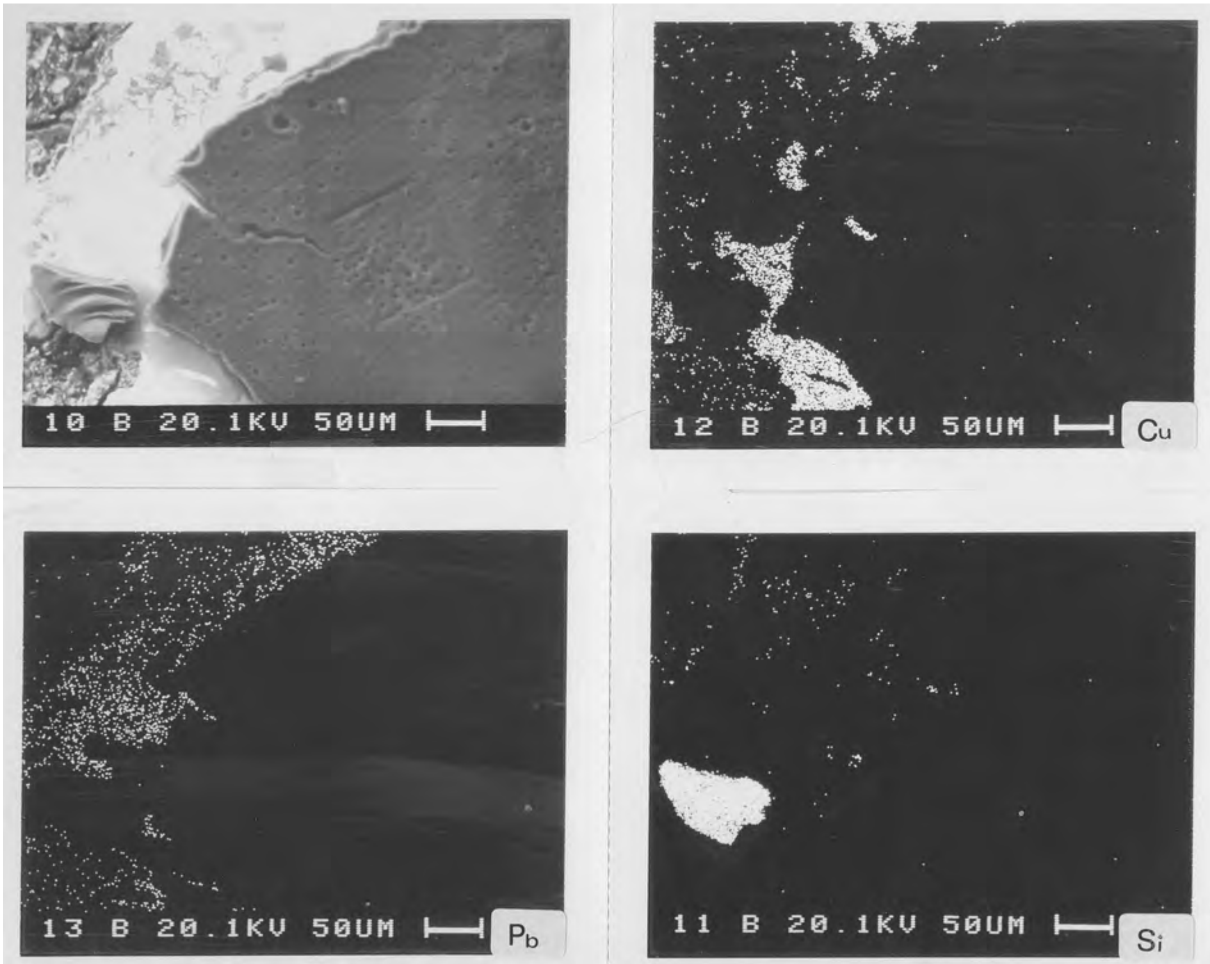


Fig. 27 – Electron Probe Micro-Analysis (EPMA) maps from E3 (bar is = 50 μm).

The XRD spectra confirmed that the material is composed essentially of metallic copper, though the Cu_2O signals are also significant. Rather than slag, this fragment can be defined as a lump of unrefined copper. Simply oxidant re-melting and slagging, followed by reduction beneath a layer of charcoal, stirring with a freshly cut wood stick (see Part I) could drastically reduce the iron and lead content.

The metallographic structure resembles that of the less pure fragments found at Baccus Simeone: copper sulphide, iron oxide, copper oxide inclusions, intergranular lead (Figure 27).

Two rusty-looking nodules were discovered at the edge of a layer of red clay surrounded by stones in the middle of hut K, one (E4, Figure 28) weighing 9.5 g, the other 2.5 g.

Another nodule of similar appearance was found attached oddly enough to the surface of a vase retrieved from the same room (Figure 29). The X-ray diffractograms recorded on powdered material and on polished sections revealed the presence of crystalline phases such as metallic copper, or maybe a copper alloy containing small amounts of tin, iron oxides and fayalite. Metallographic observation showed the copper globules to be embedded in a non-metallic matrix.

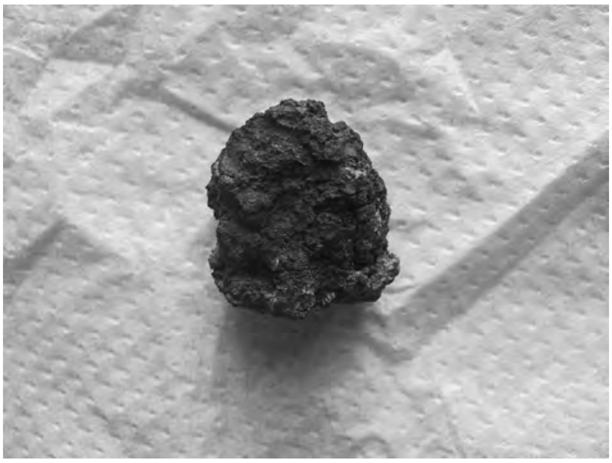


Fig. 28 – Rusty-looking nodule from hut *K* at Genna Maria site, Villanovaforru (CA).

Some pieces of slag examined come from the Bruncu Madugui site at Gesturi (entrance to hut 6, E5). X-ray diffraction analysis indicated the crystalline constituents to include fayalite, wustite and metallic copper. EPMA observations of the microstructure revealed fayalite with typical needle-like crystals, grains of metallic copper, abundant copper sulphide and copper and iron sulphide (matte) inclusions.

Another piece of “slag”, found at the Sa Sedda ’e Sos Carros site in the territory of Oliena (NU) will be discussed in the paragraph on the beginnings of iron metallurgy in Sardinia.

In conclusion, some of the finds studied here are very likely pieces of slag produced during copper extraction processes. As they were unusable waste, their presence is thought to be associated with locally performed smelting operations. The circumstantial evidence is certainly very strong. The problem of locating the site and quantifying these processes remains.

Fig. 29 – Another rusty-looking nodule, found in a vase from area *K* at Genna Maria site, Villanovaforru (CA).

F – Bronze artefacts from Pinn’e Maiolu, Villanovaforru

(Archaeological file 25)

Fig. 30 – A blade with serration, from Pinn’e Maiolu, Villanovaforru (CA).

Up to now, few working tools were analysed in Sardinia, though the first use of metal was in fact for the fabrication of weapons and ornaments. Two bronze artefacts have been studied here, a blade (F1, Figure 30) with a regular succession of small teeth along the edge and a sickle (F2, Figure 31).

As can be seen from the photograph, both objects had holes at the tangs, complete with rivets, where the handles were attached.

Two samples were removed from the serrated blade, one tooth and a bit from one of the pins.

Two samples were also taken from the sickle, one shaved from one of the pins while a bit was removed from the cracked end of the inner part of the cutting edge.

The most distinctive feature of the blade is obviously the serrated edge. Several hypotheses have been advanced as to the nature and function of this tool. Some claim that it is a small saw or in any case a tool used for woodwork (see for example DeJesus 1982). However in Atzeni (1994) is discussed the hypothesis that the serrated edge is the result of stress corrosion on a plain blade.

Chemical composition determined by means of AAS is shown in Table 12.

Fig. 31 – A sickle, from Pinn’e Maiolu, Villanovaforru (CA)

Table 12
Chemical composition (AAS, %, or ppm where indicated) of the Pinn'e Maiolu site in Villanovaforru.

	Sn	Fe	Pb	Ag	Sb	others
blade, tooth (F1)	11.0	0.02	1.5	0.07	< 0.05	Zn 70 ppm
blade, pin (F1)	13.1	0.024	0.0089	0.0063	0.025	Zn 29 ppm
sickle, pin (F1)	6.4	0.03	5.6	0.02	0.05	Bi < 0.2 ppm

The low iron content detected in all samples probably indicates efficient refining of the copper used.

The sample taken from the sickle pin was found to contain a significant amount of lead, believed to have been intentionally added. Lead isotope ratios were determined as: 2.128 (208/206), 0.872 (207/206) and 17.896 (206/204). These ratios match the lead signature of Sardinian galena deposits, those of the Monteponi-Iglesias mining district, for example. However these ratios are to be intended as representative of the lead additions rather than of the lead impurities contained in the copper (Gale 1997, Stos-Gale 1995, 1996, 1997).

The metallographic observations made on sections of the artefacts revealed two common features: the extensive presence of non-metallic inclusions elongated in the direction of hammering (Figure 32) to shape and harden the cutting edge, and a characteristic corrosion pattern penetrating into the metal along the slip planes created in the grains by hammering (Panseri 1957, Stagno 1992, Atzeni 1994). Copper had redeposited in the outer corroded areas of the sickle (Chase 1994, Leoni 1991).

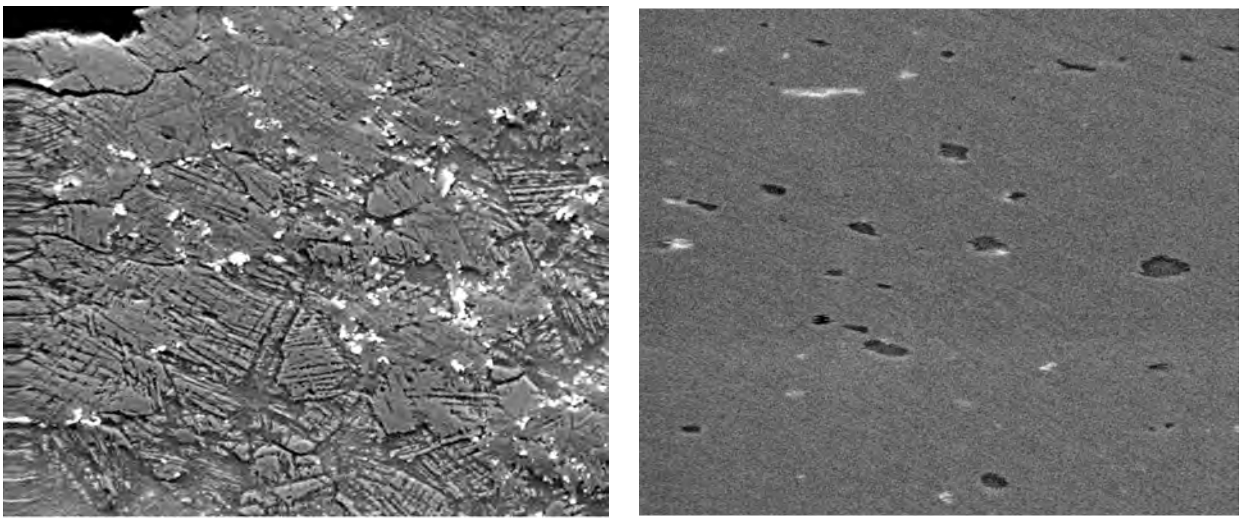


Fig. 32 – Metallographic view on sickle F2, from Pinn'e Maiolu, Villanovaforru (CA).

G – Other bronze artefacts (probably not crafted in Sardinia)

(Archaeological files 11 and 22)

Fig. 33 – Sword G1, from a Siniscola (NU) judiciary seizure.

Among the archaeological objects confiscated in a judiciary seizure at Siniscola (NU), there is a series of well-crafted and exceedingly well preserved bronze blades. Precisely because of their excellent state of preservation and after visual examination of the entire hoard, it was decided to remove small samples for archaeometric characterization from just two of the weapons (the others were in any case too long to be introduced into the device used for performing semi-quantitative SEM+EDS analyses).

Archaeologists maintain that the blades were not crafted in Sardinia. The results of the study are included in this volume for comparative purposes, to eventually identify similarities that may exist with bronze metalworking during the same period.

The first object, a 28 cm dagger, (G1, Figure 33), thought to be of Italic craftmanship, was practically intact, apart from a crack at the end of the five-holed tang. Three of the holes still contained the rivets. A small sample was removed near to the crack.

The second artefact was a 75 cm long sword, again practically intact (G2, Figure 34), with typical “fenestrated” tang. A small sample of metal was shaved in a lengthwise direction from the point where the hilt meet the blade, using a 1 mm drill.

Chemical analysis (Table 13) indicated both weapons to be composed of a 9% bronze, perfectly suitable for achieving maximum efficiency in terms of blade hardness and resilience. Worthy of note is the purity of the alloy used to manufacture the sword.

As can be seen, the composition of the two weapons is generically comparable with other bronze artefacts objects recovered in Sardinia.

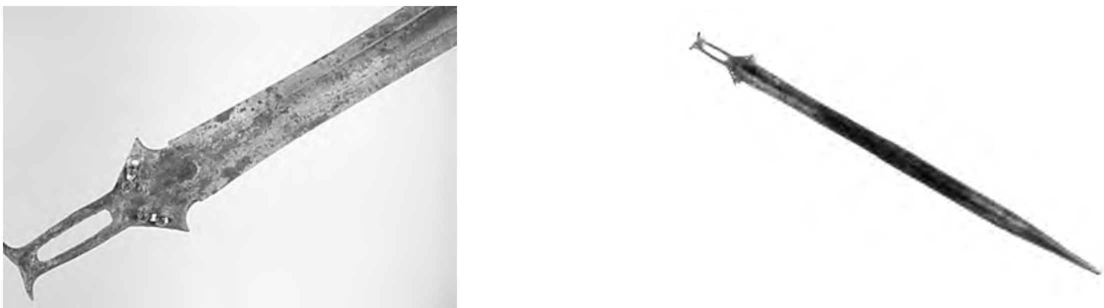


Fig. 34 – Dagger G1, from a Siniscola (NU) judiciary seizure.

Table 13
Chemical analysis (AAS, % or ppm where indicated) of two blades presumably of foreign craftmanship (Cd < 0.03 ppm)

	Sn	Fe	Pb	Zn	Ag	Sb	Bi	Ni
Dagger, G1	9.5	0.03	1.3	0.005	0.03	0.27	0.06	0.21
Sword, G2	9.0	0.05	0.006	0.002	0.01	< 0.2 ppm	< 0.2 ppm	< 0.1 ppm

H – Nuragic foundries ?

As discussed earlier, key evidence for gaining an understanding of metallurgical culture lies, not in the discovery of metal artefacts but of “objects” associated with ancient metal production processes: furnaces, crucibles, bellow nozzles/tuyeres, casting moulds, pieces of ingots, metalworking debris and slags. In spite of the fact that, to date, no sound evidence has been found either of metal extraction from ores (primary metallurgy), or of mining activity, Late Bronze/Early Iron Age levels of some settlements in Sardinia provide hypothetical evidence of casting operations starting from ingots or recycled metal (secondary metallurgy). The results described below refer to the materials unearthed in the nuragic complexes at Santa Barbara in the municipality of Bauladu (OR), Sa Sedda ’e sos Carros in the municipality of Oliena (NU) and in the Santu Antiogu site at Villanovaforru (CA).

Ha – Santa Barbara, Bauladu

(Archaeological file 29)

The crucible sherds and remains of terracotta casting moulds (Figures 35-40) unearthed in the nuragic site at Santa Barbara (Bauladu, OR) are firm evidence that the site was a foundry for the production of metal artefacts. However no traces of slag have yet been found (Gallin 1994, Atzeni 1995).

Fig. 35 – Crucibles fragments; left and above: Ha1, max dimension 4 cm; right and up: Ha2, max dimension 10 cm; down Ha3, max dimension 11 cm.

The photo in Fig. 35 shows the remains of a clay crucible, labelled 1326 (Ha1), which had an original capacity of 100-150 cm^3. The inner surface of the crucible, spongy and vitrified as a result of exposure to high temperatures, was found to contain 0.21% copper, far higher than the copper content of the outer surface (0.01%).

Find A160/162 (Ha2) shows the remains of a hole of square section for inserting a handle and facilitate pouring. Encrustations of coppery material can clearly be distinguished with the naked eye on the terracotta shown in the top of Figure 35, probably also a piece of crucible.

The shape of another find, C41 20-30 (Ha3), crafted from the locally available basaltic rock also suggests it to be a piece of a crucible, though it bears no traces of alteration or encrustations.

Some very interesting finds are the pieces of ceramic material, interpreted as casting moulds (Fig. 36).

The photo of Figure 37 shows one of the most complicated (but easier to interpret) objects. It is a pouring cup from which runners depart for transporting the molten metal into the mould (Taylor 1959, Somigli 1966, Tylecote 1986, Mattusch 1988).

The remains of the runners and pouring cups were used for the “roots” of numerous bronzetti (bronze figurines) to connect the figurines to their base. The root of the “standing bull” shown in plate X,3, clearly shows the purpose they served (Atzeni 1992b). Find 105 (Ha4) appears never to have been used; it may well be a standard part designed to be added to a mould.

Figure 37 shows a pouring cup attached to a Y-shaped runner, A118 (Ha5); between the ends of runners a carefully smoothed base has been hollowed out for accommodating an object of cylindrical shape. This appears to bear some resemblance to find C52 shown in the same photo.

The shape of this object suggests that the molten copper was made to flow around the sides of the cylinder, the core, which was removed once the metal had solidified, leaving a hollow for inserting a handle. Hammers or picks could be manufactured with a similar device.

The rational design and the concept of modularity of these objects is surprising.

Fig. 36 – Pouring cup and runners; find Ha5, max dimension 10.5 cm.

Fig. 37 – Terracotta mould fragmentes; find Ha6, cilindrical piece diameter 2.6 cm.

A number of point-shaped ceramic finds have also been recovered (Figures 38 and 39). These are thought to be cores used in casting moulds for producing spearheads, which once removed from the solidified metal would have left a hollow where the shaft was placed. In some of the finds, protuberances are still visible. These probably served as spacers or to hold the core in place (Somigli 1966, Tylecote 1986).

Fig. 38 – Terracotta cores fragments.

Fig. 39 – Close-up view of a core.

Other fragments, like those shown in Figure 40, show a design cast in relief on the surface.

A ring or small band could have been produced in the example shown here.

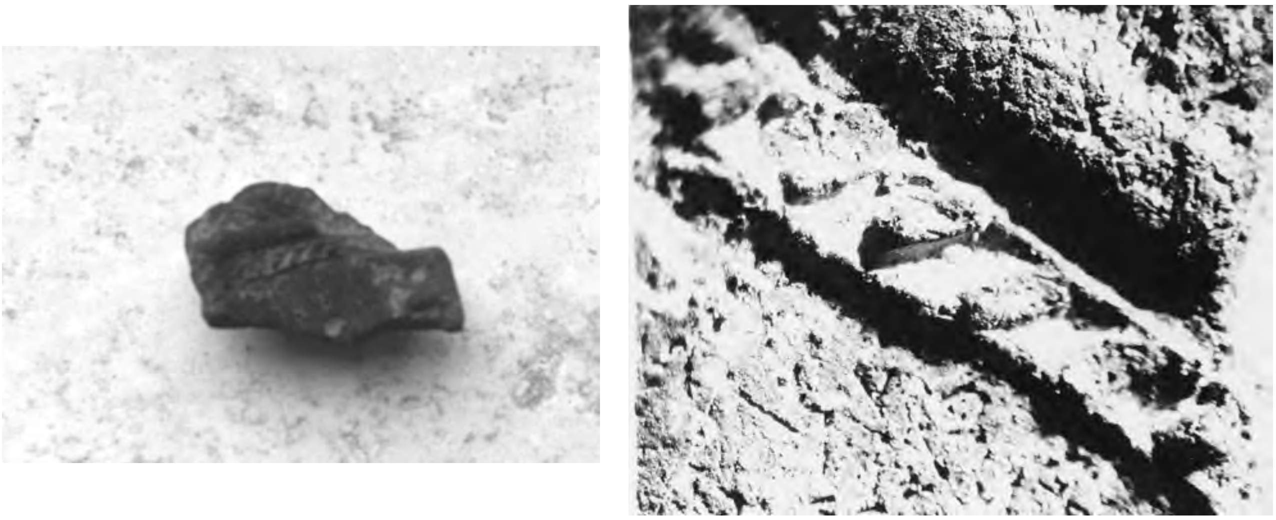


Fig. 40 – Terracotta mould fragment with negative imprint; band 2 mm wide.

Fig. 41 – A cruet-like object (crucible ?) wih pouring-cup.

The photo of Figure 41 shows an almost intact cruet-like object, with tapered sprue, of almost identical size and shape as the artefacts described above. Encrustations of vitrified clay are visible on part of outer surface which was found to have a far lower Cu content than the inner surface, 0.05 % against 0.20 %. This object was probably used for preparing alloys from molten material. Being closed, contact with air was limited, thus preventing oxidation which would have impaired the quality of the cast material.

For a more detailed characterization of the finds, petrographic observations were also conducted, supplemented by a geological survey of the area for the purpose of identifying the raw material used for fashioning the terracotta artefact.

Petrographic analyses were conducted on samples removed from finds A160-162 (crucible), A118 (the cruet-like object) and C3 40 pav (Ha9) (cylindrical core). The study revealed the finds to contain fragments of basalt and andesite and a ferrous material coating of the groundmass, while the paragenesis consists of plagioclase, sodic plagioclase, sanidine and quartz. XRD analysis indicated the presence of clinoenstatite and crystobalite, evidence of exposure to temperatures of over 1000 °C. The geology of the area is characterised by a basal volcanic formation composed of autoclastic fragments of andesitic lava of the chalco-alkaline Oligo-Miocene which formed a series of small N-S trending domes. In the northern part of the study area these rocks are overlain by massive ashy-pumiceous pyroclastic rocks produced during explosive volcanic eruptions. These rocks are overlain by sandy-marly sediments of the Langhian transgression which took place during the Miocene. These sediments are in turn covered by the basalt flows of the Plio-Quaternary cycle and recent alluvial deposits, which attain great thickness to the W of the archaeological site.

Local raw materials were used to fashion the finds, namely argillized pyroclastic rocks. The composition of the soil near the excavation area is substantially the same as that of the ceramic artefacts (Table 14).

Table 14

Chemical composition (XRF, %) of mould terracotta and soil samples from S. Barbara site.

	terracotta	soil
SiO_2	68.82	68.63
Al_2O_3	13.80	13.65
Fe_2O_3	2.58	2.38
CaO	1.50	1.40
TiO_2	0.20	0.20
MnO	0.08	0.07
MgO	2.10	2.38
K_2O	3.12	3.02
Na_2O	2.05	1.54
P_2O_5	0.02	0.02

Thermal tests were performed on the the pyroclastic rocks outcropping in the area to assess their stability. At temperatures of over 1000-1150 °C the rock begins to soften, becomes vitrified and blisters, in other words it develops the typical frothy, glassy structure observed on the inner surface of crucibles (Atzeni 1995).

The foundry earth must ensure that crucibles, and especially casting moulds, remain dimensionally and chemically stable at the process temperatures required. At the same time it should be sufficiently permeable to air to enable easy removal, thus allowing the molten metal to flow smoothly into all parts of the mould cavity (Taylor 1959). In some cases the moulds were clearly made of numerous layers of earth.

The earth used for making moulds and crucibles is worked in the same way as for any other terracotta product and should be completely dried out before use. Any moisture contained in the terracotta would be abruptly released in the form of steam on contact with the molten metal, creating a safety hazard and impairing the quality of metalwork. The crucibles certainly only remained sufficiently stable for a few castings, but given the ready availability of the raw materials, it could easily be replaced.

Some of the exposed surfaces are covered with a uniform black patina, presumed to be residues of the wax used in the “lost wax” technique.

Numerous shapeless scraps of coppery material were recovered in a small area comprised between rooms 4 and 5 and the adjacent courtyard. Though most of these fragments, identified as metalworking debris were almost completely mineralized some of them had a preserved metal core. Five pieces of debris were analysed, three of which were found to be of copper and two of bronze, containing iron and lead as main impurities. Relatively high proportions of silver were also detected (Table 15).

Table 15
Chemical analysis (AAS, ppm or % were indicated) of copper scraps from santa Barabara, Bauladu (Bi < 0.2 ppm).

	Sn	Fe	Pb	Zn	Ag	Sb	Ni	Cr	Co
Ha 10	390	2300	240	90	1410	140	20	< 40	< 10
Ha 11	350	2300	110	30	70		20	< 40	< 10
Ha 12	730	2.60 %	3700	1300	100	50	48	120	840
Ha 13	7.90 %	600	2100	90	1400	< 500	< 1000	< 200	< 70
Ha 14	4.80 %	4900	2000	90	800	< 500	< 1000	< 200	< 70

Fig. 42 – Some coppery finds from Santa Barbara site, Bauladu (OR).

Some of the finds are of pure copper. The arsenic content is always below the detection limit of the analytical method (6 ppm). Most of the finds are made of a bronze alloy containing up to 11 % tin. The minor constituents nearly always include lead. H26 has the highest lead content, 6.7 %, which actually exceeds the tin content and also the zinc concentration is unusually high (0.52 %). The antimony and bismuth contents are usually below the detection limits, that of silver ranges from 100 to 300 ppm.

Table 16
Analysed copper finds from Santa Barbara, Bauladu (OR).

	type	inventory mark (Gallin)
Ha 15	Bar fragment	C59 *livello* 2A 65cm
Ha 16	Shapless debris	C47 40 *a pavimento* AMB IBP 3A
Ha 17	Shapless debris	C47 40 *a pavimento* AMB IBP 3A
Ha 18	Dagger blade fragment	C29 AMB4 40-50 3A SB87
Ha 19	Shapless debris	C29 AMB4 40-50 3A SB87
Ha 20	Rivet, hook-like	AMB 3 C11 10-20 1B
Ha 21	Pierced sheet fragment	AMB 2 C1 30-40 2B
Ha 22	Shapless debris	C17 60-ROSSO 4A AMB ICP
Ha 23	Pierced sheet fragment	C17 20-30 2A AMB ICP
Ha 24	Rivet	C17 60-ROSSO 4A AMB ICP
Ha 25	Beads, coil-like	C25 30-40 2B AMB ICP SB 86
Ha 26	Shapless debris	SB 87 C25 50-60 LIV 3B AMB 4
Ha 27	Shapless debris	C40 0-10 1A AMB IAP
Ha 28	Shapless debris	C68 3B (-255) AMB 7
Ha 29	Shapless debris	C68 4A AMB 7 29-8-88
Ha 30	Rivet, hook-like	C68 LIV 2A AMB 7
Ha 31	Wire	C73 1M LIV INIZIO 1.M.1 AMB 9-30
Ha 32	Shapless debris	SB 87 C47 30-40
Ha 33	Shapless debris	C29 50-60
Ha 34	Shapless debris	C29 50-60
Ha 35	Shapless debris	C21 ROSSO-PAV
Ha 36	Shapless debris	C47 40 *a pavimento*
Ha 37	Shapless debris	C48 50-60
Ha 38	Shapless debris	C19E -190 cm 3B AMB 11

Table 17
Chemical analysis (AAS,% or ppm) of copper finds from Santa Barbara, Bauladu (OR) (As : < 0.5 ppm, Bi < 0.2 ppm).

	Sn, %	Fe, %	Pb, %	Zn, ppm	Ag, ppm	Sb, ppm
Ha 15	0.05	0.057	0.045	32	18	< 1
Ha 16	6.40	2.400	1.1	170	10	< 1
Ha 17	4.50	0.100	0.21	26	10	< 1
Ha 18	11.20	0.390	1.2	95	23	< 1
Ha 19	4.70	0.063	0.004	11	20	< 1
Ha 20	8.90	0.028	1.4	21	300	910
Ha 21	0.15	0.038	0.10	31	630	1900
Ha 22	6.70	0.053	0.69	100	240	1100
Ha 23	0.16	0.160	n.r.	12	50	< 1
Ha 24	7.20	0.023	0.31	32	150	320
Ha 25	2.20	0.085	0.008	26	60	
Ha 26	5.00	0.270	6.7	5200	100	
Ha 27	0.54	0.065	0.68	27	160	
Ha 28	5.30	0.120	0.34	46	250	< 1
Ha 29	0.31	0.090	0.21	86	230	
Ha 30	0.03	0.390	0.02	31	140	450
Ha 31	10.70	0.190	0.63	15	170	730
Ha 32	3.70	29.800	0.46	330	170	< 1
Ha 33	0.06	0.440	0.003	19	70	< 1

	Sn, %	Fe, %	Pb, %	Zn, ppm	Ag, ppm	Sb, ppm
Ha 34	1.20	0.140	0.14	40	260	
Ha 35	n.r.	0.270	0.014	120	200	
Ha 36	7.50	2.900	3.5	28	90	
Ha 37	1.50	0.270	0.52	66	220	
Ha 38		0.580		380		

Table 18
lead isotope ratios (ICP-MS) of copper finds from Santa Barbara, Bauladu

	$^{208}Pb/^{206}Pb$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{204}Pb$
Ha 16	2.139	0.822	18.072
Ha 21	2.098	0.854	18.258
Ha 22	2.120	0.874	18.209
Ha 23	2.096	0.844	18.611
Ha 27	2.095	0.852	18.398
Ha 28	2.062	0.866	17.917

Lead isotope ratios for six finds are shown in Table 18.

The isotope signatures for Ha 16, Ha 21 and Ha 22 (and perhaps Ha 23) are compatible with a Sardinian source. Corrosion had significantly altered Ha 27 and Ha 28 and while seemingly contradictory data were obtained for Ha28, the ratios for Ha27 suggest again a Sardinian source. However source attribution concerns the alloy as a whole and it might not correspond to the copper used for the alloy if the lead came from a different source (Gale 1997, Stos-Gale 1995, 1996, 1997).

Hb – Sa Sedda 'e sos Carros, Oliena.

(Archaeological file 31)

In the past the hundreds of pieces of metal or of material associated in some way with metallurgical activities, recovered at the Sa Sedda 'e Sos Carros site at Oliena (NU), lead archaeologists to believe that there some form of metal recycling/remelting was carried out. However, unlike the Santa Barbara site at Bauladu which abounds in remains of crucibles and casting moulds there is yet no concrete evidence to suggest that Sa Sedda 'e Sos Carros was a foundry.

In this section we describe the characteristics of a series of around forty copper-base finds. These include fragments of spearheads, blades, ornamental objects, votive swords, boat, figurines, sheets, etc. Other finds, composed chiefly of iron, are discussed in a later section.

The chemical composition of the samples from the finds is shown in Table 19.

Most part the finds were of bronze, with a Sn content between 7 and 12 % by weight. Another group of finds, identified as pieces of ingot (probably of the "bun" type) was found to contain only minor amounts of tin. The other constituent generally present in significant amounts is lead. Lead content of as much as around 10 % was detected in some finds. This is not unusual for bronzes of this and subsequent ages, particularly in bronzes used for fashioning ornamental objects. In some cases a high lead content appears to be accompanied by small amounts of tin. This suggests that perhaps when tin was not readily available early metalworkers resorted to a macroscopically similar metal as an alternative (though in terms of strength and specific gravity they differed significantly and lead could never functionally replace tin!).

The bronzes did not generally contain more than 2 % iron. The highest values are associated with low tin content.

Among the trace elements, zinc and silver are always present in amounts of a few tens and of a few hundred ppm respectively. Object Hb7 contained an unusually large amount of zinc (1% =10000 ppm), but in general the zinc content is well below 500 ppm.

Table 19

Chemical analysis (AAS, concentrations in %) of copper objects from Sa Sedda 'e Sos Carros-Oliena (n.r.: undetectable, Sn: n.r. < 2 ppm, Sb: n.r. < 0.2 ppm; As < 0.5 ppm e Cd < 0.03 ppm).

		Sn	Fe	Pb	Zn	Ag	Sb
Hb 1	Sheet fragment	7.60	0.036	0.10	0.0031	0.0031	0.66
Hb 2	Spearhead	9.50	0.010	0.33	0.0035	0.0035	0.21
Hb 3	Twisted wire	5.20	0.015	0.12	0.0048	0.0048	0.03
Hb 4	Sheet fragment	7.90	0.042	3.60	0.0051	0.0051	0.17
Hb 5	Band	7.40	0.024	0.03	0.0029	0.0029	n.r.
Hb 6	Sheet fragment	11.60	0.036	3.30	0.0015	0.0015	0.22
Hb 7	Sheet thick fragment	1.40	2.200	0.50	1.0	1.0	0.72
Hb 8	Bun ingot bit	n.r.	0.059	0.12	0.0013	0.0013	0.19
Hb 9	Spearhead plug	11.80	0.037	0.56	0.0038	0.0038	0.04
Hb 10	Spearhead point	7.60	0.073	0.47	0.0011	0.0011	0.13
Hb 11	Axe fragment	7.40	0.100	1.00	0.0091	0.0091	0.10
Hb 12	Pin	7.90	0.045	0.03	0.0840	0.0840	0.17
Hb 13	Votive sword tang	2.80	0.790	0.69	0.0250	0.0250	0.03
Hb 14	Spearhead	9.50	0.120	0.33	0.0032	0.0032	0.10
Hb 15	Bun ingot bit	n.r.	0.450	0.06	0.0007	0.0007	n.r.
Hb 16	Casting scrap	9.40	0.035	0.56	0.0130	0.0130	0.22
Hb 17	Casting scrap	7.10	0.040	0.69	0.0130	0.0130	0.25
Hb 18	Sheet thick fragment	5.50	1.500	1.70	0.2400	0.2400	0.35
Hb 19	Casting scrap	1.60	0.020	9.70	0.0015	0.0015	0.05
Hb 20	Sword tang fragment	7.90	0.082	0.95	0.0093	0.0093	0.16
Hb 21	Thick ring bit	0.05	0.017	0.23	0.0023	0.0023	0.21
Hb 22	Bull head figurine	0.58	1.800	7.70	0.0310	0.0310	0.18
Hb 23	Scrap	n.r.	0.043	0.62	0.0130	0.0130	n.r.
Hb 24	Scrap	n.r.	0.013	0.03	0.0012	0.0012	0.09
Hb 25	Votive sword fragment	3.80	1.900	1.20	0.0120	0.0120	0.14
Hb 26	Spearhead	9.00	0.063	1.10	0.0340	0.0340	0.32
Hb 27	Bun ingot bit	n.r.	0.320	0.12	0.0290	0.0290	n.r.
Hb 28	Sheet fragment	5.50	0.510	0.15	0.0140	0.0140	n.r.
Hb 29	"maleppeggio" bit	6.10	2.200	0.69	0.4300	0.4300	0.29
Hb 30	Rivet (?)	9.10	0.033	0.46	0.0160	0.0160	0.26

		Sn	Fe	Pb	Zn	Ag	Sb
Hb 31	Sheet fragment	13.00	0.020	0.01	0.0028	0.008	0.05
Hb 32	Scrap	0.16	0.120	0.70	0.0560	0.024	0.12
Hb 33	Scrap	0.07	0.038	2.30	0.0012	0.030	0.12
Hb 34	Scrap	n.r.	27.6	4.7	0.014	0.1	n.r.
Hb 35	Point (?)	10.30	0.061	0.79	0.0034	0.040	0.14
Hb 36	Sheet fragment	10.60	0.079	0.18	0.0061	0.019	n.r.
Hb 37	Sheet fragment	0.15	0.130	0.48	0.0014	0.011	0.26
Hb 38	"L-shape" bit (?)	2.50	0.025	10.4	0.0016	0.025	0.08
Hb 39	Axe fragment (?)	13.00	0.560	1.20	0.0310	0.082	n.r.
Hb 40	"Maleppeggio" bit	11.40	0.790	1.20	0.0420	0.054	0.16
Hb 41	Casting scrap	n.r.	0.140	3.20	0.0940	0.100	0.06
Hb 42	Boat figurine bit	0.37	0.009	5.50	0.0010	0.021	0.06
Hb 43	Rectangular handle	3.90	0.066	0.36	0.0013	0.042	0.16

Table 20

Lead isotope ratios (ICP-MS) of some copper finds from Sa Sedda 'e Sos Carros, Oliena.

	$^{208}Pb/^{206}Pb$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{204}Pb$
Hb 2	2.060 2.091	0.861 0.853	17.987 18.243
Hb 6	2.094	0.865	18.244
Hb 9	2.122	0.863	18.452
Hb 11	2.135	0.880	18.171
Hb 19	2.069	0.844	18.785
Hb 33	2.115	0.861	18.484
Hb 38	2.063	0.845	18.846

Table 20 shows the lead isotope ratios for some of the finds. As we have mentioned, for a correct interpretation of these data, we have to bear in mind that the significant amounts of lead contained in some objects, are certainly to be attributed to lead added to the copper. Thus the isotope ratios of these additions have overprinted the lead contained in the copper as an impurity. As often happens when analysing objects that are not primary copper ingots, data interpretation is rather difficult and in some cases may actually be impossible. The least dubious source attribution is, perhaps, that of bronze Hb6. The lead isotope ratios are compatible with Sardinian ore deposits (Gale 1997, Stos-Gale 1995, 1996, 1997), but here again the lead content suggests that the ratios concern the lead added to the copper during alloying, and not the metal contained in the copper ore. By contrast, Hb2 matches Cypriot fingerprints. The exceedingly high lead content of Hb19 and Hb38 certainly indicates that the lead was added to the copper, though the lead isotope data match fairly closely copper of Cypriot origin.

Lastly Hb33, Hb11 and Hb9 contain minor amounts of lead, but not sufficiently small to be regarded unquestionably as an impurity of the copper ore. The lead isotope ratios are similar to the Sardinian fingerprint but the ratio for 204 is not so convincing.

Hc – Thermally altered stone remains at Santu Antiogu, Villanovaforru (a metallurgical furnace debris?)

(Archaeological file 28)

The key element in metallurgical processes is obviously the furnace, in particular for extracting metals from ores, preparing alloys and for casting objects. The interested reader should for instance consult Tylecote (1967), Rehder (1986) and Wagner (1986), for general considerations and descriptions of different furnace designs. To date nothing that can actually be identified as a smelting furnace has yet been discovered in Sardinia. Recent evidence (Balmuth 1983) does not support what Taramelli reported in 1918 as being the so-called "Ortu Commidu foundry" at Sardara (CA).

Consequently, the numerous pieces of stone recovered at Santu Antiogu in the municipality of Villanovaforru, despite being found at the surface, are potentially of great interest. In fact they show evident signs of alteration undoubtedly due to exposure to "high" temperatures. Figure 43 shows depth of penetration of local alteration (concentrated effect near to a *tuyère*?). In Figure 44 the actual drop-shaped downward flow of the softened stone is clearly visible on find Hc2. Figure 45 shows the frothy texture of the Hc3 microstructure indicating the onset of melting along with copper coloured encrustrations (unfortunately it was not possible to perform chemical determinations on it).

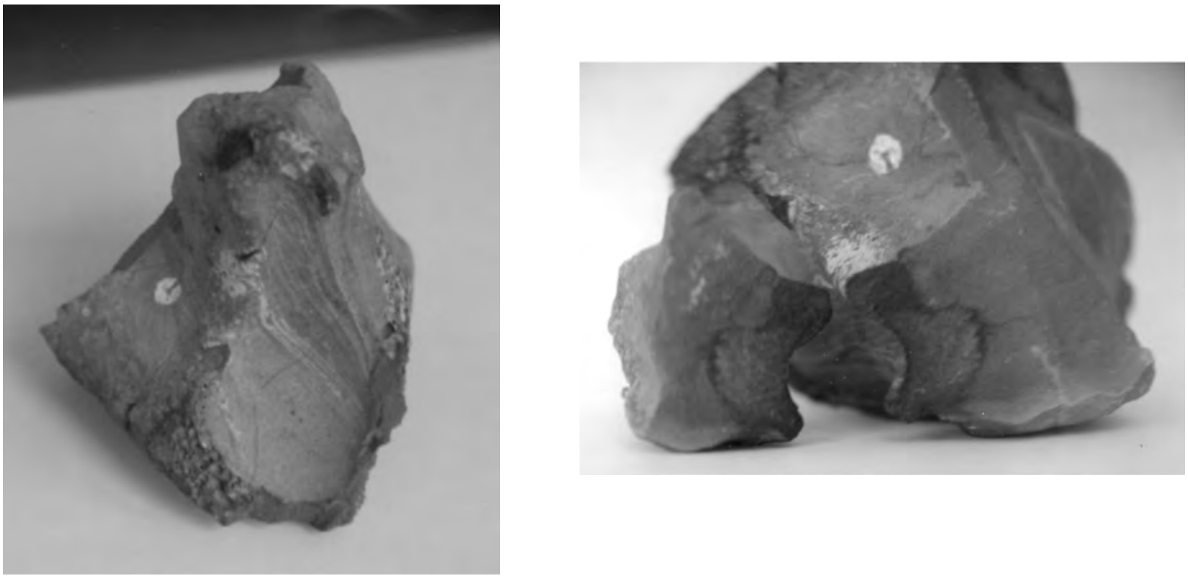


Fig. 43 – Localised thermal alteration on stone piece Hc1 from S. Antiogu site.

Figura 44 – Drop-shaped downward flow of the softened stone piece Hc2 from S. Antiogu site.

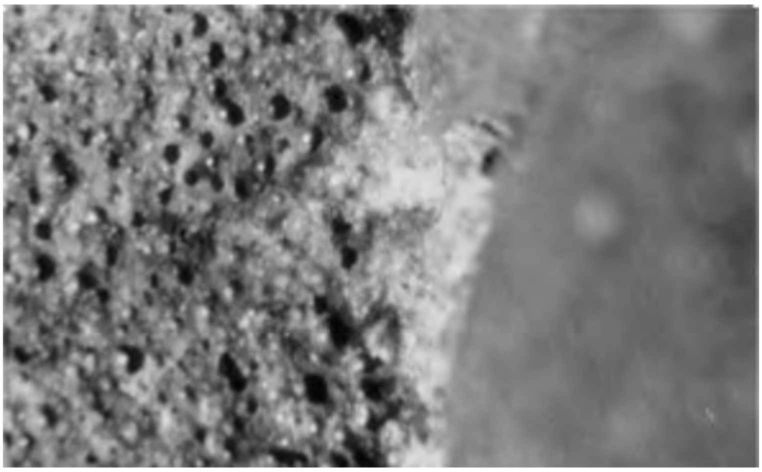


Fig. 45 – Blisters and green stain on Hc3 stone piece from S. Antiogu site.

Thermal tests carried out in the laboratory on an unaltered fragment cut from Hc1 showed the material to withstand temperatures of up to 1100 °C, above which the original brick red colour started to darken. At 1150 °C the stone begins to soften, becoming greyish-black and at 1200 °C it takes on a treacly appearance accompanied by the formation of a vacuolar structure. The resulting mineralogic changes were monitored by means of X-ray diffraction analysis (XRD) and confirmed 1150 °C as the limit temperature. The disappearance of the characteristic quartz peaks and the modified diffraction pattern of the original feldspar peaks in the XRD spectra resemble those recorded on samples taken from the finds.

Thus, the temperatures required to produce the alterations observed in the stone are clearly compatible with the temperatures attained in metallurgical processes, for example of copper which, we recall, melts at 1083 °C.

We also critically examined other potential causes of the alterations. A forest fire would certainly not have been able to produce the alterations observed and such high temperatures are unlikely to be attained in kilns for firing clay or for the production of lime. Lightning, on the other hand, causes rock to melt and vitrify, hence coining the term “fulgurites”, and produces similar alterations. On a large scale these effects can be attributed to the impact of meteorites (Bertolani 1972, Clocchiati 1990).

This problem can only be conclusively solved by further archaeological explorations at the site to search for evidence of, for example, clay linings, slag and metalworking debris. Should additional data support the hypothesis that these are actually the remains of a metallurgical furnace, then this would be the first such find recorded in a Sardinian protohistoric context.

I – Bronze figurines (*bronzetti*)

(Archaeological file 17)

Within the framework of this project, we studied twelve bronze figurines housed in Cagliari's National Archaeological Museum. This is the first time that a study of this kind has been made possible: paradoxically, analytical data for figurines from foreign collections are already reported in the literature though some are of dubious origin and authenticity (Balmuth 1978, Riederer 1980, Tylecote 1984, Balmuth 1998).

We conducted a series of investigations on the bronze figurines indicated in Table 21 (the names are those attributed by Lilliu (1966), to which the interested reader is referred for details of findspots and morphometric features). Photos of three of the figurines are shown in pl. XI.

Table 21
The twelve bronze figurines studied from the National Archaeological Museum in Cagliari.

	Inventory no.	Denomination	Provenance
I 1	84	worshipping warrior with shield on shoulders	unknown
I 2	110	demon	Abini, Teti (NU)
I 3	93	worshipping warrior with shield on shoulders	Abini, Teti (NU)
I 4	104	hero with 4 eyes and 4 arms	Abini, Teti (NU)
I 5	121	worshipping woman	Abini, Teti (NU)
I 6	128	worshipping warrior with shield on shoulders	Abini, Teti (NU)
I 7	116	worshipper with braids	Abini, Teti (NU)
I 8	163	offering figure with loaf	unknown
I 9	207	standing bull	Abini, Teti (NU)
I 10	216	yoke	Abini, Teti (NU)
I 11	144	offering woman with short cape	unknown
I 12	145	priestess with *stola*	unknown

Table 22
Chemical analysis (AAS) of bronze figurines from the National Archaeological Museum in Cagliari (moreover: Bi < 500 ppm; Sb < 600 ppm, but I1: Sb=1200 ppm).

	Sn, %	Fe, %	Pb, %	Zn, ppm	Ag, ppm	Ni, ppm	Co, ppm
I 1	10.3	0.200	0.59	80	860	160	140
I 2	9.5	0.250	0.70	150	650	210	200
I 3	9.3	0.120	0.99	120	830	200	160
I 4	9.4	0.035	0.29	80	230	290	170
I 5	10.8	0.170	0.31	150	780	210	150
I 6	12.4	0.045	0.42	120	620	250	41
I 7	0.27	0.011	0.29	970	6.5 %	380	< 4
I 8	13.1	0.230	0.14	32	45	280	160
I 9	9.4	0.029	0.70	49	100	420	100
I 10	12.0	0.050	6.50	48	10	280	28
I 11	10.0	0.029	0.06	47	110	190	84
I 12	5.9	0.930	0.68	140	1400	200	150

The finds to be analyzed were chosen on the basis of the "root" by means of which, in antiquity and indeed also nowadays, the figurine was inserted into the base and which we have interpreted as the remains of casting runners and pouring cup. In this way it was possible to remove samples without damaging in any way the exposed part.

Compositional analysis of the alloys is shown in Table 22 (Atzeni 1991a, 1992b).

The *bronzetti* are generally of tin bronze, with tin contents ranging from 5.9 to 12.4 %. Adding relatively large amounts of tin avoided uptake of atmospheric oxygen by the molten copper, and gave products of a better quality, though in the specific case the superior mechanical properties were not a necessary requisite. The figurines always contain a certain amount of lead; the high percentage observed in find I 10 certainly indicates that lead had been added to the alloy. The addition of lead, when slagged prior to casting, produces deoxidizing effects and improves the castability of the metal, all key factors for obtaining the intricate shapes required in *bronzetti* production. Unlike the suspected fakes, the figurines examined here contained only minor amounts of zinc (see next section) (Santoni 2000).

Metallographic examination performed using the electron probe microanalysis (EPMA) showed frequent inclusions of copper oxide Cu_2O, copper sulphides and to a lesser extent of lead. The statuette I 1 contained grains of copper composed of almost pure copper, probably due to redeposition in the course of the corrosion (Chase 1994, Leoni 1991).

The most surprising result obtained for this series of analyses was that the tin in find I7 had been entirely "replaced" by silver. Ag does not actually become alloyed to copper because of its low solubility in the solid form. In fact inclusions observed in the metallographic section contained extremely large concentrations of silver (88%) accompanied by around 5% lead (EPMA). It is perhaps no accident that the two metals are associated as the precious metal could have been probably extracted by means of cupellation.

Though extremely uncommon, analytical data reported for a nuragic boat figurine from a foreign collection, revealed silver contents of 5.11 and 6.30 % (Riederer 1980). This discovery is all the more surprising as, contrary to commonplace thinking, evidence collected to date shows that the use of silver is rare in the nuragic cultural context. Kuleff (2002) discusses possible reasons for the presence of silver in archaeological finds composed of copper alloys (brasses, not bronzes and of Medieval age).

Fig. 46 – The root of the "standing bull" *bronzetto* and pouring cup and runners from S. Barbara site.

Lead isotope determinations (ICP-MS, Angelini 1995) gave ratios in the following range:

$^{208}Pb/^{206}Pb$: 2.90 ÷ 2.20

$^{207}Pb/^{206}Pb$: 0.65 ÷ 0.80

$^{206}Pb/^{204}Pb$: 17.2 ÷ 18.0

The data match the isotope signature of typical ore deposits in Sardinia (Gale 1997, Stos-Gale 1995, 1996, 1997). However, as repeatedly mentioned above, a word of warning. The lead content of the alloys is generally rather high and it is fair to presume that the addition of this metal gives a distorted picture of the ratios of the copper ore itself. The ratios determined for find I 10 lie at the limits of the range, probably precisely because a large amounts of lead (6.5 %) were added to the alloy. In the light of these considerations it is evident that the ratios determined cannot be regarded as providing conclusive evidence for provenancing the base metal (copper).

As for the production technique, it is commonly believed that the figurines were cast using the "lost wax" process (Maryon 1998). Our findings confirm this hypothesis and provide further details. Recalling the discussion above regarding the Santa Barbara foundry at Bauladu, in our opinion the "root" observed in many *bronzetti* is nothing other than the remains of the casting runners and the pouring cup feeding the mould.

Figure 46 shows one of the ceramic finds discovered at the Santa Barbara-Bauladu site alongside a well-known "standing bull" *bronzetto* (see previous paragraph). Of course the figurines were cast top down.

L – Fake bronze figurines

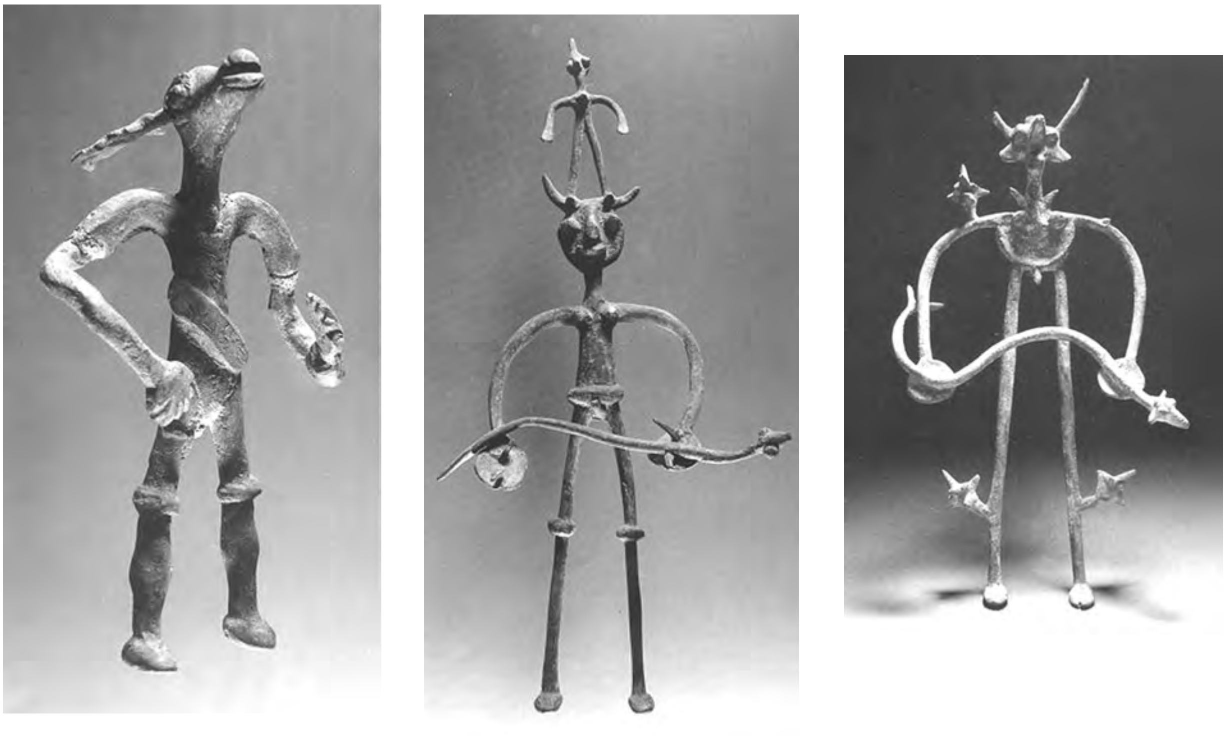


Fig. 47 – Fake *bronzetti*: the “Sardo-Phoenician idols”; from left L29, L25 and L24.

The study of fake figurines falls outside the scope of the evolution of metallurgy in prehistoric and protohistoric Sardinia, with which this research project is concerned. However, these fakes are briefly mentioned here because their very existence has created some confusion in the past. The fakes concerned are the hundred or so “Sardo-Phoenician idols” traded and probably produced in the 19th Century (Fleming 1988, Pais 1881, Lilliu 1975). The lesson gained from this occurrence must not be forgotten.

Chemical analyses and metallographic observations were carried out on thirty one of these figurines (L 1-31) on the occasion of the “Fakes and Fakers” exhibition which took place in Villanovaforru in 1988-1989. Three of the fakes are shown in Figure 47.

The variability in the concentrations of the principal constituents suggests that the figurines were produced using recovered material rather than smelting specific proportions of pure base metal. Another possibility is that the figurines were produced at different times or by different foundries.

The copper alloys contain significant amounts of zinc, in addition to Sn and Pb. In the 20th Century zinc was one of the pillars of Sardinia’s mining and metallurgical sector, accounting for some 40 % of marketable metal ores production in the period 1851-1948 (Carta 1948). Some important primary metal production and refining plants continue to operate on the island (Patrizi 1985, SAMIM 1990). The presence of Zn in metal objects claimed to be prehistoric or protohistoric is however almost always a sign that they are not authentic (Fleming 1988). Significant amounts of zinc have only been reported in tables published in the past by Vodret (1959) but these can be attributed to systematic analytical errors as later investigations confirmed (Atzeni 2003a, 2003b, Demurtas 1999). As far as the unusual presence of zinc is concerned, it is well known that this metal rarely occurs in the metallic form in nature, and though zinc bearing ores are fairly abundant in Sardinia (Sartori 1929, Toja 1948, Rolandi 1959), the peculiarities of zinc metallurgy would have made it difficult for early metalworkers to recognize it as a metal. (Craddock 1985c, Smith 1918). In fact, though it can be separated from the most common zinc bearing ores (blende, smithsonite and calamine, respectively a sulphide, carbonate and hydrated silicate) by means of the usual carbothermic processing, zinc has a very low boiling point (907 °C). In the vapour state it rapidly reacts with the carbon dioxide contained in the fumes, recombining therewith to form zinc oxide. To avoid reoxidation it requires the design of special devices for cooling-condensing the fumes in the absence of oxygen and carbon dioxide (Craddock 1985c; Morgan 1959; Wills 1986). Moreover, brasses can be made *via* cementation, *i.e.* adding the ore to molten copper along with a layer of charcoal, but this technique has only been documented to exist in the second half of the 1st millennium B.C. (Craddock 1980, 1985c).

Table 23
Chemical composition (AAS, %) of samples from the "Sardo-Phoenician idols".

	Sn	Fe	Pb	Zn	Ag	Sb	Bi
L 1	6.8	0.15	3.5	2.0	0.036	0.21	0.010
L 2	2.5	0.17	2.2	2.9	0.066	0.30	0.014
L 3	1.3	1.10	3.0	2.8	0.063	0.17	0.027
L 4	4.1	0.02	6.5	0.1	0.054	0.15	0.010
L 5	5.4	0.44	3.8	10.8	0.061	0.24	0.017
L 6	4.8	0.66	5.2	7.8	0.150	0.24	0.023
L 7	2.2	0.19	2.0	1.8	0.059	0.20	0.010
L 8	6.0	0.40	4.5	5.1	0.063	0.23	0.027
L 9	3.3	0.87	1.5	0.4	0.055	0.15	0.013
L 10	3.6	0.82	6.8	8.4	0.086	0.81	0.019
L 11	9.7	0.30	3.9	2.3	0.068	0.20	0.069
L 12	5.5	0.50	3.6	1.03	0.091	0.28	0.048
L 13	13.2	0.30	3.7	3.7	0.100	0.46	0.034
L 14	2.7	0.45	4.8	6.5	0.079	0.18	0.028
L 15	8.0	0.45	10.3	6.3	0.073	0.18	0.039
L 16	10.4	0.61	4.9	2.8	0.078	0.27	0.038
L 17	6.8	1.15	6.2	4.2	0.080	0.29	0.033
L 18	2.2	0.18	1.4	3.8	0.040	0.09	0.050
L 19	4.4	0.20	3.4	0.2	0.050	0.13	0.010
L 20	5.4	0.43	5.3	4.2	0.076	0.35	0.042
L 21	6.1	0.72	4.3	8.0	0.110	0.31	0.025
L 22	9.4	0.58	2.7	1.8	0.058	0.25	0.022
L 23	3.8	0.36	3.7	3.0	0.070	0.17	0.035
L 24	3.2	0.37	3.5	6.5	0.052	0.18	0.051
L 25	1.9	0.41	1.9	1.8	0.057	0.15	0.012
L 26	4.6	0.35	2.8	4.5	0.064	0.10	0.037
L27	5.6	0.23	3.5	1.9	0.076	0.24	0.036
L 28	7.1	0.47	2.8	2.3	0.060	0.19	0.022
L 29-a	8.1	0.79	5.3	3.6	0.079	0.38	0.030
L 29-b	8.7	0.65	5.0	3.6	0.081	0.40	0.033
L 30	7.9	0.30	2.5	7.6	0.077	0.38	0.016
L 31	6.0	0.25	7.8	2.3	0.100	0.24	0.032

Table 24
Chemical analysis (EDS, %) of two recently-made fakes.

	Cu	Sn	Zn
archers (L 32)	80	4	16
two-shielded warriors (L 33)	76	2	22

Table 24 shows the composition of two recently judiciary seizured bronze figurines (L32, L33); unlike the "Sardo-Phoenician idols", these figurines are stylistically compatible with those today recognized as genuine.

These fakes are composed of brass, probably obtained by resmelting knick-knacks or piping made from the Italian commercial alloys CuZn15 and CuZn20 used for nowadays production and more readily available and economical than true bronzes. Observation of metallographic sections revealed pitted, chlorine-rich surfaces but no deep intergranular corrosion, suggesting that the figurines were treated to look as antiques, or an attempt was made to do so, by immersing them in salt water and/or hydrochloric acid.

Of course, not always fakers make such gross errors in alloy composition and in these cases archaeometric investigations for evaluating the authenticity of archaeological objects assessment go beyond simply determining the elemental chemical composition. However, it is a pleasure to find that people who are prepared to pay out great sums of money to obtain pieces of Sardinia's archaeological heritage, are often simply duped.

M – The beginnings of iron metallurgy in Sardinia ?

(Archaeological files 31 and 20)

Iron ores occur far more commonly than copper bearing ores, and even more so than minerals from which tin is extracted (Selmi 1873, Durrer 1949). It is no coincidence that iron has been defined a "democratic" metal as opposed to the "aristocratic" nature of bronze. Iron ores are also mined in Sardinia and between 1851 and 1948 production totalled 532,000 tons against 75,000 tons of copper (Carta 1948).

Iron metallurgy marked a turning point in ancient metal production techniques. There are two aspects that distinguish iron metallurgy from copper extraction and copper and bronze working and both involve greater complexity in practical (and conceptual) terms. Copper and bronze could be melted, but the same cannot be said of iron which, in its pure form, melts at temperatures of over 1500 °C, far higher than the thermal stability of the materials used by primitive metalworkers. Moreover, iron by itself is an almost useless material because of its inferior strength (the malleability of iron is similar to that of copper !). Iron becomes really useful when alloyed with carbon to produce what is known as steel when it contains up to 2.1 % carbon. Optimum strength is probably obtained for alloys containing around 0.8 % C (alloys with a carbon content of > 2.1 % are known as "cast iron" and have different properties, in a certain sense less significant for early metalworkers concerned with finding a valid alternative for bronze. Incidentally, the presence of carbon has also been exploited for dating archaeological objects but not with very satisfactory results.

The problem lies in the fact that ancient bronzes were produced by adding a specific amount of tin to the melt whereas for iron+carbon alloys the carbon was absorbed by the iron in the solid (or at the most pasty) state from the charcoal used as fuel for the furnace; carbon uptake occurred spontaneously and was governed by the temperature and by the time these elements remained in contact (not by weighing and adding). Furthermore, the iron alloys had to be quenched to take full advantage of their strength potential.

The reasons why one material supplants another lie not only with technology but are also closely related with the geopolitics of natural resources. This is certainly true of bronze versus steel in the centuries spanning the 1st millennium B.C. in Asia and Europe. And as always happens, the appearance of a new product does not necessarily mean the material it has replaced will fall into disuse. On the contrary, bronze continues to be used especially for ornaments and statuary whereas the late advent of electricity caused the demand for copper to soar (besides, the Stone Age is in full swing, stone being the main constituent of concrete, the most widely used material in the world today!).

Archaeometrically speaking, the tendency of iron alloys to corrode more than copper alloys, poses an insurmountable obstacle for a rigorous characterization of the earliest finds, at least those retrieved in hot, humid regions (Delpino 1988).

We have examined some finds discovered at the Sa Sedda 'e Sos Carros site in Oliena, and a single object unearthed at the Antigori site at Sarroch, consisting of rusty iron plate affixed to a lead artefact.

At Sa Sedda 'e Sos Carros, along with the hundreds of copper fragments described in an earlier section, a series of ferrous finds were recovered. Archaeometric investigations have already been carried out on some of these finds. For example, Tylecote (1984) describes the results of metallographic analysis on a piece of white cast iron whereas Lo Schiavo (1990) reports compositional determinations showing the co-presence of significant amounts of iron, copper and lead. EDAX analysis on single phases revealed the presence of the iron/phosphorus eutectic with 10 % and 27 % by weight P (melting temperature of 1049 and 1264 °C, respectively).

In this investigation, first of all a true iron object was characterised (M1; inv 59024). Its original shape is difficult to define: *spatula*, shovel ? Today remains only a tang about 4 cm long and 1 cm wide, cracked at one end and connected at the other by means of rounded shoulders to an emicyrcular "blade", again cracked which an estimated width of 6÷7 cm. A small section was removed from the cracked end of the handle for analysis.

Three pieces of indefinite shape, generically identified as "slag", were also examined. They shared one feature in common, their rusty appearance. The M4 (inv. 58963) is a pin-rod roughly 4 cm long with thickness varying from 7 to 10 mm, completely oxidized with a fibrous-woody appearance. The other shapeless pieces of "slag" examined were find M 2 (non inven., c. r), with deep pits, and rusty outer surface in some places with veins of copper and M 3 (non inv.).

Table 25 shows the composition of these finds.

Table 25
Chemical analysis (AAS, %) of the iron finds.

	Fe	Pb	Cu	Zn	Ag	Other elements
M1	65.2		0.025	0.0008	0.045	Sn 0.03 %
M2	71.9	1.5	11.0	0.0008	0.590	Sn 0.07 %
M3	27.6	4.7		0.014	0.01	
M4	48.4	0.003		0.0038	0.0004	

Metallographic observations on samples of M1 revealed a compact and uniform ferritic structure with inclusions of silicate slag containing wüstite dendrites. EDS analysis did not detect any copper inclusions, in agreement with the low Cu content determined by AAS analysis. This copper concentration (250 ppm) is lower than those reported by Åström (1986) for iron objects from Cyprus dated to the 1200 B.C. (360÷4100 ppm). Åström suggested that the iron was produced by processing slag from chalcopyrite smelting (Charles 1994, Maddin 1996, Mapelli 2000). In the case at hand this hypothesis is rather feeble.

Analytical results confirmed find M4 to be an iron corrosion product (around 50 % Fe, in different oxidation forms (XRD), the remainder being mostly oxygen). Metallographic observations did not reveal any metallic iron but indicated the typical silicate inclusions of the slag. The "woody" appearance is typical of forged iron, and is caused by the elongation of residual slag during hammering and its stability with respect to the metallic part (Atzeni, 1997b).

Of particular interest is find M2 which turned out to be magnetic. X-ray diffraction analysis showed the presence of metallic alpha iron and copper, iron oxides in different oxidation states and copper sulphides.

The metallographic section is porous, with pore sizes of up to a few millimetres. The matrix has a steel grey colour and in some of the samples the copper coloured inclusions are visible to the naked eye. These inclusions have the typical microstructure of "prehistoric" copper, *i.e.* they are accompanied by (sub)inclusions of copper sulphides and oxides and metallic lead. EDS analysis showed 3÷5 % of the iron to be evenly disseminated. Globules of copper have been observed in the intergranular pores of the matrix, the copper having a lower melting temperature than iron and its alloys. Often these globules are surrounded by a layer of altered material, a corrosion product of the ferrous matrix (iron is less "noble" than copper).

In the intergranular spaces of the ferrous matrix is a component which has the unmistakable appearance of a eutectic. The microstructure is practically identical to that reported by Tylecote (1984) who identified the eutectic as ledeburite. In some places the corroded layers retain the eutectic structure. SEM+EDS observations of the two eutectic phases showed a light coloured phase in relief, and a dark coloured phase in depression. Fe appears to be the only constituent. Only traces of copper have been determined (our SEM+EDS equipment is not set up for C determinations). The other phase exhibits a substantially similar spectrum. The matrix grains are composed essentially of Fe with a few percent of Cu and Pb. The lead-rich inclusions observed are probably iron phosphides.

The Vickers microhardness of the copper inclusions tested at 20 g load gave a mean value of 100 kg/mm^2 (equivalent SI value 981 N/mm^2), while the ferrous matrix attains values close to 800 kg/mm^2 (equivalent SI value 7845 N/mm2) and the eutectic over 1500 kg/mm^2 (equivalent SI value 14710 N/mm^2).

This kind of by-product could also be regarded as a raw material for iron/steel metallurgy. The usable metal content is very high (72 %) and does not differ substantially from the iron content of magnetite, one of the most valuable minerals (Durrer 1949). However the move up from cast iron to steel (referred to in modern terminology as the "indirect" method, as opposed to the "direct" method of extracting iron from ores even at temperatures lower than 1000 °C, followed by carburation *via* cementation, in the solid/plastic state during forging) would have involved solving technical problems almost certainly beyond the abilities of early metalsmiths (Craddock 2003).

M2 was more likely a by-product of smelting a chalcopyrite type ore. During the reduction process, the iron initially present as sulphur became roasted to oxide, but the unavailability of silica in the area meant that slagging, which would have generated a fayalite type mineral, could not be carried out. The reducing and carburation conditions of the furnace on the other hand led to the partial formation of cast iron (Maddin 1996, Mapelli 2000). Cast iron with a 4.3 % carbon content (the eutectic known as ledeburite) melts at around 1150 °C. With a melting temperature of a little over 1200 °C are the alloys containing 3.9 – 4.7 % C. So it is possible that the cast iron examined here formed in the molten state. The presence of a eutectic in the microstructure along with the position and shape of the phases with low melting point would appear to be confirm this.

In conclusion, M2 is probably a slag from primary copper production (see remarks in earlier section on slag). Here again the presence of slag suggests that some smelting activities were carried out locally, also bearing in mind the clues provided by the lead isotope ratios reported below.

Table 26 gives the lead isotope ratios for those finds for which it was possible to remove a sample large enough to conduct isotope determinations. The data obtained should be regarded with some caution in view of the fact that little is known about the reliability of this method for ferrous matrices and corrosion can perhaps cause data corruption. Bearing in mind these limitations, the samples of slag examined have similar characteristics and are compatible with a Sardinian source, while for the *spatula*/sholve M1, the only real object in iron, once again, a Cypriot signature cannot be ruled out.

Lastly, regarding the roughly one mm thick rusty plate attached to a piece of lead unearthed at the Antigori nuraghe at Sarroch, it was found to be composed of 52 % Fe, 6 % silica, the remainder probably consists of oxygen combined with the iron in form of iron oxides. Only traces of Ag, Bi, Sb, Cu, Zn and Pb were detected. The shapeless piece of lead (Nb10) to which it was attached, weighing 36 g, had part of its surface coated in black slag, sand and carbon inclusions (see next section on lead). The same encrustations were observed on find Nb11, probably part of Nb10.

Table 26

Lead isotope ratios (ICP-MS) of finds M 1, M 2 and M 3 from Sa Sedda'e sos Carros site.

	$^{208}Pb/^{206}Pb$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{204}Pb$
M 1	2.078	0.848	18.37
M 2	2.132	0.881	17.99
M 3	2.113	0.885	17.91

N – Lead

Lead is the *fil rouge* of the entire metallurgical history of Sardinia, from its beginnings up to the present day (Alba 1996, Tangheroni 1985, Amat 1991, Gouin 1867, Rolandi 1954-1956, Perillo 1985). So this section is devoted wholly to it and contains a description of the numerous studied finds and discusses the related metallurgical problems.

A broad variety of objects fashioned in antiquity with this malleable, ductile and corrosion resistant metal with low melting point, includes small sculptures, sealers for filling spaces in masonry, waterproofing sheets, weights for fishing lines and other uses, clamps for repairing pottery, ammunition for slings, alloy constituent, etc. However lead never become important for making weapons, work tools or prestigious ornaments (Krisko 1979).

Certainly the main reason for the importance of lead ores was that they are a major source of silver. Lead ores can contain significant amounts of silver as impurity and during smelting most of this precious metal passes into the melt. Silver can then be separated from lead by means of cupellation (Pl. XII.1-3) (Bachmann 1993).

In this section we discuss the results of investigations carried out on lead finds from the sites of Santa Barbara – Bauladu (OR), Antigori – Sarroch (CA), Genna Maria and Pinn'e Maiolu – Villanovaforru (CA) (Atzeni 1987, 1991b, 1992a-c, 2003c). Additional archaeometric data are presented in Part II of this volume.

Na – Lead from Santa Barbara, Bauladu

(Archaeological file 29)

The main types of lead objects usually unearthed in prehistoric sites in Sardinia are represented at the Santa Barbara site, in particular clamps for repairing pottery vessels (Figures 48-49) (Atzeni 1991a).

Fig. 48 – Two lead finds fom Santa Barbara, Bauladu (OR); left Na8, right Na3.

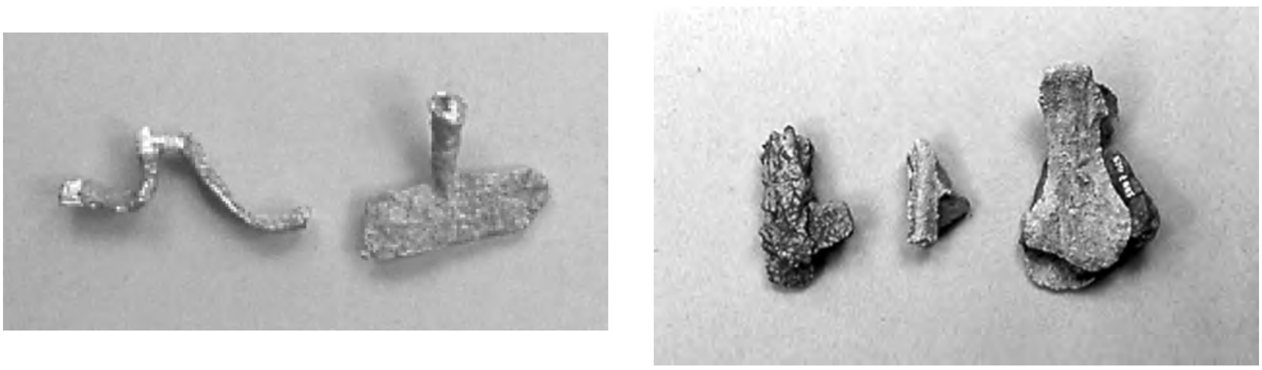


Fig. 49 – Lead clamps for repairing pottery from Santa Barbara, Bauladu (OR).

The finds characterised are listed in Table 27.

Table 27
Lead finds from S. Barbara, Bauladu.

	Archaelogical signature	type	weight, g
Na 1	SB87 C44 30-40 2B AMB 4 nord del muro	Clamp	15.98
Na 2	C68 3A	Sheet fragment	5.22
Na 3	SB87 A29 C44 30-40	Wedge shaped	808
Na 4	C101 2A cm 30	Bar	63.87
Na 5	C64 3B Lead Ingot AMB?	Clamp deformed	51.51
Na 6	C67 2A AMB 7 SE	Bar	25.42
Na 7	C3 40+6 PAV LEVEL 3B AMB ICP	Molten splash	45.66
Na 8	SB C17 AMB ICP Rosso 60 LEV 4A	Sheet rolled	110
Na 9	STRUTTURA 8 LEVEL 3A -39 cm	Lead-blob (?)	20.61
Na 10	C26 2C	Clamp	6.73
Na 11	C65 LEVEL2BAMB7 LEAD& CERAMIC	Clamp	30.58
Na 12	C37 20-30	Clamp	8.57
Na 13	SB87 C1 50-60 LEV 3B AMB 2	Clamp	11.77
Na 14	SB87 C29 40-50	Drop shaped	4.32
Na 15	SB87 C40 50-70 LEV 2CD AMB IAP	Clamp	30.25
Na 16	C47 LEV 2B AMB IBP	Clamp	15.99
Na 17	SB 87 C7 AMB 2 PAVIMENTO	Clamp	31.33
Na 18	C72 AMB LEVEL 1A	Cross shaped	21.55
Na 19	C68 4A AMB 7 LEAD MENDING	Sheet fragment	8.63
Na 20	SB 87 C48 40-50	Sheet fragment	7.32
Na 21	C47 LIVELLO 2B AMB IBP	Clamp	52.36
Na 22	C68 4A AMB7 lead and pottery	Clamp in pottery	29.44

Table 28 shows the chemical composition of the objects examined (finds Na21 and Na22 were not sampled so as not to alter their appearance).

Table 28 : Chemical analysis (ICP-MS, ppm) of lead finds from S. Barbara-Bauladu.

	Cu	Ag	Fe	Sn	Cs	As	Zn	Sb	Bi
Na 1	325	41	29	5	1	1	18	1	1
Na 2	164	39	< 20	2	<1	<1	59	1	1
Na 3	268	65	< 20	2	2	<1	29	3	1
Na 4	592	19	125	35	2	<1	49	67	7
Na 5	50	58	87	<1	2	<1	203	<1	1
Na 6	684	57	231	<1	2	<1	<1	7	21
Na 7	287	69	< 20	463	1	<1	75	<1	1
Na 8	305	55	< 20	4	2	<1	45	1	1
Na 9	427	56	< 20	5	4	5	19	29	21
Na 10	458	59	132	34	1	3	26	6	16
Na 11	292	65	120	31	1	48	<1	4	1
Na 12	377	62	< 20	49	1	32	111	13	21
Na 13	306	48	109	5	1	<1	50	2	1
Na 14	287	67	106	11	2	126	<1	<1	1
Na 15	300	68	88	1	7	49	<1	<1	1
Na 16	292	67	217	2	6	<1	23	1	2
Na 17	281	57	160	11	2	<1	<1	4	1
Na 18	418	53	121	1187	3	74	37	62	75
Na 19	468	56	60	6	2	<1	57	5	1
Na 20	284	37	168	230	1	<1	<1	<1	1

The main trace constituent is copper with concentrations of around 300 ppm, but which can reach as much as 600 ppm and more. The silver content never exceeds 70 ppm.

Varying concentrations of iron, tin and zinc have been determined: up to 231 ppm iron, tin ranging from around 1 ppm (Na15) to as much as 1187 ppm (Na18), and zinc content varying from “not detectable” to 200 ppm.

Generally arsenic is below the detection limit of the analytical method, only in some cases were amounts of up to 70 ppm detected. Cesium, tallium, lithium and selenium are present in amounts of a few ppb and are undetectable. Ultra-traces of uranium and cadmium are almost always present (a few ppb).

With respect to their bismuth and antimony content, the finds can be divided into two groups: the first including Na4, 6, 9, 10, 12, and 18 (“high” concentrations), the second the remainder of the finds in this series (“low” concentrations).

Nb – Lead from Antigori, Sarroch

(Archaeological file 20)

Six clamps for repairing pottery Nb 1- 6 (AG 1-6) and seven pieces of uncertain identification Nb 7-13 (A1-7) from the Antigori site were characterised (see Figure 50). Isotopic composition was also determined for the series Nb14-17 (Table 29).

Table 29 : Description of finds Nb 14-17

	type	weight, g
Nb 14	shapeless fragment	9.0
Nb 15	molten splash	35.6
Nb 16	sheet with holes	10.2
Nb 17	clamp	23.4

Clamps Nb1 and Nb2 are still attached to pieces of pottery. Nb1 is of particular interest as the mark of the cloth onto which the molten metal was cast, is clearly visible.

Among the other finds, worthy of mention is Nb9 (A3) a piece of sheet about 5 mm thick, with the beginning of a cut, carried out by using a shear-like tool, judging from the mark it has left; Nb10 (A4), is probably Nb11 (A5) connected to it, presents rusty plates which are discussed in the previous section on iron, and blackish encrustations that appear to be slag.

The finds recovered from the Antigori site are made of relatively pure lead. Table 30 gives the copper and silver content, the elements most frequently contained in the series of finds that it was possible to sample.

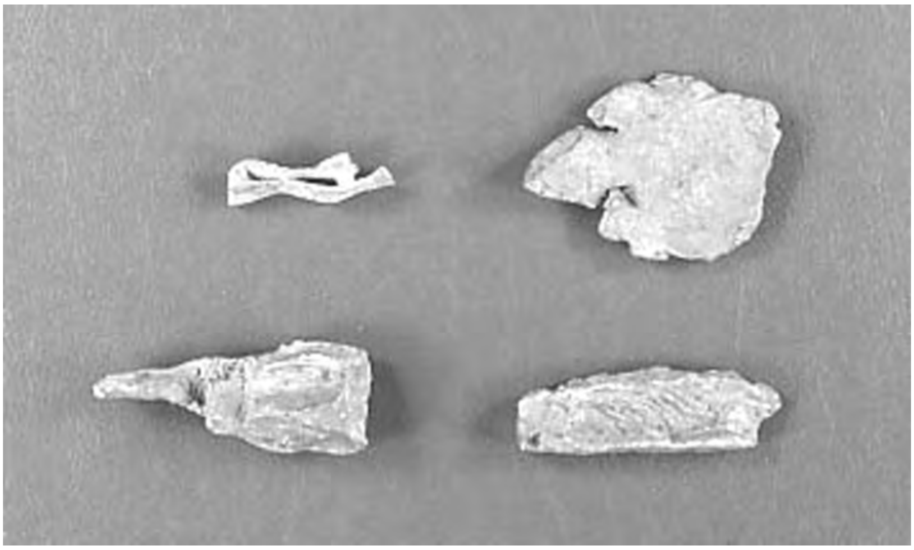


Fig. 50 – Lead finds from Antigori; from the top downwards and from left to right, Nb 6, 7, 8 and 9.

Table 30

Chemical analysis (AAS, ppm) of lead finds from Antigori, Sarroch.

	weight, g	Cu	Ag
clamps			
Nb 1	27	400	100
Nb 2	59	400	80
Nb 3	61	300	120
Nb 4	18	400	80
Nb 5	61	500	230
Nb 6	9	300	105

	weight, g	Cu	Ag
others			
Nb 7	134	250	81
Nb 8	99	190	127
Nb 9	102	680	45
Nb 10	36	400	40
Nb 11	38	400	30
Nb 12	10	300	30
Nb 13	29	380	50

Nc – Lead from Genna Maria, Villanovaforru

(Archaeological file 34)

Fig. 51 – Pierced lead sheets from Genna Maria, Villanovaforru (CA) .

We examined a number of clamps used for repairing pottery (Pl. XII.4), unearthed in the huts of the village labelled 10 (samples Nc1a-d), 12 (samples Nc3a-b) and F (samples Nc2a-c), a few foil/sheets recovered from room 16 (Nc4) as well as another unstratified find (Nc7) along with a galena nodule, again unstratified (Nc12) (Atzeni 1991b, 1992c).

Several samples were removed from some of the clamps which proved useful for assessing the heterogeneity of the materials, and for a better evaluation of the compositional data reported in the literature (Atzeni 1991b).

The sheets are about 1 mm thick. Nc4 (C16a) weighs 96 grams and, though folded when found, they appeared to have had originally a semi-circular shape. The finds from the same room 16 include, in addition to some small fragments, sheets Nc5 (C16b), weighing 324 g, and Nc6 (C16c), weighing 681 g. From the latter sheet, which has an estimated area of 500-600 cm^2, a piece was "torn" off. Similar metal sheets were found unstratified and labelled CX; the largest of these are Nc7 (Cxe) weighing 314 g probably originally semicircular, and Cxf (Nc8) weighing 240 g. Of a certain interest are the three small sheets Nc9-11 (Cxh), 40X50 mm weighing 12 g, roughly 60X35 mm weighing 17 g and 20X11.5 mm weighing 0.9 g with perforated edges which appear to have been made with a sewing needle (see Figure 51).

The galena nodule, Nc12, roughly 60 mm in diameter and weighing 380 g is composed of virtually pure galena, with around 5 % quartz. The concentrations of Sb (900 ppm) and Ag (230 ppm) are significant. The nodule also contained copper (20 ppm), zinc (40 ppm), nickel (10 ppm), Bi (40 ppm), Fe (< 100 ppm) and Cd (< 10 ppm).

The chemical composition of the sampled finds is shown in Table 31.

Table 31
Chemical analysis (AAS, ppm) of lead finds from Genna Maria, Villanovaforru.

	Cu	Ag	Sb	Bi
Nc 1a	330	320	60	20
Nc 1b	350	310	70	45
Nc 1c	300	150	60	20
Nc 1d	310	130	60	20
Nc 2a	260	130	60	20
Nc 2b	190	190	50	20
Nc 3a	300	110	60	20
Nc 3b	310	300	70	80
Nc 3c	300	270	140	44
Nc 4	310	270	60	20
Nc 7	290	160	50	20

Sb and Bi concentrations are similar to those observed in the first group ("high concentrations") from the Santa Barbara site at Bauladu.

Metallographic analyses conducted on some of the finds substantially confirmed the purity of the metals examined here (Atzeni 1991b).

A macrograph of a clamp pin recovered in room F in the Genna Maria village clearly shows the different grain sizes – small grains in the outer parts of the pin (cooled and solidified more rapidly) increasing in size in the core which cooled more slowly. The metallographic section of sheet metal revealed a grain orientation orthogonal to the surface, and suggests that the sheet was cast from molten metal and solidified starting from the contact plane, rather than being hardened by hammering (grains elongated parallel to the surface). In both cases it is fair to presume that no recrystallization has taken place over time.

In conclusion, both the compositional and the metallographic data clearly show the high purity/quality of the lead. This can be achieved relatively easily by means of the "low hearth" technique, probably similar to the smelting technique used in prehistoric ages.

Compositional data for lead smelted in a modern blast furnace (San Gavino plant in Sardinia) give, for example, silver content of around 130 ppm, copper of around 20 ppm, bismuth of 150÷250 ppm, antimony of about 50 ppm, with peaks of around 250 ppm, and tin and zinc concentrations of 50 ppm. Electrolytic lead contains 20÷120 ppm silver, 20÷200 ppm copper, 150 ppm bismuth and 50 ppm antimony, arsenic, tin and zinc. The smelting technique used by early metalworkers to make the finds examined here produced a high quality metal, at the expense of extraction efficiency (high concentrations of metal reporting in the slag). In the late 1800's evidence exists that "Roman" slag was resmelted as source of lead (Carta 1948).

The objects from the S. Barbara site contain no more than 70 ppm silver, which compares favourably with the silver content of the metalworking debris and pieces of ingots found at Antigori (30÷50 ppm), but is lower than that contained in similar objects recovered from the Genna Maria (110÷320 ppm) and Antigori (80÷230) sites. The amount of silver was too small to justify its recovery *via* cupellation. Well-crystallized galena ores usually contain small quantities of silver. These ores were easier to recognise by early metalworkers and easier to work (Selmi 1874b).

Nd – Lead from Pinn'e Maiolu, Villanovaforru

(Archaeological file 25)

Fig. 52 - "Roman" lead pipe from Pinn`e Maiolu, Villanovaforru (CA).

The piece of lead piping (Nd1) unearthed at Pinn'e Maiolu is included in this section merely for comparative purposes as it is dated as "Roman". The flattened/folded pipe is 91.2 cm long, has an estimated diameter of roughly 30 cm and a thickness of around 4 mm (Fig. 52). The piping has three holes with diameter of approximately 1.8, 4.9, 1.9 cm which appear to have been created when welds of lateral pipes snapped.

The results of chemical analysis are given in Table 32.

Metallographic analysis revealed a structure that differed in part from the other samples for the presence of inclusions that EDS analysis showed to contain relatively high concentrations of cadmium.

Lead isotope analysis of lead finds

Table 33 shows the lead isotope ratios of some of the finds recovered from the S. Barbara, Antigori and Pinn'e Maiolu sites (Cincotti 2001).

Table 32
Chemical analysis (AAS, ppm) of piece of lead piping from Pinn'e Maiolu, Villanovaforru.

Sample	Cu	Ag	Sn	Li	Ni	Zn	Sb	Bi
Nd 1a	914	39	158	4	< 1	26	4	43
Nd 1b	899	35	180	4	< 1	73	3	37
Nd 1c	798	45	305	5	57	41	< 1	3

Table 33
Lead isotope ratios (ICP-MS) of lead finds.

	$^{208}Pb/^{206}Pb$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{204}Pb$
from S. Barbara			
Na 1	2.122	0.873	17.849
Na 2	2.116	0.873	17.828
Na 3	2.127	0.872	17.923
Na 4	2.082	0.837	18.776
Na 5	2.124	0.872	17.902
Na 6	2.104	0.851	18.445

	$^{208}Pb/^{206}Pb$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{204}Pb$
Na 7	2.131	0.875	17.896
Na 8	2.120	0.876	17.893
Na 9	2.086	0.845	18.539
Na 10	2.107	0.864	18.139
Na 11	2.122	0.875	17.864
Na 12	2.089	0.842	18.564
Na 13	2.123	0.872	17.890
Na 14	2.125	0.875	17.851
Na 15	2.126	0.875	17.877
Na 16	2.128	0.874	17.870
Na 17	2.125	0.873	17.914
Na 18	2.094	0.849	18.372
Na 19	2.124	0.874	17.855
Na 20	2.125	0.874	17.875
from Antigori			
Nb 3	2.120	0.871	18.109
Nb 7	2.093	0.848	18.514
Nb 14	2.085	0.837	18.728
Nb 15	2.084	0.839	18.705
Nb 16	2.082	0.838	18.746
Nb 17	2.121	0.868	18.137
from Pinn'e Maiolu			
Nd 1a	2.089	0.840	18.606
Nd 1b	2.079	0.838	18.645
Nd 1c	2.087	0.838	18.740

The data frequently match the isotope signature of Sardinian ore deposits of Cambrian (Na1, 2, 3, 5, 7, 8, 11, 13, 14, 15, 16, 17, 19 and 20 from S. Barbara, pratically the entire "low" Sb and Bi concentration" group; Nb3 and 17 from Antigori) and Hercynian age (Na6 and 10) while for Na4, 9, 12 and 18 the ratios suggest a Hercynian age Sardinian or Tuscan source. The isotope fingerprints of the Antigori finds labelled Nb14, 15 and 16 also correspond to galena-bearing deposits in Tuscany.

However it should be mentioned once again, that given the relative accuracy of the ICP-MS data recorded here and the quality of comparable data reported in the literature, there is some data overlap between the Sardinian ores and the data for some galena deposits in Spain and southern France, which warrant further investigation (Fiorini 1991, Trincherini 1993, Hunt Ortiz 2003, Ploquin 2003).

The data for the piece of piping from Pinn'e Maiolu, which we recall has been dated to Roman times, are compatible with a Tuscan or Iberian source (Stos-Gale 1995). Several other lead objects dated as Roman discovered in Sardinia have isotope signatures that do not correspond to Sardinian ore deposits (Pinarelli 1995, Bigagli 2000, Riccardi 2000)

Lead clamp manufacturing technique

The use of lead for the clamps used to repair small and large pottery vessels is believed to have been common practice in nuragic settlements. The low melting temperature of lead, 327 °C, which could be reached in a domestic fire, and the availability of the metal obviously means that it was cheaper to repair the broken containers than to acquire new ones. The interesting feature of these clamps are the textile impressions on the plate on which they were cast. They are visible for example on a clamp from the Antigori site at Sarroch and on another at Santa Barbara, Bauladu (Figure 53).

We attempted to reproduce this process in the laboratory. In some experiments, two pieces of cane were inserted through holes made in a piece of pottery around 2 cm thick and fixed in place with a layer of clay. Molten lead (at about 400 °C; the viscosity is 2.3 cPoise, two times that of the water at ambient temperature, the specific gravity is 10.6 g/cm^3 (Hofmann 1970)) was then poured into these "runners", obtaining an efficient "weld", almost identical to those observed on archaeological finds (Figure 54). The whole operation took no more than ten minutes, confirming that this simple repair technique was probably done at home.

Figure 55 shows the impression of the cloth "moulds" used to contain the molten metal on the cast lead. The cloth can be used dry or wet.

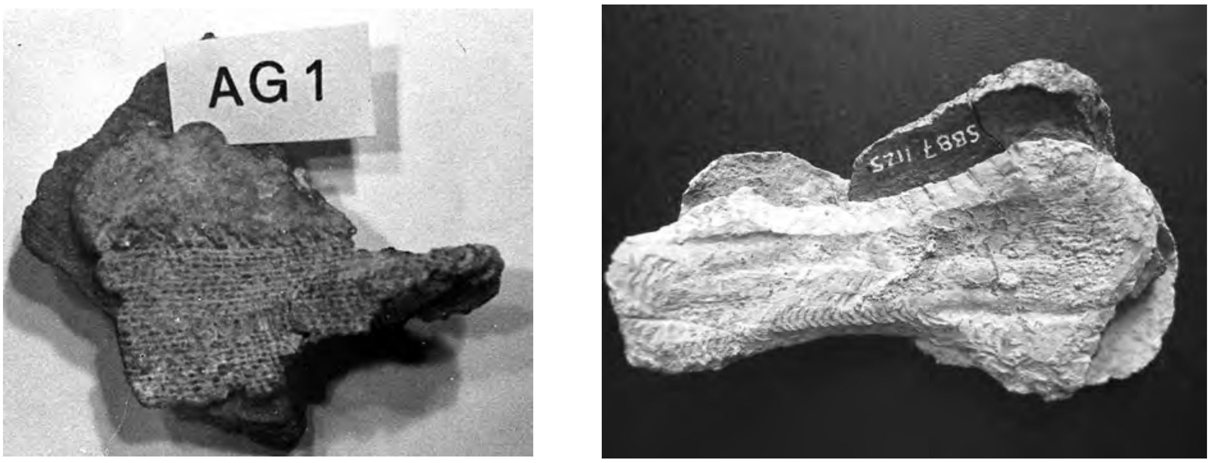


Fig. 53 – Clamps with textile marks; left from Antigori (CA), right from S. Barbara (OR).

Fig. 54 – Lead clamps produced in our laboratory.

Fig. 55 - Textile marks on lead plates produced in the laboratory.

O – Silver objects

(Archaeological file 1, 30, 35 and 36)

One of the most intriguing aspects of silver metallurgy in Sardinia lies in the fact that while a large number of silver objects have been discovered which are dated to early prehistory, *i.e.* to a time when metal was generally scarce, only sporadic silver finds have been retrieved in layers attributed to later nuragic prehistory, when metals were being widely used.

The characterization of some finds dated to different ages discussed here provides a starting point for unravelling this complicated issue.

Dozens of silver ornamental objects (rings, earrings etc.) have been unearthed at the Cungiau Sa Tutta prenuragic *necropolis* at Piscinas (CA). Some of these finds, often visibly mineralized, are shown in Figure 56.

Examination of the metallographic section of a sample removed from the cracked end of O1 revealed the structure shown in Figures 58 and 59. The inner core, which EDS analysis showed to be composed predominantly of silver with traces of Cl and Br, is still compact but numerous pits can be observed in the thick alteration layer, composed chiefly of chloride and bromide. The calcium signal is sometimes detected at the interface between the inner core and outer crown (Devoto 1985, Rehren 1996). The specific volume of silver is 95 mm^3/g compared to 180 mm^3/g for chloride and 154 mm^3/g for bromide. These significant differences can account for the uneven growth of the alteration layers on the metal.

From the hollow of a stone bead necklace found in the same *necropolis* a small, extremely thin and brittle roll was recovered (O3, diameter 4 mm, length 12 mm). It was found to be of completely mineralized silver, the main constituents being chloride and bromide, accompanied by some sulphur bands. It was suggested that this object is the remain of a coating which originally covered the whole bead.

Within the framework of this project no silver finds that can be dated unequivocally to the mature nuragic civilization have been brought to our attention.

However, we have characterised a number of other silver finds: two open-ended bracelets (O4 and O5), an earring, or circular wire hair ring (O6) with hooked end, all of unknown age, but hypotetically dated from the nuragic age to the late Medieval, as well as five votive slender leaves or ears of corn, crafted in silver sheet, attributed to the Punic civilization (O7-O11). The only slightly mineralized surface of the finds indicates that these objects are far more recent than those retrieved at Cungia sa Tutta, Piscinas, examined above.

The two bracelets are part of a hoard found at Loculi (Nuoro). O4 is solid and intact (Figure 60) and of a browngreenish colour. One end of find O5 had snapped off and the bracelet had a silvery surface, the result of harsh cleaning (Fig. 61). The earring O6 (Fig. 62) was found in the S. Pietro di Torpè nuraghe (NU). The five small leaves O7-O11 were found in the Su Gorroppu canyon at Orgosolo (NU). They have an opaque silvery lustre and greenish copper encrustations (Fig. 63).

The physical properties of the finds are shown in Table 34.

Table 34
Physical properties of silver finds of the O4-O11 series.

	weight, g	length, mm	width, mm	thickness, mm
bracelet O 4	178.7	74.5	21.0	4.5÷9.5
bracelet O 5	23.3	48.0	12.5	1.8÷2.2
earring O 6	2.0	80.0		diam. 2.0
leaf O 7	2.8	77.0	8.0	0.8÷1.4
leaf O 8	1.7	66.0	5.4	0.7÷1.3
leaf O 9	2.5	64.5	7.7	0.1÷1.7
leaf O 10	2.5	53.5	12.0	0.6÷1.5
leaf O 11	2.3	50.1	0.6	0.8÷2.0

These finds were made of silver-copper alloys. Average percentages of Ag in the patina and in the metal surface locally bared using a lancet, were determined by means of SEM+EDS. The results are given in Table 35.

Table 35
Chemical analysis (EDS, %) of silver finds of the O4-O11 series.

		O 4	O 5	O 6	O 7	O 8	O 9	O 10	O 11
patina	Ag	96	98	88	98	98	96	91	92
	Cu	4	2	12	2	2	4	9	6
metal	Ag	88	99	96	80	95	88	97	69
	Cu	12	1	4	20	5	12	3	31

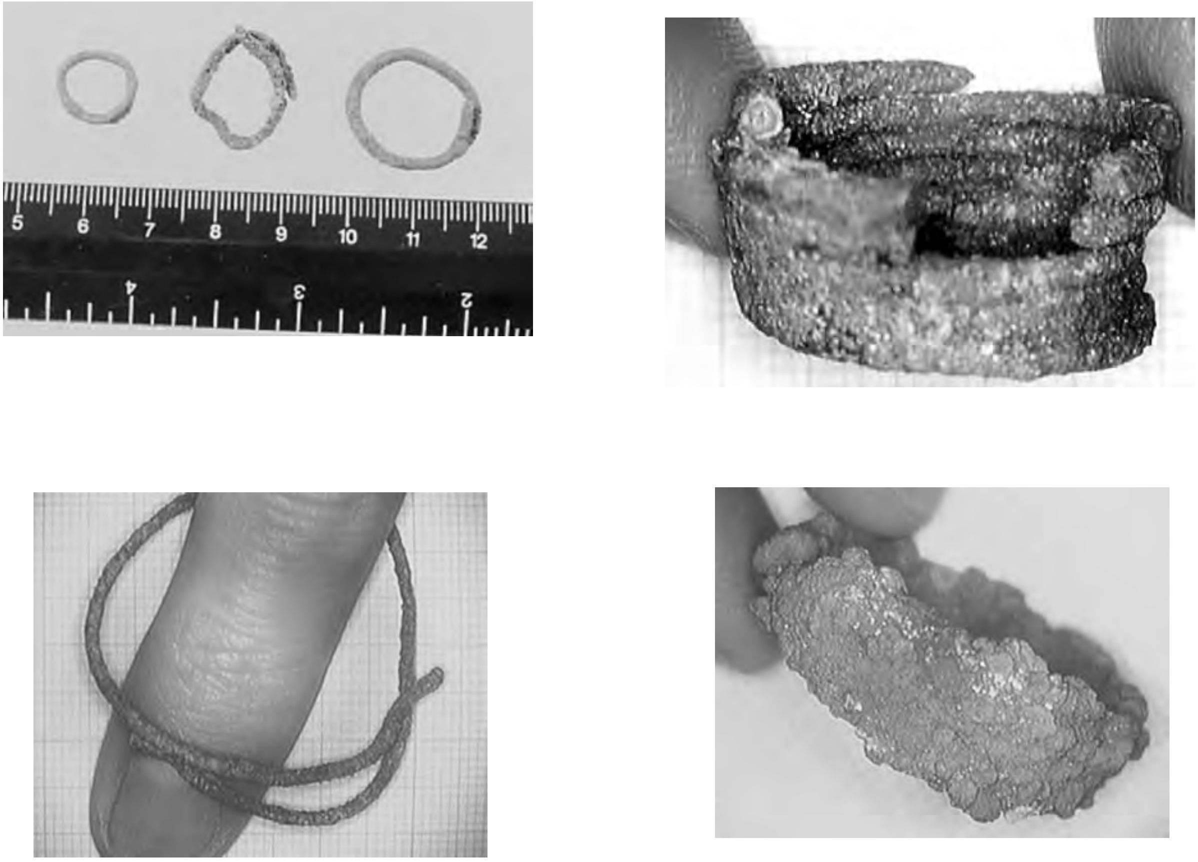


Fig. 56 – Silver finds from Cungiau Sa Tutta, Piscinas (CA).

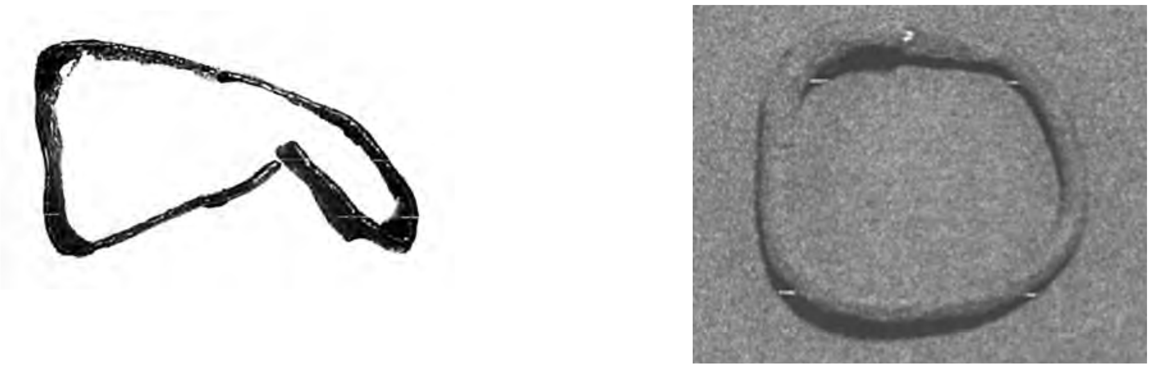


Fig. 57 – The two rings analysed; left O2, right O1.

Table 36
Chemical analysis (AAS, % or ppm where indicated) of two silver rings from Cungiau sa Tutta, Piscinas.

	Ag	Cu	Pb	Fe	Zn
O 1	41.8	0.10	0.048	0.027	0.008
O 2	82.7	0.01	< 0.1 ppm	0.130	0.022

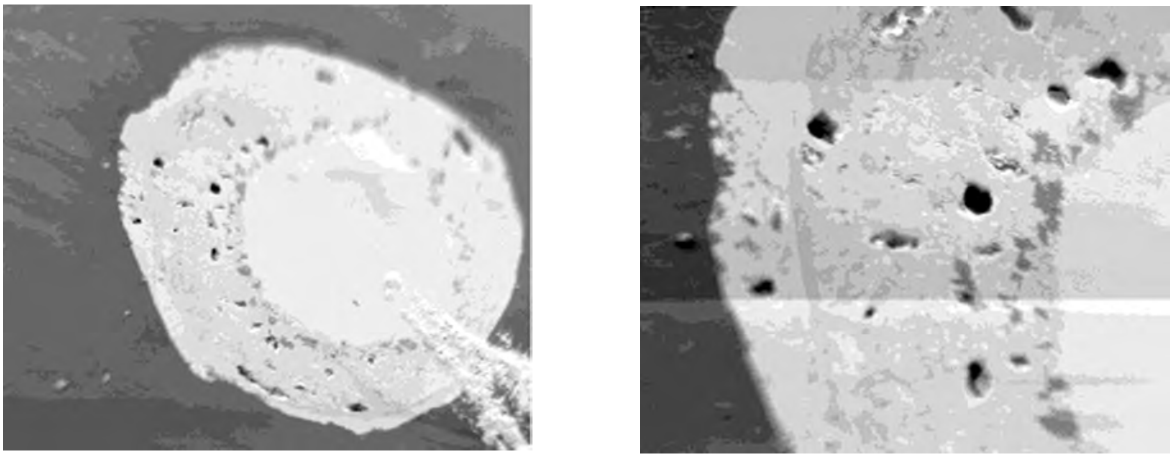


Fig. 58 – Cross section of O1: metallic core, outer mineralized crown; a detail on the right.

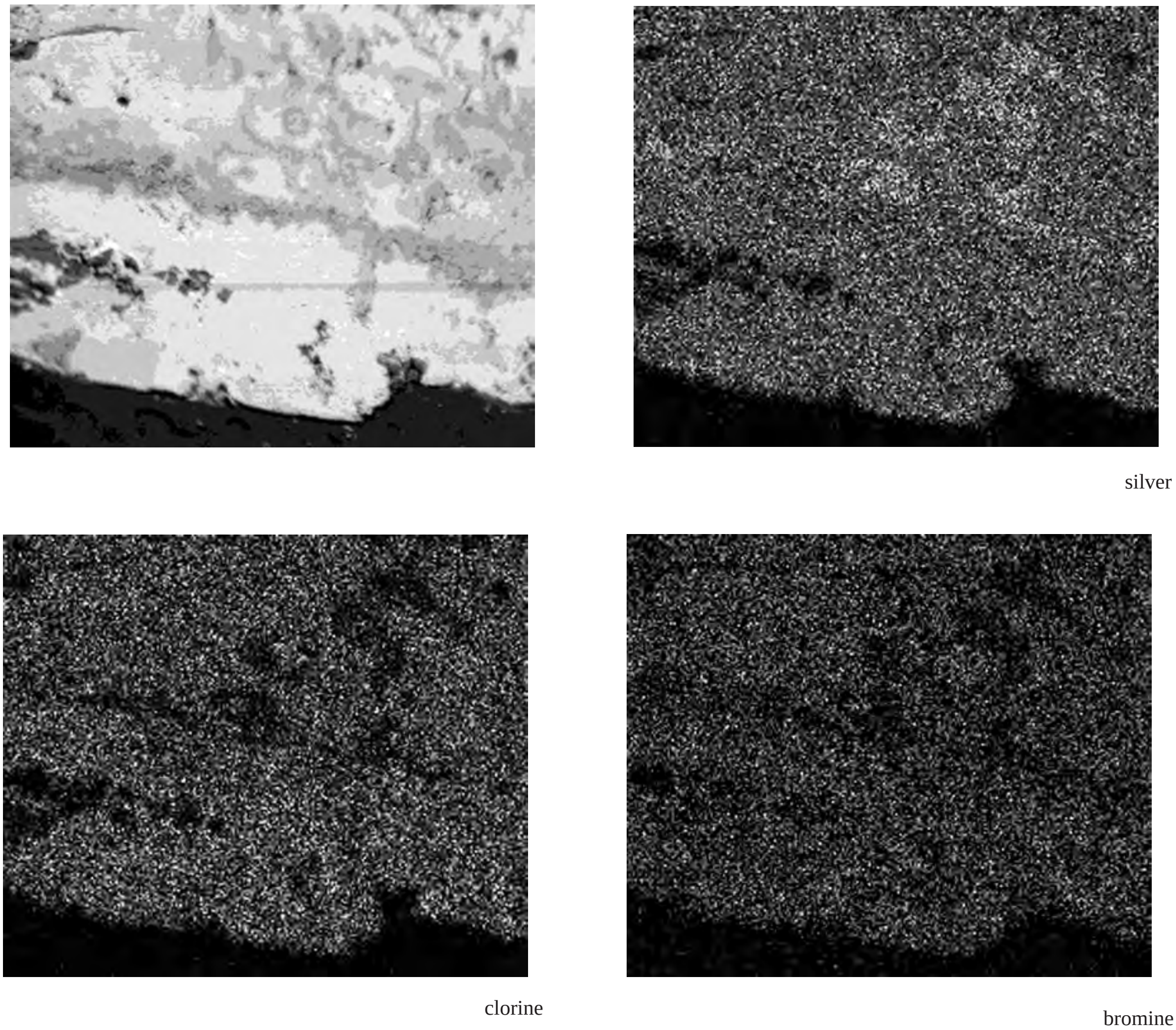


Fig. 59 – Elemental compositional map (EDS) of the outer mineralized layer of O1.

The patina often contained higher concentrations of silver than the underlying layer, because of the leaching of copper, a less noble metal than silver. Weak iron, magnesium, aluminium, lead, and chlorine signals were also detected, all elements commonly contained in the soil.

The most abundant corrosion products are chloride, bromide and sulphide. Small encrustations of copper compounds have been observed in the small leaves and in the bracelet O4.

Small samples removed from the finds were also analysed using the AAS technique. However, as part of the silver was present in the form of chloride some difficulties were encountered in preparing the analytical solutions and for this reason the data are to be considered purely indicative. The results are shown in Table 37.

Table 37

Chemical analysis (AAS, %) of some silver finds.

	Ag	Cu	Pb	Fe	Zn
O4	73.4	24.9	0.39	0.033	0.005
O5	82.5	2.0	0.76	0.37	0.007
O6	72.4	7.4	0.42	0.24	0.027
O7	77.8	5.1	0.38	0.15	0.006
O8	83.5	13.9	1.90	0.11	0.007
O9	46.1	51.5	0.84	0.32	0.025

The copper and silver concentrations differed from those determined using EDS, further confirmation that the surface is enriched in silver, the nobler element.

Metallographic examination of the bracelet O5 showed that the microstructure is affected by intergranular corrosion/mineralization. Alternating bands of small and large grains can also be observed. Hammering and annealing of the bracelet led probably to recrystallization occurring preferentially in the more hardened zones.

The silver/copper eutetic (melting temperature 780 °C; 72 % Ag) was clearly identified in the metallographic section of leaf O7. Pits are also present in the near-surface region, probably created by the dissolution of copper-rich precipitates (Devoto 1985).

Vickers microhardness tests (load 15 g) conducted on the metallographic section (EDS determinations on test points revealed 99 % Ag) yielded a mean value of 64 kg/mm^2 (628 N/mm^2 in SI units). Microhardness tests carried out on “modern” 99.99 % silver wire and silver sheet gave mean values of 65 and 69 kg/mm^2 respectively (SI equivalent 637 and 677 N/mm^2).

In conclusion, we can only say that today very little is known about silver metallurgy in prehistoric Sardinia. The earliest finds, though numerous, are poorly preserved, making it impossible to collect conclusive analytical data. No silver objects certainly dated to the nuragic age were discovered. The only silver contained in nuragic objects is a minor constituent of copper and bronze artefacts and traces in lead.

Fig. 60 – Silver bracelet O4 from Loculi (NU).

Fig. 61 – Silver bracelet O5 from Loculi (NU).

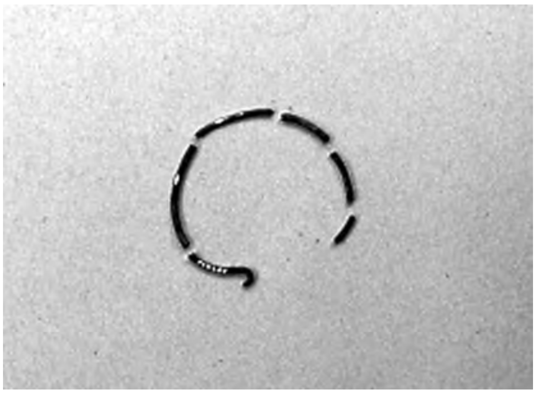


Fig. 62 – Earring (?) O6 from Torpè (NU).

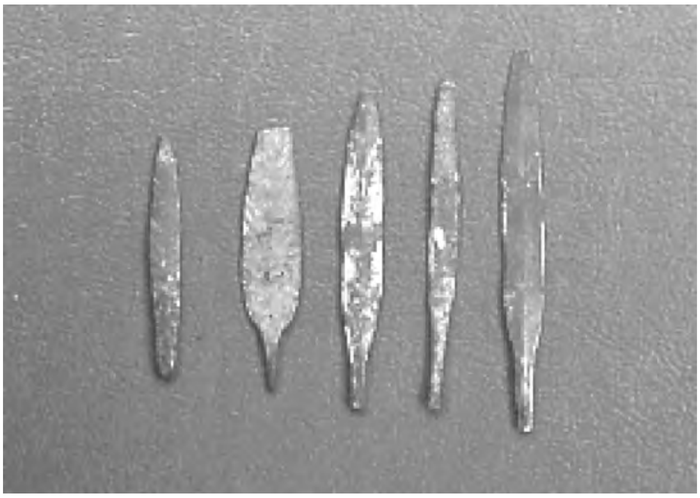


Fig. 63 – The five small silver “leaves” (from the left: O11-O7) from Su Gorroppu (NU).

P – Objects in gold-silver alloy

(Archaeological files 5 and 19)

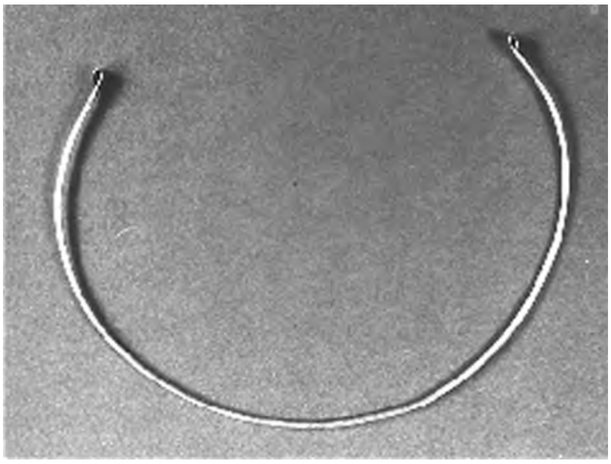


Fig. 64 – The gold necklace P1 from Bingia 'e Monti,Gonnostramatza (OR).

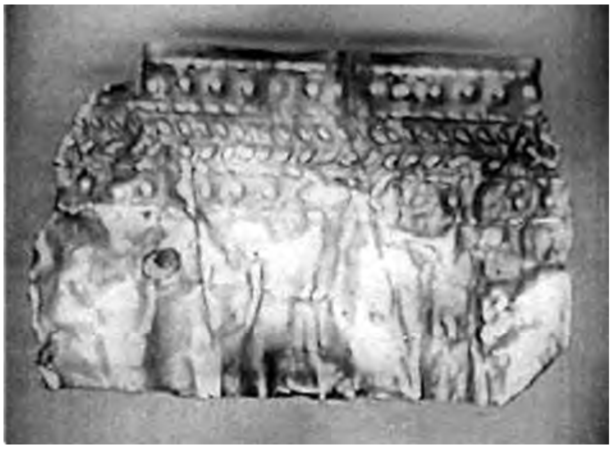


Fig. 65 – Fragment of a gold decorated sheet P2 from the cave Su Benatzu, Santadi (CA).

Two of the extremely rare gold finds discovered in Sardinia have been characterized here. The dates of these artefacts fall at the limits of the time span covered in this volume. The earliest (P1) is a gold necklace unearthed in a burial chamber at Gonnostramatza (OR) while the second and more recent object (P2) consists of a piece of gold sheet found in the Pirosu-Su Benatzu cave at Santadi (CA).

It is almost certain that the gold used in antiquity, often naturally-alloyed with silver and to a lesser extent with copper, was never mined on the island. The presence of these objects, albeit rare, in an archaeological context provides unequivocal evidence that since the early ages, Sardinia had established "connections" which enabled it to get hold of very high quality metallurgical products.

The necklace, or torques, from Bingia 'e Monti, Gonnostramatza (Fig. 64) consists of a pale yellow gold wire about 2 mm in diameter, with flattened ends, folded outwards. The necklace is 295 mm long and weighs 11.46 g.

Given the quality and exceptional importance of this find, no samples were removed for analysis. The only determinations performed were non-destructive SEM+EDS analyses in order to measure, in semi-quantitative terms, the elemental surface composition.

The almost rectangular piece of gold sheet recovered from Su Benatzu (Fig. 65 and pl. XII, 5) clearly was part of a larger ribbon-like object. The brownish-yellow sheet fragment has a length of 29 mm, width of 19 mm, thickness of around 0.3 mm and weighs 0.78 g.

In this case, besides non-destructive analyses by SEM+EDS, also metallography was carried out on a small fragment from the edge.

The necklace was found to be composed of a gold/silver alloy containing copper as main impurity (Table 39).

Table 38

Chemical analysis (EDS, % averaged over several points) of the necklace found at Bingia 'e Monti, Gonnostramatza.

	Patina	Metal beneath the patina
Au	65	51
Ag	32	45
Cu	2	3

As can be clearly observed, the surface contains higher concentrations of gold compared to silver than the underlying metal. For a composition similar to the metal layer, it is estimated that the necklace should have weighed about 20 % more than its actual weight. This suggests that the inner core of the necklace might contain even lower concentrations of gold.

Similar analyses carried out on points of the near-surface metal on the gold sheet discovered at Su Benatzu (P2) yielded the following mean values: Au 79 %, Ag 18 % and Cu 3 %. Again this find is composed of a gold/silver alloy, though in this case the Au content is higher than in the necklace.

Microscopic observations of the surface of the Gonnostramatza necklace (Fig. 66) and of the piece of gold sheet from Su Benatzu (fig. 67), revealed the presence of streaks oriented in the same direction and scratches probably caused by wear and/or cleaning.

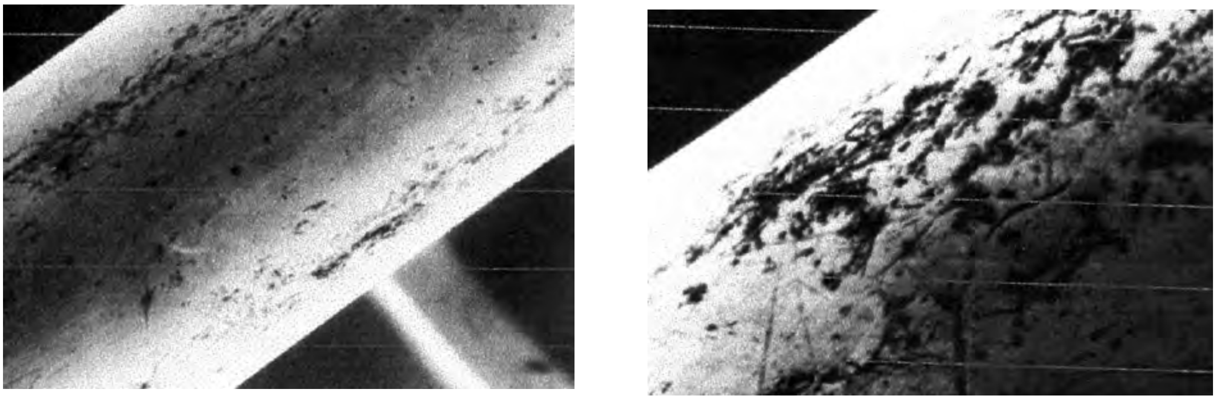


Fig. 66 – Macro-view on the necklace P1 surface.

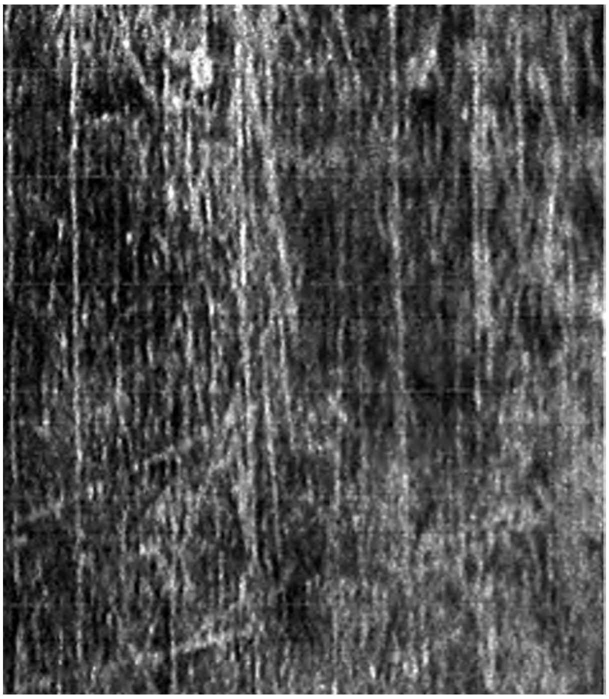


Fig. 67 – Macro-view on the fragment P2 surface.

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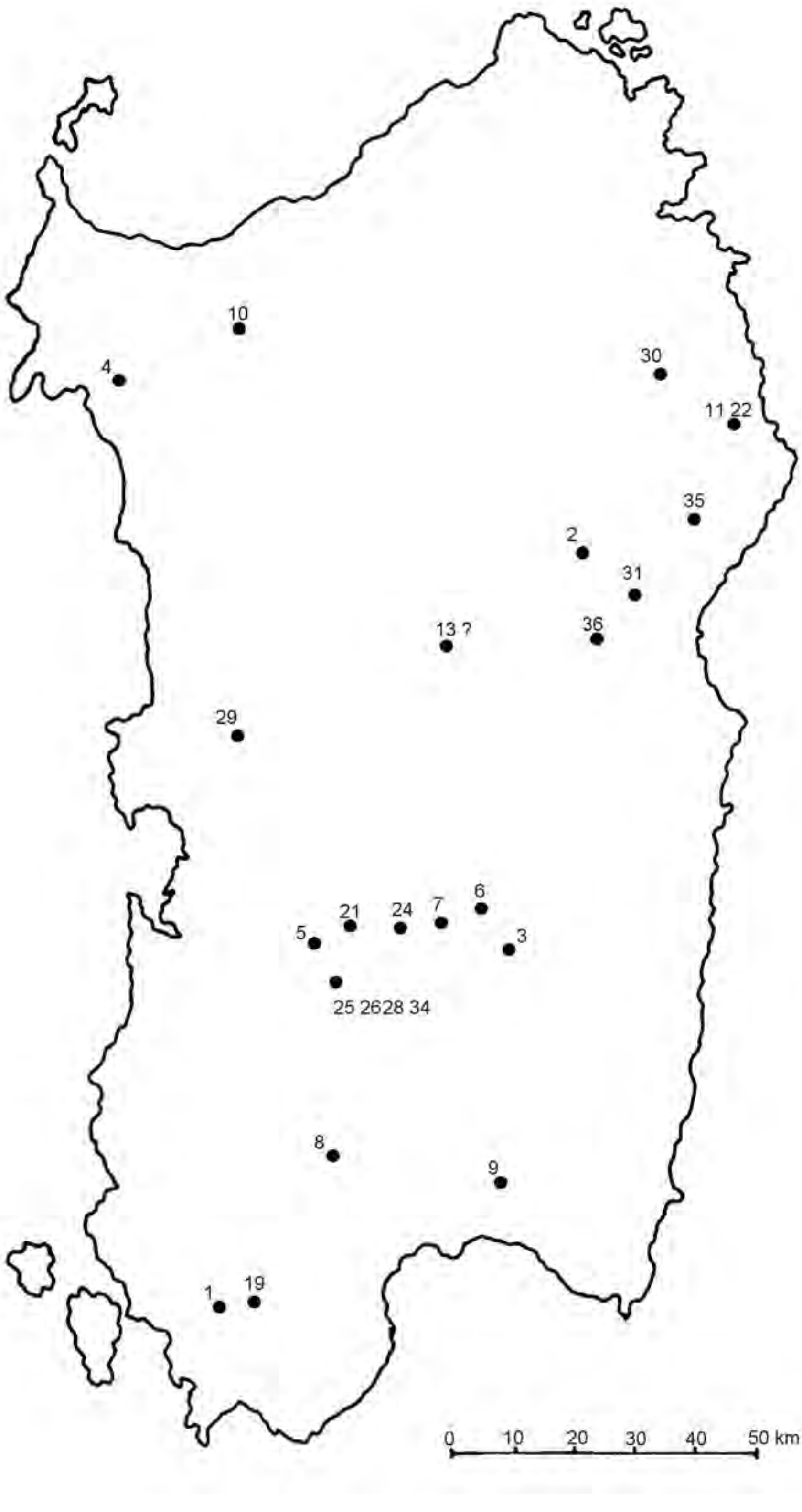
ARCHAEOLOGICAL FILES

The file numbers indicate the chronological sequence of the finds and their contexts (index p. 411). File 17 (Teti) and file 20 (Antigori) are in Part II.



Archaeological file 1

Piscinas (Cagliari) Loc. Cungiau Su Tuttui o Sa Tutta.
(Luisanna Usai)

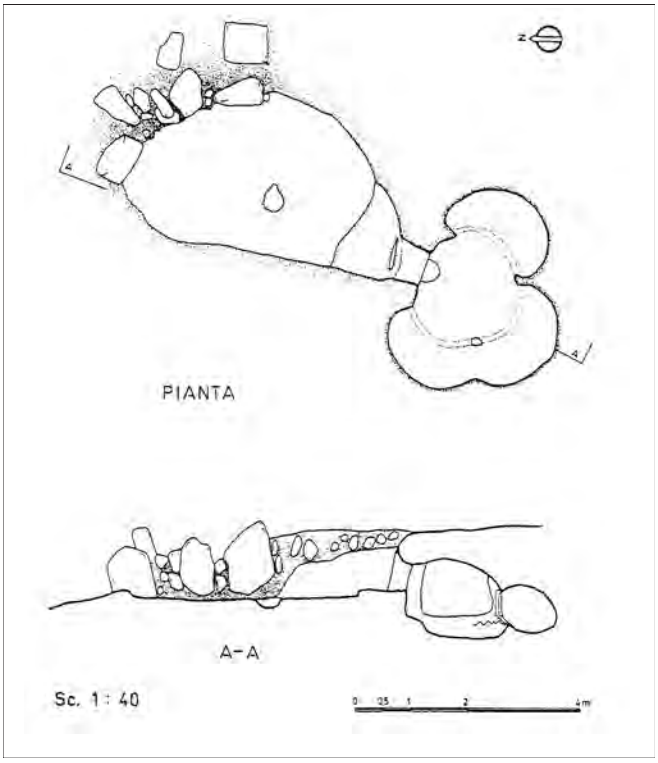


Fig. 1 – Piscinas (CA), Cungiau Sa Tutta: ground plan and cross-section of tomb 2 *(drawn by Claudio Pisu).*

A large tomb in the hypogean *necropolis* of Piscinas, with a series of small, round hollows in the west corner of the *anticella*, has long been known. In the 1990s two tombs, and part of the deposit of the corridor of the big tomb mentioned above (no. 1), were completely excavated (nos. 2 and 9).

The *cella* of tomb 1, widely reused possibly already in antiquity, did not produce archaeological material, whereas Filigosa-culture material and copious Monte Claro fragments were found in the corridor.

The most interesting tomb is without doubt no. 2, both for its elaborate structure and for its material.

At an initial phase of the excavation (1990), in the tomb a small *cella*, almost circular and with three niches arranged in a cross, was brought to light. The niches are higher than the floor and have a concave back with a slight raised ridge on the outside edge. The central niche is framed with a singular incised decorative motif, not completely distinguishable. The frame is double, incised without much care and irregular, and follows the sides of the opening. It ends on the long upper side with a motif *a dente di lupo* on the left. On the right the state of preservation does not allow to establish how the motif ends. It is probable that the motif on the right showed analogies to the surviving one, even if not symmetrical. A further decorative element, also incised and *a denti di lupo*, runs along the wall, near the bottom under the central niche and under the one to the right.

A second excavation (1994) led to the identification of another room more or less semicircular in shape, communicating with the *cella*. The west wall is straight, while the east one is curved. The structure is singular because the east-north-east part of the perimeter was constructed in antiquity with great slabs placed on end; access to the room is in the straight wall on the west

There is no doubt that this room was used for burials with grave goods. The contexts of the two rooms are attributed to the same culture, even if there may be a slight chronological discrepancy in the realization and the utilization of the two sepulchral spaces. As to the pottery, besides the small “tulip” vases, there are carinate cups with vertical perforations, small vases with more or less distinct necks and with generally rounded bellies, and simple cups with inwards turned rims.

In tomb 2 the pottery is accompanied by a large quantity of metal objects (silver and copper).The items in silver in particular are well documented: they are a series of rings, consisting of a simple band, or, more frequently, spirals, and some bracelets in fine wire, wound in spirals. The rings have exact analogies in other burial contexts in Sardinia, whereas for the moment there is nothing akin to the fine bracelets.

Amongst the numerous items in copper there are two flat axes, various rings and bracelets, a pair of fragmentary daggers and a series of points with foliate blades, long and narrow, with a small tang with rounded base. The characteristic details and the absolute lack of internal comparisons make it difficult for the moment to understand the use and purpose of these small objects (functional or ritual?) (Usai L. 1996; 2000). On the other hand, in all the grave goods from Piscinas uncovered so far there is a total absence of obsidian production, whereas in tomb 2 there are numerous necklace beads. In addition to the silver elements, 170 stone beads of various shape were found.

The pottery context of the small hypogean tomb, no. 9, is only partly similar to that illustrated above. Beside the shapes with small necks and the “tulip” shapes, there are also numerous open shapes with spherical belly, often with the rim markedly enlarged and flattened on the top.

These last pottery shapes may represent the latest phase of the culture, as would also be indicated by the appearance of the surface of the vases from tomb 9, which is gene-

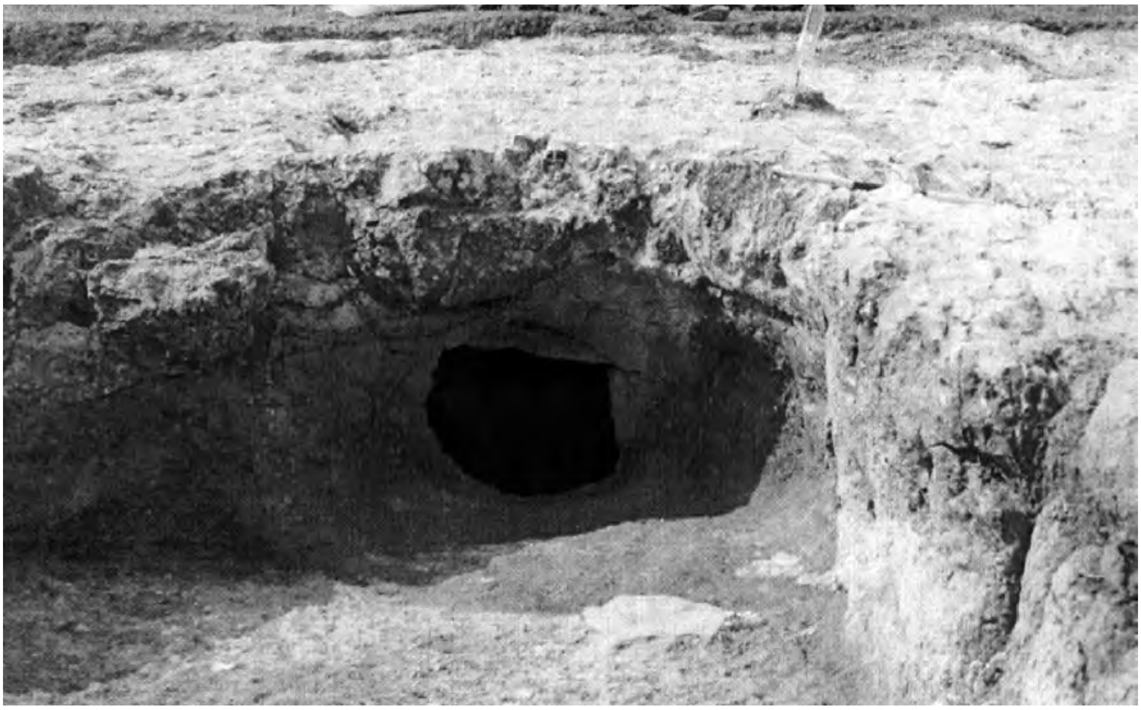


Fig. 2 – Piscinas (CA), Cungiau Sa Tutta: tomb 2.

rally rough and opaque, not polished and with clear signs of slipping, as in the vases from tomb 2.

On the basis of comparisons with other contexts on the island, and from the nature of the material, there seem to be no doubt that the Piscinas contexts belong to the Filigosa culture (Early Aeneolithic). There are, however, new elements to be added to the already known categories of the culture, which seem to characterize a Sulcis *facies* (Usai L. 1998).

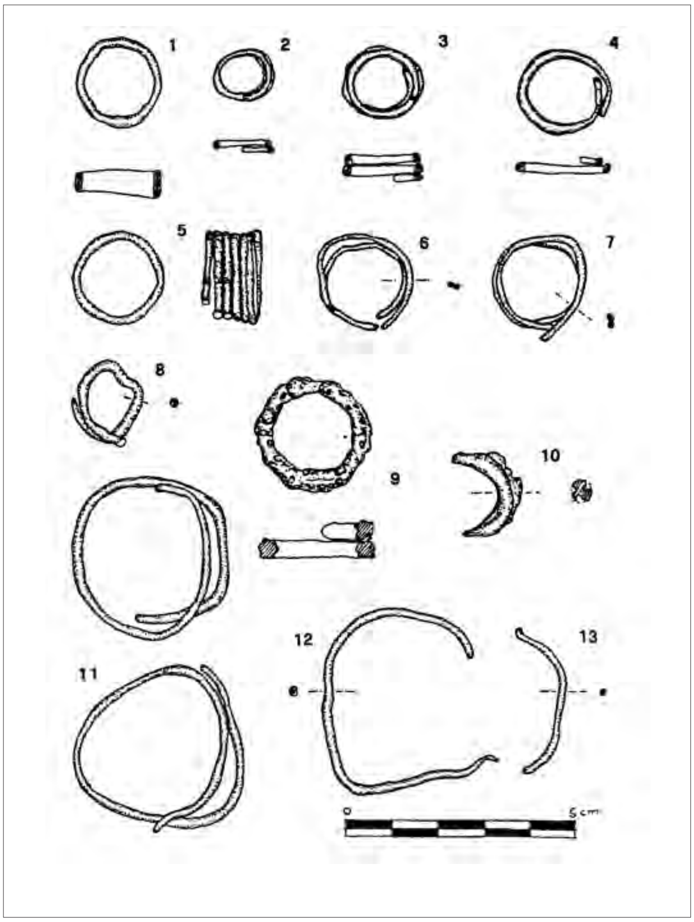


Fig. 3 – Piscinas (CA), Cungiau Sa Tutta: objects for ornament in silver from tomb 2 *(drawn by Franco Mereu).*

Fig. 4 – Piscinas (CA), Cungiau Sa Tutta: objects for ornament in silver from tomb 2.

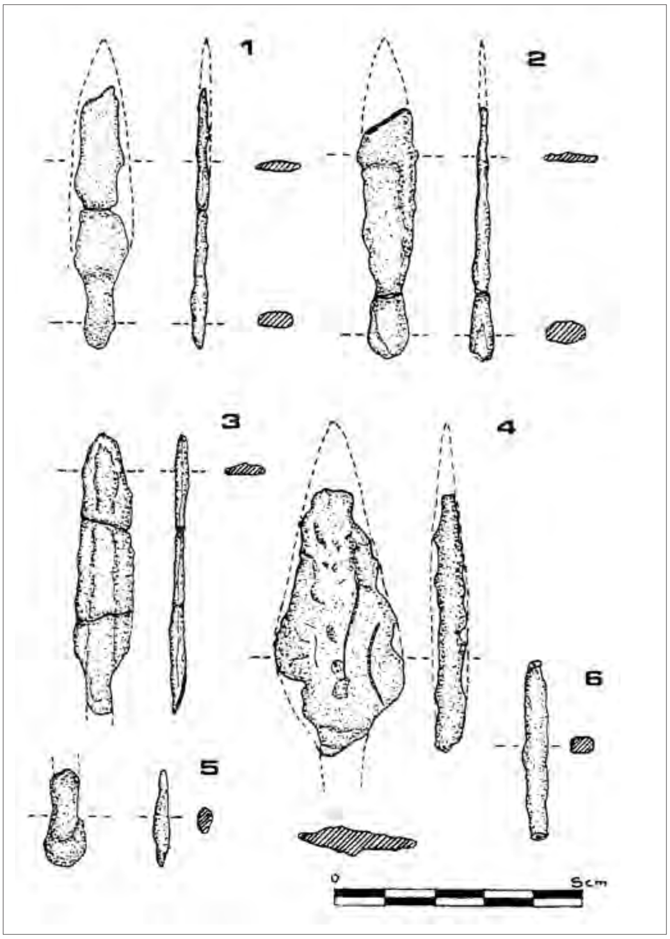


Fig. 5 – Piscinas (CA), Cungiau Sa Tutta: copper elements from tomb 2 *(drawn by Franco Mereu).*

Fig. 6 – Piscinas (CA), Cungiau Sa Tutta, tomb 2: a: point (?) of copper; b. small point of copper *(phot. Leonardo Corpino).*

Fig. 7 – Piscinas (CA), Cungiau Sa Tutta: fragmentary dagger of copper from tomb 2 *(phot. Leonardo Corpino).*

Fig. 8 – Piscinas (CA), Cungiau Sa Tutta: axe of copper from tomb 2 *(phot. Leonardo Corpino).*

Fig. 9 – Piscinas (CA), Cungiau Sa Tutta: miniature axe of copper *(phot. Leonardo Corpino).*

Archaeological file 2

Nuoro, Janna Ventosa, tomb I.
(Fulvia Lo Schiavo)

The first reference to the *domus de janas* situated at the gates of Nuoro, on the slope of Monte Ortobene, is by Domenico Lovisato (1887). Later, the surveys and the photographs of the five hypogean chambers, with a brief descriptive catalogue of each one, were published on the occasion of an exhibition on a survey and catalogue project of the monuments of the district of Nuoro (Contu F., Cicalò 1981, 37-63): on this occasion, the name adopted for the whole area was “Maria Frunza”.

Tomb 1, which stands at a certain distance from the others and near to the local road, is called the tomb of “Janna Ventosa”, and was excavated in October-November 1985 (Foschi 1985).

In addition to the T-shaped *cella*, with two wide lateral platforms and already recognizable from the first inspections, the *anticella* was identified. This was rectangular with rounded corners, a ritual fireplace and an oval small pit at the centre. The front part, beyond the carefully worked threshold, communicated with a *dromos* delimited at the sides by two small walls. This arrangement, known as “megalithic”, is not unknown in other tombs in the Sassari and Nuoro regions (Ferrarese Ceruti 1980, 58-59).

Whereas the other tombs were empty, tomb 1, in spite of having its back knocked out and its *dromos* reused in later times, has provided a considerable quantity of pottery and stone finds, which indicate the final of the Ozieri culture (Foschi 1998, 278).

“At the higher levels of the *anticella* was found material probably from the Monte Claro culture, including a metal foliate dagger, with a central ridge and rectangular tang with a hole at the end, 26 cm long, which has analogies at Serra is Araus” (“*A quote superiori nell’anticella è stato rinvenuto materiale di probabile cultura Monte Claro fra cui un pugnale metallico foliato con costolatura centrale e codolo rettangolare con foro all’estremità lungo cm 26, che trova confronti a Serra is Araus*”) (Foschi 1985, 35 fig. 26. 9).

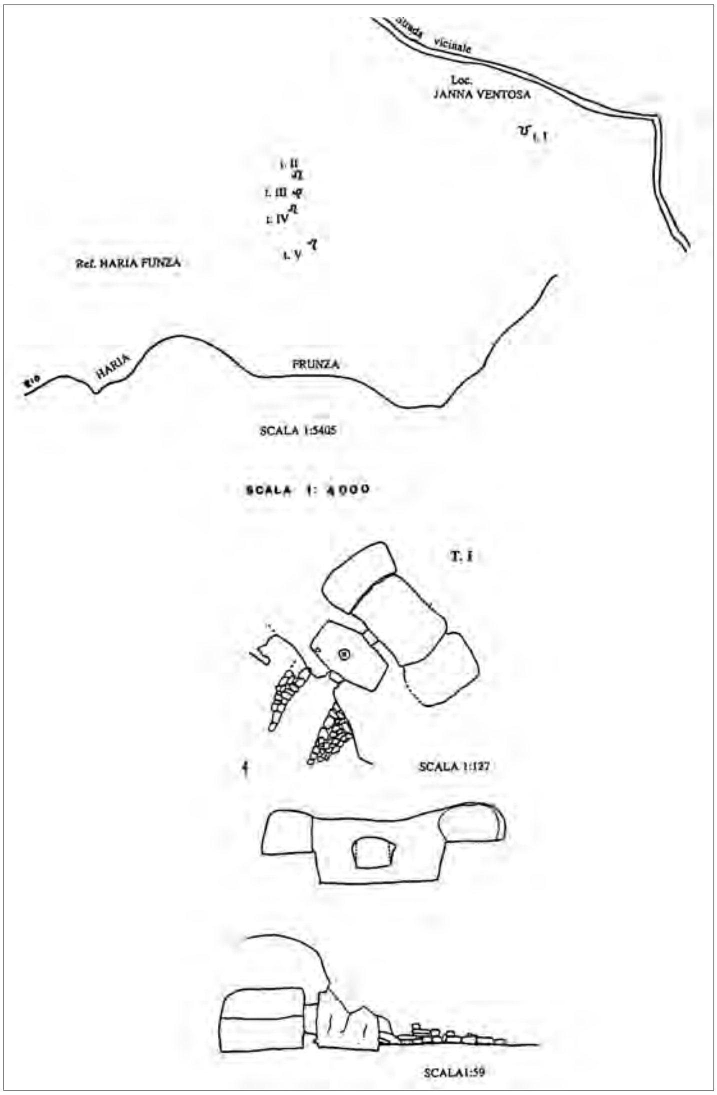


Fig. 1 – Nuoro, Janna Ventosa: topography of the *necropolis*; ground plan and cross-section of tomb I *(after Foschi 1998, figs. 26.1-2).*

Furthermore, in a very thin layer above the upper stones of the corridor, were found many fragments belonging to two Beaker Vases, believed to be of Iberian origin.

Finally, also on top, there was evidence of reuse in nuragic and Roman times and as a temporary shelter in recent times: therefore the lower strata were sealed off by the subsequent deposits (Foschi 1996).

B2. dirk with foliate blade, with a high and rounded shoulder and tang slightly flattened and holed at the top. L. 23.7 cm (Lo Schiavo 1989, 284 no. 15 fig. 1.1).

Subsequent examination of this shape of dirk and of its characteristic form with tang led to the discovery that the associations with Monte Claro material is repeated especially at Serra Is Araus (mentioned above), here at Janna Ventosa, and then at Orroli, Su Motti (see Archaeological file 3). Similar shapes with tang, but smaller in size, have been found in the Monte Claro tombs at Sa Duchessa and Via Basilicata in Cagliari; even thinner is the small dagger with tang from Cresia is Cuccurus at Monastir, similarly associated with Monte Claro material (Lo Schiavo 1989, 284-286).

E. Atzeni had the small dagger from the Via Basilicata analysed; "…it is like the small knife blade from the tombs of Sa Duchessa …it turned out to be of pure copper" ("…*come la lama di coltellino proveniente dalle tombe di Sa Duchessa … è risultato di puro rame*") (Atzeni 1967 note 14; Lilliu G., Ferrarese Ceruti 1959, 36-37, tab. XXV, 2; Cincotti, Demurtas, Lo Schiavo 1998, 160).

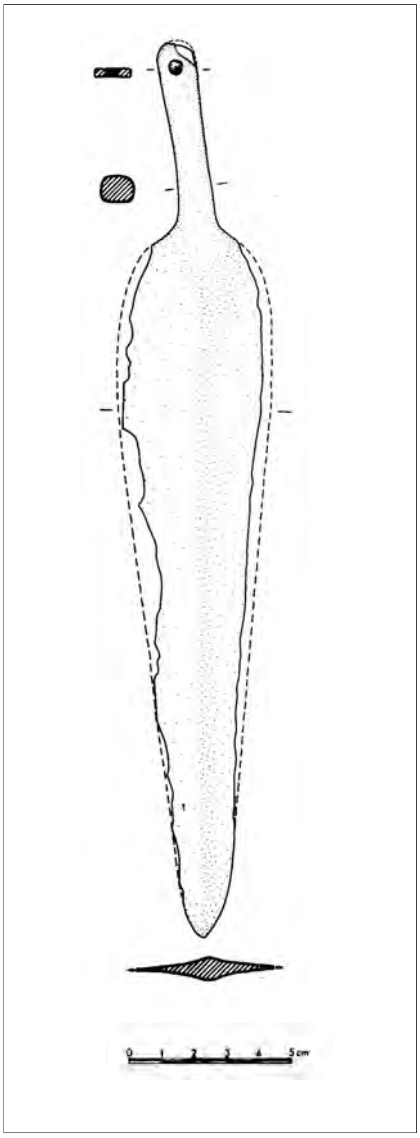


Fig. 2 – Nuoro, Janna Ventosa: Tanged dagger *(after Lo Schiavo 1989, fig. 1.1)*.

Archaeological file 3

Orroli (Nuoro), Su Motti or Su Monti.

(Fulvia Lo Schiavo)

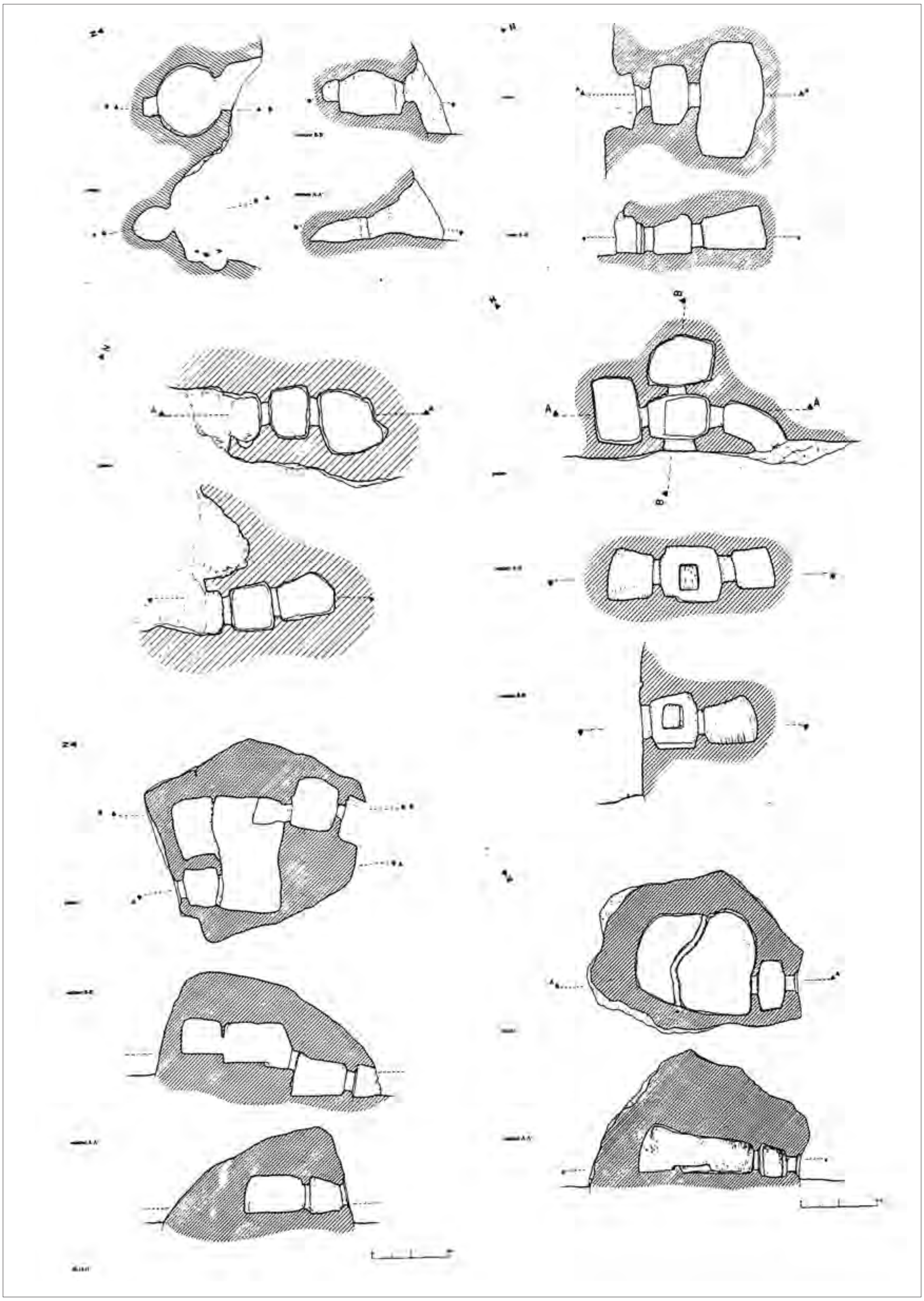


Fig. 1 – Orroli (NU), Su Motti: ground plan and cross-section of the principal *domus de janas (from Archeosystem 1990, 358-366).*

An imposing bastion of basalt, with the evocative name of “Corona Arrubia” (“Red Crown”), rises on the northern periphery of the town of Orroli. Gigantic blocks, fallen away from the wall, created at the base heaps of landslide debris spread over a vast area of the slope, in which some fifteen hypogean tombs were dug, both in the rock and in the erratic blocks.

The *necropolis* of Su Motti (or Su Monti) includes six one-celled, two two-celled and three multiple-celled *domus*, unfortunately long deprived of their archaeological deposit; the burial chambers are rather small, with well shaped doors (Contu 1972; Archeosystem 1990, III,13.2-17, 358-366).

Much material was gathered between the heaped blocks of the landslide, where natural passages and galleries held finds of considerable value, dating to various cultural *facies*: “basket” vases, hemispherical bowls, carinate bowls, tripod vases, all richly decorated, and abundant stone industry in flint and obsidian dated to the Ozieri phase (Sanges 1990; 1997).

Amongst the objects attributable to the Monte Claro archaeological *facies* there are fragments of jars, *dolia*, *situlae*, tripods with band handles, flattened rims and with “grains of rice” decoration and grooves and fluting running horizontally and vertically, sometimes with highly polished effect, on surfaces which are mainly reddish, with exact reference to the “Cagliari” aspect of this culture; a small dagger with tang was also found (Sanges 1988).

A smaller group of fragments belongs to the Beaker culture.

It is probable that the hollows – as well as the real hypogean chambers – were used for burial, and that these masses of material are the remains of grave goods; however, we can not exclude other ritual uses. Furthermore, on the edge of the *plateau* and on the flat areas behind it, the traces of a settlement, datable from the Late Neolithic Ozieri period to the Late Chalcolithic period of the Beaker culture have been identified.

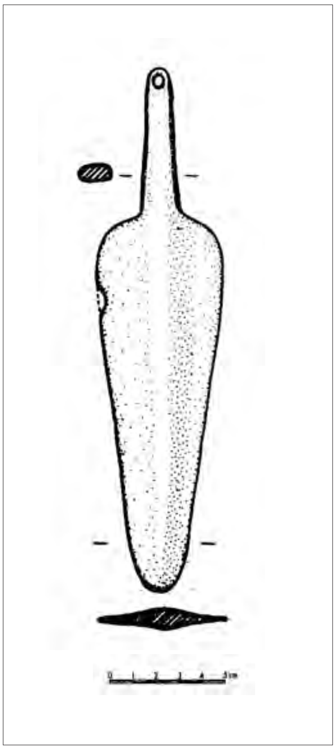


Fig. 2 – Orroli (NU), Su Motti o Su Monti: small tanged dagger *(after Lo Schiavo 1989).*

A1. Small copper dagger, with foliate blade, rounded shoulder, flattened tang, tapered and holed at the end. L. 11 cm (Lo Schiavo 1989, 284 no.16, fig. 1.4; Cincotti, Demurtas, Lo Schiavo 1998, 160).

The shape of the small dagger recalls that of the examples, twice the size, from Janna Ventosa, Nuoro (see archaeological file 2) and of those, similar in size, from Sa Duchessa and from Via Basilicata in Cagliari (this last “was of pure copper” (“*risultato di rame puro*” according to E. Atzeni’s analysis), as well as the thinner example from Cresia is Cuccurus, Monastir.

Archaeological file 4

Olmedo (Sassari), Monte Baranta.

(Fulvia Lo Schiavo)

The site of Monte Baranta is on the south-west edge of a vast terrace which dominates the plains to the south-east and as far as the gulf of Alghero to the south-west, and was densely populated from Neolithic times up to the Middle Ages.

The megalithic complex consists of a massive wall, set apart from the edge of the *plateau* and enclosing a group of square-plan huts and a sacred area with menhirs and a megalithic circle; on the edge of the *plateau* rises an enclosure-tower, open on the side of the sheer precipice, exploiting this natural defence.

The abundant finds document distinct and not long-lasting phases of occupation. The construction of the whole complex belongs to the Monte Claro archaeological *facies* (middle of III millennium), characterized by the "Sassari" pottery style; this was then abandoned, for unknown reasons, but neither suddenly nor dramatically.

The reoccupation of the site dates to the Bonnanaro B or Sa Turricula *facies* (Middle Bronze Age I), during which the courtyard of the tower-enclosure was accessible from the north corridor, while the west corridor was closed from the outside in such a way as to obtain a usable room, found full of material which is defined as "Monte Baranta type", on account of its homogeneous and recognizable appearance.

The remains of the occupation in the following phases of the nuragic period, from Middle Bronze II to the Final Bronze period, are scarcer, and stratigraphically later.

Finally, in historical times, there are scattered occupations over the whole area. No burials relating to any of the phases of occupation of the site have been identified.

The excavations were carried out in the 1980s, and were immediately followed by preliminary reports; restoration and consolidation works were carried out in 1992; a complete edition of the excavation was published in 2002 (Moravetti 1981; 2002).

Although the courtyard does not offer a very clear stratigraphic sequence, the presence of Monte Claro pottery is confirmed in the lower strata, and pottery from the Monte Baranta type up to historical times in the upper strata.

The only metal artefact from the complex, a *spatula*, was found in the tower-enclosure, in stratum II of sector C of the courtyard; a pestle was recovered in the same stratum and in the

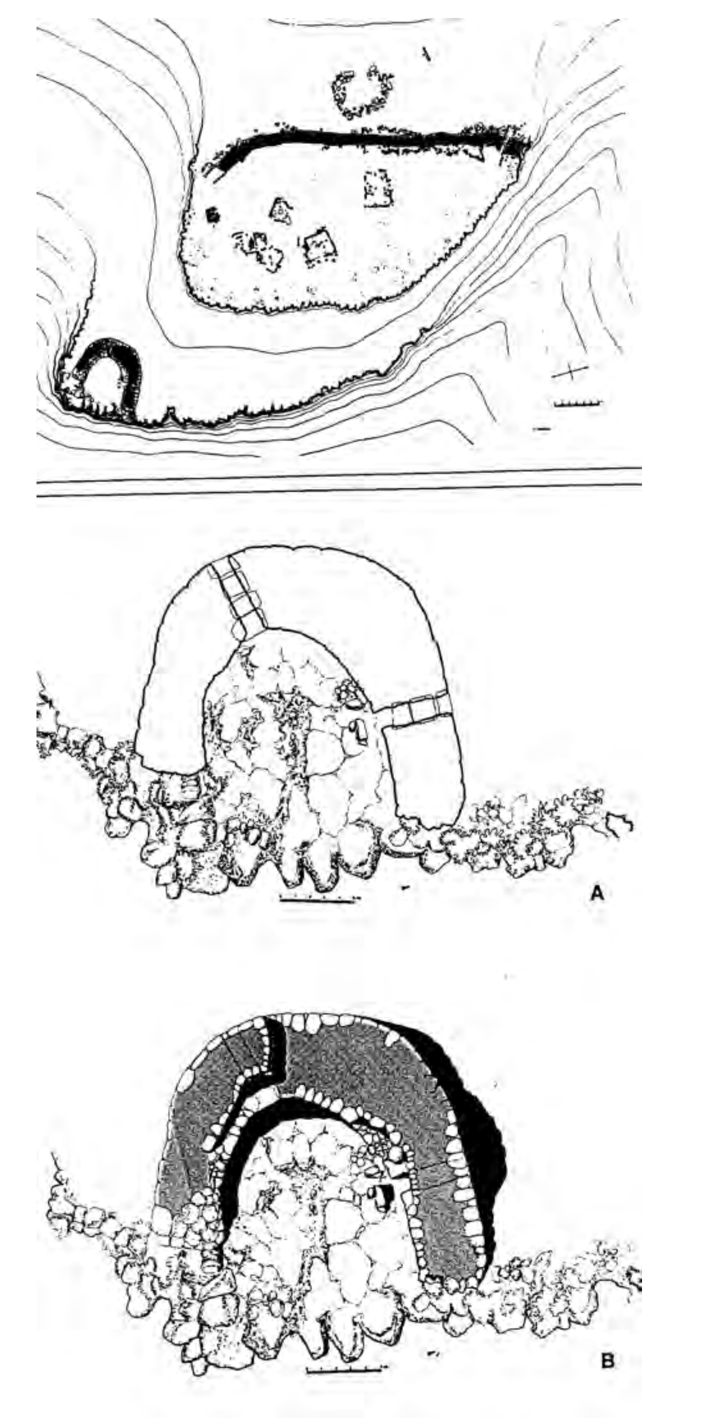


Fig. 1 – Olmedo (SS), Monte Baranta: general planimetry; ground plan and axonometric plan of the tower-enclosure (after Moravetti 2002, figs. 12, 14).

layer above a fragment of an unclassifiable vase (Moravetti 1981, 287 fig. 1; 2002, 53, 177, no. 195-196, figg. 120, 6-7).

C1. *Spatula* with simple base, parallel edges, rounded tip, lenticular in cross section. L. 13 cm (Inv. no. 497) (Moravetti 1981, 287, fig. 1; 2002, 177, no. 194, figg. 118. 9, 122).

There are no analogies for the shape of this object, neither in Sardinia nor outside. A drawing of the piece, with the kind permission of A. Moravetti, was published almost twenty years ago and from then on no similar items have been reported. (Lo Schiavo 1986, 233 fig. 16.2 and not 16.3; Lo Schiavo 1989, 284 no. 18, fig. 1.4: in note 51 the preceding quotation is exact).

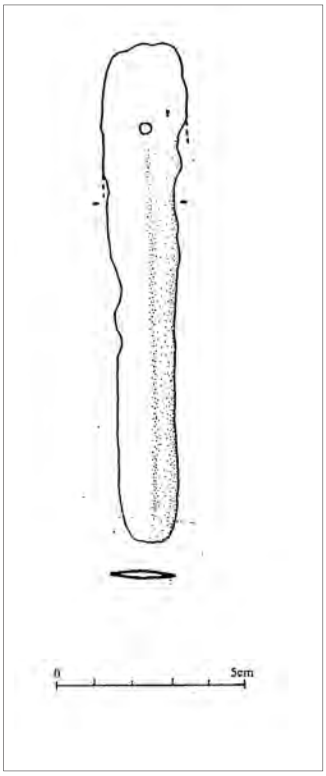


Fig. 2 – Olmedo (SS), Monte Baranta: *spatula (after Lo Schiavo 1986).*

Archaeological file 5

Gonnostramatza (Oristano), Bingia ’e Monti.
(Luisanna Usai)

The hypogean-megalithic tomb of Bingia ’e Monti has at the back a rectangular niche, dug in the soft rock and a megalithic body built up against it.

There are just a few fragments remaining of the first hypogean structure, of the Monte Claro phase, while the context from the Beaker period, associated with many skeletal remains, is particularly rich.

It is an extraordinary collective burial covering a wide span of generations documenting the moments of transition from the Beaker to the Bonnanaro cultures, between the Aeneolithic and the Early Bronze Age.

The rich grave goods hold a vast repertoire of smooth and decorated pottery, and also many objects in metal, bone, shell and stone, typical of Beaker contexts. Prominent amongst the ceramic shapes are various polypoid vases and a small ovoidal vase, as well as the classic cups.

The metal objects are represented by two rectangular small daggers of copper and by nine awls of copper or bronze, as well as a torques in gold, solid and round in cross-section, with open flattened and folded outwards heads (code P1).

The upper stratum of the burial is attributable to the Bonnanaro culture. The pottery, amongst which appears several tripods and some types of ornamentation in shell and wild-boar tusk, indicate the oldest phase of this culture, a phase which still reflects the Beaker influence (Atzeni 1996).

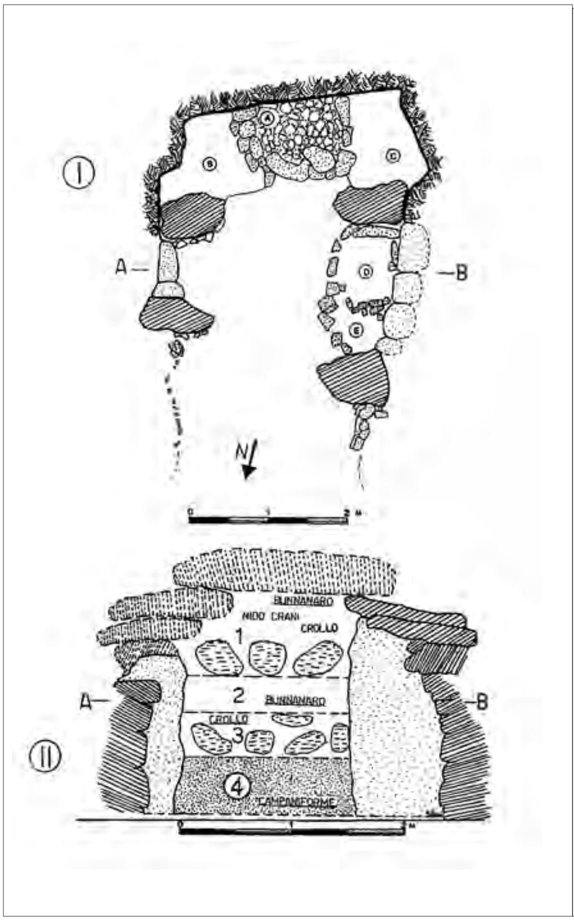


Fig. 1 – Gonnostramatza (OR), Bingia ‘e Monti: ground plan and cross-section of tomb *(after Atzeni 1998).*

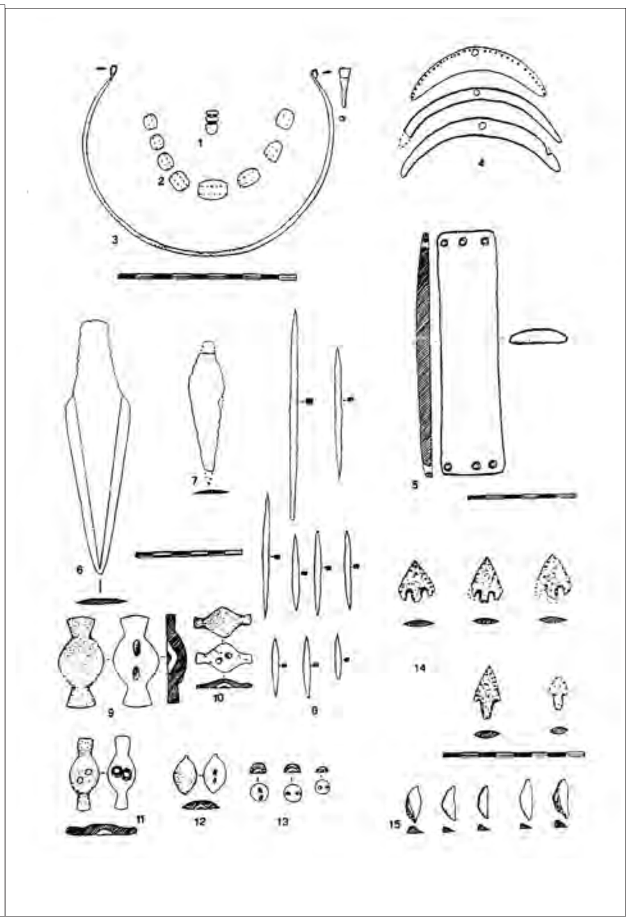


Fig. 2 – Gonnostramatza (OR), Bingia ‘e Monti: finds from the Beaker phase *(after Atzeni 1996).*

Archaeological file 6

Villanovatulo (Nuoro), cave I of Frommosa.

(Fulvia Lo Schiavo)

The territory of Villanovatulo is one of the lesser known of the Sarcidano area, and has never been archaeologically surveyed; of the two excavations, the very short one in cave I at Frommosa, was characterized by fortuitous finds and no systematic research was carried out.

This gap in our knowledge is particularly serious, because the hilly massif on which the caves open is in a strategic position, and dominates from its high position the middle course of the Flumendosa, while the territory in general is situated between the rugged heights of the Barbagia di Seùlo and the fertile plains and low hills of the territory of Isili. It is perhaps not by chance that the burial identified contained grave goods, not abundant but culturally very important, and was characterized by two small copper daggers and a small obsidian knife with a Bonnanaro vase (Contu 1970, 432; Sanges 2000, 115).

The pottery repertoire of the Nuoro region belonging to the Bonnanaro culture is typologically very modest, numerically scarce, as are the places where it is found; one of these is the cave Frommosa I, in which was found a carinate bowl, with a high vertical shoulder and a very low belly. (Ferrarese Ceruti , Germanà 1978 fig.227; Ferrarese Ceruti 1997, 245, 360). There are very few metal objects which belong with certainty to the Bonnanaro culture, and these are the one from Muros (see archaeological file 10) and the two from Frommosa. (Ferrarese Ceruti 1981, LXXIV, fig. C73; Lo Schiavo 1986a, 235; 1989, 286; Cincotti, Demurtas, Lo Schiavo 1998, 160, fig. 2).

B4. Small dagger with narrow, foliate blade, sloping shoulder, long, flat tang with a hole at the edge (a breakage), lenticular in cross-section. L. 10 cm (Ferrarese Ceruti 1981, fig. C73 on right; Cincotti, Demurtas, Lo Schiavo 1998,160).

B5. Small dagger with narrow, foliate blade, trapezoid base distinguished with a little tooth, a hole at the centre of the base, lenticular cross-section with only the slightest hint of a midrib. (Ferrarese Ceruti 1981 fig. C73 on left; Cincotti, Demurtas, Lo Schiavo 1998, 160, fig.2).

From the typological point of view, the two small daggers found associated in a single burial inside Frommosa seem to belong to different types: the first, with a short, flat tang, seems reminiscent of the Monte Claro shapes, in particular the small dagger from Via Basilicata, Cagliari (Lo Schiavo 1989, fig. 1, 6). The difference is that the tang is not distinct from the shoulder, but just gradually tapers.

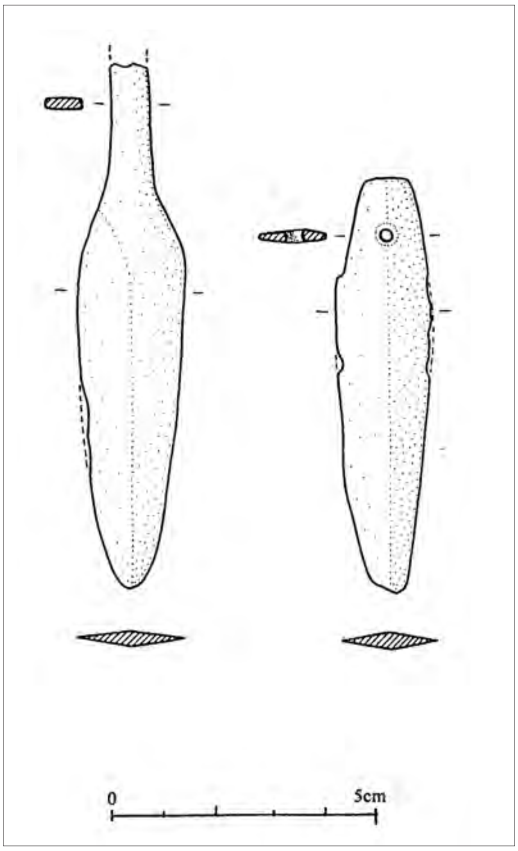


Fig. 1 – Villanovatulo (NU), Frommosa cave: a. small tanged dagger; b. small distinct simple base dagger *(drawn by Antonio Farina)*.

The second small dagger, with simple holed base, is unusual on account of its distinct trapezoidal shape, which has no exact analogies, but more or less fits the shapes of the final Chalcolithic and Early Bronze Age periods.

The association of the two pieces, together with a small obsidian knife and a high bowl with low belly, typical of the ceramic shapes of the "Nuorese" style of the Bonnanaro, dates the pieces unequivocally to the Early Bronze Age phase[1].

1. The sentence "the same can be said of one of the dagger of Frommosa, Villanovatulo (fig.2) (n. 8)" (Cincotti, Demurtas, Lo Schiavo 1998, 160) refers exclusively to the words "of an indisputable local shape and presumably local production" (*ibidem*) and not to the attribution to the Monte Claro culture. Also the pieces were wrongly numbered: the one with the simple base (here no. B5) was presented and discussed before the one with the tang (here no. B4).

Archaeological file 7

Isili (Nuoro), megalithic tomb of Murisiddi.

(Fulvia Lo Schiavo)

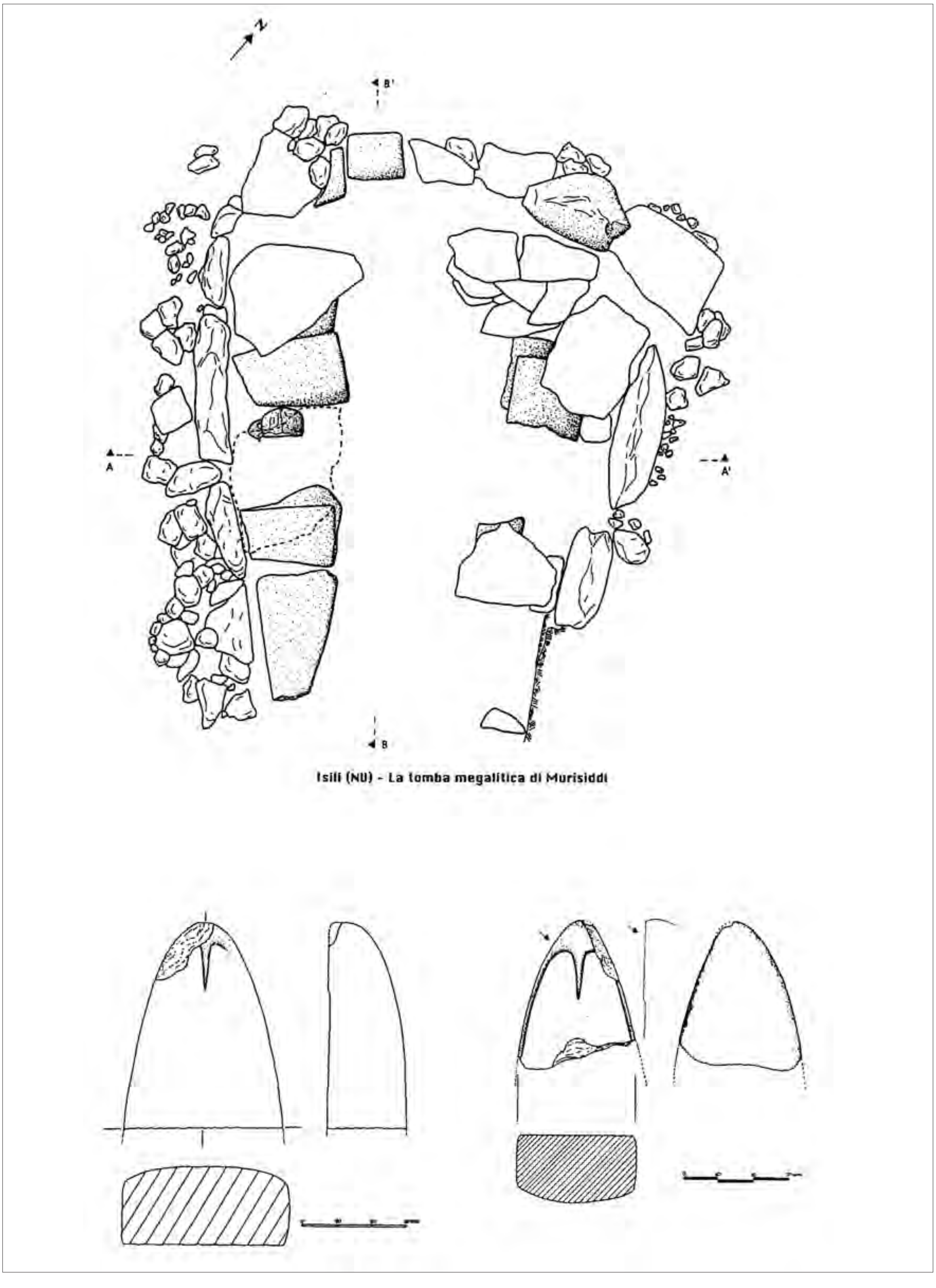


Fig. 1 – Isili (NU), Murisiddi: planimetry of the megalithic tomb *(after Perra 2000)*; *statue-menhirs* i, ii *(after Saba 2000; 1993).*

The megalithic tomb of Murisiddi was discovered by chance, when the works to repair the access road to the dam of Is Barroccus in the territory of Isili cut through the front part with the access and brought to light some *statue-menhirs* which had been reused for the construction.

The archaeological excavation revealed the presence of a megalithic chamber tomb, similar to the well-known one at Aiodda di Nurallao, situated not far away, the rear part of which rests on the naturally steep rock of the slope; on the whole the structures consist of *statue-menhirs*, whole and fragmentary, of which 33 have been identified, arranged so as to form the walls, the two lateral plinths and the covering of the two niches built in this way. There was thus confirmation of the dating of the *statue-menhirs* of the Sarcidano area, which in the monuments of the Early Bronze Age are now found desecrated and downgraded to coarse stone material.

The human remains, belonging to at least a dozen individuals, are not joined together anatomically, since the deposit has been considerably disturbed and the tomb deprived of its covering.

Some vases were recovered, among them a hemispherical bowl with elbow handles, a tripod and a carinate bowl, which are clear indicators of an attribution to the Bonnanaro A archaeological *facies*, confirmed by objects of ornament, such as cylindrical and olive-shaped necklace beads made of spondylus shells, two bone elements, chips and microliths of obsidian, and, of particular importance, a stone brassard, with concave sides and four holes at the ends, as well as the two small daggers and an awl. (Perra 2000, forthcoming).

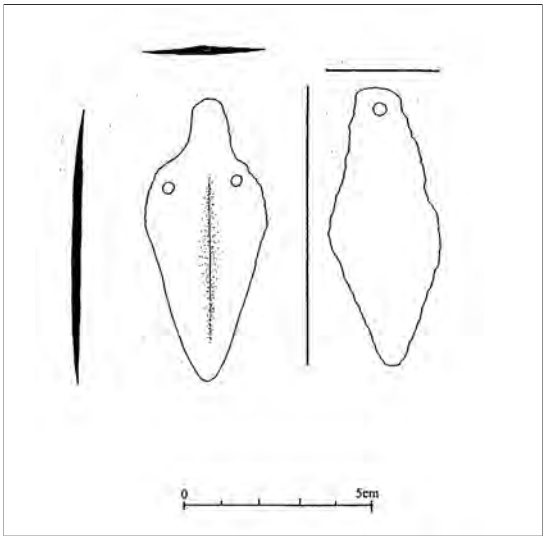


Fig. 2 – Isili (NU), Murisiddi: a. (A3) small distinct simple base dagger; b (A2) small distinct simple base dagger *(drawn by A. Saba).*

A2. Small dagger with simple base and short triangular blade, wide simple trapezoidal base with hole, completely flat. L. 7.5 cm (Perra, forthcoming, fig. 59 on left; Cincotti, Demurtas, Lo Schiavo 1998, 160).

A3. Small dagger with short, rounded tang, rounded shoulder with two holes, slightly thickened at the middle. L. 7.6 cm (Perra, forthcoming, fig. 59 on right; Cincotti, Demurtas, Lo Schiavo 1998, 160, fig. 2).

The analyses have revealed that the composition is 100 % copper (Cincotti, Demurtas, Lo Schiavo 1998).

Archaeological file 8

Decimoputzu (Cagliari), Sant'Iroxi
(Luisanna Usai, Fulvia Lo Schiavo)

The tomb

The tomb came to light in 1987, during the works for the construction of the communal gymnasium, on the north-east slope of the hill of Sant'Iroxi (San Giorgio), on the south-east periphery of the town of Decimoputzu.

The characteristics of the material found inside the tomb led the people of Decimoputzu to call this *hypogeum* "The Tomb of the Warrior", and with that name it entered archaeological literature.

Hollowed out of a bed of sandstone, the *hypogeum* has the layout of a classical *domus de janas* made up of a corridor and two cells positioned on an east-west axis.

The tomb structure was dug by Ozieri peoples, as shown by some sherds of that culture found on the floor, but the more complete grave goods belong to distinct phases of the Bonnanaro culture.

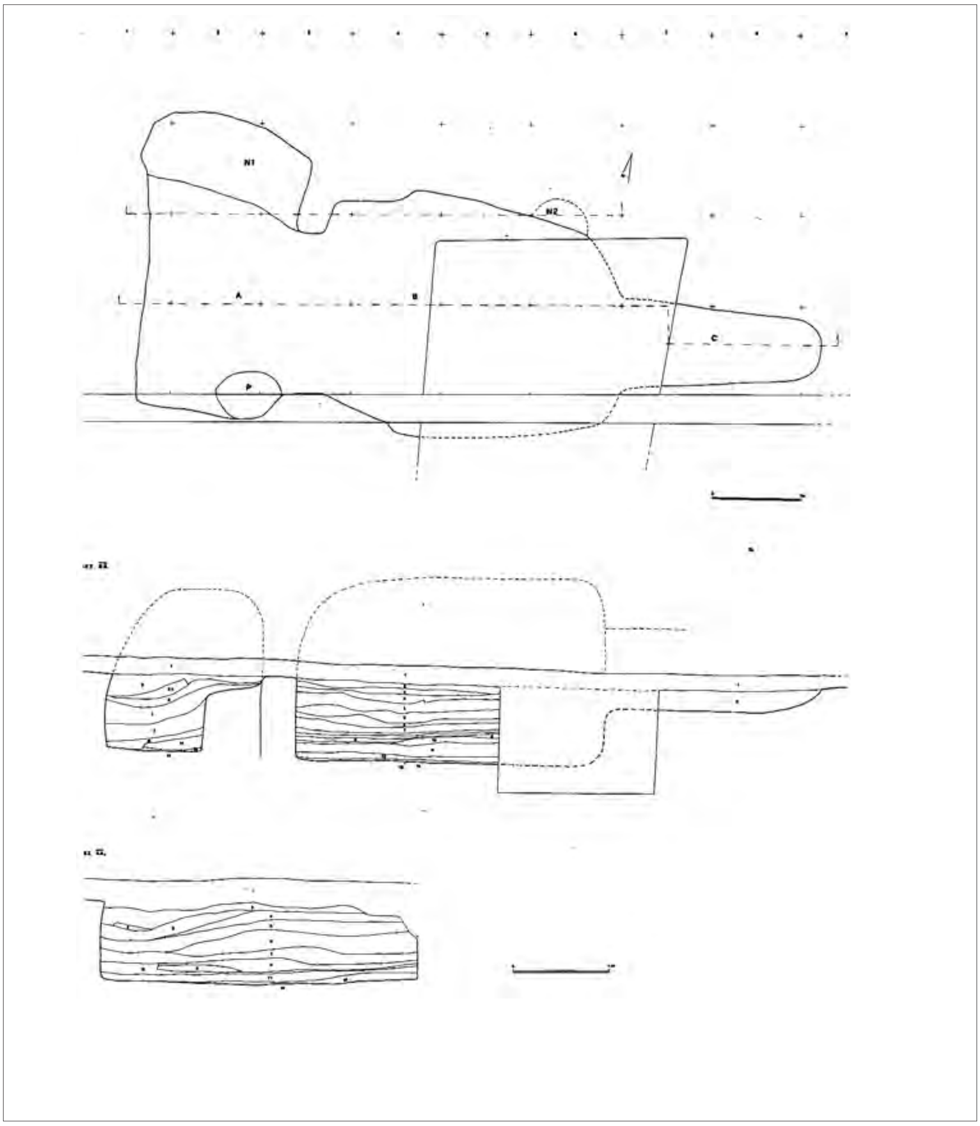


Fig. 1 – Decimoputzu (CA), S. Iroxi: planimetry and cross-section of the tomb *(after Ugas 1990, pl. IX-X)*.

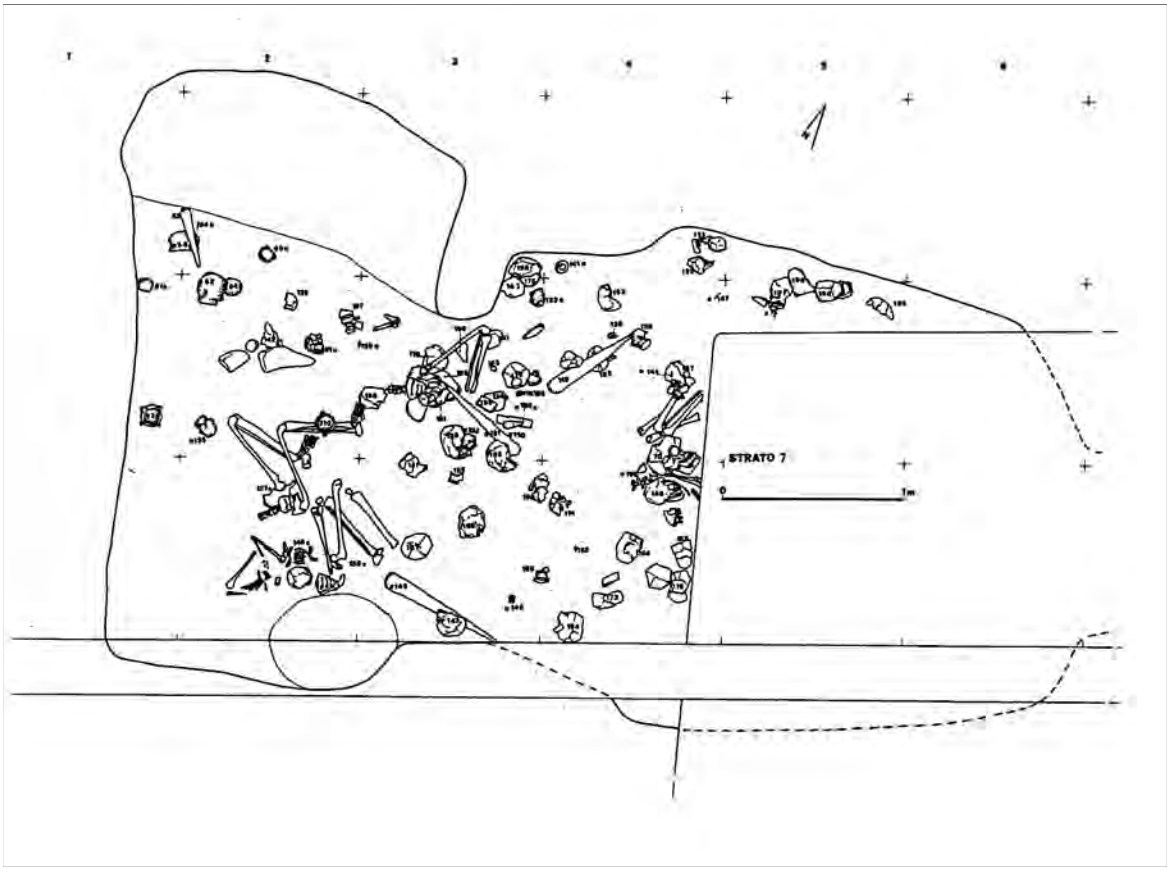


Fig. 2 – Decimoputzu (CA), S. Iroxi: excavation plan of the stratum 7 *(after Ugas 1990, pl. XIV).*

The oldest phase, to which eight vases belong, five of which are tripods, five awls, a tiny dagger in copper, are from the Early Bronze Age (1700-1650 BC).

The most recent phase, characterized by the different vase shapes, which are on the whole closed with two or four handles, by skewers and awls, but above all by copper daggers and swords, indicates a date of use of the tomb in the transitional period between the Early and Middle Bronze Age periods (between the end of XVII and the first half of XVI centuries BC).

The bones found in association with the material document the burial of the dead in a huddled position. (Luisanna Usai).

"Argaric" swords

The exceptional feature of the discovery of the *hypogeum* of S. Iroxi consists in the richness of the array of weapons and other metal objects belonging to the last phase, in addition to the fact of containing a deposit which was un-disturbed and had been in use over a span of at least two thousand years. There were 6 short and 20 long drifts, 21 awls, 2 needles, 5 daggers and 13 swords, on account of the presence of which the Tomb of the Warrior owes its name.

G. Ugas divided the swords into short, from 30.9 to 39 cm (5 examples: finds B7-B11); medium, from 50 to 55 cm (3 examples: finds B9);); long, from 61 to 72 cm (5 examples: finds B6-B8).

All swords, regardless of length, are characterized by an absolutely flat blade, without any sort of ridge or thickening at the centre, except for a visible hammering-out along the sides to form the cutting-edge. It is very likely that they were formed in one-piece moulds and that the hammering of the edge was part of the finishing operation.

The other constant element is the semicircular simple base with many rivets (from 5 to 7, not in proportion to the length of the blade), all of the same size, arranged in a semicircle; the line of the lower edge of the hilt is straight and clearly defined.

The characteristics which define the Sardinian swords also distinguish them from the El Argar swords, even if there are still analogous parameters, namely the broad long blade without midrib and the simple base with numerous rivets.

The typology of the El Argar swords has been dealt with exhaustively by Martin Almagro Basch, who has distinguished the types and subtypes: from the analysis and from the comparison with the Sardinian examples, the conclusion is that the Sardinian swords are akin to an Argaric model, but are of local manufacture (Lo Schiavo 1992, 73).

In fact the early dating assigned by G. Ugas to the strata in which the S. Iroxi swords lay, dating to the Bonnanaro A2 *facies*, distinct from the earlier one of Bonnanaro A1 and from the following one of Sa Turricula, and dated "between the end of XVII and the first half of XVI centuries BC" ("*tra la fine del XVII e la prima metà del XVI secolo a.C.*") (Ugas 1990, 103; 1999, 114-115), would confirm the impossibility of the import of the Sardinian swords from El Argar – to which, amongst other things, Almagro had attributed a very late dating-; on the contrary, it is the proof of a parallel evolution from a common basis, probably to be found in the Beaker heritage (Lo Schiavo 1992).

The sword of Maracalagonis belongs to this type of production (see Archaeological file 9); it comes from another locality in southern Sardinia, as far as we know, from a megalithic tomb and not a hypogean one, which increases the cultural span of the use of this shape.

A further basis is provided by the association with daggers, points and awls, which are in no way different from those found in the whole island, except in their abundance and the wide range of their sizes.

The "Argaric" swords of S. Iroxi are therefore perfectly contextualized and a clear example of the original application of common models, reworked according to requirements.

Table of the swords (from Ugas 1990)

Layer 5								
File	172	p.60,	tav. XXVIII:9.		Sword:	short,	l. cm 31,5	
Layer 7								
,,	348	,, 68	,,	8	,,	short,	l. cm 30,9	
,,	349	,, 69	XXX	1	,,	long,	l. cm 59,9	
Interlayer 7a								
,,	395	,, 70	XXX	2	,,	long,	l. cm 66,6	
,,	396	,, 70	XXIX	1	,,	medium,	l. cm 51,8	
Interlayer 7b								
,,	408	,, 71	XXIX	2	,,	long,	l. cm 50,2	sample B6
,,	409	,, 71	XXXI	3	,,	medium,	l. cm 54,7	
Layer 13								
,,	497	,, 76	XXXI	1	,,	long,	l. cm 72	sample B7
,,	498	,, 76	XXXI	2	,,	long,	l. cm 65,6	sample B8
,,	499	,, 77	XXX	3	,,	medium,	l. cm 50	sample B9
,,	500	,, 77	XXIX	3	,,	short,	l. cm 39	
,,	501	,, 77	XXVIII	7	,,	short,	l. cm 33	sample B10
,,	502	,, 77	XXVIII	10	,,	short,	l. cm 38,5 (graph. rec.)	sample B11

Archaeological file 9

Maracalagonis (Cagliari), megalithic tomb (?) at the periphery of the town.
(Fulvia Lo Schiavo)

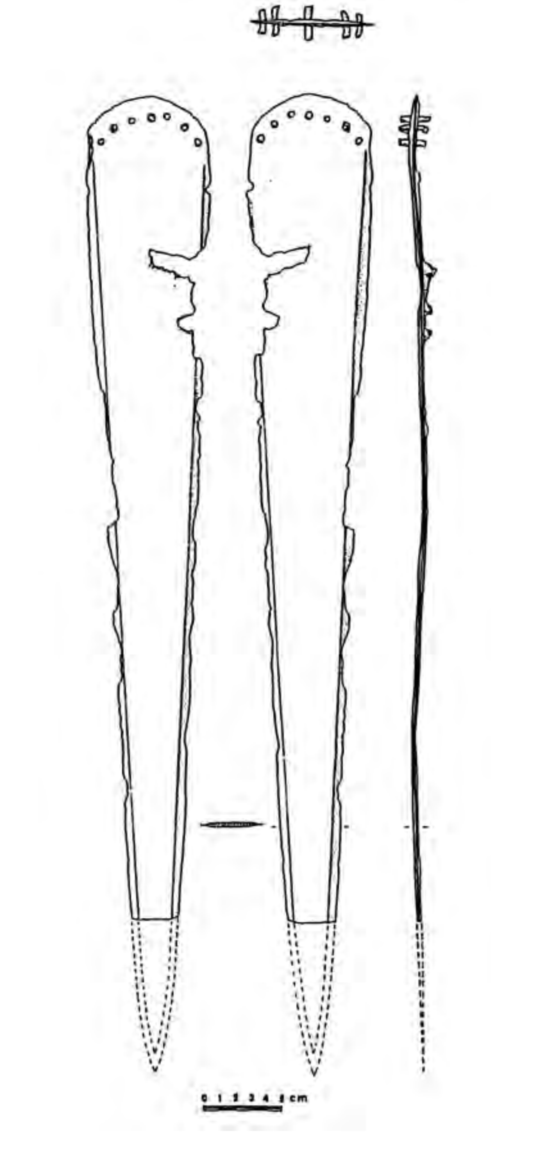


Fig. 1 – Maracalagonis (CA): “argaric” sword *(after Lo Schiavo 1992, fig. 1).*

During ploughing of a peripheral area of the present day urban centre of Maracalagonis were found the remains of a stone structure, probably a megalithic tomb, from which a sword was recovered. This remained in private hands for some years (Lo Schiavo 1986, 236), until it was deposited at the Museo Sanna in Sassari.

It is a very long and broad example, with flat blade and simple rounded base with seven holes for rivets, five of which are still *in situ*.

B1. Large sword, with long, broad blade, triangular in shape, simple, rounded base and seven holes for rivets, five of which are still *in situ*; completely flat cross-section, except for hammering at the border of the cutting edge. L. (reconstructed) 60 cm; width 7.6 cm. (Ferrarese Ceruti, Lo Schiavo 1991-1992, 136).

For a long time, this weapon did not seem to have analogies in the local typologies, up to the discovery of the tomb of S. Iroxi (mentioned in Lo Schiavo 1989, note 71); here were found swords to which it is identical in shape (see file no. 8). It was then hypothesized because of archaeological and typological reasons, that it was a locally produced weapon, like the swords of S. Iroxi, strongly influenced by the Iberian models of the El Argar swords, and therefore parallel, in the evolution of the shape, to the most ancient of those, and independent from them (Lo Schiavo 1992).

This hypothesis is also backed up by analytical data. Although the outcome of Vodret’s analyses (1959) left some perplexity on account of the high zinc content, subsequent verification in fact showed an alloy of arsenical copper, with isotopic affinities with Sardinian ore-bodies. (Cincotti, Demurtas, Lo Schiavo 1998, 160, fig. 3).

Archaeological file 10

Muros (Sassari), hut I of Sa Turricula.
(Fulvia Lo Schiavo)

The locality of Sa Turricula in the countryside of Muros was discovered as result of the finding of pottery material in the site and in the nearby tomb in the locality of Funtana 'e Casu. Excavations started at the beginning of December 1972, continued for the whole month, and then begun again as a second season in October 1976.

Hut 1 is part of a wider context of dwellings positioned on the steep southern slopes of Monte Tudurighe.

In the first season (1972) two trenches were explored, respectively named A and B, while in the second season (1976) the rock near the surface was almost immediately found. In the first it was possible to investigate deeply, with the discovery of a stratigraphic series which had been disturbed only slightly at the surface level. In the lowest stratum (lower stratum 3), intermingled with the stones of the floor and adjacent to the small south wall of the hut, a hearth was found, the charcoals of which were C14 analysed (1510 BC = 3460 BP, uncalibrated) (Ferrarese Ceruti, Germanà 1978, note 35).

The material from Sa Turricula gave for the first time the exceptional opportunity of assessing an inhabited site of the Bonnanaro culture, of which up to then only burials had been known. The notable differences, initially attributed to the nature of the source, were subsequently ascribed to the development of the Bonnanaro culture into two phases, the Bonnanaro B *facies*, or Korona Moltana, to be attributed very closely to the Early Bronze Age, and the other, known as the Bonnanaro B *facies*, or Sa Turricula, which fits the first part of the Middle Bronze Age (MBA1), itself by then the initial phase of the nuragic civilization (Ferrarese Ceruti 1981, LXXIII, fig. p. LXXXII; Ferrarese Ceruti 1991-1992).

For this reason the small, one-tower nuraghe at Sa Turricula, which rose right near the village, was completely explored, in the search for confirmation of whether its erection coincided with the period of existence of the village. Expectations were disappointed, however, by the fact that the construction of a rich favissae in the nuraghe in Roman times had swept away all trace of prehistoric occupation.

Material contemporary with and subsequent to that of the village was recovered in the nearby dolmenic gallery tomb at Funtana 'e Casu (in the territory of the district of Osilo) (Ferrarese Ceruti 1978; 1981, LXXIII, fig. p. LXXII).

Fig. 1 -Muros (SS), Sa Turricula : photo of the excavation trench *(after Ferrarese Ceruti 1978, fig. 59).*

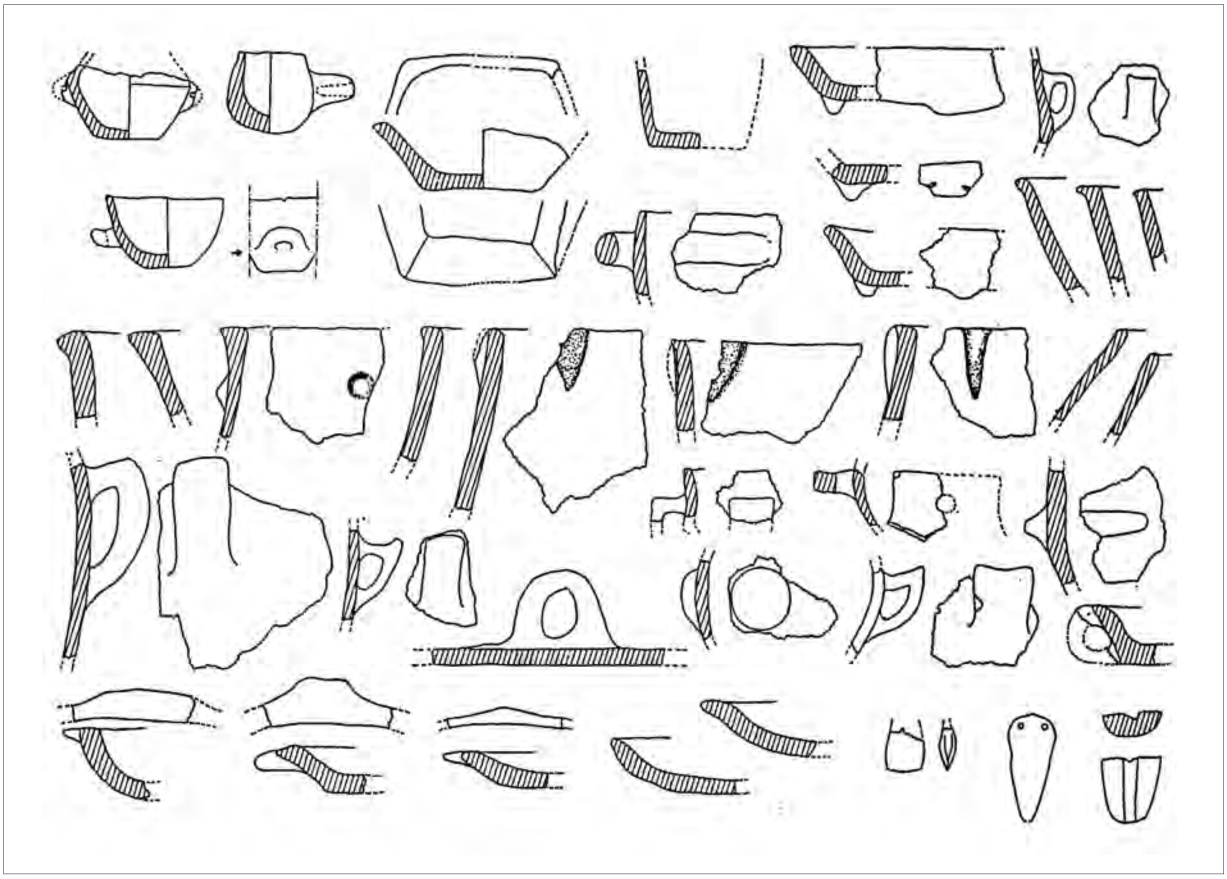


Fig. 2 -Muros (SS), Sa Turricula : typology of Sa Turricula pottery *(after Ferrarese Ceruti 1989, tab. LXXIb).*

B3. Small dagger with simple rounded base, slightly wider than the blade, with two rivets: blade short and broad, almost flat in cross-section, except for two slight and wide hammerings along the edges. L. 7.5 cm (Lo Schiavo 1986a, 235 fig.16.5; 1989, 286; Cincotti, Demurtas, Lo Schiavo 1998, 160, fig.1).

The small dagger was found in the 1976 season, in the lower stratum 3, and Ferrarese Ceruti observed its affinities with the Polada-2 form from the mainland. (Ferrarese Ceruti 1981, LXXIV, fig. p. LXXIIb, at the bottom on left and C50).

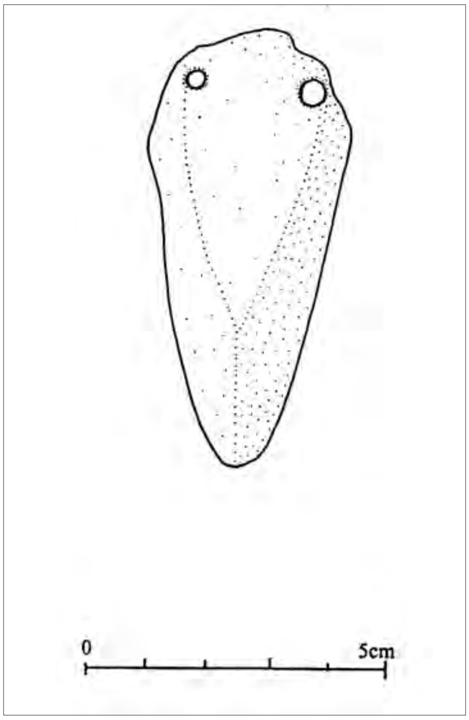


Fig. 3 -Muros (SS), Sa Turricula : small simple base dagger *(after Lo schiavo 1978, fig. 59).*

Archaeological file 11

Siniscola (Nuoro), simple base dirks.
(Fulvia Lo Schiavo)

In February 1974 the Questura confiscated at Siniscola some illegally held archaeological material; this was passed to the Soprintendenza and displayed for the first time four years later at the Museo Speleo-Archeologico of Nuoro, which had just been opened. In addition to the dirks under examination here, the confiscated items included a fenestrate sword (see file no. 22), a pair of bronze fire tongs, in excellent condition, and two small glass balsamaria. (Lo Schiavo 1978b).

"Siniscola" provenance, therefore, does not refer to the place of discovery, but just to the place were the confiscation occurred, even though that part of the Baronia district, which borders on the valley of the Posada, is propitious for discoveries of particular interest. Similarly, there is no guarantee of any association between the artefacts; for instance, the two balsamaria are clearly from the Roman period.

The three dirks are characterized by their simple base fixed with five rivets and by the robust blade, lenticular in cross-section, for which a comparison has been proposed with the Roncoferrato and, in particular, the Castione types, defined by V. Bianco Peroni (1970, 14-15, nos. 13-14, 18-20) and dated, on the basis of central-European comparisons, to the Middle Bronze Age: therefore, it is a form of weapon contemporary to the large flanged axes.

Two further examples, vaguely similar on account of the simple base, are known in Sardinia. The first is a dagger with simple base, markedly triangular with five holes arranged at an angle to the top, from the locality of S. Marco di Settimo S. Pietro (Nuvoli 1988, 40, 42, tab. V).

The second is a small dagger (18.3 cm) from the nuraghe Su Mulinu at Villanovafranca (Ugas 1987, 79, fig. 5 nos. 6, 17), of whose base as result of breakage only a part remains, with two holes at the edge. This piece is the only one found in place in the stratum in association with pottery of the Middle Bronze Age, which confirms the dating of the shape (Ferrarese Ceruti, Lo Schiavo 1991/1992, fig. 4).

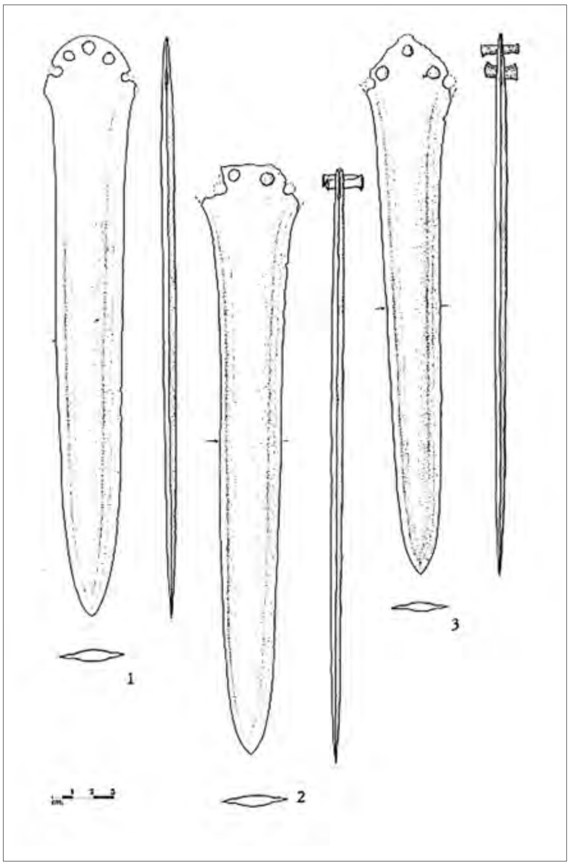


Fig. 1 - Simple base dirks *(after Lo Schiavo 1978, tab. XXVI, 1-3).*

Archaeological file 13

Ottana (Nuoro) ?, Hoard(?)
(Fulvia Lo Schiavo)

In 1977, the Soprintendenza Archeologica for the provinces of Sassari and Nuoro acquired an interesting complex of bronze weapons, found in an unspecified site in central Sardinia, approximately in the zone of Ottana (Lo Schiavo 1980, 340). The impossibility of verifying this information is still now a serious handicap for the assessment of these artefacts, although other discoveries which have occurred in the meantime in Sardinia have led to the widening and deepening of the study; it is reasonable to expect further progress in the future.

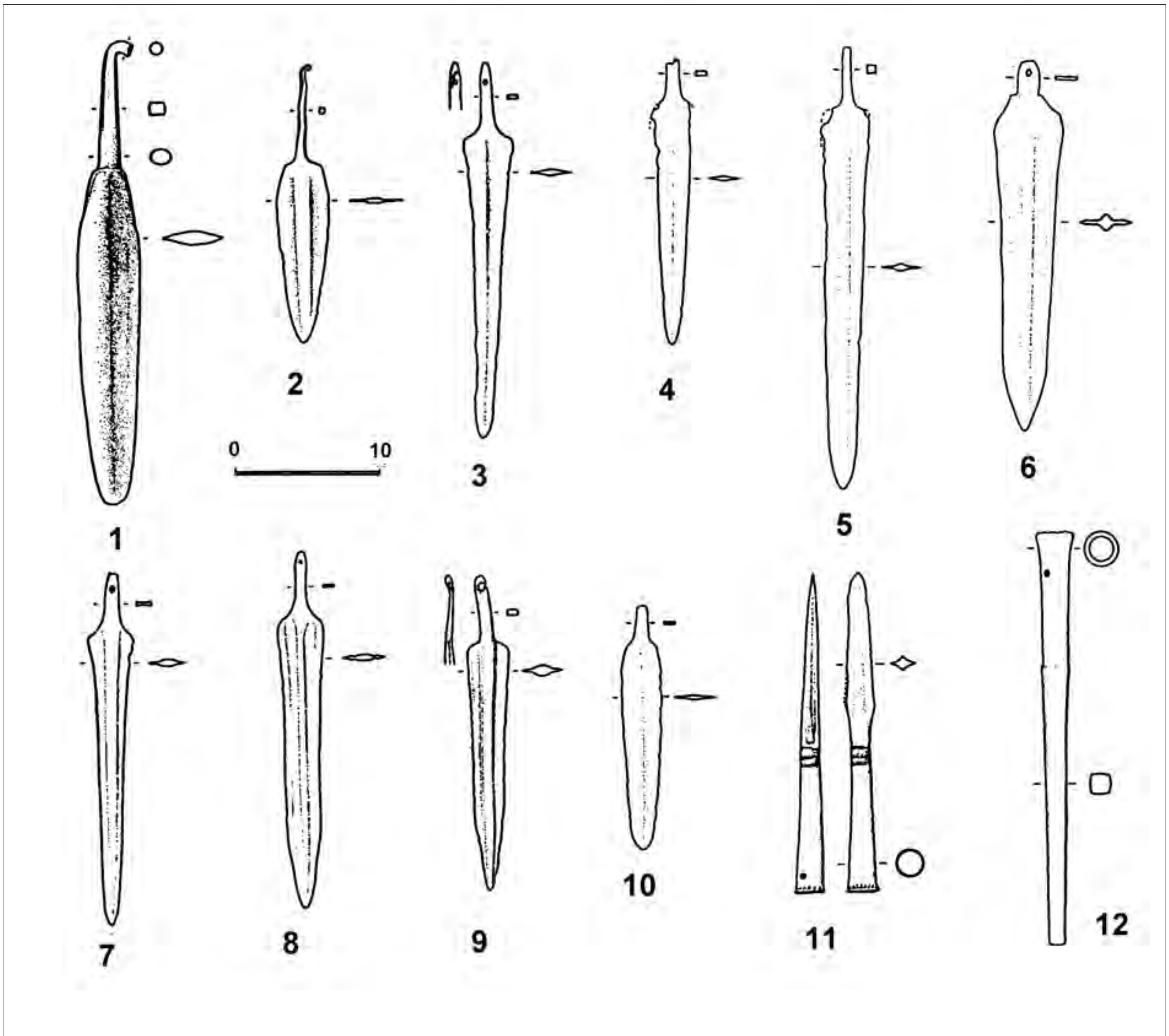


Fig. 1 - Ottana (NU) ? : complex of bronzes *(after Lo Schiavo 1980, figg. 2-3).*

1. Dirk with hooked tang (code A4)

Narrow blade, oval in shape, biconvex in cross-section, of considerable thickness, shoulder narrowed and rounded; massive tang, elliptical in cross-section above the shoulder, almost square at the centre, circular at the hook. L. 31.7 cm. (Lo Schiavo 1978a, tab.XXIII,1; 1980 fig.1,1; 2,1; 1982, 277, fig.7 on left; 1986, 237-8; Lo Schiavo, Macnamara, Vagnetti 1985, 9, fig. 3,1).

2. Dagger with hooked tang (code A5)

Foliate blade with midrib wide and flattened, wide and almost straight shoulder, massive tang, rounded polygonal in cross-section. L. 19 cm. (Lo Schiavo 1978, pl. XXIII,2; 1980 fig. 1,2; 2,2; 1982, 277, fig. 7 on right.; 1986, 237-8; Lo Schiavo, Macnamara, Vagnetti 1985, 9, fig. 3,2).

3. Tanged dirk with hole

Triangular, long narrow blade, with shoulder wide and oblique, midrib not distinct, tang thin with rectangular cross-section, with ends flattened and rounded, with hole. L 25.7 cm. (Lo Schiavo 1978, pl. XXIII,3; 1980, fig.1,3; 2,3).

4. Tanged dirk with hole

Triangular long and narrow blade with wide, oblique shoulder, midrib wide and flattened with distinct edges, tang thin with rectangular cross-section, end flattened with hole. L. 24.1 cm. (Lo Schiavo 1978, pl. XXIII,4; 1980, fig.1,4; 2,4).

5. Tanged dirk with hole

Blade long and narrow, with oblique shoulder, sides slightly wavy, central ridge rounded, tang thin and rectangular in cross-section, ends flattened, with irregular small hole. L. 24.4 cm. (Lo Schiavo 1978, pl. XXIII,5; 1980, fig. 1,5; 2,5).

6. Tanged dirk with hole

Triangular and narrow blade with oblique shoulder, rounded, wide and distinct central ridge, massive tang, square in cross-section, end flattened with hole. L. 21.5 cm. (Lo Schiavo 1978, pl. XXIII,6; 1980, fig. 1,6; 2,6).

7. Tanged dagger with hole

Blade long and narrow, lenticular in cross-section, with short oblique shoulder, tang rectangular in cross-section, ends flattened with hole at edge, resulting from breakage. L. 19.1 cm. (Lo Schiavo 1978, pl. XXIV,1; 1980, fig. 1,7; 3,1).

8. Tanged dirk

Blade long and narrow, with straight shoulders, both fragmented, midrib rounded, tang square in cross-section. L. 29.2 cm. (Lo Schiavo 1978, pl. XXIV,2; 1980, fig. 1,8; 3,2).

9. Dirk with short flanged handle, with hole

Blade wavy in outline and with triangular point, with oblique shoulder, central ridge rounded and strongly marked, short, almost rectangular flanged handle, with hole at centre. L. 24.7 cm. (Lo Schiavo 1978, pl. XXIV,3; 1980, fig. 1,9; 3,3).

10. Tanged dagger

Blade long and narrow, lenticular in cross-section, with short oblique shoulder, flattened tang, rectangular in cross-section. L. 19.1 cm. (Lo Schiavo 1978, pl. XXIV,4; 1980, fig. 1,10; 3,4).

11. Trunnion Spearhead

Blade short and narrow with shoulder barely marked, rhomboid in shape, midrib strongly marked with sharp edge, long trunnion; decoration with two parallel bands, herring-bone pattern, separate with parallel grooves, at the base of the blade, and with a row of little bumps at the base of the joint; two holes above the bumps. (Lo Schiavo 1978, pl. XXIV,5; 1980, fig. 1,11; 3,5).

12. Trunnion Spearbutt (code A6)

Solid head, square in cross-section, slightly flared trunnion, distinguished by a narrowing; two holes right through in the upper part. (Lo Schiavo 1978, pl. XXIV,6; 1980, fig. 1,12; 3,6).

Comment

The pieces described belong to different types, each with its own particular area of distribution and its chronologies.

As for the two blades with hooked tang, initially the affinity with the large family of the so-called “hook-tanged weapons” or “Cypriot daggers”(1) was noted. The daggers with the holed tang are however characteristic of the Arreton Down *facies* (second phase of the Wessex culture: Camerton-Snowshill, Aldbourne)(2).

The acquisition of the complex of weapons from Ottana took place at the peak of the discussion on this subject, and

1. The wide bibliography on the subject has been assembled and presented in Lo Schiavo 1980, 347 note 1.
2. Even bigger is the bibliography on Wessex: see Lo Schiavo 1980, 348-350 notes 3-8 and above all note 9 on p. 350.

seemed to resolve the question in favour of a possible encounter between Cypriot and western influences, at least in the area of the central-western Mediterranean, where a local production, drawing on both cultural worlds, could fully justify the visible typological differences.

In the long span of time since then - more than twenty-five years - and in the rich panorama of the discoveries which have occurred, the mainland and central-European component has been taking on an ever more consistent outline.

It can now be reasonably hypothesized that this type of sword, dirk and dagger, characterized by a large tang, with ends enlarged or not, folded into a hook or straight, with and without holes at the base of the blade, but always with a narrow and sloping base, widespread in northern Italy in the Recent Bronze Age period (Bianco Peroni 1970 nos.64-78; Carancini, Peroni 1997; 1999), and belonging to the multiform and exceedingly vast family of the tanged weapons (Vagnetti 2000), may have appeared in Sardinia too, where, like the flanged axes, they were freely reproduced (see below p. 280-281).

Archaeological file 19

Santadi (Cagliari), Pirosu-Su Benatzu.
(Luisanna Usai, Fulvia Lo Schiavo)

The cave and the pottery

The use of natural caves as places of worship are to be also listed amongst the numerous manifestations of the nuragic civilization; the cave of Su Benatzu di Santadi is the most important amongst the sanctuary caves, for the richness of its deposit.

The cave opens not far from the town of Santadi, at the base of a crest of limestone rocks. Numerous openings give access to it; from the principal one, along a lateral ramification, one reaches a wide chamber, in which was found an extraordinary accumulation of votive objects at the end of the 1960s.

The objects deposited in the cave consisted of hundreds of vases of various shapes, often miniature ones, which document the repetition of rites from the Middle Bronze Age up to the dawn of the Iron Age.

On account of the particularly large number of objects found, the vase shapes discovered in the cave-sanctuary constitute an important repertoire for the nuragic period, unfortunately not supported by excavation data.

On the basis of the analysis of the pottery, it can be affirmed that the use of the cavity for cultural purposes began in the Middle Bronze Age, but that it developed mainly in the Recent and Final Bronze Ages. Use of the cave in the First Iron Age, however, documented also by way of radiocarbon dating, would seem rather sporadic and short-lived. *(Luisanna Usai).*

The bronzes *(see page 348-351, Fig. 6-9, 13)*

There is also a sad absence of excavation data as far as the material is concerned; in fact everything points to the probability that a good part of the most valuable finds was removed before reaching the public collections.

The objects surviving whole are very few: a heart-shaped boat, with straight handle terminating in a ram's protome, and a locally produced miniature Cypriot-type tripod.

Amongst the weapons are two full-sized gamma-hilted daggers, in addition to which there are a further four daggers - two made of votive swords -, other fragments, four sword stumps, of the Monte Sa Idda type; and the head of a javelin.

Amongst the tools, which are almost absent, as is always the case in nuragic votive contexts, there is a sickle blade and a fragment which could be from a fixed-handled spit.

Amongst the ornaments, there are 9 pins with mobile heads, two of which are still inserted, and two items for fastening folds, a pendant in the form of a flanged axe with handle, a fragment of *fibula* similar to the double-resorte type, 8 bracelets, 13 whole and fragmentary rings, and a further 7 fragments of rod. *(Fulvia Lo Schiavo)*

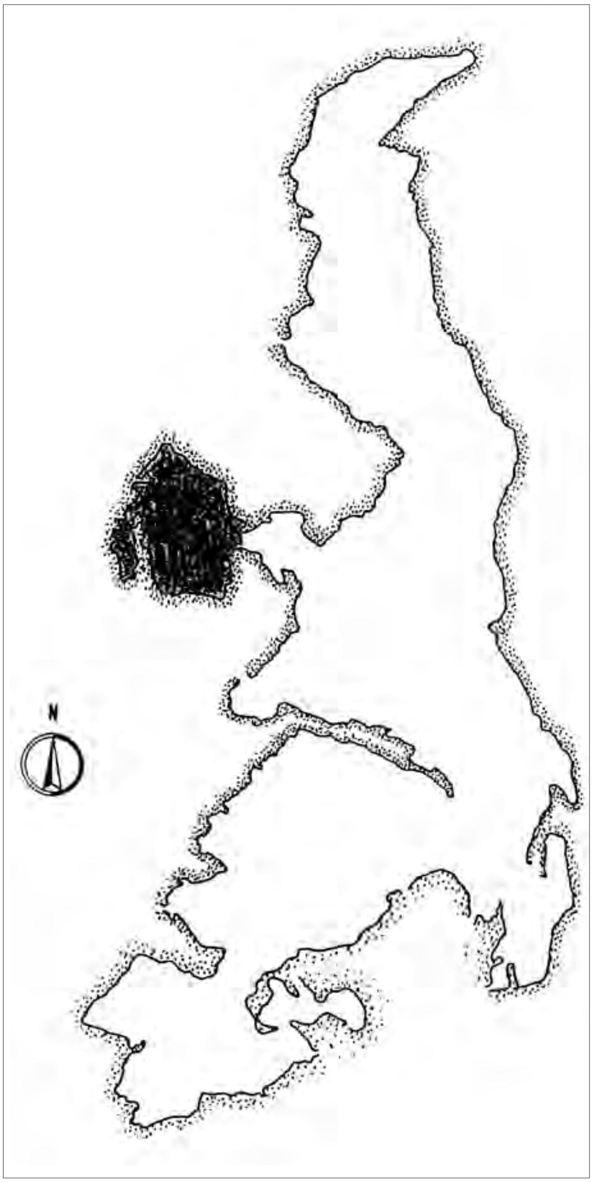


Fig. 1 -Santadi (SA), Pirosu-Su Benatzu : planimetry of the cave *(after Usai L., Lo Schiavo 1985).*

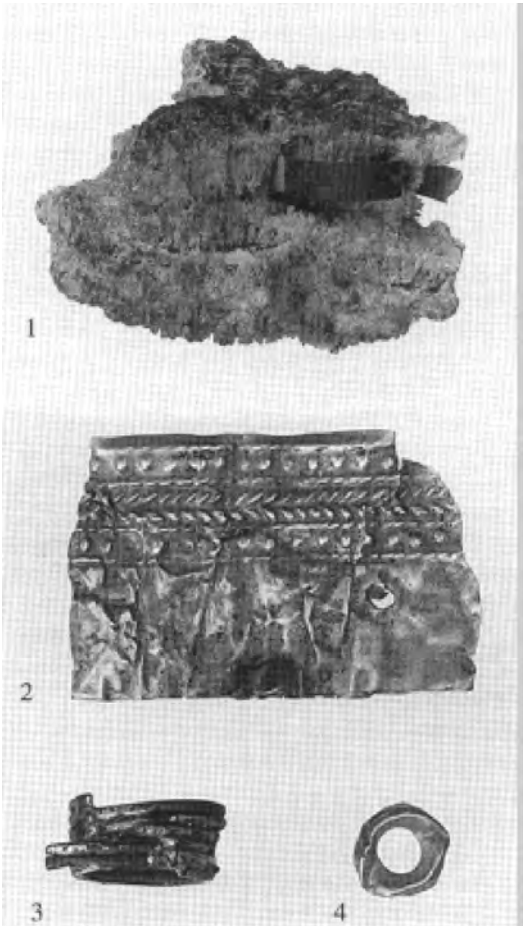


Fig. 2 - Santadi (CA), Pirosu-Su Benatzu : 1. bronze earrings in calcareous concretion; 2. gold leaf fragment; 3. gold spiral ringlet; 4. gold cilindric bead *(after Usai L., Lo Schiavo 1995)*.

The objects of precious metals

There are only three objects not of bronze, and these are a small spiral ring and a cylindrical bead, both in sheet and apparently of gold.

The most interesting piece is a small fragment of *repoussé* sheet (code P2), decorated with two rows of little balls at the sides of a plaited motif, edged in cabling. It has been suggested that this is the remains of a Cypriot diadem, of the type used both for covering the eyes or the mouth of dead person and for decorating the coiffure. In this second case, the other two objects may also have belonged to the same headdress, of which unfortunately very little survives. *(Fulvia Lo Schiavo)*.

Archaeological file 21

Baradili (Oristano), Santa Maria: hoard.

(Luisanna Usai)

The oxhide ingots from Baradili were given to the State in 1947 by Dr Antonio Cabras, together with other prehistoric pieces and ones from historical times. The collection, as can be gathered from the act of donation, included chance finds made in the territory included between the Tuili, Villanovafranca, Serri and Baressa districts.

The collection, which Cabras himself described briefly in a note of 1950, was handed over to the then Sovrintendente, Rafaello Delogu, and was acquired by the Museo Archeologico Nazionale di Cagliari.

In spite of its importance, the donation remained long in the storerooms of the Cagliari museum, practically unknown even to the specialists, but fortunately it survived in good condition. The moving of the material over the last few years has in fact led to some small losses, but the collection has survived almost complete.

The ingot fragments were part of a large hoard held in a big ceramic container. The site and the circumstances of the discovery are well described by Cabras, who writes that the hoard was discovered in the Santa Maria region, to the south of Baradili in 1937, during works to construct the road which joins Baradili with the cemetery.

According to what Cabras reports “a workman engaged on the excavation found at a depth of about seventy centimetres below ground level a vessel in terracotta, in the form of a bowl fifty centimetres high, containing about two hundred fragments of raw copper, of various sizes” (“*un operaio addetto ai lavori di scavo scoprì alla profondità di settanta centimetri circa dal livello del suolo, un recipiente di terracotta, a forma di pentola, dell’altezza di cinquanta centimetri, contenente circa duecento frammenti di rame grezzo, di varie dimensioni*”).

Cabras recovered 154 fragments, weighing in all 23.200 kg, while some fifty fragments appear to have been taken by unknown persons and dispersed. Cabras himself had an analysis made, a summary of the results of which is as follows: “silica: present; copper: present; tin: 3.7 %: it is a bronze” (“*silice: presente; rame: presente; stagno: 3,7 %; trattasi di un bronzo*”).

Various surveys carried out by Cabras in the place of discovery led to the recovery of other material, mostly grindstones and fragments of the great vase which contained the ingot fragments (Cabras 1950).

It is difficult to provide chronological indications for the hoard under consideration on the basis of the reports which have reached us. Examination of the container might provide a chronological indication, but the fragments of the vase have been dispersed in the deposits of the Museo di Cagliari. The presence of a fragment of a *dolium* amongst the surviving material is not certain proof that the container was of that shape.

Archaeological file 22

Siniscola (Nuoro), fenestrate sword.
(Fulvia Lo Schiavo)

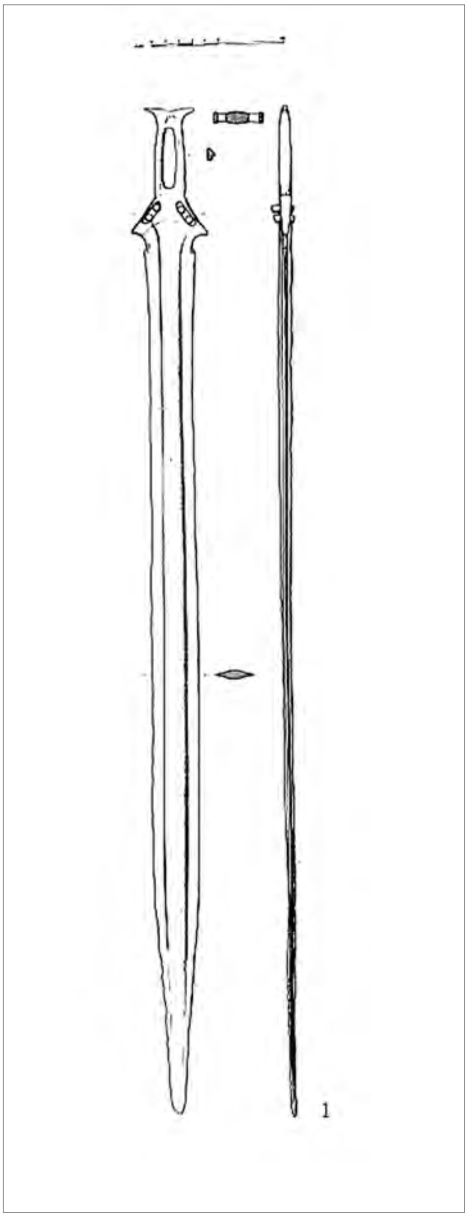


Fig. 1 -Siniscola (NU) : the fenestrate sword *(after Lo Schiavo 1978b, tab. XXVII, 1).*

As already said with reference to the dirks (see file no. 11), the provenance of this sword, all circumstances of its discovery and its associations, are unknown.

Fenestrate sword "carp's tongue" ("*a lingua di carpa*") blade.

Hilt with large rectangular opening and swallow's-tail end, fins with two rectangular openings and two rivets on each side; base of the blade V-shaped; marked ricasso; long narrow blade with parallel cutting edges, with the tapering end "*a lingua di carpa*"; rib rounded and not protruding, marked on the sides with two thin grooves. H. 75 cm. Alt. cm 75 (Lo Schiavo 1978b, 87, no. 4, pl. XXVII,1).

The elaboration of the flanged-hilted swords, characteristic of the Bronze Atlantic III phase, consists of the fenestrate swords, whose handle, in addition to other details of shape, has fairly wide openings in place of the holes for rivets, while the blade is narrow and straight, sharply tapering away at the point in a shape which is defined as "carp's tongue" ("*a lingua di carpa*"); this characteristic is found in the swords from the hoard of Huelva, and for this reason are sometimes called "Huelva-type" (Almagro Basch 1940, Ruìz-Galvez Priego 1995).

The example recovered at Siniscola is in fact of this form, and it can be presumed that it has been brought from outside, even if Coffyn (1985) maintains that it presents some differences from the Iberian swords.

A fragment of hilt of fenestrate sword was recognized by V. Bianco Peroni (1970, 97-98, no 269-270) in the hoard of S. Marinella, dating to the close of the Bronze Age: the fact is particularly indicative both for the dating of the type, well within the Final Bronze Age, and for the function of go-between which Sardinia undoubtedly had for materials of Iberian type, towards the opposite Tyrrhenian shore, and even more so towards the interior of central Italy. *(Lo Schiavo, D'Oriano 1990)*.

Archaeological file 24

Gesturi (Cagliari), Brunku Madugui – Hut 6.
(Ubaldo Badas)

Settlement area on the upper part of the *plateau* (giara) of Gesturi (Cagliari) The oldest part of the complex, with an archaic nuraghe, dated to the MBA 1 (16th-14th c. BC), excavated by G.Lilliu in 1962, has in its vicinities a Final Bronze Age settlement (11th – 9th c. BC), which was first studied by Lilliu and later by M.G. Puddu (1980-83) and by A. Usai (excavation 1990). The arrangement of the village is typical, with round huts, connected by linear sectors around a central court, as it is the case with more recent buildings in the village of Barumini (CA). From the entrance of hut 6, excavated by Lilliu, comes a fragment of slag with Final Bronze Age pottery, which partly anticipates geometrical shapes of the Early Iron Age. Unpublished.

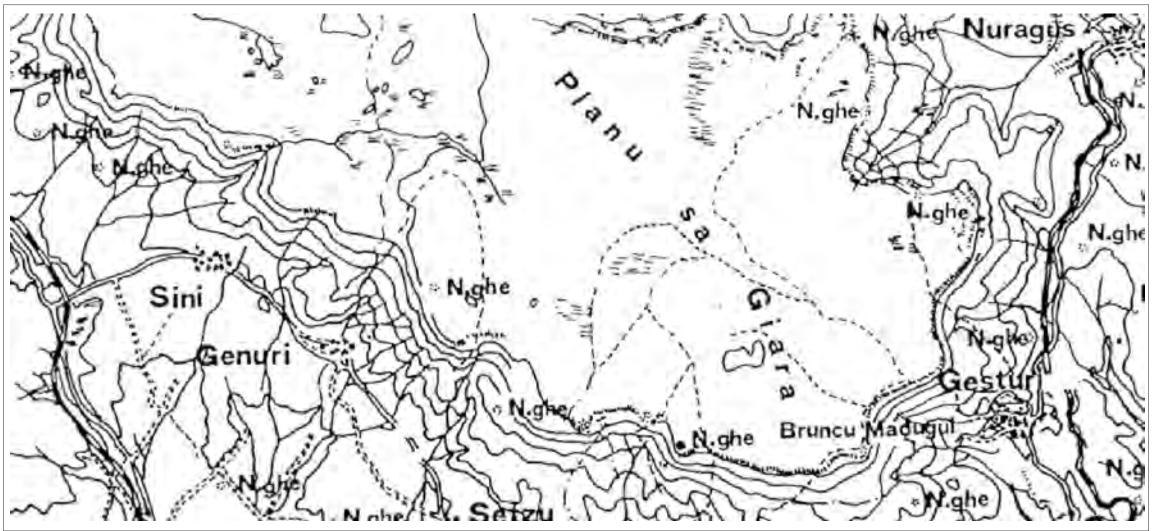


Fig. 1 - Gesturi (CA) : geographic location of the nuraghe Brunku Madugui.

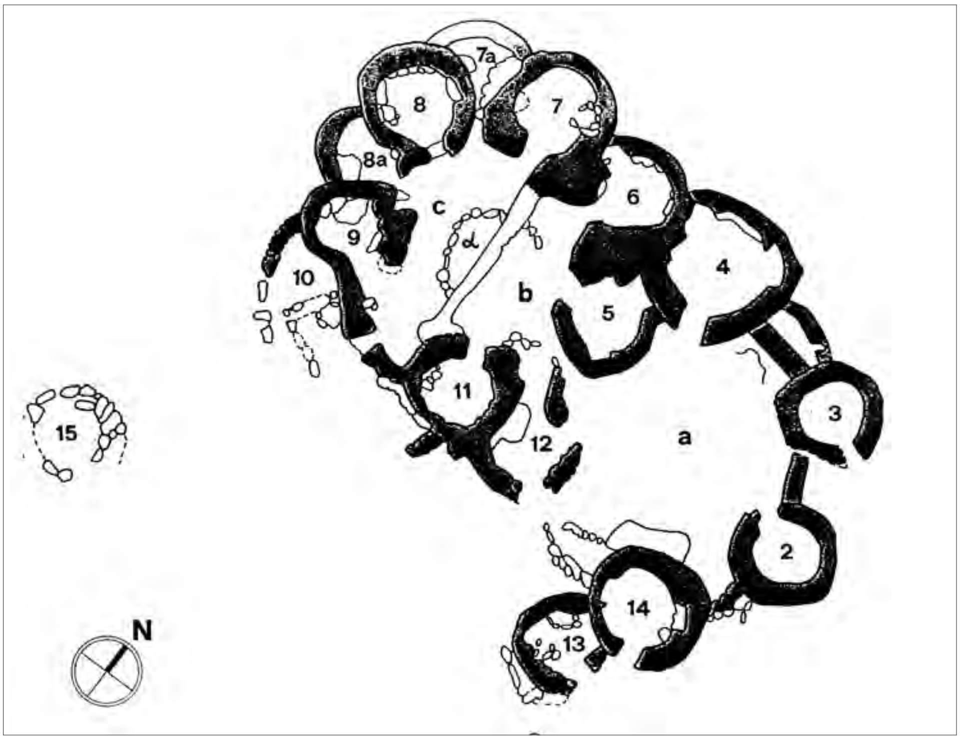


Fig. 2 – Gesturi (CA), Bruncu Madugui: planimetry of quarter A of the nuragic settlement.
(drawn by G. Rizzetto).

Archaeological file 25

Villanovaforru (Cagliari), Pinn'e Maiolu.

(Ubaldo Badas)

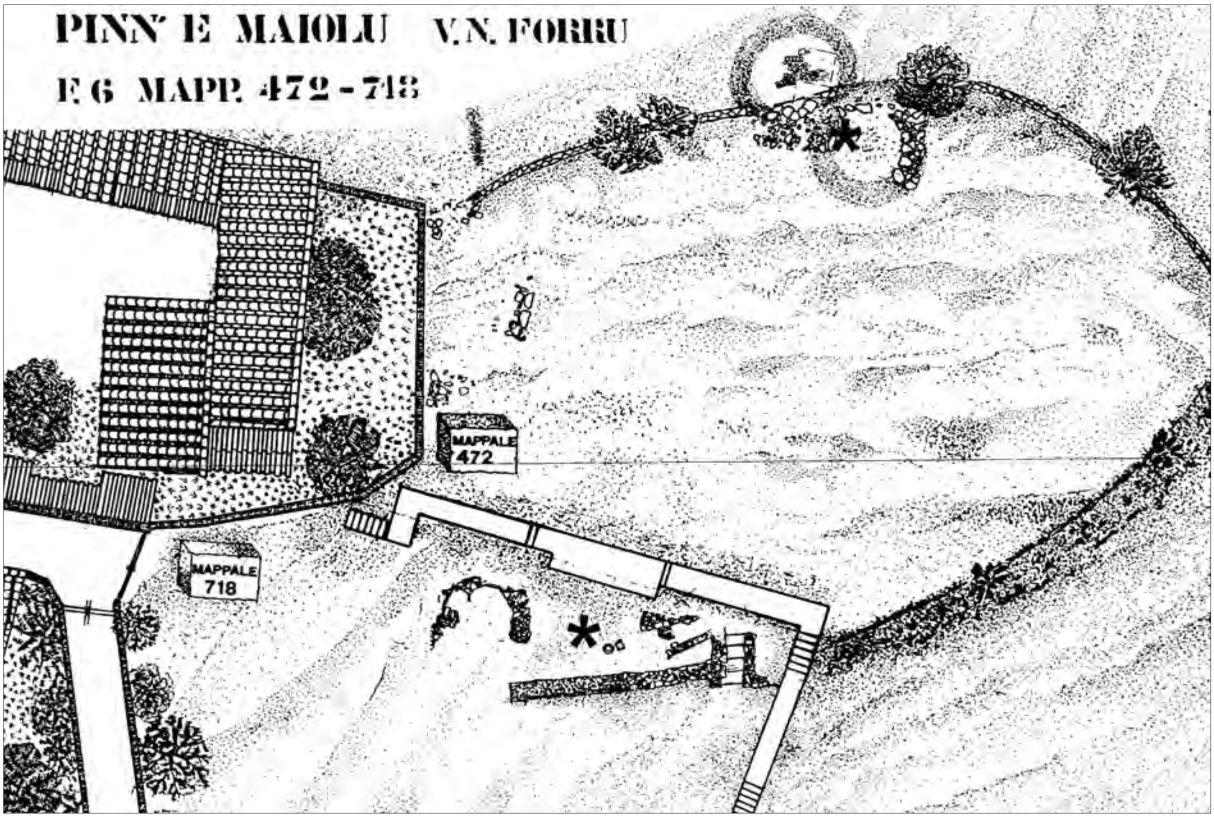


Fig. 1 -Villanovaforru (CA), Pinn`e Maiolu : the site. Asterisk indicates the point where the analysed samples were found.

The archaeological site, situated on the outskirts of the village of Villanovaforru, has been partly occupied by a housing development and covers now an area of roughly 10.000 m², on level and sloping ground at an elevation of between 338 and 305 m above sea level, oriented NE-wards. At the point where the two surfaces meet, the sparse remains of a Nuraghi megalithic construction are visible, reduced to a just a few courses of stone.

Between 1982 and 2001 excavations were carried out intermittently around the ruins of the nuraghe and on the sloping ground nearby. In the latter area, archaeological excavations brought to light the remains of dwellings surrounded by a thick wall, though severely damaged by diggings, carried out for building a house. The ceramic materials are mostly dated to the Late Bronze, but some finds are to be dated to the Early Iron Age, their distinguishing feature being the small concentric circle decoration. This research is unpublished.

Around the remains of the nuraghe there is evidence of reoccupation in Phoenician times, with the presence of black painted Campanian products. Results of archaeological excavation to be published.

On 21.03.1995, a piece of flattened, perforated lead tube, with jagged edges, weighing 11.300 kg (find Nd1) was unearthed in the reoccupation level of one of the towers of the demolished nuraghe. The associated material has been dated to the Late Phoenician/Roman Republic, and lies over a level of nuragic pottery at the bottom.

Two metallic objects were discovered within Map 718:

F2. A riveted sickle with cracked end (missing). One of the rivets of unusual length suggests that the blade once fitted into a sturdy wooden or horn handle. Uniform corrosion.

F1. Blade with small rivets and holes aligned along major axis. Both blade edges toothed suggesting a small sawing tool.

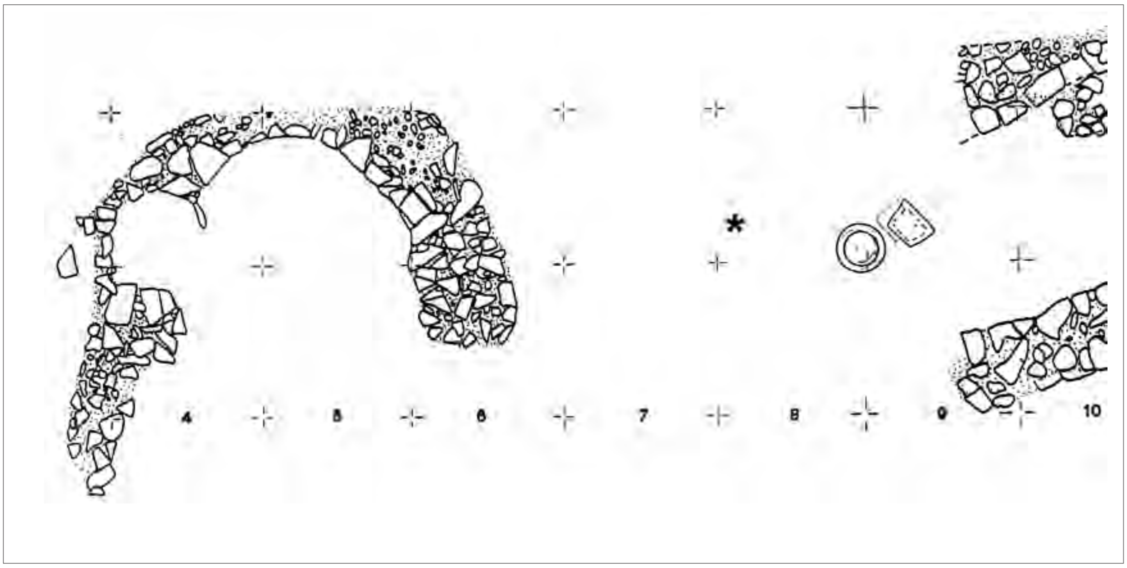


Fig. 2 -Villanovaforru (CA), Pinn`e Maiolu : traces of the settlement (map 718) *(drawing by Vilma Pilloni).*

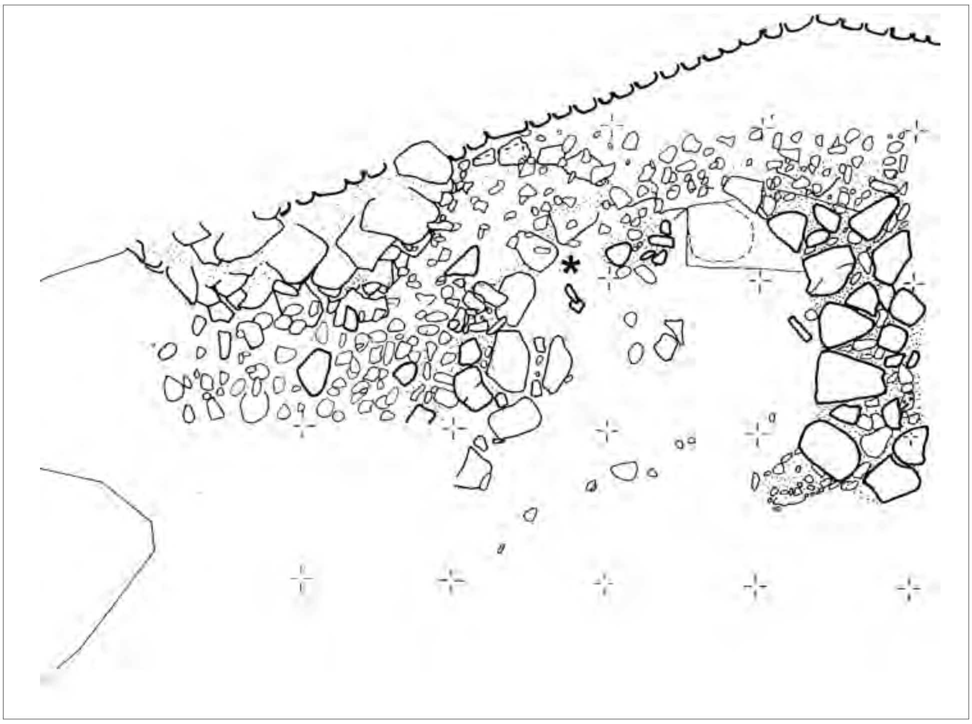


Fig. 3 - Villanovaforru (CA), Pinn`e Maiolu : traces of settlement (map 472) *(drawing by Vilma Pilloni).*

Archaeological file 26

Villanovaforru (Cagliari), Baccus Simeone. I.G.M. 225 I NE.
(Ubaldo Badas)

The site, oriented eastwards, is situated in a hilly area, not far from a natural spring (mitza, local toponym of Phoenician origin) on the border with the municipality of Sanluri (CA), on a sloping terrain at elevations between 258 e 270 s.l.m.. The surrounding area, also at higher elevations, hosts the remains of a nuragic settlements, incuding what is believed to be a smelting furnace in the Santu Antiogu area. The stones lining the inner wall of the furnace were analysed at the Department of Chemical and Materials Engineering at the Cagliari University. The association between these stone finds and clay objects recovered on the surface suggests a Middle Bronze I Age. The ceramic materials known to be associated with the foundry site can be dated to the Late Bronze Age.

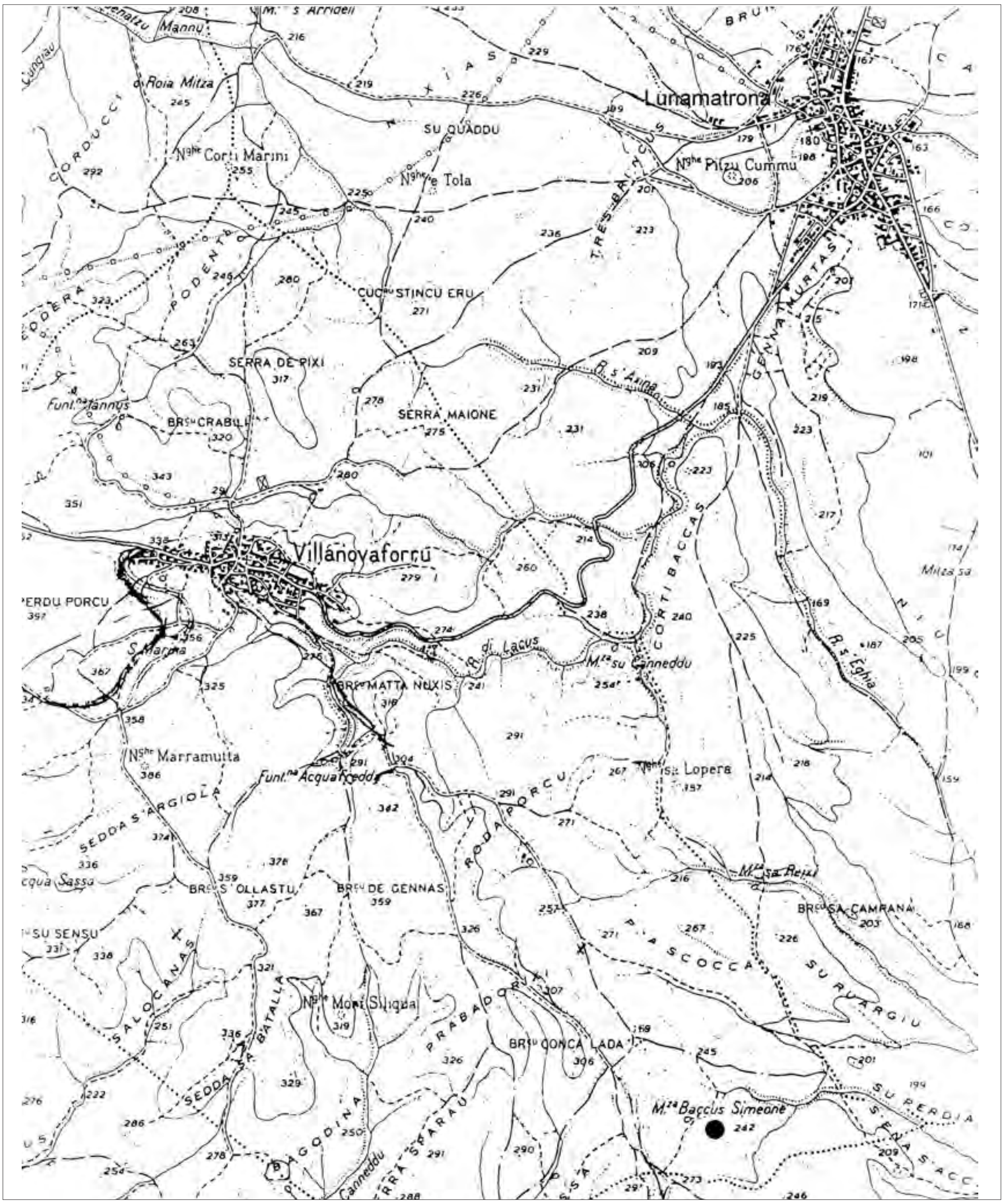


Fig. 1 - Geographical location of the archaeological site.

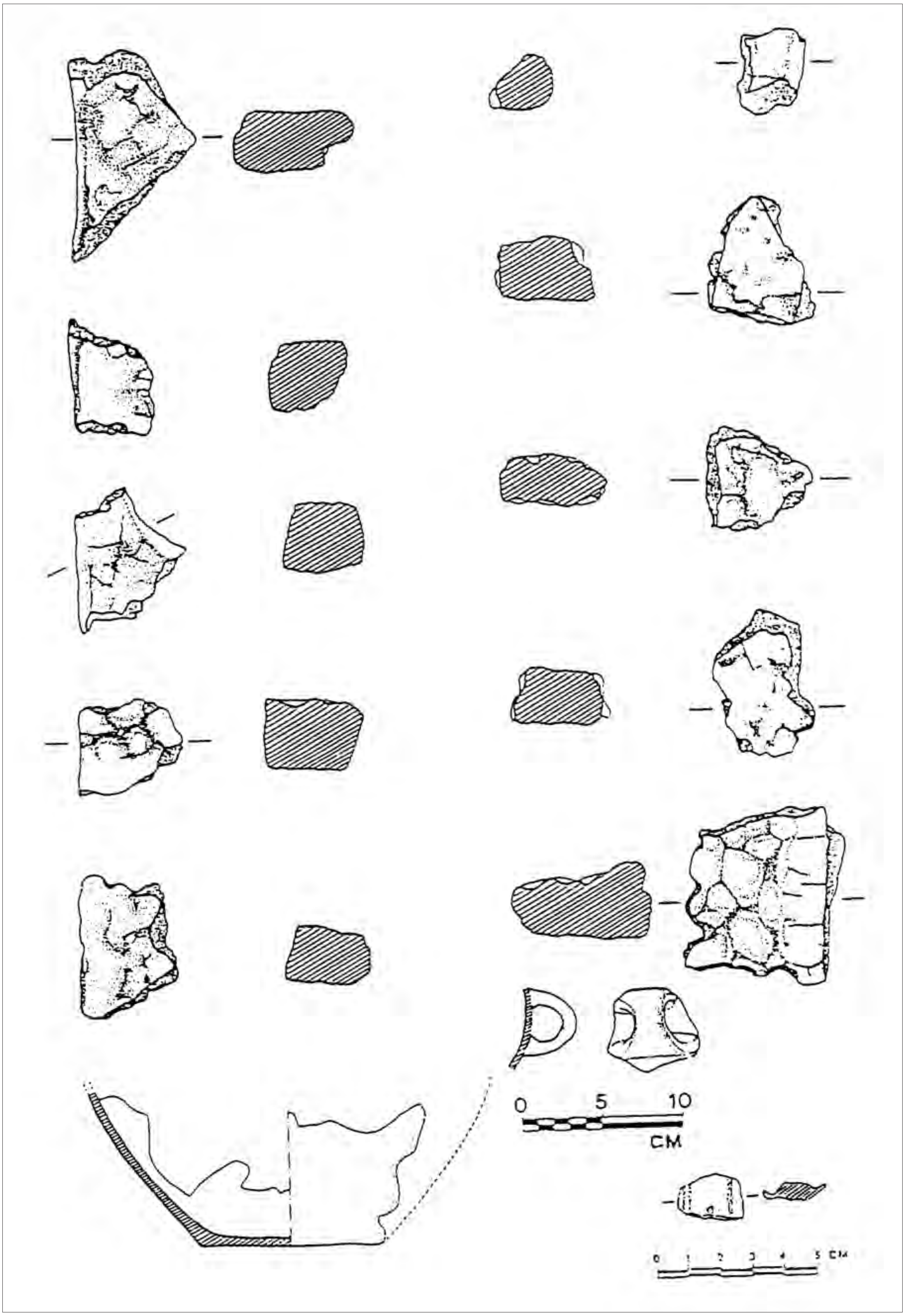


Fig. 2 -Villanovaforru (CA), Baccus Simeone : hoard *(after Badas 1999).*

In 1980 pieces of copper were accidentally discovered in the hoard. The first find recovered was part of an oxhide ingot. Following this discovery, on 27 January 1983 archaeologists using a metal detector set about recovering the rest of the material scattered over an area of 50 x 5 m, by ploughing, which had removed the upper part of the hoard and its container. The remains of the clay container lay 30 cm beneath ground level. It contained fragments of oxhide ingots, smelting debris and other shapeless fragments, as well as a single piece of a votive sword. A total of 101 half-worked pieces of metal including 10 fragments of oxhide ingots, 49 fragments of bun ingots and pieces of lenticular shape, cast without crucible, 42 fragments of uncertain size.

The following objects were analysed by the Department of Chemical and Materials Engineering at the Cagliari University: BS 2, BS 26, BS 54 (1985), BS 2, BS 19, BS 24, BS 26, BS 35, BS 54, BS 60/12, BS 60/20 (1986). Other analyses were performed by F. Lo Schiavo, R. Maddin, J.D. Mulhy and T. Stech in 1985 and later by J. A. Merkel, in addition to those carried out, from 1987 onwards, by N.H. Gale and Z.A. Stos-Gale. The investigations concerned BS 1, BS 2, BS 3, BS 4, BS 5, BS 7, BS 9, BS 10, BS 13, BS 45 (oxhide ingots) , BS 6, BS 11, BS 27, BS 34, BS 53, BS 59, (bun ingots). It has been suggested, that the pieces of oxhide ingot belonged to a single ingot or to a batch of ingots smelted during one operation, by using ores mined from the same deposit. The results are discussed in Lo Schiavo *et al.* 1990.

Fig. 3 – Villanovaforru (CA), Baccus Simeone: broken *olla* (round vessel) with copper fragments *(photo by Soprintendenza Archeologica di Cagliari e Oristano).*

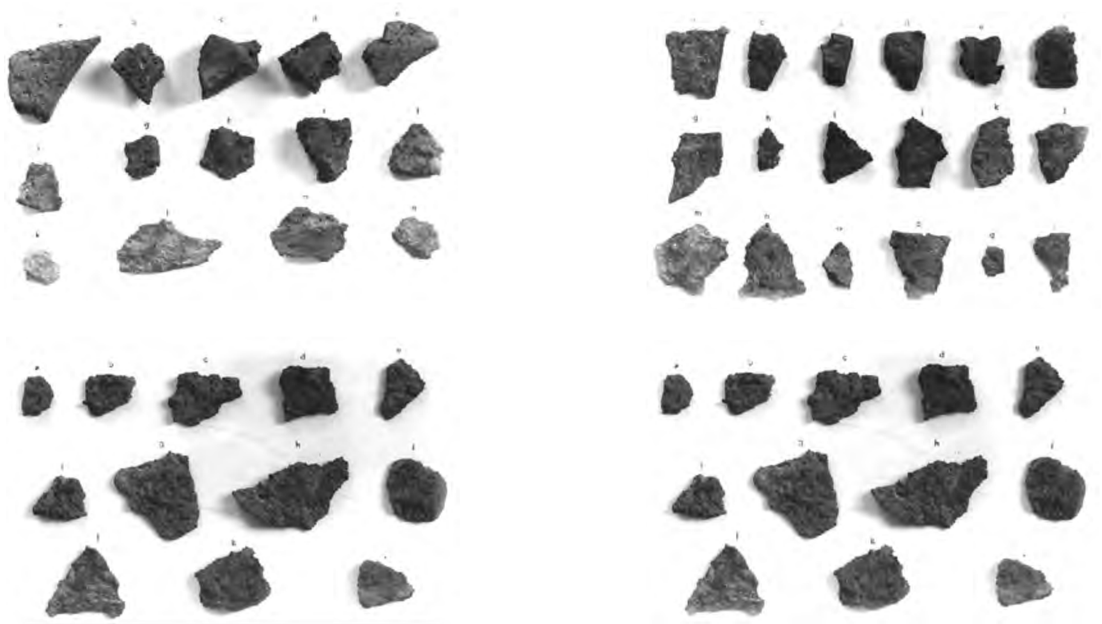


Fig. 4 – Villanovaforru (CA), Baccus Simeone: some of the copper fragments *(photo by Soprintendenza Archeologica di Cagliari e Oristano).*

Archaeological file 28

Villanovaforru (Cagliari), Santu Antiogu.
(Ubaldo Badas)

The site covers an extensive area bordering with the municipality of Sanluri, in the territory of the ruins of Sant'Antioco (Santu Antiogu) church at 296 m a.s.l.

Situated on a ridge and severely disturbed by ploughing, accessible by country lane and affected by agrarian transformations, the site has seen the succession of a number of prehistoric frequentations between the Middle Bronze Age 1 (16th-14th Century B.C.) and the Early Iron Age (9th-8th Century B.C.)

Some of the ceramic artefacts recovered from the surface were associated with fragments of local rock (Miocene fossiliferous marls) studied here. (Atzeni *et al.* 1987).

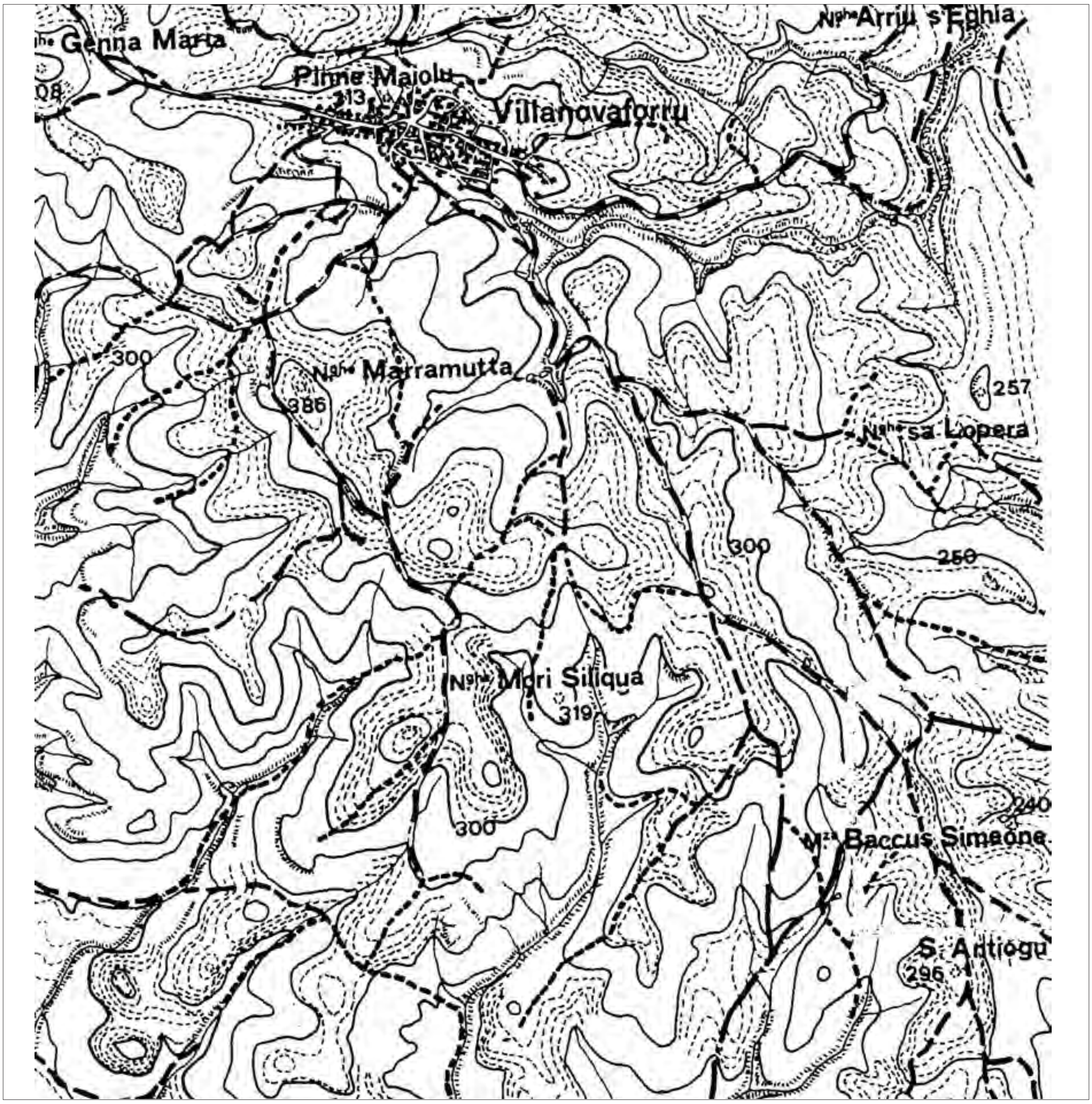


Fig. 1 – Topographic map with the most important archaeological sites of the territori of Villanovaforru (CA): Genna Maria, Pinn'e Maiolu, S. Antiogu, Baccus Simeone.

Archaeological file 29

Bauladu (Oristano), S. Barbara. Metal workshop.
(Fulvia Lo Schiavo)

The complex nuraghe of S. Barbara, Bauladu (Oristano), is situated on a hill at an altitude of 635 m, at the edge of a rich agricultural zone near the Rio Mannu, a tract densely occupied during the nuragic age, where in an area of 22 square km there are at least 24 nuraghi.

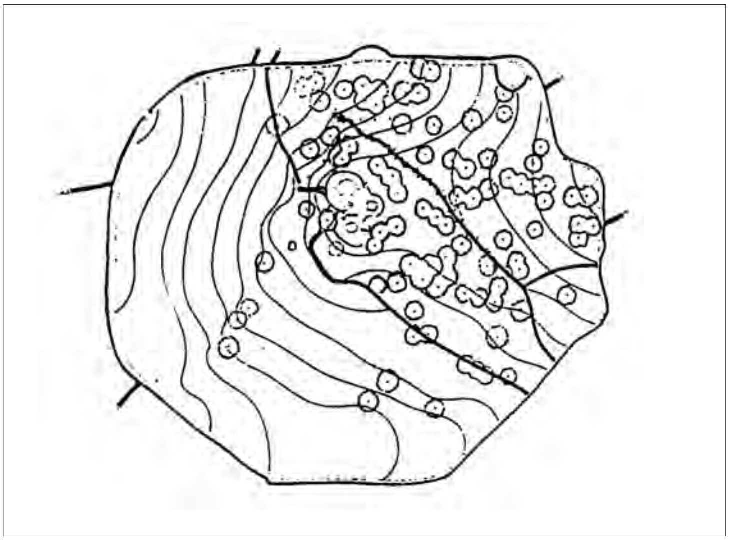


Fig. 1 -Bauladu (OR), S. Barbara : plan of the area *(after Gallin, Tykot 1993).*

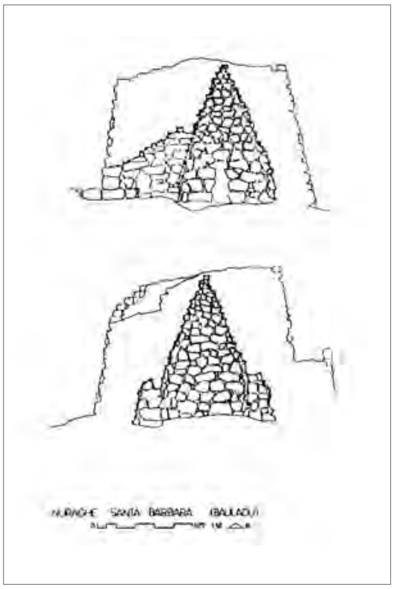


Fig. 2 - Bauladu (OR), S. Barbara : cross-sections of the central tower of the nuraghe *(after Gallin, Tykot 1993).*

The room on the ground floor of the central tower, which measures 5 m in diameter, has three niches and is covered with a high tholos (more than 10 m high). There are two added towers on the east side of the nuraghe, still partially buried; a third has been discovered on the north side and perhaps there is a fourth on the west side.

Around the nuraghe, a cyclopic compound of 440 m with towers marks off about 1,5 hectares, inside which rises an extensive nuragic village. One of the blocks is arranged around a wide paved courtyard and is formed of almost rectangular rooms and two characteristic structures, a large "Meeting Hut" ("*Capanna delle Riunioni*"), with benches along the walls, and a "Bread-making Room" (with bench and adjacent tank) created from a single block of worked stone; the tank is divided by a partition with a communicating hole at the bottom. The nuragic occupation has been attributed to the Final Bronze/Early Iron Age, while there are traces from subsequent occupations by the Phoenicians, Romans and in mediaeval times (Gallin, Sebis 1989; Gallin, Fonzo 1992).

The archaeological excavation of the years 1986-89 brought to light conspicuous traces of a metalworking workshop (Ha1-Ha38; Na1-Na22): crucibles, terracotta moulds, funnels for the molten metal and channels for pouring and distribution of the molten metal, cores and distancing rods for the casting moulds, scraps, fragments of copper and lead, and fragments of bronze artefacts (Atzeni C. *et al.* 1991; 1992a; 1992b; 1994; 1998; Gallin *et al.* 1994; Gallin, Tykot 1993).

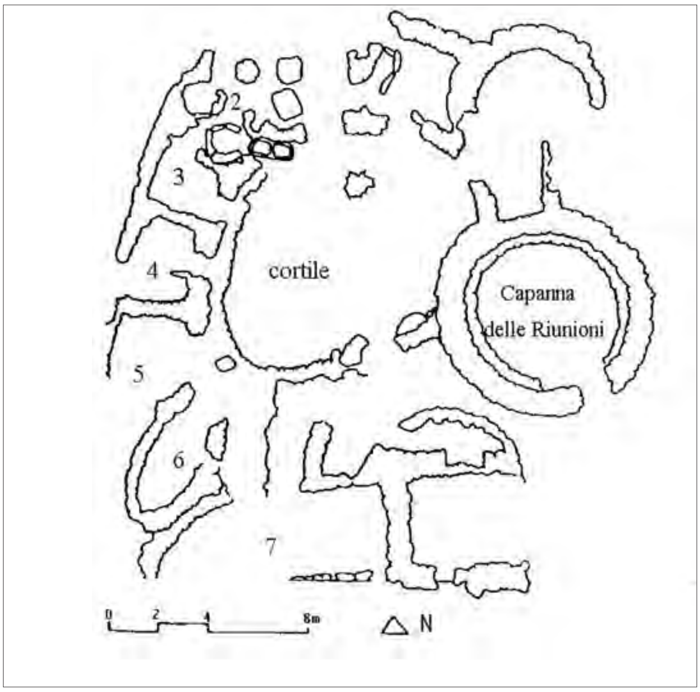


Fig. 3 - Bauladu (OR), S. Barbara : survey of a zone of the village *(after Gallin, Tykot 1993).*

Archaeological file 30

Torpè (Nuoro), nuraghe S. Pietro.
(Fulvia Lo Schiavo)

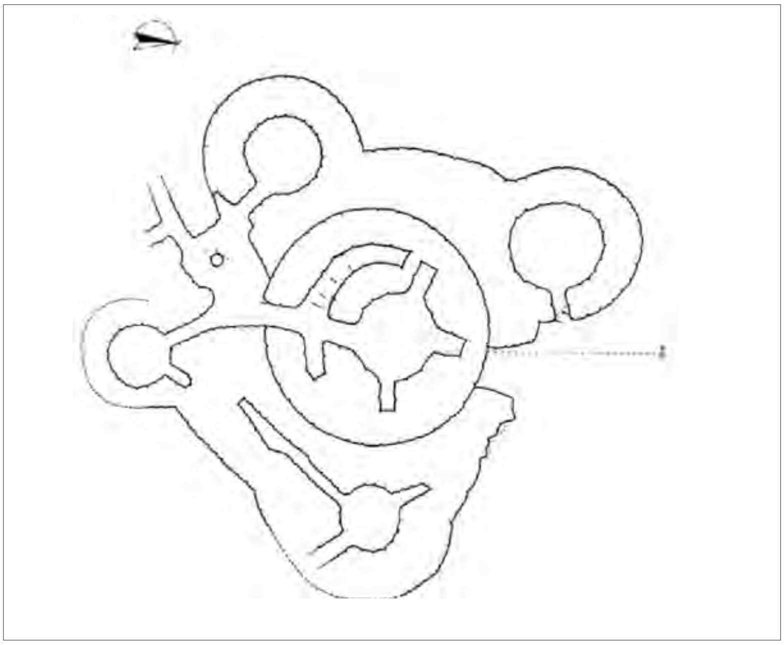


Fig. 1 - Torpè (Nuoro), S. Pietro : general planimetry *(after Fadda 1985).*

In September 1973, in the wake of illegal excavations, a first excavating season was organized in the nuraghe S. Pietro at Torpè, a monument of a complex layout and very rich in material; however, in the first campaigns it was found to be completely plundered, above all in the part of the central tower which had suffered most at the hands of the looters (Lo Schiavo 1974, 549-560, no. 76; 1976; 1978c).

The work began again in 1981, and it was found that it was a four-tower monument with pairs of towers added to the sides, in which the deposit seemed intact, with the vases placed on the benches, one inside the other. (Fadda 1981; 1985, 2; 1990, 1).

In the first intervention, in the courtyard in front of the central tower and in the entrance passage was found a complex of bronzes: a fragment of a bronze figurine, a pendant in the form of a bar, a fragment of bent rod, two biconical beads of bronze wire wound in a spiral, a globular bead, a fragmentary small bow *fibula* and a mirror with open-work handle; also four almost triangular blocks of lead and a lead sheet, an iron spit, a silver hair-clasp and earring (reperto O6) (Lo Schiavo 1978c, pl. XXXVIII,2; Cincotti, Massidda, Sanna, Lo Schiavo 1998, 192, fig. 3).

Of particular value and interest is the mirror which has been several times illustrated and commented on (Lo Schiavo 1974, pl. CIIa; 1976, pl. XIV; 1981, fig. p. 325; 1986, fig. 133; 1991, fig. 2; 2000a, fig. p. 84, p. 86).

It can be deduced from the very noticeable traces of fire, which calcined the stones of the passage and that part of the small courtyard, while a considerable layer of ashes extends also to part of the chamber, that there was a sudden abandonment of the monument, which may have been used partly as a *sacellum* in the last nuragic phase; this interpretation is supported by the discovery of three blocks of lead already almost shaped for being fixed into the stones, to hold the bronze figurines and the offerings, of which some traces were left *in situ*, such as the foot still with traces of the casting channel on the sole.

In tower “*f*”, almost in front of the central tower, was found an undisturbed stratigraphy beginning from the Middle Bronze Age, in which were found other nuragic bronze artefacts; many centuries later, in Roman times, it was used as a granarium and two baskets containing grain were found there (Fadda 1985, 84-86; D’Oriano 1986).

Archaeological file 31

Oliena (Nuoro), Sa Sedda 'e Sos Carros.
(Fulvia Lo Schiavo)

The locality of Sa Sedda 'e Sos Carros is situated on the right side of the valley of Lanaittu, near the cave of Sa Oche, at the foot of the Tiscali hill. It is a wide area covered with thick vegetation in which the remains of a vast nuragic settlement can be distinguished; its exact extension cannot be ascertained on account of the destruction caused by the activities of the charcoal-burners at the beginning of XX century and that of the shepherds who constructed a large sheepfold and other structures with stones removed from the village.

The Lanaittu valley was densely populated throughout the whole Bronze Age: we know of the settlements of Su Curruttone, on an outflow of basaltic rock at the opening of the valley, that of Ruinas, destroyed by the planting of an experimental vineyard, the huts inside the first chamber of the Corbeddu cave, and the village constructed inside the karstic dolina at the top of the Tiscali hill.

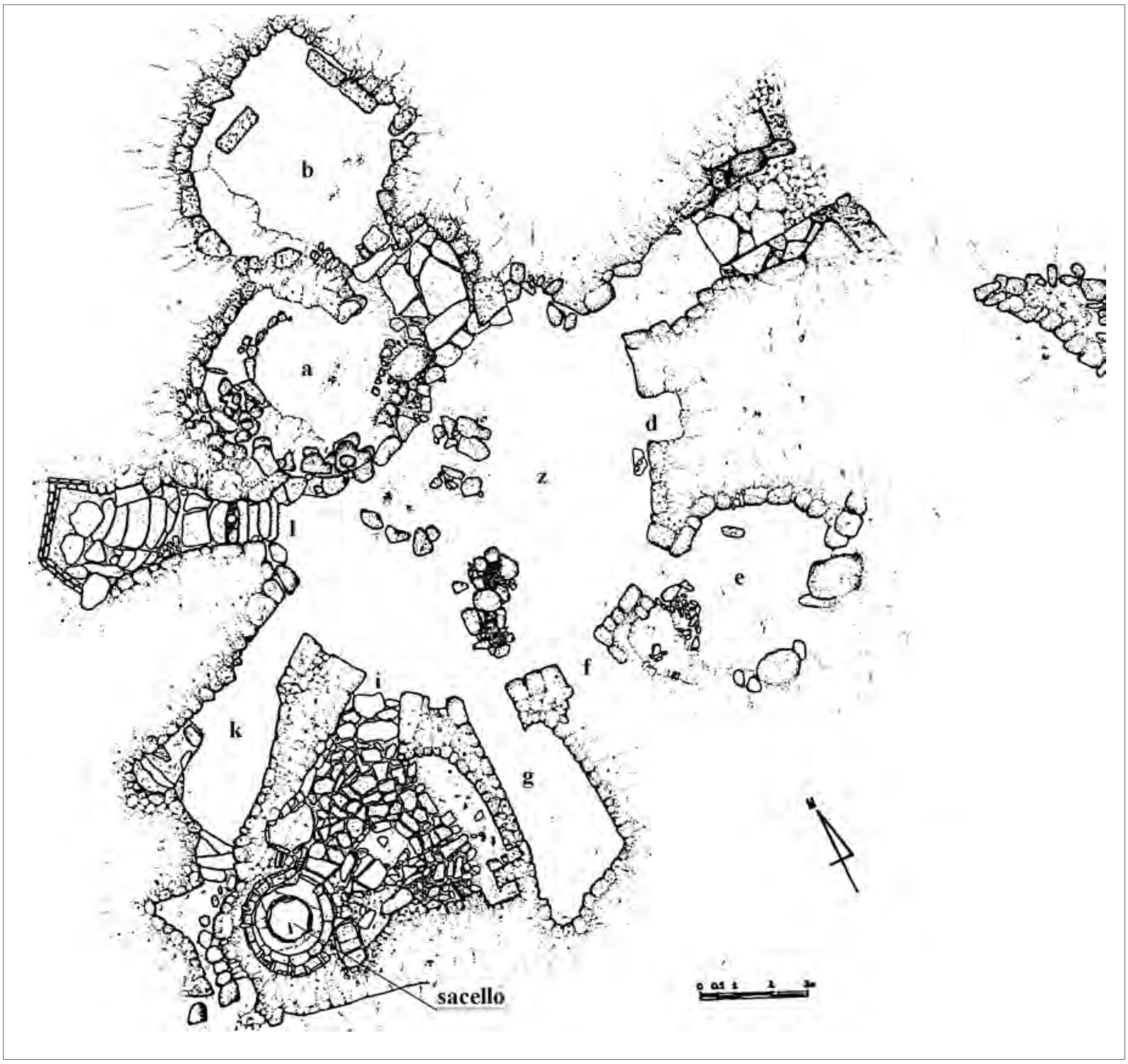


Fig. 1 - Oliena (CU), Sa Sedda `e sos Carros : general planimetry *(after Fadda 1993).*

All recesses and cavities of the two limestone walls of the valley were used for burials in the various phases of the Bronze Age, and human bones, ceramic and bronze material gathered there. They are reminiscent of the cave of Sisaia, the small cavity of Sas Furmicas and the one of Su Benticheddu; furthermore at the bottom of the valley, at the feet of the village of Carros, there is the giant's tomb of Sa Oche, in front of the mouth of the cave with the same name.

The first excavating season at the site of Sa Sedda 'e Sos Carros was in 1977, following the discovery of many bronze finds. The ground plan of a great elliptical courtyard (12 x 7 m) came to light, with the uphill rooms leaning on the limestone wall and the downhill ones delimited with high walling. Evidence of continuous use, from at least the Recent Bronze up to the Iron Age, was clear from the beginning, as was the reuse of the building blocks.

Excavations started again in 1991 and continued until 1994, alternating with the restoration of exceptional structures in the meantime brought to light. Further excavations were conducted at the beginning of this century, unfortunately alternating with serious damage. Only preliminary reports exist of all these interventions, and it cannot be said that the village has been fully explored (Lo Schiavo 1976a; 1978a, 1981; Fadda 1993; Lo Schiavo, Sanges forthcoming).

Even this rapid description shows clearly the complexity and the difficulty of interpreting the different functions that the various rooms had during the various phases of occupation.

Beginning from the great staircase "*l*", which led from the terrace uphill right inside the courtyard, and continuing clockwise, there is room "*a*", with a bench along the wall against the slope; adjacent to this is room "*b*" communicating with room "*c*" and with three steps. Then follows room "*o*", ca. 5 m in diameter and surviving for almost its whole height; to the right again is room "*d*" a large *atrium*, elliptical in shape with side walls jutting out slightly and with floor in large limestone slabs and two wide benches along the walls: this turned out to be the principal access to the great courtyard into which open all the entrances of the complex. While all that is left to see of rooms "*n*"ed "*f* " are the jambs of the entrances, room "*e*", which opens between them, was already well delineated before the works and looked out on the valley.

The great novelty of the 1990s was the discovery of an exceptional *sacellum* constructed inside room "*i*", which in turn is flanked by two other narrow rooms, "*g*" and "*k*",serving almost as access rooms. The *sacellum* corresponds to the known characteristics of nuragic architecture, such as those of the "Bread-making Room": it is therefore a small round building, a structure realized in equal courses and with circular bench along the walls, with a large basin at the centre, a big tank on the left side and two hearths at the two sides of the entrance. However, here the similarities end in that the room of Carros presents a band of parallelepiped blocks of lime-stone, with heads of ram-dripstones in relief, halfway up the isodomic facing constructed with blocks of basalt.

An extraordinary quantity of votive offerings was accumulated in the room: as well as some ten small bronze boats, complete or in fragments (Lo Schiavo 2000), an exceptional *askos* with double necks, one of which in the shape of a bull protome (Fadda 1993, fig. 28; Lo Schiavo 2002, fig. 9), a pile of pieces of raw metal heaped under the tank, etc.

The discovery of the *sacellum* renders more complex the interpretation of the functions of the site: it was initially suggested (Lo Schiavo 1976) that it was a smelting workshop, on account of the presence of much fragmented material and scraps, planoconvex ingots of copper, iron etc (Lo Schiavo 1981) (codes Hb1-Hb43; M1-M4). It still seems a plausible hypothesis that this was a place where artisan activities linked to metalworking were conducted, but evidently the exact spot has not been identified nor have the implements: remains of furnaces, tuyères, stone and clay moulds, scraps, etc.

In comparison with other "Bread-making Rooms" (*"Vani della Panificazione"*), such as are found in all large nuragic villages, and sometimes with more than one in the same village, that of Carros is much more elaborate, rich and evidently respected and venerated; in fact, although having been damaged by a powerful flood from one of the caves and karstic siphons up the hill, the *sacellum* was restored in antiquity and continued in use for several centuries, during which the nuragic offerings were left undisturbed and sometimes even on view.

Archaeological file 34

Villanovaforru (Cagliari), Genna Maria.

(Ubaldo Badas)

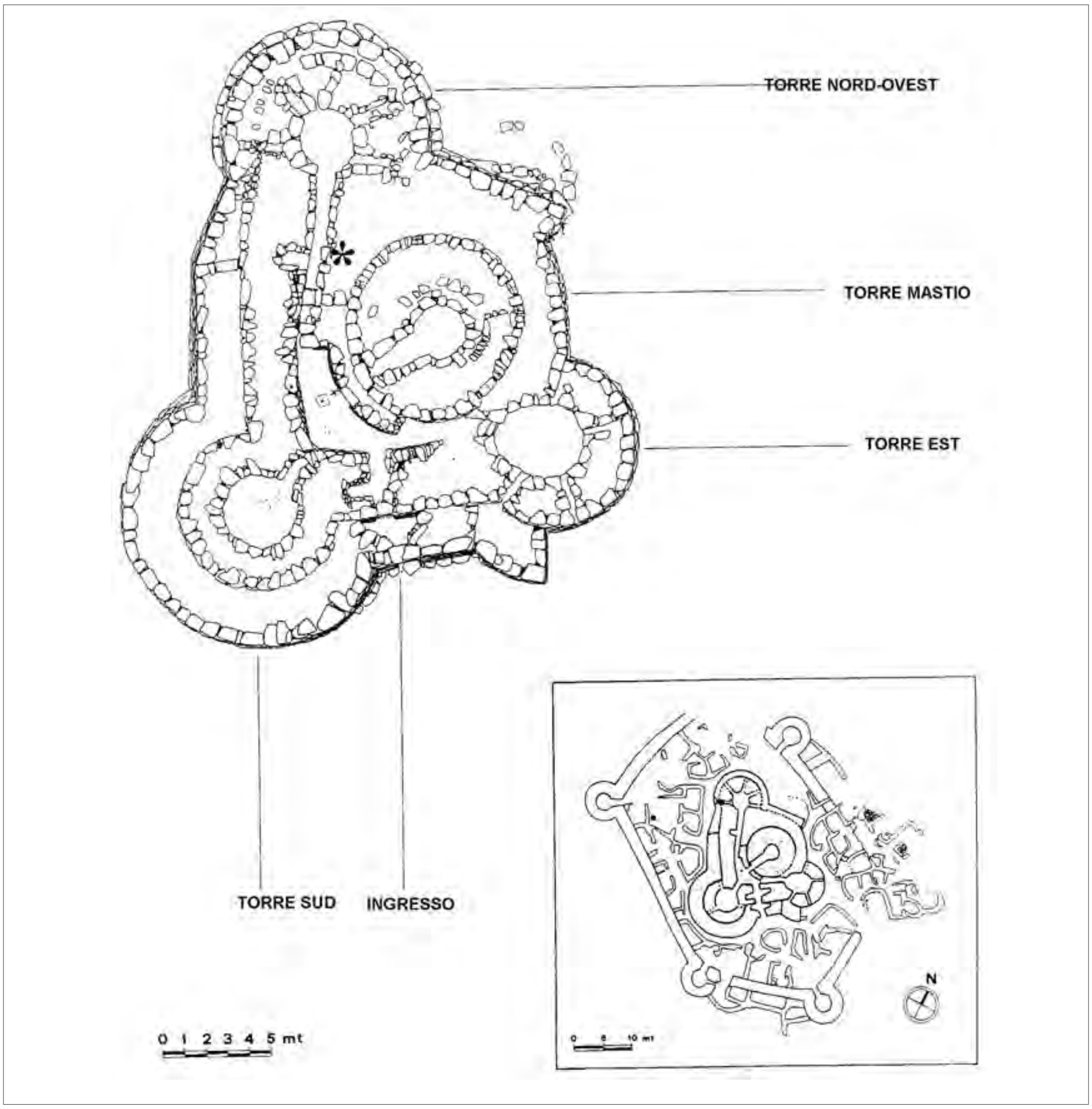


Fig. 1 -Villanovaforru (CA), nuraghe Genna Maria : planimetry *(drawn by Valentino Tuveri).*

The site has been explored in part, at the top of a hill at 408 s.l.m. The archaeological complex stands in a commanding position, which overlooks the Medio Campidano plain to the S, Marmilla from NW to SE Monte Arci and the Bay of Oristano to the W.

The excavations started in 1969 by Enrico Atzeni of the Cagliari University, were never concluded and most of the results are unpublished, except for a few preliminary observations (Badas 1987; Lilliu 1989). Part of the votive hoard discovered in the main tower and courtyard and dated to Phoenician-Roman times, was described by Lilliu C. *et al.* (1993).

The nuragic complex consists of a central tower, enclosed by a three-towered bastion, surrounded by an inner wall, and of a village, erected in later times, partly overlaying the NE curtain wall. Long stretches of the curtain wall are still standing, as is the lower part of its five towers. A large number of ceramic, stone and metallic finds, recovered from the village, were studied and dated to the Early Iron Age (9th-8th Century B.C.) The village was abandoned for unknown reasons and occupied sporadically, up until the end of the 6th Century B.C. From the end of the 4th c. B.C., until the beginning of the 7th century A.D. the site was used as a place of pre-Christian worship.

The burial places of the early settlers, who occupied the site from the Middle Bronze Age I onwards, have never been found.

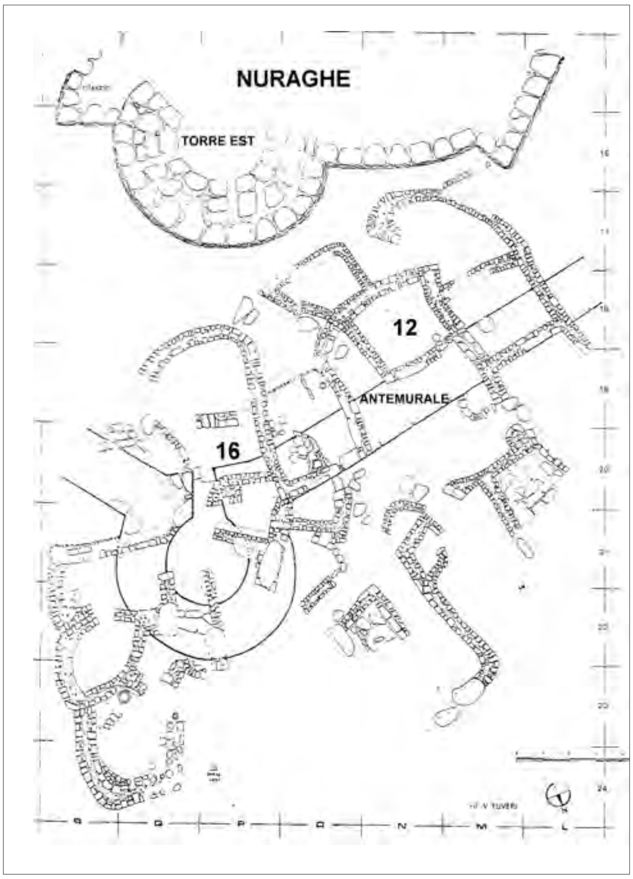


Fig. 2 - The rooms 12 and 16 of the settlement *(drawings by Valentino Tuveri).*

SW corridor of the nuraghe

A fragment of metallurgical slag with a "ferrous look" and high specific weight was found during conservation works between some boulders of the right NW corridor wall of the trilobate nuraghe. The find is of difficult interpretation, but for sure earlier than the Early Iron Age.

Room 12

Some metallic finds with an external surface of light green color were found in the room 12 of the village, sector NE.

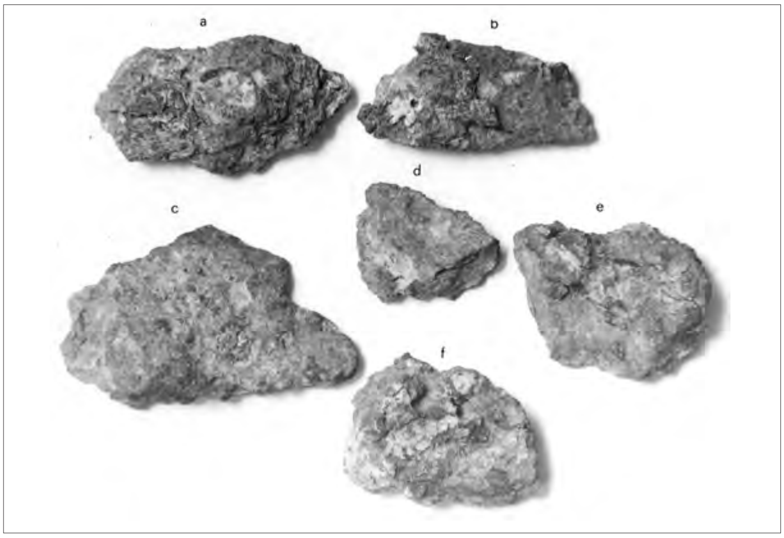
The graphic shows a plano-convex ingot (diam.10 cm), with the shape of, possibly, the bottom of a clay crucible. The finds look like a hoard for later reuse, but this never happened, because the village was abandoned.

The piece was found 08.11.1973. The analysis of the find was carried out, after request of M. Balmuth, by R.F. Tylecote, University of Newcastle/Tyne, GB, in 1983 (Tylecote *et al.* 1983). The possibility that the 6 finds might have belonged to a copper ingot was excluded, because of the high lead percentage (Pb 64 %, Cu 23 %). These are most probably remains of a faulty casting.

Next to some metallic fragments with a light green surface, on 08.11.1973, in Room 12 of the village, sector NE, a fragment with a "ferrous look" and quartz inclusions was found. The associated pottery is dated to the EIA (9^{th} – 8^{th} c. BC) (Atzeni *et alii* 1987).

Room 16

In the room 16 of the village, sector ENE, were found 5 thin, ripped or crumpled, lead sheets, with perforations along the edge. More sheets were found in uncertain stratigraphy in the same room. The associated pottery is dated to the EIA (9^{th} – 8^{th} c. BC). Unpublished.



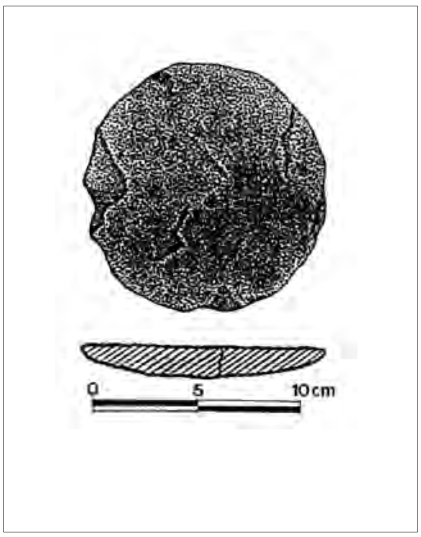


Fig. 3 -Villanovaforru (CA), Genna Maria, room 12 : 1. fragmentary plano-convex ingot *(fot. Sopr. Arch. Ca e Or)*; 2. reconstruction of 1. *(drawing by Valentino Tuveri).*

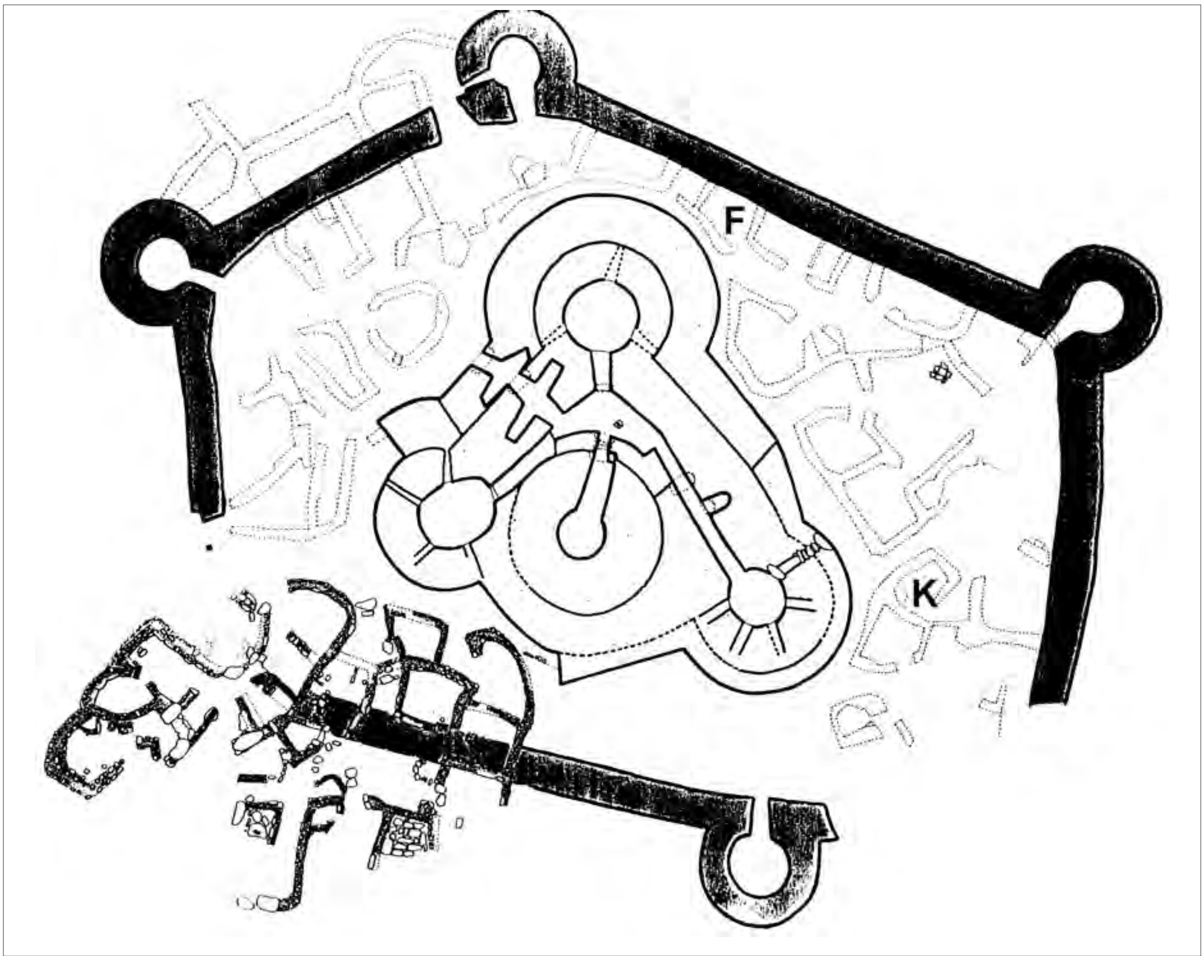


Fig. 4 -Villanovaforru (CA), Genna Maria : The Rooms F and K of the settlement *(drawing Mariano Pistis).*

Room K

During the excavations by Atzeni 1972, in the area WNW, inside the room K, next to a possible pyrotechnological area characterized by burnt clay, inside Room K, was found a small amphore with two handles, a cylindrical neck and expanded lip. On its external wall there were ferruginous concretions. More remains of the same kind were found nearby. The datation, after the pottery find, is EIA (9^{th} – 8^{th} c. BC). Unpublished.

Room F

Lead artefacts were found in the settlement, often used as repairs on pottery, also of large size, with textile imprints, or put aside for recycling in case of other repairs.

This is for example the case in Room F, along the wall SW, in which 7 pieces were found, associated with EIA pottery. The date of the find is 04.09.1972. Unpublished.

Archaeological file 35

Loculi (Nuoro), hoard in the town.

(Fulvia Lo Schiavo)

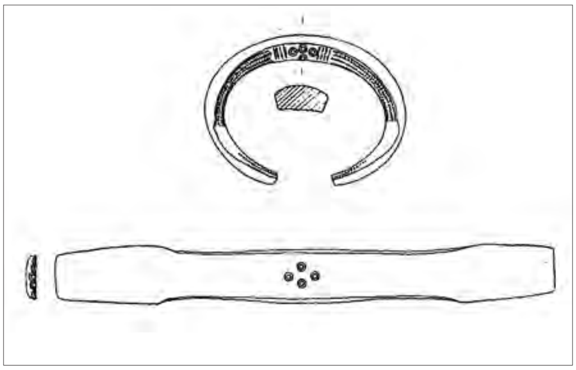


Fig. 2 - Loculi : silver bracelet *(after Moravetti 1978b).*

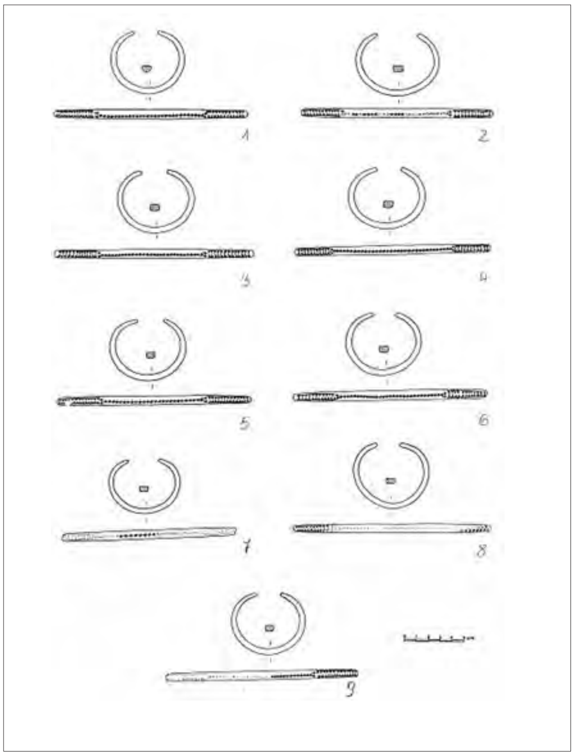


Fig. 2 - Loculi : nine bronze bracelets from the hoard *(after Lo Schiavo 1981).*

"From a single hoard, consisting of an *impasto* vase found by chance in the courtyard of a house in Loculi come nine bronze bracelets (nos 6-14) and one of silver (no. 16), all the elements in vitreous paste of a necklace and twenty-six Phoenician and Sardo-Phoenician coins,…." ("*Da un unico ripostiglio, costituito da un vaso d'impasto rinvenuto casualmente nel cortile di un'abitazione di Loculi, provengono nove braccialetti di bronzo (nn.6-14) ed uno d'argento (n.16), tutti gli elementi in pasta vitrea di una collana e ventisei monete puniche e sardo-puniche, …*") (Moravetti 1978, 141).

The nine bracelets of bronze are of bronze rod, an open ellipse in shape and with planoconvex cross-section, decorated on the back with a "running dog"("*cane corrente*") motif at the centre and two areas of small triangles opposite each other, filled in with little rings at the ends (Lo Schiavo 1974, 549 fig.4b; 1981 fig.347; Moravetti 1978b, 142, 144-5 nos. 6-14).

The silver bracelet (code O4) is very similar in shape and identical in decoration to that found in the abyss of Ispinigoli, Dorgali (Moravetti 1978, 138, no.18, pl. XLVII,7; Lo Schiavo 1981, fig. 348; in press 2, fig. 11,12); its shape is an open ellipse, similar to the bronze examples, but thicker, and is decorated on the upper and lower borders with a herring-bone motif, alternating with rings, and with a cruciform motif with circles on the inside (diam. cm 6,9 x 5,5 x 1,9) (Lo Schiavo 1974, 549, fig. 4a; Moravetti 1978a, 146, no.16; Cincotti, Massidda, Sanna, Lo Schiavo 1998, 192, fig. 1)[(1)].

Both these large bracelets of solid silver, one found in the hoard of Loculi (fig. 11, 11) and another in the abyss of Ispinigoli, Dorgali (Moravetti 1978a, 138 no.18 tab.XLVII,7; Lo Schiavo 1981 fig. 348; in press fig.11,12), are of the same type as a third one from Irgoli too (Pais 1881 p. 378 no.4 tab. VI; Fois 2000, 132 no. 65), housed in the Museo Sanna, together with a fourth. The last bracelet is given dubiously as coming from Telti (?), but perhaps this is from Irgoli too, because, like the third one, it is decorated with a plait and not a herring bone design like the other two (Fois 2000, 132 no. 66).

Although the associations of the first two are not decisive for the dating since Phoenician and Sardo-Phoenician coins also were present at Loculi and since Ispinigoli cannot be called a closed context, we can but hypothesize that these bracelets are of nuragic production on the basis of the affinities in shape and decoration with the bronze examples, even though they are not exactly identical (Moravetti 1978, 136-8, nos. 1-16, tab. XLVII,1 and 4, XLVIII,1-8).

1. Sometimes, in the former bibliography, "Orosei" is indicated as a provenance (see Lo Schiavo 1974; Cincotti, Massidda, Sanna, Lo Schiavo 1998, *contra* see Lo Schiavo 1981), because the hoard from Loculi was kept at Orosei, in the Cabras Collection.

Archaeological file 36

Orgosolo (Nuoro), Su Gorroppu.
(Fulvia Lo Schiavo)

In the summer of 1988, during a speleological expedition in the Supramonte di Urzulei-Orgosolo, numerous archaeological finds from the nuragic and Roman ages were found on the surface and in a landslide in front of the entrance of a small cave, frequented by animals.

Since in the course of the expedition numerous excavations, presumably illegal, had been noted in nuraghi encountered along the path, Gorroppu, Flumineddu–Titione, and in the village of Donnarigoro, the finds were collected with the intention of handing them over to the competent authorities and provisionally stored in the premises of the soon-to-be-constituted Museo Civico di Scienze Naturali of Faenza; the Soprintendenza Archeologica per l'Emilia-Romagna was swiftly advised, and saw that the Soprintendenza Archeologica per le Provincie di Sassari e Nuoro was informed.

Finally in November 1988 the finds were handed back and since then have been housed in the Museo Speleo-Archeologico of Nuoro.

The speleologists from Faenza, the effective discoverers, had reported removing detritus in order to widen the passage which led into another perhaps vaster cavity; in the course of this the archaeological material came to light. The indications of stratigraphic positioning have not been lost, and this is of great value for the interpretation of the context. The material is very heterogeneous, both for the typology of the objects and for their cultural attribution (Sanges 1993).

The bronze artefacts date to the nuragic age: a small flanged axe, a fragment of amulet in the form of a small gamma-hilted dagger, 5 small daggers of various types, a large pin of the type with mobile head (but the head is missing) and two more pin shafts or awls, a herring-bone decorated wheel with thirteen spokes.

9 small fragments of bronze rod, circular in cross-section, may belong to the same cultural milieu; these could be rivets of swords or daggers, and in fact all have one beaten end.

It is not difficult to ascribe to nuragic production the 13 fragments of lead: nodules, remains of clamps, bits of molten lead for fastening bronze offerings, and in fact in one of them remains a fragment of votive sword.

However, of uncertain attribution are a simple ring in bronze rod, circular in cross-section, 3 small cylinders of bronze sheet wrapped round and decorated with groups of incised round dashes, a spring with 6 turns and the two ends flattened, and three rivets.

Three small pieces of silver sheet are from the Hellenistic period (codes O7-O11), with stem and decorated with cut-out toothed design and incised herring-bone pattern. A pair of similar examples, still unpublished, were found near the nuraghe Adoni of Villanovatulo, in a complex of material probably forming part of a hoard hidden in the upper part of the structure (Sanges 2000, 489); another "leaf" of gold, perhaps from a Hellenistic crown, was found in the votive deposit of the nuraghe Genna Maria of Villanovaforru (Lilliu C. 1993, 31, fig. 11).

62 coins of the Roman Empire date from II to V century AD (Guido 1995).

Given the conditions in which the discovery was made, it is practically impossible to reconstruct the nature of the deposit without investigating by way of archaeological excavation. The material, however, almost all accords with a votive deposit of long duration.

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List of analysed finds

(total number of finds: 261)

A – Copper artefacts (no. 6)

Code	Archeological file nos.	Inventory number	Metal	Type	Provenance	Analytical methods
A1	N. 3	N. 2	Copper	Dagger blade	Su Motti or Su Monti Orroli (NU)	EDS
A2	N. 7	N. 5	Copper	Dagger blade	Murisiddi Isili (NU)	EDS
A3	N. 7	N. 6	Copper	Dagger blade	Murisiddi Isili (NU)	EDS
A4	N. 13	N. 11	Copper	Dagger blade	Ottana (NU)	EDS AAS
A5	N. 13	N. 12	Copper	Dagger blade	Ottana (NU)	EDS
A6	N. 13	N. 22	Copper	Spearbutt	Ottana (NU)	EDS, AAS ICP-MS

B – Arsenical copper artefacts (no. 11)

Code	Archeological file nos.	Inventory number	Metal	Type	Provenance	Analytical methods
B1	N. 9		Copper + Arsenic	Sword blade	Maracalagonis (CA)	Met., AAS ICP-MS, H.
B2	N. 2	N. 1	Copper + Arsenic	Sword blade	Janna Ventosa (NU)	SEM + EDS AAS
B3	N. 10	N. 7	Copper + Arsenic	Dagger blade	Sa Turricula Muros (NU)	SEM + EDS
B4	N. 6	N. 8	Copper + Arsenic	Dagger blade	Frommosa Villanovatulo (NU)	SEM + EDS ICP-MS, H.
B5	N. 6	N. 9	Copper + Arsenic	Dagger blade	Frommosa Villanovatulo (NU)	SEM + EDS
B6	N. 8	N. 408	Copper + Arsenic	Sword blade	S. Iroxi Decimoputzu (CA)	EDS
B7	N. 8	N. 497	Copper + Arsenic	Sword blade	S. Iroxi Decimoputzu (CA)	Met., AAS,ICP-MS, H., EDS
B8	N. 8	N. 498	Copper + Arsenic	Sword blade	S. Iroxi Decimoputzu (CA)	Met., EDS
B9	N. 8	N. 499	Copper + Arsenic	Sword blade	S. Iroxi Decimoputzu (CA)	EDS
B10	N. 8	N. 501	Copper + Arsenic	Sword blade	S. Iroxi Decimoputzu (CA)	EDS
B11	N. 8	N. 502	Copper + Arsenic	Sword blade	S. Iroxi Decimoputzu (CA)	Met., EDS

C – The earliest bronze artefacts (no. 5)

Code	Archeological file nos.	Inventory number	Alloy	Type	Provenance	Analytical methods
C1	N. 4	N. 3	Bronze	*Spatula* (?)	M. Baranta Olmedo (NU)	AAS
C2	N. 13	N. 15	Bronze	Dagger blade	? Ottana (NU)	SEM + EDS AAS
C3	N. 13	N. 16	Bronze	Dagger blade	? Ottana (NU)	AAS
C4	N. 13	N. 17	Bronze	Dagger blade	? Ottana (NU)	AAS SEM + EDS
C5	N. 13	N. 18	Bronze	Dagger blade	? Ottana (NU))	AAS

D- Hoard of copper fragments (no. 31)

Code	Archeological file nos.	Inventory number	Metal	Type	Provenance	Analytical methods
Da1	26	BS 2	Copper	oxhide ingot fragment	Baccus Simeone Villanovaforru (CA)	AAS ICP-MS
Da2	26	BS 3	Copper	oxhide ingot fragment	Baccus Simeone Villanovaforru (CA)	AAS ICP-MS
Da3	26	BS 24	Copper, impure	Type ? fragment	Baccus Simeone Villanovaforru (CA)	AAS EPMA
Da4	26	BS 26	Copper	Bun ingot fragment	Baccus Simeone Villanovaforru (CA)	AAS EPMA
Da5	26	BS 30	Copper	Bun ingot fragment	Baccus Simeone Villanovaforru (CA)	AAS
Da6	26	BS 35	Copper, impure	Scrap	Baccus Simeone Villanovaforru (CA)	AAS
Da7	26	BS 54	Copper, impure	Scrap	Baccus Simeone Villanovaforru (CA)	AAS EPMA
Da8	26	BS 60/12	Copper, impure	Scrap	Baccus Simeone Villanovaforru (CA)	AAS EPMA
Da9	26	BS 60/15	Copper, impure	Scrap	Baccus Simeone Villanovaforru (CA)	AAS
Da10	26	BS 60/20	Copper and iron	Scrap or Matte ?	Baccus Simeone Villanovaforru (CA)	AAS EPMA
Da11	26	BS 60/32	Copper, impure	Scrap	Baccus Simeone Villanovaforru (CA)	AAS
Da12	26	a	Copper	Sheet frg.	Baccus Simeone Villanovaforru (CA)	AAS

Code	Archeological file nos.	Inventory number	Metal	Type	Provenance	Analytical methods
Da13	26	b	Copper	Sheet frg.	Baccus Simeone Villanovaforru (CA)	AAS
Da14	26	c	Bronze	Votive sword frg.	Baccus Simeone Villanovaforru (CA)	AAS
Da15	26	d	Copper	Sheet frg.	Baccus Simeone Villanovaforru (CA)	AAS
Da16	26	g	Copper	Sheet frg.	Baccus Simeone Villanovaforru (CA)	AAS
Da17	26	l	Copper and lead	oxhide ingot frg.	Baccus Simeone Villanovaforru (CA)	AAS
Db1	21	Bar 1	Copper	Ingot (?) frg.	Baradili (OR)	AAS ICP-MS
Db2	21	Bar 2	Copper	Ingot (?) frg.	Baradili (OR)	AAS ICP-MS
Db3	21	Bar 3	Copper	Ingot (?) frg.	Baradili (OR)	AAS ICP-MS
Db4	21	Bar 4	Copper	oxhide ingot frg.	Baradili (OR)	AAS ICP-MS
Db5	21	Bar 5	Copper	Ingot (?) frg.	Baradili (OR)	AAS ICP-MS
Db6	21	Bar 6	Copper	Ingot (?) frg.	Baradili (OR)	AAS ICP-MS
Db7	21	Bar 7	Copper	Ingot (?) frg.	Baradili (OR)	AAS ICP-MS
Db8	21	Bar 8	Copper	Ingot (?) frg.	Baradili (OR)	AAS ICP-MS
Db9	21	Bar 9	Copper	Ingot (?) frg.	Baradili (OR)	AAS ICP-MS
Db10	21	Bar 10	Copper	Ingot (?) frg.	Baradili (OR)	AAS ICP-MS
Db11	21	Bar 11	Copper	Ingot (?) frg.	Baradili (OR)	AAS ICP-MS
Db12	21	Bar 12	Copper	Ingot (?) frg.	Baradili (OR)	AAS ICP-MS
Db13	21	Bar 13	Copper	Ingot (?) frg.	Baradili (OR)	AAS ICP-MS
Db14	21	Bar 14	Copper	Ingot (?) frg.	Baradili (OR)	AAS ICP-MS

E- Copper slags and metalworking scraps (no. 5)

Code	Archeological file nos.	Inventory number	Metal-Material	Type	Provenance	Analytical methods
E1	34	Corr. NW wall	Copper, oxides, silicates	Slag	Genna Maria Villanovaforru (CA)	AAS, EPMA, XRD
E2	34	room 12,1	Lead and copper	Foundry scrap	Genna Maria Villanovaforru (CA)	AAS, EPMA, XRD
E3	34	room 12,2	Copper, impure	Foundry scrap	Genna Maria Villanovaforru (CA)	AAS, EPMA, XRD
E4	34	room k	Copper, silicates	Foundry scraps	Genna Maria Villanovaforru (CA)	XRD, Met.
E5	34	atrium Hut no. 6	Copper, oxides, silicates	Slag	Bruncu Madugui Gesturi (CA)	XRD EPMA

F- Bronze artefacts from Pinn'e Maiolu, Villanovaforru (no. 2)

Code	Archeological file nos.	Inventory number	Metal	Type	Provenance	Analytical methods
F1	25		Bronze	Blade with serration	Pinn'e Maiolu (CA)	AAS, Met.
F2	25		Bronze	Sickle blade	Pinn'e Maiolu (CA)	AAS, ICP-MS, Met.

Ha- nuragic foundries ? S. Barbara, Bauladu; clay and copper finds (no. 38)

Code	Archeological file nos.	Inventory number	Material	Type	Provenance	Analytical methods
Ha1	29		Clay	Crucible sherd	S. Barbara Bauladu (OR)	
Ha2	29	1326	Clay	Crucible sherd	S. Barbara Bauladu (OR))	AAS, XRD, Petr.
Ha3	29	A 160/162	Clay	Crucible sherd	S. Barbara Bauladu (OR)	
Ha4	29	A 167	Clay	Crucible sherd	S. Barbara Bauladu (OR))	
Ha5	29	A 105	Clay	Pouring cup and runners	S. Barbara Bauladu (OR)	
Ha6	29	A 118 + C 52	Clay	Pouring cup, runners, core	S. Barbara Bauladu (OR)	XRD, Petr.
Ha7	29	A 101, A 194, A 119, etc.	Clay	Cores	S. Barbara Bauladu (OR)	XRD, Petr.

Code	Archeological file nos.	Inventory number	Material	Type	Provenance	Analytical methods
Ha8	29	C 683B	Clay	Mould sherd	S. Barbara Bauladu (OR)	
Ha9	29	A 106 and 197	Clay	Cruet-like	S. Barbara Bauladu (OR))	AAS
Ha10	29	C 21	Copper	Scrap	S. Barbara Bauladu (OR)	AAS
Ha11	29	C 29 50-60	Copper	Scrap	S. Barbara Bauladu (OR))	AAS
Ha12	29	C 29 50-60b	Copper	Scrap	S. Barbara Bauladu (OR)	AAS
Ha13	29	C 47-40	Bronze	Scrap	S. Barbara Bauladu (OR)	AAS
Ha14	29	C 29 30-44	Bronze	Scrap	S. Barbara Bauladu (OR)	AAS
Ha15	29	C 59 livello 2A 65 cm	Copper	Bar fragment	S. Barbara Bauladu (OR)	AAS
Ha16	29	C 47 40 a pav. AMB IBP 3A	Bronze	Shapeless debris	S. Barbara Bauladu (OR)	AAS ICP-MS
Ha17	29	come B1	Bronze	Shapeless debris	S. Barbara Bauladu (OR)	AAS
Ha18	29	C 29 AMB4 40-50 3A SB87	Bronze	Dagger blade fragment	S. Barbara Bauladu (OR)	AAS
Ha19	29	come C1	Bronze	Shapeless debris	S. Barbara Bauladu (OR)	AAS
Ha20	29	AMB 3 C11 10-20 1B	Bronze	Rivet, hook-like	S. Barbara Bauladu (OR)	AAS
Ha21	29	AMB 2 C1 30-40 2B	Bronze	Pierced sheet fragment	S. Barbara Bauladu (OR)	AAS ICP-MS
Ha22	29	C17 60 ROS-SO 4A AMB ICP	Bronze	Shapeless debris	S. Barbara Bauladu (OR)	AAS ICP-MS
Ha23	29	C17 20-30 2A AMB ICP	Bronze	Pierced sheet fragment	S. Barbara Bauladu (OR)	AAS ICP-MS
Ha24	29	C17 60 ROS-SO 4A AMB ICP	Bronze	Rivet	S. Barbara Bauladu (OR)	AAS
Ha25	29	C25 30-40 2B AMB ICP SB 86	Bronze	Beads coil-like	S. Barbara Bauladu (OR)	AAS
Ha26	29	SB 87 C25 50-60 LIV 3B AMB 4	Bronze	Shapeless debris	S. Barbara Bauladu (OR)	AAS
Ha27	29	C40 0-10 1A AMB IAP	Bronze	Shapeless debris	S. Barbara Bauladu (OR)	AAS ICP-MS
Ha28	29	C68 3B (-255) AMB7	Bronze	Shapeless debris	S. Barbara Bauladu (OR)	AAS ICP-MS

Code	Archeological file nos.	Inventory number	Material	Type	Provenance	Analytical methods
Ha29	29	C 68 4AMB 7 29-8-88	Bronze	Shapeless debris	S. Barbara Bauladu (OR)	AAS
Ha30	29	C 68 LIV 2A AMB 7	Bronze	Rivet, hook-like	S. Barbara Bauladu (OR))	AAS
Ha31	29	C 73 1M LIV INIZ 1.M.1 AMB 9-30	Bronze	wire	S. Barbara Bauladu (OR)	AAS
Ha32	29	SB 87 C47 30-40	Bronze	Shapeless debris	S. Barbara Bauladu (OR))	AAS
Ha33	29	C29 50-60	Bronze	Shapeless debris	S. Barbara Bauladu (OR)	AAS
Ha34	29		Bronze	Shapeless debris	S. Barbara Bauladu (OR)	AAS
Ha35	29	C 21 ROSSO-PAV	Bronze	Shapeless debris	S. Barbara Bauladu (OR)	AAS
Ha36	29	C47 40 a pavimento	Bronze	Shapeless debris	S. Barbara Bauladu (OR)	AAS
Ha37	29		Bronze	Shapeless debris	S. Barbara Bauladu (OR)	AAS
Ha38	29	C 19E - 190 cm 3B AMB 11	Bronze	Shapeless debris	S. Barbara Bauladu (OR)	AAS

Hb- nuragic foundries ? Sa Sedda’e Sos Carros, Oliena; copper finds (no. 43)

Code	Archeological file nos.	Inventory number	Material	Type	Provenance	Analytical methods
Hb1	31	41202	Bronze	Sheet fragment	Sa Sedda’e Sos Carros Oliena (NU)	AAS
Hb2	31	41198	Bronze	Spearhead	Sa Sedda’e Sos Carros Oliena (NU)	AAS ICP-MS
Hb3	31	41287/6	Bronze	Twisted wire	Sa Sedda’e Sos Carros Oliena (NU)	AAS
Hb4	31	58950	Bronze	Sheet fragment	Sa Sedda’e Sos Carros Oliena (NU)	AAS
Hb5	31	41095	Bronze	Band	Sa Sedda’e Sos Carros Oliena (NU)	AAS
Hb6	31	41201	Bronze	Sheet fragment	Sa Sedda’e Sos Carros Oliena (NU)	AAS ICP-MS
Hb7	31	41203	Bronze	Sheet thick fragment	Sa Sedda’e Sos Carros Oliena (NU)	AAS

Code	Archeological file nos.	Inventory number	Material	Type	Provenance	Analytical methods
Hb8	31	0L2	Bronze	Bun ingot fragment	Sa Sedda'e Sos Carros Oliena (NU)	AAS
Hb9	31	41210	Bronze	Spearhead plug	Sa Sedda'e Sos Carros Oliena (NU)	AAS ICP-MS
Hb10	31	41153	Copper	Spearhead point	Sa Sedda'e Sos Carros Oliena (NU)	AAS
Hb11	31	41063	Copper	Axe fragment	Sa Sedda'e Sos Carros Oliena (NU)	AAS ICP-MS
Hb12	31	41091	Copper	Pin	Sa Sedda'e Sos Carros Oliena (NU)	AAS
Hb13	31	41187	Bronze	Votive sword tang	Sa Sedda'e Sos Carros Oliena (NU)	AAS
Hb14	31	41464	Bronze	Spearhead	Sa Sedda'e Sos Carros Oliena (NU)	AAS
Hb15	31	41475	Copper	Bun ingot frg.	Sa Sedda'e Sos Carros Oliena (NU)	AAS
Hb16	31	41262	Bronze	Casting scrap	Sa Sedda'e Sos Carros Oliena (NU)	AAS
Hb17	31	41262 2°	Bronze	Casting scrap	Sa Sedda'e Sos Carros Oliena (NU)	AAS
Hb18	31	41019	Bronze	Sheet thick fragment	Sa Sedda'e Sos Carros Oliena (NU)	AAS
Hb19	31	41004	Bronze	Casting scrap	Sa Sedda'e Sos Carros Oliena (NU)	AAS ICP-MS
Hb20	31	40993	Bronze	Sword tang fragment	Sa Sedda'e Sos Carros Oliena (NU)	AAS
Hb21	31	40989	Copper	Thick ring fragment	Sa Sedda'e Sos Carros Oliena (NU)	AAS
Hb22	31	40995	Bronze	Bull head figurine	Sa Sedda'e Sos Carros Oliena (NU)	AAS
Hb23	31	58995	Copper	Scrap	Sa Sedda'e Sos Carros Oliena (NU)	AAS
Hb24	31	1579/80	Bronze	Scrap	Sa Sedda'e Sos Carros Oliena (NU)	AAS
Hb25	31	41418	Bronze	Votive sword fragment	Sa Sedda'e Sos Carros Oliena (NU)	AAS
Hb26	31	41441	Bronze	Spearhead	Sa Sedda'e Sos Carros Oliena (NU)	AAS
Hb27	31	1567/80	Copper	Bun ingot fragment	Sa Sedda'e Sos Carros Oliena (NU)	AAS
Hb28	31	41048	Bronze	Sheet fragment	Sa Sedda'e Sos Carros Oliena (NU)	AAS

Code	Archeological file nos.	Inventory number	Material	Type	Provenance	Analytical methods
Hb29	31	26692	Copper	“Maleppeggio” fragment	Sa Sedda’e Sos Carros Oliena (NU)	AAS
Hb30	31	59019	Copper	Rivet	Sa Sedda’e Sos Carros Oliena (NU)	AAS
Hb31	31	41086	Bronze	Sheet fragment	Sa Sedda’e Sos Carros Oliena (NU)	AAS
Hb32	31	4N/A	Bronze	Scrap	Sa Sedda’e Sos Carros Oliena (NU)	AAS
Hb33	31	4N/B	Copper	Scrap	Sa Sedda’e Sos Carros Oliena (NU)	AAS ICP-MS
Hb34	31	4N/D	Bronze	Scrap	Sa Sedda’e Sos Carros Oliena (NU)	AAS
Hb35	31	59018	Copper	Point	Sa Sedda’e Sos Carros Oliena (NU)	AAS
Hb36	31	59013	Bronze	Sheet fragment	Sa Sedda’e Sos Carros Oliena (NU)	AAS
Hb37	31	59014	Bronze	Sheet fragment	Sa Sedda’e Sos Carros Oliena (NU)	AAS
Hb38	31	59015	Copper	“L-shaped” fragment	Sa Sedda’e Sos Carros Oliena (NU)	AAS ICP-MS
Hb39	31	41073	Bronze	Axe fragment	Sa Sedda’e Sos Carros Oliena (NU)	AAS
Hb40	31	41077	Bronze	“Maleppeggio” fragment	Sa Sedda’e Sos Carros Oliena (NU)	AAS
Hb41	31	41154	Bronze	Casting scrap	Sa Sedda’e Sos Carros Oliena (NU)	AAS
Hb42	31	41161	Bronze	Boat figurine fragment	Sa Sedda’e Sos Carros Oliena (NU)	AAS
Hb43	31	41167	Bronze	Rectangular handle	Sa Sedda’e Sos Carros Oliena (NU)	AAS

Hc- nuragic foundries ? S. Antiogu, Villanovaforru (no. 3)

Code	Archeological file nos.	Inventory number	Material	Type	Provenance	Analytical methods
Hc1	28		Stone	Thermally alte-red stone piece	S. Antiogu Villanovaforru (CA)	XRD, Thermal analysis
Hc2	28		Stone	Thermally alte-red stone piece	S. Antiogu Villanovaforru (CA)	XRD
Hc3	28		Stone	Thermally alte-red stone piece	S. Antiogu Villanovaforru (CA)	XRD, SMO

I- Bronze figurines, *bronzetti* (no. 12)

Code	**Archeological file nos.**	**Inventory number**	**Material**	**Type**	**Provenance**	**Analytical methods**
I1		84 warrior	Bronze	Figurine	unknown	AAS, Met., ICP-MS
I2	17	110 demon	Bronze	Figurine	Abini Teti (NU)	AAS, ICP-MS
I3	17	98 warrior	Bronze	Figurine	Abini Teti (NU)	AAS, Met., ICP-MS
I4	17	104 hero	Bronze	Figurine	Abini Teti (NU)	AAS, Met., ICP-MS
I5	17	121 worshipping woman	Bronze	Figurine	Abini Teti (NU)	AAS, Met., ICP-MS
I6	17	128 warrior	Bronze	Figurine	Abini Teti (NU)	AAS, Met., ICP-MS
I7	17	116 worshipper	Copper and silver	Figurine	Abini Teti (NU)	AAS, EPMA Met., ICP-MS
I8		163 offering figure	Bronze	Figurine	unknown	AAS, Met., ICP-MS
I9	17	207 ox	Bronze	Figurine	Abini Teti (NU)	AAS, Met., ICP-MS
I10	17	216 yoked oxen	Bronze + lead	Figurine	Abini Teti (NU)	AAS, Met., ICP-MS
I11		144 woman	Bronze	Figurine	unknown	AAS, Met., ICP-MS
I12		145 priestess	Bronze	Figurine	unknown	AAS, Met., ICP-MS

L- Fake bronze figurines (no. 33)

Code	**Archeological file nos.**	**Inventory number**	**Material**	**Type**	**Provenance**	**Analytical methods**
L1		idol s.f. N. 1	Bronze +Pb + Zn	Figurine	unknown	AAS
L2		idol s.f. N. 2	Bronze +Pb + Zn	Figurine	unknown	AAS
L3		idol s.f. N. 3	Bronze +Pb + Zn	Figurine	unknown	AAS
L4		idol s.f. N. 4	Bronze +Pb + Zn	Figurine	unknown	AAS
L5		idol s.f. N. 5	Bronze +Pb + Zn	Figurine	unknown	AAS

Code	Archeological file nos.	Inventory number	Material	Type	Provenance	Analytical methods
L6		idol s.f. N. 6	Bronze +Pb + Zn	Figurine	unknown	AAS
L7		idol s.f. N. 7	Bronze +Pb + Zn	Figurine	unknown	AAS
L8		idol s.f. N. 8	Bronze +Pb + Zn	Figurine	unknown	AAS
L9		idol s.f. N. 9	Bronze +Pb + Zn	Figurine	unknown	AAS
L10		idol s.f. N. 10	Bronze +Pb + Zn	Figurine	unknown	AAS
L11		idol s.f. N. 11	Bronze +Pb + Zn	Figurine	unknown	AAS
L12		idol s.f. N. 12	Bronze +Pb + Zn	Figurine	unknown	AAS
L13		idol s.f. N. 13	Bronze +Pb + Zn	Figurine	unknown	AAS
L14		idol s.f. N. 14	Bronze +Pb + Zn	Figurine	unknown	AAS
L15		idol s.f. N. 15	Bronze +Pb + Zn	Figurine	unknown	AAS
L16		idol s.f. N. 16	Bronze +Pb + Zn	Figurine	unknown	AAS
L17		idol s.f. N. 17	Bronze +Pb + Zn	Figurine	unknown	AAS
L18		idol s.f. N. 18	Bronze +Pb + Zn	Figurine	unknown	AAS
L19		idol s.f. N. 19	Bronze +Pb + Zn	Figurine	unknown	AAS
L20		idol s.f. N. 20	Bronze +Pb + Zn	Figurine	unknown	AAS
L21		idol s.f. N. 21	Bronze +Pb + Zn	Figurine	unknown	AAS
L22		idol s.f. N. 22	Bronze +Pb + Zn	Figurine	unknown	AAS
L23		idol s.f. N. 23	Bronze +Pb + Zn	Figurine	unknown	AAS
L24		idol s.f. N. 24	Bronze +Pb + Zn	Figurine	unknown	AAS
L25		idol s.f. N. 25	Bronze +Pb + Zn	Figurine	unknown	AAS
L26		idol s.f. N. 26	Bronze +Pb + Zn	Figurine	unknown	AAS

Code	Archeological file nos.	Inventory number	Material	Type	Provenance	Analytical methods
L27		idol s.f. N. 27	Bronze +Pb + Zn	Figurine	unknown	AAS
L28		idol s.f. N. 28	Bronze +Pb + Zn	Figurine	unknown	AAS
L29		idol s.f. N. 29	Bronze +Pb + Zn	Figurine	unknown	AAS
L30		idol s.f. N. 30	Bronze +Pb + Zn	Figurine	unknown	AAS
L31		idol s.f. N. 31	Bronze +Pb + Zn	Figurine	unknown	AAS
L32		idol s.f. N. 32	Brass + Sn	Figurine	unknown	EDS
L33		idol s.f. N. 33	Brass + Sn	Figurine	unknown	EDS

M- The beginnings of iron metallurgy in Sardinia ? (no. 5)

Code	Archeological file nos.	Inventory number	Material	Type	Provenance	Analytical methods
M1	31	59024 "paletta"	Iron	*Spatula*, shovel ?	Sa Sedda'e Sos Carros Oliena (NU)	AAS, SEM+EDS, Met., ICP-MS
M2	31	non inv. (c.r.)	Cast iron and copper	Slag	Sa Sedda'e Sos Carros Oliena (NU)	AAS, Met.+H., XRD, SEM+EDS, ICP-MS
M3	31	non inv.	Iron, lead, oxides	Slag	Sa Sedda'e Sos Carros Oliena (NU)	AAS, ICP-MS, XRD
M4	31	58963 "rod"	Iron oxides	Pin	Sa Sedda'e Sos Carros Oliena (NU)	AAS
M5	31		Iron oxides	Plate	Antigorri, Sarroch (CA)	AAS

N- Lead (no. 52)

Code	Archeological file nos.	Inventory number	Material	Type	Provenance	Analytical methods
Na1	29	SB87 C44 30-40 2B AMB 4 nord del muro	Lead	Clamp	S. Barbara, Bauladu (OR)	SSA, Met., EDS, IPC-MS
Na2	29	C68 3A	Lead	Sheet fragment	S. Barbara, Bauladu (OR)	AAS, Met., EDS, ICP-MS
Na3	29	SB87 A29 C44 30-40	Lead	Wedge-like	S. Barbara, Bauladu (OR)	AAS, ICP-MS
Na4	29	C 101 2A 30 cm	Lead	Bar	S. Barbara, Bauladu (OR)	AAS, ICP-MS
Na5	29	C64 3B Lead Ingot, AMB ?	Lead	Deformed clamp	S. Barbara, Bauladu (OR)	AAS, ICP-MS
Na6	29	C67 2A AMB 7 SE	Lead	Bar	S. Barbara, Bauladu (OR)	AAS, ICP-MS
Na7	29	C3 40+6 pav. level 3B AMB ICP Pb07	Lead	Molten splash	S. Barbara, Bauladu (OR)	AAS, ICP-MS
Na8	29	SB C17 AMB ICP Rosso 60 lev. 4a Pb08	Lead	Rolled sheet	S. Barbara, Bauladu (OR)	AAS, ICP-MS
Na9	29	Struttura 8 Level 3A-39	Lead	Lead-blob (?)	S. Barbara, Bauladu (OR)	AAS, ICP-MS
Na10	29	C26 2C Pb10	Lead	Clamp	S. Barbara, Bauladu (OR)	AAS, ICP-MS
Na11	29	C65 level 2BA MB7 lead & ceramic	Lead	Clamp	S. Barbara, Bauladu (OR)	AAS, ICP-MS
Na12	29	C37 20-30 PB 012	Lead	Clamp	S. Barbara, Bauladu (OR)	AAS, ICP-MS
Na13	29	SB87 C1 50-60 lev. 3B AMB 2	Lead	Clamp	S. Barbara, Bauladu (OR)	AAS, ICP-MS
Na14	29	SB 87 C29 40-50	Lead	Drop-shaped	S. Barbara, Bauladu (OR)	AAS, ICP-MS
Na15	29	SB 87 C40 50-70 lev. 2CD AMB IAP	Lead	Clamp	S. Barbara, Bauladu (OR)	AAS, ICP-MS
Na16	29	C47 lev. 2B AMB IBP	Lead	Clamp	S. Barbara, Bauladu (OR)	AAS, ICP-MS
Na17	29	SB 87 C7 AMB 2 pavimento	Lead	Clamp	S. Barbara, Bauladu (OR)	AAS, ICP-MS
Na18	29	C72 AMB lev. 1A	Lead	Cross-shaped	S. Barbara, Bauladu (OR)	AAS, ICP-MS
Na19	29	C68 4A AMB 7 lead mending	Lead	Sheet	S. Barbara, Bauladu (OR)	AAS, ICP-MS
Na20	29	SB 87 C48 40-50 Pb 20	Lead	Sheet	S. Barbara, Bauladu (OR)	AAS, ICP-MS

Code	**Archeological file nos.**	**Inventory number**	**Material**	**Type**	**Provenance**	**Analytical methods**
Na21	29	C47 livello 2B AMB IBP	Lead	Clamp	S. Barbara, Bauladu (OR)	
Na22	29	C68 4A AMB7 piombo e ceramico	Lead	Clamp with ceramic	S. Barbara, Bauladu (OR)	
Nb1	20	AG 1	Lead	Clamp	Antigori, Sarroch (CA)	AAS
Nb2	20	AG 2	Lead	Clamp	Antigori, Sarroch (CA)	AAS
Nb3	20	AG 3	Lead	Clamp	Antigori, Sarroch (CA)	AAS, ICP-MS
Nb4	20	AG 4	Lead	Clamp	Antigori, Sarroch (CA)	AAS
Nb5	20	AG 5	Lead	Clamp	Antigori, Sarroch (CA)	AAS
Nb6	20	AG 6	Lead	Clamp	Antigori, Sarroch (CA)	AAS
Nb7	20	A1	Lead	Fragment	Antigori, Sarroch (CA)	AAS, ICP-MS
Nb8	20	A2	Lead	Fragment	Antigori, Sarroch (CA)	AAS
Nb9	20	A3	Lead	Sheet	Antigori, Sarroch (CA)	AAS
Nb10	20	A4	Lead	Fragment	Antigori, Sarroch (CA)	AAS
Nb11	20	A5	Lead	Fragment	Antigori, Sarroch (CA)	AAS
Nb12	20	A6	Lead	Fragment	Antigori, Sarroch (CA)	AAS
Nb13	20	A7	Lead	Fragment	Antigori, Sarroch (CA)	AAS
Nb14	20	RM1	Lead	Shapeless	Antigori, Sarroch (CA)	ICP-MS
Nb15	20	RM2	Lead	Shapeless	Antigori, Sarroch (CA)	ICP-MS
Nb16	20	RM3	Lead	Pierced sheet	Antigori, Sarroch (CA)	ICP-MS
Nb17	20	RM4	Lead	Clamp	Antigori, Sarroch (CA)	ICP-MS
Nc1	34	GM1	Lead	Clamp	Genna Maria, Villanovaforru (CA)	AAS, 4 samples

Code	Archeological file nos.	Inventory number	Material	Type	Provenance	Analytical methods
Nc2	34	GM2	Lead	Clamp	Genna Maria, Villanovaforru (CA)	AAS 3 samples
Nc3	34	GM3	Lead	Clamp	Genna Maria, Villanovaforru (CA)	AAS 2 samples
Nc4	34	C16a	Lead	Sheet	Genna Maria, Villanovaforru (CA)	AAS
Nc5	34	C16b	Lead	Sheet	Genna Maria, Villanovaforru (CA)	
Nc6	34	C16c	Lead	Sheet	Genna Maria, Villanovaforru (CA)	
Nc7	34	CXe	Lead	Sheet	Genna Maria, Villanovaforru (CA)	AAS
Nc8	34	CXf	Lead	Sheet	Genna Maria, Villanovaforru (CA)	
Nc9	34	CXh1	Lead	Sheet	Genna Maria, Villanovaforru (CA)	
Nc10	34	CXh2	Lead	Sheet	Genna Maria, Villanovaforru (CA)	
Nc11	34	CXh3	Lead	Sheet	Genna Maria, Villanovaforru (CA)	
Nc12	34		Galena	Nodule	Genna Maria, Villanovaforru (CA)	AAS
Nd1	25	TP (1, 2, 3)	Lead	Pipe	Pinn'e Maiolu, Villanovaforru (CA)	AAS, EDS, IPC-MS

O- Silver objects (no. 11)

Code	Archeological file nos.	Inventory number	Material	Type	Provenance	Analytical methods
O1	1	R 879	Silver	Ring	Cungiau Sa Tutta, Piscinas (CA)	SEM+EDS, AAS, Met.
O2	1	R 882	Silver	Ring	Cungiau Sa Tutta, Piscinas (CA)	SEM+EDS, AAS, Met.
O3	1		Silver	Roll in bead	Cungiau Sa Tutta, Piscinas (CA)	SEM+EDS, AAS, Met.
O4	35	N. 33	Silver	Bracelet	Loculi (NU)	AAS, SEM-EDS, ICP-MS
O5	35	N.34	Silver	Bracelet	Loculi (NU)	AAS, H., SEM-EDS, ICP-MS
O6	36	N. 37	Silver	Leaf	Su Gorroppu, Orgosolo (NU)	SEM-EDS ICP-MS

Code	Archeological file nos.	Inventory number	Material	Type	Provenance	Analytical methods
O7	36	N. 38	Silver	Leaf	Su Gorroppu, Orgosolo (NU)	AAS, ICP-MS
O8	36	N.39	Silver	Leaf	Su Gorroppu, Orgosolo (NU)	AAS, SEM-EDS, ICP-MS
O9	36	N. 40	Silver	Leaf	Su Gorroppu, Orgosolo (NU)	SEM-EDS, ICP-MS
O10	36	N. 41	Silver	Leaf	Su Gorroppu, Orgosolo (NU)	SEM-EDS, ICP-MS
O11	30	N.36	Silver	Earring	S. Pietro, Torpè (NU)	AAS, ICP-MS

P- Objects in gold-silver alloy (no. 2)

Code	Archeological file nos.	Inventory number	Alloy	Type	Provenance	Analytical methods
P1	5		Gold and silver	Necklace *(torque)*	Bingia'e Monti, Gonnostramatza (CA)	SEM+EDS, SMO
P2	19		Gold and silver	Ornated sheet fragment	Bingia'e Monti, Gonnostramatza (CA)	SEM+EDS, SMO

Analytical Methods Legend:

AAS	Atomic Absorption Spettroscopy.
EDS	X-ray Energy Dispersive Spectroscopy.
EPMA	Electron Probe MicroAnalysis (wavelenght dispersive spectroscopy).
H.	MicroHardeness, Vickers type.
ICP-MS	Inductively Coupled Plasma with Mass Spectrometry.
Met.	Metallography with optical microscopy.
Petr.	Petrography with optical microscopy.
SEM	Scanning Electron Microscopy.
SMO	Optical Stereomicroscopy.
XRD	X-ray Diffractometry (CuKa radiation).
XRF	X-ray Fluorescence spectrometry.

PART IV

ARCHAEOLOGY

ARCHAEOLOGICAL PREFACE

Fulvia Lo Schiavo

The reason for this preface is the need to emphasize some facts, which are fundamental for the understanding of both, the chapters that follow, and also the spirit in which this volume was written, as far as the part devoted to archaeology is concerned.

It would be a serious misunderstanding to think that Part IV – Archaeology – provides the reader with a complete and general picture of archaeology in Sardinia, a summary of the historical events and respective socio-economic and cultural aspects. Readers would certainly not be able to be in clear on the monothematic discussion, inevitably full of gaps. Our intention is to document, to the greatest extent possible and with the most up-to-date information, the finds studied in our archaeometric research. On the other hand, it would be belittling to simply provide, in the following pages, an account of the archaeological background of the artefacts and of the sites, in which they were unearthed: in this case, maps would have been sufficient.

We attempted instead to give a measure and a quantitative and temporal dimension to metallurgy in pre- and proto-historic Sardinia, so, that the reader could, never and and from no viewpoint, fall into the error of believing, that the volume offers exhaustive information. It is simply a complete and up-to-date panorama and data, based on current information. The fact that archaeology has been placed in Part IV, at the end of the volume, is an indication of the emphasis we want to place on this aspect. The number of analytical and archaeometric data presented here is not a large, but it was our intention to focus the attention of reader and experts on the data themselves and on the metals and alloys investigated. The choice of following an order or, in many cases, of presenting the data in non-sequential manner, in terms of age of civilizations and artefacts, was left to the analysts.

The main focus in this volume is on the metals of ancient Sardinia, on the geological and ore deposits characteristics, on the original discovery, the understanding of the different characteristics, the search for metal bearing ores, the "invention" and/or imitation followed by implementation of production procedures and finally the introduction of the semi-worked raw materials and finished products into a supply and internal and external distribution circuit.

The absolutely not simple task of the archaeologists was that of drawing the perspective lines between the data, known to be correct, the information presented and dicussed in the first three parts, including the archaeological files, and the remaining whole universe of ancient Sardinia. This is not to diminish the importance of the data, but, quite on the contrary, to emphasize the exemplifying value and rarity of the indications.

Because these are in fact just indications. The archaeometric study was restricted to a small number of finds, that just happened to be better preserved, and not chosen according to criteria of statistical significance. The analyses have cast a glimmer of light on the vast unknown.

For example, a strikingly large number of metal finds was unearthed in sites referred to as "pre-nuragic", a general term used to describe archaeological periods from the Neolithic to the Bronze Age, covering more than a millennium of prehistory, through the succession of at least five distinctly characterized archaeological facies. Related to these, the finds analysed (A1-6, archaeological files 3, 7, 13; B2-5, archaeological files 2, 10, 6) are a drop in the ocean, but sufficient to indicate without doubt the trials and use of the all most important metals and also of some basic alloys.

Even less information is available about the period of transition between the pre-nuragic and late nuragic Ages: except for a few pieces from the much debated Ottana (?) (C2-5, Archaeological file 13), just one object appears to be made of bronze, though this seems to be dated to the Chalcolithic (C1, Archaeological file 4). The unique shape of this find - nothing comparable was ever found either in Sardinia or elsewhere - and the scant typological evidence of its associations are certainly a matter of perplexity.

The large swords discovered at Maracalagonis and S. Iroxi in southern Sardinia (B1 and B6-11, Archaeological files 9 and 8) and fashioned after the Argaric model, were found to be made of a copper-arsenic alloy. It has not been possible to extend the investigation to daggers, awls, pins and drifts also recovered from the S. Iroxi *hypogeum* because of their poor state of preservation.

Only one analysis was performed on daggers with simple tang (G2, Archaeological file 11), and none on the earlier axes with raised edges, which are distinctive items of the first phase of the nuragic production, and chronologically dated to the early Middle Bronze Age.

On the other hand, a fairly large number of analyses, - though, considering the large amount of finds, still insufficient - was carried out on copper ingots, in the shape of stretched oxhides with four more or less well defined corners, and on a lesser number of plano-convex or bun ingots, often broken into small pieces and associated with the former (Da1-17, Archaeological file 26; Db1-14, Archaeological file 21). The artefacts are rather crude and mostly shapeless, but they are evidence of long distance trading from the Eastern to the Central Mediterranean. Up to now, connections from this point of view with the Atlantic routes remain unknown.

This is not the place to anticipate what is illustrated in this volume, but more and more details are emerging day by day with new archaeological and archaeometric evidence. The multi-faceted nature of the Mediterranean interconnections of nuragic Sardinia gradually unfolds.

Decidedly not enough analyses have been performed on the bronze objects of the nuragic Age. Thousands of artefacts, covering the entire time span from the early and late Middle Bronze Age up to the beginning of the early Iron Age (roughly 16th-10th/9th century B.C.) and every aspect of the production have been recovered: weapons, tools, bronze statuettes, and examples of functional uses of metal, as for instance the lead clamps for repairing pottery vases or other vessels (Na1-22, Archaeological file 29; Nb1-17, Archaeological file 20; Nc1-17, Archaeological file 34; Nd1, Archaeological file 25). Out of respect for the artefacts, only the fragments recovered in the two “smelting sites” of S. Barbara-Bauladu and Sa Sedda ’e sos Carros-Oliena (Ha1-38, Hb1-43, Archaeological files 29 and 31), were analysed. Special attention was focused on the bronze figurines. A small group, from a single sanctuary (I1-12, Archaeological file 17) was studied, while the other specimens analysed , I1, I8, I11-12, are, according to Lilliu, of unknown origin. The results obtained by analysing these figurines, can however be compared with the data published by non-Sardinian researchers. At last are presented the results of analyses carried out on some fake figurines (L1-33), which are representative for the large number of fake statuettes, passed off as authentic pieces.

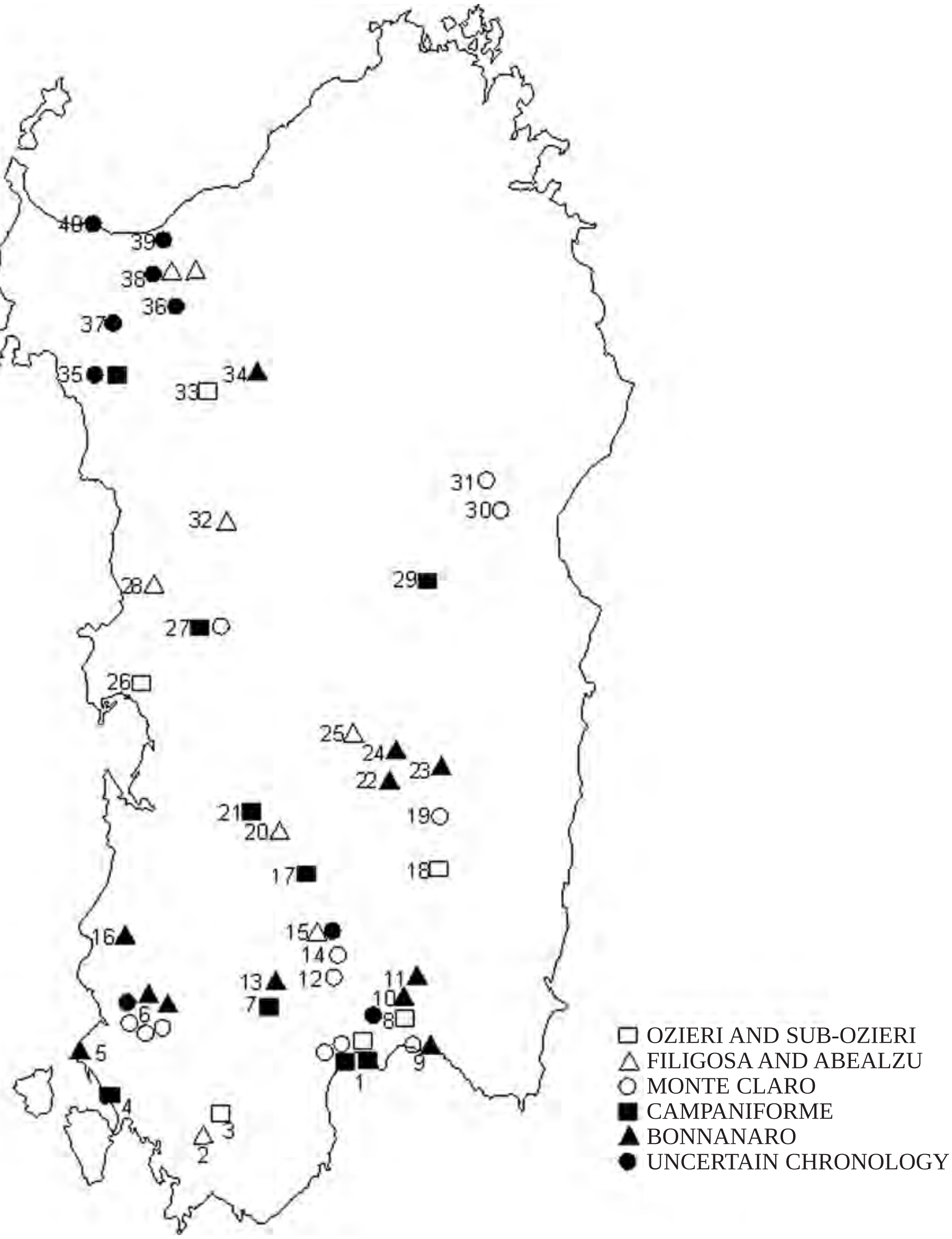
Some determinations have been performed on pieces of iron found among archaeological material at Sa Sedda ’e sos Carros (M1-4, Archaeological file 31) and on another piece attached to a lead clamp from the Antigori nuraghe at Sarroch (M5, Archaeological file 20). The old idea, that iron metallurgy developed in Sardinia at a late stage, has been shaken by elements, which suggest, that this is a preconception, continuing to this day, even among archaeologists (see Part IV, chapter 7). The iron objects discovered are badly preserved, in a much worse condition, than the artefacts made of other metals or alloys, so that it proved difficult to sample and analyse them. This is a further reason, why little attention was devoted to iron in this volume. Furthermore, the widespread use of this metal, which supplanted bronze in the Iron Age, changed the aspects of metal production and working in Sardinia.

Regarding the silver finds, a chronological gap of more than 2500 years exists. A large number of prehistoric and historic silver artefacts was recovered, but only rare specimens dated to the nuragic Age (O1-11, Archaeological files 1, 35, 36, 30).

As for gold (P1-2, Archaeological files 5 and 19) the described artefacts account for half of the objects of gold recorded up now in Sardinia. It is no coincidence, that the two artefacts are separated by many centuries and can be referred to cultures on opposite banks of the Mediterranean..

Lastly, it should be pointed out, that the terminology used in this volume for metallurgical tools and processes, is the terminology traditionally used by archaeologists, though recognizing that specialists in metallurgy will find not strictly correct the terms used. Hopefully, the first positive outcome of this volume will be a complete multilingual glossary which will become familiar to all experts involved in archaeometallurgy, be they ore deposit geologists, metallurgists or archaeologists.

As a whole, the aim of this volume is that of providing scholars and researchers with an important tool for an integrated interpretation of the historical and archaeological information related with ancient metallurgy. To facilitate this, all available references, and particularly the most recent works, have been cited, as can be observed both in the following text and in the archaeological files referring to the ore deposit geology and to archaeometry.



Ozieri e Sub-Ozieri : Selargius – Su Coddu (8); Goni – Pranu Mutteddu (18); Villaperuccio – Montessu (3); Pirri-Cagliari – Terramaini (1); Cabras – Cuccuru S'Arriu (26); Thiesi – Sa Korona di Monte Majore (33)
Filigosa e Abealzu : Villagreca – Serra Cannigas (15); Siddi – Scaba'e Arriu (20); Piscinas – Cungiau'e Sa Tutta (2); Cuglieri – Santa Caterina di Pittinurri (28); Macomer – Filigosa (32); Laconi – Corte Noa (25); Sassari – Monte d'Accoddi (38); Sassari – Monte Cabula Muntones (38)
Monte Claro : Iglesias – Cuccuru Tiria (6); Iglesias – Grotta della Volpe (6); Iglesias – Monte Casula (6); Quartu Sant'Elena – Simbirizzi (9); Monastir – Cresia Is Cùccurus (14); San Sperate – Su Fraigu (12); Cagliari – Via Basilicata (1); Cagliari – Sa Duchessa (1); San Vero Milis – Serra Is Araus (27); Nuoro – Janna Ventosa (31); Orroli – Su Monti (19); Biriai – Oliena (30)
Campaniforme : Cagliari – San Bartolomeo (1); Cagliari – S. Elia (1); Sanluri – Padru Jossu (17); Siliqua – Sa Serra Masì (7); San Giovanni Suergiu – Locci Santus (4); Gonnostramatza – Bingia'e Monti (21); San Vero Milis – Serra Is Araus (27); Ollolai – San Basilio (29); Alghero – Cuguttu (35)
Bonnanaro : Quartu Sant'Elena – Perda Bona (9); Iglesias – Cuccuru Tirìa (6); Iglesias – Grotta del Ginepro (6); Fluminimaggiore – Grotta di S'Oreri (16); Soleminis – Is Calitas (11); Settimo San Pietro – Cuccuru Nuraxi (10); Decimoputzu – S. Iroxi (13); Portoscuso – Su Stangioni (5); Villanovatulo – Frommosa (23); Isili – Murisiddi (22); Nurallao – Aiodda (24); Bonnanaro – Corona Moltana (34)
Uncertain chronology : Villagreca – Sa Corona (15); Selargius – Su Coddu – S'Ariana (8); Alghero – Anghelu Ruju (35); Ossi – Mesu'e Montes (36); Sorso – Sant'Andrea (39); Sassari – Monte d'Accoddi (38); Porto Torres – Su Crucifissu Mannu (40); Olmedo – Monte Baranta (37); Iglesias – Grotta Prima delle Quattro Stagioni (6)

1.

PRE-NURAGIC METALLURGY RECORDS

Luisanna Usai

1. Introduction

TRADITIONAL CHRONOLOGY		DENDRO C14	SARDINIA	MAINLAND GREECE		TRADITIONAL CHRONOLOGY
1800		2300				
	EBA 1		BONNANARO			
1700		2000				
	EBA 2		S.IROXI			
1600		1700				1600
	MBA 1		SA TURRICULA		I	
1500		1600			II	1500
	MBA 2					
1400		1500	"METOPE" IMPRESSED WARE (SAN COSIMO) "A PETTINE" IMPRESSED WARE			1400
	MBA 3			MYCENAEAN	IIIA	
1300		1365		(LATE HELLADIC)		1300
	L B A					
	RBA				IIIB	
1150		1200	"A PETTINE" IMPRESSED WARE CARINATED BOWLS COLLARED JARS: THICK-RIM JARS "GREY" WARE			
1125	FBA 1					1190
1100		1150				
			NURAGIC FBA 1-2 PRE-GEOMETRIC POTTERY		IIIC	
	FBA 2					
1000		1080		SUBMYCENAEAN		
	FBA 3		NURAGIC FBA 3 GEOMETRIC POTTERY			1050
900		1020				
850	EIA	950	NURAGIC EIA			
525		525				

Chronological sequence of Bronze Age Sardinia

Fig. 1 – Chronological table of the pre-nuragic age.

The work by Fulvia Lo Schiavo, "The origins of metallurgy and problems of metallurgy in the Ozieri culture" ("*Le origini della metallurgia ed il problema della metallurgia nella cultura di Ozieri*", Lo Schiavo 1989), remains fundamental for the study of the most ancient metal finds from Sardinia. From a basis of known data on the origins of metallurgy in Asia Minor and mining activities in Europe, she examines the various known contexts in Sardinia with particular reference to the oldest ones, subjects to which the author returns several times (Lo Schiavo 2000; Lo Schiavo 2003, 600-602), and also in part in the present volume.

Although the problems highlighted at the time have not been definitively solved, as we shall see better in detail, much progress has been made in our overall knowledge of the pre-nuragic period (fig. 1). The identification of the various cultural phases from the Palaeolithic period[1] up to the transition to the nuragic period is certainly of importance. The identification, with new studies and re-examination of old contexts, of the San Ciriaco phase, which preceded the Ozieri culture[2], is of particular consequence for the subject dealt with here; this led to the reassessment and improved identification of what was to be considered the highest cultural expression of the pre-nuragic age.

On the other hand, the improved portrayal of the final phase of the Ozieri culture as a distinct aspect [Sub-Ozieri phase (Ugas 1997, 55-57; Usai L. 1998, 217-218, 228, 231) or painted Ozieri (Lo Schiavo 1992, 120)], according to the most up-to-date denominations) leads to a better understanding of the transition from Final Neolithic to the Chalcolithic.

In addition, the two phases of Filigosa and Abealzu appear ever more distinct, even if some authors still prefer to consider them as a unity (Usai L. 1998, 217-218, 231; Ugas 1998 b, 252-253; Melis 2000, 8).

The Monte Claro culture has also been enriched with new data, illustrating in particular its monumental aspects[3].

1. On the early appearance of man in Sardinia, see Martini 1999.

2. Everyone agrees on the stratigraphic positioning of the San Ciriaco culture, while there is disagreement on the precise chronological span, either in the course of the passage from Middle Neolithic period to Recent Neolithic (Lugliè 1997; Alba 2000) or in this last phase (Santoni, Bacco, Sabatini 1997). If this last dating is the most acceptable, it would not be necessary, in all cases, to move the Ozieri culture into the Early Aeneolithic, but rather into the Final Neolithic.

3. On the Monte Claro culture, see Moravetti 1993-1995 for the latest position.

The various Beaker contexts discovered in the last years also seem important, and have led to a more precise dating of the aspects which become current in Sardinia between the end of the Aeneolithic and the Early Bronze Age periods (Atzeni 1998). It has been confirmed that the Bonnanaro culture is to be placed in this last period, as far as the Corona Moltana aspect is concerned[4].

The metal discoveries from pre-nuragic Sardinia fit into the periods and cultures briefly summarized here. Some of these long-known finds have been described in detail by Lo Schiavo 1989, and others more or less exhaustively published in recent years.

Bearing all this in mind, it has been decided to summarize all data so far known, briefly giving the contexts of the provenance of the new finds, with particular emphasis on those stratigraphically most certain.

The contexts will be examined in chronological order, leaving to the end those of uncertain dating. In the examination of the material it has been decided to go as far as that attributable to the Bonnanaro phase known as Corona Moltana, as this is considered to mark the end of the pre-nuragic phase[5].

The files which follow refer to contexts whose metal finds have not been analysed, or for which the data on the metallic composition is rather general; other parts of the text can be referred to for objects subjected to detailed analysis and to their various monumental and material contexts.

2. The finds and the contexts

2.1. The Ozieri culture and the Sub-Ozieri phase

Su Coddu, Selargius (Cagliari), area of the village

The above mentioned site, which has been referred to from the metallurgical point of view by F. Lo Schiavo on the basis of oral information, has now been partially published.

The use of the area of Su Coddu for residential purposes continued for several centuries; excavation has in fact clearly revealed the older «hut bottoms», generally with fairly developed ground plans but very little set into the ground, attributable to the Ozieri culture, and more recent «hut bottoms», generally circular and rather deep, dating to the Sub-Ozieri phase. In addition to the residential structures, there are plenty of remains of hearths, siloes and various wells, dug deep down to the aquifer, both from the Ozieri phase and from the Sub-Ozieri one. Of particular importance are the artefacts of silver and copper and their slags found in the Ozieri-phase «hut bottoms» (huts 21, 36, 67, 65, 37). However, it is in the Sub-Ozieri phase that there is an increase in the evidence of metalworking, with a parallel decrease in stoneworking. Slags and some artefacts of copper and silver have been found in various structures (42, 65, 51), in particular a pin, square in cross-section, from hut 32 and a fragment of silver sheet from hut 51.

Bibliography: Lo Schiavo 1989, 283 (file no. 5); Ugas, Usai, Lai 1985 (in particular 13, 19-20); Ugas 1993, 25; Ugas 1997, 49-57, fig. 42 (slags).

Pranu Mutteddu, Goni (Cagliari), Tomb V "Su Nuraxeddu"

In a vast burial area, situated near the remains of a settlement, hypogean tombs alternate with a series of "circle" tombs, generally characterized by the presence of two or three concentric and rounded rows of standing stones, with dolmen corridors for access to the sepulchre. The tomb types differ in their internal layouts, according to whether they are designed for single or collective burials. In tomb II there is a *domus de janas* dug out of a great monolithic block of sandstone, brought from far away and placed on a beaten surface of clay and sand. In other cases we find twin-celled chambers, rounded or elongated one-celled chambers, single-bodied cists with small, four-cornered access doors, all in small blocks (fig. 2).

Another extraordinary feature of the *necropolis* of Pranu Mutteddu is the presence of some fifty menhirs which mark the place, which is sacred and dedicated to funerary worship, arranged in pairs or in small groups and also in rows.

Elements typical of the Ozieri culture have been found in all the tombs. Outstanding amongst the pottery are two miniature vases and a small plate, all densely decorated. Amongst the stone artefacts, in addition to various flint blades and numerous flint arrowheads, there are a *stiletto* and a small flint dagger, which are finely worked and have for the moment no analogies from other Sardinian contexts (fig. 3-4).

The discovery in tomb V of two small rings, in a circular, flat band, probably used as necklace beads (fig. 4, above right), seems particularly important.

Bibliography: Atzeni, Cocco 1989; Lo Schiavo 1989, 283 (file no. 3).

4. Confirmation of the chronological span now also comes from the dating of the tomb of Is Calitas di Soleminis (Manunza 1998, 76-77; 2001, 681).

5. Sanges 2000, 18; Cincotti, Demurtas, Lo Schiavo 1998, 159; on the problems of the phases of the transition between the pre-nuragic and nuragic periods, see, amongst others, Ugas 1998b, 255-256.

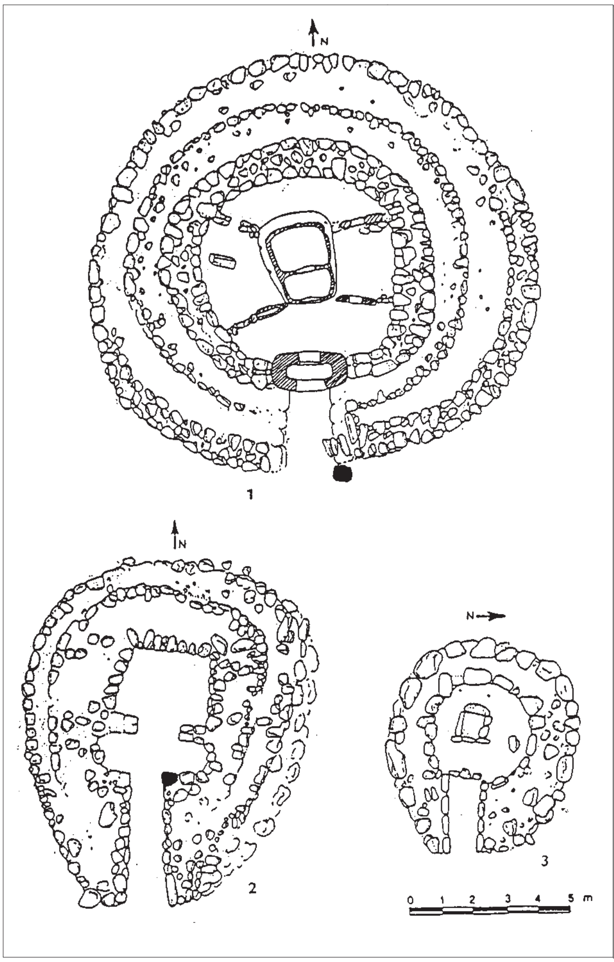


Fig. 2 – Ground plants of tombs II (1), V (2), III (3) at Pranu Mutteddu di Goni *(after Atzeni, Cocco 1989).*

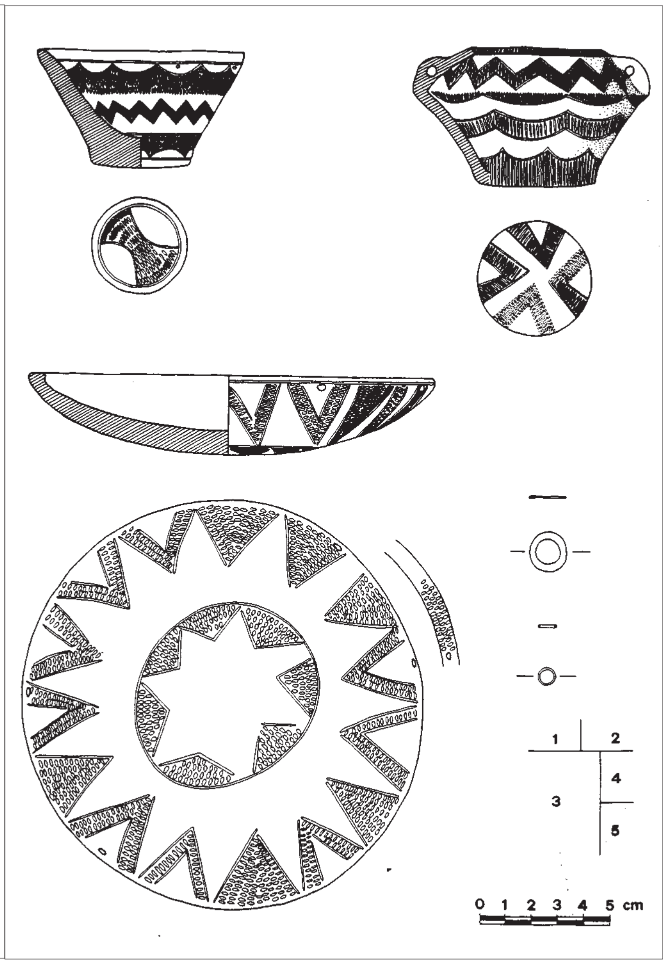


Fig. 3 – Miniature vases from tomb II; bowl and silver elements from tomb V at Mutteddu di Goni *(after Atzeni, Cocco 1989).*

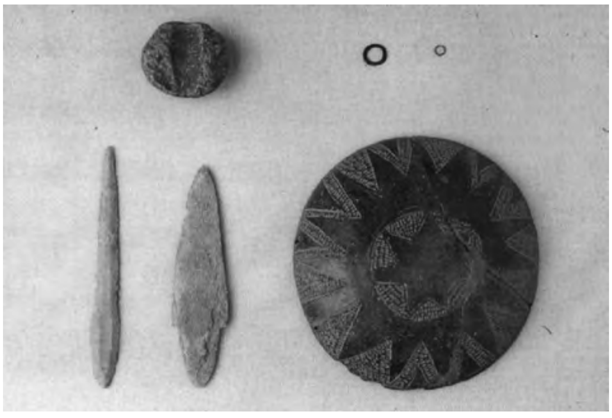


Fig. 4 – Grave goods from tomb V at Mutteddu di Goni.

Montessu, Villaperucciu (Cagliari), hypogean megalithic tomb

The *necropolis* of Montessu, consisting of about forty tombs, offers various types of ground plan, from the one-celled type, to the trefoil-shaped one, to the one with a longitudinal projection, including some examples which are particularly monumental.

On the walls of some of the tombs, there are decorations in incised work, *bas-reliefs* and painting.

In the area in front of the tomb structures there are often megalithic structures, designed to mark spaces probably linked to ritual functions.

A small ring made of flat copper band and a round piece of silver wire were found in a tomb of megalithic restructuring, together with Sub-Ozieri clay fragments, but the *necropolis* must have produced other metal artefacts, which are still wholly unpublished.

Bibliography: Lo Schiavo 1989, 283 (file no. 4); Atzeni 1988a, 450; 1996; Melis 1999, 30; 2000, 83.

Terramaini, Pirri – Cagliari, village

The village of Terramaini, though known from the end of XIX century, was only excavated partially in the 1980s. The excavated huts were inside the urban area of Pirri between Via delle Cicale and Via delle Rane, but there must have been one vast settlement, or, more probably, various small villages of huts, distributed over the slight heights which dominate the lake of Molentargius and the flat ground of the channel of Terramaini.

As for the materials from the Sub-Ozieri phase, to be noted in particular are vessels in dark *impasto*, in rather rigid shapes and without decoration, and pots of highly refined clay, pale in colour, mostly flask-shaped vases, often decorated with overpainted geometrical motifs.

In one of the excavated «hut bottoms» was found a small, shapeless fragment of copper, preserved inside a fragment of rather unrefined clay. The clay fragment, which seems to belong to some low and wide shape, could be part of a spoon crucible.

Bibliography: Usai L. 1987, 181.

Cuccuru Arrius, Cabras (Oristano), village

This site was already known at the end of XIX century and it was subsequently repeatedly examined, and then carefully excavated at the end of the 1970s. The excavation revealed a *necropolis* from the Middle Neolithic period, a vast settlement of the Recent Neolithic and Chalcolithic periods, a nuragic well temple, to which was annexed and partially superimposed a cultural area from late Phoenician and Roman republican times, and a *necropolis* from Roman imperial times.

From the San Ciriaco phase and up to the Aeneolithic period various residential phases are documented, partly superimposed on each other, but on the whole localized in different but adjoining areas. Archaeological research has brought to light very numerous archaeological deposits, easily distinguishable on account of the characteristic grey-blackish colour and of the many examples of material in stone and clay and clay residues, identifiable as the remains of huts, but also of hearths, siloes and trenches for the rubbish from the various hut-dweller settlements. The utter absence of stone foundations indicates that the habitations were constructed wholly of stakes and branches on artificial hollow depressions in the ground, mostly oval in shape.

In the more recent «hut bottoms», dating to the Sub-Ozieri phase, were found various copper items. In sector F in particular were found fragments of a broad dagger blade and various awls, square in cross-section, while an awl was also found in «hut bottom» 38 (sector A).

Bibliography: Atzeni 1981, M 105; Lo Schiavo 1989, 282 (file no.2); Santoni 1991 (33, tab. III, 3 for the spike in particular).

Grotta Sa Korona di Monte Majore, Thiesi (Sassari)

The cave consists of an entrance, a vast central chamber and of numerous minor recesses.

The archaeological deposit has suffered serious damage at the hands of unauthorized excavators, but systematic exploration has uncovered a stratigraphy which documents in sequence the culture of the Ceramica Impressa, of Bonu Ighinu and of Ozieri.

There are reports of the discovery of a copper bead from a necklace and of traces of oxidation on a bone find which should date to the Ozieri culture, given that this marks the last phase of occupation of the cave.

Bibliography: Lilliu 1967, 43-47; Foschi Nieddu 1984; 1989; Lo Schiavo 1989, 282 (file no.1).

2.2. The Filigosa and Abealzu cultures

Serra Cannigas, Villagreca (Cagliari), hypogean tomb (?)

Devastated and reburied by ploughing, the tomb probably consisted of a broad and low *hypogeum* "*a forno*", dug at no great depth in the marly east slope of a characteristic elongated hill.

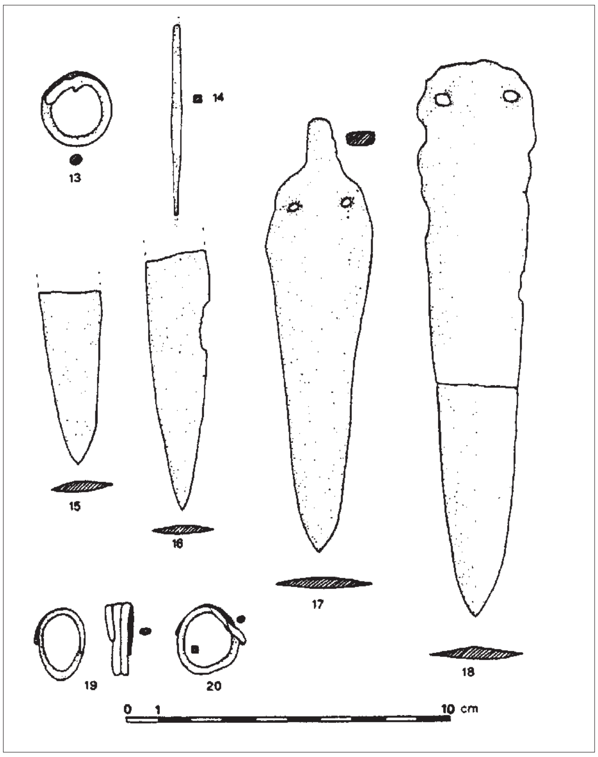


Fig. 5 – Copper and silver finds from the burial of Serra Cannigas at Villagreca *(after Atzeni 1985).*

The material, which was removed from the tomb and then found its way into private collections, consists of a large quantity of ceramic finds, which in part can be compared with finds from Filigosa, and in part with those from Abealzu.

Of particular significance is the presence of numerous metal items of copper and silver, only some of which reached the Museo Archeologico Nazionale of Cagliari. According to verbal reports, in fact, numerous metal objects have disappeared.

The preserved metal artifacts are the following (fig. 5):

- small copper ring in a simple spiral;
- middle fragment of awl or pin in copper, square in cross-section;
- two end fragments of copper dagger blades;
- copper dagger with short tang, curved at the tip, with two small holes in the blade;
- copper dagger with rounded tang, with two holes for the rivets;
- small copper double-spiral ring;
- small silver simple-spiral ring.

A further ten rings in copper and silver of the same types described above and also in the form of a simple soldered ring are documented in a photo. A further five small daggers, apparently of the same type as those surviving, must have disappeared.

Bibliography: Atzeni 1985, 14-35, note 11, fig. 7, nos. 13-20; tab. IV, nos. 1, 3-6, tab. V (objects in metal); Lami 1999.

Scaba'e Arriu, Siddi (Cagliari), hypogean tomb

The original *hypogeum* was constructed at the time of the Ozieri culture and then reused during the Aeneolithic period, as is documented by the remains from the Filigosa, Abealzu and Monte Claro cultures; in the last phase a dolmen corridor was built in the *anticella*.

A small silver ring was found in the Filigosa and Abealzu culture levels.

Bibliography: Badas, Usai E. 1988; 1998; Ragucci, Usai E. 1999, 178.

Cungiau 'e Sa Tutta (or Tuttùi), Piscinas (Cagliari), necropolis (Archaeological file 1)

A large tomb in the hypogean *necropolis* of Piscinas has long been known, with a series of small round holes near the west corner of the *anticella*. In the 1990s, two tombs were completely excavated (nos. 2 and 9), and part of the deposit of the corridor of the big tomb mentioned above (no. 1). The *cella* of tomb 1, which had been widely reused, perhaps already in antiquity, did not contain archaeological material, whereas material from the Filigosa culture and very many Monte Claro fragments were found in the corridor. The most interesting tomb is undoubtedly no. 2, both for its structural layout and the material found in it. In a first excavation phase of the tomb (1990) a small almost circular *cella* was revealed, with three niches arranged in a cruciform ground plan; these are raised above the level of the floor of the *cella* and have a concave back with a raised strip on the outside edge. The central niche is framed by an unusual incised decorative motif, not altogether comprehensible. A further decorative element "*a denti di lupo*", also incised, runs along the wall, under the central niche and the right one.

A second excavation (1994) led to the discovery of another, more or less semicircular room. The west wall is straight, while the east one is curvilinear. The singularity of the structure is that the east-north-east part of the perimeter was constructed in antiquity with great slabs positioned on edge; there is access to the chamber through the straight west wall.

There is no doubt that the last-discovered room was used for burials with their relative apparels. The contexts of the two chambers are to be attributed to the same culture, even if there may have been a slight chronological difference between the construction and the use of the two burial spaces.

As for the pottery, in addition to small "tulip" vases, there were found carinate cups, with vertical perforation, small vases with their necks more or less distinct and with the belly generally rounded, simple cups with turned-in rims.

In tomb 2, the pottery is accompanied by a large quantity of metal objects (silver and copper). There is, in particular, a wealth of examples in silver: these are a series of rings, in simple bands or, more frequently, in spiral, and of some bracelets in fine wire, also spiralled. The rings are precisely similar to those from other burial contexts in Sardinia, whereas for the moment nothing similar to the thin bracelets has been found. Amongst the numerous copper items, there are two flat hatchets, various rings and bracelets, a pair of fragmentary daggers and a series of points with long, narrow foliate blades and narrow, small tangs with rounded ends. The particular characteristics and the utter lack of internal comparable material make it for the moment difficult to understand what purpose and use these small objects served (practical or ritual?).

There are numerous necklace bits in polished stone, a good 170 stone beads of various shapes.

The vase contents of the small hypogean tomb no. 9 are only in part similar to that illustrated above.

In addition to the shapes with small neck and "tulip" shapes appear many open ones with spherical bowl, often with the rim decidedly thickened and flattened on top. These last could represent the latest phase of the culture, as the appearance of the surfaces of the vases from tomb 9 would indicate; these are in general rough and opaque, not polished and with clear signs of stippling, as in the vases of tomb 2.

On the basis of comparisons with other island contexts, as well as on account of the characteristics of the material, there seems no doubt that the Piscinas contexts belong to the Filigosa culture (Early Aeneolithic). There are new elements to be added to the already known categories of shapes used in the culture, which seem to characterize a Sulcis *facies*.

Bibliography: Usai L. , 1996, 241-245; 1998, 218-228, figg. 23.4-23.8; 2000.

Santa Caterina di Pittinurri, Cuglieri (Oristano), hypogean tomb

The apparel from the Santa Caterina *domus de janas* at Pittinurri, uncovered as result of the development of the small centre, is of particular scientific importance because it has not been subject to tampering, the tomb having remained untouched up to today.

The excavation of the tomb, which consists of an entrance corridor, an *anticella* and three small *cellae*, revealed many burials, mostly found in the three most internal *cellae*. In these *cellae* very few items were found, such as arrowheads, silver rings, and necklace element, while many vases were discovered in the *anticella* and in the corridor, together with animal remains, in particular lower and upper jaw-bones, clear evidence of ritual offerings.

The existence in the *anticella* of two different levels in which there is a clear difference in the types of ceramic indicates two different periods following each other in the Early Aeneolithic Age, and which document the Filigosa and Abealzu cultural phases.

From *cella* C come two silver rings; one consists of a thin band with its ends overlapping, and, given its dimensions, it would seem to be a hairband or bracelet, while the other one consists of a simple, thin wire (fig. 6).

Fig. 6 – Silver finds from the tomb of Santa Caterina at Pittinurri.

In *cella* D, however, was found a small silver spiral ring and a minute ring, also of silver, perhaps an element of a chain.

Bibliography: Cocco, Usai 1988; 1988 a (figs. 13 and 14: silver elements); Lo Schiavo 1989, 287-288.

Filigosa, Macomer (Nuoro), tomb III

The Filigosa *necropolis* consists of four *domus de janas* with long access corridors.

The tomb in which was found the most significant body of material is number I, so much as to have given the name of the site to the cultural phase.

The vast selection of objects found in the tombs includes, in addition to the numerous vase shapes, spindle-whorls, loom weights, arrowheads, and a small wooden vase.

In tomb III was found a small spiral, silver ring with the ends tapering.

Bibliography: Lo Schiavo 1989, 283 (file no. 8); Foschi Nieddu 1986, (particularly for the small ring: 10); 1990; Lo Schiavo 2000, 29.

Corte Noa , Laconi (Nuoro), allée couverte

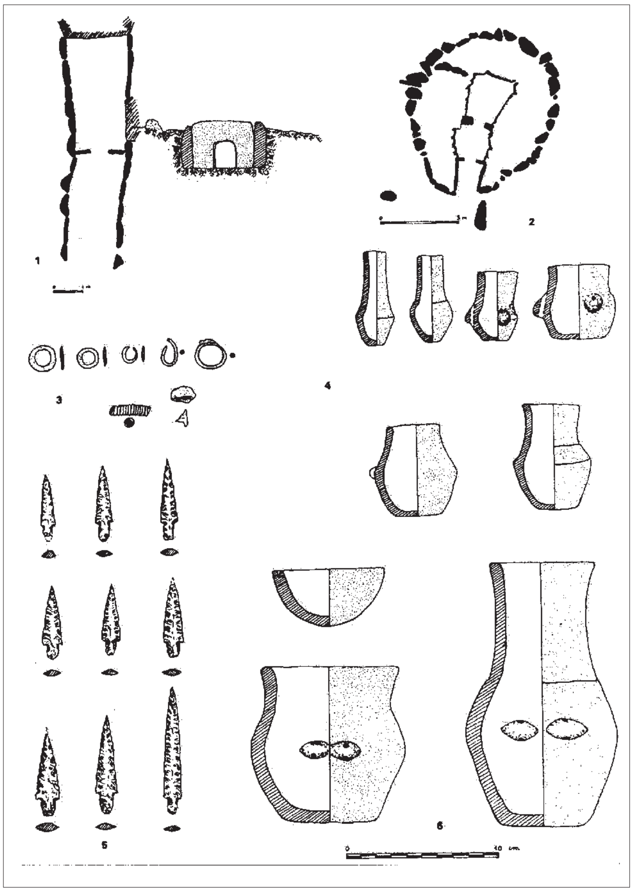


Fig. 7 – Megalithic tombs in the territori of Laconi and grave goods of the Abealzu phase *(after Atzeni 1988).*

The *allée couverte* at Corte Noa is a gallery grave of upright slabs, divided by a large slab with hole. The excavation of the residual deposit yielded, in addition to a few decorated Ozieri-Filigosa-type fragments, several pieces of material from the Abealzu *facies*. These were tripods, necked vases, some in miniature, bowls of different sizes with pairs of small rounded protuberances, obsidian arrow tips, and necklace beads. Of particular importance were the metal objects, consisting of small rings and small spirals in copper and silver, and of scraps of lead (fig. 7).

Bibliography: Lo Schiavo 1989, 283 (file no. 9); Atzeni 1988

Monte d'Accoddi, Sassari, megalithic altar and village

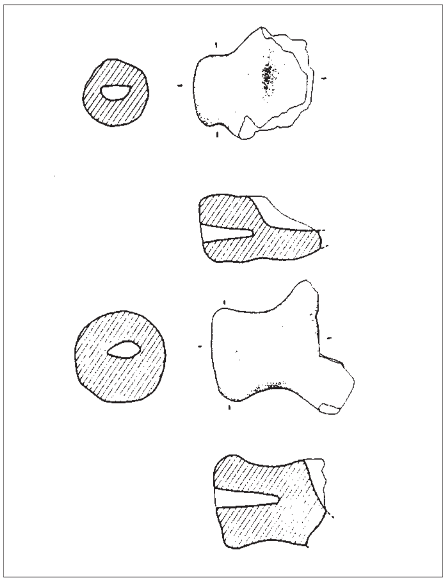


Fig. 8 – Clay crucibles from Monte d'Accoddi, Sassari *(after Lo Schiavo 2000).*

The history of this megalithic monument and of the surrounding area has been recently reconstructed in detail, both as regards the settlements of the San Ciriaco and Ozieri phases, and as regards the two phases of the sanctuary ("*Tempio rosso*" or "Red Temple" and "Terrace Temple" or "*Tempio a Gradoni*"). However, the lack of an overall publication of the excavations makes it rather difficult to date the various metallic objects reported.

Some data can be gathered, however, on the basis of the scarce bibliographical indications.

In particular, two crude clay spoon-shaped crucibles, with a short and stubby cylindrical handle which has at its centre a deep, narrow cavity, belong to the Filigosa phase (fig. 8); on the remaining part of the internal wall of the crucibles traces of copper incrustations can be made out.

Bibliography: Contu 1988, 443; Lo Schiavo 1989, 283 (file no. 7); Lo Schiavo 2000, 27-28; Lo Schiavo 2003, 597-600.

Monte Cabula Muntones, Sassari, settlement

The settlement occupies a naturally protected *plateau*, at the centre of which lies a menhir, broken into two lumps.

Excavation has uncovered some small scraps of copper, as well as pottery fragments from the Abealzu culture.

Bibliography: Basoli 1988; Basoli 1989, 32

2.3. The Monte Claro culture

Cave of Cuccuru Tirìa or S. Lorenzo, Iglesias (Cagliari)

The material found in the disturbed funerary deposits demonstrate the use of the cave during the phases of the Monte Claro, Beaker and Bonnanaro cultures. Several lead repair clamps belong to the Monte Claro culture. In one instance, the clamp survives on a decorated bowl, which, in its shape and decoration, shows close analogies with similar forms from the Cagliari area. Furthermore, the other vase shapes from the cave, mostly undecorated, document the typical *facies* of the Sulcis area of the culture. Three copper awls are also to be attributed to the Monte Claro phase.

Bibliography: Alba 1996, 36; 1996a, 25; Atzeni 1981, XLIII, fig. 22; 2001, 32, figs. 1-6,A-B (fig. 4: clamps); Lo Schiavo 1989, 282 (file no. 11).

Cave of the Fox (Grotta della Volpe), Iglesias (Cagliari)

The cave of the Fox, also known as "*Grotta di Corongiu de Mari*", is a modest cavity, situated at the feet of Monte Marganai; in it have been found pieces from the Monte Claro, Beaker and Bonnanaro cultures.

Some copper awls and a dagger fragment, also of copper, are attributed to the Monte Claro phase of use of the cave for burial purposes. The dagger differs from the type more common in this phase, foliate with a long thin tang, which is rectangular in shape, with a row of holes at the apex.

A large, fragmentary lead clamp also belongs to the Monte Claro culture; on account of its size, it would suit well the restoration of a large vessel of the type found in the vase repertoire of that culture.

Bibliography: Alba 1996, 41; Alba 1996a, 23, fig. 1,1; Atzeni 2001, 32, figs. 6 (C), 7 (nos. 1-4: metal elements).

Cave of Su Mrajani di Monte Casula, Iglesias (Cagliari)

In the cave have been found pieces which go from the early Neolithic up to historical times. On a fragment of ceramic from the Monte Claro culture survives a lead clamp.

Bibliography: Alba 1996, 41: Alba 1996a, 23-24, fig. 1, no. 2.

Simbirizzi, Quartu Sant'Elena (Cagliari), hypogean tomb

The three tombs identified and excavated, although only partially preserved, seem to be of the "*a forno*" type, characteristic of the Monte Claro culture, as the best preserved tomb shows, namely no. 2, consisting of a pit-entrance " *a calatoia* ", rectangular in shape and of an elliptical *cella*. Tomb 3 produced a copper pin , as well as ceramic apparel (a *situla*, two bowls, a plate and a tripod).

Bibliography: Usai E. 1987; 1988.

Cresia Is Cùccurus, Monastir (Cagliari), hypogean tomb

In the area of a village of the Ozieri and Monte Claro cultures was discovered the cross-section of a burial, in the cuttings made in the soil for the irrigation of the fields.

The tomb, of the "*a forno*" type, contained many skeletons piled up as in an ossuary. In addition to Monte Claro ceramic fragments, a small dagger in copper with long tang was found.

Bibliography: Atzeni 1981, XLIII, fig. 24, a; Lo Schiavo 1989, 284 (file no. 12), fig. 1, 7.

Su Fraigu, San Sperate (Cagliari), hypogean tomb

Excavation works carried out in the 1980s as result of the widening of the SS 131 uncovered in this locality five tombs of the Monte Claro culture. In one of these (tomb 14), with an elliptical trench and an access hole reduced at the base, were found ornamental objects of copper and silver. There was a tubular, silver bead, belonging to a necklace bead, or bracelet, a pendant of a necklace or earring in twisted copper wire, two elements of a copper necklace and an element from a silver necklace.

Bibliography: Ugas 1987, 117-118; 1993a, 100.

Via Basilicata, Cagliari, tomb IV

Various hypogean "*a forno*" tombs, single or multiple, arranged at the bottom of vertical entrance pits, attributable to the Monte Claro culture, were uncovered over the years in the course of the development works for the city of Cagliari. In addition to the tomb discovered in 1906 on the hill of Villa Claro, which gave its name to the culture, various other ones came to light during the excavations for the Casa dello Studente in the Sa Duchessa area, during the 1950s.

Four tombs were discovered and excavated in 1965 in Via Basilicata, while another burial was identified in Via Trentino.

The tombs of this vast burial area have permitted the documenting of funerary architecture typical of the Monte Claro culture, with rituals which include single inhumations, with burials on the left side, or multiple inhumations, in more spacious cells, with platforms on three sides of the perimeter for the holding of the dead.

From tomb IV, in addition to the typical pottery, comes a copper dagger, with foliate blade and sturdy tang, rectangular in cross-section.

Bibliography: Atzeni 1981, XLIII, fig. 24b; 1986, 27, fig. 7, tabs. IX-XVI (tab. XVI, 2: dagger); Lo Schiavo 1989, 284 (file no. 13), fig. 1, 6.

Sa Duchessa, Cagliari, hypogean necropolis

Amongst the material recovered in this burial area in 1956 is a small copper dagger, with foliate body and the tang square in cross-section.

Bibliography: Lilliu, Ferrarese Ceruti 1960, 36-37, tab. XXV, 2; Atzeni 1967, 177, note14; Lo Schiavo 1989, 284 (file no. 17), fig. 1, 5.

Serra Is Araus, S. Vero Milis (Oristano), tomb VII

The tomb is principally known for the discovery of a tomb (denominated as I), with a *stele* for the closure of the entrance "*a pozzetto*" which portrays in a highly stylized manner a multi-breasted female divinity.

Subsequent excavations and research have identified a further dozen one-celled tombs with entrance "*a calatoia*", with abundant elements attesting the use of the *necropolis* from phases of the Ozieri culture to periods of the Monte Claro, Beaker and Bonnanaro cultures.

Tomb VII also held an interesting stratigraphy, with a Beaker-Bonnanaro level, above a Monte Claro culture level. From the Monte Claro level come two copper daggers with foliate blade and tang with rectangular cross-section, in one case with a hole at the end.

Bibliography: Lilliu 1957, 20-35; Atzeni 1975, 22-23; Lo Schiavo 1989, 284 (file no. 14); Lo Schiavo 2000, 29.

Janna Ventosa, Nuoro, tomb I, hypogean with dolmen corridor (Archaeological file 2)

The *domus* is situated, along with a further four, at the gates of Nuoro, on the slopes of Monte Ortobene. The tomb is arranged with a *dromos*, delimited on both sides by two small walls, an *anticella* with ritual hearth and oval hollow at the centre, and with a *cella* furnished with two broad platforms at the sides.

In the *anticella* was found a large quantity of pottery and stone pieces, considered to be from a phase later than the Ozieri culture, as well as material probably from the Monte Claro culture, including a metal dagger. The dagger, with foliate blade, its shoulder high and rounded and its tang slightly flattened and holed at the end, is wholly similar to other examples found in Monte Claro funerary contexts, in particular in the Cagliari region.

In the corridor were found numerous fragments belonging to two Beaker vases, but there are also traces of the reuse of the tomb in nuragic and Roman times.

Bibliography: Foschi 1985; 1998; Lo Schiavo 1989, 284 (file 15); Fadda 1991, 15-16.

Su Monti o Su Motti, Orroli (Nuoro), hypogean necropolis (Archaeological file 3)

The *necropolis* is situated at the foot of a basalt wall; the *domus*, with the entrance door almost always carefully squared, opens into great erratic blocks of basalt, or, more rarely, into the rock face. Some natural recesses were also used for the burials.

Below the burial area, a great depression in the ground appears full of small and large blocks from the collapse of the wall standing above, amongst which have formed hollows, which are mostly inaccessible. In the cracks of this fallen rock thousands of pottery fragments have been recovered, mostly from the Ozieri culture, but also material from the Monte Claro and Beaker cultures.

A copper foliate dagger is attributed to the Monte Claro culture.

Bibliography: Sanges 1988; 1997; Lo Schiavo 1989, 284 (file 16); Fadda 1991, 13-15.

Biriai, Oliena (Nuoro), village-sanctuary

The Monte Claro culture village-sanctuary consists of a high place, marked with great monoliths arranged in a semicircle, numerous dolmens and various dwellings; these have a masonry base, are rectangular in shape, sometimes with the back wall apsed, and are divided into various rooms.

Only one metal object has been found, and not a very important one at that; it is an awl with curved point, of uncertain purpose, found at the base of a wall of hut no. 8.

Two objects found in hut 10, identified by the author as *tuyère*s, may have been linked to metal-working.

Bibliography: Lo Schiavo 1989, 284 (file 19); Castaldi 1999 (in particular 125, tab. IX,1, 140, tab. XXII, 2 and 3 and tab. LVII, 15 for the objects cited).

2.4. The Beaker facies

Cave of San Bartolomeo, Cagliari

The cave, which has now been destroyed, was found and explored in 1871 by Orsoni, who recovered numerous items, now held in the Museo Pigorini in Rome.

Situated on the west side of the promontory of S. Elia, the site is part of a vast area with attestations of residential and burial use dating from the Early Neolithic period to historic times.

The stratigraphic sequence identified by Orsoni does not seem correct, but, on the basis of subsequent analysis of the contexts, it is clear that there was prolonged occupation of the cave from at least the Recent Neolithic period to the Early Bronze Age. The lack of adequate stratigraphic analogies makes its difficult to date the metal finds accurately: a flat axe in copper with splayed edge, four dagger blades with tang and, in one case, with holes for rivets, a copper awl. On the basis of analogies from other known contexts, however, the materials are attributed to the Beaker phase.

Bibliography: Pinza 1901, cols. 15-21, figs. 5-6 , tab. III, 5 and 5a (metal elements); Lo Schiavo 1980, 7-9; Ferrarese Ceruti 1981, LXIII C 38, C 41-42; Atzeni 1986, 28, fig. 3, fig. 8, fig. 9 (1-7, 11: bronze finds); Lilliu 1988, 167; Santoni 1992, 17; Castia 1995.

Cave of S. Elia, Cagliari

This cave was also excavated by Orsoni, and had already probably disappeared in the time of Taramelli, perhaps as result of the activities of the nearby limestone quarries; from it comes an awl in copper and the fragment of another one with bone handle.

The cave was certainly already in use in the Early Neolithic period, as is evidenced by four fragments decorated with cardium-shell impressions. The rest of the material is of the Beaker and Bonnanaro cultures. The awls are usually attributed to the Beaker phase.

Bibliography: Pinza 1901, coll. 22-23, tab. III, 1, 5 (awls); Lo Schiavo 1980, 9-10; Ferrarese Ceruti 1981, LXIII.; Atzeni 2003, 65-66.

Padru Jossu, Sanluri (Cagliari), hypogean tomb

The *hypogeum* of Padru Jossu, carved into a rocky bank of sandstone, is a rounded trapezoid in shape, tending towards an oval, with two niches and a bench. The entrance, damaged by irrigation works, may have been *a pozzetto* or with a horizontal access.

The excavation has revealed an interesting stratigraphic sequence with very distinct cultural levels attributable to the Monte Claro culture and the two subsequent phases (A and B) of the Beaker cultural current.

From the Monte Claro culture levels, damaged by later use in Beaker times, come human remains, a small necklace of pierced shells and fragments with typical grooved decoration.

In the levels attributable to the Beaker A phase were found, along with skeletal human remains, animal offerings, mainly of sheep. The vases are on the whole decorated with typical motifs obtained with impressions with a toothed instrument. The shapes too (tripod, carinate cup, one-handled beaker, carinate bowl and basin) are characteristic of the earliest phases of the Beaker period. There are numerous ornaments made of shells, small fox’s teeth and bone, accompanied by the typical buttons in bone, with a V piercing, bone needles and awls.

From this level come four barrel-shaped beads in silver, only one of which is whole, and a disk of silver sheet with four or more holes for fastening a handle which indicate use as a small mirror rather than as a pendent.

The only object in copper is a small dagger, of which there are just traces left of the central part. This was probably a form with triangular blade and a tang *a lingua* with a hole for riveting.

The most recent strata of the tomb, from the Beaker B period, are characterized by undecorated pottery pieces, in particular hemispherical, umbilicate bowls. There are very numerous ornamental elements belonging to necklaces formed of thin plates and shell discs, fox’s canine teeth, and bone beads. Amongst the stone finds are brassards (armlets) with four or six holes and obsidian microliths.

Metal is documented in the form of a small copper dagger, with saw-edged trapezoidal tongue and triangular blade with sharpened edges; the dimensions would indicate a miniature version of a dagger for cult purposes, or a tip of a javelin. There are also six awls in copper, thickened at the centre and square in cross-section.

Bibliography: Ugas 1988; 1998 (fig. 7, 26-27, fig. 12, 8-12: metal elements); 1998a (figs. 56-67: metal elements).

Sa Serra Masì, Siliqua (Cagliari), hypogean tomb with megalithic additions

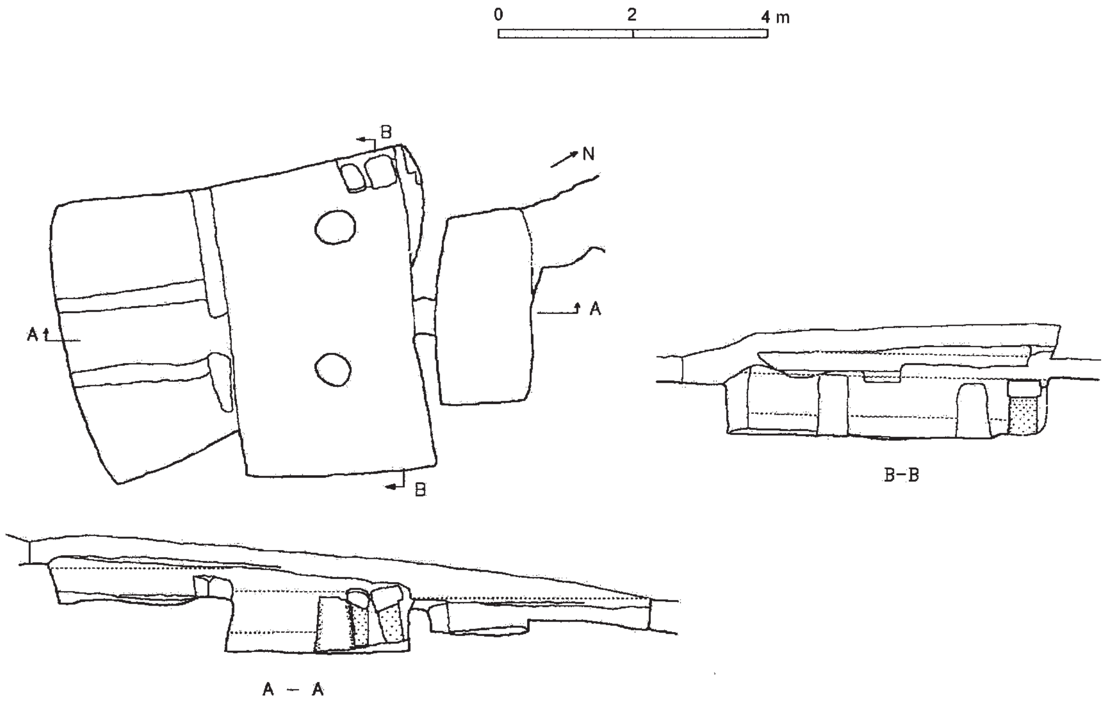


Fig. 9 – Siliqua (CA), Sa Serra Masì: round plan and cross-section of the tomb *(by Claudio Pisu).*

The tomb, which has completely lost its roof on account of decay in antiquity and damage from more or less recent ploughing, consists of a short corridor and three cells, positioned axially, the central one of which is the widest and deepest, and with two columns not perfectly symmetrical (fig. 9).

A sort of cist open on two sides and created with well-finished U-shaped elements backs onto the east wall of the main cell. The realization of this isolated burial space seems linked to the tomb's final phase of use, both on account of the excavation data and for the evident adaptation of the structure, which appears reconstructed on the south side of the central cell.

The tomb, perhaps not with the ground plan that we see today, was made in the time of the Ozieri culture. This is shown by some fragments with typical decoration or with unusual motifs, tripod feet, a fragment of a spherical pommel and a marble statuette of the cruciform type already associated in other contexts with the Ozieri culture.

The use of the tomb must have continued for several centuries up to the Sub-Ozieri phase, but was then abandoned until the end of the Aeneolithic period.

At that time the burial chamber was reused by Beaker peoples, who, having levelled the earlier deposits, as is

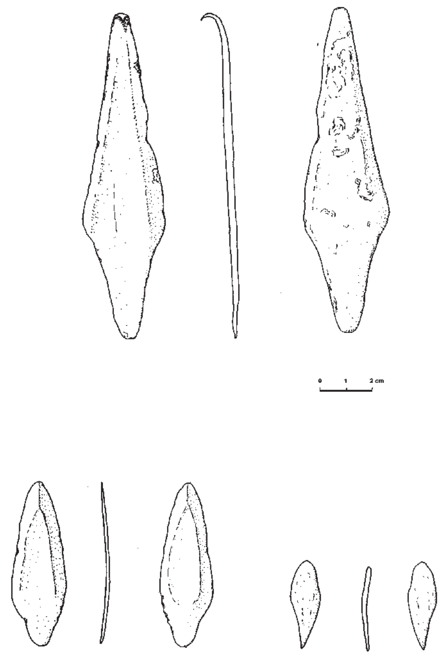


Fig. 10 – Daggers and tip from the tombof Sa Serra Masì at Siliqua *(drawn by Roberto Sirigu).*

demonstrated not only by the fragmentary state of the pottery pieces but also by the bone remains of the older burials, deposited their deads in the cell at the bottom, and constructed at the same time the small megalithic structure in the cell with the columns.

The material of the Beaker burials includes, in particular, some vase shapes which have survived whole or partially fragmented, various metal objects, some armlets/brassards, and numerous bone objects for ornamentation. As for the metal elements, the excavation brought to light two daggers and six awls of various sizes, some very small, and a foliate spike with triangular tang which calls to mind the Palmela-type arrowheads (fig. 10).

Bibliography : Usai L. 2001.

Locci Santus, S. Giovanni Suergiu (Cagliari), hypogean necropolis

The *necropolis*, long known about but only examined stratigraphically here and there, consists of monocellular tombs with *a pozzetto* access and by more complex *hypogea*, constructed vertically or arranged in lobes, in accordance with a scheme very widespread in the area of Sulcis.

Amongst the material recovered long ago, which found its way into the Doneddu collection, there is also a triangular copper or bronze dagger, with a tongue with toothed edges for the handle.

Bibliography : Atzeni 1995, 131-132, fig. 18, no. 4, fig. 26 ; Usai L. 1998 a, 317.

Bingia'e Monti, Gonnostramatza (Oristano), hypogean megalithic tomb (Archaeological file 5)

The hypogean-megalithic tomb of Bingia'e Monti has a niche, rectangular at the back, excavated in the soft rock, and a megalithic mass lying against it.

There are only a few fragments surviving from the first hypogean settlement from the Monte Claro phase, whereas the Beaker context, which includes numerous skeletal remains, is particularly rich.

It is an extraordinary common burial covering a broad span of generations, which documents the moments of transition from the Beaker to the Bonnanaro period, between the Aeneolithic and the Early Bronze Age.

The rich grave good contains a vast selection of smooth and decorated pottery and also numerous items in metal, bone, shell and stone, typical of Beaker contexts. Amongst the pottery forms, in addition to the classic cup, stand out various vases with several feet and an ovoid dish.

The metal objects consist of two small rectangular daggers in copper and of nine awls in copper or bronze, as well as of a torque in fine gold and silver rod, circular in cross-section, with open ends, flattened and curved. This jewel has precedents in the Aeneolithic neckpieces from central Europe, but can be compared above all to types of the Polada culture from the Early Bronze Age period.

The uppermost stratum of the burial is attributable to the Bonnanaro culture. The pottery, which includes some tripods and some types of ornament in shell and wild-boar tusk, indicate the oldest phase of this culture, which still reflected the influence of the Beaker culture.

Bibliography: Atzeni 1996b; 1998 a, 254-260; Usai L. 1998a, 298-315.

Serra Is Araus, S. Vero Milis (Oristano), tomb VII

From the same hypogean tomb in which were found two Monte Claro-culture daggers came also a Beaker-phase dagger.

Bibliography: Atzeni 1975, 22-23, tab. XXIX, 3; Ferrarese Ceruti 1981, LXIII.

San Basilio, Ollolai (Nuoro), a rock shelter

This is a settlement inside an enormous rock shelter. Excavation has documented the use of the shelter from the Middle Neolithic to the Recent and Final Bronze Age periods.

A triangular small dagger was discovered in a Beaker level.

Bibliography: Fadda 1988; 1993; Lo Schiavo 1989, 285; 2000, 30.

Cuguttu, Alghero (Sassari), domus de janas

From one of the tombs of the *necropolis* comes a series of objects in copper, probably originally associated with ceramic material dating to the Early Bronze Age period, but evidently still under the influence of the Camapaniforme *facies*.

The metal finds, all of copper or bronze, consist of an awl, two thin-banded bracelets, two small rings and a fine spiral in flat wire.

Bibliography: Taramelli 1909, fig. 1; Ferrarese Ceruti 1981, LXV.

2.5. Bonnanaro Culture

Perda Bona, Quartu Sant'Elena, tomb (megalithic?)

The tomb, which was destroyed by building works along the Viale Clombo, seems to have been constructed out of great upright slabs.

From this burial, which belongs to the Bonnanaro culture, come a rectangular small dagger with rounded shoulder and with holes for rivets , and an awl or pin, crushed at the centre, in copper or bronze.

Bibliograhy: Atzeni 1986, 28-29, tab. VIII, 2; 1998, fig. 8,20.

Cave of Cuccuru Tirìa or S. Lorenzo, Iglesias (Cagliari)

From this cave comes also a small triangular dagger of the Bonnanaro culture.

Bibliography : Atzeni 2001a, fig. 6 B, 4.

Cave of Ginepro, Iglesias (Cagliari)

The Grotta del Ginepro is situated in the area of Serra de Tanas, above high vertical cliffs, on the south side of

Monte Marganai. Inside it has been found Monte Claro- and Bonnanaro-culture pottery and a copper dagger with triangular blade, curved at the base and with two holes for rivets, which were still in place, attributable to the Bonnanaro phase.

Bibliography : Alba 1996b, 36-37, fig. 2, no. 1; Alba 2001, 39, fig. 5, no. 1.

Cave of S'Oreri, Fluminimaggiore (Cagliari)

The cave, which was chiefly known for the Bonnanaro-culture pottery recovered at the end of XIX century, has produced, at various times, pottery from the Abealzu and Monte Claro cultures, as well as significant material from the Early Bronze Age period. Amongst these last are included three fragments of copper daggers, with a simple, rounded base, furnished with holes, and four other blade fragments; these may belong to the daggers mentioned above, at least in three cases, while the fourth fragment may belong to a sword.

Bibliography : Alba 1996b, 32-36, fig. 1, nos. 8-13.

Is Calitas, Soleminis (Cagliari), trench tomb

In the locality of Is Calitas, situated to the south-east of the modern residential area of Soleminis, a trench burial came to light, which was exclusively used during the Bonnanaro culture.

In the stratigraphic excavation were found about sixty deads; of these, skulls and skeletal parts were discovered, in some cases still attached to one another.

The pottery found in the tomb recalls shapes widely found in Bonnanaro contexts: hemispherical cups, truncated cone-shaped and carinate, and tripod vases with carinate belly.

In addition to the pottery, the grave goods consisted of bronze awls, of a rectangular two-holed brassard, and of an exceptional number of necklace elements. These were, in particular, crescent-moon-shaped pendants made of boar tusks, of teeth of *canides*, of the atrophied canine teeth of deer, and rings made from shells.

Nine bronze awls, of various sizes, were found in the tomb.

Bibliography: Manunza 1998 (in particular: 73, 76, tab. XIX, 2-10 for the awls); 2001.

Cuccuru Nuraxi, Settimo San Pietro (Cagliari), tomb A

The tomb is of the trench type, elliptical in shape with walls protected by stones cut roughly into slabs and originally perhaps covered by large slabs.

The sepulchral apparel consists of some objects in metal (Fig. 11), as well as pottery which is evidently of the Bonnanaro culture. These are a very thin sheet of copper or bronze or silver [6], shaped like a willow leaf with a small hole at one end, an awl or pin in copper or bronze, and a fragment of pin in copper or bronze.

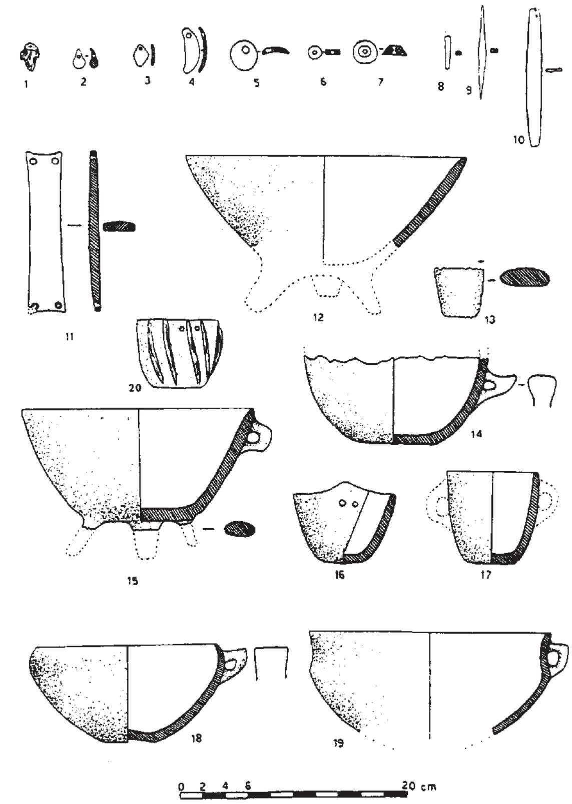


Fig. 11 – Settimo San Pietro (CA), Cuccuru Nuraxi: grave goods from tomb A *(after Atzeni 1996).*

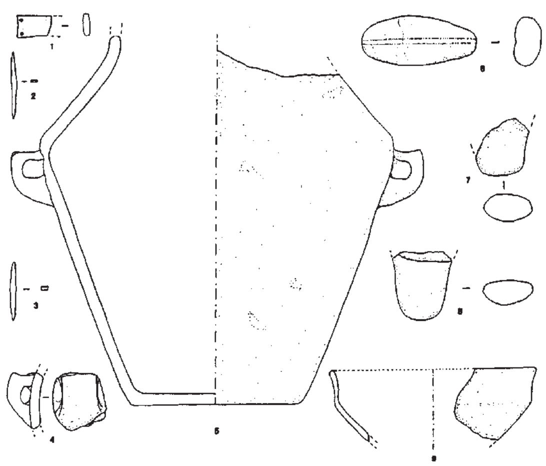


Fig. 12 – Portoscuso (CA), Su Stangioni: finds from the dwelling structure *(drawing Eliseo Lai).*

6. There is contrasting information on the metal used for the sheet. However, on the basis of the most recent indications (Lo Schiavo 2000, 31; Atzeni 1998, 251), it is believed that it is silver.

Bibliography: Atzeni 1958, 102-109, tab. XIII, 1,3,4; 1986, 28; 1996a, 406, fig. 7, nos. 8-10; 1998, 251, fig. 8,1-19 (8-10: metal elements).

Su Stangioni, Portoscuso (Cagliari), residential structure

The dwelling structure consists of a roughly rectangular room with an entrance opening on the short side, base in masonry made of small stones, floor in pebbles and a central hearth. The pottery fragments recovered belong to cups, large vases with enlarged rims, to carinate forms, to tripods with squat square feet. The whole context, including a fragment of brassard, is evidently of the Bonnanaro culture. In the structure were found two lozenge awls in copper or bronze, square in cross-section (fig. 12).

Bibliography: Usai L.1996a, fig. 27; 1999 (in particular: 240, fig. 7, 3-4 for the awls).

Cave I of Frommosa, Villanovatulo (Nuoro) (Archaeological file 6)

The first chance discovery of human skeletal remains and Bonnanaro-culture pottery finds was followed by the systematic excavation of the archaeological deposit. The excavation led to the discovery of other bone and ceramic material (including some which belonged to the Abealzu cultures), five obsidian arrow tips with tang and fins, a flint knife, a pendent-awl in mica-schist, two necklace beads in bone, two copper dagger blades and an awl also in copper.

The only items of all these finds to have been published, at least in part, are a bowl with high vertical shoulder and very low belly, and the two small copper daggers, all from the Bonnanaro culture.

Bibliography: Contu 1970; Ferrarese Ceruti, Germanà 1978, 24, tab. XXVII, 1; Ferrarese Ceruti 1981, LXXIV, C. 73; Cincotti, Demurtas, Lo Schiavo 1998, 160, fig. 2; Lo Schiavo 2000, 31.

Murisiddi, Isili (Nuoro), megalithic tomb (Archaeological file 7)

The tomb, which is roughly rectangular in shape and with an entrance thought to have faced south-east, is fundamentally characterized by the reuse in the whole structure of *statue-menhirs* which have been deliberately broken up. In spite of the damage the monument has suffered, thirty-three fragments of *statue-menhirs* have been identified, many of which were incorporated in the masonry of the tomb. The symbols in relief on the flat face of the statues are exclusively schematic representations of the face.

The archaeological deposit seemed mixed up and the human remains were not found joined together, but the *crania* of a dozen individuals were recovered.

The funerary stratum produced some vases, including a tripod, which allow us to attribute the burials to the Bonnanaro culture. Other elements of the apparel are a brassard with four holes, necklace beads made of shells, two disc-shaped elements in bone, flakes and microliths in obsidian, as well as an awl and two small daggers in copper, one with a simple base and the other with a short tang.

Bibliography: Lo Schiavo 2000, 31; Perra 2000.

Aiodda, Nurallao (Nuoro), megalithic tomb

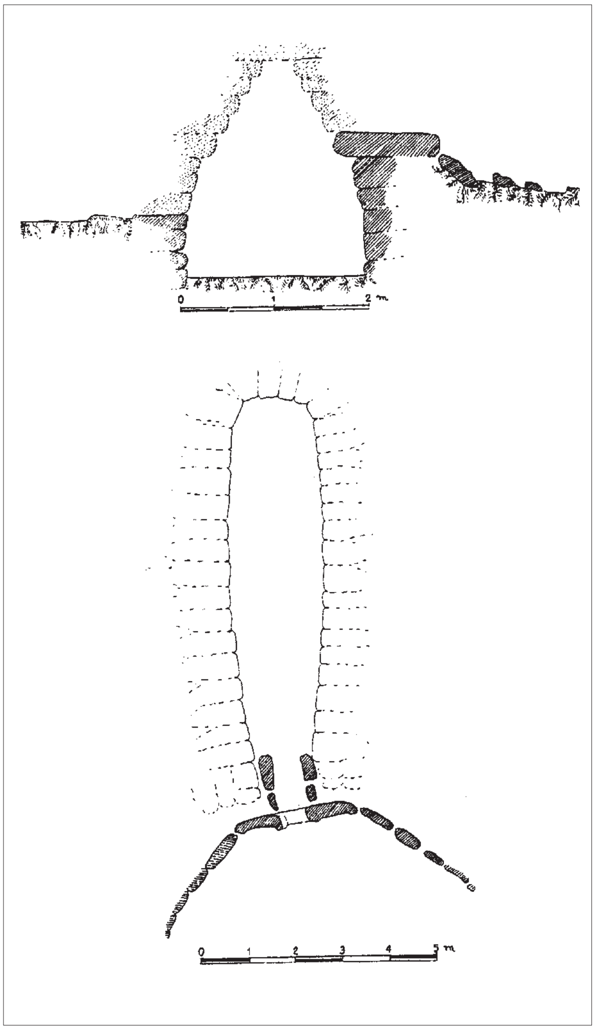


Fig. 13 – Ground plan and cross-section of the tomb of Aiodda at Nurallao *(after Atzeni 1979).*

The tomb is Naveta-shaped, and is set into the slope of a hill. The front prospect is a semicircular *exedra*, added at a later building phase. In the masonry structure numerous stumps of *statue-menhir* were reused.

In the burial chamber were found numerous “lozenge” pins in copper or bronze.

The tomb is dated between the end of the Copper and the beginning of the Bronze Age.

Bibliography: Sanges 2000a.

Corona Moltana, Bonnanaro (Sassari), hypogean tomb

In 1889 numerous vases were recuperated in the *domus de janas* of Corona Montana, which then gave their name to the Bonnanaro culture and are today housed in part in the Museo Archeologico of Cagliari and in part in that of Sassari.

There was also found a small band ring in bronze, today kept in the deposits of the Museum of Cagliari.

Bibliography: Vivanet 1891; Pinza 1901, coll. 84-85; Ferrarese Ceruti, Germanà 1978, note 57, tabs. XVII-XVIII, XX; Usai L. 1991, 5.

2.6. Uncertain chronology

Sa Corona, Villagreca (Cagliari), tower-hut

This circular structure, constructed in courses of irregularly many-sided or rounded limestone blocks, dominates an extensive hut-dwelling settlement of the Monte Claro culture. The characteristics of the structure, which appears to be without *tholos* but in a dominating and strategic position, suggest that the building be taken as a “hut-tower”.

The excavation of the internal deposit uncovered pottery fragments typical of the Monte Claro culture, together with others, undecorated, of Ozieri tradition and also abundant material attributed to an archaic phase of the nuragic period. It is therefore difficult to date the copper or bronze dagger, with flat blade and two small rivets at its base, which was found in the deposit, although the typology is reminiscent of Aeneolithic examples from Serra Cannigas.

Bibliography: Atzeni 1966, (in particular fig. 11, b: dagger); 1981, XLV, fig. 25

Su Coddu-S’Ariana, Selargius (Cagliari)

E. Atzeni mentions the discovery in a Monte Claro pocket of a copper dagger point, analysed by the University of Cagliari. In the light of the recent and extensive excavations at the site of Su Coddu, the attribution to the Monte Claro seems doubtful, as only Ozieri and Sub-Ozieri material was discovered in the settlement. However, «hut bottoms» and other Monte Claro structures have been discovered in the cuttings of the Bia de Sestu, near today’s SS. 554. This site may be identified as that mentioned by Atzeni as Su Coddu-S’Ariana.

Bibliography: Atzeni 1967, 177, note 14; 1986, 26-27; Ugas 1997, 57.

Anghelu Ruju, Alghero (Sassari), hypogean necropolis

The burial complex of Anghelu Ruju, which has been investigated in the course of various excavations since 1903, is made up of numerous *hypogea* cut into a flat outcrop of sandstone.

The architectural typologies are mostly of the arrangement of entrance *a pozzetto* and irregular ground plans, with a cell which is often *a forno*, with a central T-shaped nucleus with *dromos* access.

The dating of the *necropolis* goes from the Recent Neolithic to the Early Bronze, with material from the Ozieri, Filigosa. Abealzu, Monte Claro, Beaker and Bonnanaro cultures.

The reuse of the sepulchres does not allow us to identify completely the cultural sequence of the various tombs. It seems particularly difficult to establish the association of the metal objects with the vase contexts. However, it seems that most of the copper or bronze material belongs to the Beaker culture. To be attributed to this phase are some short small daggers with tang, perhaps of copper, and an unusual triangular arrowhead of the same material. Awls with flattened lozenge-shaped parts of copper or bronze, and wire and narrow decorated sheets in silver, coming from tombs XXX and XVII, are to be attributed to the Beaker culture, or to the following Bonnanaro one.

Amongst the material from tomb XIV has been identified a *tuyère*, attributed to the Beaker phase, even if only Ozieri, Filigosa and Abealzu material has been found in the tomb; it would therefore seem more realistic to attribute it to the Aeneolithic phase of Filigosa or Abealzu.

Bibliography: Ferrarese Ceruti 1981, C 32; Demartis 1986; 1998; Manunza 1990, 49, tab. II, 10; Lo Schiavo 2000, 28; Melis 2000, 84, tab. 68, no. 752 a.

Mesu’e Montes, Ossi (Sassari), tomb II

The *domu*, which consists altogether of twelve rooms, is of the T-shaped type, distinct in that the cells open in correspondence with the cross-axis of the second room. The largest cell has a rich and varied repertoire of ornamentation, with motifs in architectural taste which portray symbolic representations in a style which is manifestly magico-religious.

In the tomb has been found, although not in stratigraphic sequence, material from the last phase of the Ozieri culture, as well as from the initial Abealzu Filigosa, Monte Claro and Bonnanaro cultures. Amongst the material found features also a bronze blade, probably of a dagger, very corroded and with gaps and without its midrib. The blade is attributed to the Aeneolithic period, but the problem of its exact dating remains open.

Bibliography: Demartis, Canalis 1985 (66, 72, fig. 19, no. 5: dagger).

Sant’Andrea, Sorso (Sassari), burial

The few remains of a burial recovered still *in situ* consist of a skull, long bones and fragments of a Beaker pot. In the earth removed by clandestine excavators was also found a small triangular dagger in copper or bronze, which may be linked to the burial.

Bibliography: Demartis 1992.

Monte d’Accoddi, Sassari

In addition to the fragments of crucible mentioned before, there are some artefacts in metal from the excavations at Monte d’Accoddi; these are still unpublished and have not been dated, even if objects in copper or bronze are present from the deepest strata onwards.

From the Contu excavations, there are 14 awls; 8 fragments; a triangular dagger; 3 small, flat, simple hatchets; an axe-shaped pendent, all of “arsenical copper/bronze”; a small circular disc in silver; a small bowl and a fragment of lead; the shapeless lump of galena.

A flat axe with large cutting edge has been attributed to a phase of the Bonnanaro culture still under Beaker influence (Contu 1996, 392, fig. 3, 16; Lo Schiavo 2000, 27).

No metallurgical analyses have been performed. The material is substantially unpublished, apart from references in Contu 1988a; 1988b; 1992; 1995; 1997; 1998 (Contu, com. pers. 9.IX.01).

Bibliography: Contu 1996, 392, fig. 3, 16; Lo Schiavo 2000, 27; 2003, 597-600.

Su Crucifissu Mannu, Porto Torres (Sassari), hypogean necropolis

The hypogean complex discovered by chance in 1956 was scientifically explored during the years 1972-80, but the results of those studies have so far remained mostly unpublished.

All the *domus* at Su Crucifissu are multi-celled and have *a pozzetto* access, except for three which show signs of having been rebuilt with long *dromoi*. The establishment of almost all the *domus* dates to the Ozieri culture, but there are also present many examples of burials carried out in the later Monte Claro, Beaker and Bonnanaro cultures.

The tomb to have produced the most scientifically interesting data is XVI; the *hypogeum*, in fact, has preserved up to today the stone covering at the external hatch, maintaining intact the internal stratigraphic succession, which goes from the Recent Neolithic to the Early Bronze Ages and summarizes the whole history of the *necropolis*.

The point of a small dagger is attributed to the Monte Claro-phase use of tomb XVI.

There are furthermore general information about two small daggers and a flat axe with straight edges, attributed to the Beaker phase and about other finds (small daggers, awls, fragments of rods, circular in cross-section or twisted), dating to the Bonnanaro culture.

Bibliography: Ferrarese Ceruti 1972-74; 1981, C 38; Demartis 1998a, 14-22; Lo Schiavo 2000, 31.

Monte Baranta, Olmedo (Sassari), megalithic complex (Archaeological file 4)

The fortified system of Monte Baranta is situated at the end of a *plateau*, and consists of a semi-elliptic enclosure-tower and of a massive wall which encloses a group of huts (at least six) with straight walls and divided internally into several rooms.

On the outside of the enclosure, menhirs and a megalithic circle mark a clearly separate sacred area.

The abundant finds document phases of existence which are distinct but not covering a long span. The creation of the whole complex is dated to the Monte Claro culture; after a period of abandonment the site was reoccupied in the Middle Bronze, as is attested by many pottery finds of the Bonnanaro type. This is the phase of occupation which is documented by the largest number of finds, but there has also been discovered material dating to the Recent-Final Bronze Age.

The only metal artefact was found in the enclosure-tower and comes from the Monte Claro culture; it is a *spatula* with simple base and parallel edges, rounded point and lenticular in cross-section. In the upper quarter, there is a hole in the centre. The analyses carried out have demonstrated the use of bronze for the making of the item, for which reason the attribution to the Monte Claro phase seems doubtful, to say the least.

Bibliography: Moravetti 1981 (in particular fig. 1 for the *spatula*); 1998, 162-164, figs. 19.4-19.9; 1993-1995 (in particular for the metal object: 177, figg. 118, 9, 122); Lo Schiavo 1989, 284 (file 18).

Cave I of the Four Seasons, Iglesias (Cagliari)

In the cave has been found pottery from the Monte Claro and Bonnanaro cultures, and from the Middle Bronze Age. A copper dagger, with triangular elongated blade and very curved base and two holes for rivets which were still in place, was also found in the cave; it was attributed to the Bonnanaro culture, but there are no stratigraphic data to give a definite dating.

Bibliography: Alba 1996b, 38, fig. 2, no. 2; 2001, 39, fig. 5, no. 6.

2.7. Indirect testimony : the statue-menhirs

The testimony of the weapons portrayed on the male menhir-statues, while becoming ever more consistent over last years, has yet to find confirmation in the discovery of at least one real object which could have served as model.

The type of dagger most commonly portrayed is that with triangular blade, with long straight sides and rounded base corners; sometimes a V-shaped incision is inserted in the blade (fig. 14). There may also be the repetition of the representation with double blades.

In a menhir-statue of Serra Monte Arcu di Isili - and similar types are found on other statues – is depicted a dagger with triangular blade with convex sides and straight ends, fastened to a long rectangular handle, on which is inserted a large rounded-trapezoidal pommel.

Another type, represented in a dagger of Poloidòni (Isili), is characterized by a large blade with long convex edges and rounded point, fastened to a square handle ending with a pommel which is truncated-ogival in shape.

The type of dagger portrayed in the menhir-statues is not always easy to interpret. Apart from the possibility of symbolic representations, as in the case, for instance, of two statues from the territory of Laconi, it seems that in the

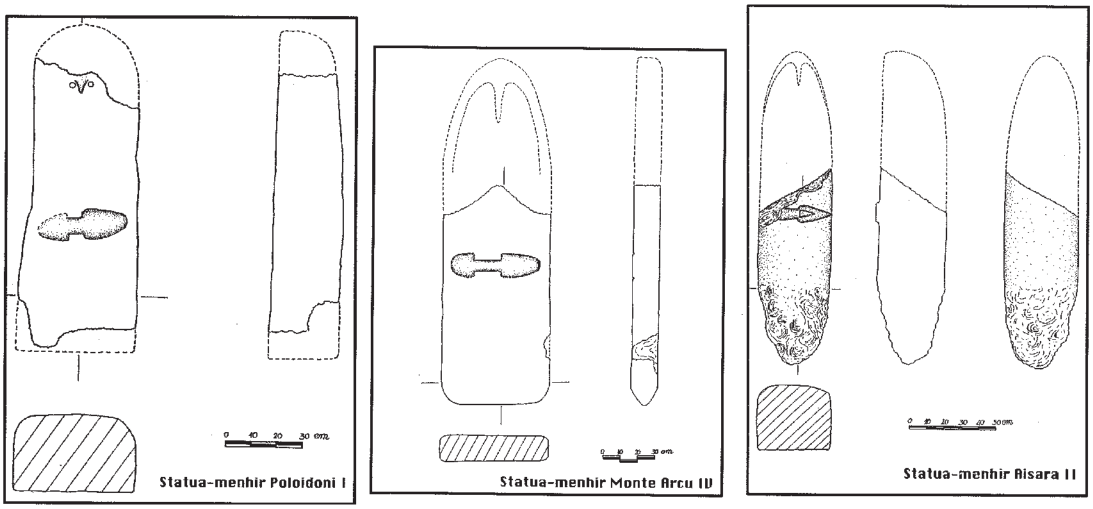


Fig. 14 - *Statue-menhirs* from the territory of Isili *(after Saba 2000).*

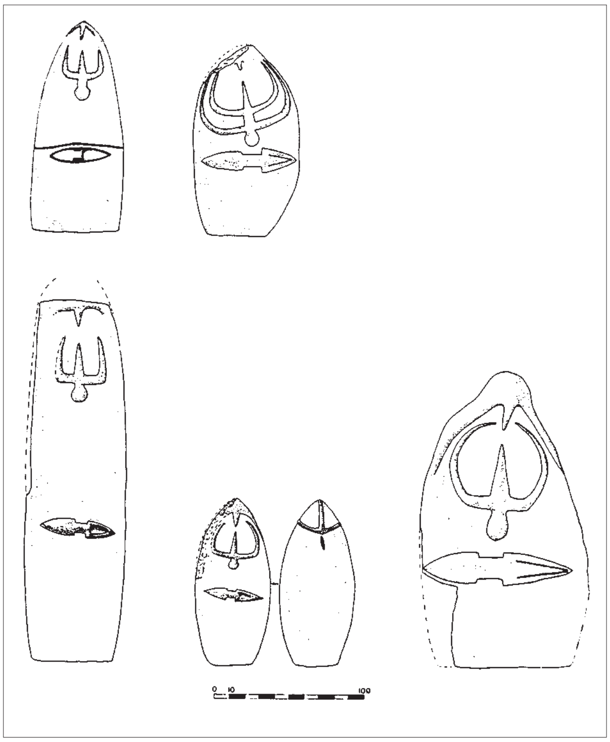


Fig. 15 - *Statue-menhirs* from the territory of Laconi *(after Atzeni 1979).*

case of rounded blades the weapon may be stored in a sheath, and therefore it may not be possible to identify the exact shape of the dagger (fig. 15).

The menhir-statues are now dated to the Aeneolithic period, and certainly to before the beginning of the Early Bronze. The reuse of large pieces of stele as building stones in some tombs with Bonnanaro apparels (Aiodda di Nurallao, Murisiddi di Isili) is a fundamental indirect proof of this. A more precise dating to the Abealzu and Filigosa phases, however, derives from finds in various localities of the Laconi territory, where the menhir-statues are found in areas which have produced on the surface or in burial monuments materials from those cultures.

Bibliography: Atzeni 1979; 1994; 1997; Lo Schiavo 2000, 30; Saba 2000; Murru 2000.

3. Conclusions

As we can see, although the data available sometimes uncertain, it is sufficient in quantity and of such a type as to allow to us to work out some conclusions.

Some contexts, and more specifically those of Pranu Mutteddu di Goni and Su Coddu di Selargius, to which should perhaps be added that of Grotta di Monte Majore di Thiesi, would indicate the use of the first artefacts in metal, or even the manufacture of these *in loco*, given the presence of slags in the hut bottoms at Selargius already by the time of the Ozieri culture, which is now almost unanimously placed in the Recent Neolithic period (AA.VV. 2000, 8). This waste in particular, however, cannot be taken as proof, as it is without confirmatory analyses[7]. As far as the Pranu Mutteddu objects are concerned, then, these come from a context in which the other materials denote a much later phase of the culture. The decoration of the vases, although reflecting the well-known one from the classic Ozieri contexts, shows a rather coarse technique. The small dagger and *stiletto* in flint, which are absolutely unique so far in Sardinia, are furthermore reminiscent of Aeneolithic contexts from outside the island (Atzeni, Cocco 1989, 201-202). The tomb typology itself, in addi-

7. It is important to stress that the waste has never been analysed (Ugas 1993, 25).

tion, seems rather unusual in the framework of the Sardinian Recent Neolithic period (Atzeni, Cocco 1989, 201-202).

The evidence from the first Aeneolithic period is much more consistent, beginning from the Sub-Ozieri phase up to the Filigosa and Abealzu phases[8]. As well as the variety of the objects (weapons, instruments, jewels) the presence of various metals is also significant: copper, silver, lead. The richest context is certainly that of tomb 2 of Cungiau Sa Tutta di Piscinas, where, in certain association with Filigosa pottery items, were found copper and silver rings, copper daggers and spikes, copper pins and two triangular hatchets, also in copper [9].

If, as would appear to be the case, the cultural attributions are exact, to these material elements could also be added the *tuyère* from Anghelu Ruju and the two spoon crucibles from Monte Accoddi, which are evidence of production *in loco*[10].

To this direct evidence can also be added the indirect evidence represented by the male menhir-statues.

Furthermore, all the material, monumental and artistic documentation of the first Sardinian Aeneolithic period forms a picture which marks a detachment, albeit gradual, from earlier Neolithic experiences, but which fits the putting into practice of the first metalworking experiences [11].

In spite of the Monte Claro culture being so widespread over the territory, there are not so many material testimonies as far as metalworking is concerned. Although it is true that ….” the Monte Claro culture is the first during which there is manifested a typological individuality with the shape of the daggers…” (“ *la cultura di Monte Claro è la prima durante la quale si manifesta una precisa individualità tipologica soprattutto con la foggia dei pugnali”*) (Lo Schiavo 2000, 24), there are not many other attestations to confirm the material picture. In addition to the confirmation of the use of lead (Atzeni 2001, fig. 4) the discovery of two *tuyères* in the Biriai site seems particularly significant (Castaldi 1999, 140, tabs. XXII, 2-3 and LXVII, 15; Lo Schiavo 2003, 602).

As far as the Beaker evidence is concerned, it coincides, as has already been said[12], with that of a vast area in the west; it cannot be denied, however, that the ever greater documentation from Beaker contexts in Sardinia and the close links which are established with the subsequent Bonnanaro culture (Atzeni 1996a) may have a precise significance in subsequent cultural developments.

In conclusion, on the understanding that there is a lack of direct proof of metalworking activity and elements demonstrating the technology employed, it can be maintained that from the archaeological point of view many indications point to local production in the period under examination for the greater part of the metal finds from Sardinia. This is in consideration of the fairly large number of finds, particularly from the most ancient phases, and of the presence of some particular shapes to which nothing comparable is found in contexts outside the island.

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8. The most up-to-date list of the finds from the phase under examination, before this synthesis, is in Melis 2000, 81-88, tabb. 110-11.
9. In addition to the table attached to the analyses in this present work, see Usai L. 1996; 1998; 2000.
10. The possibility of the first experimentation of the use of fire in the treatment of copper in Sardinia and Corsica at the beginning of III millennium BC is in Lo Schiavo 2003, 602.
11. On the various material and monumental components of the Early Aeneolithic period, see Melis 2000.
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2.
THE FIRST COPPER AND BRONZE FINDS, FROM THE BEGINNING OF II MILLENNIUM

Fulvia Lo Schiavo

1. The immediate precedents

TRADITIONAL CHRONOLOGY		DENDRO C14	SARDINIA	MAINLAND GREECE		TRADITIONAL CHRONOLOGY
1800		2300				
	EBA 1		BONNANARO			
1700		2000				
	EBA 2		S.IROXI			
1600		1700				1600
	MBA 1		SA TURRICULA		I	
1500		1600			II	1500
	MBA 2					
1400		1500	"METOPE" IMERESSED WARE (SAN COSIMO) "A PETTINE" IMPRESSED WARE			1400
	MBA 3			MYCENAEAN	IIIA	
1300		1365		(LATE HELLADIC)		1300
	L B A					
	RBA		"A PETTINE" IMPRESSED WARE CARINATED BOWLS COLLARED JARS; THICK RIM JARS "GREY" WARE		IIIB	
1150		1200				
1125	FBA 1					1190
1100		1150	NURAGIC FBA 1-2 PRE-GEOMETRIC POTTERY		IIIC	
	FBA 2					
1000		1080		SUBMYCENAEAN		
	FBA 3		NURAGIC FBA 3 GEOMETRIC POTTERY			1050
900		1020				
850	EIA	950	NURAGIC EIA			
525		525				

Chronological sequence of Bronze Age Sardinia

Fig. 1 – Chronological table of Bronze Age Sardinia *(after Lo Schiavo 2003).*

If we wish to proceed in a critical way and on confirmed bases, we can talk of "metalworking" only in the presence of smelting workshops, slag, casting moulds and scraps, associated together in such a way as to constitute a sure document of the activity of refining minerals, of production of artefacts, finishing, decoration, repairing and transformation of objects, in defined and specialized places.

Further on (see Part IV, chapter 3) these documents will be analysed from the archaeological point of view, in an attempt to trace the characteristic lines of nuragic metallurgy. Here, however, we intend to examine what went before, that is to say what were the forerunners, the most archaic phases and the most ancient characteristics of this phenomenon. It is of particular interest, from the archaeological and historical points of view, to pick up any lines of continuity or, conversely, changes of orientation and of influence.

The problem is that the most debated and least definable period of the exceedingly rich, multiform, varied and interesting history of ancient Sardinia is the very one which precedes the nuragic civilization, and more precisely the long and troubled period which goes from the end of the Chalcolithic to the beginning of the Middle Bronze Age, embracing more or less the end of III millennium and the first two or three centuries of II millennium. This imprecision in the chronological references already reveals the serious uncertainty in the relative parameters. From the cultural point of view it is the period in which, as successors to the archaeological *facies* of Monte Claro, appear and become defined the archaeological *facies* of the Beaker and Bonnanaro, and then that of S. Iroxi, this last principally featuring in the south, although this may depend on the absence of sufficient publications of sites and materials from the other regions of the island.

With the sole scope of tracing the lines of this complex history, mention is made of the abundance of artefacts, above all pottery, which are found in the *domus de janas* and in tombs of other types, as against the very scarce documentation in settlement sites, the complete disappearance of monuments, unless we exclude burial monuments which continue strongly from the previous *facies*, and the parallel decline in the quality of the pottery, especially when compared with some refined productions in the Monte Claro style. It must be emphasized that the dimensions and elegance of some Monte Claro vases, particularly the grooved, *situla*-shaped ones with highly-polished decoration, display an undeniable skill in the firing and equal mastery in the construction of adequate furnaces and in the control of their functioning, leading to the structural and chromatic effect of the final product.

As far as metallurgy is concerned, we are far from having available documents which attest the same skill in the arts of casting and the production of items, at least up to today, that is to say until daggers, like the ones portrayed on the *statue-menhirs* of the Sarcidano and the adjacent areas, are actually found. All the finds available belonging to the archaeological *facies* of Monte Claro are very few and extremely simple.

Fewer and of less high quality are the metal objects that can be definitely referred to the following period : small daggers, awls, small hatchets, amongst which stands out the exceptional, indeed unique, gold collar from Gonnostramatza. Apart from anything else, these are artefacts found in tombs, and never, so far, directly where they were worked. Local production, in short, cannot be ascertained on either technological or typological grounds, and, on the contrary, the shape of the items emphasizes that they belong to a vast world of western production, which approximately coincides with that of the Beaker style. This scarce and inconsistent presence can be judged to be local only on archaeological grounds.

2. The "Argaric" swords (Fig. 2)

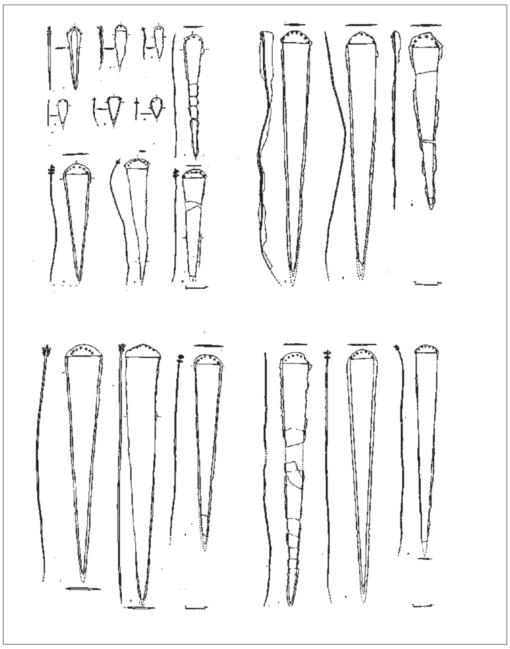


Fig. 2 – Decimoputzu, S. Iroxi: daggers and "Argaric" swords *(after Ugas 1990).*

The metal artefacts of the period which immediately precedes the nuragic civilization, including that known as "di S. Iroxi", which can be dated to the advanced phase of the Early Bronze Age, can be declared, although only on the basis of very slender evidence, to be of local production and with typological affinities with western production. In the *hypogeum* called "di S. Iroxi" (see Archaeological file 8), the large flat swords, with simple semicircular base fixed with many rivets (between 5 and 7) are found together with daggers, small daggers and awls, no different at all from those found over the whole island, except for their abundance and the large range of sizes. The sword of Maracalagonis in fact comes from another locality in southern Sardinia, and, as far as we know, from a megalithic tomb, and not from a hypogean one (see Archaeological file 9).

Bearing in mind all this, an analogy with the Argaric swords has been suggested, not as a hypothesis of importation, but as a further element indicating local production, in the broad sweep of western influences and affinities. In fact, the late dating assigned by G. Ugas to the strata in which were found the S. Iroxi swords, which belong to the Bonnanaro A2 *facies*, distinct from the earlier Bonnanaro A1 and the later Sa Turricula f*acies*, to the period "between the end of XVII and the first half of XVI centuries BC" ("*tra la fine del XVII e la prima metà del XVI secolo a.C.*") (Ugas 1990a, 103), confirms the impossibility of the importation of the Sardinian swords from El Argar. On the contrary, it would prove the parallel evolution with common features, deriving in all probability from the Beaker culture, as we said above (Lo Schiavo 1992)[1].

3. The large flanged axes (Fig. 4-5, 6.1-4)

The most ancient nuragic monuments - the so-called "corridor" nuraghi, or, according to some, the "protonuraghi" or pseudonuraghi" - have not so far produced metal artefacts, nor have the most ancient forms of axes and dirks been subject to metallurgical analysis; for this reason we start from a situation of extreme uncertainty. The most certain elements are for the moment the typological and archaeological ones, and on these are based the observations on the most ancient nuragic production.

The large flanged axes are now an established fact, since G. L. Carancini, in his many studies on the axes of the Italian mainland, identified the "Sezze type" as representative of the first moment of the Early Bronze age in central Italy and matched it with a Sardinian shape called "Orosei type", because they were the axes which cor-

1. It is exactly this context, of which are part not only the concept of "megalithism", which taken on its own is rather evanescent, but also the much more concrete one of the archaeological Beaker *facies* and of its subsequent developments, whose western associations are beyond doubt, which renders improbable, just on account of the swords from S. Iroxi and Maracalagonis, a formal association with the large sword (80 cm) found in the Palace of Mallia in Crete in a MMI-II context (ca 2000-1700 BC) (Chapoutier-Charbonneaux 1928, tab. I; Branigan 1974, 16, tab. 11, no. 486; van Effenterre 1980, fig. 524). This sword, on account of the great thickness of the blade with its hammered cutting edge, the base slightly curving with four rivets, is not typologically similar to the Sardinian swords. The association is not therefore justifiable from the point of view of shape, as well as being isolated culturally.

responded to those found in the nuragic complex of Sa Linnarta at Orosei (Peroni 1971; Carancini 1992/93; 1997; Lo Schiavo 1978; Carancini/Peroni 1999)[2].

Subsequently, a specific study on this sort of instrument established its typological definition (Lo Schiavo 1992b): they are flanged axes of large size (from 26.6 cm to 24), whose shape is elongated, almost rectangular, with a short cutting edge, straight or slightly curving, high edges (2.7 - 2 cm) in relation to the limited thickness of the blade (1.2 - 0.6 cm), the lateral outline elliptical.

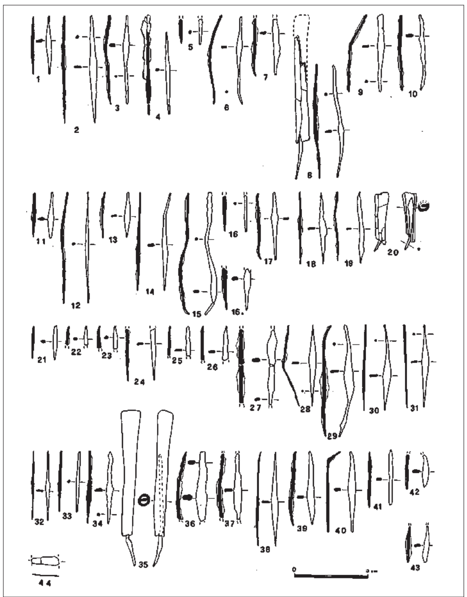
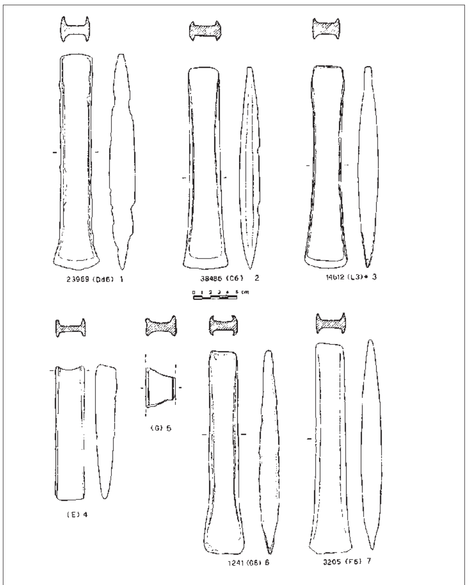
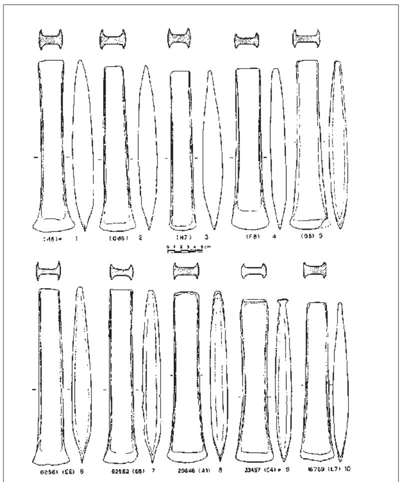


Fig. 3 – Decimoputzu, S. Iroxi: awls and drifts *(after Ugas 1990).*



1-2. Usini; 3. Ozieri; 4. Oschiri; 5. Olbia; 6. "Nurra"; 7. Unknown Prov.

Fig. 4 – Large flanged axes from Sassari province *(after Lo Schiavo 1992).*



1-3. Orosei, La Linnarta; 4. Orosei, Nurake; 5. "Nuorese"; 6-7. Villagrande Strisaili; 8. Meana; 9. Lanusei; 10. Nuragus.

Fig. 5 – Large flanged axes from Nuoro province *(after Lo Schiavo 1992).*

There are examples, remarkably homogeneous in shape, from some fifteen localities throughout central-northern Sardinia which have generally produced a few pieces each, with the exception of two localities, Nule (Sassari) and Ilbono (Nuoro). In the first there was a real hoard containing 21 axes, assembled 100 metres from the nuraghe Sisine at Nule (Taramelli 1927, 159-165; Lo Schiavo 1992b, figs. 1-3). At Ilbono there were seven examples, of which only six of this type, in the Collezione Gouin, according to Pinza, which came from "giants' tombs....at Ilbono and Ottava..." ("*sepolcri di giganti ... di Ilbono e di Ottava ...*") (Pinza 1901, 267 note 3; Lo Schiavo 1992b fig. 4).

Although these have not so far been found in stratigraphic contexts and in connection with monumental structures, nor in association with other pottery or metal artefacts, the typological characteristics of the "Orosei type", or, perhaps more correctly, "Nule-Ilbono type", show it to be closely and convincingly akin to the central Italic type, to the point that a hypothetical dating not far from that attributed to the "Sezze type" would be confirmed, that is to say within the Middle Bronze Age and no later, even if not at the very beginning. In fact, a second confirmatory element is the very wide distribution in the island of similar but typologically distinct types, which come from contexts of the Final Bronze Age or even of the Recent Bronze Age (Lo Schiavo *et al.* 2004). The conservatism of the nuragic forms is also striking; this is in contrast to the elaboration in shape of the mainland models, which keep the hollow at the heel and take on a sinuous shape with distinct and ever

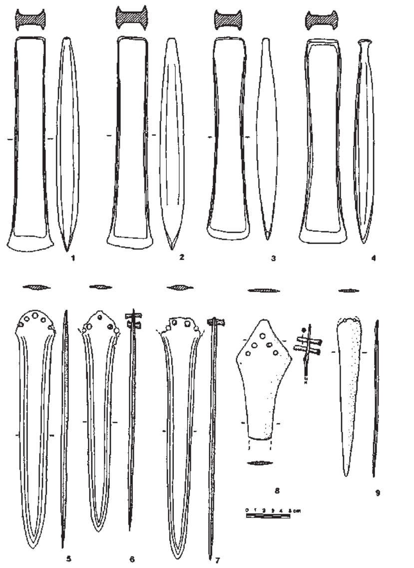
2. Carancini/Peroni 1999, note 37 a p. 28; p. 14 note 54, tab. 12,4-5; 13, 7-8; see preceding bibliography.

more pronounced winglets (Carancini, Peroni 1999, tabs. 12-13).

This form, which is essential for the understanding of the first phases of nuragic metallurgic production, has not so far been the object of any sort of metallurgical or technological analysis.

Production in a two-piece mould seems evident, but, as Carancini has hypothesized in the case of the mainland examples, the moulds may have been in perishable sandstone, as so far no trace of them has been found. Two-piece mould production is certain for the flanged axes of the following periods, some of which have a cross-section with the midrib corresponding to the joint between the two parts (see below p. 289).

4. Dirks and daggers with simple base (Fig. 6, 5-9)



Flanged axes: 1. Nule; 2. Ilbono; 3. Ozieri; 4. Lanusei; Simple base daggers: 5-7. Siniscola; 8. Settimo S. Pietro; 9. Villanovafranca

Fig. 6 – Middle Bronze Age axes and weapons: *(after Ferrarese Ceruti, Lo Schiavo 1992).*

Little more can be said about three dirks found at Siniscola, without the context of provenance, characterized by the simple base fixed with five rivets and with robust blade, lenticular in cross-section, which, it has been suggested, are comparable to Roncoferraro and, above all, Castione, types, defined by V. Bianco Peroni and dated, on the basis of central European comparisons, to the Middle Bronze Age. It is therefore a form of weapon contemporary with the large flanged axes, of which the number of examples found is limited to these three, and to two other similar ones, a dirk with simple base from the locality of S. Marco di Settimo S. Pietro (Nuvoli 1988, 40, 42, tab. V) and a small dagger (18.3 cm) from the nuraghe Su Mulinu at Villanovafranca (Ugas 1987, 79, fig. 5 nos. 6, 17). This last is the only one found in its stratum, in association with pottery material from the Middle Bronze Age, which would confirm the dating of the form (Ferrarese Ceruti, Lo Schiavo 1991/1992).

5. The complex of Ottana (?) (Fig. 7) (see Archaeological file 13, codes A4-A6)

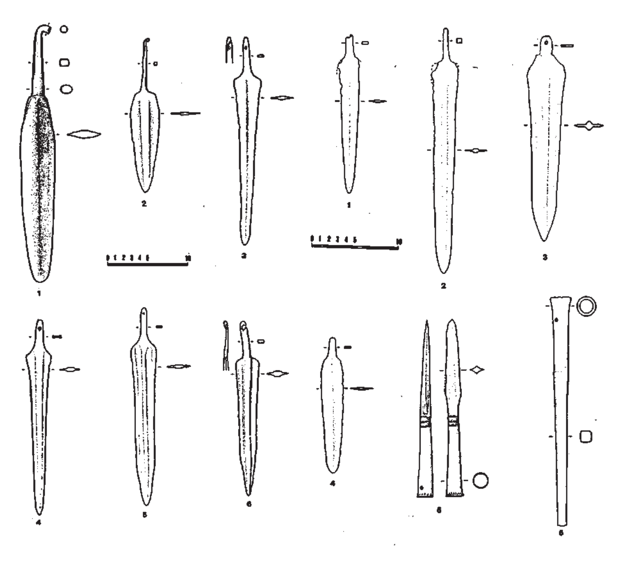


Fig. 7 – Ottana (?). Complex of bronze weapons *(after Lo Schiavo 1980).*

In 1977, the Soprintendenza Archeologica for the provinces of Sassari and Nuoro acquired an interesting complex of bronze weapons, found in an undetermined site in central Sardinia, somewhere round the zone of Ottana (Lo Schiavo 1978a; 1980, 341). The impossibility of verifying the information remains a serious gap in the assessment of the artefacts, even if other discoveries made in Sardinia in the meantime have led to the broader and more detailed study of the matter : we may justifiably expect further progress on this score in future.

It involves one dirk with hooked tang, four dirks and a dagger with holed tang, one dirk and one dagger with tang, one dirk with a short handle with hole, and one spearhead and one tip, both with trunnion socket.

These weapons belong to different types, each with its particular area of distribution and chronology. In the case of the two blades with hooked tang, their affinity with the large family known as the "hook-tanged weapons" o "Cypriot daggers" was noted at the beginning[3].

Given, therefore, the endless characterization of this class of weapon, in spite of its variety and its Aegean-

3. The enormous bibliography on the subject was assembled and presented in Lo Schiavo 1980, 347, note 1.

Oriental distribution and centre in Cyprus, the finding of a few more than twenty “Cypriot daggers” in Europe, known about since the end of XIX century, has excited great interest and lively discussions. In a magisterial synthesis dealing with all the pros and cons, T. Watkins concluded in the negative: none of these pieces could be held to have come from Cyprus in antiquity, but rather were brought west by modern travellers and merchants (Watkins 1976).

Although wide-ranging and well-documented, Watkins' work has not closed the discussion, both because other items of the same type were found in Europe (Gomez 1975; Gerloff 1975), and because some believed they recognized representations of these weapons on two Breton *allées couvertes*, and because a typological reference was observed between the “Cypriot” hook-tanged daggers and the daggers with holed tangs, characteristic on the other hand of weapons for throwing, from the Arreton Down *facies*, complementary to and contemporary with the second phase of the Wessex culture (Camerton-Snowshill, Aldbourne), datable to the transition period, on the continent, from Early to Middle Bronze Ages, and the first part of this last[4]. Lastly, following another discovery, also “from antiquity”, the argument has been taken up again by D. Brandherm, who, in a broad and close examination, reaches the conclusion that perhaps not all weapons defined as “Cypriot daggers” in Europe can be considered to be of recent provenance (Brandherm 2000).

The acquisition of the weapons from Ottana occurred at the height of the argument, and seemed to resolve the question in favour of a possible meeting between the Cypriot and western influences, at least in the area of the central-western Mediterranean, where local production drawing on both cultural worlds could fully justify the visible typological differences. Apart from anything else, at the same period was published a hoard from Sansueña, Rosines de Vidriales, Zamora (Delibes de Castro 1980), which, along with other factors, contained daggers with tangs with and without holes (about 3-5) and a spear point, undecorated but almost identical in shape to the Ottana one. In this way the theory of local production as a consequence of “crossed” influences would be reinforced.

As has been explicitly said and demonstrated, the two daggers with hooked tang from Ottana do not have convincing analogies in Cyprus, but only very generic ones and in the ancient a broad chronological span from the Early Cypriot I and III (2300-1900 BC). Equally unsatisfactory on account of their vagueness are the similarities pointed to for the spearhead and tip in shapes of Late Cyprus I; the head, particularly on account of its decoration, can be attributed to local production, although there are still no really acceptable parallels, except, as far as shape goes, for the Spanish example.

Analogies for the dirks with holed tang, nos. 3-7, point to the west, while no. 8 is somehow intermediate between the real “Cypriot daggers”, and the Arreton Down-type dirks, no. 10, are more difficult to collocate on account of the simplicity of their shape.

Meanwhile, two daggers with hooked tang and two holes at the base of the blade, akin to the Pépinville- and Arco-type swords, were found in one of the megalithic tombs of Is Lapideddas at Gonnosnò (Ugas 1990b; 1999, 114, tab. 56, 14-15). The attribution cannot be questioned, in spite of the absence of graphic documentation, on account of the presence of the two holes at the base of the blade, which in one case still held the rivets inserted. If there are some grounds for doubt, this derives from the notably smaller dimensions in relation to those of the Pépinville swords, with which they may be convincingly compared. We may reasonably hypothesize that these types of sword, dirk and dagger, characterized by the big tang, with end thickened or not, bent into hook or straight, with or without holes at the base of the blade, but always with the base narrow and sloping, widespread in northern Italy in the Recent Bronze Age (Bianco Peroni 1970, no 64-78; Carancini, Peroni 1997; 1999), and belonging to the multiform and vast family of tanged weapons (Vagnetti 2000), may have also appeared in Sardinia, where, like the flanged axes mentioned above, they were liberally reproduced (Lo Schiavo *et al.* 2004).

The problems posed by the Ottana complex remain open, therefore, further complicated by the unexpected result of the metallurgical and lead isotopes analyses.

6. The metalworking production of the Recent Bronze Age

The metal artefacts which can be linked in some way to the Recent Bronze Age in Sardinia are so few that it is convenient to list them by category, while discussing their implications.

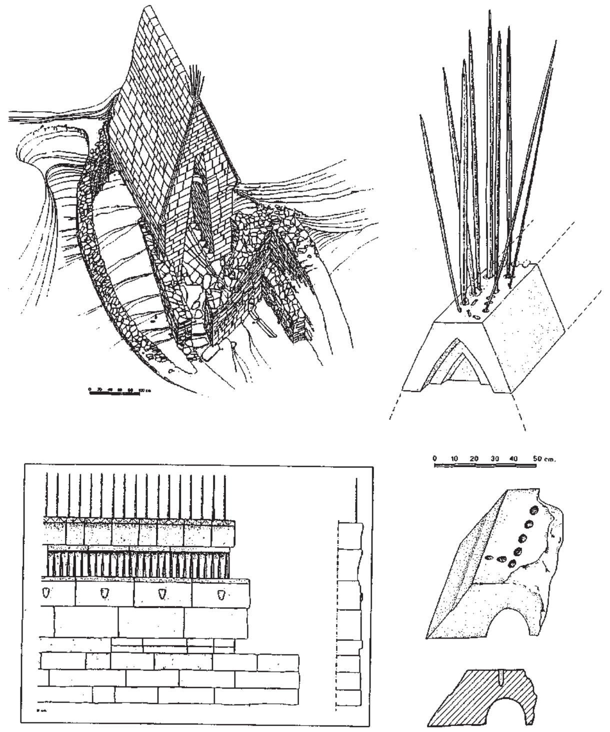
6.1. The oxhide ingots (see below pp. 317-331)

6 fragments of oxhide ingot, 12 fragments of votive sword, a small chisel, square in cross-section, and various attempts at casting, in the hoard of the nuraghe Albucciu at Arzachena, inside a small Kommos-type *olla* (Campus, Leonelli 1999), can be attributed to the Recent Bronze Age with certainty. It is not surprising to find oxhide ingots in Sardinia in the Recent Bronze, in times corresponding to MicIIIB; in fact, it should be assumed that they may have arrived at an earlier moment if we are to accept as valid the reports of the two whole oxhide ingots, found in the foundations of a nuraghe at S. Antioco-Bisarcio. These must have therefore arrived during the erection of the monu-

4. Even more extensive is the bibliography on Wessex: see Lo Schiavo 1980, 348-350, notes 3-8 and above all note 9 on p. 350.

ment, and perhaps, as may have been the case with the *alabastron* of the Arrubiu, obliterated as foundation sacrifices. It is known, in fact, that they had already begun to circulate in the Mediterranean from XIV century onwards. As for Sardinia, it is to be noted that, although there are many undatable contexts, we pass from the few finds which were certainly older to a extended distribution over the whole island in the Final Bronze Age period (see chapter IV).

6.2. The votive swords *(see below p. 310)*

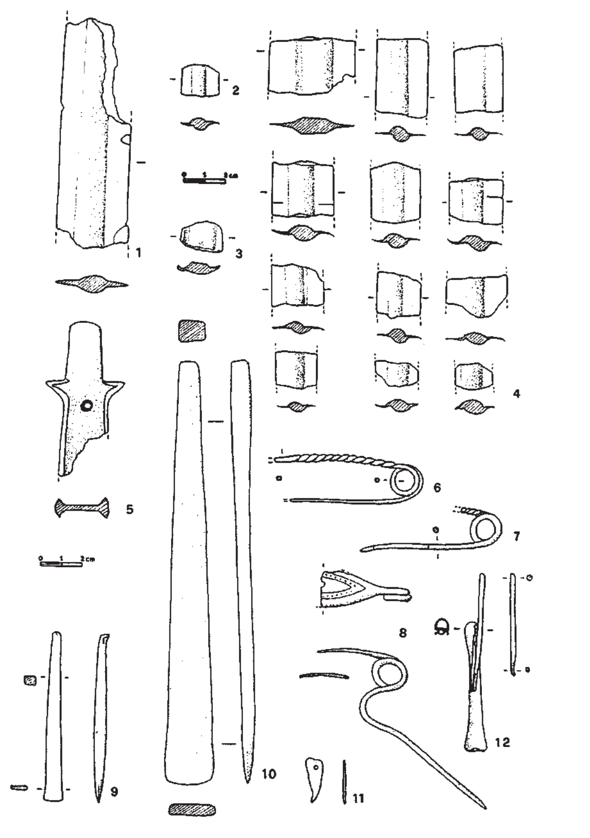


1-2. Orune, Su Tempiesu; 3. Fonni, Gremanu; 4. Siligo, Monte S. Antonio

Fig. 8 – Votive swords on temple structures *(after Lo Schiavo 2002).*

As well as the fragments from the Albucciu and Baccus Simeone hoards, a fragment of votive sword was found in stratum 3a of the upper room of tower c of the nuraghe Antigori at Sarroch (Fig. 9.1), while in stratum 4 was found a fragment of worked iron, together with a Cypriot-type wish-bone handle (Ferrarese Ceruti 1986, 184-5). Another fragment of votive sword was found in the nuragic unstructured hut of Via Cappuccini in Iglesias (Alba 1987) (fig. 9. 2).

As for the votive swords, the problems of the origin are twofold: that of the first use and that of the shape. As for the first use, it is now beyond doubt that they are votive objects. The metallurgical analyses have now been joined to the archaeological assessments, showing how, rather than being of bronze, they are of an alloy of copper with a very small quantity of tin, totally unsuitable, on account of its flexibility and fragility, for use as a weapon, having been anyway rendered almost useless by the two sides not being perfectly symmetrical. This explains how, since they are found fixed pointing upwards on the "ceremonial wall" which divides in two the inside of the Tempio Rotondo of Fonni, Gremanu, or on the top or pediment of the roof of other well temples or sacred springs, such as S. Antonio at Siligo and Su Tempiesu at Orune, it is not surprising that a substantial number of fragments is found, amongst the offerings (Lo Schiavo 1998 with preceding bibliography). It seems more than likely that these, coming from a sacred weapon, may have been religiously recovered and reused as dagger blades or as an offering in hoards. An indirect but convincing proof of the symbolic value of this form of sword is provided by the immense success it later enjoyed, reused in pieces as blades for gamma-hilted daggers, which were another weapon constantly associated with the adult male in nuragic society and frequently offered as an amulet in the temples, until it became the preferred weapon, clasped in the hands of the bronze figures of warriors.



1. Sarroch, Antigori; 2. Iglesias, Via Cappuccini; 3. Villanovaforru, Baccus Simeone; 4 e 9. Arzachena, Albucciu; 5. Fonni, Gremanu; 6. Siligo, Monte S. Antonio; 7. Sorso, Serra Niedda; 8. Serri, S. Vittoria; 10. Gesturi, Nuracc'e Deu; 11. Villa S. Pietro, Perda 'e Accuzzai; 12. Villanovatulo, Adoni.

Fig. 9 – Recent Bronze Age metal objects *(after Lo Schiavo et al. 2004).*

On the problem of the origin of the shape, there is at the moment no solution on offer, but just indications for future research. Certainly in the case of this "weapons-worship" ("*oplolatrico*") object (Lilliu 1966, p. 364 no. 258), which depict most clearly the cult of weaponry, a new form, and therefore "insignificant" to the majority, cannot have been "invented"; rather a known form was consecrated, even if of alien provenance, perhaps just for being the functional sword *par excellence*. The Mycenaean "horned swords", types C, G and H (Sandars 1961, 1963), corresponding to the "*Hörnerschwerter*" types 1-3 (Kilian-Dirlmeier 1993), characterized by the thinness of the blade, which is strengthened by a strong midrib almost cruciform in cross-section and balanced by a handle with winglets that stick out. This handle is vaguely reminiscent of some examples of hilt from nuragic votive swords, such as the splendid whole example from Villasor, Su Scusorgiu, displayed in the Museo Archeologico Nazionale of Cagliari, together with a further thirty-nine votive swords with simple bases and lacking handles (Fig. 10).

The fragment from Vivara, Punta d'Alaca, which has a hole on the edge from a break and a narrow blade with strong midrib which does not join properly, already compared with the Mycenaean swords (Giardino 1998), may with some doubt be associated either with the nuragic votive swords or with the forms which were the models for these last.

6.3. The flanged axes from the Recent Bronze Age (of a type at present not definable)

As said above, the flanged axes are the most ancient class of metal artefacts of nuragic production and can certainly be dated to the beginning of the Middle Bronze Age. It is equally certain that the same class, with shapes that are very similar but clearly distinguishable for the smaller length and the edges barely raised above the level of the blade, is found in associations in hoards from various phases of the Final Bronze Age. For the Recent Bronze Age there are no associations which allow us to establish the types to which they belong, but it is beyond doubt that the class continues between the Middle Bronze and Final Bronze Age.

6.4. Other artefacts

To be noted are the sheet with hole ("pendant"?) from the megalithic tomb of Perda 'e Accuzzai at Villa S. Pietro (Fig. 9.11), together with two *ollae* from the Recent Bronze Age and a third miniature one, and together with many beads of vitreous paste, amongst which is a segmented one and a rosette-shaped pale green one; the small awl in copper or bronze, with handle in bone (Fig. 9. 12) and lead clamps of the Recent Bronze Age stratum from the courtyard X of the nuraghe Adoni at Villanovatulo; scraps of copper or bronze from the Recent Bronze Age stratum of courtyard Y; the small chisel in the nuraghe Albucciu hoard (Fig. 9.9); a large chisel, long and thin, of a shape so far little known in Sardinia, was found by E. Atzeni in the village of Gruxi 'e Crobu, at the foot of the nuraghe Nurac'e Deu at Gesturi (Lilliu C. 1985, 61)[5] (Fig. 9.10).

Although very few and variable in nature and form, these articles demonstrate the knowledge, on the part of the nuragic peoples of the Recent Bronze Age, of the technique of working by hammering (sheet), of casting in moulds (chisels) and of manufacturing simple but functional tools.

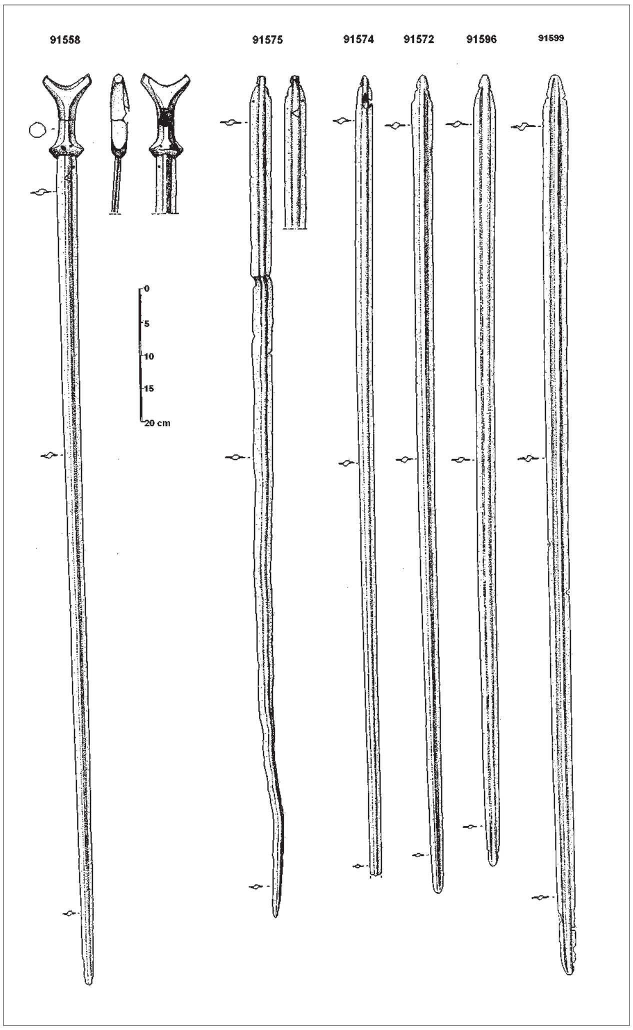


Fig. 10 – Villasor (CA), Su Scusorgiu: votive swords. *(drawn by Tatiana Cossu).*

5. Amongst the shapes probably to be attributed to the Recent Bronze Age period can be included the daggers with solid metal handles, which are near to the Augst B shapes. The nuragic daggers with solid metal handles, which in the Final Bronze Age period seem to fall into various types and classes of size, from the life-size to the miniature amulet, have no recognized precedents in Sardinia. Given that the shape is already mature in the Final Bronze Age period and the similarity already noted by V. Bianco Peroni with the Augst B-type daggers with solid handles (Bianco Peroni 1994, nos. 1663-1670), we can suppose that, as in the case of the flanged axes, there were remote antecedents and a long development of shape which continued even through the Recent Bronze Age.

6.5. The technology of copper, bronze, lead and iron

In addition to all these metals mentioned, we must note the lead clamps for the restoration of vases and the scraps of copper or bronze from the Recent Bronze Age stratum of courtyard B of the nuraghe Su Sonadori of Villasor. In the nuraghe Adoni of Villanovatulo lead clamps from the Recent Bronze Age stratum of courtyard X, together with an awl with handle, and scraps of copper or bronze from the Recent Bronze Age stratum of courtyard Y; primary copper slag from the *atrium* of hut 6, Recent Bronze Age level, of the village of Brunku Màdugui at Gesturi; “slag from copper smelting” (“*scorie di fusione in rame*”) (fide Ugas), together with lumps of clay, baked bricks and Recent Bronze Age pottery from “unstructured hut” 3 of Via S. Sebastiano /Via Giardini at S. Sperate. We can say, therefore, that there is a serious, even if we hope temporary, gap in the archaeological sources concerning the places in which the metals were worked; these would reveal the level reached and the technological links. Furthermore systematic metallurgical analyses are lacking. We can but attempt, therefore, to recompose a general scheme by way of clues, this too to be viewed as a path for future study.

In the Recent Bronze Age there is a visible continuation of the central European current of influence *via* mainland Italy, as is shown by the evolution of the flanged axes, and there is the enrichment with new forms, such as the Pépinville-type sword and similar, perhaps even produced locally, judging by the peculiarities of shape which the artefacts found in Sardinia show.

Next to this current of mainland influence reappears, and becomes decidedly dominant, a new wave from the Aegean (after that of remote origins), of which the votive swords are perhaps an echo, and certainly from Cyprus, indicated above all by the oxhide ingots (see chapter IV) and with them by the arrival, together with the working of copper, of new skills, such as that of iron, known but not practised on large scale (see chapter VII), and of lead, which on the other hand enjoys the greatest popularity and very widespread and almost inordinate use.

In the Recent Bronze Age, and already perhaps from the Middle Bronze Age, there is evidence of a new era in nuragic metalworking, in which Cyprus has an ever-growing influence, to the point that it becomes certain that not only was there an exchange of skills and technological “know-how”, but that also small groups of individuals arrived, probably the artisans themselves, on a seasonal basis, who may have acted as ferment for the human and material resources, which were in perfect condition and well-disposed to receive it and develop it at the rate of a hundred to one. The very scale of this technological explosion indicates that the beginnings had been evolving over a fairly extended period, including at least all the Recent Bronze Age period, given that by the beginning of the Final Bronze Age the process seems already mature and complete.

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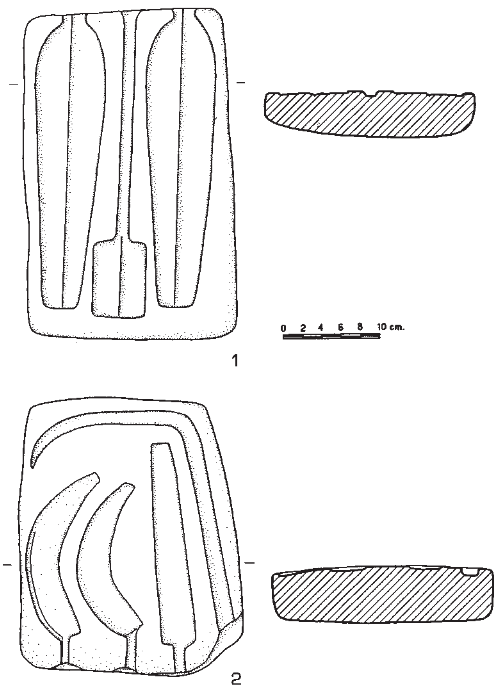
3.
EARLY DOCUMENTS ON NURAGIC METALLURGY

Fulvia Lo Schiavo

1. Casting in mould (plate XIII)



1. Irgoli, Ruinas; 2. Sardara, unknown provenante.

Fig. 1 – Simple one-piece moulds *(after Lo Schiavo 1992).*

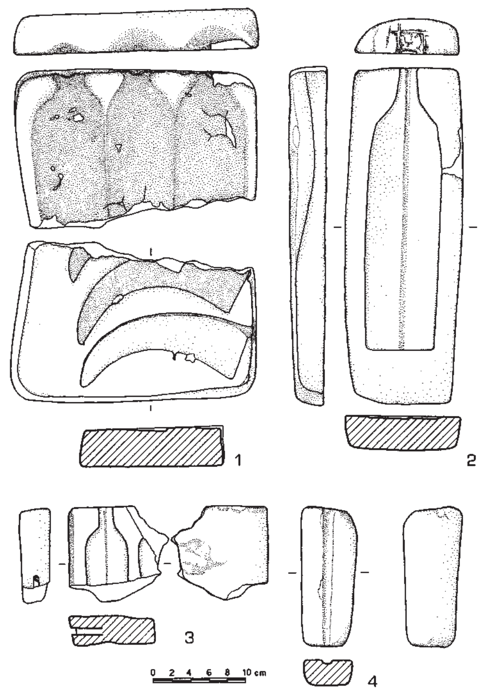


Fig. 2 – Simple one-piece moulds from Ozieri, S. Luca *(after Lo Schiavo 1992).*

Many moulds are known in Sardinia, made of steatite, talc, limestone and schistose rocks. They belong to various categories : one-piece simple moulds are those which consist of a single block in which is hollowed out the shape of the object to be produced. Molten metal was poured into the mould, and protected with a flat stone which served as a cover, to prevent the formation of gas bubbles from sudden or uneven cooling. Items produced in one-piece moulds are recognizable in that they have a flat face or hollowed in one direction only, such as the flat axes, or the double axes with neck, without raised parts, protuberances or ribbing on the opposite side (figs. 1-2).

In the case of the complex one-piece moulds, the block is worked on two, three or four sides, each one used with a flat covering for closure.

The two-piece moulds, on the other hand, are composed of two blocks of stone, the faces of which are placed one over the other, and, during the casting of the object, this is created by the joining of the two shapes hollowed out on the two sides. The complex two-piece moulds can be defined as those in which one or both the stones making up the two-piece mould are worked on more than one face (fig. 3).

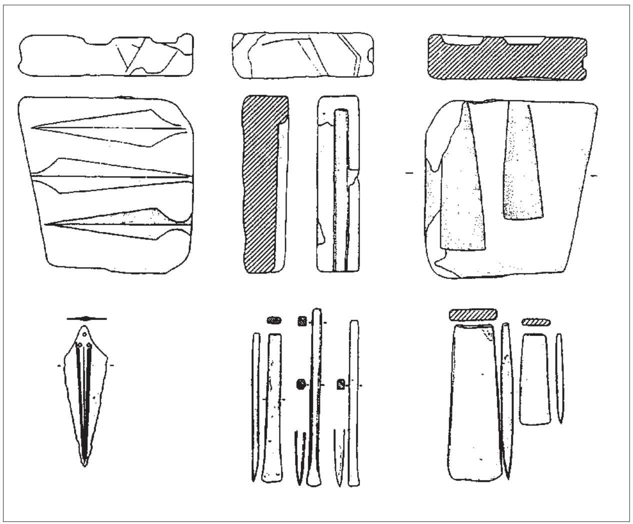


Fig. 3 – Complex double mould from Monte Acuto, Ozieri, with objects comparable to the shapes carved on the stone *(after Lo Schiavo 1998).*

The two parts of the mould or the single mould with its cover were firmly bound together with plant fibres that were green or had been moistened and run through grooves purposely cut on the backs of the mould. These were then positioned vertically, with the upper part, in which had been hollowed a conical recess known as the "casting funnel" on top. It is almost certain that the two parts were sealed with clay or other insulating material and bound closely together, but so far no casting workshop has been found such as might make it possible to ascertain the details of the casting technique[1].

The metal was poured from a crucible of clay *impasto* of considerable thickness, with a robust handle and a pouring spout. When the metal was completely cold, the mould was opened and the artefact, which was still in a raw state, was extracted and finished : the "casting funnel" was cut off together with the "casting channels" and all the "casting fins", where the metal oozes out of the form, and the traces of these imperfections were filed away.

In the case of weapons and instruments, the cutting-edge of swords, daggers, razors and axes was hammered and made thinner and the points of pins were sharpened. Finally the object was decorated with burins, points and instruments of various types, and was then perfectly finished.

In Sardinia, there are examples of objects produced in moulds and left rough, with the "casting funnel" still in place and used as a peg, sunk in lead, in a hollow made in the rock of a "Table of the Offerings", to fasten the object, in this specific case a dirk, with the point upwards in the sanctuary. A particularly evident example is some unfinished dirks from the Sacred Well of Camposanto at Olmedo, which still have around the "casting funnel" the remains of the lead used for setting it (Lo Schiavo 1992; 2000).

2. The moulds for the casting of tools

The overall study of nuragic casting moulds, undertaken years ago (Becker 1984) and whose completion has been announced, has been long awaited. In the meanwhile, many examples and new data have been added to the corpus, and some considerations have emerged with absolute clarity. We will here limit ourselves to some observations, with exclusive reference to tools for work (including axes). The place of finding of the mould is usually linked to nuraghi or nuragic villages, or else to settlement sites, or, more rarely, to sanctuaries or places of worship.

The shapes of the tools for work are on the whole associated with other instruments, more rarely with weapons: in addition, the shapes of weapons (swords, daggers, spearheads and spearbutts) are on the whole rarer. In the list which follows, (see Appendix I), in two cases a chisel is associated with the shape of a spearhead (nos 1 and 21).

Amongst the tools, the chisels or flat axes in their various forms are absolutely the most frequently produced tools (forty moulds), not only singly but also in groups of two, three and four, and on the various faces of the mould. The double axes follow (12 shapes), the small axe-adzes ("*maleppeggio*") (3 shapes), the sickles (7 shapes) and the *spatulae* (5 shapes). Other items which are represented only once are hard to identify, with the exception of the palettes, of which complete examples survive, of Cypriot provenance or in imitation of Cypriot models (Lo Schiavo, Macnamara, Vagnetti 1985). Chisels are also the tools usually associated with all the other ones.

It must be observed that up to today moulds for the casting of flanged axes have not been found. The hypothesis that this instrument alone was produced not in the characteristic nuragic mould in steatite, but in perishable ones, of clay or sandstone, which were destroyed after use, is difficult to maintain, since no fragments have ever been found. The fact remains, however, that none of the moulds found could have served for the production of the most typical and widespread nuragic axe, not even if they underwent long finishing after the initial casting.

Another problem is that of the production of the bronze rods, such as those of the awls, pins, *stilettos* etc. The hypothesis that use was made of stones so far defined as "sharpeners", more precisely defined as "lingot moulds" ("*lingottiere*"), in which short bars could have been formed, to be then lengthened and tapered with hammering, cannot be completely discarded, but should be confirmed by specific analysis. (Lo Schiavo 2004)

1. Experiments to reproduce ancient processes, carried out recently, have ascertained that, to have a perfect casting, with the liquid metal flowing into every part of the mould, and to prevent progressive inconsistent cooling, it was necessary to preheat the mould (Steffgen, Wirth 1999).

3. Lost-wax casting

Lost-wax casting was already known in Cyprus and the Near East in the Bronze Age, and it was from Cyprus that this process reached Sardinia. It is called “lost wax” in that the figure that was to be made was first modelled in wax in all its smallest details, including the “vent channels” and at the top (at the feet of the figure) the “channels for the distribution of the molten metal” with the “casting button”. Once completed, the wax model was covered in raw clay, which was then baked; with the heat, the wax ran away, leaving the shape free and creating a mould in which the bronze was poured. This flowed and filled the whole mould. It was then necessary to wait for the mould to cool, before breaking it and eliminating it.

Finishing consisted of cutting and filing away all the traces of the production process; sometimes other pieces were attached, nailed on or cast on top to complete and enhance the object. In the case of the small bronzes, the finishing is usually perfect: the transversal elements which served to allow the metal to fill all parts of the figure were then cut away and every trace of them cancelled (fig. 4)[2].

There are no records so far in Sardinia of cases of lost-wax casting on a terracotta core, when, in order to create objects of large size but hollow on the inside and not very heavy, a layer of wax was spread on a core of clay, which remained inside the bronze product or else was extracted from it, leaving a more or less thin wall of metal, in proportion to the size of the object.

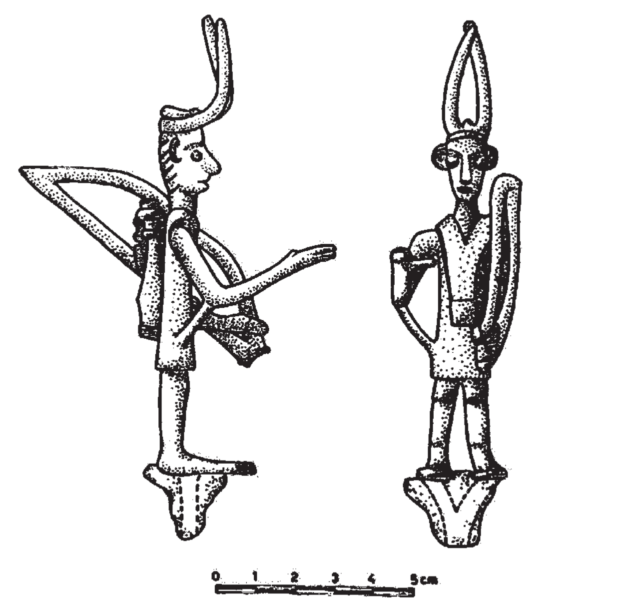


Fig. 4 – Bronze figurine from Sorso, Serra Niedda: worshipping archer, with the bow on his left shoulder and with the right forearm raised in the greeting gesture. See, from the elbow to the side, a small bar, a “casting channel” not filed away *(after Lo Schiavo 2003).*

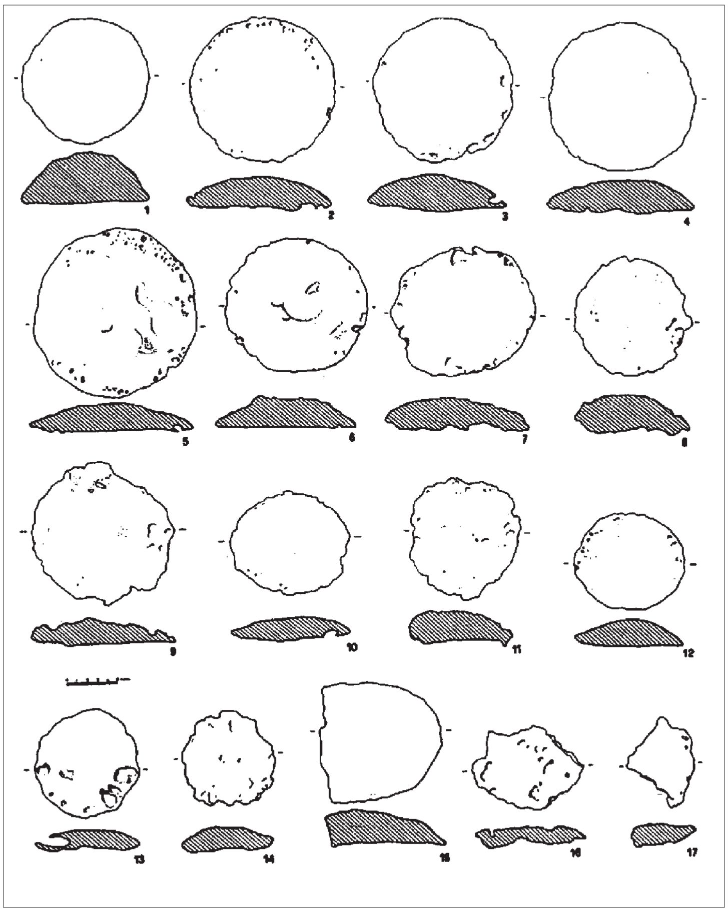


Fig. 5 – Torralba, Hut 1 hoard: planoconvex ingots “*panelle*” *(after Lo Schiavo 1998).*

4. Casting workshops and metal workshops

For the very nature of the work it is extremely difficult, if not impossible, to find identifiable traces of it. It happened in the past, and unfortunately sometimes happens today, to come across an archaeological site - mainly a temple or sanctuary - so badly devastated, with the structures almost razed to the ground or with the offerings spread all over the place, as to defy any interpretation : in these cases, the presence of piles of fragments of bronze artefacts and pieces of ingots of unidentifiable types, especially if accompanied by remains in the form of ashes and charcoal, has led to the interpretation as a casting workshop. A famous example is that of S. Vittoria di Serri (see Archaeological file 23, p. 102-103), where there is evidence of a ruinous fire, but where it is not certain that we can agree with Taramelli that this was really the location of a casting workshop.

2. At the moment I only know of one exception, from Sorso, Serra Niedda, see Fig. 4 (Rovina 2002, 12; Lo Schiavo 2003, 91 note 34, fig. 6).

Taramelli (1918) interpreted as a casting workshop an establishment next to the nuraghe Ortu Comidu, but this was then disputed both by Lilliu (1953) and, after archaeological excavations, by M. Balmuth (1986; 1987).

We must therefore make clear the parameters which can lead to the defining of a "casting workshop". The mass and variety of artefacts, fragmented or not, is not enough, nor the presence of pieces of copper ingots, for which there are a number of cases of hoarding, in or out of vases, indeed sometimes in simple holes in the ground. Unequivocal indications would be the remains of furnaces, of slag (examined by specialists in archaeometallurgy), of crucibles, of *tuyères*, of ashes and charcoal etc., such as can derive from the treatment of metals and repeated and continuous smelting operations. So far not all these elements have been found in association, and for this reason we have not been able to identify a site of the "primary" working of the ore (smelting) - with the exception now, perhaps, of Sant'Antiogu at Villanovaforru (see Archaeological file 28) - and for this reason it has not been possible to reconstruct the characteristics of this work for the nuragic age.

For the identification of a "metal-working" workshop, on the other hand, meaning a site for the production, finishing and repairing of objects, is necessary the presence - in association with each other - together with fragments of bronze items, of scraps of smelted metal, of working residues (such as S. Barbara at Bauladu (see Archaeological file 29) and in hut 4 of the village of S. Anastasia of Sàrdara (see Archaeological file 27, p. 104), where were found the "casting funnels" and the "channels for distribution of the molten metal" still sunk in the clay of the form, of cores and distancers for the casting moulds, of moulds and of various types of ingot and pieces of metal ready for smelting: copper, lead, iron (as at Sa Sedda 'e Sos Carros - see Archaeological file 31), or tin (as at Forraxi Nioi e a S'Arcu 'e is Forros - see Archaeological file 32, p. 105).

Almost on account of adverse fate, none of these four sites has been completely explored, and nor have adequate illustrations of them been supplied. They are in fact very extensive complexes of which we still know too little, and the traces of metal-working activity are dispersed, it would appear, away from the specialized institutions where you would expect to find them in order be able to make the comparison with analogous sites. In none of these cases - except for the above-mentioned and very recent one of Sant' Antiogu - have the structures and the instrumentation required for such work been identified (furnaces, for instance, and moulds are lacking).

In many ways the case of Sardara is exceptional. There was the good fortune to find a room set up as a metal-working workshop, inside a nuragic village already noteworthy, for the presence both of an "Assembly Hut" (no. 5) and for at least two Well Temples, separated from the other structures by an enclosing wall and rich in highly interesting artefacts, amongst which are hoards of bronzes and lead ingots (Ugas, Usai L. 1987, 67-200)[3]. Unfortunately, one third of hut 4, inside which were found, in secondary deposit, the remains of casting moulds in terracotta, unequivocally used for the production of objects with the lost-wax process, is obliterated by a building of the modern historic centre (Ugas, Usai L. 1987, 201-204).

5. Slags and scraps

"Slags" is a term which is often used improperly: archaeologists, generally without any analytical determination, mention "slag" as though it were synonymous with metallurgical "waste", and are therefore completely untrustworthy. In turn, the metallurgists, when confronted with real slag, do not always record the analytical composition, with the result that it remains vague.

In the case of Sardinia, this is particularly serious, because effectively slags has not been found so far, except in minute quantities, in the area of the ore beds, nor in that of the metal-working workshops. If we recall the mountains of slag in Cyprus, so huge and monumental, such as that at Skouriotissa, as to be declared a national monument, the discrepancy between the two islands is very serious. To explain the absence of slag in the areas that are presumably of primary working, it is commonly hypothesized that the ancient waste, being still very rich in metal, was reworked in XIX century and exploited until finished and there was physically none left, very greatly affecting the topography of the places (see Appendix II, fig. 1: the plan of Funtana Raminosa, drawn by Megy and sent by him to Antonio Taramelli: Lo Schiavo 1966). This is also the interpretation competently put forward by Roberto Valera for the mining area of Sulcis-Iglesiente (see Part II, chapter 2). All we can say is that an argumentum *ex silentio*, on this delicate subject, in which even the work procedures are unknown and of which the slag is perhaps the only valid indicator, is undoubtedly very feeble.

With such premises the few records of slag made by metalworkers[4] assume great importance, such as those from Forraxi Nioi, analysed by Tylecote (Tylecote, Balmuth, Massoli Novelli 1983, 1984). In this volume are recorded all the data on the first slag found, in Sardinia, in closed and controlled archaeological contexts, such as the site of Brunku Madugui at Gesturi, the hoard of Baccus Simeone at Villanovaforru and the nuragic village of Genna Maria at Villanovaforru (see Archaeological files

3. "26. Slag from the smelting of copper" is mentioned by G. Ugas from S. Anastasia of Sardara, level IV of hut 1 (or "of the little Channels") ("*delle Canalette*") - exactly where the hoard of oxhide ingots comes from (Ugas, Usai 1987, 169-170).

4. For this reason it cannot be sufficiently stressed that it would be of fundamental importance to trace and analyse the slag from Su Coddu di Selargius, because it could throw a determining light on the metalworking of the origins (Ugas, Lai, Usai 1985/1989; Ugas *et al.* 1989).

24, 26, 34). The preceding summary dates to 1985 (Lo Schiavo *et al.* 1985).

Nurallao (Nuoro), nuraghe Nieddìu

Sandro Putzolu, at the time (1985) director of the mine at Funtana Raminosa and Gianbattista Novelli, a geologist, recorded that "in the past" the copper was transported *via* a pass to the south of the area of the mine, from which there is access to a *plateau* which leads to the territory of Nurallao. This route passes rich deposits of kaolin, excellent as refractory material for the construction of smelting furnaces; for this reason this route was examined in a search for traces of metal-working. The nuraghe Nieddìu is now almost covered with production waste, but the people of the area mention that round about were "many furnaces". Slag was recovered by M.L. Ferrarese Ceruti and by P.F. Virdis and studied by Zwicker (Zwicker, Virdis, Ferrarese Ceruti 1980), who found that it is on the whole a complex of copper, iron, sulphur, zinc and lead, analogous with the composition of the ores of Funtana Raminosa (Virdis *et al.* 1983, 1115-1117). The analyses of the lead isotopes show that both the slag and the ores from the deposit come within the isotopic field of Sardinia, traced using the analyses carried out by the Gales (Virdis *et al.* 1983, 1117-1118). According to Zwicker, one of the ingots from Serra Ilixi could also have been produced with copper from Funtana Raminosa, even if the isotopic data do not come into the same field (Zwicker *et al*. 1980; Lo Schiavo *et al*.1983).

Nurallao (Nuoro), nuraghe Enna

At about one km from the nuraghe Nieddìu is the nuraghe Enna, not excavated, around which, on the surface, has been found some slag, which appeared to be primary slag (Maddin). In the vicinity of the nuraghe Enna there is a vein of haematite, which could have been very important as a fluidifying agent in the operations of smelting copper.

Gesturi (Nuoro), nuraghe Tana

At about 10 km to the south of Nurallao, on the southern slope of the Grande Giara, is the nuraghe Tana, around which has been found much slag. This has proved to be from primary smelting of copper and "non-tapped", that is to say left to cool together with the metal in the furnace, and then broken up by hand (Lo Schiavo *et al.* 1985, 317). A note of caution is necessary because, although the majority of the finds on the surface are nuragic, material from the Roman period was also found in the vicinity (Lilliu C. 1985). Lilliu records having noted slag remains around other nuragic sites in the area, but in smaller quantities than those of the nuraghe Tana. U. Zwicker, who visited the site in 1983, took slag from it for analysis.

In the opinion of the metallurgists (R. Maddin and T. Stech), the transport of the material away from the area of the mine and the working of it in places near to the settlements, but also near to other sources of raw materials, such as clay, wood and water, as would seem the case with Funtana Raminosa, has analogies in south-west Europe, where, at Rudna Glava in Serbia (Jovanovic 1979) or at Aibunar in Bulgaria Černych 1987), there is no trace of metal-working activity in the vicinity of the mines. The contrary happens in Cyprus (Stech 1982, 110-111) and at Timna (Conrad, Rothenberg 1980): the choice would seem to be determined by local conditions and not by cultural factors (Lo Schiavo *et al.* 1985, 317).

Mores (Sassari), nuraghe Runaghetta; Tula (Sassari), nuraghe Sa Jaga

The slag collected in these two sites, of which the first is known on account of the discovery of a small vessel in porous basalt, on four feet, similar to that found in the wreck of Capo Gelidonya, has turned out to be slag deriving from ironworking (Lo Schiavo *et al.* 1985, 317).

6. The crucibles

In addition to two very small examples dating to prehistory[5], various forms of crucible are known from nuragic Sardinia.

G. Webster found a fragment of crucible, consisting almost of just the short, stubby handle, with a conical hollow and with the remains of the internal wall curved inwards, in the levels of tower A of Duos Nuraghes at Borore, dated by him to LBA2 (1200-900 BC). The piece was situated in a semicircle of small stones, above an area of scattered pebbles, which has been interpreted as the remains of a small furnace and which showed signs of intense fire (ash, charcoal, burnt stones and sherds), but no evidence of metallurgical activity, except for some presumed bits of copper slag and indefinable tiny fragments of copper or bronze gathered in other parts of the floor; there were two hearths in the north and west zones (Webster 2001, 54, fig. 4.1; 4.2.15).

The crucible from the nuragic village of Genna Maria, Villanovaforru is rounded in shape, with cylindrical handle, and small lateral spout (Badas 1987, 144, tab.V above; Campus, Leonelli 2000, 749, pl. 477, no. 7, 1117. Cro.1), while that from the nuraghe S. Pietro at Torpè, is still unpublished. The examples from Palau, loc. Chjainu (Lo Schiavo 1996, 77 no. 57 fig. 9.9.2) and from an unknown

5. These are two spoon crucibles from Monte d'Accoddi, see p. 263, Fig. 8. Crucibles identical to these in shape and size have been found in Corsica at the site of Terrina IV, dating to the first half of III millennium, in an epoch corresponding, therefore, to our "Ozieri Dipinto" and Filigosa-Abealzu, together with slag, *tuyères* and an awl in arsenical copper; the metallurgical characteristics of the slag and of the crucibles' incrustations would demonstrate the exploitation of the small local ore deposit of Linguizetta. (Lo Schiavo 2000).

locality of the Nuorese, Pau collection, are rounded in shape but have serious breaks. Another fragment, unpublished, has been found in the nuragic village near the nuraghe Pulpalzos of Alghero.

"A vessel with elliptical mouth and vertical handle attachment fixed from the rim to the base, with the purpose of pouring, may be attributed, with some doubts, to the category of crucibles or ladles", from Ittireddu, nuraghe Funtana, Galli excavations ("*Un recipiente con imboccatura ellittica e con attacco di ansa verticale impostata dall'orlo al fondo - atto a versare - può essere dubitativamente ricondotto alle categorie dei crogioli o dei mestoli*", da Ittireddu, nuraghe Funtana, scavi Galli) (Campus, Leonelli 2000, 749, pl. 477, no. 8, 1117. Cro.1).

The best-preserved example also comes from the nuraghe Funtana at Ittireddu, and is a massive crucible, square in shape, with very thick walls and flat bottom, with a large and short handle, inside which there is a hollow with a very clear imprint of a spear point, as though this robust weapon was used to lift it up. On its inside have been found traces of incrustations of metal and of vitrification (Galli 1985/1989, 106, fig.11).

Now we add the fragments of crucible from S. Barbara at Bauladu, illustrated here (see Part III, chapter 1Ha), and the one, only mentioned, from Giva Molas at Villasor (oxhide file 27).

7. The tools for the working of metals (see Part IV, chapters 4.2)

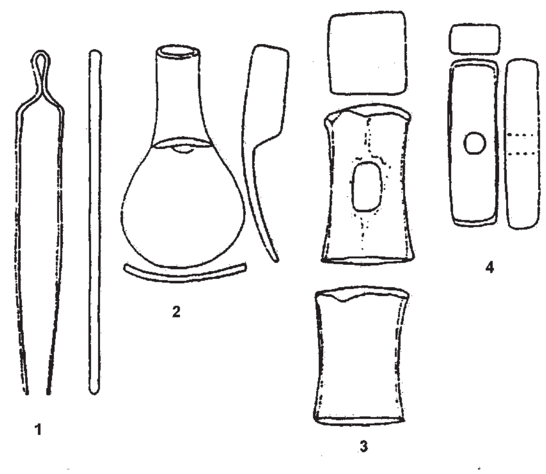


Fig. 6 - The tools for the working of metals: 1. fire tongs from Siniscola; 2. charcoal shovel from unknown provenance; 3. sledgehammer from Nuchis; 4. rising hammer from Perfugas *(after Lo Schiavo 1981).*

The few known examples of hammers are very important for the affinities of form and function which can be established with Aegean metalworking in general and Cypriot metalworking in particular. Two of these, one of unknown provenance in the Antiquarium Arborense of Oristano and one from Nuchis, belong to the category known as "sledgehammer" (fig. 6.3) and used for breaking up rock with the purpose of extracting from it the nodules of metal ore and for pulverizing them. The third one, from Perfugas, which is slender and elongated with two rounded ends, known as a "rising hammer", that is to say, literally, a hammer for lifting (fig. 6.4), in that with constant beating on a metal disc of a certain thickness were produced bowls, basins, cauldrons and other laminated vessels. It seems certain, from the traces of wear that have been found, that pick-axes with broken points and double axes with damaged cutting edge were used as hammers, as was the case with those in the hoard of Funtana Janna at Bonnanaro.

The fire tongs (fig. 6.1), also widely represented amongst Cypriot tools of the Final Bronze Age for the working of bronze, are anything but rare in Sardinia, where so far seven examples are known, from Siniscola, Sassari, Dorgali and of unknown provenance; two of these, from Torralba and Sardara, were discovered in recent excavations and in ascertained associations. It is a practical and functional instrument to use in a casting workshop, for handling metal objects in the process of being worked, for example for extracting them from the casting moulds or for holding them near the fire for subsequent hot hammering or finishing.

The charcoal shovels, known in Cyprus, in the same contexts and of the same dating as the tongs, have a square flanged blade and a long curved handle, with a characteristic finial in the form of a bird-shaped protome, folded back, which served as a hook for hanging it up. In the casting mould from Irgoli, the shape of one of these shovels is hollowed out. There is an almost whole example in a private collection in Oristano. A fragment of this type of shovel, found amongst the bronzes of Sa Sedda 'e Sos Carros, has turned out from the analyses to be of local manufacture.

A shovel of quite a different shape, rounded in profile and trunnion socket handle (Fig. 6.2), is an example from the Sulcis, reminiscent of analogous instruments from Cyprus, which are, however, much bigger. (Lo Schiavo 2000; Lo Schiavo, Macnamara, Vagnetti 1985).

8. The anvils

Of the vast range of types of anvil documented in nuragic Sardinia, only very few are known and illustrated. They are enough, however, to confirm that it was a variable instrument and specialized.

Three conical objects, with one end sharpened and the other rounded and separated more or less by a narrow shaft, are known; one from the hoard of Chilivani at Ozieri, the other from the nuraghe Su Cobelciu at Chiaramonti and the third in the Dessì collection. In the case of the first, Taramelli had already suggested that it might be a "small anvil" ("*incudinetta*"), to be fastened to a wooden surface, using the rounded part as a support, for instance for hammering and finishing small sheet objects.

A more complex anvil, elongated pyramidal in shape with a conical rod sticking out at right angles for fastening, is documented at Forraxi Nioi (Fiorelli 1882, tab. XVIII, 23) and another similar one, smaller, is in the Museum of Cagliari, of unknown provenance. A simple small pyramid, with a rod sticking out at right angles was reported in the hoard of Lula, Savadde (Lo Schiavo 1994), and a fragment of an object of the same sort could be the one mentioned by Vivanet in the hoard at Lei (Vivanet 1890, 335,"half of a hammer" "*metà di un martello*").

There are also more simple shapes, such as that which Taramelli (1921, 497, fig. 1) describes as "....hammer head approximately cylindrical in shape with two circular lentil-shaped bumps" ("*... battente di martello di forma a un dipresso cilindrica con due bitorzoli circolari a lente*") from the hoard of Lotzorai, mentioning another one from the hoard of Maddalena at Lei, which Vivanet (1889, 171; 1890, 335) had defined as a "pestle" ("*pestello*").

Also to be perhaps interpreted as an anvil is a "small oblong, square implement" ("*stromentino bislungo quadrato*") (Spano 1876, 16 tab. no.17), that is to say an elongated parallelepiped with a conical hollow at the centre in which would have been inserted a dowel for fastening it to the work surface, with the other end rounded with wear, from the hoard of Sarule[6].

Finally, the massive double axe with small round hole and rounded end, from the nuraghe Su Cobelciu at Chiaramonti, could have served as an anvil on both sides, using the hole to insert a peg for fastening it: in fact it is too small for fitting a handle for lifting and using the heavy implement as a hammer (Fig. 2.3, p. 345).

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6. The last anvil (?) to be illustrated - and certainly the most elaborate shape, in spite of its small size, - ended up at the Badisches Landesmuseum of Karlsruhe, and consists of a curved part, rhomboidal in shape and with rounded end (9 cm long) with a short cylindrical handle (4.2 cm high), really a "foot" for fixing it. (Jurgeit 1999, no. 9, tab. III; 2002, no. 3, pl. I b-c).

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APPENDIX 1

LIST OF MOULDS
FOR CASTING TOOLS

Fulvia Lo Schiavo

After Lo Schiavo F. 2004, Produzione, distribuzione e conservazione degli strumenti da lavoro nella Sardegna nuragica, in *L'artisanat métallurgique dans les sociétés anciennes en Méditerranée occidentale. Techniques, lieux et formes de production*, Ravello, 4-6 maggio 2000, 229-261.

Province of Sassari

1. A. Axe-adze - **B.** 4 chisels, from Nurra (Spano 1872, 27, no. 46, pl. 46; Becker 1984, fig. 7.3).

2. A. Spearhead - **B.** concave-side chisel, from unknown locality in the Sassari area (coll. Urru, unpublished).

3. Chisel, from Ploaghe (unpublished).

4. 3 chisels, from Sorso, Monte Cau (Pais 1880, 409-410).

5. A. 2 chisels, rounded in cross-section (?) - **B.** chisel or spear tip from Sorso, Monte Cau (Pais 1880, 409).

6. Long sickle (?), from Palau loc. Chjainu (Lo Schiavo 1996, 71, fig. 9.9).

7. A. chisel - **B.** chisel - **C.** 2 chisels, one of which with lateral *apophysis* (?), from Arzachena, Capichera (Lo Schiavo 1996, 72, fig. 9.3).

8. A. 3 sickles - **B.** 3 *spatulae*, from Ozieri, S. Luca (Lo Schiavo 1990, pl. IV, 1).

9. *Spatula*, from Ozieri, S. Luca (Lo Schiavo 1990, pl. IV, 2).

10. *Spatula*, from Ozieri, S. Luca (Lo Schiavo 1990, pl. IV, 3).

11. A. Double axe - **B.** large axe-adze, from Ittireddu, Monte Zuighe (Galli 1983, 48, no. 1, pl. XLI).

12. 3 disc “shovels”, from unknown locality in the Sassari area (coll. Urru), unpublished.

Province of Nuoro

13. Large curved sickle (?), from Posada (?) (unpublished).

14. 2 *spatulae* and 1 shovel, from Irgoli, Ruinas (Spano 1873, 32, pl. no. 12; Pinza 1901; Lo Schiavo 1990, pl. III,1).

15. 3 chisels, from Nuoro, Pratobello (coll. Floris) (Lo Schiavo 1978, 114, no. 4, pl. XL).

16. A. chisel - **B**. chisel - **C.** chisel, from Nuoro, Pratobello (coll. Floris) (Lo Schiavo 1978, 114, no. 5).

17. A. double axe - **B.** 2/3 chisels - **C.** double axe - **D.** *Panella* (?), from Nuoro, Pratobello (coll. Floris) (Lo Schiavo 1978, 114, no. 6).

18. A. chisel - **B.** chisel - **C.** chisel - **D.** chisel, from Nuoro, Pratobello (coll. Floris) (Lo Schiavo 1978, 114, no. 7).

19. Double axe, from Nuoro, Perdas Arbas loc. Corte (unpublished).

20. A. Double axe - **B.** disc shovel - **C.** 2 chisels, 2 hatchets (?) - **D.** *fibula* or small ingot (?), from Ottana (Tanda 1990, fig. 17a-b, pl. XIII).

21. A. Spearhead - **B.** 2 chisels, from Dorgali, Serra Orrios (Lo Schiavo 1980).

22. A. Double axe - **B.** Double axe, from Urzulei, Sa Domu 'e s' Orku (Taramelli 1917, figg.1-2).

23. A. 2 double axes - **B.** chisel and axe-adze, from Belvì, Pedradudda (Spano 1872, 27 no. 45, pl. no. 45; Pinza 1901, figg. 94-94b).

24. A. chisel - **B.** disc and 2 chisels - **C.** chisel - **D.** chisel, from Serri, S. Vittoria (unpublished).

25. 2 disc “shovels”, from unknown locality in the Nuoro area (coll. Pau), (unpublished).

Province of Oristano

26. A. chisel - **B.** chisel, from S. Vero Milis, S'Uraki (Taramelli 1917, 102).

27. A. double axe - **B.** double axe - **C.** double axe, from S. Vero Milis, S' Uraki (Taramelli 1917, 101).

Province of Cagliari

28. 2 sickles + 1 *spatula* + 1 hook (?), from Sardara (Pinza 1901, fig. 27; Lo Schiavo 1990, pl. III,2).

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Spano G. 1873, *Memoria sopra l'antica Cattedrale di Galtellì e Scoperte Archeologiche fattesi nell'isola in tutto l'anno 1872*, Cagliari.

APPENDIX II

FUNTANA RAMINOSA AND AN ARCHAEOLOGIST'S INTUITIONS

Fulvia Lo Schiavo

Funtana Raminosa in the district of Gadoni (Nuoro), situated in the heart of the Barbagia of Seùlo, is one of the areas which have been most thoroughly examined topographically, in the search for ancient traces of minings and ancient settlements. It has been established that there are various nuragic settlements surrounding the metal ore basin, although they are not close to it. Traces of "ancient" minings and workings were noted by the technicians reopening the mining of the deposits, but nothing was found, or nothing was kept, which could definitely be referred to the nuragic period.

There is still, however, correspondence between the Soprintendente alle Antichità of Sardinia at that time, the archaeologist Antonio Taramelli, and A. Megy, who was responsible for the mining works first at Funtana Raminosa and then in another mine in the zone of Laconi, of which, on account of its interest, a summary has been given in another publication (Lo Schiavo 1996).

There are 5 pencil sketches, undated and drawn on the writing paper of the Soprintendenza, whose heading in one instance can be seen on the back, and therefore probably done by Megy in the course of a meeting with Taramelli. In addition there is a slightly bigger illustration, portraying the area of Ribasso Mariano, and the larger survey representing the whole area of the mine of Funtana Raminosa, both drawn in pen and coloured ink.

If we bear in mind that the topography of the places has been entirely modified, these sketches take on very great documentary importance; two of them were reproduced in the 1980s, when the problem of the terms of technological and archaeometallurgical comparison between Sardinia and Cyprus was just beginning to be tackled (Lo Schiavo 1982). Subsequently all of them were illustrated, in black and white (tracings by A. Farina) in a broader work which tried to synthesize the situation regarding knowledge about mines and metalworking in Sardinia from the archaeological point of view (Lo Schiavo 1996).

On account of the unique opportunity of having available colour reproduction on the cd-rom, and, given its quality, of being able to enlarge the details of the larger survey with written notes and signs which at some points are almost miniature, this seemed the best possible place to represent all the images, with a new ordering and new captions.

In addition, the text of the letter of Taramelli to Megy of 20 September 1916 is offered in its entirety; in this the Archaeologist thanks the engineer for having confirmed with his observations his "archaeologist's intuitions", to which he dedicates a long *excursus*[1].

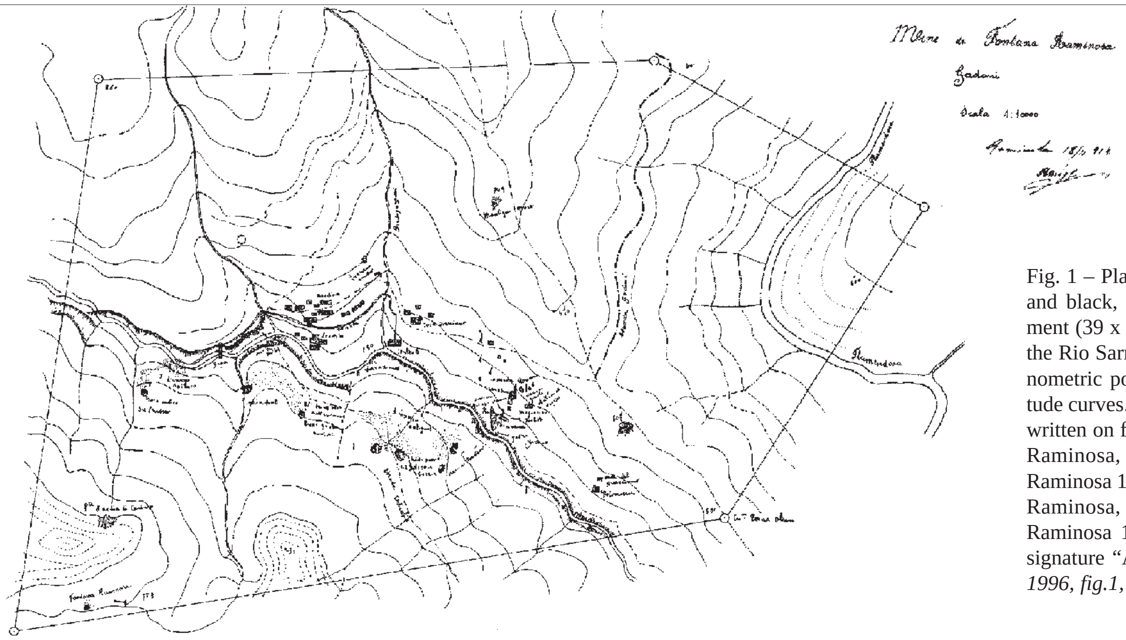


Fig. 1 – Planimetric survey, done in pen and black, red and blue ink, on parchment (39 x 21/21.7 cm), of the valley of the Rio Sarraxinus, set within five trigonometric points and complete with altitude curves. On the left at the top there is written on four lines: "Mines of Fontana Raminosa, Gadoni, Scale 1.10000, Raminosa 18/II 914" ("Mine de Fontana Raminosa, Gadoni, Scala 1:10000, Raminosa 18/II 914"), followed by the signature "A. Megy". *(after Lo Schiavo 1996, fig.1, tracing by A. Farina).*

1. In giving the captions of Megy, we have tried to reproduce the Italian and French terms he used, with the exception of "*esportato*", used by him twice (nos. 4 and 7), one of which (no. 4) writing and cancelling the term "*asportato*", which is in fact the correct term. In the transcription of Taramelli's letter, we have slightly modified the position of the punctuation, and, in one case, substituted the word "*massime*" with "*soprattutto*".

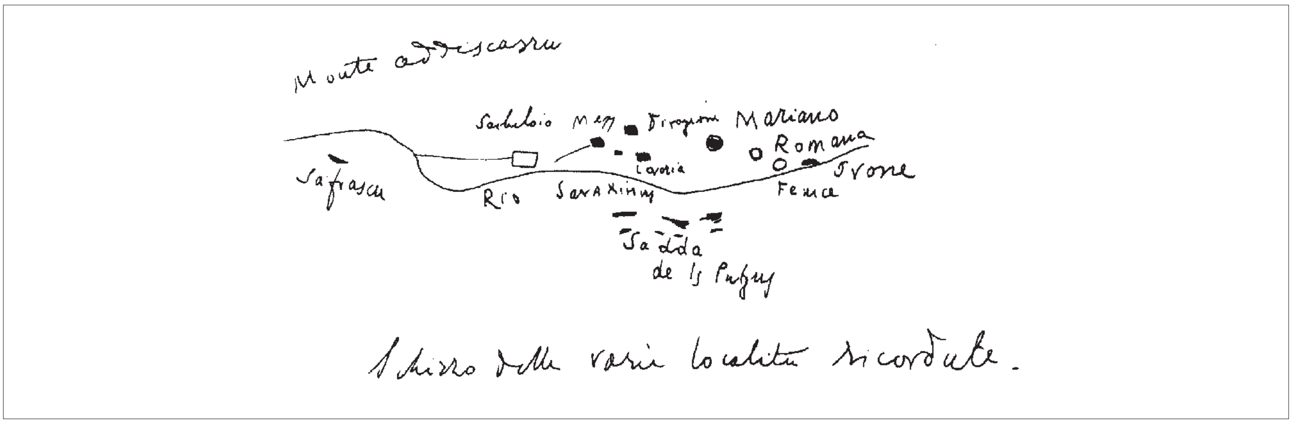


Fig. 2 – “Sketch of the various localities mentioned” (“*Schizzo delle varie località ricordate*”) is written in pencil at the foot of the sketch on the paper of the Soprintendenza (21 x 13.3 cm), the heading of which can be seen through the paper, which represents, in draft, the same image. The names of the various zones of the workings are clearly indicated, and repeated in the following sketches “Mariano”, “Su Fruscu”, “Sedda de is Putzus”, etc. *(after Lo Schiavo 1982 fig.2 at top; 1996 fig. 2, tracing by A. Farina).*

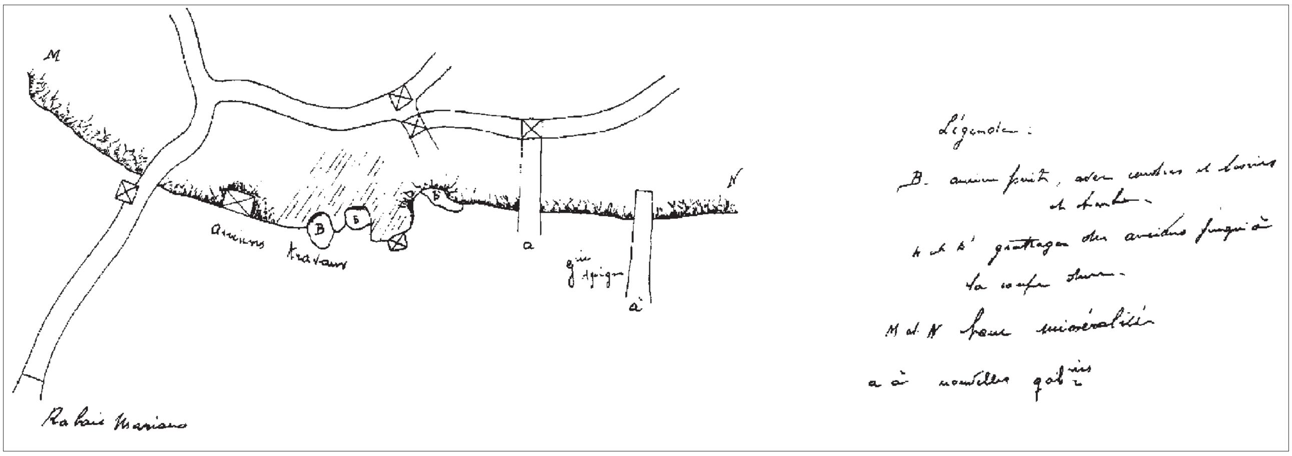


Fig. 3 – Sketch in pen with black and red ink on parchment paper (25/25.2 x 17.2/17.5 cm), illustrating the zone of the Ribasso Mariano, with the caption by Megy himself; low down and on the right side “Rabais Mariano”, and on seven lines “*Légende: B. ancien puits, avec cendres et scories et charbons; B et b’ grattages des anciens jusqu’à la coupe dure; M et N banc mineralisé; a à nouvelles galeries*”. *(after Lo Schiavo 1996, fig. 6, tracing by A. Farina).*

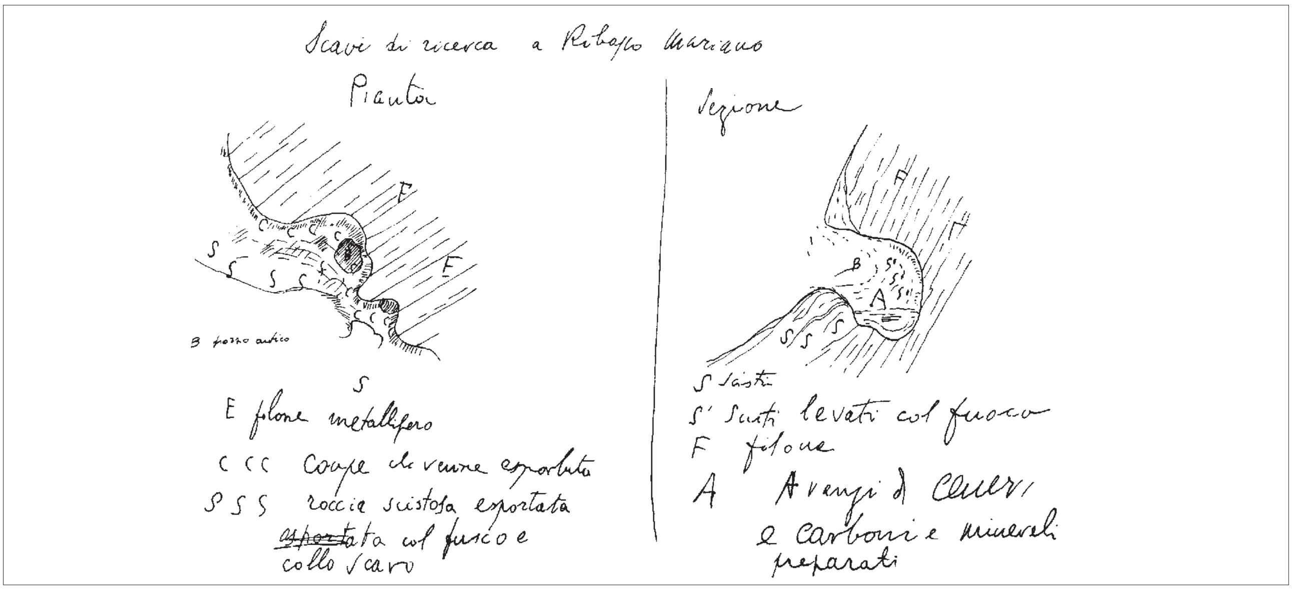


Fig. 4 – “Exploratory excavations at Ribasso Mariano” (“*Scavi di ricerca a Ribasso Mariano*”). It is written in pencil at the top of the sketch on paper (21 x 13.3 cm), divided into two, each part with the following text written on several lines: “Ground plan; E metal-bearing vein; CCC coupe which is removed; SSS schist rock removed with fire and excavation. Section; S Schists; S. Schists removed with heat; F Vein; A. Remains of ashes, charcoal and prepared ores” (“*Pianta; E filone metallifero; CCC coupe che venne asportata; SSS roccia scistosa asportata col fuoco e collo scavo; Sezione; S Scisti; S’. Scisti levati col fuoco; F Filone; A. Avanzi di ceneri e carboni e minerali preparati*”). *(after Lo Schiavo 1996, fig. 7, tracing by A. Farina).*

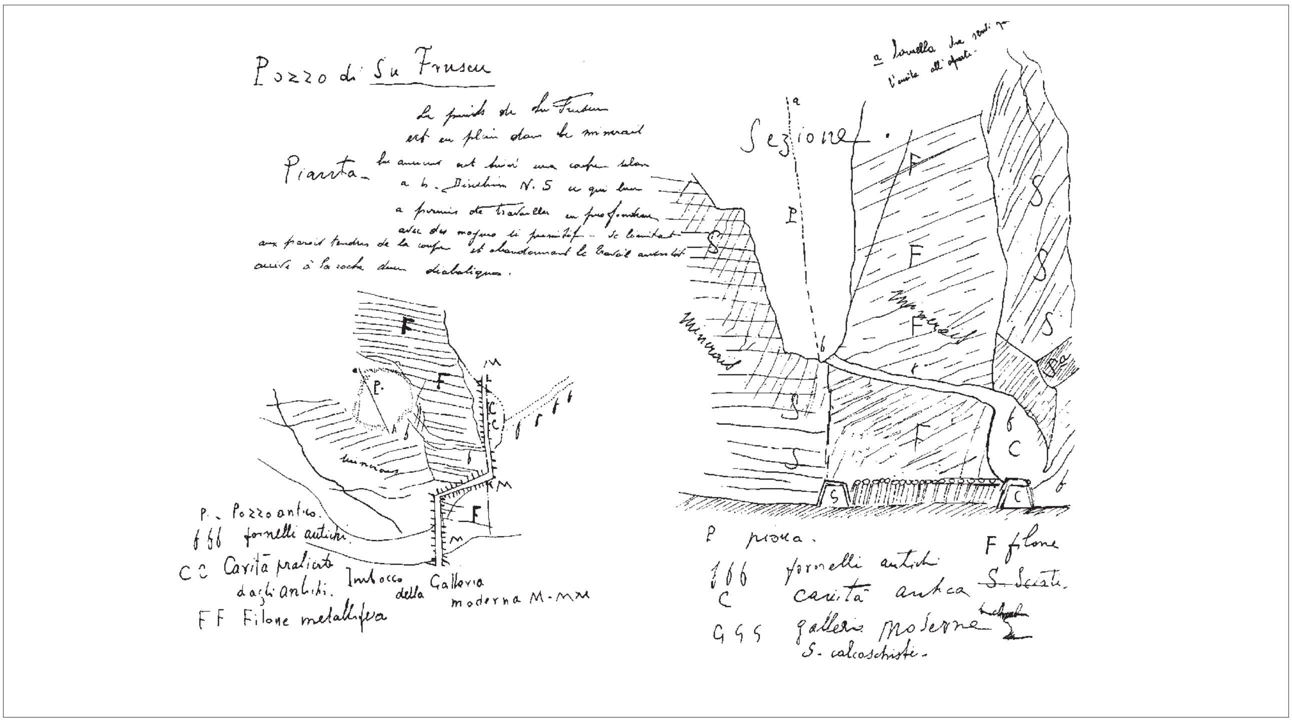
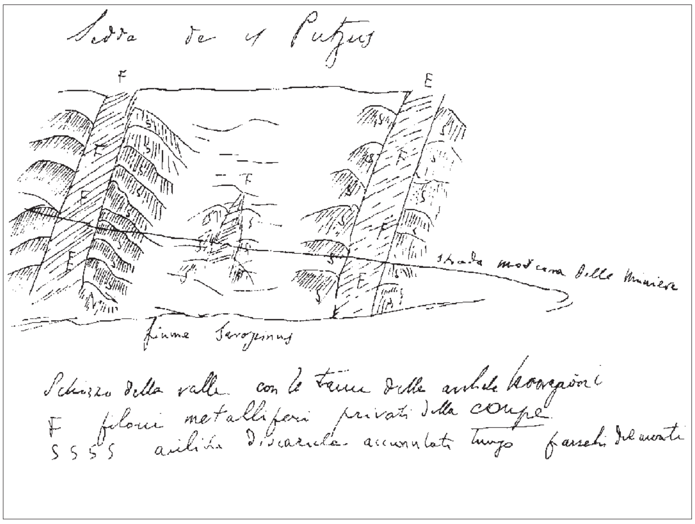


Fig. 5 – "Pozzo di Su Fruscu" is written at the top of the sketch, partly in pencil and partly in pen, in black and red ink, on paper (21 x 15.5 cm), divided in two parts, both with a different text over several lines: "Ground plan. The well of Su Fruscu is set right in the mineral. The ancients followed a cutting according to a-b Direction N – S, which allowed them to work at depth with such primitive means – limiting themselves to the soft walls of the cutting and abandoning the work as soon as they reached the hard diabatic rock. P – ancient well. fff ancient furnaces. CC Cavities made by the ancients. Entrance to the modern tunnel MMM. F. metal-bearing vein"; "Cross-section; a furnace which served as the exit to the open; P Well; fff. ancient furnaces; F vein; C ancient cavity; [S Schists: cancelled]; GGG Modern tunnel; S chalcoschists". ("*Pianta.. Le puits de Su Fruscu est en plein dans le mineral. Les anciens ont suivi une coupe selon a-b. Direction N – S ce qui leur a permis de travailler en profondeur avec des moyens si primitifs – se limitant aux parois tendres de la coupe et abandonant le travail aussitôt arrivant à la roche dure diabatique. P – Pozzo antico. fff fornelli antichi. CC Cavità praticate dagli antichi. Imbocco della galleria moderna MMM FF Filone metallifero*"; "*Sezione; a fornello che servì per l'uscita all'aperto; P Pozzo; fff fornelli antichi; F filone; C Cavità antica; [S. Scisti: cancellato]; GGG Galleria moderna; S. calcoscisti*"). *(after Lo Schiavo 1996 fig. 4, tracing by A. Farina).*



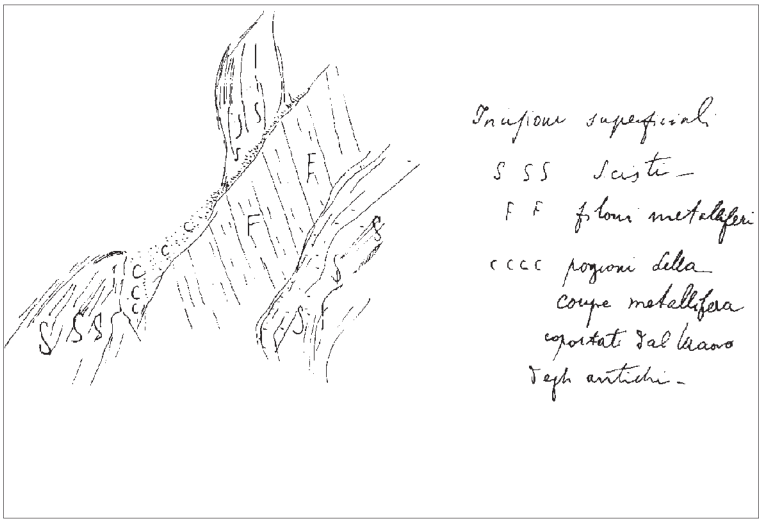


Fig. 6 – "Sedda de is Putzus" is written at the top of the pencil sketch on paper (cm 21 x 15,5), with the text halfway down and at the bottom, over several lines: "moden road of the mine; river Saraxinus; Sketch of the valley with the traces of the ancient workings; F metal-bearing veins of the cutting; SSSS ancient dumps accumulated along the sides of the mountain" ("*strada moderna della miniera; fiume Saraxinus; Schizzo della valle con le tracce delle antiche lavorazioni; F filoni metalliferi privati della coupe; SSSS antiche discariche accumulate lungo i fianchi del monte*"). *(after Lo Schiavo 1996 fig.5; tracing by A. Farina).*

Fig. 7 – "Superficial incisions" ("*Incisioni superficiali*") is written at the top on the right of the pencil sketch on paper (21 x 13.3 cm), with the caption on several linese: "SSS Schists; F F metal-bearing veins; CCCC portion of the metal-bearing cutting removed by the works of the ancients" ("*SSS Scisti; F F filoni metalliferi; CCCC porzione della coupe metallifera asportata dal lavoro degli antichi*"). *(after Lo Schiavo 1982 fig.2 at bottom; 1996 fig.3, tracing by A. Farina).*

R.a SOPRINTENDENZA
AI MUSEI E AGLI SCAVI DI ANTICHITA' DELLA SARDEGNA
Cagliari

Ill.mo Signor Megy,

While kindly informing me of the discovery of great heaps of waste rich in copper ore on the *plateau* of Sarcidano, at no distance from Nurallao and near the nuraghe Nieddìu, you asked me if I had news of archaeological discoveries, particularly of bronze objects from nuragic times, made in localities near or fairly near that rich deposit of waste.

I shall first say that I received with great pleasure the news of the observation made by an expert on your seriousness and conscientiousness, which corresponds exactly to an analogous observation made by me personally thirteen years ago, when studying the Giara *plateau* and the surrounding area for archaeological purposes. While examining the nuraghe Nieddìu in the territory of Nurallao and crossing the rolling *plateau* between this nuraghe and the one situated more to the north, called De is piluncas, I noted and collected copper ore waste, to which I referred in two of my archaeological works: "*L'Altipiano della Giara di Gesturi*", p. 74 and "*Tempio nuragico di Serri*", p. 15. This observation interested me because up to then I had tried to find a reason for the singular richness of bronzes and cast bronze material from the nuragic period in the territory surrounding the giara and up to then I had tortured myself searching for the famous locality of Serra Ilixi, in which, in 1845, at the time of the important work of the Sardinian archaeologist Sen. Giovanni Spano the five great copper ingots of Aegean origins were found, several times described and of which three are now in the Museo Nazionale at Cagliari. From then on, I say today with real satisfaction, I was very sceptical about the declarations of great scholars, such as Lovisato, Ferraris, and Stella, on the scarcity, I should say absence, of copper ores in the island of Sardinia. On the basis of an archaeologist's intuition, founded on the knowledge of analogous archaeological facts in various territories of the Mediterranean, I always believed that the great wealth of weapons and bronze objects which characterize nuragic Sardinia derived principally from natural causes, that is to say from the wealth of the copper ore deposits in the veins under the Sardinian soil.

The brilliant discoveries of the valley of the Saraxinus and of the Flumendosa, due mostly to the tenacity of yourself and to the trust still granted you by the Società Guinebertière, have served to give a scientific basis to the archaeological hypotheses and I am happy, I should say proud, that such a brilliant ray of light, lightening the darkness of Sardinian prehistory, should arrive principally thanks to the noble sons of our Sister nation, the Very Noble land of France, whence such a flame of learning and idealism have always spread around the world.

The discoveries from the Saraxinus valley and Raminosa, referred to above, of which you were kind enough to give me news up to 1909 and subsequently with generous courtesy you have always informed me of up to today, removed all doubt about the presence of deposits of copper in the heart of the island and put beyond discussion that the nuragic people, with the very simplest means at disposal, had, with surprising tenacity and centuries of work, exploited the most easily accessible parts of the great deposit and prepared enormous masses of ever richer ore of this most useful metal. It still remained, however, to discover another very important point for the solution of the problem, which is together archaeological and mineral: that is the one regarding where the treatment and the reduction of the already highly enriched ore of the pure metal took place, a problem raised by the numerous copper ingots which are discovered so frequently in the archaeological strata of the nuragic age.

The reply reaches us, or rather will reach us, from a more intense and thorough exploration of the *plateau* around Nurallao, as on the whole the observations you made would suggest, and I hope with all my heart that they can be encouraged and extended both for purely scientific purposes and for industrial purposes, which I hope will turn out to be highly remunerative.

And now I shall mention to you the principal discoveries of bronze objects and of traces of foundries I remember, made in the territory around Nurallao. Note, however, that the richness of bronze objects in a determined territory is not always an indication of proximity to a centre of production, because the intense commerce which took place in such objects in prehistoric times spread them into places very far from every mining and smelting centre, according to the needs and the wealth of each people. However, it is a positive fact that around the copper-ore-bearing centres exploited in prehistoric times we have zones still richer in discoveries of that sort. More certain as evidence of the presence of mineral deposits exploited in antiquity are the hoards, and, as they say in France, les cachettes de fondeurs, in which piles of fragments of used objects, pieces of casting, waste and ingots are found together already finished pieces.

It is above all necessary to remember that not far from Nurallao we have the great Giara of Gesturi; well, above them and on the Miocene hills which ring it all round, we have over two hundred nuraghi, another seventy at least can be observed around the Giara of Serri and in the nearby valleys of Isili, Gergei, Escolcas and Mandas. It is now proved that the nuragic civilization was entirely a Bronze Age civilization; in fact, its development is principally due to the progress made from the Stone Age to that of metals.

But to these hypothetical traces I would like to add others more conclusive and eloquent. In 1845 at Serra Ilixi, near Isili, in a locality I have not so far managed to identify, were found 5 large copper ingots from the Aegean, together with bronze objects and round small ingots of pure copper, of the type most common in Sardinia. Isolated discoveries of bronze objects from the nuragic period were made and reported at the nuraghe Adoni at Isili, the nuraghe Is Paras also at Isili, at the nuraghe Santu Antine and Biriu at Genoni, at the nuraghe Trepabulis at Nurallao. I would go on for too long if I were to mention to you all the isolated discoveries which have been reported to me from Escolca, Gergei, Nurri, Orroli, Gesturi and Mandas, etc, etc. I will just say that from this last locality comes a single object which is judged by famous scholars as a model of a nuragic temple, but which, according to the latest hypothesis put forward by a well-known military technician, General Guzzo of the Engineers, would be the model of what would have been a marvel for primitive man, namely a smelting furnace.

You see therefore that these elements all found in a radius of territory surrounding the *plateau* of the Sarcidano are already in themselves of great value, particularly if we accept the hypothesis of General Guzzo, that the small object from Mandas represents a furnace for smelting the ore. But there are ever more conclusive things in the list of Early Sardinian finds in the territory just mentioned. About thirty years ago, thanks to the rector of Villa, a great enclosure of smelters was discovered, excavated then by Sig. Nissardi, at Forraxi Nioi between Nuragus and Nurallao, and inside a large vase was found an enormous mass of whole and fragmented bronze objects, and together with these masses of scraps, ingots of pure copper, copper ore and cassiterite. This fine discovery, illustrated later by Prof. Pinza, was explained afterwards; two years or so ago I had the good fortune to find not far from there, near the nuraghe Santu Millanu, also at Nuragus, a sacred spring of exquisite manufacture and I maintain that it is the centre for the collection of all the offerings and all the ex-votos which were then supposed to be melted down by the priests, the depositaries of secrets and knowledge, linked to the search for ores and to the smelting of metals.

Recently too on the *plateau* of the small Giara di Serri at about two hours from Nurallao, I had the good fortune to find the first of the Sardinian temples to be methodically explored; and even though my office found just the remains left after a ransacking which had occurred when invaders took over the Giara *plateau* and destroyed the sanctuary venerated by the ancient Sardinians, the votive material in bronze, found amongst the ruins, which consisted of statuettes, weapons and tools, form one of the most precious collections that I have at the Museum of Cagliari.

I would like to add other important data to these, but let what I have mentioned be sufficient to demonstrate a wealth of bronze archaeological material in the area surrounding the Sarcidano *plateau*. Add that in the Museum there are several hundred objects in bronze found in the last century and that they have lost the indications of their provenance on account of misadventures in the Institute. Many of these, however, are absolutely identical in patina and shape to those from Serri and Forraxi Nioi, which indicates that the origin is not far away. I have not included in the list that I have here drawn up the prince of bronze hoards in Sardinia: the one that was found twice at Abini, near Teti, at the foot of the western slopes of Gennargentu and which included a mass of bronze weapons, tools and votive statuettes and ingots of copper enough to fill a Museum. In this hoard too, as in that of Forraxi Nioi, the types and the characters of the bronzes really seem to belong to a family; in this case too, as I recognized in a visit I made to the locality, it is a deposit made next to the temple, which was simultaneously a sacred place and a centre for the metalworking industry.

And I would have by now finished these short notes, which I could have extended, had it not been for the brief time granted me by my present occupations. Before reaching the end, however, I must inform you that Sig. Leone Gouin, who spent his life in Sardinia as mining engineer and interested himself very usefully in archaeological research, in his work entitled “Notice sur les mines de l'Ile de Sardaigne” 1867, in which he talks of the ancient cultivations of the copper mines of Gadoni with much scepticism, has a piece of information very useful to us and which I had forgotten to tell you in the past. He says: “I have come across both around Laconi, in the Arcidano, and in the plain, little bits of copper slag, almost always at the feet of nuraghi, which seem to have belonged to the Bronze Age and to come from castings which are entirely small fragments. I even found some fragments of bronze weapons in this heap” (“*J'ai rencontré souvent soit autour de Laconi, dans l'Arcidano et dans la plaine, des petits morceaux des scories cuivreuses, presque toujours aux pieds des nuragues, qui semblent apartenir à l'époque du bronze et provenir des fusions tout affait parcelles. Je meme trouvais quelque fragments d'armes en bronze dans ce tas*.”)

The engineer Gouin, who was an excellent man, wrote in such a way as to discourage and ward off possible competitors in the mining exploration; but in the quoted report, on page 135, he confesses: “Perhaps the future reserves us some interesting discoveries, but it is still very doubtful!” (“*Peut-être que l'avenir nous reserve quelques decouvertes interessantes, mais ancore est ceu fort douteux!*”). We hope that your extensive research on the *plateau* of Arcidano can provide the widest results from the industrial and scientific point of view, and, just as the gloomy forecasts of Gouin collapsed in the face of the results obtained in the territory of Gadoni, that you will also have success corresponding to hopes in the *plateau* which crowns the basin of the Isili.

I thank you for the honour you have done me by asking me to concern myself with this question from the archaeological point of view, I offer to you my best regards, and extend them also to Sig. Avv. Guinebertière.

Yours faithfully,

A.T. [Antonio Taramelli]

Cagliari XX September 1916.

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Lo Schiavo F. 1996, Miniere e metallurgia in Sardegna: la ricerca archeologica dal presente al passato, in *La miniera, l'uomo e l'ambiente. Fonti e metodo a confronto per la storia delle attività metallurgiche in Italia*, Convegno di Studi, Cassino 2-4 giugno 1994, Firenze, 187-206.

For other references by Taramelli to copper-bearing minerals, see:

Taramelli A., Fortezze, recinti, fonti sacre e necropoli preromane nell'agro di Bonorva (prov. di Sassari), *Monumenti Antichi dei Lincei*, XXV, 1919, 18: "...I here give the opinion that another source of natural richness also contributed to give vigour to the Sardinian stock of the Logudorese region and had provided it with the means for cultural defence, and this would have been the deposits of copper-bearing ore which were to be found, even if not in large quantities, in the mountains of Thiesi and Cheremule... Some of these copper-bearing veins, as was shown by Prof. Augusto Stella, in his geological study of the region, appear as easily-recognizable natural outcrops; these may have been traced and exploited by the nuragic peoples, although we still have no definite proof of this in the form of the prehistoric excavations, such as we have for the copper-bearing deposits of the high Flumendosa, in the Gadona region, thanks to the research of the excellent Sig. Megy..." ("*... Espongo qui la opinione che anche un'altra fonte di ricchezza naturale avesse contribuito a dare vigore alle schiatte sarde di questa regione Logudorese ed avesse fornito ad essa i mezzi di difesa e di cultura, e questa sarebbe appunto costituita dai giacimenti di minerali cupriferi che si trovavano, per quanto in misura non grande, nei monti di Thiesi e Cheremule ... Alcuni di questi filoni cupriferi, come dimostrò il prof. Augusto Stella, nel suo studio geologico della regione, si presentano con affioramenti naturali facilmente riconoscibili; questi possono essere stati rintracciati e sfruttati dalle schiatte nuragiche, per quanto ancora non ne abbiamo quelle prove positive di escavazioni preistoriche che ci fu dato di raccogliere per i giacimenti cupriferi dell'alto Flumendosa, nel Gadonese, grazie alle indagini dell'egregio signor Megy.* ...") [Augusto Stella, Relazione sulle ricerche minerarie nei giacimenti cupriferi del circondario d'Alghero (Sassari), in Bollettino del R. Comitato Geologico d'Italia, 1908, 4°].

Taramelli A., Il Santuario Nuragico di Serri ed i rapporti tra la Sardegna e la Penisola Iberica, *Bullettino di Paletnologia Italiana*, XLIX, 1929, 83: " ... I have referred to the richness of the subsoil of Sardinia, with copper-bearing deposits and silver-bearing lead at the surface at Gennargentu and in the area of Alghero and in the mountains of Gerrei, Sulcis and Ogliastra.. I believe that the discovery and the exploitation by the Sardinian nuragic peoples of these deposits is one of the principal factors for the wonderful flourishing of the warrior civilization. It will certainly have been Minoan sailors who first brought copper ingots to Sardinia with the signs of their linear alphabet; it will have been, let us admit it, the Almerians who first started explorations of the mineral veins of the coastal deposits near Alghero and near Neapolis and Serrucci, but it was the native Sardinians who conducted the work everywhere that the precious metal came to the surface;..."

("*... Ho accennato alla ricchezza del sottosuolo della Sardegna, con i giacimenti cupriferi e di piombo argentifero affioranti intorno al Gennargentu e nell'Algherese e nei monti di Gerrei, del Sulcis, dell'Ogliastra. Io ritengo che la scoperta e lo sfruttamento da parte di Sardi nuragici di tali giacimenti sia un fattore principale di questo fiorire mirabile della civiltà guerriera. Saranno stati certamente i navigatori minoici a portare in Sardegna i primi pani di rame con i segni del loro alfabeto lineare; saranno stati, ammettiamolo pure, gli Almerici a provocare le prime ricerche nelle vene minerarie dei giacimenti littoranei presso Alghero e presso Neapolis e Serrucci, ma chi condusse i lavori dovunque il prezioso metallo affiorava furono gli indigeni sardi; ...*")

4.
OXHIDE INGOTS, CYPRUS AND SARDINIA

1. Oxhide ingots in the Mediterranean and central Europe

Fulvia Lo Schiavo

1.1. Introduction

The first report of the discovery of oxhide ingots, at Serra Ilixi in central Sardinia in 1857, was by Canon Senator Giovanni Spano of Ploaghe, which was followed by the news of those from Haghia Triada, published by Luigi Pigorini in 1904. This subject was born, therefore, almost a century and a half ago and in the intervening years has been much enriched, both from the archaeological point of view, with the growing mass of discoveries and the resulting new chronological and cultural framework, and from the analytical point of view, with the spread of metallurgical analyses and provenance studies, so far based on the analysis of lead isotopes, combined with that of the trace elements.

As a result the bibliography has become exceedingly abundant, and ever more numerous are the excellent works of synthesis which study the problem in depth in all its aspects. The present one is only the indispensable starting point for a general reference framework.

Our purpose was to assemble an information data bank, therefore we will be limiting ourselves in this book to proposing a synthesis, with specific updatings, particularly bibliographical, on the subjects at present being discussed, enhancing the text with a new catalogue of the oxhide ingots in Sardinia. An essential complement, in that it constitutes the point of view of and from Cyprus, is the contribution of V. Kassianidou (see Part IV, chapter 4.4.)[1].

1.2. Oxhide ingots in the Mediterranean and central Europe (fig. 1)

For previous articles on the subject and for a complete catalogue of all oxhide ingots in the Mediterranean, see Buchholz 1959; Stech Wheeler *et al.* 1975; Muhly *et al.* 1977; Lo Schiavo, Vagnetti 1980; Gale, Stos Gale 1987; Muhly *et al.* 1988; Lo Schiavo 1999. As said above, we are here presenting an updated synthesis of the problem and of the bibliography[2].

Greece and Crete

The last catalogue of the Late Bronze Age ingots (LBA, 1550-1050 BC), both of the oxhide type and of other shapes, complete with bibliographical references, dates to 2000, and is accompanied by a metallurgical analysis of a vast range of samples (Mangou, Ioannou 2000). If we limit ourselves to just the oxhides ingots, the places of provenance are :

<u>Greek islands</u> :

Kea, half of an example (Caskey 1969);

Chios, a fragment (Hood 1982);

<u>Crete</u> :

Palaekastro, a fragment (Bosanquet 1904-5);

Phaistos, one example (Svoronos 1906);

Tilissos, 3 examples (Hatzidakis 1912);

Aghia Triada, 16.5 examples (Buchholz 1959);

Zakro, 6 examples (Platon 1971);

Gurnià, 3 examples (Betancourt *et al.* 1978);

Kastelli, a probable fragment (Hallager, personal comment);

Kommos, 6 fragments (Blitzer 1995);

Knossos, a fragment (KN/1962, unpublished);

<u>Mainland Greece</u> :

Mycenae, acropolis, an example (Svoronos 1906);

Mycenae, Poros Wall hoard, 12 fragments together with a planoconvex ingot (Wace 1953);

Thebes, 3 fragments (Buchholz 1959);

<u>Euboea</u> :

Cuma, 16 examples (Aravantinos 1991).

1. With the kind permission of the Author and of The Costakis and Leto Severis Foundation.

2. Given the nature of this synthesis, the unchecked citations by Bucholz, reported by Bass, are not recorded here nor are all references to miniature reproductions and to the representationls on seals (Buchholz 1959; Bass 1967).

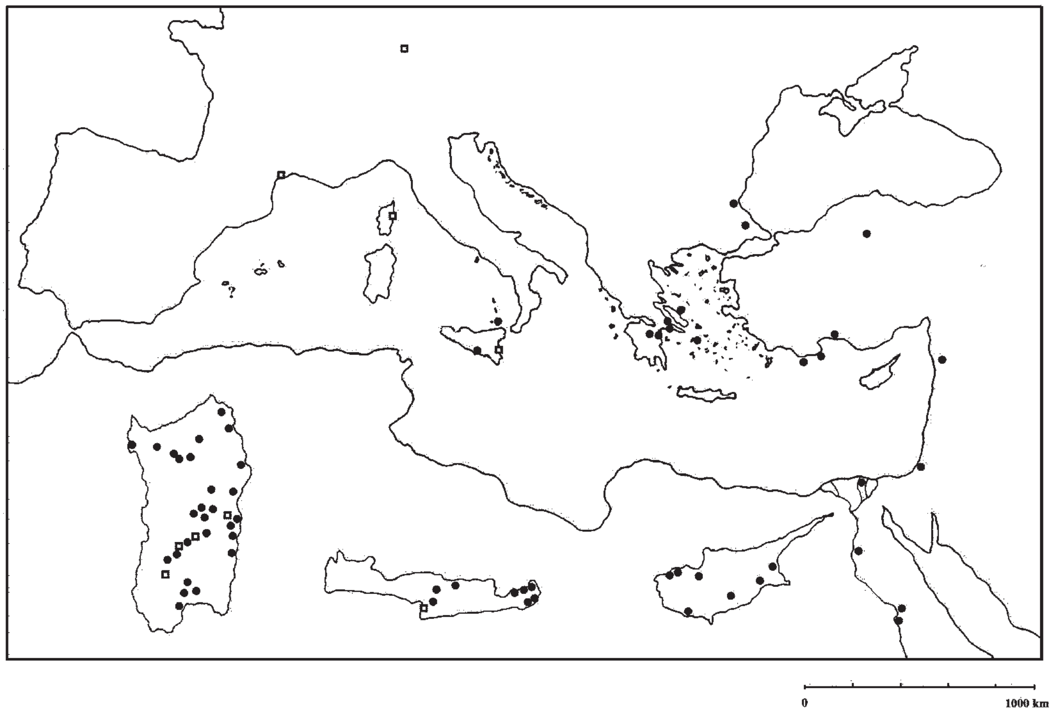


Fig. 1 – Distribution map of oxhide ingots in the Mediterranean and central Europe *(drawn by Antonio Mancini, ICEVO-CNR).*

The Authors will report how, on the basis of the lead isotopes, it has been suggested that the oxhide ingots found in the Aegean, at Mycenae, at Cuma in Euboea and at Gurnìa, are of Cypriot provenance, while it is suggested that the other ingots found in Crete, at Aghia Triada and at Tilissos, come from ore deposits in Afghanistan, Iran or central Asia, which could be explained by the more ancient dating (Gale, Stos-Gale 1986; Gale 1989; 1991; Stos-Gale *et al.* 1997). In the end they conclude that, since there is no agreement on the origin of the ingots in the Mediterranean, the place in which the ingots found in Greece were manufactured remains an unresolved problem (Mangou, Ioannou 2000, 208).

Cyprus

The island of Cyprus, which most scholars agree in identifying as the land of Alashiya mentioned in Egyptian near-eastern sources, possesses very rich reserves of copper, the exploitation of which seems to have already started in the Middle Bronze Age, reaching an extraordinary importance in the Late Bronze Age, when in almost all explored archaeological sites have been found considerable traces of its working. Finally, as result of a vast and minute exploration of the territory, a smelting workshop for the primary working of the ore was discovered at Politiko-Phorades, dating to the beginning of the Late Bronze Age (Knapp 1999; Knapp, Donnelly, Kassianidou 1998; Knapp, Donnelly, Kassianidou 1999; Kassianidou 1999; 2001, 99-100).

Strangely, only three complete oxhide ingots have been found in Cyprus, one of which was discovered in the course of archaeological excavations at Enkomi (Buchholz 1959; Catling 1964), and an almost complete one perhaps by Mathiati (Bruce 1937; Muhly *et al.* 1980). On the other hand, there are many fragments, of which we shall mention only those discovered in recent excavations (Kassianidou 2001, 98; Papasavvas 2001) :

Kalavassos-Ayios Demetrios (South 1989);

Maroni-Vournes (Cadogan 1987);

Pyla-Kokkinokremos (Karageorghis, Demas 1984)

Maa-Palaeokastro (Muhly, Maddin 1988).

Very important too are the frequent reproductions of oxhide ingots in religious and cult environments, including the two celebrated figurines of divinities, one male and one female, who rest their feet on the ingot, and including the bearers of ingots represented in the four-sided supports on wheels (Kassianidou 2001, 99).

The dating of the production of the oxhide ingots is for the moment defined by terms from outside Cyprus, in which the majority date to XIII century BC; the oldest ones, approximately datable to XVI century BC, are those found in Crete (Agia Triada, Gurnià, Zakro), while the shape is no longer in use after XI century BC. (Kassianidou 2001, 99).

The chronological production period of oxhide ingots is defined, for the moment, by data outside of Cyprus, where the majority is dated to the 13th c.; the earliest, dated to around the 14th c. are those from Creta (Agia Triada, Gurnià, Zakro). This shape is no more in use after the 11th c. (Kassianidou 2001, 99).

Further archaeological and metallurgical research is under way, including the eagerly awaited one by A. Hauptmann and R. Maddin on smelting techniques, based on the study of the crucibles of Kition and of Enkomi.

Asia Minor

Disregarding the original provenance of the metal, two shipwrecks have been found in Asia Minor, to be precise at Cape Gelidonya and at Ulu Burun, on the south-eastern coast of Turkey, in which the most substantial complexes of oxhide ingots known up to today were discovered.

The wreck of Cape Gelidonya was explored in 1960 and published exhaustively a few years later (Bass 1967). A few remains of the planking of the boat were left. 34 copper oxhide ingots, some thirty planoconvex ingots, whole and halves, as well as a certain quantity of small fragments, 19 bar ingots and three shapeless masses of tin oxide which may have come from ingots remained of the cargo .

Also found were 257 bronze artefacts, such as agricultural implements, woodworking tools, small instruments for domestic use; of weapons, only a head and the ferrule of a spear; personal and domestic objects, amongst which were sheet vessels, fittings and fragments of tripods and bronze supports, and unidentifiable fragments, such as incomplete objects and smelting waste. There was little pottery, and most of it was for everyday use. In stone, there was a hammer head, an anvil, a vase-mortar, smoothers and pestles; sixty small weights in stone and metal; in lead, net weights; very few ornaments, consisting mostly of vitreous paste and bone objects. There were fish backbones, olive stones and an ankle-bone probably belonging to the wreck and perhaps the remains of a meal. Three whole scarabs, a half-broken one and a plaque with scarab-like design on it have been interpreted as the personal property of members of the crew, and the attribution of the most recent to XVIII and between XVIII and XIX dynasties confirms the dating of the wreck to XIII century.

One of the most sensational discoveries from the point of view of the archaeological documentation, that of the wreck of Uluburun at the end of the peninsula of Kaš dates twenty years earlier; it consisted of the whole cargo of a XIV-century commercial ship, including material of various provenances, stowed in the spare spaces of the vessel and complementing the principal cargo. For this reason, unlike the earlier example, it is not possible to give a list of the artefacts, which come into numerous categories covering a very broad range of problems and number several thousand pieces (Bass 1986; 1987; Bass *et al.* 1984; Bass *et al.* 1989; Gale 1991; Pulak 1988; 1993; 1994; 1997; 2000; 2001). Amongst the objects found must be mentioned the presence of a Thapsos-Pertosa-type sword, recognized by Lucia Vagnetti, which confirms the existence of maritime communications and movement of persons and things over long distances (Vagnetti, Lo Schiavo 1989; Vagnetti 2000).

As far as the ingots are concerned, we now have a final and overall study of their structure and composition: 354 copper oxhide ingots were found, 121 discoid planoconvex ingots (or "*panelle*"), for a total of 10 tons; furthermore there were 120 whole and fragmentary tin ingots weighing a total of one ton. This exceptional discovery has led to enormous advances in our knowledge of the trade in metals and in the technology of the casting of the ingots and of the alloys in the Late Bronze Age (Hauptmann, Maddin, Prange 2002; see Part IV, chapter 6.3).

On the north coast of the Sea of Marmara, at Sarköy, another oxhide ingot has been reported, probably datable to between XII and XI centuries, while the one from Antalya, now in the Metropolitan Museum, has not been dated. A fragment of 7 kg, corresponding to about a quarter of the ingot, with its end whole and a sunken circular area near the fracture at the side, comes from Bogazköy (Harmankaya 1994; Stos Gale *et al*. 1997; Neve *et al.* 1980, 303-4, fig.22). There is an unconfirmed report of the presence of oxhide ingots in Mesopotamia, at the middle reaches of the Euphrates.

Syria

The palace of Ras Ibn Hani in Syria is still the only place in which a stone mould bearing the imprint of the shape of an oxhide ingot has been found; it was reused as a threshold, in a context of the Late Bronze age (Lagarce J. *et al.* 1983; Lagarce E., Lagarce J. 1997).

Egypt

A fragment of oxhide ingot (200 gr) was found in the Nile delta at Qantir, Piramesse, in a complex of a smelting workshop of the Late Bronze Age, with crucibles, raw materials and scraps from smelting, in the course of research and excavation by Edgar Pusch (1990 tab. V, b).

Egyptian paintings and reliefs are a documentary source of prime importance, and represent oxhide ingots both stacked up and carried on the shoulder. Bass has illustrated their repertoire, dated to the times of Hatshepsut and/or Thutmoses III (1490-1436 BC), up to the time of Ramses III (1192-1160 BC), and distributed be-tween Thebes, Karnak, Tell el Amarna and Medinet Habu (Bass 1967, 62-67).

Central-eastern Europe

In addition to reports of the finding of an oxhide ingot at Sozopol on the Black Sea there is news of other ingots fund at Tcherkovo, a further little inland, in the area of a Bronze-Age settlement (Karaitov 1978; Stos Gale *et al.* 1997).

At the 1994 London Congress *The Identity of Bronze Age Europe* the illustration, on the part of Margarita

Primas, of four fragments of at least two different oxhide ingots, apparently of the oldest pillow-shaped type (Bucholz 1b), found in 1932 and long known about but not recognized for what they were, in a hoard at Oberwilflingen in Baden-Württemberg, housed in the Württembergisches Landesmuseum at Stuttgart; the association with bronze axes with large edge of a transitional type MBA/LBA dates the hoard to no later than XIV century. The summary of the report with the illustration of a fragment (Primas 1997, 125-126 fig. 4.2) was then followed by a broad study, with metallurgical analyses and analyses of the lead isotopes. The ingots were analysed by Junghans and Sangmeister (SAM 1968, tab.3 nos.235, 239, 240, 241) and were found to be of almost pure copper, with a lead content which went from 0 to mere traces; the analyses of the lead isotopes, carried out by Ernst Pernicka, indicated that their provenance was Cyprus (Primas, Pernicka 1998).

Western Mediterranean

A fragment of oxhide ingot was found in Sicily at the beginning of XX century at Cannatello, in the area of Agrigento, and was mentioned by Mosso (1907), without indications of context or associations; however, he had it analysed (Cu 99,46 - Zn 0,16 - Sb 0,04).

The important results of the excavations carried out by G. Fiorentini and E. De Miro from 1996 onwards, lead to a better knowledge of the site, and were added to the data known at that time. It is a fortified village of the Thapsos culture, from the Recent Bronze Age; amongst the material found there is pottery from TEIIIA-AAAB, Cypriot, Maltese and even nuragic "grey"-impasto pottery, both imported and local imitations. It must have been, therefore, a stronghold of the long-distance traffic on the southern route (Vagnetti 1968; Levi 2004).

Many years later, a hoard of bronzes contained in a vase was discovered on the Acropolis of Lipari, buried under the wall of an Ausonio-II hut, but belonging typologically and chronologically to Ausonio I, as the typology of the artefacts, dating to the Recent Bronze Age, also confirms.

Of the total weight of about 75 kg, consisting of fragments of weapons (swords, daggers, spears, knives), tools (axes, sickles, saws, chisels), ornaments and personal objects (*fibulae*, pins, razors, mirrors), other artefacts (sheet metal with or without repoussé decoration, twisted and folded over), some 22.5 gr is made up of waste and residues of smelting and 58.370 kg of fragments of copper ingots, together with shapeless lumps of copper or bronze, in turn divided into large pieces (elements of which the average weight reaches 445 gr and the maximum is 750 gr), medium pieces (elements whose weight averages 150 gr, with a maximum of 300 gr), and minute pieces (elements whose weight averages 25-27 gr) (Bernabò Brea-Cavalier 1980, 756, Tab. CCCXIX; Peroni 1996, 260; Carancini, Peroni 1999, 17, 21, tabs. 29, 34).

A fragment of oxhide ingot is on display in the Museo Archeologico "Paolo Orsi" of Syracuse, from the settlement of Thapsos, now in course of analysis and study.

C. Domergue and C. Rico are responsible for the recent publication of an oxhide ingot from southern France. The piece, housed since 1996 in the Musée Paul-Valéry, was found out to sea, in the waters of Sète, Hérault, halfway between Narbonne and the delta of the Rhone. The metallurgical analyses have shown that the copper is almost pure, with 0.1 of trace elements (Domergue, Rico 2002, 150).

Another report of the discovery of a whole oxhide ingot is due to P. Arcelin, in the course of a reconnaissance project, by Daniel Istria and Roland Chessa, coordinated by Philippe Pergola, in the region of Mariana on the coast in eastern Corsica, north of Aleria. The discovery was made casually several years go in the course of agricultural works (P. Pergola, personal communication).

Reports of the finding of a load of copper ingots off the island of Formentera, in the Balearics, made by A.J.Parker (Parker 1992, 181) are unconfirmed.

1.3. The most recent discoveries in Sardinia

The already dense distribution of the findings of oxhide ingots on the island becomes ever more so by the day. Furthermore, to the discoveries of the last years must be added the many references made in the old bibliography to the presence of numerous hoards of "pieces of raw copper": at the time, and still today, it is rarely possible to distinguish between oxhide ingots, planoconvex ingots and ingots of other shapes when the remains are some small or very small fragments.

As an example, a systematic checking of the whole bibliography of Gallura has evidenced the presence of at least ten hoards with "pieces of raw copper"; a description by D. Panedda conjures up the image of a fragment of oxhide ingot in one of the pieces of copper in particular from the countryside of Olbia, Trambuccone region, Olbana locality, which "ended up in the Museo of Cagliari" ("*andarono a finire nel Museo di Cagliari*"), (Panedda 1954, 20, note 7; Lo Schiavo 1996, 68).

Since the summary of 1999, the number of sites has increased from 26 to 31 (see Part IV. chapter 3. Updated catalogue of the oxhide ingots of Sardinia).

The latest discoveries have been made in the localities of Talana (16), Villagrande Strisàili (Nuoro), Sa Carcaredda (18c); Nurallao, Nieddìu (21), in the province of Nuoro; Baràdili, Santa Maria (24); Villasor, Giva Molas (27); Monastir, Monte Zara (28), in the province of Cagliari.

Not much can be said about Talana (16), in that it is just the name of the locality in the high Ogliastra where a confiscation was made, which included amongst other materials a fragment of oxhide ingot, about whose provenance no information could be gleaned.

A little above the urban centre, on the "Margine" *plateau* situated at more than 1000m above sea level, is situated the great complex nuraghe of Bau 'e Tanca, consisting of a central tower and of two added towers on the south side, surrounded by a village; there are also some giant's tombs, one of which, built up in courses, rises at 500m from the nuraghe.

One of the huts of the village, situated a few metres from the nuraghe, was completely excavated and produced an uninterrupted stratigraphic succession from the Middle Bronze period to the Late Bronze Age; in particular in the deep stratum, together with a fragment of a cup with elbow handle in the Bonnanaro tradition, with fragments of "*tegami*" with comb decoration and various fragments of bowl with enlarged rim, was found a large planoconvex copper ingot and a foliate small simple base dagger (Fadda, Tuveri 1990).

The comune of Villagrande Strisàili is already known for the oxhide ingots found near the Corte Macceddos (or Corti Acca) nuraghe (18a), and for the extraordinary finds made near the "*megaron*" temple of S'Arcu 'e is Forros (18b) (see file no. 32).

Following some clandestine excavations in December 1989, there were excavation seasons in the following years, at the site of Sa Carcaredda (18c), already known for the presence of a nuragic village and of four large giant's tombs, hidden in the nearby wood.

Thus came to light a singular sacred monument, known as a "Round Temple" (Lo Schiavo 2000a), unusual from many aspects, consisting of a circular room, paved with slabs of granite. The hearth at the bottom of the room was contained within a small wall on which were placed shaped blocks, held together with lead clamps, which reproduced half of a four-tower nuraghe. The round room was preceded by a trapezoid *atrium*, with platforms along the walls.

On the right side of the building there is a vast space, rectangular in shape, with two pilasters, in which was accumulated a large quantity of bronze offerings from the nuragic period, and also from Roman times (a hoard of coins) (Fadda, Tuveri, Murru 1992).

Amongst the offerings were mentioned: "From the corners of the right side of the room, ...a bowl of an open shape, with a flat, deck handle, buried for depth of 15 cm, propped up at the bottom with 5 fragments of Aegean-type ingots and with 10 planoconvex ingots, totalling 10 kg in weight. From the other corner comes another bowl with small neck, with inverted elbow handles, buried for a depth of 20 cm... supported on 10 fragments of Aegean-type ingots and with 10 planoconvex ingots totalling 10 kg in weight, and furthermore, by the neck rested a flanged axe, 22 cm long ..." ("*Dagli angoli sul lato destro del vano, ... un'olla di forma aperta con anse a nastro piatto a ponte, interrata per 15 cm ... rincalzata sul fondo da 5 frammenti di lingotti di tipo egeo e da 10 panelle, per un totale di 10 kg. Dall'angolo opposto proviene un'altra olla a colletto, con anse a gomito rovesciato, interrata per 20 cm ... rincalzata da 10 frammenti di lingotto di tipo egeo e da 10 panelle per un totale di 10 kg, ed inoltre, in corrispondenza del collo, poggiava un'ascia a margini rialzati lunga cm 22 ...*") (Fadda 1995, 119).

The dating usually proposed for the monument, with the adjoining rooms, is the Recent and Final Bronze Age, with visible later building phases; the sacred place was also evidently used in Roman times.

The fragment of oxhide ingot from Nurallao, locality of Nieddìu (21), was found on the surface in the area of a nuragic sacred well, partially stripped by the digging works of a bentonite quarry; two bronze figurines, both lost, came form the site (Lilliu 1997; Sanges 2000).

"The fragments of oxhide ingots from Baradili (24) were given to the State in 1947 by Dr. Antonio Cabras and remained for a long time in the storerooms of the Museo di Cagliari. The site and the circumstancs of the discovery are well described by Cabras, who says that the hoard was found in the region of Santa Maria, south of Baradili in 1937 during works for the construction of the road which links Baradili with the cemetery: "...at a depth of about 70 cm below ground level a terracotta vessel, in the shape of a bowl, fifty centimetres high, containing about two hundred fragments of raw copper, of various sizes" (" ... *alla profondità di settanta centimetri circa dal livello del suolo, un recipiente di terracotta, a forma di pentola, dell'altezza di cinquanta centimetri, contenente circa duecento frammenti di rame grezzo, di varie dimensioni*").

Cabras found 154 fragments, weighing in all 23.200 kg, while some fifty fragments seem to have been removed by persons unknown and then dispersed. Even the fragments of the great vase-container have not been identified, for which reason the hoard is without indications for dating". (L. Usai).

The complex from Villasor, S'Acqua Cotta - Ri'e Procus region, locality of Giva Molas (27), is interesting for the site and the circumstances of the discovery, made by chance on the surface in perfectly flat land, ploughed and having had its stones removed, even though the area was already known for previous discoveries. The reason for interest lies in the fact that the nine fragments of ingot, three large and identifiable with certainty, and perhaps a further two, even if slightly smaller, were found together with 19 fragments of votive swords in sizes from medium to small. Already in the hoards from the nuraghi Albucciu-Arzachena, Funtana II-Ittireddu, Baccus Simeone-Villanovaforru are documented a few fragments of votive swords, and votive swords have been found in association with oxhide ingots in other localities, for instance at Gremanu-Fonni, and elsewhere; in this case, together with the ingots, only votive swords were found, and in considerable numbers.

The site of Monte Zara di Monastir (28), and in particular the area of Bia de Monti, is to the west of today's urban centre of Monastir, on the other side of the road S.S. 131, the widening of which led to the excavation seasons of 1986-87 and of 1992-93.

Apart from the abundant prehistoric buildings over the whole territory, those of the nuragic period are certainly huge and of great interest.

In the site of Bia de Monti three sectors have been excavated, which have produced a series of circular and rectangular structures, known about only from the preliminary data, and dating to the Recent and Final Bronze Age periods.

The fragments of oxhide ingots were mentioned by G. Ugas "In the structures 34S and 25 were found fragments of lead and pieces of copper, belonging to oxhide ingots" ("*Nelle strutture 34S e 25 sono stati rinvenuti alcuni frammenti di piombo e pezzi di rame, riferibili a oxhide ingots...*") (Ugas 1992, 210), but their discovery took place on the surface, not in association, even if not far from where were gathered "5 pieces of Argolic pottery of Mycenaean IIIB" ("*5 pezzi di ceramica argolica del Miceneo IIIB*") (Ugas 2001, 79).

1.4. The oxhide ingots and the votive swords

As already said, fragments of nuragic votive swords were found in the hoards of Albucciu-Arzachena, Funtana II-Ittireddu, of Baccus Simeone-Villanovaforru and of Giva Molas-Villasor in association with the oxhide ingots. The same association was found at Fonni-Gremanu, where fragments of oxhide ingots and votive swords were discovered together with fragments of small bronzes, in the crammed space next to the "*megaron*" Temple and between this and the Round Temple.

The votive swords (see Part IV, chapter 5)

The votive swords are all characterized by a very pronounced central midrib, generally rounded and with the two asymmetrical sections not exactly placed one on top of the other. This fact together with the length, unusual for protohistoric swords, and, in general, the absence of hilts serving to balance them, confirms their principally votive use. Metallurgical analyses conducted on fragments in the hoards of the nuraghe Albucciu at Arzachena and the nuraghe Funtana at Ittireddu have shown furthermore the presence of a very low percentage of tin, would render the weapon useless.

Since this is a category of weapons characteristic of, and exclusive to, nuragic Sardinia and of vital importance for the reconstruction of a delicate system of internal sequences and associations between artefacts, monuments and small bronzes, it is opportune to give particular attention to this subject.

A radical change of perspective on the chronology of the votive swords was determined by the recent recomposition (1994) of a hoard discovered in 1936 in the locality of S'Erenosu at Bolotana (Nuoro) and studied by Doro Levi; it consists of thirteen votive swords, all whole except for one, 100 to 130 cm long, associated with a flanged-hilted sword, of a shape which evolved locally, and derives from the western prototypes of the "pistilliform" swords, datable to the middle of the Final Bronze Age period.

The associations with oxhide ingots point to an even earlier period; these had completely disappeared from the Aegean and Cypriot production and from Mediterranean trade long before the end of the Final Bronze Age. The exact analogy between the type of ceramic container, particularly that from the nuraghe Albucciu at Arzachena (Sassari), with a similar one found at Kommos, in MycIIIB period strata, indicates the Recent Bronze Age. These new elements, determined by the very recent studies on the typology of nuragic pottery, help to confirm indications which have been long known and perhaps not assessed with sufficient attention, such as the discovery of a stump of a nuragic votive sword in stratum 3a of tower c of the nuraghe Antigori at Sarroch (Cagliari), associated with "grey" pottery, characteristic of the Recent Bronze Age (Fig. 9.1, p. 284).

Parallel to the data on the associations, there have been, and continue to be, important acquisitions relating to the link between the votive swords and the structures of the temples and sanctuaries to which they were originally destined. Amongst the best-known and most indicative is that of the bundle of votive swords fastened to the ridge of the double-sloped roof of the Fonte Sacra of Su Tempesiu at Orune, evidently at the very moment of the construction, dating to at least the beginning of the Final Bronze Age, although there are present also elements from the Recent Bronze Age (Fig. 8.1-2, p. 284). The same chronology has been proposed for the sacred well of Monte S. Antonio at Siligo, also with a double-sloped roof, of which the ridge survives almost entire and shows the holes made for the fastening of the votive swords with lead (Fig. 8.4, p. 284). There are the same indications from the excavations of the "Rotonde" at Sa Carcaredda, Villagrande Strisàili and at Gremanu, Fonni, where the nuragic swords, positioned in groups or regular rows, crown parts of the architectural structures (Fig. 8.3, p. 284), as well as being, as usual, fixed to the "Tables of Offerings".

The votive swords generally have a simple base, oblong or rounded triangular in shape, without nails, or with small nails and indentations, to the sides of the midrib. Hilts are very rare, but the few known are of different shapes, all reproduced on the small bronzes: bilobate, convex-shaped, V-shaped (Fig. 10, p. 285).

The monument found in the subterranean *sacellum* of the nuraghe Su Mulinu at Villanovafranca is an exceptional document; on the upper drum of the nuragic tower, which stands above one side of the great basin, are sculpted four hilts of votive swords which stand upright with the point upwards. Traces of inserted bronze blades can be seen. The two types of hilt, alternating, are the bilobate and convex shaped.

There are therefore numerous and substantial clues which link the votive swords not simply to the context of offerings, which could have been brought to the sanctuary over even quite a long span of time, but to the phase of the construction of the temple structure.

The votive swords held by nuragic bronze figures

There are many cases of bronze figures of warriors who held votive swords. In fact it is possible to distinguish various patterns, according to the votive sword - known as a "*stocco*" ("rapier") on account of its characteristics, considerable length and minimum width - both held in the right hand, as in the case of the so-called "*Miles Cornutus*" from Senorbì (Lilliu 1966, no. 96), 2), or in the left, for example "*I Commilitoni*" ("The Fellow Soldiers") from Teti, Abini (Lilliu 1966, no.90), or with both hands, as in the case of the ""Heroes" with four eyes and four arms"(""*Eroi"con quattro occhi e quattro braccia*", Lilliu 1966, nos. 104 - 110, 140, 141).

Considering that the majority of the evidence mentioned is substantially unpublished or edited only in an incomplete and preliminary way, it is not yet possible to draw conclusions; however, it is beyond doubt that this form of weapon had a very high emblematic value and that the repeated association with fragments of oxhide ingots is not casual and should be attributed to the origins of nuragic production (Lo Schiavo 2004).

1.5. The oxhide ingots and the vase-containers

There is now a specific study of the vase-containers, based on the solid structure of an overall typology of nuragic pottery, never attempted up to now, in which all published material has been covered, and a huge amount of unpublished material was also taken into consideration (Campus, Leonelli 1999; 2000).

The following have been examined: the small bowl with two handles, and the carinate rounded cup used as a lid from the Albucciu nuraghe at Arzachena; the carinate cup from Serra Elveghes, Olbia; the ovoid four-handled cup and the angular-profiled bowl, used as a lid from the nuraghe Funtana at Ittireddu; the lenticular large bowl and carinate basin, used as a lid from S. Anastasia di Sardara; the vertical ribbon handle with expanded edges and flat bottom, attributable to a large *olla* from Baccus Simeone, Villanovaforru. The three fragments belonging to two vases (probably a carinate cup and a bowl) from the Pattada hoard are unclassifiable.

"Almost all material can be attributed to a chronological span which goes from the Recent Bronze Age to the Final Bronze Age; the sole exception is the lenticular large bowl, which seems to be a shape used also at the beginning of the Iron Age" ("*La quasi totalità del materiale è inquadrabile in un arco cronologico che va dal Bronzo Recente al Bronzo Finale; unica eccezione è costituita dallo scodellone lenticolare che sembra essere una forma utilizzata anche agli inizi dell'età del Ferro*") (Campus, Leonelli 1999, 516), which, being a shape of great simplicity, may have been in use for a long time.

Particularly qualifying are the comparisons of the nuragic vases found at Kommos (Watrous 1989, 1992; Watrous *et al.* 1998) with those classified in the stratigraphy of the nuraghe Antigori at Sarroch, associated with Mycenaean pottery, imported and imitated, at present in the process of being studied for definitive publishing, under the editorship of L. Vagnetti[3].

We will have a more complete picture when numerous contexts in Sardinia, particularly those in the central-south of the island, of the Recent Bronze Age, are known, and when, on the other hand, the nuragic material discovered at Cannatello (Levi 2004) is published.

1.6. The results of the analyses

The problem of the results of the analyses of the lead isotope contained in the oxhide ingots is one of the most debated in the field of archaeometallurgy, both from the point of view of provenancing studies and of the studies on the technological processes of production (Stech *et al.* 1985; Stos Gale, Gale 1994; Stos Gale *et al.* 1997; Cherry, Knapp 1991; Knapp, Cherry 1994; Knapp 2000). The present state of studies and at the same time the point of view of Cyprus, which comes into the question on account of the shape, the marks and the hypotheses about provenance, is summed up by V. Kassianidou (see Part IV, chapter 4.4.).

There is no need to add anything to her observations, other than hope for further archaeological discoveries and a necessary widening of the samples and the analyses, in order to have available a wider documentary base which would be a better foundation for subsequent research. It is essential, however, given the characteristics of this synthesis, to emphasize the one dissenting voice in the chorus on the Cypriot provenance of the ingots found in Sardinia, and at the same time the one exception - by way of analysis - of the non-use of oxhide ingots for the manufacture of artefacts.

The first case concerns three fragments of ingots, which, on account of their shape and size, can be defined as oxhide, found in the Sedda Ottinnera hoard of Pattada

3. Lucia Vagnetti, with the kind allowance of Enrico Atzeni, has taken on the task of coordinating the edition of the material of Antigori, assembled in the doctoral theses of pupils of our lamented colleague and friend, Maria Luisa Ferrarese Ceruti; F. Campus and V. Leonelli also share this undertaking.

(see oxhide file no. 8), associated with a further four identical in shape, which have, however, been established as being akin to the Cypriot “fingerprint” (Begemann *et al.* 2001, 68).

In the case of these three finds (16C, F, G) it was observed that they are compositionally analogous to both the truncated conical and the planoconvex ingots from the Funtana Janna hoard at Bonnanaro and with two fragments of ingots, one very probably oxhide (inv. no. 62417) and the other almost certainly planoconvex (inv. no. 62405) from the Funtana II hoard-Ittireddu (Begemann *et al.* 2001, fig. 8). Some of the ingots from Bonnanaro have been referred to the chalcopyrites of Capo Marargiu (truncated conical ingot inv. no. 10708), to the malachite in the schists from Castello Bonvei (planoconvex ingot no. 10710) and to the malachite from Terra Padedda (planoconvex ingot inv. no. 10711). However, the lack of confirmation of the analysis of the traces and the scarcity of the samples compared is a handicap; apart from anything else, the local provenance, from the deposits of Sardinia, is considered technically and geologically plausible (Begemann *et al.* 2001, 69).

In the second case, everyone (Begemann *et al.*, Kassianidou, ecc.) agrees on the observation that the addition - deliberate or casual, to a greater or lesser degree - of lead to the alloy of copper + tin perceptibly alters the original fingerprint of the copper, which in the ingots is ever more carefully refined, and in which, with the system of the isotopic relations, can be measured this minimal residue of lead. Up to today, the analytical assessment of the use of an oxhide ingot of Cypriot copper has been considered technically improbable, if not actually impossible. Today, however, two objects which are part of the complex of “Ottana” (?), which could be have affinities with Cypriot “fingerprint”, have been reported. The fact that they are two finds whose typology is argued over and of practically unknown provenance, discovered in circumstances which cannot be assessed (see Archaeological file 13), is one of the problems of research : that of not ever being faced with an easy and smooth path, but always with routes which are extremely difficult and tortuous.

It is evident that the widening and deepening of the research is absolutely indispensable.

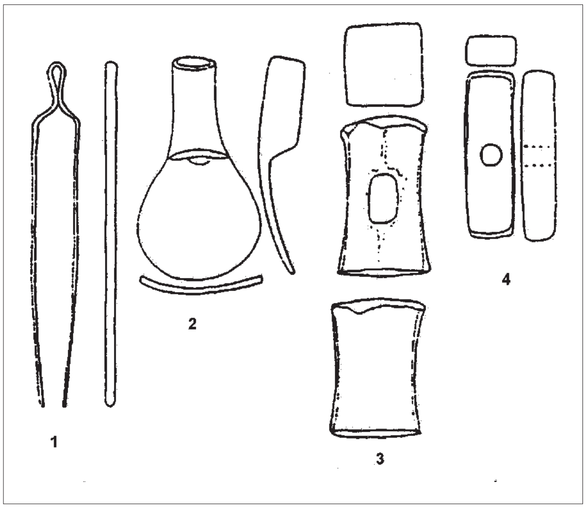
4.

2. Cyprus and Sardinia

Fulvia Lo Schiavo

The relationship between Cyprus and Sardinia does not only consist in the presence of the oxhide ingots, and therefore in the circulation of the raw material between East and West, but in a vast repertoire of pieces of evidence, grouped into three fundamental compartments: tools for working metal, double-edged instruments, and the prestige objects, which include metal vessels and their fittings and handles, and the tripods.

2.1. Tools for working metal (see Part IV, chapters 3, 7; fig. 6, reproduced again just below)



The tools for the working of metals: 1. fire tongs from Siniscola; 2. charcoal shovel from unknown provenance; 3. sledgehammer from Nuchis; 4. rising hammer from Perfugas *(after Lo Schiavo 1981).*

2.2. Double-edged tools

(see Part IV, chapter 5)

The Cypriot shapes (fig. 2.5-9)

The double axes are tools based on the principle of the double edge with a handle in the middle. It is a form imported from Cyprus or imitating Cypriot models, and are subdivided into massive double axes, double axes with parallel or diverging blades and with neck, double axes with orthogonal edges (axe-adze or "*maleppeggio*"); the same principle of the double ends also characterizes the picks (see below).

The first two forms are both represented in the Chilivani hoard of Ozieri: <u>the massive double axes</u> (fig. 2.1-2) are square in structure, with a central hole for the handle. <u>Double axes with parallel or converging edges</u> or with neck is the definition of the shapes which have a flat base and two opposite parallel or slightly converging edges, at the sides of a neck which protrudes, has a round eye at the centre and is rhomboid in profile. The local production is documented by very large numbers of casting moulds. A broken example of this second type was found in the hoard from Hut I at Santu Antine at Torralba.

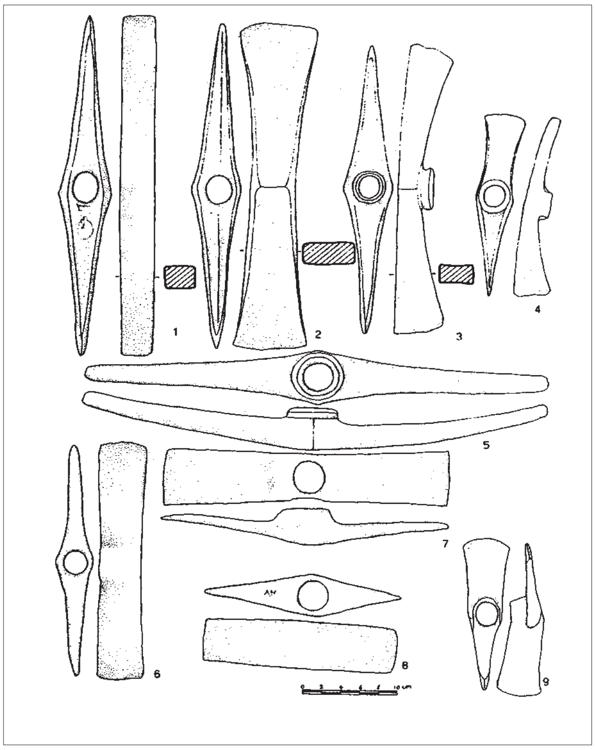


Fig. 2 – Double-edged tools: 1-5. from Sardegna; 6-9. from Cipro *(after Lo Schiavo, Macnamara, Vagnetti 1985).*

The double axes with orthogonal edges (axe-adze, or "*maleppeggio*") (fig. 2.4) (which is what these instruments are called in Italian today) are smaller than the previous ones and are completely practical thanks to the edges, opposite to each other and at the sides of a protruding neck, which has a round eye at the centre and is rhomboid in profile. There are many moulds for these too.

The picks (Fig. 2.5) are a tool which strikes us for its functionality and modernity. The shape is derived from the Cypriot type for double-edged implements with necks, while in Sardinia the two extremities are transformed into two points. It is not clear what they were used for: in fact, in the protohistoric world it was the custom to use for agricultural purposes pick made of deer horn or wood hardened in the fire. However, it is certain that the bronze pick were intensely used, because the surviving examples, with one exception, have both ends very worn, to the point that it is thought that, when they broke, they were then reused as hammers. (Lo Schiavo 2000; Lo Schiavo, Macnamara, Vagnetti 1985).

2.3. Prestige objects

(see Part IV, chapter 5)

Recently, on the question of the interrelations between Cyprus and Italy at the end of the Final Bronze period, H. Matthäus has re-examined, amongst other things, the shape of the basins with bilobate attachments decorated with lotus flowers, of Cypriot derivation: there are the two handles from the hoard of Monte Sa Idda and from the Collection Pischedda at Tadasuni. The fact that in these last the lotus flower and, overall, all the shape characteristics are missing confirms the fact that the Cypriot examples were not "copied" by nuragic artisans, but that they served as models, right there, for new and original creations. The oldest examples from Cyprus is documented in tomb 40 of Kourion-Kalorizi (Late Cypriot IIIB, first half of XI century): the consequence is that many other objects of the same type must have been familiar to local artisans, and for a long period of time (Matthäus 2001).

The tripods, *i.e.* the supports with three feet for bronze vessels (fig. 4), certainly came to nuragic Sardinia from Cyprus, both as original model and as a ritual item of prestige; in Cyprus this article was specialized to a very high level, in parallel with the production of square supports on wheels, with openwork figured scenes (Papasavvas 2001).

From the first identification of a probably imported valuable example in a private collection in the area of Oristano the repertoire of Cyprus-style bronze tripods, whole and fragmentary, has become much richer, both within Sardinia and outside it. It is now certain that, like many categories of artefacts inspired by Cypriot models, generally datable to the Late Cypriot III period, and produced in imitation of them, other examples were produced locally, liberally reinterpreting and varying the original models in dimensions and proportions, but not in the technique of manufacture, which remains that of the lost wax.

Of local production, let us mention the whole examples from the hoard of S. Maria in Paulis and from the votive deposit of the Pirosu - Su Benatzu cave at Santadi, while fragments of them have been found at Samugheo, at Villagrande Strisàili and, on the mainland, in the hoards of Piediluco-"Contigliano", and Terni and in the Romagnoli 10 tomb at Bologna (Lo Schiavo, Macnamara, Vagnetti 1985).

Lastly, there are reports of two fragments from tomb 2 of the *necropolis* of Calaceite, Teruel, in the Bajo Aragon (Rafel 2003).

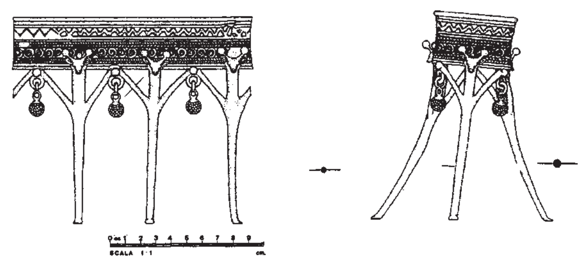


Fig. 3 – Miniature tripod-stand from the cave-sanctuary Pirosu-Su Benatzu, Santadi *(after Lo Schiavo 1985).*

It must also be emphasized that the tripod fragments from the site of S'Arcu 'e is Forros, Villagrande Strisaili (see Archaeological file 19), together with piles of whole and fragmentary ingots of various sorts, and pieces of raw metal, copper, lead, and, exceptionally, even tin, are confirmation on the one hand that there is, in one structure of the vast complex, still to be identified and explored, a metal-working workshop and perhaps even one for casting, and on the other are proof of the local production of Cypriot models.

The Cypriot-type tripods discovered in Sardinia have not been analysed, with the exception of the example from S. Maria in Paùlis, on which metallurgical analyses have been carried out (Macnamara, Ridgway D., Ridgway F.R. 1984; Craddock, Tite 1984).

These three classes of objects of Cypriot influence and almost all the artefacts which constitute them have long been presented, illustrated, discussed and cited, several times over.

The first essential fact is not only that of the undeniable presence in Sardinia of shapes which are typologically linked to the Cypriot ones, but the systematic presence and non-sporadic nature of this well-rooted and not at all casual presence in the nuragic context, resulting in an exceptional flourishing of highly original artefacts produced locally, as has been shown several times.

The second essential fact is the exclusivity of the link: in fact, where some Cypriot object was reported elsewhere, for example on the mainland, the role of Sardinia as go-between seems unquestionable, whereas, the "Cypriot connection", in its completeness and richness, as a whole, only affects Sardinia.

The third essential fact is that the Cyprus-Sardinia connection is directly and indirectly linked to metal-working: the very few pottery products, these too reported long ago (Vagnetti), are only found sporadically.

However, this reconstruction based on undeniable facts - to which the evidence of the oxhide ingots can be added - is still lacking. Another type of archaeological evidence, *i.e.* structures and materials which demonstrate the presence of people coming from Cyprus and settling in Sardinia is missing: settlements or single huts, tombs or single burials, sanctuaries and *sacella*. It is not even possible to indicate places for markets, *emporia*, where Cypriot pottery items associated with nuragic ones can be found, as happens centuries later at S. Imbenia between the nuragic peoples and the Phoenicians.

It seems decidedly difficult to accept that there was such a perfect osmosis of the Cypriot element with the local socio-economic organization that it is not possible to decipher even the traces of it, all the more so in that the worlds evidenced and the wide and homogeneous distribution of the oxhide ingots point to a profound and widespread absorption of the external element in the indigenous context.

Faced with this interpretative difficulty, a hypothesis of L. Vagnetti has been taken up again, on the existence of itinerant Cypriot metalworking artisans, who were not resident in Sardinia, and on their regular and seasonal landings, which would not have left structural remains of their passage. Furthermore, as a necessary complement, we can suppose that the local peoples were not passive receivers of inputs, but an active part of Mediterranean trade eastwards, as is indicated by the fragments of nuragic pottery found at Cannatello and at Kommos. We could perhaps propose that, if it were demonstrated that all oxhide ingots of Sardinia come from Cyprus, their transport may have been to a large extent entrusted to nuragic ships.

Nuragic ships in bronze, refined lost-wax products, objects of the greatest value, such as to take the place of sceptres, jewels and gold masks, such as to summarize at a symbolic level a citadel with its territory, dynamic quintessence of the territorial palace economy, self-managing floating emporia, perfect and concentrated representatives of the clans of provenance, are to be found, by the dozen, throughout Sardinia.

When the nuragic Civilization, on account of the vicissitudes of history which determine the beginning and end of civilizations, reaches its demise, when the copper ingot shaped like the hide of an ox has lost its economic value and its symbolic significance, when the link with Cyprus is just a distant memory, replaced at the forefront of history by other peoples, who also pass by Cyprus with their merchandise and ideas, then shall the little nuragic bronze ship, precious family testimony, sublimate its original significance, and from symbol of the Mediterranean interconnections become the symbol of the nuragic aristocracy.

4.

3. The oxhide ingots of Sardinia: updated catalogue

Fulvia Lo Schiavo

Oxhide file 1

ARZACHENA (Sassari), nuraghe Albucciu. Hoard

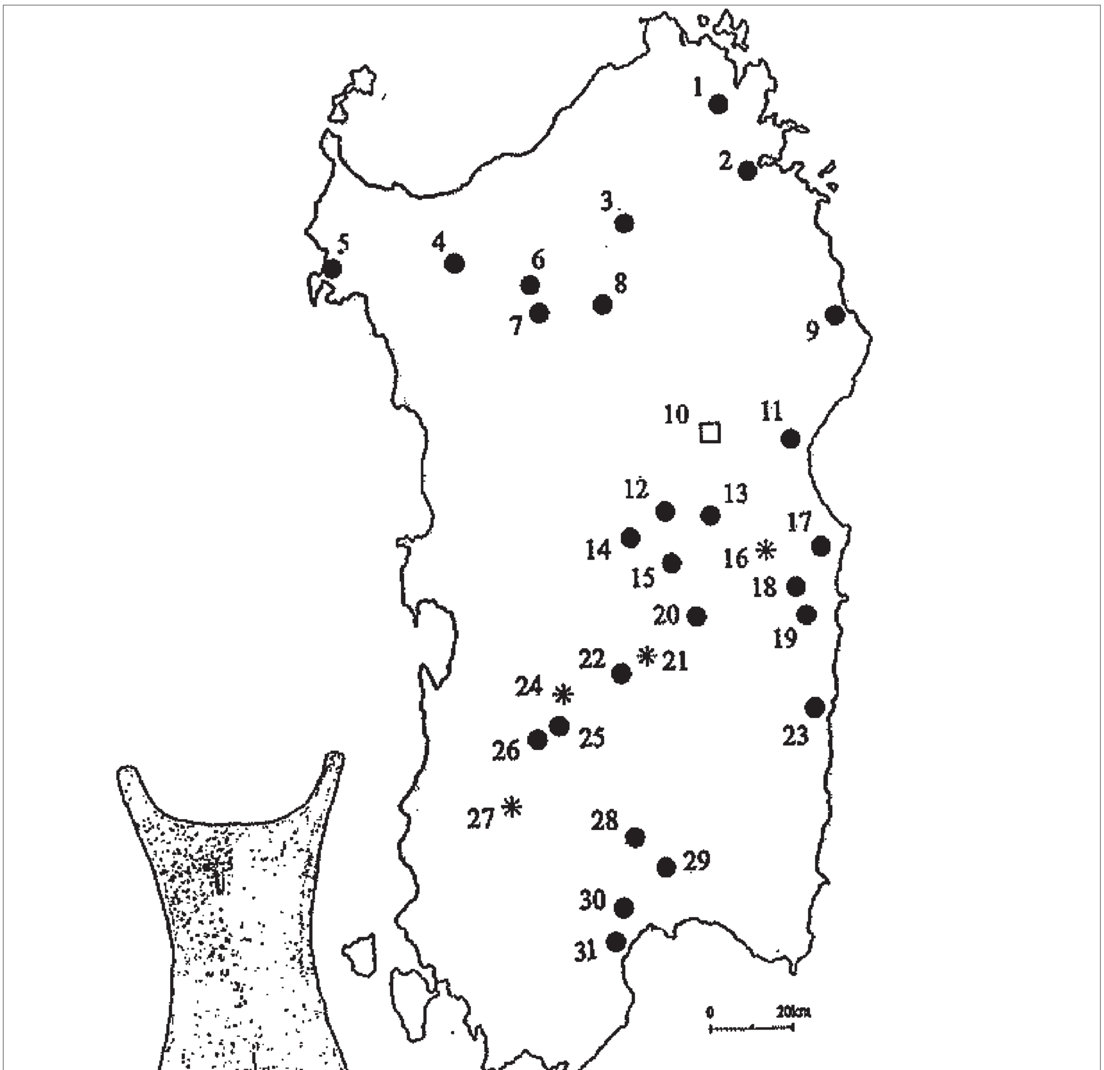


Fig. 4 – Distribution map of oxhide ingots in Sardinia.The numbers correspond to the Oxhide files, according to the district; the asterisks indicate the most recent finds.

In 1962, during the archaeological excavation of the nuraghe Albucciu (Arzachena, Sassari), an impasto bowl with a shallow bowl-cover containing six fragments of oxhide ingots together with fragments of other objects of copper alloy, was discovered on the terrace, under the floor at the base of the wall of a room constructed on top of the terrace.

The monument is one of the very few nuraghi to have been completely explored, but the results of the excavation are only known from the preliminary information. It is a “corridor” nuraghe, roughly rectangular in shape, leaning against a great granite rock, which constitutes its west side. The entrance is about halfway along the east side and from the upper part of the façade stone brackets still protrude. On the inside room “*n*” is covered by a *tholos*. A series of narrow corridors, passages and stairs lead to the terrace, on which traces of various circular structures, such as the one in which the hoard was found, can be seen.

Initially the nuraghe was dated to the advanced Iron Age, on account of the discovery of a small bronze figurine, vitreous paste beads, a wheel-shaped pendant and a fragment of an orientalizing *situla* (Lilliu 1966, no. 359). Subsequently, apart from the fact that the dating of the bronze figurines was moved far back, many small shrines housed in courtyards or internal rooms of nuraghi, in later periods than that of erection and use of the monument came to light. On the basis of the pottery material found and of the stratigraphic sequence, the monument is now dated to the period between the Recent and Final Bronze Age.

The hoard consist of 6 fragments of oxhide ingots, 12 fragments of votive swords, a small chisel, with thin and twisted tang, and 21 drippings and sheets, some of which are folded and crumpled up; the metal artefacts were contained in a small globular, two-handled jar, covered with a rounded bowl.

The shape of the vase and of the cover are now attributed to the Recent Bronze Age, on account of the analogy with similar form found in the port site of Kommos in southern Crete in a MycIIIB layer.

(Ferrarese Ceruti 1962; 1985, nota 18; Antona Ruju, Ferrarese Ceruti 1992, figg. 21, 22; Contu 1968a; Lo Schiavo 1981, fig. 281; 1982, 271-2; 1990, 18-19, no. 1; 1996; Lo Schiavo, Vagnetti 1980, 379-380; Campus, Leonelli 1999, 515, no. 6-7, fig. 8; Begemann *et al*. 2001, fig. 2).

The oxhide ingots and the associated artefacts - underwent to metallurgical and lead isotopes analysis (Maddin, Merkel 1990, 48-51; Begemann *et al.* 2001).

Oxhide file 2

OLBIA (Sassari), nuragic village of Serra Elveghes. Hoard

In 1997, during an emergency excavation in the area of a nuragic village on the periphery of Olbia (Sassari), in the locality of Serra Elveghes, at about 4.6 km to the south-east of the city, an exploratory dig revealed a stretch of nuragic wall leaning on a block of granite of medium size, under which was buried a large carinate cup containing 25 fragments of oxhide ingots (kg 10.239). (Excavation R. D'Oriano).

Of the 25 fragments found 8 must certainly be of oxhide ingots on account of their shape, 11 probably so, and 6 were too small to be identified.

The vessel is a carinate cup with the diameter at the rim slightly smaller than the diameter at the belly, the walls above the belly being slightly concave and a hint of a flared rim with prominent lip, the body truncated conical and quite deep, bottom flat and small vertical band handle fixed to the belly. It has been compared to shapes of the Final Bronze Age with some affinities to earlier forms, but similar shapes from the Iron Age are not known.

(Lo Schiavo 1998, 106-107, figg. 8-10; 1999, 503, fig. 4; Campus, Leonelli 1999, 514, no. 3, fig. 8)

The ingots have not been analysed.

Oxhide file 3

OSCHIRI (Sassari), nuraghe S. Giorgio. Hoard

The find is an old one of 23 fragments (kg 9.968), and perhaps more, handed over to the Soprintendenza in 1997, discovered in a cavity in the ground, near the nuraghe of S. Giorgio Oschiri (Sassari). According to the report, it was found at about thirty metres north of the nuraghe remains of which only a few stones on two courses are still visible.

The site is at 180 m above sea-level on a hillock which dominates the artificial Lago Coghinas, once on the upper course of the river Coghinas, in direct contact with the northern coast.

The large number of fragments and the fact that they were found all together indicates that it was a hoard; although no excavations have been carried out, the zone has been surveyed and there are no visible traces of village or of a sacred place.

Of the 23 fragments found, 12 certainly belong to oxhide ingots, 5 probably so and 6 are not identifiable.

(Lo Schiavo 1998, 107-8, figg. 11-12; 1999, 503, fig. 4).

The ingots have not been analysed.

Oxhide file 4

OSSI (Sassari), nuragic village of Sa Mandra'e Sa Giua. Fragments of a nuragic hut

Two fragments of oxhide ingots were found by chance in 1967 during the excavations for the construction of modern houses in the nuragic village of Sa Mandra 'e Sa Giua (Ossi, Sassari). An archaeological excavation was immediately carried out in the site and two nuragic huts were identified, but it was not possible to establish the original position of the ingots nor their stratigraphic associations.

In the following years, as the area was urbanized, many artefacts and metal remains were found, partly assembled in the Museo Sanna of Sassari, as "remains of copper, bronze and iron smelting" ("*resti di fusione di rame, di bronzo e di ferro*"), a flanged axe, a hoard with 15 or 16 flanged axes, a jar with a block of bronze and iron artefacts stuck together in a heap: small flanged axes, curved rods, a spearhead and other objects, as well as a great quantity of bits of ingot, irregular but tending towards spherical and flattened forms, another dagger and a fragment of awl, etc. (Ferrarese Ceruti 1985, 52).

The systematic archaeological excavations at Sa Mandra 'e Sa Giua began only in 1979 and continued in the following years, revealing the structure of most of the village and of the nuraghe. This turned out to be complex-plan structure, with a central tower and two additional frontal towers, standing side by side, with a courtyard in front.

In the right niche of the central tower, there was a nuragic small bronze figurine of a Notable. In a niche in the inner wall of the courtyard, to the left of the entrance, a store for tools for working bone (or ivory) and wood was discovered (see Part IV, chapter 7)..

As result of assiduous surveillance, as well as research and excavations conducted both by M. L. Ferrarese Ceruti and, recently, by M. Solinas, the vast dimensions of the village, of which a particularly large and well-preserved "Bread-making Room" was part, have been ascertained.

The village was dated by M.L. Ferrarese Ceruti to within the Final Bronze Age period, before the development of "geometric" pottery decorated with small circles, of which just a few odd fragments were found, on top of the structures destroyed by an extensive fire.

(Contu 1968b; Lo Schiavo, Vagnetti 1980, 381, no. 3; Lo Schiavo 1982, 272; 1990, 20-21, no. 2; in press 1; Ferrarese Ceruti 1985, 52).

The ingot fragments have been analysed (Maddin, Merkel 1990, 52-53).

Oxhide file 5

ALGHERO (Sassari), Porticciolo

In 1995, at Alghero (Sassari), in the locality of Porticciolo, at the seaside, a fragment of oxhide ingot was found on the surface, together with a fragment of plano-convex ingot.

The discovery was fortuitous, the items being found along the road, probably removed in the course of works to repair the road and then brought to light by the rains: there are not structures in the immediate vicinity. However, not far away rises the nuraghe Carru de Lu Vin, of which not much remains, and on a little open space on a sheer drop to the sea there is a ring of medium-sized stones, which enclose a mass of human bones, from an indeterminable period.

The locality is situated at 16.4 km from the mines of Calabona.

(Manconi 1993; Lo Schiavo 1998, 100; 1999, 501, fig. 2,4-5).

The fragment was not analysed.

Oxhide file 6

OZIERI (Sassari), S. Antioco di Bisarcio. Hoard

In 1958 was published an oxhide ingot, whole and bearing a mark, discovered in the years 1940-45 in a nuraghe in the locality of S. Antioco at Bisarcio (Ozieri, Sassari). It seems that two whole ingots were discovered together under the floor of the central chamber of the nuragic tower, but only one of the two survived, in a private collection, and was acquired in 1986 by the Museo Civico Archeologico of Ozieri, where it is at present on display.

The circumstances of the discovery were more widely described in a survey of the district of Ozieri, in which it is reported that three hundred metres to the east of the church of S. Antioco at Bisarcio, on the peak of the rocky hill, at 245 m above sea-level, there existed a large nuraghe; the owner of the property had it demolished in order to build a house there. For this reason the foundations on the bedrock were reached, below floor-level, and a witness to what happened reported that "exactly at the centre of the nuraghe and positioned directly on top of the rock were found two large metal slabs" ("*esattamente al centro del nuraghe e posate direttamente sopra la roccia, furono rinvenute due grandi lastre metalliche*") (Amadu 1978, 305).

Studies to establish the identity of the nuraghe from which they came have been inconclusive: there are still four nuraghi in the locality of S. Antioco at Bisarcio (nuraghi Mannu, Minore, Columbalza, Luzanas), and at least a further three sites have been destroyed in the vicinity of the church of S. Antioco. Information relating to the discovery of the nuraghe Tedde is certain, however, as is the fact that one of the two ingots has been lost. This fact indicates that it was probably a hoard, perhaps a foundation deposit.

The ingot is whole and measures 43 cm in length, 39 cm in width, and 3-4 cm in height, and weighs 22.5 kg. It is square-cornered and compact, with the ends very pronounced, and bears a "T" sign (5 cm long) deeply impressed on the front while hot.

(Lilliu 1958, 191-193, pl. 63,2, 64; Amadu 1978, 305-307; Lo Schiavo, Vagnetti 1980, 380, no. 2; Lo Schiavo 1982, 271; 1988, 82, fig. 14; Lo Schiavo 1990, 20-21, no. 3; Vagnetti, Lo Schiavo 1989, 224, fig. 28.3a).

The ingot has been analysed (Maddin, Merkel 1990, 52-55).

Oxhide file 7a

ITTIREDDU (Sassari), nuraghe Funtana. Hoard I

In 1982 and 1983 were conducted the first two excavation campaigns in the nuraghe Funtana (Ittireddu, Sassari), a complex nuraghe with a central tower and two towers added to the front standing side by side, with a courtyard in front and an outer reinforcement structure.

The first group of six fragments of oxhide ingots was discovered in the courtyard, at the base of the tower added to the right (or tower "*E*"), at the height of the architrave: it was probably a hoard concealed in antiquity in the walls or under the pavement of the first floor of the same tower. In subsequent seasons, two further fragments were discovered in the course of the excavation of the courtyard, at various levels in the stratum resulting from the collapse of the building, therefore, having presumably also fallen from the first floor and being part of the same hoard.

Of the 8 fragments found, 4 certainly belong to oxhide ingots on account of their shape, and the others probably so.

(Galli 1984, 119-120, figg. 2-3; 1986; 1989, 106; Lo Schiavo 1990, 20-23, no. 4)

The ingots have been analysed (Maddin, Merkel 1990, 52-59).

Oxhide file 7b

ITTIREDDU (Sassari), nuraghe Funtana. Hoard II

The second hoard was found in the passage to the central tower of the Funtana nuraghe at Ittireddu and consists of 44 fragments of oxhide and planoconvex ingots, large and small, and 5 fragments of votive swords, for a total of 19.710 kg, inside a big four-handled vase covered with a bowl.

As far as the typology of the vase is concerned, which has been specifically studied, nothing precisely comparable has for the moment been found; other four-handled vases, from the nuraghe Sianeddu at Cabras, from the cave Pirosu at Santadi and from the nuraghe Lugherras at Paulilatino, differ both in their dimensions and for the overall shape.

The excavation of the nuraghe Funtana has not yet been published, apart from preliminary reports and illustration of the finds of the special interest. The construction of the monument dates back to at least the Recent Bronze Age, while the majority of the materials so far known are attributed to the period from the Final Bronze Age to the beginnings of the Iron Age.

The existence of casting and metalworking activities in this place might be evidenced by the discovery of a crucible with a short handle, in which there is the deep inprint of a spearhead inserted there to lift it. It contained traces of vitrified copper slag. A small mould for the casting of daggers or spear heads was found in the excavation of the south tower.

Two more steatite moulds have been found in the territory of Ittireddu, a two-piece mould for a dagger and a multiple one-piece one for making a double axe and an axe-adze ("*maleppeggio*").

Furthermore, on the slopes of Monte Zùighe, where there is a vast nuragic village, there is a lime kiln of an indeterminate period.

Of the 44 fragments found, 19 are certainly from oxhide ingots on account of their shape, 5 probably so, 10 are from planoconvex ingots, and 10 not identifiable.

(Galli 1986; Galli 1988, 96, figg. 3, 6; Galli 1989, 100-104, figg. 6-10, 11; Lo Schiavo 1990, 20-23, no. 4; Galli 1991, 18, fig. 16; Campus, Leonelli 1999, 514-515, no. 4-5, fig. 8; Begemann *et al.* 2001, fig. 3).

The ingot fragments have been analysed (Maddin, Merkel 1990, 62-85; Martini, Garagnani 1998; Begemann *et al.* 2001).

Oxhide file 8

PATTADA (Sassari), loc. Sedda Ottinnèra. Hoard

The hoard from Sedda Ottinnera di Pattada was found on 5 March 1997, at a site in the centre of northern Sardinia, the district of Pattada, in the locality of Monte Ottinera at 900 m above sea level and at 4.5 km to the north of the urban centre.

The hoard was hidden in a narrow cavity. On the top of the same rock, there are the remains of a nuragic tower, just a few courses of stones.

All around, the remains of a nuragic village and a fountain, very simple in structure, can be seen. At about 200 m to the north-west there are two giant's tombs.

The hoard consists of 23 pieces (total weight 13.426 kg), 7 of which are fragments of oxhide ingots (7.732 kg).

There is a whole double axe, of the older massive type, and a second, thinner one, broken in half, a small double axe, a small flanged axe and half of another bigger one, four whole chisels of different shape and dimensions, three daggers with simple base, one of which decorated with incised lines, and a small fragment of a fourth with an awl inserted into one of the two holes, a fragment of decorated handle, an implement with a flat blade, perhaps a *spatula*, a few fragments of a small sheet bowl. Furthermore there are three small fragments of two vessels of *impasto* pottery, probably a large bowl and a carinate cup, too small and fragmentary to be classified and dated.

The association, satisfactorily verified for the first time, of oxhide ingots with weapons and artefacts which include Cypriot-type shapes, such as the two double axes, of Cypriot inspiration and of peculiar and characteristic nuragic types, such as the flanged axes, the chisels, the daggers and the *spatula*, is of the greatest importance.

The dating of the complex, on the basis of similar hoards, above all that of Chilivani, Ozieri, and of the typology of the material, particularly of the two double axes, which have analogies in the hoards of Cypriot bronzes of the Late Cypriot III, can be fixed right in the Final Bronze Age period, no later than XI century BC.

(Lo Schiavo 1998; 1999, 501, figg. 5-6; Campus, Leonelli 1999, 516, no. 10-12, fig. 8; Begemann *et al.* 2001, fig. 4).

The material has been analysed (Begemann *et al.* 2001).

Oxhide file 9

SINISCOLA (Nuoro), Ghiramonte

In 1995, soon after the construction of a road-tunnel, 8 fragments of ingots were found on the heaps of moved earth; these were at first thought to come from the nuragic site of Luthuthai, but later, as result of a detailed survey, it turned out that they came from the nuragic village situated up above, north of the town. The locality is called “Ghiramonte” on account of its half-moon shape, almost the edge of a dolina or a quarry; at the centre, in a dominating position, rise the remains of the Oròre nuraghe, near which are still evident traces of nuragic huts. It is therefore probable that the excavation works removed part of the village adjacent to the nuraghe or of another nuragic structure further up the hill.

The locality is at about 6.3 km from the mineral deposits of Torpè, Canale Barisone.

Of the 8 fragments found, 2 certainly are of oxhide ingots on account of their shape, 1 probably so, and three are of planoconvex ingots, 1 of a bar ingot and 1 of a disc ingot.

(Lo Schiavo 1998, 100; 1999, 501 fig. 2,2-3)

The ingots have not been analysed.

Oxhide file 10

NUORO, unknown locality

Four ingot fragments, one of which belongs to an oxhide ingot, were found in an unspecified locality of the province of Nuoro, in a period which preceded the institution of the Museo Speleo-Archeologico of Nuoro.

(Lo Schiavo 1978, 81-82, pl. XXV, 2-5; 1990, 24-25 no. 6; Lo Schiavo, Vagnetti 1980, 381, no. 4).

The fragment of oxhide ingot has been analysed (Maddin, Merkel 1990, 84-85).

Oxhide file 11

DORGALI (Nuoro), in the Isalle Valley. Isolated find

An isolated fragment of oxhide ingot was found by Dino Giacobbe near to Rio Locula in the Valle dell'Isalle (Dorgali, Nuoro). Subsequently, a planoconvex ingot was discovered at the same site, where it is probable that there was once a nuragic village.

(Sanges 1978; Lo Schiavo 1990, 22-23, no. 5; Lo Schiavo, Vagnetti 1980, 381, no. 5).

The fragment of oxhide ingot has been analysed (Maddin, Merkel 1990, 84-85).

Oxhide file 12

TETI (Nuoro), Abini. nuragic sanctuary of Abini

The presence of a vast sanctuary in the locality of Abini has long been known about; it consists of various structures inside an enclosure, amongst which is a sacred well, and a nearby nuragic village (“*Interrojas*”) (see Archaeological file 17, p. 96-97).

From 1985 onwards, inside of the sanctuary area were found and excavated many «hoards» of bronzes. Some of these are in the Museo Archeologico Nazionale di Cagliari, where they are grouped into three collections : the Collezione Timon (1865), the Collezione Vivanet (1878) and the Collezione Gouin (1882).

The dating of the sanctuary is difficult because of the presence amongst the material of vases from the Early Bronze Age (Ferrarese Ceruti 1978, 240, no. 52, fig. 229); however, we can presume that the chronological span is the same as that of other nuragic sanctuaries, between the Recent and Final Bronze Age periods.

On account of the upheavals and the savage and uncontrolled digging, caused by the very abundance of the bronze items and figurines present in the sanctuary and spread all over the place, and even placed together in vases and in holes in the ground, it is not possible to ascertain precisely the provenance of the fragment of oxhide ingot which Pigorini observed in 1904 did not belong to the Serra Ilixi ingots; the fragment remained on display together with the Teti material in the Museo di Cagliari up to its reconstruction.

Many fragments in the store of the Museo di Cagliari bear a label which says “Teti (?)”; since there are no inventory numbers, it is not possible either to confirm or to deny this indication.

(Pigorini 1904, 92, no. 2c; Balmuth, Tylecote 1976, 198, fig. 2; Lo Schiavo, Vagnetti 1980, 381-2, no. 6; Lo Schiavo 1982, 271; 1990, 24-25, no. 7; Vagnetti, Lo Schiavo 1989, 224, fig. 28.3e)

11 fragments of oxhide ingots have been analysed (Maddin, Merkel 1990, 86-101; Gale, Stos-Gale 1992, tab. 5).

Oxhide file 13

FONNI (Nuoro), Gremanu o Madau. Nuragico Sanctuary

At the foot of the hill on which rises the Sanctuary of the Springs (“*Santuario delle Fonti*”) has been brought to light, although not yet entirely, a vast sanctuary consisting of many buildings, amongst which are a "*megaron*" temple and a "Round Temple"; the exploration of the site occupied many subsequent seasons beginning in 1993 (see Archaeological file 16, p. 95).

In the 1996 excavation season 6 ingot fragments and other metal artefacts between the "megaron " Temple and the nearby "Round Temple" were found. In addition to the fragments of ingots many votive swords, the fragment of an Allerona-type sword, fragments of daggers and small daggers, a *stiletto*, pins and fragments of small bronzes were also discovered.

The bronzes and the ceramic items found so far indicate that the sanctuary was in use from the Recent Bronze Age period and not after the end of the Final Bronze Age period.

The site is at the feet of the Correboi pass, not far from the ore deposit which was briefly mined for silver in the past (see Part II, chapter 2).

Of the 6 fragments found, 5 certainly are from oxhide ingots on account of their shape and 1 from a planoconvex ingot.

(Fadda 1993; in press 1; Lo Schiavo 1998, 100; 1999, 503, nota 14; 2000)

Samples of lead from the nuragic sanctuary have been analysed. The ingots have not been analysed (Valera R.G., Valera P.G., Lo Schiavo 2003).

Oxhide file 14

ORTUERI (Nuoro), Funtana 'e Cresia. Isolated find

Two fragments of oxhide ingot were discovered in the locality known as « Funtana'e Cresia » (Ortueri, Nuoro), together with a flat copper axe, square in cross-section and of a very archaic type not common in Sardinia.

No other structures or archaeological material were identified nearby

(Lo Schiavo, Macnamara, Vagnetti 1985, 13, no. 8; Lo Schiavo 1990, 24-25, no. 8)

The two fragments of oxhide ingot and the axe have been analysed (Maddin, Merkel 1990, 104-105).

Oxhide file 15

BELVÌ (Nuoro), Ocile Isolated find

A fragment of oxhide ingot was found in 1970 during agricultural works in the locality known as "Ocile" (Belvì, Nuoro), with no other archaeological material associated.

(Lo Schiavo, Macnamara, Vagnetti 1985, 13, no. 9; Lo Schiavo 1990, 24-25, no. 9).

The fragment has been analysed (Maddin, Merkel 1990, 106-107).

Oxhide file 16

TALANA (Nuoro)

Talana is the name of a village in the high Ogliastra in which there was a confiscation; this included, along with other material, a fragment of oxhide ingot, on whose provenance no information was gathered.

A little way above the town, on the "Margine" *plateau* situated at more than 1000 m above sea level, is situated a large, complex nuraghe Bau 'e Tanca, consisting of a central tower and two towers added on the south side, surrounded by a village; there are also giant's tombs, one of which, built in isodomic courses, is at 500 m from the nuraghe.

One of the huts of the village, situated at a few metres from the nuraghe, has been completely excavated and contained a stratigraphic succession from the Middle Bronze to the Final Bronze Age; in particular, in the deep stratum, together with a fragment of cup with a elbow handle in the Bonnanaro tradition, and with fragments of pots with comb decoration and various fragments of a bowl with thickened rims, was found a large planoconvex ingot of copper and a small simple base foliate dagger.

The *plateau* is surrounded by a ring of mountains rich in nuragic structures, positioned so as to control the passes, and is crossed by a river which seems to have been subjected to embankment works in nuragic times.

(Fadda, Tuveri 1990).

The ingot has not been analysed.

Oxhide file 17

TRIEI (Nuoro), nuraghe Bau Nuraxi. Hoard

In 1984 began the excavation of the nuragic complex of Bau Nuraxi (Triei, Nuoro), which consists of a bilobate nuraghe surrounded by an outer defence, on the inside of which there were various huts.

During the 1985 season, in one of these was found a hoard of metal fragments in a bowl which fell to bits at the discovery. Amongst the fragments, it is possible to recognize a fragment of oxhide ingot and of other ingots of unidentifiable shape, together with a least one fragment of a flanged axe and one of a dagger blade, a sheet for reinforcing a spear head and a fragment of rod.

(Scavi Sanges 1984-1985; Lo Schiavo *et al.* 1987, 183; Lo Schiavo 1990, 24-27, no. 10)

The following pieces have been analysed: the fragment of an oxhide ingot, one of a planoconvex ingot, a further three of ingots of unidentifiable shapes, two fragments of casting fins and a fragment of rod (Maddin, Merkel 1990, 108-113).

Oxhide file 18a

VILLAGRANDE STRISÀILI (Nuoro), nuraghe Corte Maceddos. Hoard

In the autumn of 1984, twelve fragments, belonging to various oxhide ingots, two of which have very developed "ears", were handed over to the Soprintendenza together with other finds.

It was reported that the ingot fragments were found near the nuraghe Corti Acca (or "Corte Maceddos", district of Villagrande Strisàili) (and not "Orgosolo" as was indicated in Lo Schiavo, Macnamara, Vagnetti 1985, 64).

The monument has not been explored archaeologically, and is therefore not possible to be precise about the nature of the find, but it may be assumed that it was hoard.

(Lo Schiavo *et al.* 1987, 182-183; Lo Schiavo 1990, 26-27, no. 11).

The fragments have been analysed (Maddin, Merkel 1990, 114-115).

Oxhide file 18b

VILLAGRANDE STRISÀILI (Nuoro), S'Arcu 'e is Forros. Metal workshop

In 1985-86 there were reports of clandestine excavations in a nuragic complex of vast extension, arranged around a three-tower nuraghe and a large "*megaron*" temple (Archaeological file 32, p. 105).

During the first survey, a large quantity of raw metal was found and of fragments of ingots, both oxhide and planoconvex, together with an enormous quantity of bronze artefacts. Therefore it was immediately hypothesized that it was a large settlement with an extensive sanctuary and that in the locality there had been a metal workshop.

The many subsequent excavation seasons, concentrated mostly on the "*megaron*" temple and on the adjacent structures, confirmed these theories, most recently (October 1999) strengthened by the discovery of various fragments of tin in the form of raw metal poured into ingots of uncertain shape. There is still doubt about the exact location and the shapes of the furnaces.

The fragments of tin and lead have been analysed (Lo Schiavo, Valera R., Valera P. 2003; Valera in press).

Oxhide file 18c

VILLAGRANDE STRISÀILI (Nuoro), Sa Carcaredda

Following some clandestine excavations in December 1989, excavations were carried out in the following years, at a site already known for the presence of a nuragic village and four large giant's tombs, hidden away in the nearby wood.

Thus came to light a singular sacred monument, a sort of "Round Temple" consisting of a circular room, paved with granite slabs. The hearth at the end of the room was surrounded by a small wall on which were positioned shaped blocks, held together with lead clamps, reproducing half of a four-tower nuraghe. The room was preceded by a trapezoidal *atrium*, with benches along the walls.

On the right side of the building is a vast room, rectangular in shape with two pilasters, in which a large quantity of bronze offerings of the nuragic period, and also of the Roman period (a hoard of coins) was accumulated.

Amongst the offerings were reported, "From the corners on the right side of the room,.....a bowl, open in shape, with ribbon handles, buried to a depth of 15 cm..., propped up at the bottom by 5 fragments of Aegean-type ingots and by 10 bun ingots, for a total of 10 kg. From the other side comes another bowl with a small neck, with handles..., buried for a depth of 20 cm,... held up by 10 fragments of Aegean-type ingots and by 10 planoconvex ingots for a total of 10 kg, and furthermore, just by the neck was leaning a flanged axe, 22 cm long ..." ("*Dagli angoli sul lato destro del vano, ... un'olla di forma aperta con anse a nastro piatto a ponte, interrata per 15 cm ... rincalzata sul fondo da 5 frammenti di lingotti di tipo egeo e da 10 panelle, per un totale di 10 kg. Dall'angolo opposto proviene un'altra olla a colletto, con anse a gomito rovesciato, interrata per 20 cm ... rincalzata da 10 frammenti di lingotto di tipo egeo e da 10 panelle per un totale di 10 kg, ed inoltre, in corrispondenza del collo, poggiava un'ascia a margini rialzati lunga cm 22 ...*") (Fadda 1995, 119).

The dating generally proposed for the monument and the adjacent rooms is the Recent and Final Bronze Age, with later building phases clearly visible. The place also has evidence of cult offerings and hoarding in Roman times.

(Fadda, Tuveri, Murru 1992; Fadda 1995, 116-121; Lo Schiavo 2000a)

Oxhide file 19

LANUSEI (Nuoro), Perda 'e Floris. Sacred well or Sacred spring

The fragments of oxhide ingots from Perda 'e Floris come from the area of a nuragic village now completely destroyed; in a survey of 1977, only the presence of a few shaped blocks belonging to an isodomic structure, probably a sacred well or sacred spring.

Not far away is the locality of Selene, where a complex nuraghe with village enclosed within an outer defence, and two large giant's tombs, were excavated.

(Lo Schiavo 1978, 81-3, pl. XXV,1; Lo Schiavo, Vagnetti 1980, 382, no. 7; Lo Schiavo 1982, 272; Lo Schiavo 1990, 26-29, no. 12; Perra 2003a).

The fragment has been analysed (Maddin, Merkel 1990, 114-115).

Oxhide file 20

SEULO (Nuoro), Is Fossus

In 1995, in the course of a systematic survey of the district of Seulo, word came out of a old find on the surface of a fragment of oxhide ingot in the locality of Is Fossus, situated at 5.6 km from the mines of Funtana Raminosa.

(Lo Schiavo 1998, 100; 1999, 501-2 fig. 2, 1; Perra 2003b)

Oxhide file 21

NURALLAO (Nuoro), Nieddìu

In 1998 a fragment of oxhide ingot was handed over to the Soprintendenza; it had been found in the locality of Nieddìu, in the area of a bentonite quarry.

The zone has long been know for the presence of a nuraghe, and, right inside the quarry, of a nuragic sacred well, partially uncovered by the modern quarrying; from this came two small bronze figurines, which have now disappeared.

(Lilliu 1997; Sanges 2000)

Oxhide file 22

NURAGUS (Nuoro), Serra Ilixi ("Valenza"). Hoard?

The first discovery of oxhide ingots in Sardinia goes back to 1857, and after a preliminary news, G. Spano described the story as follows: "... seeing that ...the ploughshare was encountering much resistance, after considerable effort it upturned a stone of enormous weight,... the earth was dug up until five *stelae* were extracted...arranged in a row, one after the other." "It must also be noted that above the site from which were extracted these *stelae* there is a destroyed nuraghe, known as the Serra Ilixi nuraghe." (" *... vedendo che ... il vomere faceva molta resistenza, dopo qualche sforzo, rovesciò una lapide di molto peso, ... si fece a scalzare il terreno da dove n'estrasse sino al numero di cinque ... disposte in ordine l'una dopo l'altra. ... E' pure da notare che al di sopra del sito dove vennero estratte queste stele evvi un nuraghe distrutto detto nuraghe de Serra Ilixi.*").

So the five ingots were found all together, side by side, during ploughing, at the feet of a destroyed nuraghe known as "Serra Ilixi". At the time, it was the district of Isili, province of Cagliari; "Valenza" is the ancient name for the locality, in which there was a vast Roman settlement, and then a small church called S. Maria di Valenza.

Of the ingots, one was acquired by the Museo di Cagliari and two more by the Canon Giovanni Spano, who later left them to the same museum, where they are on display; the last two were purchased by a tinker, who presumably destroyed them.

(Spano 1857, 94; 1858, 11-15; 1872, 48-49; Buchholz 1959, 38-39; Lo Schiavo, Vagnetti 1980, 384, no. 9; Lo Schiavo 1982, 271; 1990, 28-29, no. 14).

The ingots have been analysed (Maddin, Merkel 1990, 116-119; see Part III, chapter 1).

Oxhide file 23

TERTENIA (Nuoro), nuraghe Nastasi.

The nuraghe Nastasi at Tertenia is on a small hill near the coast, in the area of Sàrala, rich in archaeological monuments, amongst which are the Aleri nuraghe, and, a little further inland, the nuraghe Longu.

The nuraghe is a complex plan irregular monument and consists of a central tower (c) and of an elliptical bastion, which incorporates two towers (d, e) and another tower to the east (b). A vast village spreads on the slope of the hill.

In 1968, in the course of the archaeological excavation of the east tower b, in the second level were found two fragments of oxhide ingot, together with a small shield belonging to a small nuragic bronze figurine and fragments of nuragic pottery; amongst these there was one with a painted band which was considered a local imitation of a fragment of Late Helladic IIIC.

The archaeological layer was, to all appearances, undisturbed.

(Contu 1968; Basoli 1980, 434, fig. 2; Lo Schiavo, Vagnetti 1980, 382, no. 8, figg. 4-5; Lo Schiavo 1982, 282; 1990, 28-29, no. 14; Re 1998, 288, no. 12)

The ingots fragments have been analysed (Maddin, Merkel 1990, 116-119).

Oxhide file 24

BARADILI (Oristano), S. Maria. Hoard

The fragments of oxhide ingots from Baradili were given to the State in 1947 by Dr. Antonio Cabras.

According to what Cabras reports "a workman engaged on the excavation found at a depth of about seventy centimetres below ground level a vessel in terracotta, in the form of a bowl fifty centimetres high, containing about two hundred fragments of raw copper, of various sizes" ("*un operaio addetto ai lavori di scavo scoprì alla profondità di settanta centimetri circa dal livello del suolo, un recipiente di terracotta, a forma di pentola, dell'altezza di cinquanta centimetri, contenente circa duecento frammenti di rame grezzo, di varie dimensioni*").

Cabras recovered 154 fragments, weighing in all 23.200 kg, while some fifty fragments appear to have been taken by persons unknown and dispersed. Cabras himself had an analysis made, a summary of the results of which is as follows: silica: present; copper: present; tin: 3.7 %: it is a bronze" ("*silice: presente; rame: presente; stagno: 3,7 %; trattasi di un bronzo*").

Various surveys carried out by Cabras in the place of discovery led to the recovery of other material, mostly grindstones and fragments of the great vase which contained the ingot fragments (Cabras 1950).

In spite of its importance, the donation remained long in the storerooms of the Cagliari museum, practically unknown even to the specialists, but fortunately it survived in good condition. The moving of the material over the last few years has in fact led to some small losses, but the collection has survived almost complete.

It is difficult to provide chronological indications for the hoard on the basis of the reports. Examination of the container might provide a chronological indication, but the fragments of the vase have been lost in the deposits of the Museo di Cagliari. The presence of a fragment of a jar amongst the surviving material is not certain proof that the container was of that shape. (Luisanna Usai)

The ingots have been analysed (see Part III, chapter 1; Archaeological file 21, p. 211; Db, p. 131-136).

Oxhide file 25

VILLANOVAFORRU (Cagliari), Baccus Simeone. Hoard (see Archaeological file 26, p. 216-218)

In a cultivated piece of agricultural land, near a natural spring known as "Mitza Baccu Simeoni", fragments of half-worked metal items were being found over several years.

In 1984 there was systematic survey of the area with a metal detector which indicated a cluster of signals, as result of which there was an archaeological excavation. In this way was discovered a hoard consisting of a large two-handled jar of which only the bottom and one handle remained, containing fragments of oxhide, planoconvex and unclassifiable ingots, scraps from smelting, slag and a fragment of votive sword; part of the material was found also outside the vase.

The so-called X-shaped handle, of expanded-edges type, is typical of the Recent to the Final Bronze Age.

(Atzeni C. *et al.* 1987, 154; Lo Schiavo 1990, 28-29, no. 15; Badas 1999; Campus, Leonelli 1999, 515-516, no. 8-9, fig. 8).

The ingots have been analysed (Maddin, Merkel 1990, 118-129; see Part III, chapter 1; Da, p. 125-130).

Oxhide file 26

SARDARA (Cagliari), nuragic village of S. Anastasia, hut 1. Hoard

The hoard was found during the excavations of 1980-84 in Hut 1 of the nuragic village of S. Anastasia, Sardara (Cagliari), near the sacred well.

The hoard was hidden below the beaten floor and consists of 57 fragments of oxhide and other types of ingot, two of which have marks, for a total of 22 kg, contained in a large carinate bowl with two handles, covered with a second, fragmentary one.

The lenticular large bowl is a shape widespread in Sardinia: this form seems to have lasted a long time, from the Final Bronze to the Iron Age. The bowl used as cover has exact analogies to examples dating to the Final Bronze Age.

Of the fragments found, 9 certainly belong to oxhide ingots, on account of their shape, 3 probably so, 4 belong to disc ingots, and 41 fragments cannot be classified.

(Ugas, Usai L. 1987, 170-171, pl. III-IV; AA.VV. 1988, 201, fig. 2; Lilliu 1988, 201, fig. 3; Lo Schiavo 1990, 28-31, no. 16; Campus, Leonelli 1999)

Oxhide file 27

VILLASOR (Cagliari), loc. Giva Molas. Hoard

In February 1995, in the locality of Giva Molas, there was an enormous operation of stone removal which had cancelled all trace of the remains of a nuragic settlement, of which two nuclei were recognizable, evidenced by stone artefacts: querns, pestles and holed hammers ("*mazze*"), and pottery: jars and bowls, and also a clay impasto crucible, fragmentary, with remains of smelting slag on the inside.

9 fragments of oxhide ingots, together with 19 fragments of votive swords, were subsequently recovered, on the surface, in perfectly flat land, ploughed and with the stones removed. Since it was reported by the person who found them that the artefacts were dispersed over a limited area, it was presumably a hoard.

Unsubstantiated reports refer to the presence in the same terrain of worked and finished blocks, such as those from a nuragic isodomic structure, but today there are no traces left. This site is 4 km west of the lead mines of Monte Zippiri.

Of the 9 fragments of ingot found, which have not been analysed, 3 certainly belong to oxhide ingots on account of their shape, 2 probably so, and 4 are not identifiable.

(Report L. Usai; inspection A. Usai; drawn by T. Cossu. Unpublished).

The ingots have not been analysed.

Oxhide file 28

MONASTIR (Cagliari), Monte Zara

The site of Monte Zara, and in particular the area of Bia de Monti is to the west of the modern town of Monastir, on the other side of the road S.S. 131, the widening of which led to the excavations in the years 1986-87 and from 1992-93.

In addition to the numerous prehistoric sites in the whole territory, the ones from the nuragic period are widespread and of great interest.

In the site of Bia de Monti three sectors were excavated in which were found a series of circular and rectangular structures, known only through preliminary reports, and dating to the Recent and Final Bronze Age.

Fragments of oxhide ingots from Monte Zara at Monastir have been mentioned by G. Ugas: "In structures 34S and 25 were found some fragments of lead and pieces of copper, belonging to oxhide ingots..." ("*Nelle strutture 34S e 25 sono stati rinvenuti alcuni frammenti di piombo e pezzi di rame, riferibili a oxhide ingots* ...") (Ugas 1992, 210); they were discovered on the surface, not in association, even if found not far from "5 pieces of Argolic pottery of Mycenaean IIIB" ("*5 pezzi di ceramica argolica del Miceneo IIIB*") had been uncovered (Ugas 2001, 79).

(Ugas 1992; 2001; Re 1998, 288, no. 10)

Oxhide file 29

SOLEMINIS (Cagliari), S'Arenagiu. Surface find

Four fragments of oxhide ingots were found in the locality of S'Arenagiu, near the modern centre of Soleminis, a few kilometres north-west of Cagliari. It is probable that they are linked to two nuragic settlements situated nearby.

(Santoni 1987, 80, fig. 6, 1-4; Santoni, Bacco 1991, 32, pl. II, 1-4 ; Lo Schiavo 1990, 30-31, no. 19).

The ingot fragments have not been analysed.

Oxhide file 30

ASSEMINI (Cagliari). Hoard

In 1863, some six years after the discovery of the Serra Ilixi ingots, a similar discovery was announced by Giovanni Spano.

As he called them "*stelae*" and mentioned that they were broken up to be sold as metal to be melted down, we can conclude that oxhide ingots had been found, not fragmentary ones, presumably part of a hoard.

(Spano 1863, 29; Lo Schiavo, Vagnetti 1980, 384, no. 10; Lo Schiavo 1982, 271; Santoni 1986, 63; Lo Schiavo 1990, 30-31, no. 17)

Oxhide file 31

CAPOTERRA (Cagliari).

Immediately after the Second World War an enormous pile of metal fragments - enough, it is said, to fill two wagons - was found on the outskirts of the urban centre of Capoterra (Cagliari) in the course of agricultural works. Only one fragment of oxhide ingot with an impressed mark, handed over in 1969 to Enrico Atzeni.

The rest of the material was taken away by tinkers and today it is not even possible to localize where it was found (communication from E. Atzeni).

(Lilliu 1973, 289, nota 132; Lo Schiavo, Vagnetti 1980, 384, no. 11; Vagnetti, Lo Schiavo 1989, 224, fig. 28.3d; Lo Schiavo 1990, 30-31, no. 18)

The ingot has been analysed (Maddin, Merkel 1990, 128-129).

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4.

4. Cypriot Copper in Sardinia. Yet another case of bringing coals to Newcastle?

Vasiliki Kassianidou

4.1. Introduction

The oxhide ingot was one of the many forms in which copper was traded in the Late Bronze Age. A significant number of such ingots, some inscribed with Cypro-Minoan symbols, have been found in Sardinia and it has been argued that they were produced from Cypriot copper. Sardinia, however, like Cyprus has rich copper deposits. This raises a number of questions : are the oxhide ingots found on Sardinia really imported from Cyprus and if they are, why are the Sardinians importing a metal which is available in their country? Whether or not the two islands were in contact is not in question, as it has been shown in numerous publications in the past (Karageorghis, 1993; Lo Schiavo, 1995; Lo Schiavo *et al.* 1985; Vagnetti, Lo Schiavo, 1989).

4.2. Copper and Cyprus

Cyprus is still today considered to be one of the richest countries in copper per surface area in the world (Constantinou 1982, 15). This natural resource was exploited at least by the Middle Bronze Age, as finds at the sites of Ambelikou-*Aletri* (Dikaios 1946; Merrillees 1984), Alambra-*Mouttes* (Gale *et al*. 1996) and Pyrgos-*Mavrorachi* (Belgiorno 1999) clearly show. It is, however, during the Late Bronze Age that production of copper reaches unprecedented levels and the trade of the metal was the basis of the economy (Knapp 1986, 44; Muhly 1996, 47).

Debris from the booming copper industry, namely slags, *tuyères*, crucible fragments and pot-bellows, have been uncovered in practically all excavated Late Bronze Age sites on the island (Muhly 1989, 301-2). In some sites, particularly Enkomi (Dikaios 1971, 500, 516; Muhly 1989, 299) and Kition (Stech *et al.* 1985; Tylecote 1985; Zwicker 1985), excavations revealed extensive metallurgical workshops. Additionally, the remains of a miner's village were found at the site of Karamallos, near the mine of Apliki (Du Plat Taylor 1952; Muhly 1989, 307). To all this we can now add the first primary smelting workshop, located at the site of Politiko-*Phorades*, which dates to the beginning of the Late Bronze Age (Knapp *et al.* 1998; 1999). The excavation, a joint project of the University of Glasgow and the University of Cyprus, under the direction of Bernard Knapp and myself, has now been completed and the scientific analysis of the finds is already under way. This will hopefully shed much needed light on the copper smelting technology of the Late Bronze Age as well as the organization of the copper industry. Apart from the archaeometallurgical finds there are numerous references to copper from the land of Alashiya - which most scholars identify with Cyprus - (Muhly 1972, 217; Knapp 1996, 3, 11; *contra* Merrillees 1972; 1987), in the contemporary written sources of the Near East and Egypt (Muhly 1972, 209-212; Knapp 1996, 8).

4.3. Cyprus and oxhide ingots

In the Late Bronze Age, copper was traded in the form of oxhide ingots. Such ingots, either complete or fragmentary, have been found from the coast of Bulgaria in the north (Dimitrov 1979, 73), to the site of Quantir in the Nile Delta in the south (Pusch 1995, 123), and from the Syrio-Palestinian coast in the east (Galili *et al.* 1986, 32), to the island of Sardinia to the West (Lo Schiavo 1989, 1998). The largest concentrations come from two LBA shipwrecks: the 13th century boat that sank near Cape Gelidonya was carrying 34 oxhide ingots (Bass 1967, 52), and the boat that sank a century earlier at Ulu Burun was carrying a truly impressive number of 354 ingots (Bass 1986, 275-277; Pulak 1988, 6-8; 1997, 235). A map showing the distribution of the oxhide ingots, as well as a more detailed discussion of their find spots, has been published by Noel Gale (1991, 201-203).

Leaving the shipwrecks aside, the largest concentrations of this type of ingot have come from the three islands of Cyprus, Sardinia and Crete and all three have been considered as a possible source (Buchholz 1959, 17; Gale 1991, 201; Muhly *et al.* 1988, 283). Cyprus, however, has always been accepted as the best candidate, even if on the island itself only three complete examples are known. Only one of these was found during archaeological excavations (the British Museum's 1896 excavations at

Enkomi), (Buchholz 1959, 28-29; Catling 1964, 267-8), while an almost complete ingot in fragments, said to be from Mathiati, was published by Bruce (1937, 641). Ingot fragments, however, have been uncovered during more recent excavations at a number of sites, namely Kalavassos-*Ayios Demetrios* (South 1989, 320), Maroni-*Vournes* (Cadogan 1987, 83), Pyla-*Kokkinokremos* (Karageorghis and Demas 1984, 63), and Maa-*Palaeokastro* (Muhly, Maddin 1988, 471). In Cyprus, however, the oxhide ingot is also depicted in other objects, some of which have a religious character. Namely these are the two cult figures, the Ingot God (Schaeffer 1965) and the Bomford Goddess (Catling 1971), who are standing on bases shaped like oxhide ingots and miniature ingots, some of which are inscribed (Catling 1964, 268-9; Webb 1999, 241). Finally, there are two, four-sided bronze stands, one at the British Museum (Catling 1964, 205) and the second at the Bible Lands Museum in Jerusalem (Matthäus 1985, 319-20) depicting men carrying oxhide ingots on their shoulders.

This type of ingot appears sometime in the 16th century and it seems to go out of use after the 11th century B.C. It is interesting to note that both of the chronological boundaries are not defined by the examples found in Cyprus, most of which date to the 13th century B.C. (Muhly 1996, 48). The earliest oxhide ingots were found in Crete (at the sites of Ayia Triadha, Gournia and Zakro) while the latest examples were found in Sardinia (Muhly *et al.* 1988, 283; Lo Schiavo 1998, 110). This is one of the reasons why some have found it difficult to identify Cyprus as the source of both the Cretan and the Sardinian ingots (Muhly *et al.* 1988, 295).

Regarding the Cretan ingots, further concern was based on the lack of evidence for an active copper industry on Cyprus at this period: up to recently the only site to produce some metallurgical finds dating to the Late Cypriot I was Enkomi (Muhly 1989, 299). According to Gale (1989, 254):

> *"At any rate, Cypriot oxhide ingots were not coming to Crete in the period 1550-1450 B.C.;indeed Cypriot copper was almost certainly not being cast into oxhide ingots as early as this. In this period oxhide ingots were made elsewhere, though we know from our work on the Middle Cypriot site Alambra that Cypriot copper was being used on a small scale as early as about 1800 B.C..."*

This statement, which was based on the archaeological evidence available at the time (as well as, lead isotope analysis, which will be discussed further on), was not unreasonable. Nevertheless, it can now be contested based on a new discovery that has come to light in the last few years. I am referring to Politiko-*Phorades*, the only excavated primary smelting workshop of the Late Bronze Age, where we have collected 3.5 tons of slag, 6000 fragments of furnace walls, 50 nearly complete *tuyères* and over 500 fragments (Knapp *et al.* 1999). The pottery indicated that the smelting activities dated to the Late Cypriot I period and this was confirmed by a radiocarbon date of 1680-1410 B.C. (95.4 % confidence) (Knapp *et al.* 1999, 135). The technology used is completely different than that witnessed at the Middle Bronze Age sites and, in fact, much more developed than was anticipated by earlier publications, which were based on the study of material derived from the urban centres (Kassianidou 1999, 91, 95). Even if the metal produced at Phorades corresponds to ten percent of the slag left behind, this means that the smelters produced something like 350 kilos of metallic copper. It would be naïve to think that we have been fortunate to find the only smelting workshop of the early LBA. Similar workshops would have been spread around the periphery of the Troodos mountains but they have not survived or lie below the enormous spoil heaps of the modern mines. The workshop at Phorades, therefore, shows that already in the Late Cypriot I, large scale production of copper had started and if so, why not also export? Let us not forget that the earliest references to copper from Alashiya date to the 18th century B.C. (Muhly 1972, 204)!

Concern was also raised regarding a Cypriot origin for the Sardinian ingots. This was mainly based on the lack of oxhide ingots on Cyprus dating to a period after the 13th century B.C. and on the assumption that the Cypriot copper industry folded or went into recession in the 12th century, after the collapse of the exchange systems (Muhly 1996, 48; 1991, 189). This, however, can now also be contested.

Regarding the production of copper after the 12th century, Maria Iacovou and I have recently presented a paper arguing that there is no real break in the industry (Iacovou, Kassianidou 2000). Direct evidence to support this statement is found in Kition, one of the few LBA sites that survives the transition to the Iron Age: the Northern workshops of the temple complex, which were involved in metallurgical activities, continued to be active in the 11th century (Karageorghis, Demas 1985, 135-138). Furthermore, during field work in the mining district of Mitsero, in the North foothills of the Troodos mountains, undertaken by the Sydney Cyprus Survey project, we recorded two sites related to mining and metallurgy, which according to C14, date to the Geometric Period (Kassianidou, in press). The continuation of the production and export of Cypriot copper, however, can further be deduced indirectly, from the wealth we encounter in the tombs dating to the 11th and 10th centuries B.C., especially those from the *necropolis* of Palaepaphos-Skales. According to Karageorghis (1983, 372),

> *"No other necropolis of the CG period in Cyprus has produced so many and such extraordinary bronzes as Skales."*

Cypriot bronze smiths, therefore, were as active as ever and were, furthermore, producing objects using novel techniques which were introduced on the island in the 11th century.

Thus even if the actual finds of oxhide ingots on the island are few, Cyprus fulfils two of the basic requirements to have been the main, if not the sole, source of copper for the oxhide ingots; it has the richest copper deposits in the area and it has solid evidence of copper production and working (in the form of slags, crucibles, *tuyères*, bellows etc.) spanning the period of use of the oxhide ingots. The fact that metallographic studies have shown that the copper of the analysed oxhide ingots has been extracted from sulphide ores (Maddin 1989, 99; Muhly *et al.* 1980, 91, 93; Muhly, Maddin 1988, 471; Zwicker 1988, 429), is yet another point that links them to Cyprus. Cypriot deposits consist almost exclusively of sulphide minerals (Constantinou 1981, 15) and, therefore, the copper industry was always based on the exploitation of this type of ores and not on oxides, carbonates, or silicates as is the case in other well known mining districts, such as Feinan (Hauptmann 1992, 11, 23), Timna (Bamberger, Wincierz 1990, 123) and even Laurion (Gale, Stos-Gale 1985, 93-95), active in this period.

What would clearly show that the ingots were produced in Cyprus are mould fragments, but these are missing: it is well known that the only mould for an oxhide ingot was found in Ras Ibn Hani in Syria (Lagarce, Lagarce 1997, 75-7). However, one should always keep in mind that in archaeology absence of evidence is not evidence of absence. Furthermore, it is by no means certain that all oxhide ingots would have been cast in a stone mould. In fact, at a conference organized by Michal Artzy in Haifa in 1998, we heard from Patricia Sibella that of the 354 copper oxhide ingots on board the Ulu Burun ship there are only a couple which are identical. She suggested that this may be an indication that they may have been produced in sand moulds (although in the discussion that followed this paper when it was presented in New York, Cemal Pulak indicated that he did not seem to share this view). That this is possible was demonstrated experimentally by Merkel (1986, 259) and Van Lokeren (2000, 275). If the ingots were produced in sand moulds then what would have remained after the casting is nothing really but sand!

The strongest support, however, for a Cypriot origin of most analysed oxhide ingots derives from lead isotope analysis (the ingots which are clearly different isotopically are those found in Aghia Triadha in Crete which date to the 16th century B.C.), (Gale, Stos Gale 1999, 272-3)[1].

By now most archaeologists are aware of the benefits of the technique as well as its limitations. The identification of provenance is based on the principle that an ore deposit has a lead isotope fingerprint (defined by three ratios of the four isotopes of lead), and that this fingerprint does not change through the process of smelting and refining. Thus the metal has the same isotopic fingerprint as that of the ores from which it was extracted (Gale 1978, 529-530; Stos-Gale, Gale 1994, 99-104). It has been argued that this is also the case even with artefacts made of tin bronze: because tin usually contains no lead, the lead isotopic fingerprint is that of the copper metal (Gale, Stos Gale 1985, 87-88). Problems do, however, arise with leaded tin bronzes, an alloy which we know was already in use during the Late Bronze Age. In this case, lead isotope analysis will determine the provenance of the added lead and not that of the copper (Gale and Stos-Gale 1985, 97).

This is not an issue for oxhide ingots, however, as they consist of very pure copper. Early on it had been suggested that they were produced by tapping the metal directly from the smelting furnace but we now know that it is impossible (Muhly *et al.* 1988, 287). First of all, a Bronze Age smelting furnace could not produce such an amount of metal (and the proportional amount of slag) (Merkel 1986, 257). Second, as already pointed out above, we know from analysis that the copper of these ingots was extracted from sulphide ores (Maddin 1989, 99; Muhly *et al.* 1980, 91, 93; Muhly, Maddin 1988, 471; Zwicker 1988, 429). Sulphide ores have to undergo a series of processes such as roasting, primary smelting, roasting and secondary smelting, and even then, the product is black copper, which needs to be refined. The copper of the oxhide ingots is so pure (although some exceptions do exist) that it clearly has passed through a series of fire refining steps (Merkel 1986, 260)[2].

At this point, I feel I should comment on the idea, presented some years ago, that oxhide ingots represent the mixture of both recycled metal and copper that originated from various mines around the Mediterranean which belonged to a Koine (Budd *et al.* 1995, 25-27). First of all, it is extremely difficult to remove the tin from bronze in order to produce copper of the purity known from the oxhide ingots (Merkel 1990, 118). Second, the idea of a Koine creates more archaeological problems than it solves: where was this metal mixed and how did they manage to always use the same proportions of copper from the various mines so as to form such coherent groups, in terms of their lead isotope fingerprint ? I agree with other scholars who have found this idea difficult to accept (Gale, Stos-Gale 1995, 35-36; Knapp 2000, 43).

But let us return to the lead isotope issue: because the oxhide ingots do form a coherent group of artefacts made of raw material, they were considered ideal subjects for the study of provenance using this new analytical method. And, therefore, the team from the Oxford Isotrace lab

1. The literature on this subject is extensive and I can only dedicate a small portion of this short paper to it. A few publications pertaining to this issue include: Budd *et al.* 1995; Gale 1991, 1999; Gale, Stos-Gale 1987; 1999; Knapp 2000; Muhly 1983; 1995; Stos-Gale, Gale 1994; Stos-Gale *et al.* 1997.

2. Chemical analyses of oxhide ingots have been published in the following papers: Buchholz 1959; Maddin 1989; Mangou, Ioannou 2000; Muhly *et al.* 1980; 1988; Tylecote *et al.* 1984.

embarked on a long-term research project on the Late Bronze Age metals trade in the Mediterranean. To do so they analysed ore samples, oxhide ingots and bronze artefacts from all over the Mediterranean. The fact is, however, that only after another group started to scrutinize their work, they multiplied their analysis of ore samples in order to better define the lead isotope fields of the main copper sources, namely Cyprus, Sardinia, Laurion and others. Since 1997, therefore, the familiar method of depicting the lead isotope fingerprint of an mining area was abandoned and the rather large Cypriot field has now been replaced by clusters, each of which represents one specific mine in the mining districts of the Troodos (Stos Gale *et al.* 1997; Gale 1999, 115).

With the new analysis and the new approach came the rather provoking conclusion that all oxhide ingots dating after 1250 B.C. are derived from the mine of Apliki and those adjacent to it (Gale, Stos-Gale 1999, 274). In this group fall the oxhide ingots from Cyprus, Kyme, Euboea, LHIIIB Mycenae, the Black Sea coast of Bulgaria, Bogaskoy, Sarkoy, Antalya, Chios, Kommos, Gournia, the sole ingot fragment from Egypt, the ingots from the Cape Gelidonya wreck and finally, all the oxhide ingots from Sardinia (Gale, Stos-Gale 1999, 271-273).

Needless to say, this statement has caused various reactions, mostly negative, among archaeologists who cannot accept that a single group of mines, located in the northwest foothills of the Troodos mountains, and no other, produced all the metal exported from Cyprus from the 13th century onwards. One of the scholars who opposed this idea more strongly than others is Knapp (1999, 106) who stated:

> *"The cultural and economic model proposed - namely that a single site and a single ore deposit was producing all or most of the copper oxhide ingots found in the Bronze Age Mediterranean - whilst bold and provocative, and coherent in analytical terms, makes little sense in economic, social, spatial or even mineralogical terms, contradicts the model we can now propose on the basis of our work at Phorades, and represents a marked change from earlier interpretations that proposed exploitation of multiple ore deposits around the Troodos."*

The Gales´ published reaction to Knapp is the following:

> *"In natural science theories which do not accord with subsequent experimental data are modified or discarded; we may expect similar rigour in archaeology"* (Gale, Stos-Gale 1999, 275).

However, I know that many archaeologists would agree with Knapp and, in fact, some have reached a point where they are not willing to accept conclusions regarding the provenance and trade of metals, which are based solely on lead isotope analysis (Muhly 1995, 58). Because this is such a controversial issue, under any other circumstances I would have kept well away from it, but for the purpose of the topic of my paper I cannot do that. The main argument for a Cypriot origin of all oxhide ingots found on Sardinia is based on the lead isotope analysis (Gale 1999, 118). Even without the support of the lead isotope data however, the idea of Cypriot copper being exported to Sardinia is not so difficult to accept and many of the arguments which can been used against it, can be countered.

4.4. Oxhide ingots from Sardinia

Let us first look at the archaeological evidence. Copper oxhide ingots, either complete or in fragments, have been found in 26 sites around the whole of Sardinia (Lo Schiavo 1989, 1998). Some of them bear impressed marks of the Cypro Minoan script (Vagnetti and Lo Schiavo 1989, 224). Although initially most had insecure archaeological contexts, which also lead to their uncertain dating, research over the last 20 years has rectified the situation (Lo Schiavo 1998, 109).

There are various points regarding the oxhide ingots found in Sardinia which are interesting:

a) the ingots are widely distributed and have been found in both inland and coastal sites (Lo Schiavo 1998, 99).

b) in Sardinia we find the latest examples of oxhide ingots which date no later than the 11th century B.C. (Lo Schiavo 1998, 110).

c) most of the ingot fragments, for which there is a secure archaeological context, were found in hoards often in association with bun ingots and scrap metal (Lo Schiavo 1989, 36). According to Knapp, Muhly and Muhly (1988, 237), one type of hoard is the Founders hoard, which consists of "material collected together for their value as metal not for the intrinsic value of the original objects. They may be characterized particularly by broken objects or scrap metal, by castings and slag, and by ingot fragments, all items lacking special significance and all being reduced to their lowest common metal denominator." Both the content of the Sardinian hoards plus the fact that some have been found in what can be defined as a metalworking workshop [for example, the hoard found at Villagrande Strisaili (Nuoro), S´Arcu ´e is Forras (Lo Schiavo 1989, 34)] can be used to identify them as Founders hoards.

The fact that the ingots are often found in fragments and within the contexts of metallurgical workshops is also an argument that they were meant to be used rather than be kept as prestige goods (otherwise we would be finding more complete examples stored away). And clearly large parts of the ingots had been used for something; the question is, for what ? Because, if we do accept the lead isotope results for the oxhide ingots, then we also have to accept those for the bronze objects from Sardinia, according to which, none of the analysed artefacts were made out of Cypriot copper (Gale, Stos-Gale 1987, 154-155). Instead, they fall well within the Sardinian fingerprint, as do the bun ingots which are often found in connection with the oxhide ingots, indicating that local deposits were being exploited (Gale and Stos Gale 1987, 154-155). This observation, combined with the late date of some of ingots found on Sardinia, is the reason why some scholars have been reluctant to accept the lead isotope analysis and as a result the Cypriot origin oxhide ingots found on the island. In fact, some had argued that Sardinia might also have been producing oxhide ingots for local and perhaps for external markets (Lo Schiavo *et al.* 1985, 13; Lo Schiavo 1988, 97). According to Jim Muhly (1996, 49):

> *"Even worse was the situation on Sardinia. There none of the analysed artefacts, especially those from Santa Maria in Paulis hoard, was made of Cypriot copper. What happened to all the Cypriot copper exported in the form of copper oxhide ingots? The answer is fairly obvious. There must be something wrong with the conclusions being drawn from the available data."*

My personal view is somewhat different. I believe that the answer to the problem lies in the chemical composition of the bronze artefacts from Sardinia (the same argument can be used for the artefacts from the Aegean, none of which was made of Cypriot copper (Muhly 1996, 49). Published chemical analyses (admittedly not numerous) show that most of the bronzes contain lead in significant levels, in other words above 1 % (e.g. Tylecote *et al.* 1984, 146). This amount of lead may have been present in the copper metal (of that which was extracted from a polymetallic ore), but it may also have been a deliberate addition (Lo Schiavo *et al.* 1987, 180).

One of the peculiarities of Cypriot copper sulphide ores is that they contain just traces of lead and as a result so does the metal extracted from them (Stos-Gale, Gale 1994, 105). Sardinian ores, on the other hand, are poly-metallic and contain significant amounts of lead (Gale 1999, 112; Tylecote *et al.* 1984, 120-122). Furthermore, in at least one area, cassiterite was found to contain lead (Tylecote *et al.* 1984, 129). So, artefacts from Sardinia composed of leaded bronze may have been produced from Sardinian copper derived from a polymetallic ore and mixed with Sardinian tin (and lead). This, of course, is most likely, but the artefacts might also be a composed of Cypriot copper mixed with Sardinian lead and tin (either local or imported), in which case, the lead isotope analysis would provide us the provenance of the lead (or the lead rich tin) and not the copper.

In a similar way, if we were to use lead isotope analysis to provenance one of the four-sided bronze stands currently at the British Museum, which is undoubtedly of Cypriot manufacture, it would probably be identified as deriving from Laurion, because it contains 20 % lead metal (Macnamara, Meeks 1987, 59). There is no doubt that this is a deliberate addition made specifically in order to facilitate the casting of such an intricate object. Indeed a number of the bronze objects that were found in Cyprus, and were identified by the Gales (1994, 215-216) as being made of imported copper, contain lead in concentrations of over 1% (some with as much as 20 %). Again this can only be interpreted as a deliberate addition and I find it difficult to understand why the possibility that their different provenience may be due to this reason is not even discussed in that publication. In a paper published in 1985, Gale and Stos-Gale (1985, 83) clearly stated that one of the basic principal conditions that must be satisfied in order to be able to use lead isotope analysis to provenance an artefact is that in the Bronze Age Mediterranean, lead metal must not have been deliberately added to copper alloys. They support this idea with the following argument (Gale, Stos-Gale 1985, 85):

> *"We concluded that out of 326 analysed objects, 92 % contain less than 1 % lead whilst 97 % contain less than 3 % lead; thus deliberately leaded copper alloys hardly occur at all in the Bronze Age. Consequently the lead in such artefacts derives from copper ores, and lead isotope analyses remain valid for determining their provenance."*

Muhly (1985) has already replied to this and the reader is referred to his paper, though I would just like to add that I find the argument rather circular. Deliberate addition of lead may have been done only in certain cases (perhaps not included among the objects that had been analysed) where the presence of lead would be deemed beneficial. As pointed out above, the tripod and four sided stands, the cast masterpieces of the Cypriot Late Bronze Age, are such objects and indeed those analysed have been found to contain high amounts of lead (Macnamara, Meeks, 1987, 58-59). Following this line of thought, I tried to see whether Sardinian objects are mostly made of leaded bronze but unfortunately the only chemical data published with the lead isotope analysis is the trace element content of the objects (Gale, Stos-Gale 1987, 165-172). Similarly, in the extensive publication of 168 lead isotope analysis results of objects from Cyprus mentioned above, the chemical composition of only 63 artefacts is published (Stos-Gale, Gale 1994, 212-216).

Considering the fact that identification of provenance is based on the lead, which even in a limited number of pieces can be shown to be a deliberate addition, I believe that the only way one can judge the validity of the interpretation of the lead isotope analysis results (because usually it is the interpretation which is problematic and not the results *per se*), is if one is provided with information on the chemical composition of the object and more specifically, the concentration of lead. I believe, therefore, that it is essential that all new publications on lead isotope analysis include, apart from the lead isotope data, the results of chemical analysis.

But to return to the issue at hand, let me clarify that I am not arguing that all bronze objects in Sardinia were made of Cypriot copper. I uphold that even if a small percentage of the objects were made of Cypriot copper, this cannot be detected if it had been mixed with some local lead to facilitate the casting. Therefore, the fact that according to the lead isotope data none of the analysed bronze objects in Sardinia were made out of Cypriot copper, is not really a strong argument against the import of Cypriot copper to Sardinia.

This brings us to another important question: Why is Sardinia importing Cypriot copper when it also has copper ores and finds which demonstrate an active metal industry (Lo Schiavo 1988, 98)[3]? One may appreciate, however, that this is a theoretical question for which I can only suggest some logical answers, although I am well aware that my 20th century logic may not apply to the Late Bronze Age.

One of the exchange systems active in this period was that of gift exchange. According to Knapp and Cherry (1994, 146):

> *"The characteristics of gift-exchange, and the bases from which one may establish some means of identifying its material correlates, includes the transfer of prestige goods between notable persons, the continuing re-circulation of such prestige goods; and the tendency not to consume such goods, which thus appear most often in the archaeological record as a result of loss, accidental breakage, or deliberate disposal in mortuary or hoarding contexts."*

Sometimes the gift exchanged is the same and in one case, pointed out by Knapp and Cherry (1994, 148), the exchange borders on the irrational: the king of Alashiya sends ivory, a non-native product, to the ruler of Egypt, an ivory producing country. According to Liverani (1979, 23), this may have been intended as a stimulus to acquire the same commodity in return but in greater amounts. Would it be senseless to consider the possibility that Cypriot copper came to Sardinia as a gift ? The problem is not only a question of who the sender was (the king of Alashiya ?), but more importantly, who was at the receiving end ? According to Lo Schiavo (1988, 96),

> *"The political and social structure seems to be based on tribes and clans, apparently organized in regional cantons. Archaeology has failed up to now to detect any rigid difference in classes, the existence of kings, or the predominance of one regional group over others."*

Furthermore, I realise that we cannot discuss the nature of the exchange system out of its chronological context. Although the majority of Cypriot finds in Sardinia date to the 13th century, contacts between the two islands continue to the 12th and perhaps to the 11th (if we accept that the oxhide ingots are made of Cypriot copper). By the 12th century, however, the political system of the Eastern Mediterranean had collapsed, and with it probably also the established, complex exchange systems. It may, therefore, be an anachronism to talk of gift exchange in the 12th century as we do not know what the political situation was at that time neither in Cyprus, nor in Sardinia.

What is extremely important is the fact that, unlike other areas, Cyprus does not really go into a period of recession after the 12th century. First of all, it adopts the new metal iron fairly quickly, while it continues, as I have argued above, to produce and use copper. There is no reason to assume that the export of copper and the search for other metals, which were not available on the island, would have ceased. Cyprus has no gold, silver or tin and yet all three are important (if not essential) and are found in one form or another in the rich tombs of the 11th century at Palaepaphos-*Skales* (Karageorghis 1983, 373). Iron, on the other hand, is available on the island and it would not have been one of the raw materials the Cypriots would have been looking for (Kassianidou 1994,79). With the collapse of the Late Bronze Age exchange system, Cyprus would have been cut off from its suppliers of precious metals (silver from Laurion or Anatolia, gold from Egypt or Anatolia, and tin from the East). It is not, therefore, unreasonable to believe that the Cypriots, who since the Bronze Age were seafaring merchants, searched for new sources. Their search led them to the West, as it would do a few centuries later the Phoenicians, for the same exact reasons. When the Mycenaean centres collapsed, the western routes that they initially controlled would have been opened to the Cypriots.

Sardinia not only was a source of some of these metals but most importantly it is on the way to the even richer metal deposits of the Iberian Peninsula. That the Cypriots brought with them their main product, metallic copper, as well as ceramics, need not surprise us. Neither should it astonish us that they managed to give it to the Sardinians who were producing their own copper. Bearing in mind the amount of time, and more importantly fuel, needed to produce this precious commodity, it is highly unlikely that anyone would reject a shipment of ready to use metal. Finally, we know from Pliny (Natural History, XXXIV, II. 3-4) that in the Roman Period copper from some areas was believed to be of better quality than that from other areas (Rackham 1952, 129). The purity of Cypriot copper and especially the absence of certain elements such as lead and arsenic, may have been a sought after quality even from the Late Bronze Age.

4.5. Conclusions

To conclude, it is my opinion that the oxhide ingots found on Sardinia were indeed imports from Cyprus. Although, I too find it difficult to believe that all post-13th century ingots came from the mine of Apliki. I agree with the more general statement made by Gale and Stos-Gale that:

3. Although the absence of significant quantities of smelting slag from this period on Sardinia is, to my mind, problematic.

"The position we do hold is that all existing scientific evidence strongly supports that all the later copper oxide ingots were made from copper smelted from copper ores coming solely from the Apliki/Skouriotissa/Mavrovouni ore region of Cyprus" (1999, 275).

This may not be so difficult to accept, if one takes into consideration the fact that those are some of the largest copper deposits in the whole Mediterranean. In modern times this region was the source of 85 % of all the copper produced on the island, (keeping in mind, of course, that the modern industry is based on a completely different set of parameters) (Constantinou 1982, 15). I do not believe that these were the only mines that were being exploited in the Late Bronze Age nor that the copper from only these mines was cast into the shape of oxhide ingots. I also believe that we need to start reconsidering the way that the Cypriot copper industry was organised in the Late Bronze Age, using this and also other new evidence, such as that provided by the excavations at Politiko-*Phorades*.

I think that the Cypriots, both smiths and traders of copper, travelled west in search for new sources of precious metals and tin. In Sardinia, they found the metals they were looking for, either locally produced or imported from the West and even North. At the moment there is no evidence, apart from a wheeled stand from Portugal, which vaguely reminds us of the Cypriot versions, that the Cypriots ever reached the Iberian Peninsula (Mederos, Harrison 1996, 238). I believe, however, that in Sardinia they would have heard of the rich mineral resources of that region and perhaps this information was used later by the Phoenicians and the Cypriots, when they did finally venture west in the Iron Age.

Note

After Kassianidou V. 2001, Cypriot Copper in Sardinia: Yet another case of bringing coals to Newcastle ? in *Italy and Cyprus in Antiquity*, New York, Italian Academy, Columbia University, November 16-18, 2000, Nicosia, 97-119.

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5.
BRONZE WEAPONS, TOOLS, FIGURINES FROM NURAGIC SARDINIA

Fulvia Lo Schiavo

The production of artefacts in copper and bronze, the working, finishing, decoration, repair and transformation of metal objects are the most unarguable proof of the elevated level reached by metal-working technology in nuragic Sardinia. For this reason, to run through, even summarily, the entire production of nuragic bronzes is very informative from the technological and metallurgical point of view, even in the absence of a wider analytical basis. In fact, considering the smallness of the material relating to the origins and the scarce and still contradictory indications on the size of the exploitation of the deposits (see Part II, chapters 1-2) and on the first operations to reduce the metallic minerals, and considering, on the other hand, the omnipresence of the oxhide ingots, whatever their provenance may be (see Part IV, chapter 4), the abundance of the artefacts of every sort, the variety of the products and the presence, both scattered in settlements and concentrated in hoards and in sacred places, are facts which cannot be overlooked.

Objects of a purely local typology and others that come from Cyprus or are an imitation of Cypriot models, shapes peculiar to the Iberian peninsula or to the Italian mainland, are found together in everyday use and in the hoards : the multiplicity of influences, which does not diminish at all the highly original characteristic of the local production, documents above all the commercial and cultural links which nuragic Sardinia maintained with the whole Mediterranean world. In confirmation of this, recent metallurgical analyses have revealed that some of the artefacts of external typology, both eastern and western, were manufactured on the island. From whatever point of view this is assessed from, this is another fact which speaks in favour of the abundance of raw materials, of ease of access to those lavishly used resources, even if it was probably regulated in a way still unknown to us.

For ease of exposition and with reference to use in civil and military life and in religious rites, the bronze items known in nuragic Sardinia can be divided into tools, weapons, objects of apparel and ornament, *toilet* objects with ritual value, ritual objects, vessels and figurative bronzes. In the light of the observations made above, the absolutely local products, the types which are apparently extraneous to nuragic typologies, and those visibly reworked *in loco* on models or on the basis of influences of external provenance will be discussed together, but with the due distinctions.

1. Tools (fig. 1)

The tools are the most extensive category of artefacts and can be grouped according to their function. For working wood there are axes, chisels, saws, files, awls, wedges; for working metal, hammers, tongs, charcoal shovels, anvils, burins; for working skins, scrapers and awls; for working the soil and other agricultural activities, pick, spades, scythes and sickles.

Like everywhere in prehistory and protohistory, in Sardinia too some unspecialized tools could have various functions, such as chisels and awls, while others, such as the axes, could also serve as weapons, and others still do not have a definable use, such as the long *spatulas* with simple base documented in the Monte Acuto. Some of these shapes of tool can be divided into many classes and various types.

1.1. For working wood

The most widespread and represented by a vast series of classes and types throughout protohistory are the axes. Perhaps for this reason, of reproducing in metal an object created in stone from the dawn of tool-making, the axe must have also served as a weapon and therefore as an object of symbolic and ritual value, as is well documented by the examples in polished stone, sometimes richly decorated and reproduced in miniature as amulets.

The precedents and the most archaic forms (see Part IV, chapter 2)

The flanged axes are narrow and elongated instruments, with a cutting edge at one end, a straight tang at the opposite end and flanged for their whole length, whence their name. Throughout the nuragic age they are the most characteristic local form. Carefully placed in piles of up to twenty examples, they were sometimes hidden, even inside the walls of nuraghi, to form a real little treasure; more often they are found in hoards, in settlements and in sporadic discoveries. They are also the most ancient nuragic product, from an original central-Italic shape which dates back to the Early Bronze Age ("Sezze-Orosei-type axe"). In Sardinia the oldest shapes are the very large ones, with high edges and straight sides, which then gradually are reproduced in different types, smaller in size and with thick edges, up to the end of the Bronze Age. A good number of these was found in two complexes, from nearby the nuraghe Sisine at Nule (Sassari) and from Ilbono, and are stored in the Museum of Cagliari.

Characteristic of a more evolved form, less developed in length and with low, thickened edges, are those which were part of the hoard from Chilivani at Ozieri, dating to the Final Bronze Age (Fig. 1.6, 9-10). Other forms of it have been documented, with curved blade, big and small, but still not exactly datable. The hoard of bronzes from Sedda Ottinnera, Pattada, in which for the first time the flanged axes were found in association with oxhide ingots, is analogous to that of Chilivani.

We are, however, in a position to know how this singular form of flanged axe was equipped with handle: in fact miniature representations have been found, such as the pendants - one in the Pirosu-Su Benatzu cave at Santadi (Fig. 8.4), another attached to the arch of a *fibula* from

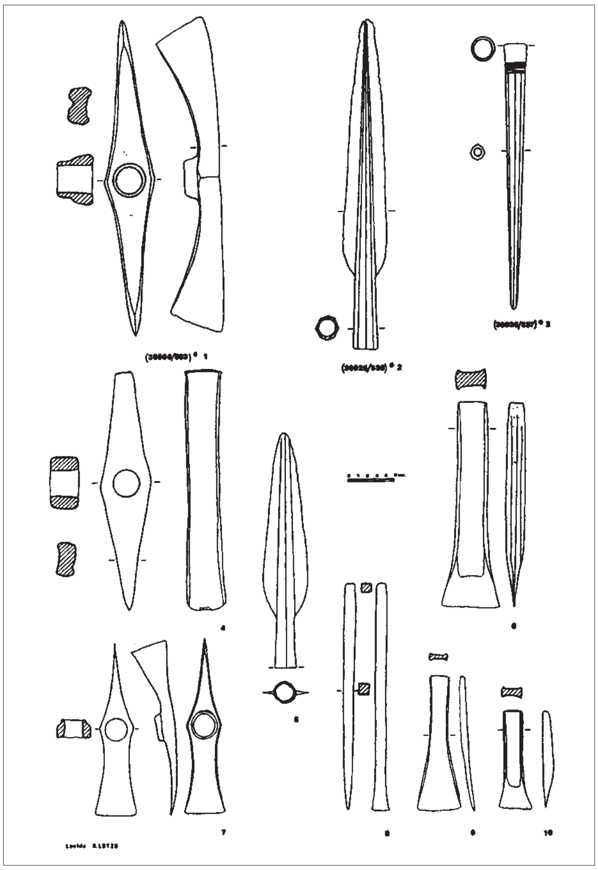

Fig. 1 – Tools and weapons from Ozieri, Chilivani (1-3) and from Ozieri, Baldosa (4-10): 1,4. double axes; 7. axe-adze ("*maleppeggio*"); 8. chisel; 6, 9-10. flanged axes; 2, 5. spear head; 3. spear butt *(after Lo Schiavo 1988).*

Tarquinia, and two further ones reproduced in the haversack of a bronze figurine - which show a curved handle and a heavy counterweight, to block and balance the blade, which is without an indentation at the tang or fins.

The Cypriot shapes

(see Part IV, chapter 4)

The Iberian shapes

The flat axes with lateral spikes or rings, with or without tang and the trunnion axes with one or two rings are characteristic of the Iberian peninsula (Fig. 5b). They are all represented prevalently in southern Sardinia, in the hoards of Monte Sa Idda at Decimoputzu and Monte Arrubiu at Sarroch.

Of these forms, note the flat axe with lateral spikes from the Flumenelongu hoard at Alghero and the trunnion axe with two rings from the Funtana Janna hoard at Bonnanaro, this last turning out on analysis to be of local manufacture.

The mainland forms

The axes, exclusively from mainland Italy, are very rare in Sardinia: one axe has been found in the same Flumenelongu hoard at Alghero.

Equally rare are the winglet axes, one of which, from Monte Pèlau, was in the Collezione Dessì at the Museo Sanna in Sassari.

The chisels are divided into two big categories, the flat ones similar to the "flat" axes of the Chalcolithic period but are rectangular in cross-section, and the narrow and elongated ones, square, rectangular or octagonal in cross-section, without hilt, which was then made of bone or some perishable material, adapted to the tool by cylindrical socket. There is a whole example and a fragment of a flat-bladed chisel, with rectangular cross-section in the Flumenelongu hoard at Alghero, and two other fragments in the Funtana Janna hoard at Bonnanaro, while there is a chisel with elongated blade, octagonal in cross-section (Fig. 1.8), from the Chilivani hoard at Ozieri.

Saws are rare (fig. 2.1); a single, almost whole example from Villanova Strisàili has two rounded ends, with a hole for fastening it to wooden handles. There is a fragment of saw from Cheremule and two from the Monte Sa Idda hoard. It is important to remember that a fragment of saw is documented amongst the bronzes of the Lipari hoard. Without any analogies at all is the blade with saw-toothing on both sides from Pinn'e Maiolu, Villanovaforru (see Part III, chapter 1.F).

Also files are not very common (fig. 2.2). An extraordinary example, perfectly whole and very large (L. 39.7 cm), with the ends smooth and rounded and the upper one elongated, was found in the territory of Olbia and first included in the Collezione De Martis and then passed to the Collezione Dessì. Numerous fragments of files of the same type have been found at Forraxi Nioi and Abini. A whole set of files, smaller and thinner, of various types,

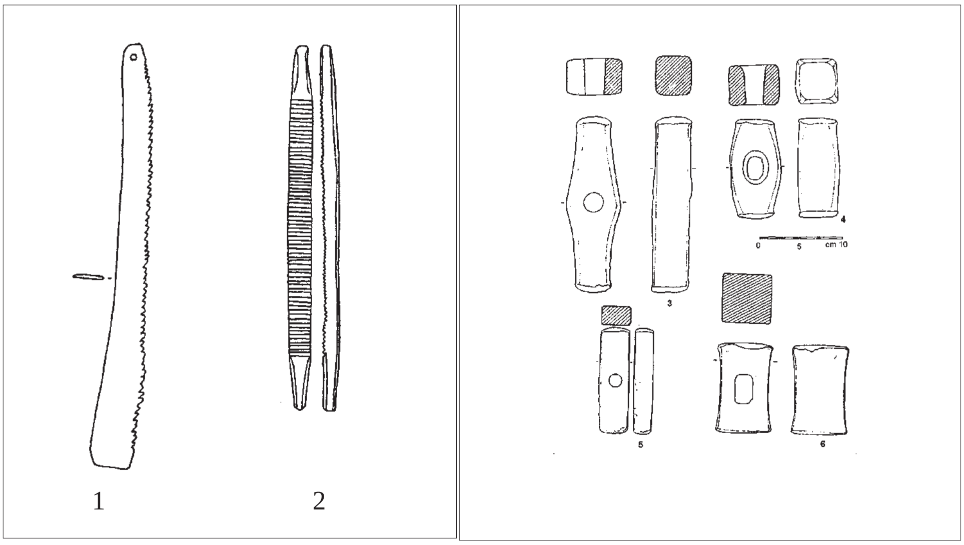

Fig. 2 - Tools: 1. Saw from Villanova Strisàili; 2. File from Collez. Dessì; 3-6. hammers: 3. from Chiaramonti, Su Cobelciu; 4. from unknown provenance; 5. from Perfugas; 6. from Nuchis *(after Lo Schiavo 2000).*

both rectangular and circular in cross-section, massive or fine and tapering, with handles in bone, were found in a niche in the courtyard of the nuraghe Sa Mandra 'e Sa Giua at Ossi.

It is difficult to give a precise definition for the awls, in absence for the moment of a specific typology, on account of the simplicity of the tool and its wide diffusion and use in every craft and in every age. It is basically a rod of bronze, circular in cross-section, with a point at one end and a simple base at the other, with a handle which is sometimes square in cross-section for better grip.

1.2. For working metal

For hammers (fig. 2.3-6) and for fire tongs, see Part IV, chapter 3.

Of the vast typological range of anvils recorded in nuragic Sardinia, only very few are known and illustrated (see Part IV, chapter 3). They are however enough to confirm the picture of a varied and specialized array.

The function of these tools, which were generally small, was that of being fixed by one end to a work-surface, while at the other end offering a curved surface on which to hammer and finish small sheet objects.

The main shapes are:

a) cylindrical, as in the Lotzorai and Silanus/Lei hoards;

b) pyramidal simple, as in the Lula and Silanus/Lei hoards;

c) pyramidal with an upright element to grip the tool better, as is documented at Forraxi Nioi and from unknown provenance at the Museo di Cagliari;

d) wedge-shaped, as in the Chilivani hoard at Ozieri, from the nuraghe Su Cobelciu at Chiaramonti and from the Collezione Dessì;

e) a parallelepiped, elongated with a conical hollow at the centre for the insertion of a peg for fastening to the work-surface and with the other end rounded and with traces of wear, from the Sarule hoard, is perhaps an anvil.

Finally, the massive double axe with a small round hole and one end rounded, from the Su Cobelciu nuraghe at Chiaramonti may have been employed as an anvil on both sides (fig. 2.3), using the hole for inserting a peg for fixing it: in fact, it is too small for a handle designed for lifting and employing the heavy instrument as a hammer.

1.3. For working skins

It is really amazing that so little is known about a subject as essential for the life of protohistoric communities as the working of skins. The use of skins amongst the nuragic peoples is particularly widely documented in the bronze figurines, for shields, parts of the armour and for parts of the clothing, such as belts, “aprons”, short mantles, footwear etc.

The tools must have been scrapers, blades and punches; amongst the bronze artefacts, the functions may have been performed by some particular sort of chisel, by daggers or by the few knives known from the island, or by awls, the same as, or similar to, those used for wood.

1.4. For working the soil and its products

For picks, see p. 313, Fig. 2.5.

Spades and hoes are completely unknown in Sardinia amongst bronze tools, and, as we said for the pick, they may have been made of wood or other organic materials.

The Scythes and sickles are documented in various shapes and sizes, both as tools and as shapes hollowed in casting moulds. A common shape is that of the curved sickle, with a simple base fixed with rivets to a handle of perishable material, with the back thickened and without a ribs, as in the example from Pinn'e Maiolu at Villanovaforru (see Part III, chapter 1F), or with two or three ribs parallel to the back. Even smaller and of a shape more similar to a short and asymmetrical dagger or to a scraper is a triangular sickle from the nuraghe Losa of Abbasanta. A casting mould illustrated by Pinza and others from S. Luca at Ozieri and from Palau, Chjainu locality, shows large scythes with thin and curved blades, almost semicircular.

1.5. For processing and cooking food

Unlike the scythes, the *spatulae* are a tool which has no comparisons outside Sardinia, nor is it immediately obvious even in the island what exactly they were used for. It is clear, however, that it was a tool widely used and distributed, given that it is represented by at least three examples in northern Sardinia and in casting mouldings from the Nuoro area: the one from Irgoli, with two impressions of *spatulae* to the sides of a shovel, as well as the one from S. Luca at Ozieri. These last two carry the profile of *spatulae* "in negative", on account of the stone having been used as the lid for a one-piece mould, in which the molten metal has caused the blackening of the upper stone (see Part IV, chapter 3).

The *spatulas* are elongated in shape, with the shoulder rounded and simple base (trapezoidal or triangular) with holes for fastening on the handle; the profile narrows towards the lower part, where it ends with a horizontal edge, perpendicular to the blade, which sometimes has a rib on one side only. The tool is therefore flexible, not particularly robust and intended for scraping extensive or elongated surfaces. It may have served to clean the cooking surface of an oven for food or for scraping the tools or vessels used in bread making.

The records on bronze spits in Sardinia are really very few, which would suggest that the use of spits made of wood hardened in the fire was widespread, and seems to prove that the central European and Mediterranean habit of the funeral banquet and of the sacredness of its equipment was extraneous to the nuragic world. In fact even the hooks and gaffs used for extracting meat from the cauldron have not been found.

A complete example of a spit with a ring at one end, followed by a stretch of twisted rod, with the rest of the rod being straight and square in cross-section, was found in the excavations of the sacred well of Irru, at Nulvi (Sassari). Other spits with fixed handles can perhaps be identified in two fragments from the Pirosu-Su Benatzu cave at Santadi (Fig. 8.13) and from the Monte Sa Idda hoard, Decimoputzu (Cagliari). Finally, there is a particularly interesting fragment of an articulated spit from the Monte Sa Idda hoard, of a type which spread from the Atlantic coasts, and of which an example has been found in a tomb at Amathus in Cyprus.

Bronze knives are extremely rare; they were evidently substituted by daggers or other cutting implements. Only four or five fragments have been found amongst the material from Sa Sedda 'e sos Carros at Oliena, but so small in size as to defy any typological classification.

2. Weapons

2.1. Offensive weapons

The main offensive weapons are swords, which from the moment of their appearance in the Bronze Age characterize a type of body-to-body combat, but then become more specialized, varying in length and with the presence also of other accompanying or complementary weapons: the dagger, the dirk or short sword and the lance. The sword also has a particular symbolic value, almost representing and summarizing the warlike essence of men and gods. This second aspect becomes a complete cult in Sardinia, of which the votive swords are the most characteristic expression.

The precedents and the most archaic forms (see Part IV, chapter 3, Fig. 2)

It is now certain that the large swords akin to the Iberian El Argar forms, documented in Sardinia at S. Iroxi at Decimoputzu and at Maracalagonis, are of nuragic production. They are blades, with very broad simple bases and a series of nails, from five to seven, between 50 and 72 cm long, and completely flat. The swords from S. Iroxi were attributed by G. Ugas to the Bonnanaro A2 *facies*, dating to "between the end of XVII and the first half of XVI centuries BC" ("*tra la fine del XVII e la prima metà del XVI secolo a.C.*"), which would suggest, together with the typological and technological characteristics, that these weapons still belong to the Early Bronze Age, immediately preceding the most typical nuragic production.

The votive swords (see Part IV, chapter 4, Fig. 8.10)

Swords in western shapes (figs. 3.1, 5.a)

Those blades of medium length which end with a handle in perishable material, bone or wood, consisting of two parts, fixed to the upper end both by way of rivets at the centre and by way of the raised edges, are known as "flanged-hilted swords". The various classes and types into which this category of swords, which is widespread throughout Europe, particularly in the central-western part, in the Bronze Age, depends on the shape the "flanged hilt" takes on, as well as on the shape of the blade and of the "*ricasso*", *i.e.* the indented part between the blade and the hilt.

Between the flanged-hilted swords, can be distinguished the particular class of the "*pistilliforme*" swords, with a blade with a strong midrib and wavy in shape, narrow at the top and bottom and wide in the lower third, while the flanged hilt has a row of rivets at the centre. This form of sword, which in France, the British Isles and the Iberian

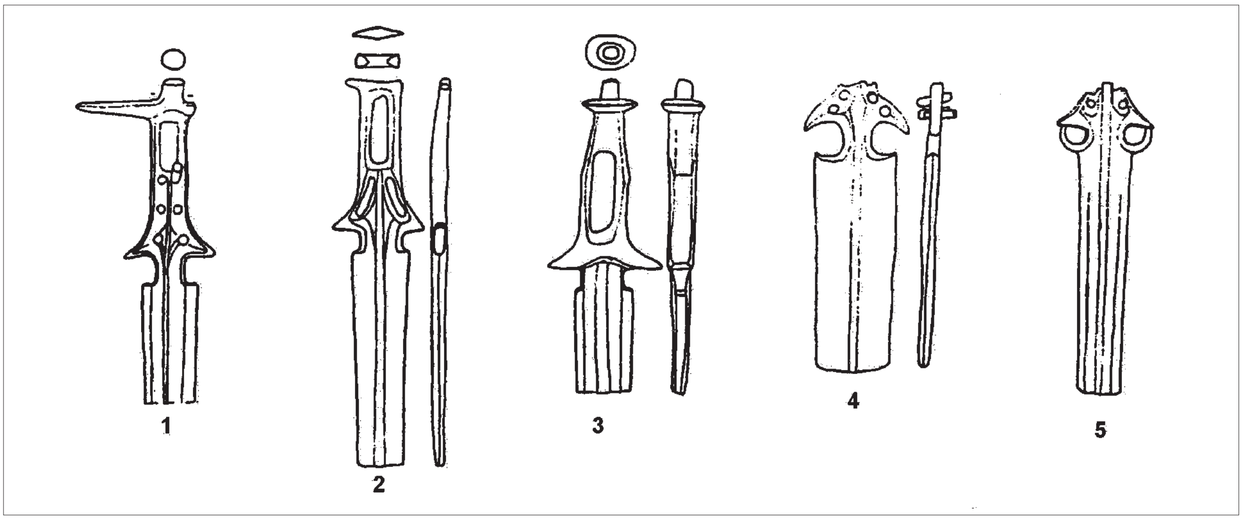

Fig. 3 – Flanged-hilted swords Monte Sa Idda type *(after Lo Schiavo 2000).*

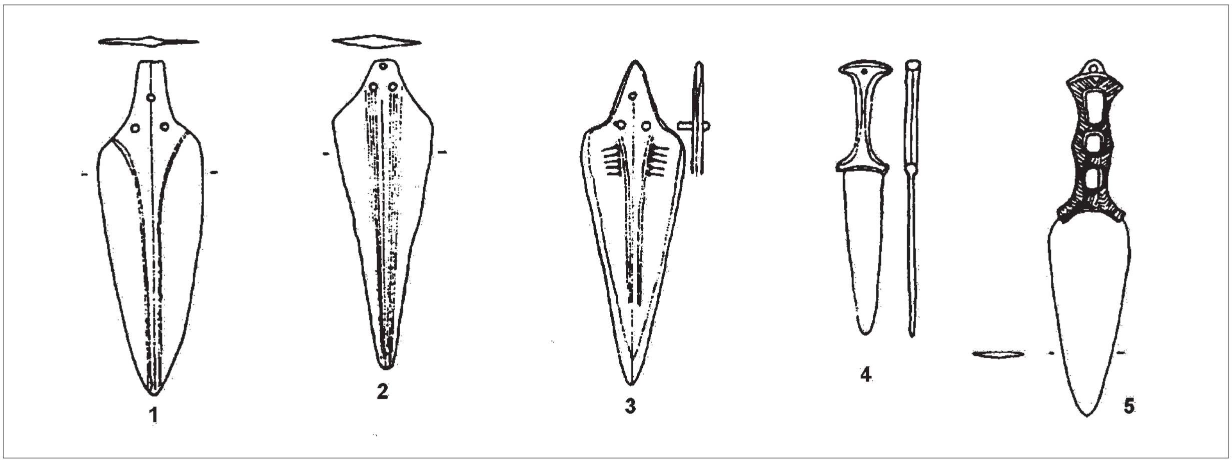

Fig. 4 – nuragic daggers *(after Lo Schiavo 2000).*

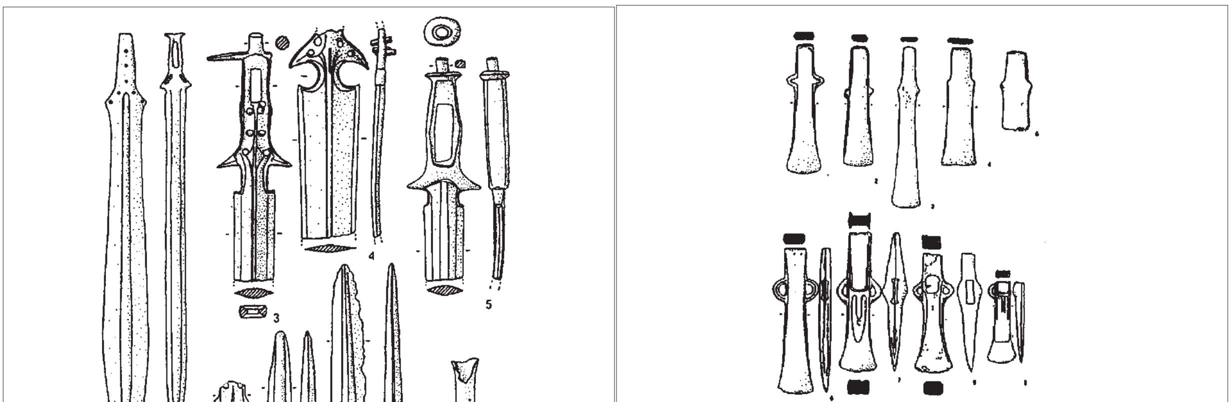

Fig. 5 – a. Iberic types weapons; b. Iberic types axes *(after Lo Schiavo 2000)*

peninsula characterizes the Atlantic Bronze II period of XI century BC, is represented in Sardinia by the swords from Oroè (or Oròre), Siniscola and is also portrayed in the hands of the bronze figurines of tribal heads and warriors, grasped in the right hand and propped on the shoulder (Lilliu 1966, nos. 7, 11, 12).

Flanged-hilted swords of nuragic production, which are recognizable for the typical decoration with small triangles and concentric rings incised on the upper part of the blade, and deriving from the pistilliforme swords, for the fact of having the shape of the blade less wide at the base than in the original models, were found amongst the bronzes of Su Tempiesu at Orune and in the S'Erenosu hoard at Bolotana, which was mentioned just above in connection with the votive swords with which it is associated.

Deriving from these, or else even a local nuragic elaboration parallel to the Huelva type from the Iberian peninsula and like that datable to X century BC, are the Monte Sa Idda-type swords, strongly characterized by having two spurs at the top of the flanged hilt and two broad rounded indentations, sometimes even two small "eyes", at the base of the blade (Fig. 3.5). Swords of this type are present in the Monte Sa Idda hoard, in the Pirosu-Su Benatzu cave at Santadi and, on the mainland, in the Falda della Guardiola hoard at Populonia.

Swords in mainland shapes

The "*antenne*" swords have a solid handle and the upper part variously decorated with two "*antenne*", which take on the form of two elaborate spirals, facing each other; the length is medium and the cross-section is angled at the centre, but there is not the strong midrib of the earlier types. A very fine example has long been known, found at Ploaghe. Bearing in mind the wide distribution including central-north Italy and central Europe to the north of the Alps, it was attributed to the Zürich type, dating to about the middle of VIII century BC. A second fragment which includes only the top of the handle and the attachment for the "*antenne*", was found amongst the bronzes from Sa Sedda 'e sos Carros at Oliena.

The simple base daggers (figs. 4.2, 7.1-4) (triangular, trapezoidal, ogival or intermediate shapes) or with short tang "*a linguetta*" daggers, with broad foliate blade and midrib, angulate in cross-section, are very frequent and widespread in the whole island, often enriched with decorations incised on the blade, generally in triangles drawn with oblique dashes. In those few happy cases in which the bone or ivory handle has survived - recently a very fine dagger with handle in elephant ivory was found in the well of S. Antine at Genoni - it reproduces exactly the forms of the solid handle dagger in bronze, with a convex upper part, concave base and moulded grip which fits well to the hand (Fig. 4.4).

The same half-moon grip can be seen above the shield of the bronze figurines of warriors, who together hold up, with their left hands, both the shield and the daggers: see, for example, the "*Miles Cornutus*" (Lilliu 1966, no. 96).

There exist various two-piece moulds for the production of dagger blades : one of them, of which both pieces survive, comes from the nuragic village of Monte Ruju of Ittireddu.

The "gamma-hilted" daggers (fig. 6.8-9), so called for the shape of the hilt which bends upwards to protect the fingers, are perhaps the most characteristic weapon of the nuragic world.

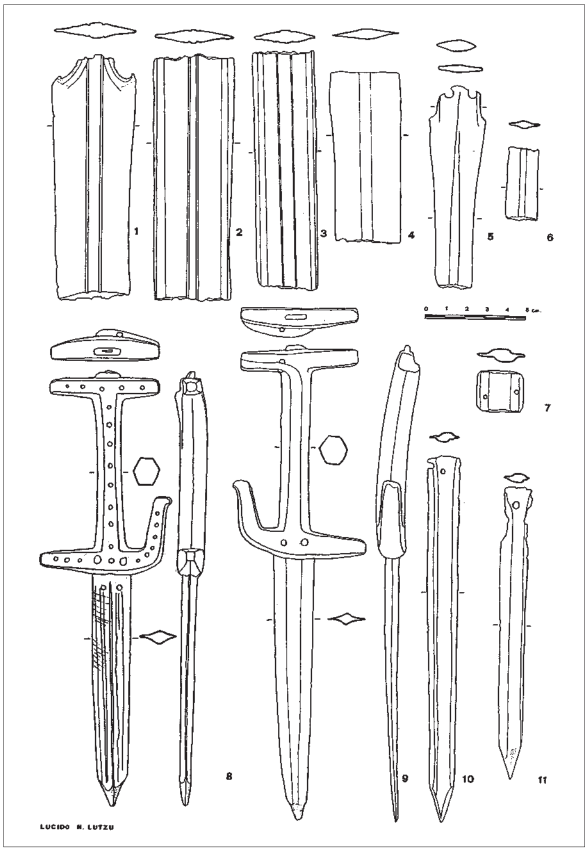

Fig. 6 – Bronzes from the cave-sanctuary Pirosu-Su Benatzu, Santadi: 1-4. fragments of swords Monte Sa Idda type; 5-6. short dagger Porto de Mòs type, and fragment of another dagger; 8-9. "gamma-hilted" daggers; 7, 10-11. daggers made of votive swords stumps *(after Usai L., Lo Schiavo 1995).*

They are known in all sizes, from small and miniature, such as the one found in the nuraghe Albucciu at Arzachena and of which was found a small mould in the nuraghe Logomake at Fonni, to bigger ones, to ones of natural size, which are real weapons. The two best preserved are those from the Pirosu-Su Benatzu cave at Santadi, are really lethal weapons, to whose heavy hilt is adapted a stump from a votive sword, sharpened for the purpose, or a *stiletto*, *i.e.* a short blade, rhomboid in cross-section, sometimes decorated, which must have been a short weapon for body-to-body fighting, not dissimilar to analogous mediaeval shapes.

This weapon can be attributed with a symbolism much superior to that of a simple item of weaponry, but in all probability was the sign of the young adult male reaching maturity within his community. See the representations ofgamma-hilted daggers on the breast of bronze figurines and on the “torch-holder” (“*torciere*”) of Tergu.

The pins with mobile heads are customarily called “*stilettoes*”; these too are documented in the left hand of warriors, such as the Warrior of the Pigorini museum.

Points and spearheads are widely documented and distributed, as full sized weapons, and as shapes hollowed into the two-piece casting moulds and portrayed in the hands of the bronze figurines. As full sized weapons, their dimensions and robustness strike us above all; both the spear and the head are characterized by a trunnion, octagonal in cross-section, often decorated at the end with ribbing alternating with a row of dots. A very recent discovery which would actually prove a weapons cult is that which occurred in the “*megaron*” temple of Su Romanzesu at Bitti, where six points and spear butts - three on each side - were found along the walls, as they fell when the wooden shaft, on which they would have been fixed, disappeared.

Several casting moulds for points and spear butts have been found.

As for the bronze figurines which carry spears, at least two, very different from each other, are known. The first was found in pit tomb no. 1 at Antas, in front of the big temple which in turn covers a Phoenician “high place”: the few ornamental objects found with the bronze figurine include “Allumiere-type” amber beads, a sort dating to XI century BC. The second is a splendid small bronze of a Head warrior, with helmet, cuirass and greaves - but barefoot, like all worshippers - and with a ram on a lead, from the sanctuary of Serra Niedda at Sorso (see Part IV, chapter 3, fig. 4.1.).

Very few bronze arrowheads have been found, when compared with the large number of archers depicted amongst the bronze figurines. A shape from Latium dating to the beginning of the Iron Age, with blade ogival in outline and trunnion socket with a spur, comes from Torralba. A few others, from a later age, with angular tip, triangular in cross-section, and trunnion with spur, were found at Ittireddu. It could be concluded that the arrowheads were not commonly produced in bronze, but in perishable materials, such as heat-hardened wood, or fish bones or bone.

2.2. Offensive and defensive weapons represnted on the bronze figurines

Of the weapons which follow, no life-size example has been found in archaeological deposts: on the other hand, not to refer to them would mean ignoring the exceptional testimony constituted by the bronze figurines already mentioned, and would also mean giving an incomplete idea of the panoply of the nuragic warrior. The diffusion of the nuragic costume of reproducing in miniature a vast range of artefacts, as well as monuments, animals, and human beings, must be borne in mind; as for weapons, therefore, as we have already seen in the case of the axes and the swords, there is not just the complete portrayal of the armed figurines, but also that of various single weapons, with talismanic and ritual value.

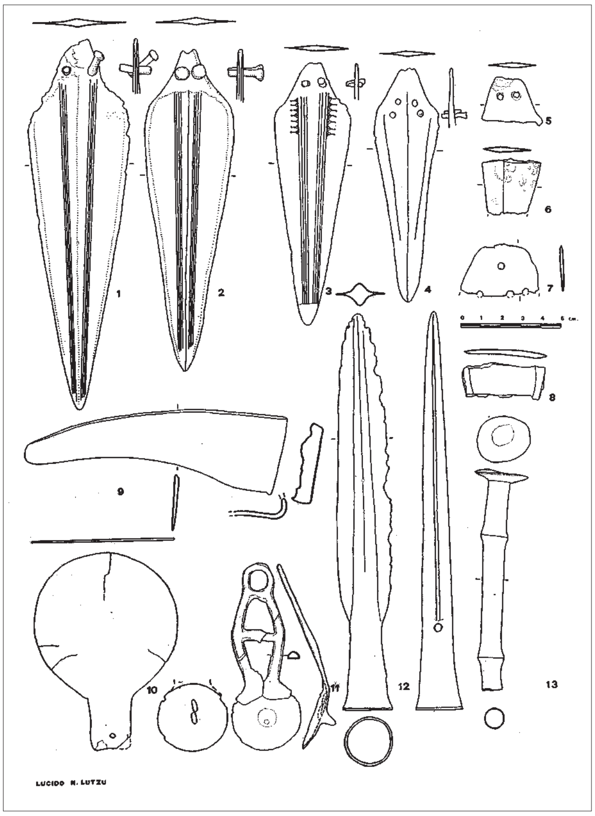

Fig. 7– Bronzes from the cave-sanctuary Pirosu-Su Benatzu, Santadi: 1-8. simple-base daggers; 9. knife; 10. mirror; 11. razor handle and stud; 12. spear heads; 13. spit handle (?)
(after Usai L., Lo Schiavo 1995).

So far no miniature representations of bows have been found, which in the bronzes of archers are either very big, as tall as the warrior himself, or small, like those brandished by the warriors from Sardara (Lilliu 1966, nos. 24-25), nor of quivers (not to be confused with the “small votive quivers”, for which see below). As for the “directional feathers”, *i.e.* the shaft terminating in a triangular feather, which some archers carry tight on their backs, next to the quiver (Lilliu 1966, no. 16), there are some examples, but they may be fragments of figirines and not isolated representations.

Not found either in their real form nor reproduced independently are the helmets, the cuirasses, the high shoulder plate, the heavy studded aprons, the greaves, and the bandoleers, while the footwear, represented in the form of sandals with high sole fixed with laces, in the case of the “priest” of Vulci (Lilliu 1966, no. 111), are not part of the apparel of a warrior, represented in the bronze figurines mainly as a worshipper and barefoot.

Shields, however, are reproduced independently and in miniature, and are found amongst the votive bronzes in sanctuaries: a particularly large example of round shield, bigger than the average carried by the bronze figurines, was found in the nuraghe-sanctuary Nurdole at Orani, in which the round surface is covered and reinforced with three discs and a grooved band, with a conical boss at the centre.

Another completely new form has now been documented amongst the material from Sa Sedda 'e Sos Carros at Oliena: it is a small miniature shield in bronze in the form of "oxhide", found at the entrance to room "*o*".

3. Objects of apparel and ornament

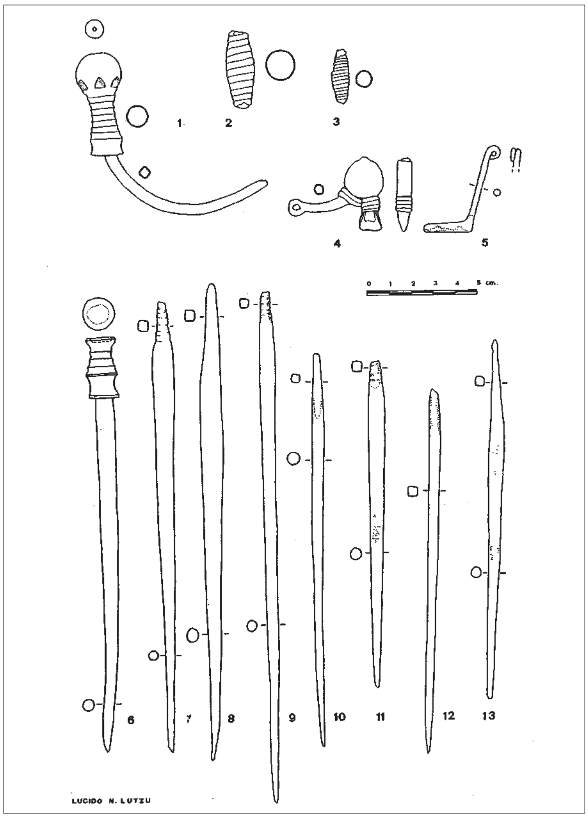

Fig. 8 – Bronzes from the cave-sanctuary Pirosu-Su Benatzu, Santadi: 1, 6-13. pins with mobile heads; 2-3. biconical spirals of wound bronze wire; 4. axe-shaped pendant; 5. fragment of *"à doble resorte" fibula (after Usai L., Lo Schiavo 1995).*

The pins (fig. 8.1,6-13) are the most commonly found object in every complex of bronzes, mainly votive; in sanctuaries, the pins were stuck between the stones of the structures as a ritual act, as happens for the daggers, which would confirm their use as weapons of offence, like the *stilettos*. On the other hand, their very wide distribution, even as a sporadic find, would indicate a generalized use as part of dressing.

The common characteristic of all the known shapes of pin is their exceptional robustness, perfectly designed to hold a group of folds, even of a heavy mantle in wool, felt or orbace (coarse wool-based fabric), fastened between the ribbed head, mobile or fixed, and a bead of bronze of various shapes, which served to hold the folds.

The pins with mobile heads are typically nuragic, and have a very robust shaft, circular in cross-section over its whole length except for the upper end, which is sometimes tapered or else square in cross-section: in both cases, it narrows sharply to allow the insertion of the globular head with ribbed neck, hollow inside (Fig. 8.1, 8-13).

The pins with fixed heads are a minority and there is nothing perfectly identical to them in the mainland typologies. What fastens the folds generally consists of biconical spiral of bronze wire (Fig. 8.2-3), but is sometimes a simple round or ribbed bead. When they are found still inserted on the shaft of the pin or in association with them, there is no doubt as to their use, but there may be some difficulty when a certain quantity of them is found in sanctuaries, when they may have formed a necklace, such as that from the nuraghe Mela Ruja in Sassari.

Objects of ornament are scarce in the nuragic world, which, it would appear, concentrated all its interest, practical, ritual and symbolic, on the cyclopean dimensions, complexity and refinement of the civil, funerary and religious monumental structures: it seems that there was no interest left for the production and use of ornaments.

With all due consideration for the gaps in archaeological documentation, it is an important fact that they not only did not produce ornaments of bronze or bone, which they could have very easily made with local raw materials and with techniques they long knew of (see Part II, chapter 2), but did not even acquire from abroad jewels in gold, silver or ivory, which were widespread in the Mycenaean and Cypriot worlds: the sole fragment of gold sheet, decorated with repoussé work, was discovered in the votive deposit of the Pirosu-Su Benatzu cave of Santadi, and the theory is that it is the fragment of a Cypriot funerary band and not a nuragic object of ornament. One of the most ancient Mycenaean artefacts, the small head in hippopotamus ivory from Mitza Purdia at Decimoputzu is an object which must have decorated a casket or other wooden object, and not a personal item. The amber beads and the beads of vitreous paste, found in funerary contexts, sanctuarial or votive, and the very few necklaces and collars in bronze are exceptions, but with reservations.

Of the necklaces made of bronze beads in the form of biconical spirals of twisted bronze wire or of simple round or ribbed beads, we have already said, when talking of the pins, that they constituted the device for fastening the folds. There are very rare occasions in which the composition of the necklace is certain and not thought to depend on modern assemblage: one of these is that from the S'Adde 'e S'Ulumu hoard at Usini, where the string of vegetal fibre holding together the beads of the necklace still survives. Another case is the one already mentioned, the necklace of bronze beads from the Attentu or Mela Ruja nuraghe of Sassari, found together with a necklace of amber beads.

An example of collars was found in the Ispinigoli cave at Dorgali which is made of rod, circular in cross-section, with little disc-like heads. Torques, or collars of twisted rod, although very frequent throughout European protohistory, are not present in Sardinia with the exception of the pre-nuragic example in gold, smooth and with heads flattened and folded outwards, from from Bingia 'e Monti at Gonnostramatza (see Archaeological file 5, p. 195).

As for the large collars with conical, hollow, decorated heads, inside which there was hooked a robust bronze rod, square or circular in cross-section, it is doubtful whether they were personal ornaments or a decoration destined to be hung or inserted into the neck of a sacrificial animal.

As for the bronze and silver bracelets (fig. 9.1-8), the same applies as was said about ornaments in general: they are in fact rare and very simple. The most widely documented form is the elliptical, open bracelet, with rounded heads and planoconvex in cross-section, only rarely decorated with incised little triangles. It would seem, from the contexts, that it was a form widespread in the Recent Bronze Age, which almost disappears in the Final Bronze Age, where it was apparently substituted by ring-shaped bracelets, with heads open and more or less superimposed over each other, circular in cross-section, or band-shaped, or ribbed-band-shaped. A small group of band-shaped bracelets decorated with incisions was found in a hut of the nuragic village of Serra Orrios at Dorgali, the theory being that it was a place of production.

What we have said above applies also, and perhaps more so, to the bronze finger rings (fig. 9. 9-15), made of rod or band-shaped, whole or with heads close or overlapping.

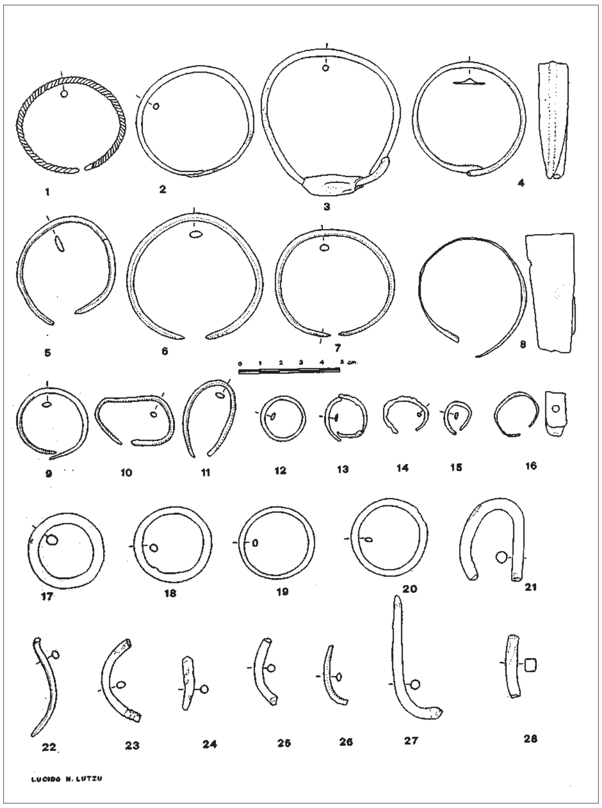

Fig. 9 – Bronzes from the cave-sanctuary Pirosu-Su Benatzu, Santadi: 1-20. arm-rings and finger-rings; 21-28. fragments of bronze rods *(after Usai L., Lo Schiavo 1995).*

As for some rare examples of ring, of a particular form and not very suitable for wearing on the finger, for instance hollow and with holes on the outside of its circumference from S'Adde 'e S'Ulumu at Usini (Sassari) and from other localities of the Nuoro area, or decorated with small discs incised with concentric rings, such as those from S. Maria in Paùlis and from S'Adde 'e S'Ulumu, or double, again from S'Adde 'e S'Ulumu, they may well not have been ornaments, but links for harnesses and bandoleers.

Although the number of *fibulae* found in Sardinia has greatly increased, now almost one hundred, the essential considerations, which have already been discussed several times, have not changed. In fact the *fibula* is an accessory and extraneous to nuragic apparel, in which the fastening of the clothes was performed with pins for the men and strings and laces for the women. All the *fibulae* known in Sardinia are clearly manufactured in Italy, and imported from there, and in a few cases from Cyprus (elbow *fibulae*) and from the Iberian peninsula (*"doble resorte" fibula,* Fig. 8.5)). The only shape which may have been produced locally, on the grounds that there is nothing identical amongst the similar types from central Italy, is that of the small *fibulae* with arch slightly lowered and rhomboid in cross-section, which have been found scattered in various localities of the island.

As for the chronological span, there are documented a few examples for each age, beginning from the Late Bronze Age up to the full Iron Age. Therefore, it must be concluded, on the basis of present knowledge, that the vast majority of *fibulae* come from Italy, either as a curiosity or in barter, or were used normally in the clothing of Tyrrhenian people with whom the nuragic people came in contact.

4. *Toilet* items of ritual value

On the basis of the documentation provided by the bronze figurines, it has been established that with very few exceptions (see Lilliu 1966, nos. 61 and 179, and perhaps also 130 and 131) nuragic men shaved regularly, and since only three or four razors are known, of various types and from various ages, we must conclude that shaving was performed with the blades of the daggers. It is well known the presence of the razor in male tombs on the mainland was a ritual fact rather than an element of the grave goods, and since in Sardinia individual burials are not known, this object is wholly alien to nuragic life and custom.

Only four razors are known, an early Villanovan double-edged razor, of the Marino type, from Nurra region, and a Vetulonia-type half-moon razor with the back an interrupted curve, dating to the second half of IX century, perhaps from Laerru. Another double-edged razor was found in the nuraghe S. Antine at Torralba and the fragment of a pierced small handle comes from the Pirosu-Su Benatzu cave at Santadi.

Also from Torralba comes one of the extremely rare examples in Sardinia of tweezers, another object more ritual than functional of the male outfit, and very common on the mainland.

Mirrors are objects which circulated widely in the Aegean and Cypriot worlds, these too certainly of ritual value. The mirrors with simple bases, namely with the handle fixed with small rivets directly to the flat bit, are documented in the west at Pantalica, where there is also one with a thin tang which is part of the flat bit. In Sardinia are known those of Cypriot inspiration, with a short flanged hilt which is part of the blade, round in shape, from the Pirosu-Su Benatzu cave of Santadi (fig. 7.10) and from a private collection, of unknown provenance.

A local type develops, probably inspired by these, with oval sheet and short tang, fastened to a pierced handle and worked with incisions with geometric and zoomorphic motifs; the most complete example comes from the nuraghe S. Pietro at Torpè; a pierced handle was found in the Costa Nighedda hoard of Oliena.

5. Ritual objects

It is well known that "buttons" did not have the function in the protohistoric world of fastening clothes, as is common today, a use which only began in the Middle Ages. Even in the Iron Age tombs, in which hundreds of "buttons" are found, they are really small decorative bosses sewn onto clothes or headwear. In Sardinia they have never been found in large quantities together, but only a few units at a time, sometimes in very elaborate forms, generally from sanctuaries or, in smaller numbers, in hoards. nuragic "buttons" appear in the tombs of central Italy, chiefly in the Villanovan world, from Populonia, Vetulonia, Tarquinia, Roselle, Lago dell'Accesa, and recently from tombs in the Iron Age *necropolis* of Pontecagnano in the Valle del Sarno, but always with one or two examples per apparel; real, practical use is therefore excluded. Apart from anything else, the basic shape is simple, conical or "*a tutulus*", but in the more elaborate examples animals and small schematic reproductions of nuraghi are represented on the top (see below for small models of nuraghi), not very practical for being inserted in buttonholes; it is likely that their value lay in being amulets, destined to the sanctuary and not to the personal apparel of the offerer.

The same applies to the pendants, whose typology is less varied, proof that they are not ornaments, but objects laden with symbolic content, some of which is still unknown to us.

We have already talked of the small flanged axes, with handles and counterweight (fig. 8.4), of the small double axes and the small gamma-hilted daggers in miniature; to these should now be added the "anchor"-shaped pendants, of uncertain interpretation.

The globule pendants are very simple shapes consisting of a small sphere with an eyelet for hanging, which stand out in the midst of the almost complete absence of ornaments from the nuragic civilization. Here too we must conclude that they are not personal ornaments, but, on the basis of the known comparisons, decorative elements for bronze tripods, imported or imitation, as in the case of the miniature bronze tripod from Santadi; whatever their purpose may have been, the number of these small objects is particularly low.

A triple-spiral pendant, with central boss, was found in tomb 2198 at Pontecagnano, together with a conical button with a bovine figurine (?), with small balls at the ends of its horns. That it is a nuragic product is assured not only by the fact that no similar objects exist on the mainland, but that it is instead a reproduction of a triple-spiral attachment for a basin or cauldron, clearly represented, one part for the whole thing, on account of its ritual value and for its content.

As far as we know, there exists one only sword-shaped pendant, from Antas (Fluminimaggiore, Cagliari).

The incomplete example from the nuraghee Albucciu at Arzachena was probably a wheel-shaped pendant or a wheel with votive value. Since it is neither the wheel of a miniature chariot, not the head of a pin, it could be a votive object.

The "small quivers" belong rather to the category of amulets, because they almost never have an eyelet or ring for hanging them up. Furthermore, there are both very small (4 or 5 cm), and very big (up to 14 cm). The traditional term of "quiver" is inappropriate, because it is in fact the sheath of a dagger, reproduced on the obverse, often in the smallest detail, while on the reverse it shows three "*stilettoes*", in which can often be recognized the outline of the globular or elaborate head of three pins. It is as if the symbol of the adult male, the dagger, and that of the combatant, the pins, are unified in one single amulet. Just to demonstrate, however, with what prudence all these hypotheses must be put forward, let us mention the presence, in the Forraxi Nioi hoard, of a dagger sheath in bronze, empty and without reproductions of pins on the back, almost full sized size (16.6 cm): again, it is an exceptional votive object, whereas the real functional object must have been made of leather.

Another object of at least double symbology is the stool/rattle. The stool, which originally must have been of wood or cork, with a round top and four legs with transverse supports, is reproduced in sandstone and placed in a prominent position in the Capanne delle Riunioni, as, for example, that of the village of Palmavera at Alghero, or of the village of Punta 'e Onossi at Florinas. The same stool is found reproduced both faithfully as a stool and also transformed into a rattle, with a long vertical shaft and with rings fixed on transverse supports, on which, in the better-preserved examples, are hung as pendants long rods, rectangular in cross-section, such as, for instance, the one from the Santa Maria in Paulis hoard at Usini.

We have already spoken above of the collars with hollow, conical, decorated heads, as possible ritual items, not as ornaments. Unfortunately the scarce documentation does not allow us to do more than hypothesize. In fact only a few incomplete examples are known: an isolated example from Nurra, another from Irgoli, a third from the Chilivani hoard, and a fourth from the Forraxi Nioi hoard. It is the presence in the Chilivani hoard, together with weapons and implements, which inclines us to interpret this object as not being a personal ornament.

The interpretation of the forked torch holders is agreed on unanimously as far as their ritual aspect is concerned, whereas their real function is much less clear. In fact, the very fine example from Tergu is decorated with representations of gamma-hilted daggers, executed with rows of incised dots and with schematic small faces in relief; the same object is held by human figurines in relief on the neck of the vases with moulded decoration from the sanctuary of S. Anastasia at Sardara. In the Museo Sanna in Sassari there is the torch holder from the Collezione Vallero, this too decorated with two small faces in relief.

Lilliu defines the celebrated "*Trofeo di Padria*" (Lilliu 1966, no. 258) as "*insegna oplolatrica*", or "the sign of the cult of weapons"; it was found at the beginning of XX century, apparently in a site known as "Sos Cunzados" or "Funtana Coberta", and therefore presumably in a well temple, in the territory of Padria, which reached the Museo Sanna by way of the Collezione Dessì. It is certainly a much more complicated composition than those documented in the nuragic sanctuaries of S. Vittoria at Serri and of Abini, Teti, where the figurines of the animals, which it was presumably hoped would be caught during the hunt, were fixed directly onto the points of the votive swords.

6. Vessels

Bronze vessels are rare everywhere in protohistory, not so much for the abundance, variety and high specialization of ceramic vessels, as for the technical complexity of the production in metal and its high value.

In nuragic Sardinia, where the absence of prestige items linked to the individual is evident, bronze vessels must certainly have had a particular sacral or symbolic value, and the tyopological variety of them has been established.

A rounded-bottomed bowl, with two small handles with two semicircular attachments decorated with concentric circles was found in the small hoard of Savadde at Lula, associated with an axe-adze ("*maleppeggio*"), with a pick with the ends broken, used as a hammer, and with a small truncated conical anvil: with all probability it still dates to within the Final Bronze Age. Another bowl is recorded and illustrated by Spano, found by him in the nuraghe Piscu of Suelli.

There is a greater number of examples of the category of jugs, all different from one another in shape and decoration. A typical askoid jug is the one from the nuraghe Ruju of Buddusò; its distinguishing characteristic is that the lower attachment of the handle is in the form of a Phoenician palmette, proof of the cohabiting of various cultural worlds, and of the coexistence and exchange of models. The object was manufactured with the lost-wax technique; in fact on the bottom is visible the joint of the disc for closing the form, inserted after the work to finish off the piece.

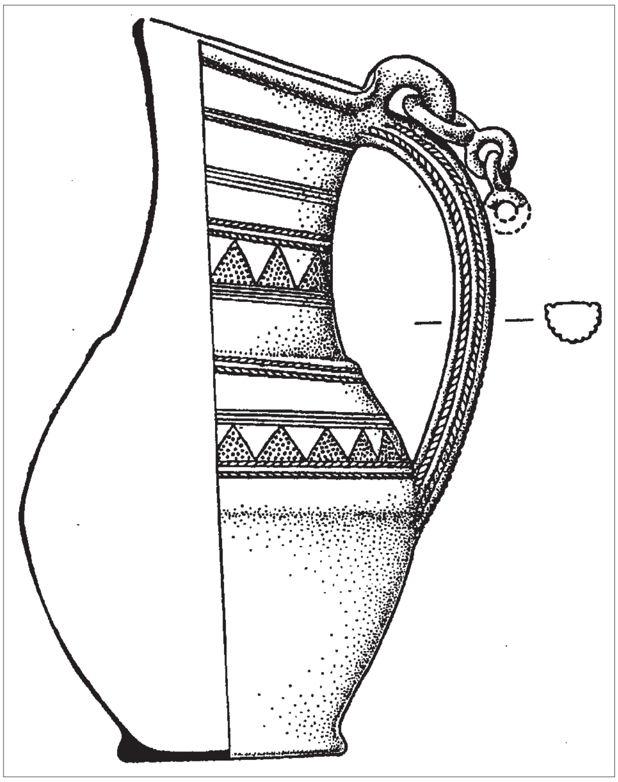

Fig. 10 – Askoid jug from S. Maria in Paulis, Usini hoard *(after Lo Schiavo 2000).*

From the S. Maria in Paulis hoard comes an oblique-mouthed jug, also made with the lost-wax process, as is shown by the massive thickness and the heavy moulded decorations: the presence of the decorative rings, inserted into the eyelet at the top of the handle, documents the application of the technique of the joint casting, not frequent at the time (fig. 10).

A second small oblique-mouthed jug, much smaller (11 cm) and decorated with herringbone pattern incised on the handle and on ribbing around the neck, has recently been identified amongst the material in the Museo Archeologico at Firenze, found at Vetulonia, but undoubtedly of nuragic production: the analogy with an impasto jug from the nuragic village of Teti, S'Urbale (Maggiani 2002) is even closer than with the example from S. Maria in Paulis.

A third example of the same type, without decoration, was found in the well of S. Antine at Genoni, with the end of a votive sword hooked to the handle, in such a way as to serve as a extension of the handle for drawing water (Bernardini, D'Oriano 2000).

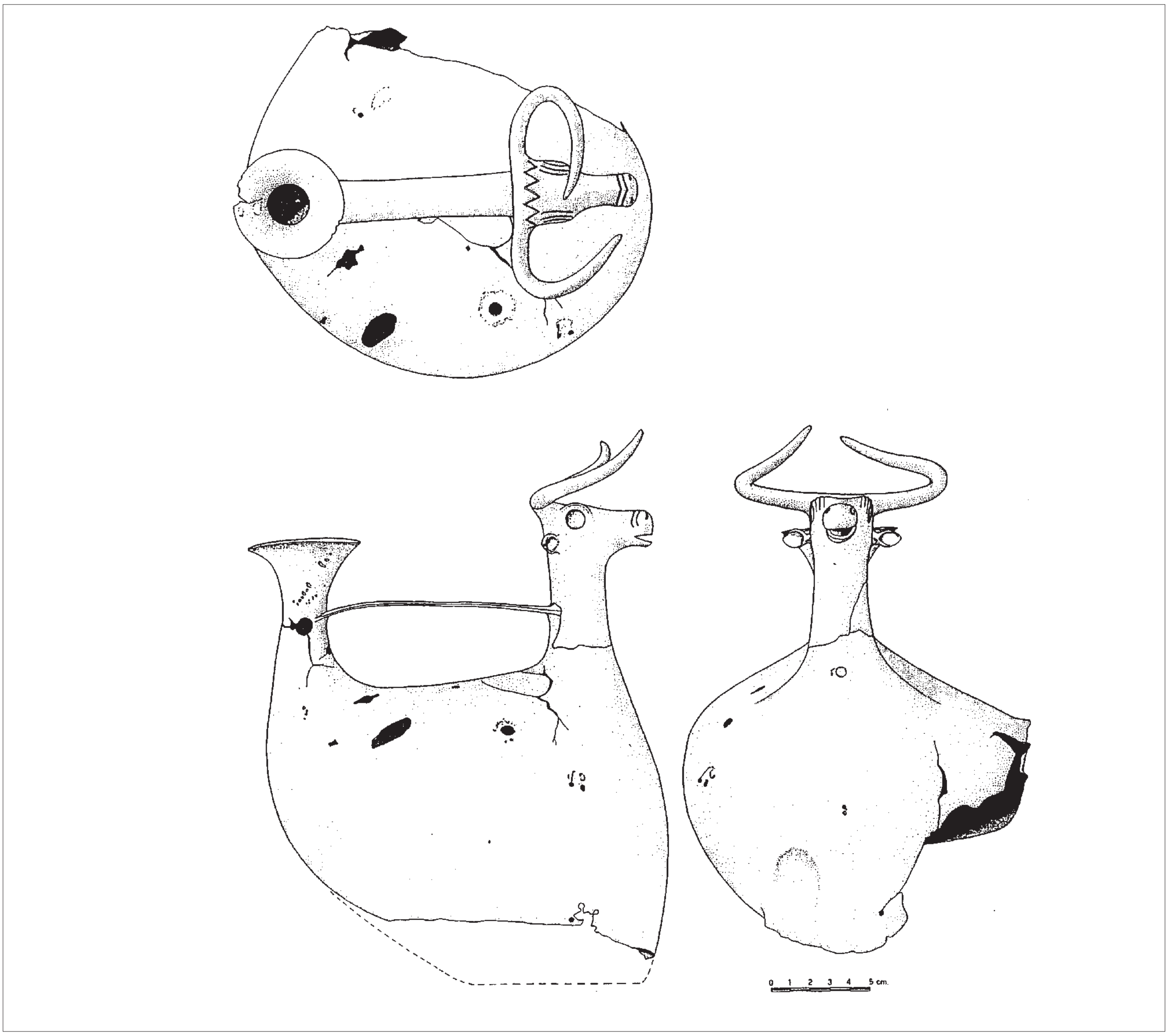

Fig. 11 – Oliena (NU), Sa Sedda ’e sos Carros : double necked *askos* with a bull protome *(after Lo Schiavo 2000).*

In the 1993 excavation of the *sacellum* of Sa Sedda 'e Sos Carros (Oliena, Nuoro) was found an exceptional example of *askos* with two necks, one with a splendid bull's head and the other expanded into a trumpet and with a sideways handle between the two. The bull's head and the other mouth were produced by casting, while the extreme thinness of the body was certainly achieved by hammering (E. Formigli). The casting, masterly in the case of the bull's head, was not so successful in the body, which presents a series of holes and gaps, some of which artisans in antiquity had tried to repair with patches.

To the category of the jugs is assimilated the “*pastiche*” from nuraghe Su Igante at Uri; the basin is in fact formed from the lower part of a bronze jug, cut in half to serve as a cup and decorated at the sides with two silver palmettes, namely two attachments from two other Phoenician jugs in silver sheet, whereas the foot of solid bronze belongs to a cup. It is therefore a composition of a local tinker whose purpose was to please a local Head. In his workshop various scraps would have been assembled, some of which were the remains of valuable vessels.

If “*situla*” (Latin word for “bucket”) is taken to mean the characteristic truncated conical sheet vessel with mobile handle, particularly widespread in central-northern Italy and central Europe between the Bronze and Iron Age, this form is as yet unknown in Sardinia. However, a small *situla*, a vessel with mobile handle, now lost, was found in the locality of Badde Ulumu, Sassari; two little handles with attachments decorated with couples of small balls remain; the neck is concave, with two deep parallel grooves at the base, and the body is rounded: overall, it does not belong to any of the types of pottery found on the island. The item was produced with the lost-wax process.

A fragment of an orientalizing *situletta*, with the characteristic decoration in bands and with leaf motifs, was found in the nuraghe Albucciu at Arzachena.

The fragments of a vessel with cylindrical body decorated with thin parallel grooves, produced in bronze with the lost-wax process, have been attributed by Taramelli to a "cist" (better *pyxis*), a form not otherwise known in Sardinia and documented solely in the Monte Sa Idda hoard.

Cauldrons and basins, with and without attachments, are known and widespread also outside Sardinia. A very fine example of complete cauldron, biconic in shape, with two quadruple-spiral attachments and handles perfectly preserved, found at Cala Gonone and published in 1963 by Margaret Guido, was for decades believed to be a modern object, on account of the excellent state of its preservation. A similar cauldron, but crumpled, even though it still has the quadruple-spiral handle attachment (for this reason it has been identified as being nuragic) was found amongst the material from the hoard of S. Francesco at Bologna, while an identical attachment comes from the Forraxi Nioi hoard, at Nuragus. A third cauldron, semicircular in shape has been recovered, crushed between the stones of a niche of room "*i*" at Sa Sedda 'e sos Carros.

The restoration of the cauldron from Sa Sedda 'e sos Carros (height 17.5 cm, maximum diameter 40 cm; diameter of mouth 34.5 cm) has confirmed what was already evident from observation of the piece from Cala Gonone, that they are vessels formed by steadily hammering a single disc of solid bronze, probably inside a wooden mould or at least on the base of something conveniently padded, with a small hammer with rounded point (see what said above about "rising hammers").

Triple-spiral attachments, both on their own and attached to a basin with cylindrical walls and rounded bottom have been found in the territory of Oliena, one amongst the bronzes of Sa Sedda 'e sos Carros, the other in the cave of Su Benticheddu. This could explain the reproduction, mentioned above, of the triple-spiral attachment as a pendant.

Other forms of attachment are known, quadruple-spiralled - a fragment was found in a tomb at Pontecagnano - triple-spiralled and double-spiralled, with small square, ribbed plaques, with a ring with small balls at the base, with ring with ribbed reinforcement, etc.

A small basin, sphere-like in cross-section, whose attachments do not survive, comes from the excavations of Spano in the nuraghe Piscu at Suelli, and others are cited in the bibliography, from Spano onwards (see Part IV, chapter 4.3).

7. Bronze figurines

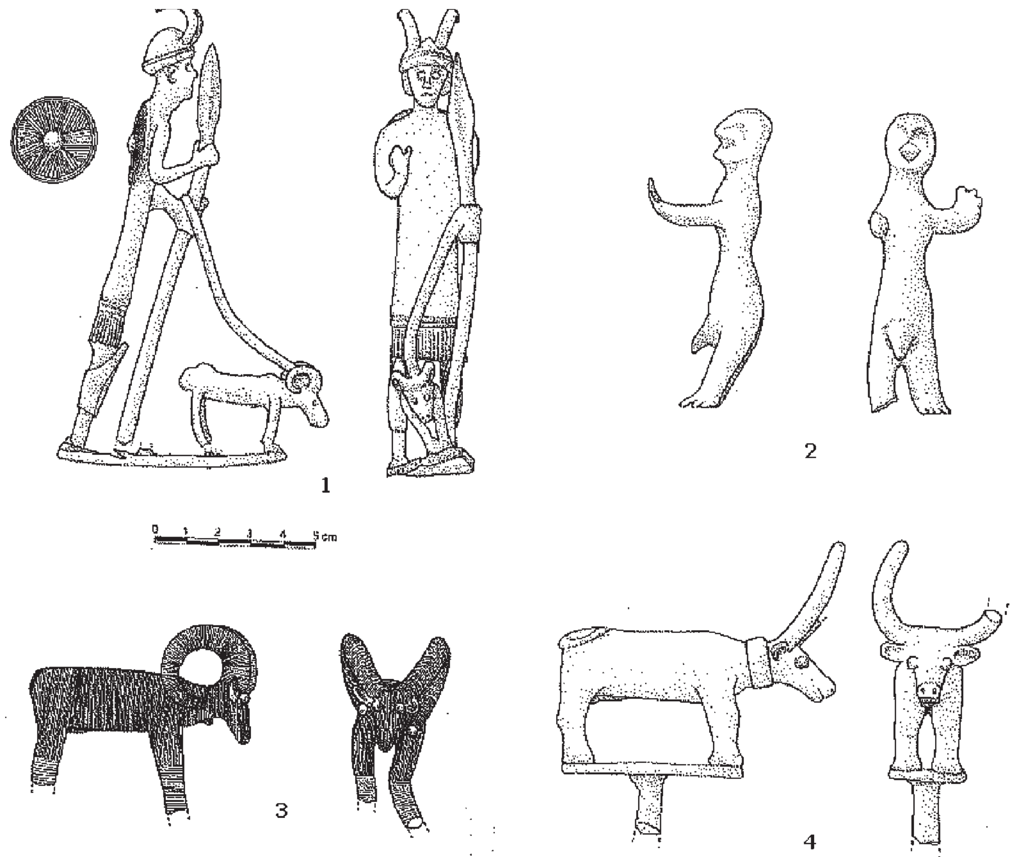

Fig. 12 - Bronze figurines frm Sorso, Serra Niedda: 1. King-Sheperd leading a ram by a rope; 2. Naked worshipper; 3. Muflon; 4. Ox with a collar *(after Lo Schiavo 2003).*

The variety of subjects portrayed in the nuragic bronze figurines is so large and is being enriched so much with continual excavations and discoveries, that it deserves having a thorough study dedicated to it soon, to update the magisterial work of Giovanni Lilliu (1966).

Here we shall just briefly mention the categories represented, with the scope of illustrating the breadth of the subjects and the expressiveness of the portrayals. In addition to their symbolic and narrative value, the mastery reached in the use of the lost-wax process and the variety of the themes remains undeniable, and places nuragic production at the very peak of originality, richness and interest for the whole Bronze Age, and not only in the Mediterranean.

7.1. Anthropomorphic figurines

There are many categories of anthropomorphic figurines portrayed by the bronzes, in what is presumably a "hierarchic" order: tribal heads, warriors wielding swords, spear-bearers, archers (see Part IV, chapter 3.5), centaurs, dignitaries, wrestlers, carriers of sticks, men with oxen, worshippers (see Part IV, chapter 3.5, fig. 4.2) and offerers, cloaked women, women with child or male figurines in their lap, women worshippers and offerers, other women, etc.

The King-Shepherd, carrying a spear and with a ram on a lead (see Part IV, chapter 3.5 fig. 4.1), found in the nuragic sanctuary of Serra Niedda, Sorso, is an *unicum* not only for nuragic bronze production, but also for all Mediterranean iconography of the Final Bronze and early Iron Age.

7.2. Zoomorphic figurines

Amongst the zoomorphic figurines documented there are domestic animals : oxen (see Part IV, chapter 3, fig. 12.4), rams, moufflons, dogs, cocks, assorted birds, and wild animals: deer, wild boar, foxes, weasel and ferrets, etc.

Oustanding are the big moufflon from the sacred well of Camposanto di Olmedo and the smaller one, but of equally exceptional quality, from the sanctuary of Serra Niedda at Sorso (see Part IV, Chapter. 3, fig. 4.3). Not only is the balanced proportion of the figurine quite admirable, but also the decorative refinement of the rendering of the hair on the back, on the hooves, and the thick transversal furrows of the great curved horns. It does not seem exaggerated to emphasize that in these two sculptures we no longer have examples of artisan metal-working, but documents of high artistic quality.

7.3. Furniture and equipment

Amongst the furniture should be mentioned: wooden cupboards, stools, caskets; jars with X-shaped handles, assorted vessels; baskets, ("*corbule*"), panniers. Amongst the implements: assorted axes.

7.4. Land and sea transport: waggons and ships

For land transport, there are two-wheeled wagons, four-wheeled wagons and sledges. There exists only one fragment consisting of a four-spoked wheel, with an axle at the centre. It is not possible to hypothesize what object it was part of, but it can be excluded that it was a pin.

Very different is the position of the boats. Commonly called "little boats", they are often and even recently considered to be lamps, on account of the system for suspending them, which was always perfect, it has generally been underestimated what an exceptional document they constitute for a very wide field of study: naval carpentry, routes, trade, social and economic organization, the value as a token of prestige and of power which they constitute and which alone can explain their survival in places and ages which can be very remote compared with those of other bronzes.

7.5. The nuragic boats

The shapes of the craft. There is no reason for not thinking that the small bronze boats were exactly what they seem to be, namely miniature reproductions of craft, sufficiently faithful to the original as to enable us to recognize in the flat-bottomed craft the "*sutiles naves*" of the most archaic shapes, in the round elongated craft the "racing" boats more suitable for rapid journeys, particularly if furnished with a mast and therefore also with a system for hoisting a sail, and in the round shorter and deeper craft, perhaps with cabin and double deck, the commercial, cargo ships. On the technical considerations of naval engineering, highly important because discussed according to chronological sequence, and on the specific interpretation of the various elements, there are now many articles by specialists, the fruit of years of study and comparison between all the portrayals of ships in the ancient Mediterranean. It must be said that in Cyprus, already from the Early Bronze Age onwards, ships were reproduced both in terracotta and bronze, as they also were in Minoan and Mycenaean frescoes and vases.

On the other hand, the hundred or so small reproductions of bronze boats, of various shapes and sizes, but all ending with an animal head on the prow, found widely on the island and in a small number also in Etruria and Lazio, constitute unquestionable data as to how the nuragic peoples, in reality or symbolically, had knowledge of the sea and of navigation.

It does not surprise us (in fact the opposite would surprise us) that the nuragic peoples, at the apogee of their civilization, chose the ship as symbol of their familiarity with the sea. The discovery of nuragic material in Crete, at Carthage, on Lipari and on the mainland can no longer be explained as the document of a commercial activity in which nuragic Sardinia was the passive producer. On the contrary, quite an opposite interpretation has been already put forward, that Iberian artefacts were acquired at source, from the far west on the Atlantic coasts, then brought to

Sardinia, and also perhaps to Sicily, certainly to the mainland and perhaps to the eastern Mediterranean too, as far as Cyprus.

On the basis of the shapes, the following can be distinguished:

a. "heart-shaped" boats, with a hull rounded or slightly ogival at one end and with a horizontal "handle" at the other end, terminating with a zoomorphic protome (fig. 13); these are the only ones for which the reference to a real boat is less direct;

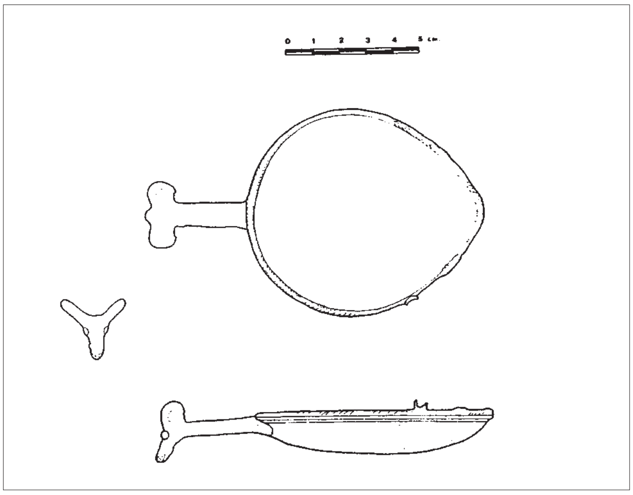

Fig. 13 – Heart-shaped miniature bronze boat from the cave-sanctuary Pirosu-Su Benatzu, Santadi *(after Usai L., Lo Schiavo 1995).*

b. flat-bottomed boats: the ships for tacking about;

c. flat-bottomed boats, with sides slightly rounded: boat sfor coastal navigation;

d. slender and elongated boats with rounded bottoms: racing boats;

e. short, deep boats with rounded bottoms: cargo boats.

Let us mention a unique example, complete and exceptional, from the nuraghe Badde Rùpida at Padria, known as the "the ship of the Sun King" ("*la navicella del Re Sole*", Fig. 14) on account of its considerable size (38 cm) and because of the excellent state of preservation: only the prow protome, the little birds which decorated the four corners of the topsail and three of the four stanchions placed to the sides of the bulwarks are missing. The hull is very large and the capacity seems to be increased by the two high, pierced bulwarks, between which it is easy to imagine a considerable volume of cargo carefully packed; on the mast is hinged a hollow cylinder on which is portrayed the square platform of the topsail, from which rise the terminal part of the mast, with the ring for hanging it all up.

7.6. Monuments

In view of the concepts expressed above, namely that everything of importance in the nuragic world was reproduced in miniature and consecrated to the divinity, the most important monuments could not be missing: the simple nuraghi, the complex nuraghi and the temples.

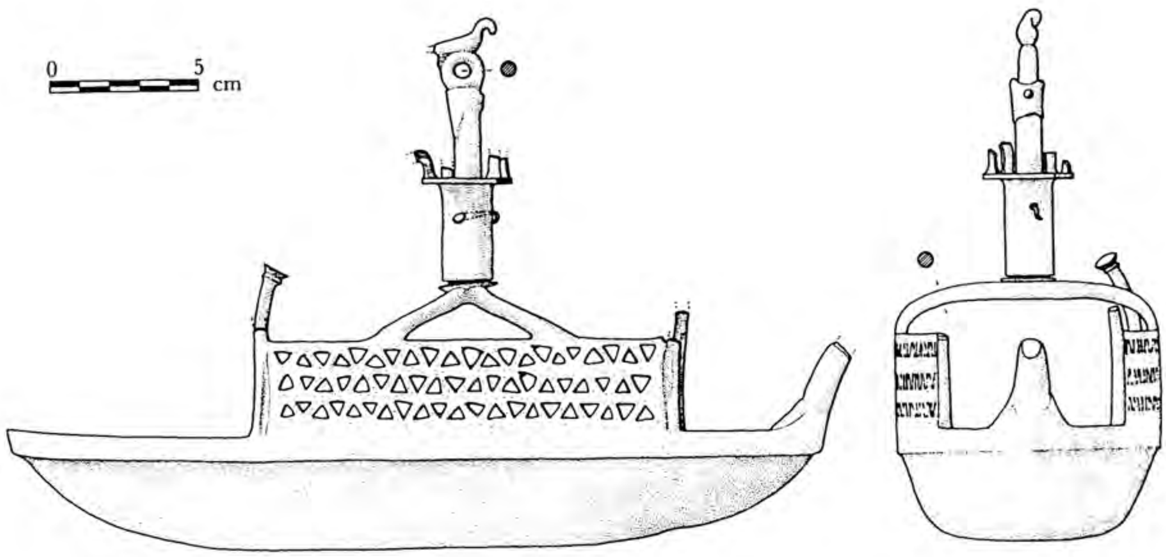

Fig. 14 - Bronze boat, so-called "Sun-King boat" from nuraghe Badde Rupida, Padria (Sassari) *(after Lo Schiavo 2000b).*

Many nuraghi, really miniature, are represented on the top of the "buttons".

The most beautiful small bronze model of a nuraghe, perfectly preserved, including the channels for the distribution of the molten metal and the casting funnel, evidently used for the attachment to the stones of the sanctuary, is that found in the sacred well of Camposanto at Olmedo; it represents a four-tower nuraghe, with the central tower twice as high as the four lateral ones.

BIBLIOGRAPHICAL NOTE

The content of this chapter is a synthesis of Lo Schiavo 2000a, pp. 48-122. The bibliography mentioned here, in addition to Lilliu 1996, which fundamental for the bronze figurines, refers to the updating and to the source of the figures.

For specific aspects or class of objects, see above, pp. 280-85, 294, 297-298.

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APPENDIX III

Hoards containing tools in nuragic Sardinia

Fulvia Lo Schiavo

See Lo Schiavo F. 2004, Produzione, distribuzione e conservazione degli strumenti da lavoro nella Sardegna nuragica, in *L'artisanat métallurgique dans les sociétés anciennes en Méditerranée occidentale. Techniques, lieux et formes de production*, Ravello, 4-6 maggio 2004, 229-261.

Ia - Hoards reported from 1850 to 1934 (in Birocchi 1934)

[Hoards containing only ingots (A), only axes (B), ingots and other objects (C), other objects without ingots (D)]

1. Barumini (?) (Cagliari), Nuracc'e Deu [Birocchi 6C]. Spano 1870, 27.

2. Baunei (Nuoro), S. Pietro [Birocchi 6D]. Spano 1871, 9.

3. Burgos (Sassari), Ortiocoro [Birocchi 25C]. Spano 1870, 29.

4. Decimoputzu (Cagliari), Monte Sa Idda [Birocchi 20C]. Taramelli 1915, 89-97; 1921, 5-98.

5. Ittireddu (Sassari), Olostiu [Birocchi 13A]. Spano 1872, 14-15.

6. Lotzorai (Nuoro) [Birocchi 15B]. Taramelli 1921, 496-8.

7. Meana Sardo (Nuoro) [Birocchi 17D]. Spano 1875, 38; 1876, 13; Lo Schiavo 2000, 157-8, no. 24.

8. Muravera (Cagliari), S. Priamo [Birocchi 21D]. Spano 1874, 9; Pigorini 1875, 39.

9. Nuchis (Sassari) [Birocchi 23B]. Spano 1876, 17; Pinza 1901, 148.

10. Nule (Sassari), nuraghe Sisine [Birocchi 22B]. Taramelli 1927, 159-165; 1928, 399-400; Lo Schiavo 1992, 240-7 figs.1-3.

11. Nuragus (Nuoro), Forraxi Nioi [Birocchi 10A]. Fiorelli 1882, 308-311; Pinza 1901, 156-162; Taramelli 1921, 78-79.

12. Nuragus (Nuoro), Serra Ilixi [Birocchi 34A]. Spano 1857, 94; Pigorini 1904, 91; Willers 1924, [36, 10].

13. Oliena (Nuoro), Guttidai [Birocchi 11D]. Spano 1876, 14-15, pl. no. 6,7,9,13,14; Pinza 1901, 148; Lo Schiavo 1980, 13, pl. II,2.

14. Oliena (Nuoro) [Birocchi 24B]. Taramelli 1923, 154-157.

15. Ozieri (Sassari), Chilivani [Birocchi 8D]. Taramelli 1922, 277; 1923, 150-164; Lo Schiavo 1988, 77-90.

16. Ozieri (Sassari), Sassu [Birocchi 33B]. Spano 1873, 24-25; Pigorini 1875, 40.

17. Sarroch (Cagliari), Monte Arrubiu [Birocchi 18C]. Taramelli 1926, 446-456; Lo Schiavo 1981, fig. 359.

18. Sarule (Nuoro) [Birocchi 32C]. Spano 1876, 16; Pinza 1901, 147, 187.

19. Silanus/Lei (Nuoro), La Maddalena [Birocchi 16D/14C]. Spano 1876, 13-14, pl. no. 2,3,5,12,15; Pais 1884, 125; Vivanet 1889, 171; 1890, 334-336; Willers 1924, 259; Lo Schiavo 1979, 81-2, no. 42-47, pl. VII, 1-6.

20. Sorso (Sassari), Monte Cau [Birocchi 19D]. Pais 1880, 409-410; 1881, 290.

21. Sorso (Sassari) [Birocchi 38D]. Taramelli, 1906, 419; Pigorini 1906, 291.

22. Tadasuni [(Oristano)] [Birocchi 39C]. Taramelli 1921, 62-63, fig.89; 1931, 20, 25, 26].

23. Tula (not "Ploaghe") (Sassari), near Bisarcio [Birocchi 28D] "nuraghe Badu 'e Trovu" [Birocchi 43D]. Spano 1872, 28-29; Pigorini 1875, 41 ("Tula "); Pinza 1901, 148 ("Ploaghe"), 150 ("Tula ").

24. Urzulei (Nuoro), Sullulè [Birocchi 44D]. Spano 1873, 32.

25. Usini (Sassari), S. Maria in Paùlis [Birocchi 31D]. Von Bissing 1928; Macnamara, Ridgway, Serra Ridgway 1984.

26. Villasalto (Cagliari) [Birocchi 46D]. Spano 1873, 8.

Ib - Hoards reported from 1850 to 1934 (added to Birocchi)

27. Olbia (Sassari), nuraghe [D] Taramelli 1904, 172; Panedda 1954, 20-21; Lo Schiavo 1996, 66-67.

28. Samugheo (Cagliari) [C] Taramelli 1903, 488-490.

29. Tempio Pausania (Sassari), Paludu [D] Tamponi 1894, 328-329; Lo Schiavo 1996, 66.

II - Hoards reported from 1934 to 1998

B - Hoards consisting only of axes

30. Ilbono (Nuoro) Lo Schiavo 1992, 246-8, fig. 4.

31. Ossi (Sassari), nuraghe Sa Mandra 'e Sa Giua. Ferrarese Ceruti 1985, 52; Lo Schiavo 1986b, 87, fig. 114.

C - Hoards consisting of axes and other bronze objects, with oxhide and planoconvex ingot fragments

32. Alghero (Sassari), nuraghe Flumenelongu. Lo Schiavo 1976.

33. Bonnanaro (Sassari), Funtana Janna. Lo Schiavo 1981, fig. 297; 1982, 275, fig. 5; 2000, 169-170, no. 33; Begemann *et al.* 2001.

34. Oliena (Nuoro), Su Benticheddu. Lo Schiavo 1978.

35. Ossi (Sassari), Sa Mandra 'e Sa Giua. Ferrarese Ceruti 1985, 52; Lo Schiavo 1991, 57, fig. 45; 2000, 112.

36. Pattada (Sassari), Sedda Ottinnera. Lo Schiavo 1998, 100-5, figs. 2-6; Lo Schiavo 1999, 503-5, figg. 5-6; Begemann *et al.* 2001.

37. Terralba (Cagliari), S'Arrideli. Lilliu 1953.

38. Torralba (Sassari), S. Antine, hut I. Lo Schiavo 1988.

D - Hoards consisting in bronze objects, without ingots or ingot fragments

39. Chiaramonti (Sassari), nuraghe Su Cobelciu. Lo Schiavo 1991, 56, fig. 44; 2000, 138-9, fig. a p.138.

40. Lula (Nuoro), Savadde. Levi, unpublished notes; Lo Schiavo 1994, 72-76, fig. 9.

41. Luogosanto (Sassari), Monti Casteddu. Selis 1969, 25-26; Lo Schiavo 1996, 67.

42. Olbia (Sassari), unknown prov. Lo Schiavo 1996, 68 sgg., figs. 9.4-8.

43. Sardara (Cagliari), S. Anastasìa, hut 5. Ugas, Usai L. 1987, 175-9, no. 81-113, pl. IX.

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6.
SARDINIA AND TIN CIRCULATION

1. Tin in the Mediterranean area : history and geology

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1.1. Introduction

The *tin mistery*, as it was defined by Bob Maddin in Matsue (1998) is still in discussion, and many authors had contributed to the debate long before that date. The terms of the question are rather clear, and the geological side seems to be sufficiently ascertained. Actually, the distribution of tin-bearing mineralisation in the Mediterranean area is well outlined, and new entries are not be expected, because of today's known geological constraints.

A new event brings additional substance to the discussion: the recent find of tin scraps in a nuragic sanctuary in Sardinia (S'Arcu 'e is Forros: Fadda 2003; Lo Schiavo 2003; Valera, Valera 2003; Valera *et al.* 2002). Particular interest is provided by the arising suggestion of tin supply from the island itself, since tin bearing mineralisation occurrences are mentioned in the literature (Penhallurick 1986), and a foundry activity is supposed to have developed in this sanctuary area. Therefore the question is open, and we are going to discuss the data and their possible contribution to the "tin mistery" debate in the light of the present, and especially the historical, knowledge.

1.2. The Sardinian tin ore deposits

It is convenient to clarify the reality of the tin occurrences in Sardinia. Most of them are known for their strict mineralogical, rather than economic, value. In the past century a moderate interest was only devoted to two deposits, both in the SW of the island: Perdu Cara (Monte Linas) and Canali Serci (Villacidro). They belong to a rich metallogenic province, well known for its long lasting production of various commodities, mainly lead, zinc, silver, fluorite, and barite, but also for the presence of molybdenum, cobalt, and copper.

Perdu Cara (or Sedda Planuceddu, Monte Linas: Zuffardi 1958; Biste 1979; Valera *et al.*, this vol., chapter 1) is a NE-SW trending vein mineralisation, 10-100 cm thick, 1500 m in length, consisting of quartz-cassiterite in the northern section, changing to quartz-arsenopyrite in the south. Cassiterite was irregularly dispersed in quartz, and also in the wall rock for few decimetres. Some small trenches and pits of indecipherable age were visible before a recent exploitation activity, which totally exhausted the deposit. Two outstanding questions arise: was BA technology adequate to the Perdu Cara primary deposit exploitation ? Was a cassiterite placer concentration possible in the local morphology ? The answer to the first question is negative, because of the difficult composition of the vein (cassiterite specks scattered in massive quartz). The second question is open: the formation of small concentrations was certainly possible in a downstream creek, and if so they were totally exploited, because no traces are visible now.

Canali Serci (Piepoli, Collari 1936; Biste 1979) is a quartz-siderite lode with sphalerite, galena, pyrite, marcasite, pyrrhotite, cassiterite, and rare stannite and tetrahedrite. Minor cassiterite is finely intergrown with major zinc and lead sulfides, and it is only visible under microscope. Again the same questions arise: was a primitive tin metallurgy viable for such a primary ore association ? Was a cassiterite placer concentration possible in the local morphology ? Both answers are negative, because only a modern flotation process can separate and concentrate each ore mineral from such a primary mixture, and only a weak geochemical increase may be expected in the stream sediments derived from the erosion of the Canali Serci lode.

In conclusion, we may say that the only hypothetical possibility, though very weak, of a Sardinian tin beneficiation was offered by an eventual small "placer" from the Perdu Cara mineralisation.

1.3. The new Sardinian tin scraps

The new tin fragments, weighing some tens of grams each, were found in association with scraps of Cu-Pb alloys, suggesting the existence of a local metallurgical activity, referred to the LBA (Fadda, 2003). Some fragments were analised to detect the Pb content and lead isotope ratios. The results are given in Table 1.

Table 1.
S'Arcu 'e is Forros: Pb content and Pb isotope ratios in tin and copper-lead alloy scraps

Sample	Pb %	208/206 Pb	207/206 Pb	206/204 Pb
Tin scrap*	0,3	2,05735	0,847325	18,5195
Cu-Pb alloys**				
AVR 123	2,5	2,127	0,868	17,969
AVR 124	0,17	2,121	0,867	17,949
AVR 125	5,4	2,116	0,875	17,764
AVR 126	3,5	2,101	0,875	17,647

[*Analytical data: E. Pernicka, 2000, pers. comm.]; [**Analytical data by the authors]

The analyses of lead isotope ratios in one of the tin scraps were kindly performed by Prof. E. Pernicka, and the results clearly show the presence of a foreign lead. In fact, if we compare the lead isotope ratios of the tin scrap (fig. 3) with those of the lead coming from the two families of Sardinian galenas (fig. 1 and fig. 2; identified as Cambrian hosted and Hercynian vein-hosted: Valera *et al.* 2002), it is absolutely clear that the lead isotope ratios from the tin scrap fall far apart from the fields of the two families, whereas the lead isotope ratios of the Cu-Pb alloys are well consistent with the field of the Cambrian hosted galenas, once more according to the trend of the nuragic leads.

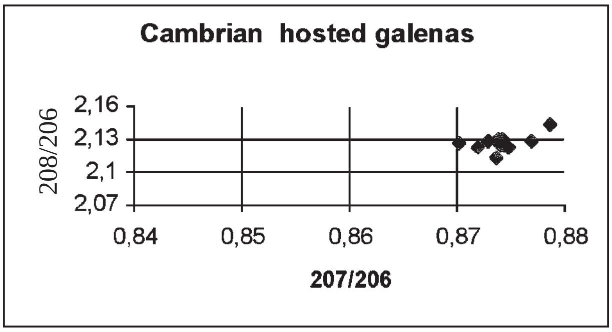

Fig. 1 - The lead isotope ratios of sardini Cambrian hosted galenas *(modified from Valera et al. 2002).*

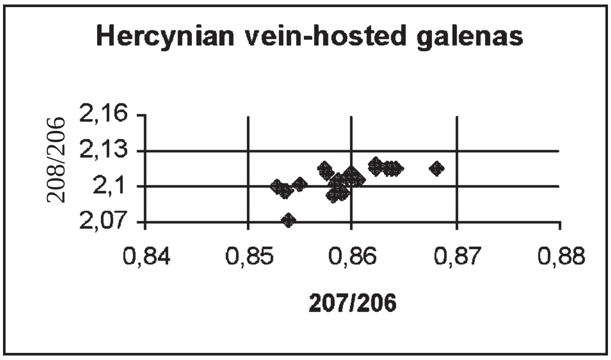

Fig. 2 - The leas isotope ratios of Hercynian vein hosted galenas *(modified from Valera et al. 2002).*

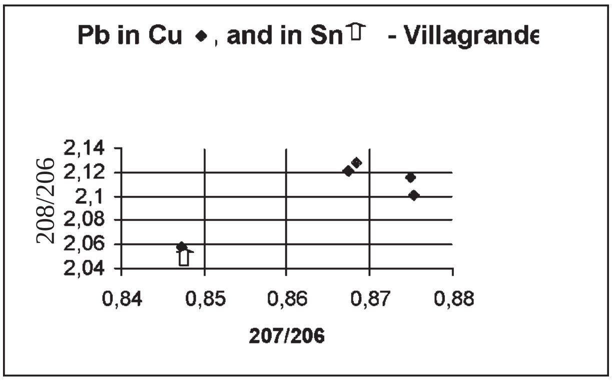

Fig. 3 - The lead isotope ratios of the metallic scraps of Villagrande.

We also analised the trace elements in different tin scraps, and the results show a rather homogeneous composition, with the exception of the Pb behaviour (fig. 4a-e: the element numbers correspond to the list in table 2; see Part II, chapter 2).

The fluctuation of the lead values can be explained by a variable addition of, or pollution by, the same metal during the metallurgic process. As cassiterite samples were not found in the sanctuary, and because of the foreign lead isotope ratios of the analysed tin scrap, we assume that its metallurgy was developed in its mother land. The actual challenge is the identification of such a mother land, a major concern for all scholars facing similar problems (Maddin 1998). In our case, a simple geological approach suggested the following procedure:

* check of the trace element patterns obtained by the analyses of different tin scraps;

* choice of a couple of elements typical and common to the trace element patterns. The selected couple must behave in a similar way in the different scraps, so that the two elements can be defined as markers. Since the Cd-Sb couple in the Villagrande tin scraps is in good agreement with such requirements, we decided to use it as the marker couple for our case;

* comparison between the trace element patterns of the Villagrande tin scraps and the trace element patterns of cassiterites from different metallogenic provinces. Only for a preliminary outline, we analysed some available samples of cassiterites from Sardinia, Tuscany, Spain, Erzgebirge, Nigeria, and China. Nigeria and China are of course only for external reference, whereas the other districts could not be discarded a priori as options for the origin of the Villagrande tin. The comparison between metal tin and tin oxide is reasonable, if we can exclude the risk of pollution by, or intentional addition of the selected markers during the metallurgic refining process. Actually the refining process should be characterised by a more or less appreciable loss of most of the trace elements contained in the starting cassiterites, rather than a concentration;

* the last step of our procedure is the possible recognition of a metallogenic province, whose cassiterites show a similar outline as per the selected markers.

The results of this preliminary approach are rather interesting. Each analised cassiterite showed a fairly distinct “personality” with peculiar trace element patterns. However only one sufficiently reliable conclusion can be drawn: *i.e.*, the lack of any link between the Villagrande tin and the Sardinian cassiterites. In fact the Cd-Sb couple has very low values in the Sardinian (Perdu Cara) cassiterites, and the same result is shown by the other cassiterites (Erzgebirge, Nigeria, Spain, China), except for the Monte Valerio sample (Fig. 5a-i, tab. 3).

In conclusion, the above data bring additional support to the exclusion of Sardinia as mother land of the Villagrande tin. The few samples of other districts we analysed seem to point rather to Tuscany, but the problem is completely open. We need a larger population of samples from the considered tin deposits, but also have to extend the sampling procedure to as many deposits as possible, which might be representative, belonging to the important tin metallogenic provinces of Erzgebirge, Hiberian Peninsula, Brittany, and Cornwall.

1.4. Early tin in Sardinia

Bronze Age metallurgy in Sardinia is well known, and its high level of activity is upheld by a great deal of products found in several sites and hoards. The first bronze artifacts appear in the so called “Bonnannaro Culture” (XVIII-XVII century BC: BA Phase I, Lo Schiavo 1997). Imported models are dominant at the beginning, rapidly followed by the birth and expansion of a local metallurgic industry. Copper, lead, and minor silver were already known in the previous Neolithic Ozieri culture, which is considered the first Sardinian metal-using culture, spanning from the end of the 4th millennium B.C. to the beginning of the 3rd millennium B.C. (Lo Schiavo *loc. cit.*). However, before the discovery of the s'Arcu 'e is Forros' tin, only three sites had been mentioned for the presence of tin by several authors (full references and detailed analysis in Lo Schiavo, this volume): the sites are Abini (Teti) and Forraxi Nioi (Nuragus), where tin ore (cassiterite) was recognized, and La Maddalena (Silanus-Lei) where the only certain metal tin described in Sardinia to date (Vivanet 1890) was found. Actually Tylecote *et al.* (1984) do not accept the classification of the Forraxi Nioi materials analysed by Cambi (1959) as cassiterite, and state that they are 90 % “corroded tin”, probable remnants of metallurgic activity. In any case the question is open, because it is not completely sure which specimens were studied by Cambi, and because they are not easily available for a check-up. Therefore the only certain and available metal tin nowadays, is the one we are discussing, described by Fadda (2003), and already announced by Valera *et al.* (2002). The material is stored at the Soprintendenza Archeologica per le province di Sassari e Nuoro (Nuoro Territorial Service).

1.5. Facts, problems, and observations

At this point we can list a number of factual data dealing with the ancient tin occurrences and metallurgy in Sardinia. These are emphasized by the S'Arcu 'e is Forros field and laboratory studies, and by a careful consideration of the data already mentioned in the literature. We shall here list the factual data that appear particularly important and meaningful to our approach:

1. S'Arcu 'e is Forros sanctuary

* chronology : LBA to EIA (Fadda 1989a, 1989b, 1991) ;

* the Pb isotope ratios of the tin scrap analysed by Prof. Pernicka are foreign to Sardinia;

* the Pb isotope ratios of the Cu-Pb alloy scraps are consistent with the Sardinian Cambrian hosted leads;

* the trace element analyses of the tin scraps are not consistent with those of known Sardinian cassiterites (Perdu Cara);

* among the large number of collected scraps no cassiterite was observed;

* the local metalworkers clearly employed only metal tin for bronze alloying.

2. Ancient metallurgy in Sardinia

* the only metal tin found in Sardinia to date (before the discovery of S'Arcu 'e is Forros) is that of Silanus-Lei (La Maddalena);

* cassiterite was certainly used in Abini, and probably in Forraxi Nioi;

* whether it be ore or metal, the tin employed in Sardinian metallurgy is to be assigned to a supply by import;

* copper and bronze objects analysed by Begemann *et al.* (2001) show a variable composition in Sn, Pb, As, Sb, Ag, and Fe content. Such variability can be frequently observed in other published analytical data. Especially lead is

well represented (Tylecote *et al.*, 1984: copper-lead ingot of table 6.7);

* an Ag-bronze, tin-free figurine, exhibited in the Cagliari Archaeological Museum as the "Bronzetto with long hair-plaits", has been analysed and described by Atzeni *et al.* (1992);

* silver, or silver-bearing artifacts are very rare in nuragic age sites;

* the trend of silver grade in the lead scraps of nuragic age is consistent with that of most of the Sardinian lead ores (see the high silver grades of nuragic lead scraps in Lo Schiavo, Valera 1998). Should any desilveration by cupellation have been performed, it would have to be done only on selected rich ores, though obtaining an imperfect recovery.

These facts are to be carefully considered, in discussing issues that can be summarized as follows :

* From a more general point of view, was the tin actually a true "base metal" for the BA cultures ?

* What about tin ore deposits in the Mediterranean area ?

* Where did the general metal supply come from ? In the S'Arcu 'e is Forros sanctuary only the lead of the copper scraps is of certain local origin, and according to isotope ratios it belongs to the Cambrian-hosted deposits of SW Sardinia (Valera *et al.* 2002);

* In particular, what about the origin of the tin ore and that of the metal tin found in the nuragic sites?

* What about the origin of the silver used for the "*Bronzetto with long hair-plaits*" ?

* Was the silver-bronze an experiment, or a first answer to foreign suggestions ? Might it be a possible reference to a "*candidum Corinthium aes*" (Giumlia-Mair 2000) ?

* Why does metal tin occur in S'Arcu 'e is Forros and La Maddalena, and why tin ore in Abini and Forraxi Nioi ? Did this depend on different sources, and/or different traders, and/or different metallurgic styles or advancements, considering that the origin of tin was foreign to Sardinia ?

* In the S'Arcu 'e is Forros scraps, lead was intentionally added to copper, and was of Sardinian origin, as said above. Was it a matter of lively metallurgic experimentation ? Was there a rule for different uses ? Was it a "salting" trick to increase the metal value ? When the lead content is particularly high, might it be referred to the general technological evolution that occurred all over Europe in the EIA, which was marked by hoards of as-cast metal artifacts with high lead contents (Huth 1998) ?

The above selection of problems outlines some of the major features of the BA metal industry, where tin origin and metallurgy seem to be the outstanding open question: the *tin mistery*. But: why a mistery? A great deal of studies and analyses that were carried out in the past decades all point towards one main conclusion: ancient metalworkers were highly skilled and capable of obtaining exceptional results. Their attitude to metals was not only matter of advanced technology, but it was also clearly based on a kind of philosophic approach. Each ore, each metal had a "meaning", not only a "value", and we should recover the same attitude if we wish to understand their mentality and behaviour, so as to solve what we have called *problems*, or *the mistery*. In short, only a modern scientist can refer to TIN as a *base metal* (Penhallurick 1986): according to a BA point of view, which was obviously substantially different from ours, the position of tin was high up in the metal hierarchy, *i.e.* it was considered a *precious metal*, characterized by a special behaviour (how else could we interpret the *tin disease* ? cf below), that had to be used only in particular conditions, because it gives a particular meaning to the artifacts. Its indispensable presence in the alloys for weapons gave it additional preciousness: *i.e.* the power, or rather, the status symbol of power. Only through the recovery of this primeval approach, turning the *tin mistery* into *tin philosophy*, may we try and give a contribution to many of the open questions. No doubt the ancient authors, whose words are the proper key to such an interesting world, are of great help.

1.6. Discussion: tin mistery or tin philosophy?

It is well known that a long, deep, and lively debate developed in the past decades among scientists about tin, which is still considered an important, rare, and valuable metal. We shall bring some contribution to the discussion on the case of tin from a number of particular angles, *i.e.* the geological and the historical, while leaving the archaeological conclusions open.

A serious discussion on the tin case must be based on its occurrence and behaviour in the earth's crust. This means, tin in nature. As regards the average tin crustal abundance, conflicting data are reported in the specialized scientific literature: from 2 to 40 p.p.m. (parts per million) according to different authors, the former being recently the most credited figure. But let us compare tin with some other metals. Generally accepted figures are: iron 50.000, copper 70, lead 16, arsenic 5, silver 0,1, and gold 0,005 (Routhier 1963). Whatever the correct value, tin crustal abundance is low, and is mirrored by the scarce occurrence of tin ore deposits. Actually an important concept must be taken into consideration in order to assign an effective weight to such figures: the relative abundance of a given element is not the only controlling factor of its efficiency in giving rise to mineral concentrations of economic value, *i.e.* to ore deposits. An essential role is also played by its behaviour in the geological processes, and in general in the processes which develop in, and on, the earth's crust: we refer to the physical-chemical leading constraints concerning solubilities, complexing, sensibility to various reactions, etc., not least, its preferred primary genetic environment, igneous (felsic or mafic), sedimentary, and metamorphic. Such a picture will help us understand why lead, whose abundance falls in the same range as tin, is much more frequent as an occurrence of ore mineral. On the other hand, the value of lead compared to tin also depends on its economic evaluation, which is in turn derived from the aforementioned meanings that were given to the metals in antiquity. Unlike lead, tin had a generally restricted use, devoted to artifacts of particular importance or sense. Therefore, in the case of metals, the meaning of *economy* in antiquity does not only refer to evaluation simply from a material point of view: it also has an undeniable *philosophic* component. All along human history, different types of *geologic bodies* (e.g. obsidian) assumed the "honour" of *ore deposits* due to their economic value as considered at a particular stage when their intrinsic value was assessed also according to a more philosophic approach.

From a genetic point of view valuable tin ore deposits are mostly associated to a group of granites that had long been called *tin granites* in the Old World (Lehmann 1990). Tin granites occur only in some particular lithospheric sections, and characterize few netallogenic districts. The Mediterranean area is very poor, almost lacking tin granites. Nevertheless, many cassiterite occurrences are mentioned, especially in the Balkan region (Ilavsky 1979), unfortunately of no practical interest, even in a BA framework. Actually, the nearest tin districts are those known since antiquity: NW Iberian peninsula, Brittany, Erzgebirge, and Cornwall.

Tin minerals are few, the most important and abundant being the tin oxide *cassiterite* (tin content 78 %). Cassiterite is a very stable mineral, with high specific gravity (7.0). It is mostly affected by the mechanics of the weathering processes, so it can give rise to secondary deposits or "placers" which are of course always associated with primary deposits related to tin granites. Only the tin sulfide *stannite* (tin content 27 %) can undergo chemical weathering processes, but its rare occurrence does not have a great influence on the geochemistry of tin.

Lead has a crustal abundance comparable to that of tin, but its occurrence in the earth crust, and its behaviour in the geochemical processes is absolutely lively and various. Its atomic radius, ionic charge, ionization potential etc. allow Pb^{2+} to replace diadochically some important elements such as Ca^{2+} and K^{+} (Rankama, Sahama 1950), and this occurs in igneous rocks. But Pb^{2+} may also proceed to the replacement of Ca^{2+} in minerals formed at lower temperatures. Therefore lead participates in many natural processes in the exogenous environment, and can be concentrated in so many different conditions, that we may frequently find it either in hydrothermal processes at high to low temperatures, or in sedimentary processes, etc. Many lead minerals are known in nature, the most important being the lead *sulfide galena* (lead 86 %), but sulphosalts and oxides are not rare. Actually galena is one of the most frequent, and economically important minerals occurring in base metal ore deposits, both of the hydrothermal and the sedimentary type, and lead ore deposits are widely distributed all over the world. Therefore lead has never been considered a precious metal, even if through its association with silver in galena it became a very important ore since the earlyest times of metallurgy, when the cupellation process was set up. Following lead, silver is also common, though in much lower quantities. Due to its brightness, aesthetics, and physical properties, silver has been considered a precious metal since the very beginning of time. Many silver-bearing ore deposits are known in the Mediterranean area, whereas tin is practically absent. So when tin first appeared in the Near East EBA cultures, it found an already well developed metallurgic tradition, especially based on arsenical copper production, and on cupellation to obtain silver. It is worth quoting that the crustal abundance of arsenic (see above) is also comparable to that of tin: but it had long been an essential component of the metallurgic know-how.

All existing finds and documents that may be examined point to the exploitation of the *experimental method* by the metalworkers, which made it possible to produce different types of alloys according to the different needs, and to process pure metals in the best possible way. The appearance of tin was a revolutionary shake in the metalworking world, because it gave a new, exciting possibility to create precious artifacts and weapons that looked very different and had unexpected physical properties. At that time the classification of known metals was very simple: gold and silver were precious, scarce but common (in the sense that they occurred in many countries); arsenic was useful but scarce although common; copper and lead were the base metals, frequent and common. Tin suddenly became essential, but it was rare, scarce and unknown in the then "developed countries". According to the Ebla tablets (Pettinato 1979) it is possible to estimate the metal ratio to 1 shekel of silver in Ebla, 2500 B.C.: gold is 4.75, tin 0.66, copper 0.02. Copper, though important, is well apart from tin, which is closer to silver.

Tin was so highly esteemed that from the beginning and for a long time, it was even purchased in remote countries, together with other valuable goods like lapislazuli, amber, and nephrite. The metallogenic province of Fergana - Tien Shan (Afghanistan: Penhallurik 1986) is one of the most accepted sources of tin, and is perfectly suitable from a geologic point of view. However, exploration soon started in countries that were then known for their mineral wealth. Unfortunately the Mediterranean area is particularly poor in tin granites, so the first positive results arrived after quite a long time, when products of the western Iberian peninsula, Brittany, Cornwall, and later of Erzgebirge became available. Perhaps a contribution was also given by Tuscany, and recent indications (Gillis 1991) assign a possibilitiy to Turkey (Bolkardag) and Macedonia (Cer). But it cannot be denied that if something fruitful such as exploitable tin ore had been found in the Mediterranean area, its memory would have been recorded and left traces today, as happened in all other known mining districts of antiquity: Ergani Maden, Cyprus, Lavrion, Sardinia etc.

In any case, tin was considered a sort of "royal metal": not only precious, but *precious and indispensable*. It was essential in the preparation of the bronze weapons - a status symbol of power as stated above. It is always mentioned in ancient literature as a highly valuable metal. A very famous passage in Homer's Iliad describes the work of Hephaestus to make Achille's shield. There tin, together with gold, is quoted as a true precious metal ("the oxen were made of gold and tin": XVIII, 574)[1]. Another reference is the arrival of the Diomede's chariot "inlaid with gold and tin" (XXIII, 504)[2].

A very authoritative voice is that of Herodotus, who describes some features of the northern European regions, when speaking vaguely about islands named Cassiterides "where tin should come from" (III: 115, 1). However, a few lines later Herodotus says that "tin and amber arrive from the extreme borders of the world", and "it seems certain that the greatest quantities of gold occur in northern Europe" (III: 115, 2; 116,1)[3], concluding that "actually, the extreme regions, surrounding the other countries, own the things we consider the finest and rarest" (III: 116,3)[4]. Therefore, according to Herodotus tin is to be classified among "the finest and rarest things".

Furthermore, describing the mineral wealth of the Iberian peninsula, Strabo quotes Posidonius saying that "among the Artabrois, the inhabitants of the north-westernmost Lusitania, the land flourishes with silver, tin, and white gold (actually mixed with silver)" (III, 2.9)[5].

We may also interpret as a reference to tin (and gold) the words of Job in the Scriptures (XXVIII, 11): "They dam up the trickling streams and bring to light the hidden treasures". However, the most conclusive definition occurs in the well known passage by Pliny the Elder (XXXIV, 47): "*Sequitur natura plumbi, cuius duo genera, nigrum atque candidum. pretiosissimum in hoc candidum, Graecis appellatum cassiterum fabuloseque narratum...*". Tin is apertis verbis declared "most precious".

This brief anthology, which could be much expanded, should bring us to a basic change of approach, to a sort of new philosophy, we would say, of the processing of the tin concept. Keeping in mind a BA point of view, tin is one of the THREE precious metals, and certainly not the least. Many authors dealt with tin, and important and well documented studies have been published in the past decades. Among them Gillis (1991) starts revealing a new feeling, when she says that "tin must have been an extremely valuable commodity", and also suggests that the tin-covered vessels in the Minoan-Mycenean world "were at least the equivalent of silver in value and status".

So tin was rare, scarce, and precious. But it was also weak, its weakness being given by the so called "tin disease", a structural instability that controls crystallisation in the pure metal state (Maddin 1998). It is the transformation α tin - β tin, which starts developing when the metal undergoes decreasing temperatures below 13 °C, and is accompanied by an irreversible architectural transformation into powder, then easily dispersed. The effects of this process must soon have been discovered by early metalworkers at the beginning of the utilisation of tin, because of the dramatic constraints of this transformation. It is likely that the appearance of the first tin ingots and their trade coincided with the solution of the tin disease problem, which was simply the addition of even low quantities of other metals to the pure metal tin. Though rough, the aforementioned experimental method depended on the availability of various minerals, mainly Bi-, or Sb-, or Cu-, or Pb-sulphides or sulphosalts. Actually (cf figg. 4 a-e, table 2) the Villagrande tin scraps contain variable but substantial lead, and a little bit higher antimony than the average values quoted by Maddin (1998). Such Sb and Pb values could explain how the tin scraps have been preserved in a stable state, though for a long time in a climate with frequent winter temperatures below 0 °C.

Giving due weight to the practice of the *experimental method* by the BA metalworkers, we can now perceive how and when the tin trade shifted from cassiterite to metal ingots. This very likely happened as soon as metal tin was stabilised, and this was clearly achieved with the development and progressive improvement of smelting, which very often involved different ore minerals, and from slight to substantial changes in processing conditions.

The same interpretation should be given to many important events of the history of metals, e.g. the invention of bronze. Actually such an invention can be explained in two ways. One should assume the existence of metallogenic districts where originally both Cu and Sn ores contemporaneously occur. In this case the primitive metalworkers followed a natural suggestion by mixing cohexisting minerals. Of course at the beginning they did not know that their mixture derived from two components, nor the relative content of each component. The other is simply provided by the experimental method, which led to the discovery of the mixture of well known copper ores with the strange metal hidden in the black sand and small pebbles which Pliny later called *calculi nigri* (XXXIV, 47). The experimental approach is clearly at the base of all the metallurgic activity in antiquity, and it is proved by the composition of metal objects occurring in extremely different sites. Of course, it had to be based on the availability of different types of metals and minerals. In the same way we may also explain the production of arsenical copper, and that of arsenical-antimonial copper, whose discovery and diffusion clearly started, and moved from fahlore-bearing districts, being soon followed by the improvement of the alloying method through the beneficiation of other As- and Sb-bearing ores. Further examples are given by copper-lead mixtures and by the addition of lead to tin. However, one of the best examples of the experimental method seems to be given by the above mentioned *bronzetto* of the Cagliari Museum, a bronze alloy with silver (6.5 %) instead of tin.

The availability of different types of metals and minerals was guaranteed by the establishment of trade routes that reached all the known mineral districts, capable of providing all the required commodities to countries short of mineral wealth. On the other hand the flow of goods may also have acted as a suggestion for the beneficiation of local mineral resources previously unknown to the local people because of a lack of metallurgic experience. We must look inside this framework to get an idea of the origin of silver in the production of the Ag-bronze figurine, keeping in mind that silver was a rather uncommon metal in nuragic culture, though well represented in Sardinian galenas.

1.7. Conclusions

The above discussion leads to some interesting conclusions, though it leaves many open questions. First of all we support the clear evidence of the outstanding position of tin in the BA metal hierarchy. Tin was maintained as a true precious metal for a long time, and was essential to the production of powerful weapons. It was so important, that we cannot expect to find a source of tin in the Mediterranean area or its immediate surroundings, forgotten by history for about two millennia and unknown even to Strabo and Pliny. Its supply from the Far-East was suddenly interrupted when Mari was destroyed, but it was soon replaced by the new western sources that became available and were beneficiated: NW Iberia, Brittany, and later Cornwall and Erzgebirge.

The metal trade routes were of strategic importance, and were certainly accompanied by an exchange of know-how. The skill and experience of the metalworkers were continuously improved through experiment aimed at obtaining the most useful and the newest products. F. Braudel (1998) says that itinerant metalworkers and smiths are well known characters in the Near East history, and their traveling since the beginning of the 3rd millennium is absolutely certain.: at about 2500 B.C. in the big towns of the Near East, metalworking is owned by guilds of foreigners who jealously preserve their secrets, and do not mix with the citizen communities. The results of this lively metallurgy are given by the metal mixtures and alloys found all along the history of the BA and later. In particular, the nuragic "*Bronzetto with long hair-plaits*" could have been prepared as an experiment to improve the aesthetics approaching the *candidum Corinthium aes* (Giumlia-Mair 2000), and the lead-copper mixtures of Villagrande could have been in line with the general technological evolution that occurred all over Europe in the EIA, and was marked by hoards of as-cast metal artifacts having high lead contents (Huth 1998).

The evolution of the knowledge and use of tin was clearly marked by problems relating to the instability of its two phases. The refinement of the know-how to correct it was an important step, and was achieved through the deliberate (or unintentional?) addition of "impurities" like Pb, Sb, and Bi. Stabilising the precious phase was a brilliant result, and it was rapidly transformed into the improvement of the tin trade that changed from cassiterite to tin ingots.

The combined presence of both tin ore and metal tin in Sardinian bronze metallurgy may be explained in two ways: the simpler being the technological evolution from a smelting process based on the copper + tin ore couple ("cementation": Cambi 1959; Herdits *et al.* 1995) to an evolved smelting process based on copper + metal tin, when tin ingots were made available and disease-free directly at the source of the ore deposit. Actually in the preliminary phase of the development of metallurgy, we may presume that the production of bronze was obtained everywhere by cementation. Of course, we may consider that some metalworkers preferred to transform the cassiterite into metal tin themselves, but it is difficult to imagine a possible prevalence of demand on supply in primitive trades.

Therefore the geological data suggest that the occurrence of metal tin scraps at Villagrande should be interpreted as the document of a second and more evolved trading phase, whose chronology is not yet possible to determine with a reliable precision, within the long time span of the sanctuary (after the Recent Bronze Age to the beginning of the EIA). Still disputable is the origin of the metal.

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Notes

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1.

Ἐν δ᾽ ἀγέλην ποίησε βοῶν ὀρθοκραιράων·
αἱ δὲ βόες χρυσοῖο τετεύχατο κασσιτέρου τε,
μυκηθμῷ δ᾽ ἀπὸ κόπρου ἐπεσσεύοντο νομόνδε
πὰρ ποταμὸν κελάδοντα, παρὰ ῥοδανὸν δονακῆα.

2.

αἰεὶ δ᾽ ἡνίοχον κονίης ῥαθάμιγγες ἔβαλλον,
ἅρματα δὲ χρυσῷ πεπυκασμένα κασσιτέρῳ τε
ἵπποις ὠκυπόδεσσιν ἐπέτρεχον·

3.

Ἐξ ἐσχάτης δ᾽ ὦν ὅ τε κασσίτερος ἡμῖν φοιτᾷ καὶ τὸ ἤλεκτρον. Πρὸς δὲ ἄρκτου τῆς Εὐρώπης πολλῷ τι πλεῖστος χρυσὸς φαίνεται ἐών.

4.

Αἱ δὴ ὦν ἐσχατιαὶ οἴκασι περικληίουσαι τὴν ἄλλην χώρην καὶ ἐντὸς ἀπέργουσαι τὰ κάλλιστα δοκέοντα ἡμῖν εἶναι καὶ σπανιώτατα ἔχειν αὐτά .

5.

Ἐν δὲ τοῖς Ἀρτάβροις, οἳ τῆς Λυσιτανίας ὕστατοι πρὸς ἄρκτον καὶ δύσιν εἰσίν, ἐξανθεῖν φασι τὴν γῆν ἀργυρίῳ, καττιτέρῳ, χρυσίῳ λευκῷ (ἀργυρομιγὲς γάρ ἐστι) ·

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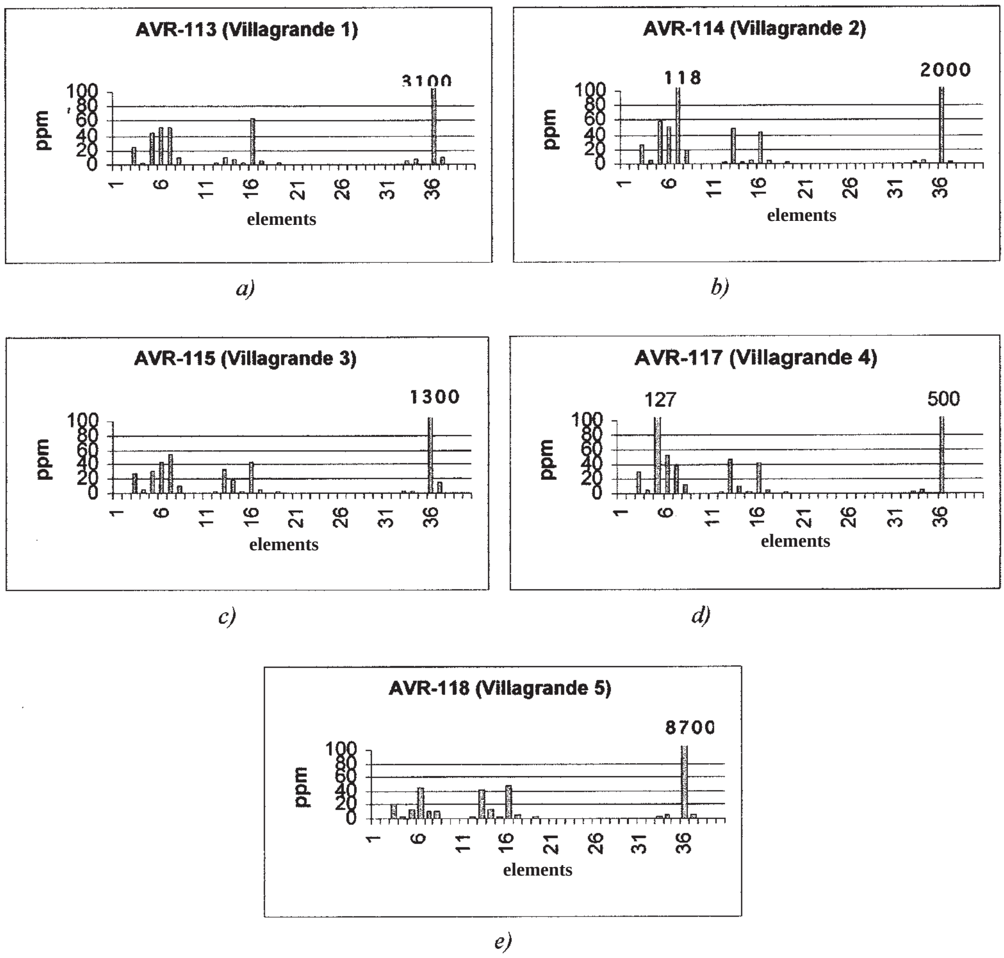
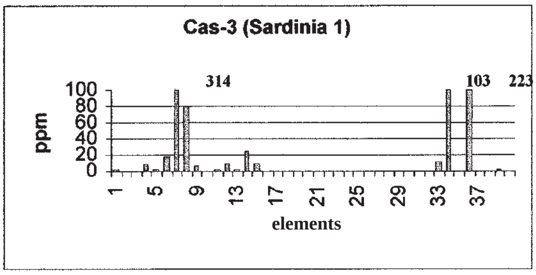
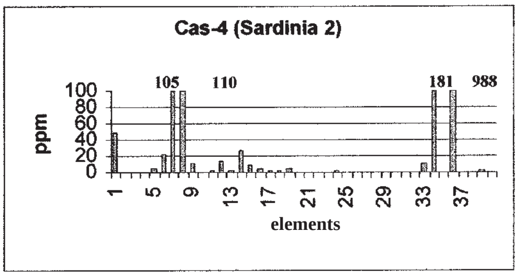


Fig. 4 (a-e) - Trace element patterns in five tin scraps from Villagrande (element numbers in Table 2 and 3).

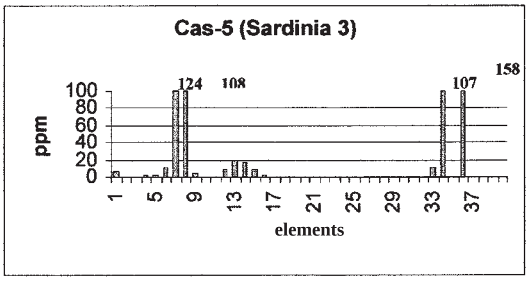
Fig 5 - Trace element patterns of cassiterites from different areas. a-d: Sardinia (Perdu Cara);
e: China (unknown deposit); f: Erzgebirge (Cinovec);
g: Spain (Mina Casualidad, Zamora);
h: Nigeria (unknown placer);
i: Tuscany (Monte Valerio)
(element numbers in Table 2 and 3).


Cas-3 (Sardinia 1)
314
103 223
ppm
elements

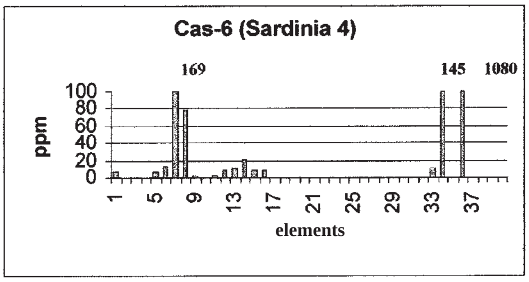
a


Cas-4 (Sardinia 2)
105 110
181 988
ppm
elements

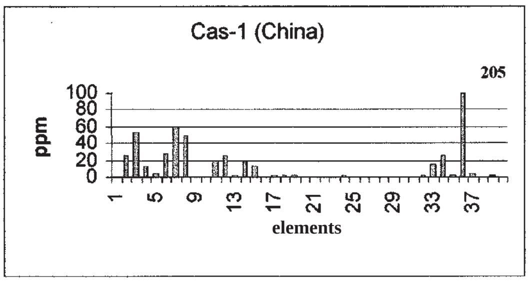
b


Cas-5 (Sardinia 3)
124 108
107
158
ppm
elements

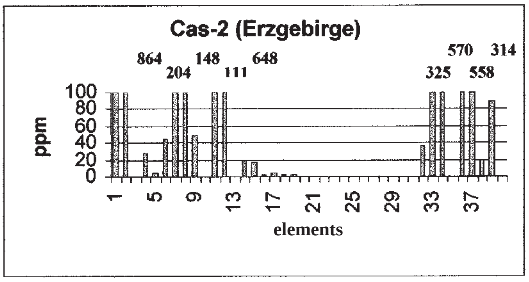
c


Cas-6 (Sardinia 4)
169
145 1080
ppm
elements

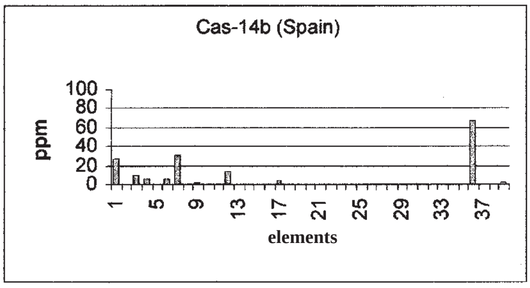
d


Cas-1 (China)
205
ppm
elements

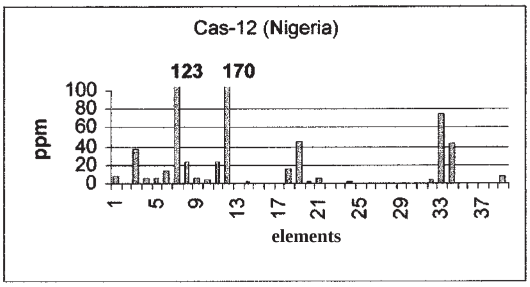
e


Cas-2 (Erzgebirge)
864 148 648
204 111
570 314
325 558
ppm
elements

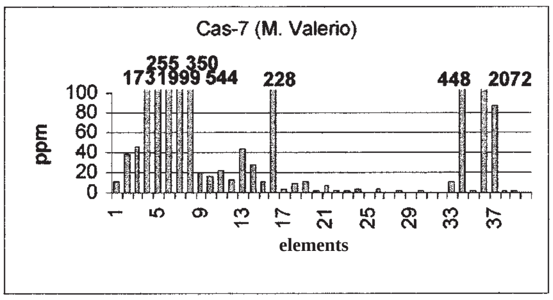
f


Cas-14b (Spain)
ppm
elements

g


Cas-12 (Nigeria)
123 170
ppm
elements

h


Cas-7 (M. Valerio)
255 350
1731999 544
228
448 2072
ppm
elements

i

Table 2
Trace element grades in some tin scraps of S'Arcu 'e is Forros

PPM	AVR-113	AVR-114	AVR-115	AVR-117	AVR-118
1 - Li	nd	nd	nd	Nd	nd
2 - Sc	1.2	1	nd	Nd	nd
3 - V	23.6	27.1	28.4	31	20.9
4 - Cr	3.4	5.2	5.4	4	3.5
5 - Co	42.7	58.9	29.6	127	12.5
6 - Ni	50.6	51.1	43.3	53.3	43.6
7 - Cu	51.3	118	55	38.3	10.9
8 - Zn	10.6	19.5	9.6	11.8	10
9 - Ga	0.1	0.2	0.2	0.3	0.2
10 - Y	nd	nd	nd	Nd	nd
11 - Zr	nd	nd	nd	Nd	nd
12 - Nb	2	1.6	1.6	2.1	1.8
13 - Cd	9	50	33	48	42
14 - In	7	3	19	11	12
15 - Mo	3.3	4.5	2.2	3.6	1.9
16 - Sb	63.7	43.1	44	42.2	48.4
17 - Cs	4.8	4.9	5.2	5.2	6.2
18 - La	0.3	0.5	0.3	0.4	0.5
19 - Ce	2.3	2.6	2.5	2.6	3.1
20 - Pr	nd	nd	nd	Nd	0.2
21 - Nd	nd	nd	nd	Nd	nd
22 - Sm	0.7	0.8	0.9	0.9	0.9
23 - Eu	0.5	0.7	0.8	0.8	0.9
24 - Gd	0.3	0.3	0.2	0.3	0.3
25 - Tb	nd	nd	nd	Nd	nd
26 - Dy	nd	nd	nd	Nd	nd
27 - Ho	nd	nd	nd	Nd	nd
28 - Er	nd	nd	nd	Nd	nd
29 - Tm	nd	nd	nd	Nd	nd
30 - Yb	nd	nd	nd	Nd	nd
31 - Lu	nd	nd	nd	Nd	nd
32 - Hf	nd	nd	nd	Nd	nd
33 - Ta	3.8	3.1	3	3.1	3
34 - W	6.8	4	3.4	3.8	4.6
35 - Tl	0.5	0.4	0.4	0.3	0.3
36 - Pb	3100	2000	1300	500	8700
37 - Bi	10.4	1.4	14.6	1	4
38 - Th	nd	nd	nd	Nd	nd
39 - U	nd	nd	nd	Nd	nd

Table 3

Trace element grades in various cassiterites (in ppm). Cas-1: China; Cas-2:Erzgebirge; Cas-3,4,5,6 : Sardinia (Perdu Cara); Cas-7: Monte Valerio; Cas-12: Nigeria ; Cas-14b : Spain.

	Cas-1	Cas-2	Cas-3	Cas-4	Cas-5	Cas-6	Cas-7	Cas-12	Cas-14b
1 - Li	nd	99.8	2.8	49	5.7	5.7	11	7.3	27.1
2 - Sc	25.7	864	nd	nd	nd	Nd	39	nd	Nd
3 - V	52.6	Nd	nd	nd	nd	Nd	46	37.2	10.4
4 - Cr	13.3	27.2	8.5	nd	2.5	Nd	173	6.3	6.2
5 - Co	5.3	5.3	2	4,2	2.3	6.5	255	5.2	Nd
6 - Ni	26.6	43.9	16.7	21.4	11.5	12.2	1999	12.8	6.5
7 - Cu	58.6	204	314	105	124	169	350	123	31.2
8 - Zn	48.9	148	79	110	108	78,2	544	23.4	nd
9 - Ga	Nd	48.6	6.1	10.4	3,8	1,3	19.5	5.9	2.7
10 - Y	0.6	Nd	nd	nd	nd	nd	17	3.1	Nd
11 - Zr	19.5	111	1.5	2.2	1	1.6	22.4	23.7	Nd
12 - Nb	26.1	648	8.5	12.5	8.9	9.4	13.5	170	14.1
13 - Cd	2	Nd	2	2	19	11	43	1.4	0.77
14 - In	19	20	25	26	16	22	27	nd	nd
15 - Mo	11.8	16.9	9.5	9.3	9	8.7	11.1	nd	nd
16 - Sb	Nd	2.3	1	3.7	2.7	8.5	228	nd	nd
17 - Cs	2.8	5	nd	1.5	1	nd	3	nd	3.3
18 - La	1.2	1,1	0.5	1.6	nd	0.5	8.2	16	nd
19 - Ce	1.3	1.8	0	3.4	nd	0.2	10.2	45	0.64
20 - Pr	0.7	0.5	0.3	0.7	0.3	0.4	2.5	2	nd
21 - Nd	nd	nd	nd	nd	nd	nd	7.1	5.7	nd
22 - Sm	0.3	nd	nd	0.3	nd	nd	2.4	0.8	nd
23 - Eu	1	0.8	0.8	0.9	0.7	0.7	1.5	nd	nd
24 - Gd	1.2	1	0.8	1.3	0.8	0.9	3.8	1.2	nd
25 - Tb	0.24	nd	nd	0.1	nd	nd	0.6	nd	nd
26 - Dy	nd	nd	nd	nd	nd	nd	3.3	0.59	nd
27 - Ho	nd	nd	nd	nd	nd	nd	0.7	nd	nd
28 - Er	0.4	0.3	nd	0.2	nd	nd	2.5	0.38	nd
29 - Tm	nd	nd	nd	nd	nd	nd	nd	nd	nd
30 - Yb	0.2	0.4	nd	nd	nd	nd	2.1	0.47	nd
31 - Lu	0.6	0.4	0.4	0.4	0.3	0.3	0.6	nd	nd
32 - Hf	1.3	35.2	nd	nd	nd	nd	nd	4.1	nd
33 - Ta	15.8	325	10.9	11.4	10.4	10.9	11.5	73.9	nd
34 - W	25.5	570	103	181	107	145	448	42.8	nd
35 - Tl	1.1	0.8	0.6	0.8	0.5	0.6	1	Nd	nd
36 - Pb	205	558	223	988	158	1080	2072	Nd	67
37 - Bi	3.7	124	1	0.8	0.8	0.7	87.2	Nd	nd
38 - Th	nd	18.9	nd	0.4	nd	nd	2.2	Nd	nd
39 - U	1.9	88.6	1.2	1.3	0.6	0.5	2.3	7.8	1.6

6.

2. The problem of early tin from the point of view of nuragic Sardinia

Fulvia Lo Schiavo

F. Lo Schiavo, The problem of early tin from the point of view of nuragic Sardinia, in "*Le problème de l'étain à l'origine de la métallurgie - The problem of early tin*", Section 11, 2nd Colloquium, Acts of the XIV UISPP CONGRESS, University of Liège, Belgium, 2-8 Sept., 2001, A.Giumlia-Mair & F. Lo Schiavo eds., BAR Intern. Serier 1199, 2003, 121-132.

The paper is focussed on the archaeological aspects of metallurgical research and on the archaeological conclusions that can be drawn from the results of metallurgical studies, with special attention to nuragic Sardinia. The chronological setting (fig. 1) is not object of the present discussion, as there are now enough data on Mycenaean pottery, found in local context and also on nuragic materials found outside of the island.

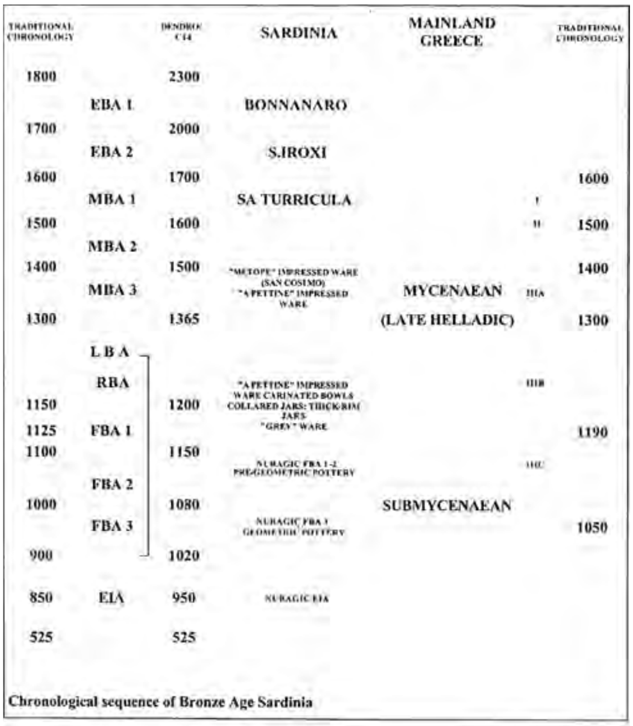


Fig. 1 – Chronological table of Bronze Age Sardinia.

2.1. Metallic tin in nuragic Sardinia

The discovery of metallic tin[1] in archaeological complexes of nuragic Sardinia was recognised only in three almost contemporary cases in the past: by F. Vivanet (Fiorelli 1878), E. Pais and F. Nissardi (Pais 1884; Baux & Gouin 1884; Fiorelli 1890) in the nuragic sanctuary of Abini, Teti (Nu); by F. Nissardi (Fiorelli 1882; Nissardi 1884) in the hoard of Forraxi Nioi, Nuragus (Nu); by F. Vivanet (Fiorelli 1890) in the "foundry" of La Maddalena, Silanus/Lei (Nu). Nowadays (1999) there are new finds by M.A. Fadda and R. Valera (Fadda 2003; Valera, Valera 2003) in the sanctuary of S'Arcu 'e is Forros, Villagrande Strisàili (Nu) (fig. 2).

Since these sites are well known, attention would be drawn on an essay of archaeological interpretation, with reference to the presence of tin.

1. "The use of the term "metallic" tin is redundant; there is no "non-metallic" tin. Tin is a metal and should be distinguished from other, as the case may be, "tin ore" or "tin oxide" etc. Tin is blue (or even sky blue) and lead is greyish. Both are heavy. Furthermore, as I have often said and published, tin would not have survived over the years when the ambient temperature fell below 13 C, as it would have during the Sardinian winter; it would transformed to the grey variety and have disintegrated as a powder and mixed with the earth." (R. Maddin, pers. comm.). In this paper, the use of "metallic" tin is just a help for non-metallurgists, in order to define tin already smelted and ready to be alloyed with copper, possibly in the regular or irregular shape of an ingot. For a similar use, see Muhly 1985, 278, 279, sgg.

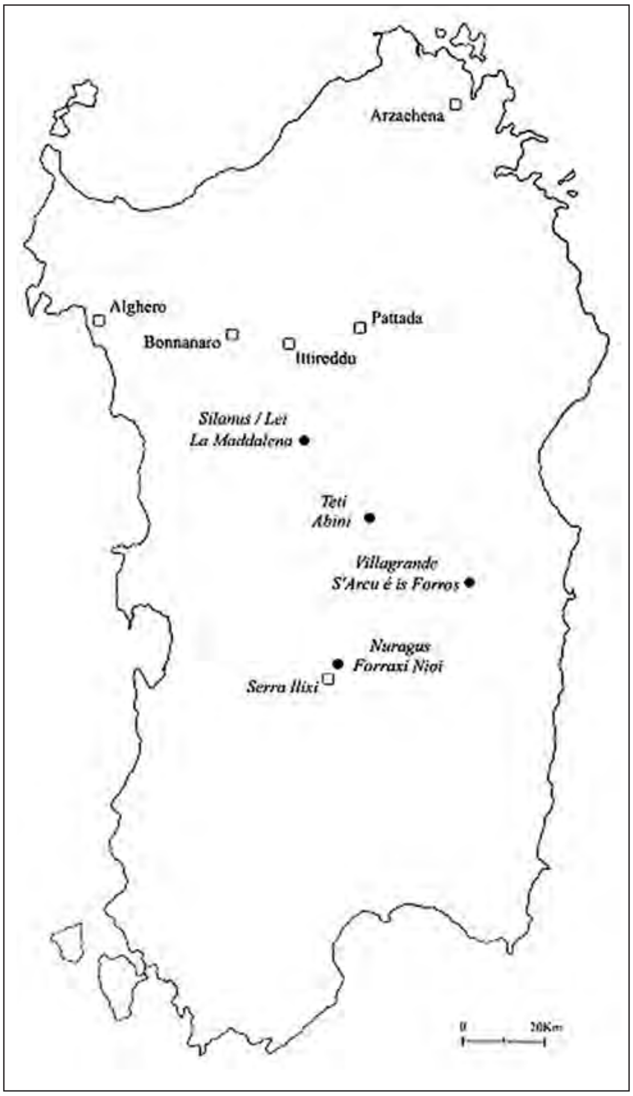


Fig. 2 - Geographic location of the sites mentioned in the text *(drawing by Antonio Mancini).*

Up to know, Abini (Teti district, Nuoro province) was referred to as a "hoard", and the same Ettore Pais, who published it in 1884 (Pais 1884), defined it "*ripostiglio*". On the contrary, the study of the oldest bibliography[2] (Spano 1865, 7; Pinza 1901, 163; Taramelli 1931), as well as the result of recent excavations, demonstrate out of any possible doubt that it is a "typical" nuragic sanctuary, with a Temple (difficult now to say if it was a Spring Temple or a Well Temple) and with other structures, built up with the characteristic refined "isodomic" masonry, within a wider enclosure.

In three different occasions, this site was merciless ravaged and looted. An enormous quantity of bronze offerings was collected; part of it is conserved in the National Archaeological Museum of Cagliari, assembled in three collections: Timon Collection (1865), Vivanet Collection (1878) and Gouin Collection (1882). They take the names from the collectors who bought the bronzes from the peasants (Timon, Vivanet) or excavated the pieces (Gouin) and gave them to the Museum. Further, the bronzes found by A. Taramelli in the 1929-30 excavations (Taramelli 1931) should also be added.

All old descriptions are so inadequate that it is impossible to figure out the original situation. In many cases there are references to groups of offerings in pots or buried in holes in the ground: it is plausible, by comparing the data with the situation of other nuragic Sanctuaries, that, near the Temple to the Water God/Goddess and in the sanctuary, there were more than one hoard.

Unfortunately we cannot exactly reconstruct the content of each deposit found in the past, and have to wait for the results of archaeological excavations under way, which might give a better understanding of the site (Fadda, Tuveri & Murru 1992, 250-251; Fadda 2000). We also have to consider that the sanctuary is located near the nuragic village of "*Interrojos*" (Fiorelli) or of "*Interroga/Interrogas*" (Gouin, Pais), and this renders more complex the archaeological reconstruction and widens the chronological span, since here also EBA Bonnannaro pottery was found (Ferrarese Ceruti 1978, 240, no. 52, fig. 229).

At Abini, Vivanet (Fiorelli 1878; Pinza 190, 155) reported the presence of more than 6 kg of tin ore fragments, together with copper plano-convex ingots ("bun ingots", Italian "*panelle*") and fragments of lead and iron.

In 1904 Pigorini noted in the Cagliari Museum a fragment of oxhide ingot, which did not belong to the Serra Ilixi ingots (Pigorini 1904, 92, no. 2c; Balmuth, Tylecote 1976, 198, fig. 2; Lo Schiavo, Vagnetti 1980, 381-2, no. 6; Vagnetti, Lo Schiavo 1989, 224, fig. 28.3e). Further, many oxhide ingots fragments in the deposits of Cagliari Museum bear the indication of "Teti (?)" as provenance (Lo Schiavo 1990, 24-5, no. 7). There is no reason to reject this indication, but it is impossible to locate them more precisely in time and place.

2. The most difficult to interpret is the description of Léon Gouin who, allowed to conduct a regular excavation on the site, did not follow it directly, leaving the work to an inexperienced assistant - rising everybody critics (Pigorini 1865, 77; Pinza 1901, 156; Taramelli 1931, 48) - who went on digging without a proper method, collecting bronze objects, now in Cagliari Museum in the Gouin Collection. Gouin says: "*Dans une sorte de caveau souterrain entre trois nuragues, caveau formé de gros blocs, recouvert d'une matière bitumeuse et de terre, s'est trouvé un dépôt contenant des faisceaux de longues épées liées par de bandes de cuivre, des statuettes, de beaux instruments de bronze, de poignard, de pain de cuivre et de l'étain oxydé (cassitérite).*" (Baux, Gouin 1884, 195) ... " *A Teti les nuragues sont groupés, on en compte onze sur un espace de quatre hectares environ. Trois d'entre eux, peut-être (?) étaient reliés par une muraille, au milieu de l'enceinte s'est trouvé le caveau.*" (Baux, Gouin 1884, 198).

All oxhide ingots labelled "Teti (?)" were analysed by R. Maddin. He comments that, from the metallurgical point of view, they appear to be very similar to the ones from Ittireddu. Minor differences, concerning the trace elements, can be referred to the variations of the flux. The presence of so little iron indicates the result of a refining operation of an originally "impure" copper. Tin is absent (Maddin & Merkel 1990, 86-104). Lead isotope analyses were carried out on artefacts from Teti provided by Dr. H. Schickler, Stuttgart by N. Gale and Z. Stos-Gale (Gale & Stos-Gale 1992, tab. 5).

Ettore Pais (1884, 147) adds that "*ad Abini si sono trovati frammenti di cassiterite, biossido di stagno, come pure se ne sono trovati nella fonderia di Forraxi Nioi*" ("at Abini, as well as in the Forraxi Nioi foundry, fragments of cassiterite, tin dioxide, were found"). It was precisely the presence of these ore and metal fragments to convince Pais, and before him Nissardi, the excavator of Forraxi Nioi (Nuragus district, Nuoro province), that in both cases they were dealing not with votive deposits but with foundries. Concerning Abini, Pais and Nissardi observed that the offerings, *i.e.* the bronze figurines, were pulled away from the "Tables of Offerings", so that the legs were broken and the feet were still stuck in the lead that fixed them to the stones. In their opinion, this profanation of the votive offerings could be explained only by an hasty assemblage of the bronzes, aimed to re-melt them, made in a great hurry because of an impending danger.

Pais wrote his work on Abini after the discovery and the three main episodes of looting and excavation of the site (Pais 1884). On the contrary, Filippo Nissardi personally excavated (though in only one week, from Dec.1st to Dec. 7th, 1881) the site of Forraxi Nioi and concentrated on the study of the metallurgy of both complexes. Apart from the final printed edition, he left many hand-written notebooks and papers[3], from which it is possible to evaluate precisely the evolution of his understanding of the matter. He generally speaks of "bronze", in the case of complete or fragmentary ingots and of all kinds of "green" metal, without any chemical analysis - as unfortunately happens also today. His first reference to tin was "*una materia grigiastra, pesante, in apparenza una scoria*" ("a greyish and heavy stuff, apparently a slag"). Only at the end of his work, after he studied the same kind of material, found in Abini, and after having had both analysed, he declares: "*quella sostanza grigiastra, pesante che in seguito all'analisi riconobbi per minerale di stagno, cassiterite, con qualche pezzo di stannina, sottoposti a torrefazione, che è il primo trattamento del minerale*" ("after analysis I recognised as tin mineral that greyish and heavy material, cassiterite, with some pieces of stannine, treated by roasting, which is the first treatment process of the ore") (see also Baux, Gouin 1884, 203; Pinza 1901, 162).

By the stratified disposition of the pieces of ore and of fuel (lignite?), and of animals bones, that he thought were necessary to add phosphor to the smelting, he came to the conclusion that the container was in fact a crucible.

In 1983 and 1984 Ronald Tylecote described the remains of what was formerly examined by Cambi and by Vodret (Cambi 1959a, 427; Vodret 1959, 257, no. 3), and stated that what they interpreted as cassiterite treated in a crucible, was in fact 90 % "corroded" tin and that, if this was to be interpreted as a crucible, it was a unique case of a crucible heated from the inside and not from the outside and therefore a melting process without slags, with a few comparable examples in Cyprus (Tylecote, Balmuth & Massoli Novelli 1983, 70, note 40; 1984, 134; Muhly 1985, 286).

Tylecote was particularly interested in the presence of a copper smelting slag rich in iron, that is fayalite (iron silicate) in a glassy matrix. In his conclusions, he said that this slag, in the case it was the first example of many others to be found, could be the solution to the problem of nuragic metallurgy. Since it was impossible to check these materials recently, Tylecote observations are precious. Lead isotope analyses were carried out by N. Gale and Z. Stos-Gale on artefacts from Forraxi Nioi, provided by Dr. H. Schickler, Stuttgart (Gale, Stos-Gale 1992, tab. 5).

From the archaeological point of view, Forraxi Nioi is far from being fully published. It has not been possible to locate the site of the discovery from the original description. Only few of the materials collected in the pottery buried in the ground were illustrated in the 1882 preliminary notice and some of them, extrapolated from the context, were studied and published[4]. The chronological span goes from ripe FBA (about XI c. BC) to the Iron Age (about VII c. BC.).

The third site of old discovery of metallic tin is La Maddalena, at the border of Silanus and Lei districts, Nuoro province. Groups of tools, weapons and ornaments, and pieces of metals, among which Vivanet mentions "*un pezzo di metallo bianco del peso di 700 grammi che sottoposto ad analisi chimica, risulterebbe essere stagno puro*" ("a piece of white metal weighing 700 gr that a chemical analysis demonstrated to be pure tin") were found in different locations and different periods (Spano 1876; Fiorelli 1890). Nothing remains of this "white metal".

Only few of the bronze artefacts are still in the Museums of Cagliari and Sassari. A shaft-hole axe, two

3. The warmest thanks are due to Maria Luisa Ferrarese Ceruti, who many years ago allowed me to check the Nissardi papers and warmly supported a thorough archaeometallurgical study based on them.

4. Since many years a complete catalogue of nuragic bronzes, with an essay of reconstruction of their contexts is under way. For a preliminary overview of the bronzes collected and exhibited in the Sassari Museum, see Lo Schiavo 2000.

flanged axes, a chisel, a fragment of a second one, and a long spear-butt - were described and illustrated by Spano (Spano 1876, 15, pl. no. 6, 7, 9, 13, 14; Pinza 1901, 149-150). He gave them to the Sassari Museum and they were published one hundred years after his death (Lo Schiavo 1979, 81-82, no. 42-47, pl. VII, 1-6).

The fourth and recent discovery happened in the nuragic Sanctuary of S'Arcu 'e is Forros[5], Villagrande Strisàili district, Nuoro province.

In 1985-86 clandestine diggings took place in a nuragic village, dominated by a huge "*megaron* temple", and seriously damaged structures and stratigraphy. The date goes from the LBA to the beginning of the EIA. During the first survey and in the following archaeological excavations, heaps of scrap metal and fragments of both copper oxhide and plano-convex ingots, of lead ingots and of bronze artefacts have been found (Fadda 1991; 2003; Vagnetti, Lo Schiavo 1989; Lo Schiavo 1990, 26-27, no. 11a). In October 1999, a few fragments of metallic tin have also been collected from the ground, confirming the firm belief that a foundry, serving the sanctuary, must have existed on the site, however it is not yet possible to recognise the location of the furnaces (Fadda 2003; Valera 2003).

From the evaluation of the old and new archaeological discoveries the assumptions are :

1. It is highly probable that in the past much more metallic tin was found on nuragic sites, generally considered hoards or foundries, namely where metallurgical operations could have taken place, and went unrecognised. Regrettably, this could have happened and be happening also nowadays, mostly in rescue excavations. The problem is that only seldom a specialist is present. It was a lucky case in Villagrande Strisàili with Roberto Valera, who was able to recognise this metal, mistaken for lead because "greyish and heavy" ("*materia grigiastra e pesante*" Nissardi 1884) (see also R. Maddin opinion on this matter, note 1)[6].

2. In the cases described above, metallic tin was found together with copper, lead and iron bars (nothing is said of silver). This allows the supposition that on these sites melting and alloying operations could have taken place.

3. Up to now, no stone moulds carved in steatite - the local refractory stone commonly used in nuragic Sardinia - were found. However, since in the past raw pieces of baked clay were not preserved, as still can happen today in rescue excavations, where looters often destroy the site, turning it upside-down in their treasure-hunting, terracotta- and soft stone moulds could have existed and the use of the lost-wax process for the production of bronze objects and figurines is also a possibility.

4. In three of the four cases mentioned above, with the exception of Villagrande, still in course of evaluation, and in the other nuragic complexes known up to now, there are no traces of smelting operations. No remains of smelting furnaces were found. However it is possible that melting and alloying operations were carried out in the sites, for the production of objects and figurines: see Santa Barbara, Bauladu (Atzeni C. *et al.* 1991; 1992a; 1992b; Atzeni C. *et al.* 1994; Gallin *et al.* 1994; Gallin, Tykot 1993), Santa Anastasia, Sardara (Ugas, Usai L. 1987) and Genna Maria, Villanovaforru (Atzeni C. *et al.* 1998).

2.2. The percentage of tin in ingots and artefacts

Copper ingots

Without entering into the debated question of the provenance of the copper oxhide ingots, the analyses confirm that all oxhide ingots, with very few exceptions, are of almost pure copper (Maddin & Merkel 1990; Begemann *et al.* 2001). A low level of tin is considered "the normal level of impurities in smelted metal of this period ... that could have come from a contaminated ore deposit" (Tylecote *et al.* 1983, 84; Vodret 1935, 111; Maddin & Merkel 1990, 92-93; Begemann *et al.* 2001, 55).

Scientists do not agree on the relationship between oxhide and bun ingots: some of them notice evident metallurgical differences (Garagnani & Martini 1998; Atzeni C. *et al.* 1998; Demurtas 1998), while others, analysing the same pieces, find "no significant differences in trace element abundances" (Maddin & Merkel 1990; Begemann *et al.* 2001, 51).

However they agree in excluding the possibility that the bun ingots could have been the first smelting product, used to produce, in a second melting operation, the oxhide ingots. The archaeometallurgical and archaeological problem concerning the reason for producing two different shapes of copper ingots in Cyprus - as they are found in the Cape Gelidonja and Uluburun cargoes, as well as all over Sardinia - is still open (Pulak 2000, 2001).

Bronze ingots

In three or four cases there is such a high percentage of tin that it is possible to speak of "bronze ingots".

A fragment of an oxhide or bun ingot is in the second hoard of Ittireddu (inv. no. 62405, Sn 6.8 / 2.2 %: Maddin & Merkel 1990; Sn 11: Begemann *et al.* 2001, 51, no. 5);

5. The name of the site is reported as "S'Arcu 'e is Forros" by M.A. Fadda, as it is the actual common spelling, while on the IGM 1:25.000 is written "S'Arcu 'e is Forras".

6. Gouin reports the discovery of a wreck near Carloforte island in southern Sardinia, consisting in 17 kg of copper ingots of "unusual" oval shape, together with a consistent quantity of tin ingots, soon sent and sold in Marseille. Also associated were little elongated (25 cm, 150 gr) brass (Cu 85,294, Zn 14,016, Sn 0,059) ingots (Baux, Gouin 1884, 203). It is impossible to connect the finding to nuragic period.

another " measurable " content of tin (130 ppm) is in Ittireddu 62417 (Begemann *et al.* 2001, tab. 1).

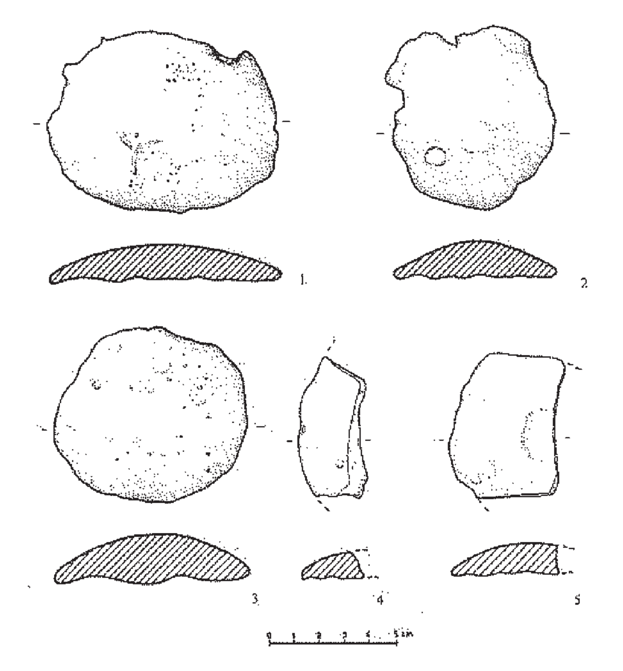


Fig. 3 – Little bronze ingots from the nuragic Sacred Well of Camposanto, Olmedo (Sassari). 1. Inv. no. 502; 2. Inv. no 503; 3. Inv. no 504; 4. Inv. no 505; 5. Inv. no 506 *(drawn by Antonio Farina).*

A little bun ingot from Camposanto, Olmedo (Sn 15.67 %), was analysed by Vodret; he also mentions two "ingots", one from Monte Pelau-Bonnanaro and one from unknown provenance, with respectively 8,57 % and 7,32 % of tin (Vodret 1935, 1959).

The question has no clear solution, both from archaeometallurgical and archaeological point of view. In the case of Ittireddu II hoard, there is a true close complex with 45 fragments, some of them of tiny dimensions. Of course it is impossible to distinguish the composition without a metallurgical analysis.

The five (three complete and two sections) little bun ingots are part of the few votive offerings left by the looters in 1926 in the nuragic Sacred Well of Camposanto, Olmedo (Taramelli 1933) (fig. 2). They are unique for their tiny dimensions and low weight (inv. no. 502, diam. cm. 9, h. cm. 1,4; gr. 359), compared to the natural size - for example - bun ingots of Flumenelongu hoard (inv. no. 10249, diam. cm. 13,8 x 13, h. cm. 3,5/4; gr. 1752). They seem mostly miniature reproductions of real bun ingots. It was a widespread custom in nuragic period to have miniatures for any kind of bronze figure: men and women, animals, monuments, furniture, weapons and tools, which were subsequently deposited in the sanctuaries. Therefore it is possible that they were not used for melting, but as a votive offerings. On the whole, on these few and disputable cases it is not possible at the moment, to recognise a rule or a pattern.

Tin in bronze artefacts

There are many more analyses of oxhide ingots than of bronze figurines, and there are only very few and occasional weapons and tools analyses. For those carried out in a less recent past; unfortunately, we have not enough reference to identify the objects [Vodret 1959, tabb. 3-6 (tab.4); SAM 1960; Tylecote, Balmuth, Massoli Novelli 1983, tab. 6 (tab. 5)]. The "artefacts" analysed in recent times are often only tiny fragments of rods and sheets and it is impossible to reconstruct and to evaluate archaeologically their original shape.

Tab. 1

Tin in weapons and in tools, according to the different metallurgical analyses: Vodret 1959, tab. 3 p. 261, tab. 4 p. 263, tab. 5 p. 264-5 (only weapons, metallic strips and tools).

Oggetti	Località	Cu	Sn	Pb	Fe	Ni	Zn	SiO2
Bandelle	Abini (Teti)	96,56	1,15	0.14	0.03	0.01	2.24	
Bandelle	Abini (Teti)	95,89	1,62		1,75		0.375	
Pugnale votivo	Abini (Teti)	85.6	10,85	0.06	0,15		2,87	
Spada votiva	Abini (Teti)	86.86	9,26	0.03	0.01	0.03	3.02	
Spada votiva	Abini (Teti)	96.53	2.21	0.46	0.51		0.22	0.04
Puntale lancia	Nuragus	86.61	8.67	0.43	0,27		1,89	0.3
Puntale lancia	Nuragus	87,08	10,04	0.11	0.08		2,73	
Puntale lancia	Abini (Teti)	91.11	7,82	0.6	0.09	0.04	0.11	
Puntale lancia	Abini (Teti)	93,22	5,7	0.14	0.18	0.07	0.12	
Spada combattimento	Nuragus	87.48	10.27	0.32	0.1		2.1	
Spada combattimento	Abini (Teti)	94	4,8	0.87	tracce	0.05	0.22	
Spada combattimento	Abini (Teti)	94.1	5,31	0.06	0.3		0.15	0.03
Spada combattimento	Abini (Teti)	85,63	12,77	0,02	0.09		1.37	
Spada combattimento	ignota	91.21	5.3	0,87	0.11	tracce	2.63	0.82
Spada lama larga	Maracalagonis	90,36	0,32	0.08	0,01	tracce	8.27	0.68
Lama pugnale (framm.)	Olmedo	93.22	5,77	0.07	0,19		0.002	0.4
Frammento pugnaletto	Serra Ilixi	82.5	11.28		0,53	tracce	5.02	
Frammento pugnaletto	Isili	82.5	11.28		0,53	tracce	5.02	
Spada combattimento larga	Maracalagonis	90.36	0.32	0.08	0.01	tracce	8.27	0.68
Puntale lancia	Nuragus	86.61	8,67	0.43	0.27		1.89	0.3
Punta lancia	Nuragus	87.08	10.04	0,11	0.08		2.73	
Spada combattimento	Nuragus	87.48	10.27	0.32	0.1		2.1	
Lama pugnale	Olmedo	93.22	5.77	0.07	0.19		0.002	0.4
Bandelle	Abini (Teti)	96,56	1.15	0.14	0.03	0.01	2.24	
Bandelle	Abini (Teti)	95,89	1,62		1.76		0.18	
Punta lancia	Abini (Teti)	91,11	7.82	0.6	0.09	0.04	0.11	
Punta lancia	Abini (Teti)	93.22	5.7	0.14	0.18	0.07	0.12	
Spada combattimento	Abini (Teti)	94	4.8	0.87	tracce		0.22	0.05
Spada combattimento	Abini (Teti)	85.63	12.77	0.02	0.09		1.37	
Spada combattimento	Abini (Teti)	94.1	5.31	0.06	0.3		0.15	0.03
Spada votiva	Abini (Teti)	86.82	9.26	0.03	0.01	0.03	3.02	
Spada votiva	Abini (Teti)	96,53	2.21	0.46	0.51		0.22	0,04
Pugnale votivo	Abini (Teti)	85.6	10.85	0,06	0.15		2.87	
Ascia bipenne	Lotzorai	84.29	11.59	0.43	0.18		2.84	
Ascia bipenne	incerta	89.13	4.15	5.6	0,26		tracce	0.75
Ascia piatta	incerta	94.01	3.9	1.56	0.04			0.78
Accetta	Lei	87.65	6.24	1.16	0.31		2.69	2.75
Accetta a margini rialzati	Terralba	83.36	9.61	0.23	0.09		3.71	3.16
Accetta a margini rialzati grosse	Terralba	80.24	10,47	0.82	0.11		4.39	4.62
Accetta a margini rialzati contorta	Terralba	90.11	5,13	1.6	0.03		3.01	
Accetta a margini rialzati norm.	Abini (Teti)	85,26	9,36		0.001		5.64	
Accetta a margini rialzati norm.	Nule	85.44	9.17		0.002		5.25	
Accetta a margini rialzati norm.	Ozieri	83.78	8.52	3.5	0.01		3.65	1.01
Accetta a margini rialzati norm.	Sarrok	97.15	0.38		0.001		2.22	0.19
Accetta a margini rialzati norm.	Quartu S.Elena	87.11	9.26		0.001		2.8	1.61
Accetta a margini rialzati norm.	Tertenia	90.57	7.6	0.45	tracce		1.53	
Accetta a margini rialzati norm.	Gairo	96.02	0.9	0.34	tracce		3,21	
Accetta a margini rialzati norm.	Lotzorai	83.07	13.07	0.002	tracce		3.57	
Frammento lima	incerta	85.12	13.05	0.76	0,02		1.55	
Frammento sega	incerta	87.58	10.87	2.06	tracce		2.08	2.65
Accetta a margini rialzati	Gairo	96,02	0.9	0.35	tracce		3.21	
Accetta	Lei	87.65	6.24	1.16	0.31		2.69	2.75
Accetta a margini rialzati	Lotzorai	83.07	13.07	tracce	tracce		3.57	
Ascia bipenne	Lotzorai	84.29	11.59	0.43	0.18		2.84	
Accetta a margini rialzati	Nule	85.44	9.17		0,002		5.25	
Accetta a margini rialzati	Ozieri	83.78	8,52	3.5	0.01		3.65	1.01
Accetta a margini rialzati	Quartu S.Elena	87.11	9.26		tracce		2.8	1.61
Accetta a margini rialzati	Sarrok	97.15	0.38		tracce		2.22	0,19
Accetta a margini rialzati	Terralba	83.36	9.61	0.23	0.09		3.71	3.16
Accetta a margini rialzati grossa	Terralba	80.24	10.47	0.82	0.11		4.29	4.62
Accetta a margini rialzati contorta	Terralba	90.11	5.13	1.6	0.03		3.01	
Accetta a margini rialzati	Tertenia	90.57	7.6	0.45	0.001		1.53	
Accetta a margini rialzati	Abini (Teti)	85.26	9.36		tracce		5.64	

Tab. 2

Tin in weapons and in tools, according to the different metallurgical analyses :

Oggetti	No.	Località	Sn	Pb	As	Sb	Ag	Ni	Bi	Co	Fe
Rivet	7942	Abini	10	0.67	0.83	tr	0.18	0.03			tr
Rivet	7943	Abini	10	0.89	0.08		0.01	0.02			strong
Dagger	7944	Abini	9	0.03	0.54	tr	0.03	0.03			tr
Dagger	7945	Abini	5	1	0.68	tr	0.2				tr
Dagger	7946	Abini	> 10	0.08	0,17	tr	0,02	0.01	0,009		tr
Dagger	7948	Abini	> 10	0.12	0.74		< 0,01	0.35			some
Dagger	7956	Abini	1.25	0.03	0.09		tr	0.02			strong
Dagger	7957	Abini	> 10	0.09	0.49		tr	0.02			tr
Dagger	7958	Abini	9.1	0,05	0.96		0.01	0.36		0.06	some
Dagger	7961	F. Nioi	6.7	1.45	0.27	0.54	0.2	0.25	0.011		some
Dagger	7964	F. Nioi	7.5	4.9	0.61	0.3	0,17	0.03	0.02		some
Axe	7960	F. Nioi	10	2.6	1.05		0,49	0.03			stong

a. SAM 1960 in Tylecote, Balmuth, Massoli Novelli 1983, 68, pl. 6 (only weapons, rivets and tools).

Oggetti	British M. No.	Località	Cu	Sn	Pb	As	Sb	Fe	Ni	Co	Bi	Zn	Ag
Dagger	1926.5 - 11.6	S.M.Paulis	88	8,7	1,3	0,12	0,025	0,8	0,035	0,035	0,003	0,03	0,05
Dagger blade	1926.5 - 11.8	S.M.Paulis	89	9.3	1,1	0,2	0.2	0.15	0,4	0,015			0,24
Spearhead	1926.5 - 11.7	S.M.Paulis	87	11	0.8	0,15	0,2	1,1	0,03	0,045		0,03	0,05
Ferrule	1926.5 - 11.9	S.M.Paulis	91	4,5	0,8	0,43	0,03	1,8	0,03	0,035		0,02	0,09
Double axe	1926.5 - 11.18	S.M.Paulis	88,5	10,8	0,7	0,3	0,01	0,4	0,02	0,015			0,06

b. Tylecote, Balmuth, Massoli Novelli 1983, 73, pl. 11, also in Craddock 1976, 109; Craddock, Tite 1984, 20-21 (only weapons and tools).

Oggetti	No.	Località	CU	Sn	As	Zn	Pb	Fe	Ni	Ag	Co	Mn
Votive sword	20947	Albucciu	99.05	o.97	0.18	0.59	0,11	0,1	0.32	0.007	0.008	
Votive sword	62385	Ittireddu	97.67	0.8	0.18	0.23		0.25	0.22	0.12	0.01	0.009
Axe	SS-B	Flumenelongu	82.6	1.31			0.06		0.14	0.29		
Axe	SS-C	Flumenelongu	85.47	10.94	0.09		1.39		0.19	0.62		
Axe	SS-D	Flumenelongu	90.71	5.83	0.23	0.002	0.93	0.028	0.018	0.003		
Bar	SS-A2	Flumenelongu	75.91	0.16	0.03	0.004	16.82		0.28	0.002		
*	SS-A4	Flumenelongu	65.78	5.6	0.64	0.002	25.39		0.019	0.26		
Axe	SS-I	Funtana Janna	85.75	11.6		0.008	0.013	0.003	0.02	0.26		
Axe	SS-J	Funtana Janna	85.28	9.85		0.008	0.013	0.003	0,02	0.026		
Axe	SS-K	Funtana Janna	85,23	12.3	0.06	0.002	0.04	0.009	0.013	0.034		
Axe	SS-L	Funtana Janna	81.13	10.8		0.09	0.64	0.52	0.017	0.02		
Axe	SS-M	Funtana Janna	82.75	12.5	0.21	0.006	0.91	0.013	0.017	0.11		
Axe	SS-N	Funtana Janna	84.72	12.8		0.009	0.25	0.035	0.012	0.047		
Spearhead	OI-4	Sa Sedda 'e Sos Carros	85.83	11.54	0.26	0.004	0.35	0.025	0.031	0.08		
Spearhead	OL5	Sa Sedda 'e Sos Carros	89.17	7.46	0.17	0.002	0.44	0.075	0.048	0.16		
Vot. sword	OL-6	Sa Sedda 'e Sos Carros	92.82	5.05	0.36	0.27	0.73	0.7	0.032	0.03		
Rod	OL-8	Sa Sedda 'e Sos Carros	94.24	5.74	0.33	0.009	0.65	0.25	0.031	0.01		
Axe blade	OL-9	Sa Sedda 'e Sos Carros	89.83	6.98	0.25	0.01	1	0.11	0.37	0.08		
Vot. sword	OL-16	Sa Sedda 'e Sos Carros	94.46	7.46	0.51	0.019	5.21	0.17	0.019	0.11		
Rod	OL-18	Sa Sedda 'e Sos Carros	87.58	10.99	0.03	0.14	0.38	0.012	0.026	0.08		
Rod	OL-19	Sa Sedda 'e Sos Carros	93.6	3.03	0.16	0.2	1.43	0.17	0.027	0.09		
Rod	OL-20	Sa Sedda 'e Sos Carros	88.66	8.23	0.26	0.009	0.9	0.16	0.013	0.05		
Rod	OL-21	Sa Sedda 'e Sos Carros	89.28	5.35	0.12	0.046	2.76	1.41	0.024	0.02		

* Handle fragment ?

c. Lo Schiavo, Maddin, Merkel, Muhly, Stech 1990, 51, 85, 145, 153, 167.

Tab. 3

Tin in weapons and in tools, according to the different metallurgical analyses: Begemann, Schmitt-Strecker, Pernicka, Lo Schiavo 2001, 60-61, pl. 3.

SARDINIAN ARTIFACTS

	Sample	Cu %	Sn ppm	Pb ppm	As ppm	Sb ppm	Co ppm	Ni ppm	Ag ppm	Au ppm	Fe ppm	Zn ppm	Se ppm	Te ppm
Implements														
Arzachena														
chisel	20976	89	143000	690	3800	135	530	289	300	14.8	<550	31	61	85
Bonnanaro														
double axe	10712	86	110000	2400	2530	390	97	206	890	3.5	220	70	40	<20
double axe	10713	90	116000	950	750	1610	22	650	470	0.63	520	<20	135	<25
socketed axe	10714	93	101000	710	1090	530	16	520	430	7.8	<300	<15	42	<20
double axe	10715	92	123000	3650	840	134	65	283	300	1.34	980	57	13	<10
axe blade	10716	92	105000	280	2170	390	16	370	350	10.3	160	9	38	<15
axe blade	10717*	92	103000	250	2120	370	16	380	340	10.2	<250	15	35	<15
axe blade	10718*	90	86000	160	1790	310	16	370	293	9.1	138	11	30	<10
Oliena														
spatula	58981	91	139000	430	5300	161	233	320	207	17.8	<700	16	61	102
Pattada														
double axe	1	90	103000	2560	2770	97	221	295	610	3.3	2390	198	27	<15
double axe	2	87	119000	1350	2900	82	215	227	460	4.0	7700	263	28	<20
axe adze	3	86	99000	2410	8300	188	137	247	580	3.5	550	256	24	<20
flanged axe	4	86	133000	2140	2570	131	277	340	430	4.2	7400	207	39	<20
flanged axe	5	89	121000	1580	3200	124	265	285	490	6.2	2680	133	39	<40
chisel	6	89	85000	1960	3400	118	470	390	570	5.9	5800	166	31	24
chisel	7	84	110000	4000	2590	133	172	297	580	5.1	2280	116	32	<20
chisel	8	90	112000	1000	5500	91	320	202	800	3.6	4900	380	39	<30
chisel	9	89	68000	3780	3700	141	149	277	710	5.1	8200	239	40	<30
handle of a chisel	10	83	109000	2040	3400	116	254	291	850	3.1	10700	298	40	<20
dagger	11	89	94000	1680	2400	139	170	249	320	17.2	1370	111	58	<20
dagger	12	90	74000	4780	3300	154	380	360	960	8.8	5600	179	35	<30
dagger	13	85	112000	3370	1700	84	232	281	370	3.6	3800	196	25	<15
Sword fragments														
Arzachena														
	20974A	99	<200	2730	9200	97	2	<7	13600	2.4	<1000	222	31	<70
	20974B	92	16200	50	2170	83	61	340	30	5.0	740	390	79	50
	20974C	98	17400	20	1390	42	28	191	20	3.4	1720	420	115	42
	20974D	100	9300	510	2240	144	201	310	114	5.3	1110	620	78	45
	20974E	97	9600	450	1920	57	123	298	30	4.6	790	117	89	49
	20974F	101	10100	230	1950	60	79	420	41	4.9	1500	137	94	49
	20974G	100	3300	90	2870	79	176	290	43	6.7	1360	237	76	58
	20974H	105	4700	40	2000	52	86	261	37	5.2	1450	150	92	63
	20974I	106	8500	150	1920	57	100	380	32	4.8	2550	350	114	51
	20974K	95	11200	60	2300	55	279	380	32	5.4	2360	283	60	41
	20974L	99	21700	390	2480	95	66	270	26	4.0	1270	118	114	42
	20974M	97	7800	40	1650	47	113	330	29	4.3	2460	241	83	46
Ittireddu														
	62385	101	11500	450	2530	118	100	340	246	5.7	1540	210	86	58
	62385A	83	75000	7400	1910	141	74	263	235	5.9	230	32	64	23
	62385D	100	4800	370	1470	38	37	210	26	3.8	1840	550	112	48
Non-descript metal														
Arzachena														
	20975A	102	<60	60	21	7	1230	<75	288	0.36	13700	<60	97	<40
	20975B	94	<70	4090	53000	420	31	165	2520	1.36	11900	1560	21	<60
	20975C	87	<110	5130	39000	1940	74	520	4400	0.98	12300	1660	24	<80
	20975D	104	<30	2350	18100	50	6	79	630	0.69	160	299	13	<10
	20975E	101	<250	900	4400	86	1	<1	32000	0.97	<2000	640	<1	<10
	20975G	103	<30	10	480	8	9	114	211	1.04	610	9	73	<15
	20975H	102	<150	3100	6300	118	2	<70	36700	1.14	<1000	590	23	<70
	20975R	99	<75	10	53000	450	<1	<35	1150	0.26	<500	20	2	<50

* Same object

The highest percentage of tin is said to be in ornaments, followed by tools and finally by weapons; the percentage is not always "standard", but there is no doubt on the fact that it is a deliberate alloy (Sn from 4,9 to 11,6 %: Cambi 1959a; Sn from 7,6 to 16,27 %: Vodret 1959; Sn from 8.1 to 11 %: Giardino 1987 fig. 9.8, 1995, fig. 84 based on Tylecote, Balmuth, Massoli Novelli 1983 and Craddock 1984).

Recent analyses of the hoards of Albucciu-Arzachena, Funtana-Ittireddu, Funtana Janna-Bonnanaro (Begemann *et al.* 2001) (tab. 3) and Flumenelongu-Alghero (Marabelli *et al.* in preparation) included a wider choice of tools and weapons. The results are different and show a greater variety of composition within the same category of objects (Sn from 6.8 to 14.3 %, average 10,8 %: Begemann *et al.* 2001, 53) and many new interesting metallurgical aspects.

a) Votive swords

The lowest percentage of tin was found, in previous analyses (Vodret 1959, 262), in the "*bandelle*", the metallic strips used to bind together groups of votive swords. The votive swords - as already remarked in the past (Baux, Gouin 1884, 195, 204) - are very long (80/120 cm) and thin weapons, characterised by a strong midrib, asymmetrical on the two sides. They were stuck, point up, on the top of the roofs of the nuragic Temples (Su Tempiesu-Orune, and Monte S. Antonio-Siligo), on the top of the "Ceremonial Wall" of Gremanu-Fonni Round Temple and on the "Tables of Offerings" (Ugas, Usai L. 1987; Fadda 1993; Fadda, Posi 2003; Lo Schiavo 1997).

They can be found broken in short pieces of about 25 cm, sometimes adapted as blades to the most typical nuragic "gamma-hilted" daggers.

The tiniest fragments (2/5 cm) were found in Albucciu-Arzachena, Funtana-Ittireddu and Baccus Simeone-Villanovaforru hoards, associated, among other things, with oxhide ingot fragments. At Albucciu-Arzachena and Funtana-Ittireddu the percentage of tin is around Sn 1 % (Begemann *et al.* 2001, 62), as if the bronzesmiths knew that this was not going to be a functional weapon, but a votive object, produced to be an offering, whose breakage was eventually foreseen and the fragments ritually re-adjusted.

The main point is the chronology: the Albucciu hoard is dated to the RBA (about XIII cent. B.C.) and the Baccus Simeone-Villanovaforru and Funtana-Ittireddu II (Lo Schiavo *et al.* in press) have the same chronology or are perhaps just a little later (end of RBA/beginning LBA), *i.e.* they are dated at the beginning of the most typical nuragic production.

b) Bronze figurines

In general the percentage of tin of the bronze figurines varies (Sn 2.2 to 11.8). There is relatively little lead and contamination with iron, probably due to the use of iron tools, or to mixed chalcopyrite ore deposits (Balmuth, Tylecote 1976; Balmuth 1978; Tylecote, Balmuth, Massoli Novelli 1983, 1984).

The very few notable exceptions demonstrate how important it is to widen the data-base and to evaluate the different compositions; one of these exceptions is the bronze figurine of a long-braided and huge-handed man, from Abini (Lilliu 1966, 217-219, no. 116; Atzeni C. *et al.* 1992a): Sn 0.27 ; Ag 6.5 ; Pb 0.29 ; Zn 0.09 ; Fe 0.01 ; Ni 0,03 ; Co <0.004. Another almost identical bronze figurine is apparently made of "standard" tin-bronze (Lilliu 1966, 216, no. 115 from Urzulei).

2.3. The level of "know-how" of the nuragic bronzesmiths

1. The most ancient and typical nuragic product of the RBA are votive swords: they are deliberately without or with very low tin; the lowest tin level is also found in the metallic strips used to bind together votive swords.

2. The oxhide, plano-convex and truncated-conical (Bonnanaro) ingots so far analysed are made of pure copper, evidently second refining (Merkel 1986; Maddin, Merkel 1990). Some of them show a lead-isotope fingerprint corresponding to the local Sardinian ores (Begemann *et al.* 2001, 57)[7]. Some of the hoards so far analysed are RBA or beginning of the FBA.

3. The bronze artefacts show a "standard" bronze composition and generally a correlation between the use of the object and its tin percentage; the "deviations" can be the result of remelting scrap.

The statistical data-base we possess up to now, is not large enough to allow the distinction of definite patterns. Nevertheless, there are still exceptions which deserve careful study: one is the "mixed bag" from Albucciu-Arzachena, where the little fragments are not scraps, but perhaps show the tinkering with various kind of ores or else experimental essays of melting and alloying (Begemann *et al.* 2001, 63).

2.4. Open problems

nuragic Sardinia seems to have developed a metallurgical technology at the level of Mediterranean Bronze Age. Still, there are inexplicable questions, difficult to answer also elsewhere in the Mediterranean:

1. Why did they produce and trade, on an internal and external network both oxhide and bun ingots ?

7. See in Begemann *et al.* 2001 the updated bibliography on Sardinian copper ingots analyses.

2. Did Bronze Age workshops practise a "standard" empirical alloying, based on the colour, or did they employ a weighing and measuring system, based on precise ponderal scale ? And if yes, which ponderal system ?

3. Were bronze ingots commonly in use ? Why are they so rarely found ?

4. Were tin ingots commonly in use ? Were they rarely found because of the instability of pure tin ? Is this a sufficient explanation for finding everywhere so many oxhide and no tin ingots ?

5. Where and how took smelting operations place ?

In nuragic Sardinia "metallurgy does not seem to have created social changes but rather responded to it" (Muhly & Stech 1990, 209). A next step was to ascertain that: "with the present data at hand, it is clear that during nuragic times, artefacts made of bronze were not just imported into Sardinia but also manufactured locally" (Begemann *et al.* 2001, 73).

As archaeological research go deeper and as our knowledge of tin sources and trade widens (Muhly 1973, 1982, 1985; Gillis 1990, 1991; Gillis, Clayton, forthcoming; Begemann *et al.* 1999; Wen Yi *et al.* 1999; various contribution on tin in the Mediterranean, in Giumlia-Mair, Lo Schiavo 2003), the more fundamental appears the role of this large island, rich in resources and in landing places, and just on the route of western tin, in a moment in which the eastern tin ores could have been difficult, if not impossible, to get (Lo Schiavo 2001; Kassianidou 2001, 110).

Still, Mycenaean presence and Cypriot metallurgical influence in nuragic Sardinia are undeniable and still the provenance of metallic tin found in Villagrande Strisàili still remains unknown.

Many more analyses and archaeological evaluation are needed, to help solving the problems, but the archaeological elements collected so far are highly stimulating.

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6.

3. The trade of tin and the island of copper

Vasiliki Kassianidou

3.1. Introduction

The role of Cyprus as a copper producer and exporter is well known (fig. 1). This is supported both by archaeological evidence from the island and abroad, and by textual evidence, if one accepts the identification of Alashiya with Cyprus (Muhly 1972, 217; Knapp 1996a, 3, 11; *contra* Merrillees 1972; 1987; Bass 1997, 156; Bass 1967, 77). Cypriot copper in the form of oxhide ingots has been found from the Bulgarian coast in the north (Dimitrov 1979, 73), to the Nile Delta in the south (Pusch 1995, 123), and from the coast of Haifa in the east (Galili *et al.*1986, 32) to the island of Sardinia in the West (Lo Schiavo 1989; 1998) (fig. 2). In order for copper, however, to be turned into a harder and, therefore, more useful material, it had to be alloyed with another metal. The first alloys to be used were those of copper and arsenic but by the Middle Bronze Age the metal used with copper to produce bronze, was tin (Charles 1980, 168, 172). Tin was not available on the island, and therefore, it had to be imported. The scope of this paper is twofold: on the one hand it will consider the effect that the introduction of tin-bronze had on the Bronze Age society of the island and on the other it will contemplate the possible role of Cyprus in the trade of tin in the Eastern Mediterranean.

3.2. Cyprus and Copper

Cyprus, the third largest Mediterranean island, is still today considered to be one of the richest countries in copper per surface area in the world (Constantinou 1982, 15). The exploitation of these copper deposits must have started in the Early Bronze Age, although the earliest archaeological evidence we have relating to the mining and smelting of copper ores dates to the Middle Bronze Age or the so-called Middle Cypriot Period (1900-1600 BC) (see below). Copper, however, is but one of Cyprus's natural resources. Equally significant although often forgotten, are the now somewhat depleted forests of Troodos, which in Antiquity provided fuel for the smelting furnaces, the pottery kilns, and other installations, but also timber for the construction of buildings and most importantly of ships. According to Muhly (1986, 49): “What the Amarna letters from the king of Alashiya, emphasize most of all is Cyprus as a source of wood and a centre of shipbuilding”. The fertile Mesaoria plain provided arable land for the cultivation of grain, while the foothills of Troodos ideal conditions for the cultivation of the vine and the olive. This natural wealth is made even more important by the island's geographic position in the Eastern Mediterranean, in the crossroads between the East and the West. The natural wealth in metal and timber and the geographical position of the island could not but lead it, eventually and rather belatedly, to the centre of the intricate system of trade which started to develop in the Middle Bronze, peaked in the Late Bronze Age and finally collapsed during the 12th century BC. Central to this trade was the export of copper from Cyprus to the neighbouring countries both East and West and the import of metals absent from the island such as gold, silver, lead and of course tin.

3.3. Tin and Tin-Bronze in Cyprus

Tin-bronze makes its first appearance in Cyprus in the transition between the Early Bronze Age and the Middle Bronze Age (*i.e.* Early Cypriot III (2000-1900) to Middle Cypriot I (1900-1800 BC), but the few early objects which on analysis were found to contain tin, are thought to have been imported (Weinstein Balthazar 1990, 161). Arsenical copper and unalloyed copper, however, retain their predominance during the Early Bronze Age and most of the Middle Bronze Age. Lead isotope analysis indicates that the copper, with only few exceptions, is local (Stos-Gale and Gale 1994, 116). It was already known, through Dikaios excavations at Ambelikou, that the exploitation of the rich copper deposits of the Troodos had started in the Middle Bronze Age (Dikaios 1946; Merrillees 1984). Recent excavations by Belgiorno (1999; 2000) at the site of Pyrgos- Mavrorachi, where significant amounts of copper smelting slag have been uncovered in what looks like an industrial setting, strongly support the early findings. It is also significant that the analysis of the slags from this site undertaken by Giardino (2000, 23) have shown that the copper was extracted from sulphide ores.

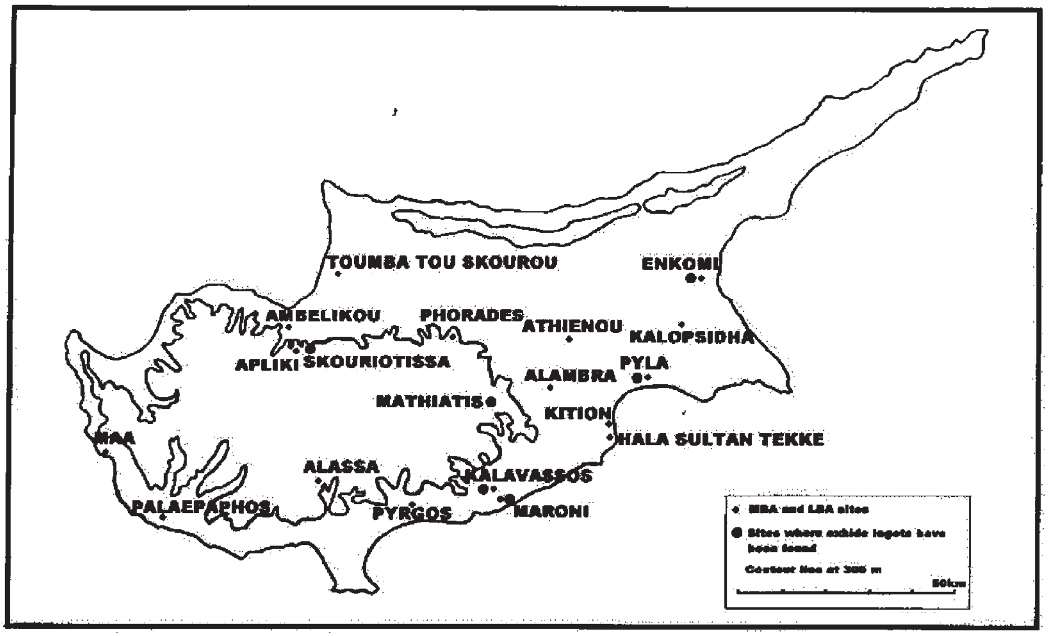

Fig. 1. Map of Cyprus showing MBA and LBA sites mentioned in the text, and sites where copper oxhide ingots have been found

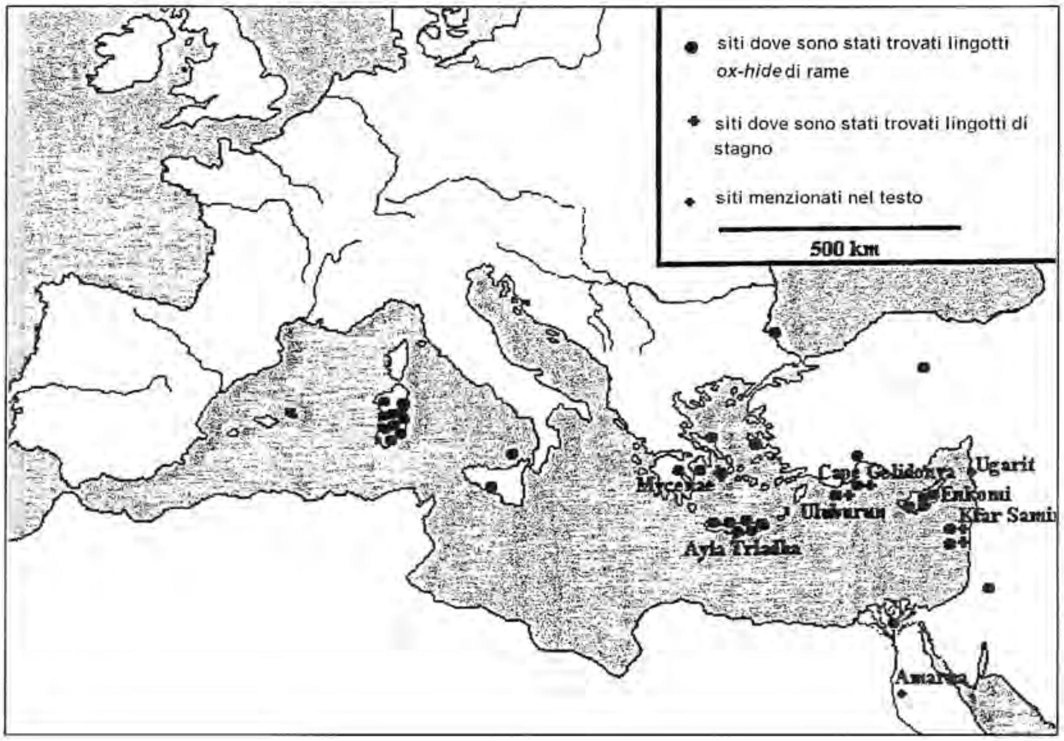

Fig. 2. Map of the Mediterranean showing sites mentioned in the text, and sites where copper oxhide and tin ingots have been found.

As for the arsenic, although the Cypriot massive sulphide-copper ores have a relatively low arsenical content, there are polymetallic ores rich in arsenic in what is called the Limassol Forest area (Bear, 1963, 36). According to geological reports the arsenic content in the polymetallic ores of Pevkos mines ranges between 0,5 and 7,6 % (Gass *et al.* 1994, 185). It has, therefore, been suggested that these may have been exploited in antiquity, and that they were mixed with coppr metal to produce arsenical bronze (Swiny 1982, 71). This would make Cyprus self sufficient, as far as, base metals are concerned, which is quite significant since in the Early Bronze Age and the beginning of the Middle Bronze Age, Cyprus has only limited contacts with its neighbouring lands (Knapp, Cherry 1994, 42).

It is in the early 2nd millennium, the Middle Cypriot I (1900-1800 BC), that the first objects of tin-bronze, which may be locally made, appear. However, according to Weinstein Balthazar (1990, 161), these may in fact have been made of recycled tin-bronze deriving from imported finished objects. That tin-bronze was recycled, seems to be indicated by the significant number of tin+arsenic+copper alloys, which are believed to have been the result of mixing local arsenical copper with imported tin-bronze (Weinstein Balthazar 1990, 162). Tin-bronze takes quite some time to get established and by Middle Cypriot II (1800-1725 BC) or Middle Cypriot III (1725-1600 BC) it is still only about half the objects produced that were made of tin+bronze or tin+arsenic+copper alloys. Furthermore, the smiths seem to reserve this new alloy only for certain types of the limited repertoire of metal objects (Weinstein Balthazar 1990, 431). At the beginning tin-bronze was used for riveted knives and toggle pins, while in the Middle Cypriot III period shaft hole axes are also made of this alloy. Hook tang weapons, scrapers, awls, tweezers and pins were still made of arsenical bronze until the end of the Middle Bronze Age.

Interestingly enough, based on the archaeological evidence both from Cyprus and abroad, the second half of the Middle Bronze Age marks the beginning of Cyprus' involvement in the complex, international, state controlled and centred on palace economies, trade system of the Eastern Mediterranean. Cypriot pottery has been recovered from various sites of this period in the Levant, Egypt and Anatolia (Muhly 1985, 29; Knapp, Cherry 1994, 42). Although pottery, understandably forms the majority of Cypriot exports (since ceramics, unlike copper, are much more visible archaeologically, due to the nature of the material which is durable and of course cannot be recycled), the written sources suggest that Cyprus (if we accept the identification of Cyprus with Alashiya) has already started to supply copper to the states of the Near East. Some of the earliest references to the copper and bronze from Alashiya comes from Mari and is dated to the first half of the eighteenth century BC (Muhly 1972, 204).

It is in the Late Bronze Age (1600-1050 BC) that tin-bronze is finally established and, I believe that this is intimately associated with other major changes and developments that take place on the island. In the Late Bronze Age large urban centres are established on the coast, mainly the south, south-eastern and south-western in sharp contrast with the previous period where the majority of sites is located further inland in arable lands and in close proximity to the Troodos (Knapp 1994, 283). Monumental public and religious architecture, writing (in the form of the Cypro-Minoan script which until today remains undeciphered), foreign imports and burials of individuals who clearly belong to a different class mark the emergence of a complex society (Knapp 1994, 282). The sharp increase in the amount and variety of foreign imports clearly show Cyprus' active involvement in the trade mechanisms of the Eastern Mediterranean (Knapp and Cherry 1994, 43-6). Finally, at this time Alashiya appears in Egyptian, Hittite, and Near Eastern texts commonly as a producer and exporter of copper (Muhly 1972, 209-212; Knapp 1996, 8). These texts indicate the presence of a king who corresponded with the Pharaoh of Egypt and the king of the Hittites and one who used state agents (*tamkaru*) to conduct foreign trade (Knapp 1994, 287).

The prosperity of the island is believed to have derived from the ever-increasing trade in ceramics, raw materials, and organic products, with the Near East and the Aegean (Karageorghis 1996, 66). The main product exported from Cyprus was, however, copper and, in the Late Bronze Age there is a marked increase in the number and variety of metallurgical finds from practically all excavated sites (Knapp 1994, 287; Knapp 1986, 44; Muhly 1996, 47; Muhly 1989, 301-2). The fact, that copper workshops have been found in the precincts of sanctuaries, in Kition and Athienou, as well as, the discovery of two bronze cult figures shown standing on an copper oxhide ingot: the Ingot God (Schaeffer 1965) and the Bomford Goddess (Catling 1971) have led some to argue that the copper industry was intimately associated with religion (Karageorghis and Demas 1985, 253-4; Karageorghis 1976, 170). Knapp (1996, 10) has opposed this idea and has suggested instead that:

> "*To organise and legitimise control over an island culturally if not politically divided, developing élites established unequal access on essential resources or prestige goods, and adopted legitimising symbols (e.g. miniature ´Votive´ ingots, bronze figurines and stands, clay cylinder seals) that enabled them to co-opt goods and labour, ostensibly on the community's behalf, for their own political and economic goal*" (Knapp 1996, 17).

I believe that the introduction of tin-bronze, a material that although had comparable mechanical properties to arsenical bronze was nevertheless preferable because it enabled the smith to produce a more consistent and reliable alloy (Charles 1978, 29), strengthened the status of the ruling class. By introducing an alloy, which requires the use of a metal that was not locally available but could only be acquired through international trade, the elite could control one of the essential commodities for the smooth function of the economy. The control of the import and therefore access to tin, the material with which bronze tools, weapons and other objects necessary for all aspects of the economy were made, was a much more critical factor in this effort to establish power over the rest of the population, than the control of other exotic prestige goods such as foreign pottery, ostrich eggs, fayence, etc.

With the introduction of tin-bronze, the craft of metalworking was greatly developed and apart from a greater variety of tools and weapons than the limited one which characterized the Middle Bronze Age, the workshops of Enkomi, Hala Sultan Tekke and other sites produced true masterpieces such as the tripod and four sided stands, which were widely exported, and the Horned God which remains one of the largest cast bronze statues of this period in the Mediterranean world (Papasavvas 2001, 214-5). These objects gave further prestige to their owners, the elite based in the urban centres (both coastal and inland), and made them stand apart even more from the inhabitants of the small inland agricultural and industrial villages, who produced the agricultural products and the copper on which the economy was based (for discussions of the proposed model of a threefold settlement system in Late Bronze Age Cyprus, see: Catling 1962; Keswani 1993; Knapp 1997).

But this is only half of the story. I believe, as I will try to show, that, the same elite, which was controlling the import and distribution of tin within Cyprus, was also involved in the distribution and trade of tin to other major centres of this period.

3.4. Cyprus and the trade of tin

In a paper published in 1977, Maddin, Wheeler and Muhly (1977, 45) announced the discovery of two tin ingots, on the surface of which were inscribed two marks (fig. 3). The two ingots had been bought for the Haifa Municipal Art Museum and lacked any secure archaeological context (Artzy 1983, 52). However, the marks had been identified as belonging to the Cypro Minoan script and, therefore, the ingots were dated to the Late Bronze Age (Maddin *et al.* 1977, 46).

Although, analysis had shown that tin was among the materials carried by the ship that sank off the Cape Gelidonya (Bass 1967, 83; Maddin *et al.* 1977, 44), it was not certain that it was in the form of ingots and some did suggest that it may have been the tin ore, cassiterite (tin oxide), thus fuelling the debate once again on whether tin-bronze was produced by mixing copper with metallic tin or with cassiterite (Charles 1978, 26).

The discovery of the tin ingots, therefore, was extremely significant because here was finally proof that tin was traded in its metallic form. Even more significant, for the purpose of this paper, was that the marks were identified as Cypro-Minoan, and this led the three scholars, R. Maddin, T. Wheeler and J.D., Muhly, to the following conclusion (Maddin *et al.* 1977, 46):

> *"Secondly it is probable that, both metals necessary in the making of bronze, were distributed by an administrative complex centred on Cyprus. Although the source of the tin is unknown, it passed through Cyprus where it received the markings, which are also found on some copper ingots of LBA date".*

In other words, from the moment of the first discovery of tin ingots, the question of Cyprus' involvement in the trade of this metal was also raised, and it is the issue that I will develop in the remainder of this paper.

A few years later, Artzy (1983, 52) published two more ingots, which were found in a car workshop in Haifa, where they were being used for soldering broken radiators. The new ingots were not only identical in size and shape with the previous two, but they were also engraved with two marks. In fact, one of the ingots had identical marks to one of the earlier discovered ones (Artzy 1983, 52). The four ingots, therefore, were rightly identified as belonging to the same group or cargo of a ship. There was one difference, however, and that was the presence of a moulded head on one of the new ingots, which clearly had been produced when the ingot was cast (fig. 4). On stylistic grounds Artzy (1983, 52) dated the figure to the fifth century BC and identified her as Arethusa, a fountain goddess who appears on Syracusan coins of this period. She then proceeded to search for the engraved symbols on syllabaries of the fifth century BC which led her to suggest that the symbols may in fact be Iberian (Artzy 1983, 53). Therefore, she cautiously suggested that the ingots might have been produced in Iberia, sometime in the first quarter of the 5th century BC (Artzy 1983, 54). I have not located any published reactions to this proposition, which refuted both the Late Bronze Age date of the tin ingots, and the allocation of the marks to the Cypro-Minoan script.

The sea of Haifa in two different locations, however, produced even more inscribed tin ingots, which were found together with other objects clearly dating to the Late Bronze Age. The first group of five tin ingots was discovered at the site of Kfar Samir (at the Hishule Carmel coast) in association with a copper oxhide ingot, as well as, perforated stone anchors of a type which is usually identified as coming from either Cyprus or the Syro-Palestinian coast (Galili *et al.* 1986, 25). The ingots weigh between 2,2 and 4,2 kg and have an irregular plano-convex shape (Galili *et al.* 1986, 25). The marks were inscribed on the flat side of three of the ingots when the metal had hardened (figg. 5-6); (fig. 5a-c); although not certain, the excavators tentatively identified them as belonging to the Cypro-Minoan script.

In the same general area of the Kfar Samir coast, another group of tin and lead ingots was discovered together with perforated stone anchors and other objects, some of which are of Egyptian provenance (Raban and Galil 1985, 326). The finds were dated to the 14th-13th century BC (Raban, Galili 1985, 327). A total of ten tin ingots were recovered, eight of which were bar-shaped (Raban, Galili 1985, 327). The ingots were badly corroded and only one of them clearly bore inscribed marks, which unfortunately could not be clearly seen. The other two ingots were much larger, weighing 27 and 37 kg each, and hemispherical in form. One of the two had been sawed in half in antiquity. As they are heavily concreted, it was very difficult to see whether they had also been inscribed. The five small lead ingots, of varied shape and weight ranging from to 0.68-6.94 kg, on the other hand, all bore inscribed marks, which were tentatively identified as Cypro-Minoan (Raban, Galili 1985, 327; Misch-Brandl *et al.* 1985, 9).

Thus, apart from the initial four ingots whose Late Bronze Age date had been dismissed, a total of fifteen tin ingots, which dated to the Late Bronze Age and were inscribed with marks that could very possibly belong to the Cypro-Minoan script, were recovered from the Kfar Samir coast. Although the question of Cyprus´ involvement in the trade of tin during the Late Bronze Age was back on the table for discussion, it has not really been addressed again and the discoveries in Haifa received less attention than they deserve.

This is possibly because in the same period a much more impressive shipwreck was discovered, and subsequently excavated, off the south-western coast of Anatolia, at the site of Uluburun also known as Kaš (Bass 1986; Bass *et al.* 989; Pulak 1997; 1998; 2000; 2000b; 2001; Sibella 1996). The wealth and variety of the cargo led to the conclusion that this could only have been a royal ship, which loaded with finished objects and raw materials in a port in the Eastern Mediterranean was heading West (to the Aegean?) to an unfortunately unknown destination (Pulak 2001, 48-9; 1998, 218-9; 1997, 255-6). As it is well known, the ship carried almost ten tons of copper in the form of 354 oxhide ingots, and 121 bun and oval ingots (Pulak 1997, 235; 1998, 193; 2000a, 140-5). More significantly it carried almost a ton of metallic tin in the form of oxhide ingots, bun ingots, rectangular slabs, as well as, sections of large thick disks and a unique example similar in shape to a stone anchor with a large hole at the end (Pulak 1997, 239; 1998, 199; 2000a, 150-1; Maddin 1989, 101-4). Many of the tin oxhide ingots had been sectioned in antiquity to halves, and quarters (Pulak 1997, 239; 1998, 199; 2000a, 150; 2001, 22).

The following discussion is based on the latest available publications on the shipwreck and may have to be modified as new results on this material are published, especially since at the time of the publications conservation and study of the ingots was still underway. At least 160, of the 176 copper oxhide ingots that had been cleaned and conserved, bear marks on the rougher side (Pulak 2000, 141). The oxhide ingots were incised with one, and some with as many as three marks (Pulak 1997, 235; 1998, 194; 2000, 146), and they had been stored in such a way on the ship, that the marks would have been visible (Pulak 2000, 141). More than half of the bun ingots were also inscribed, but they bear only single marks incised on the smooth mould side (Pulak 1998, 134; 2000, 146). Only one of the three complete tin oxhide ingots recovered from the site was conserved and it was inscribed, as were the sectioned tin ingots (Pulak 1997, 240; 2000, 150, 153). In the latter the mark was centred on the fragment, indicating that the incision had been made after the ingots had been sectioned (Pulak 1997, 240; 2000, 153).

Thirty-two marks have thus far been identified on the Uluburun ingots (for a published table of the marks see Sibella 1996, 9; Pulak 1998, 196; 2000, 146). These are often repeated on the different shaped copper oxhide ingots and the copper bun ingots, while one mark is found both on a tin oxhide ingot and a copper oxhide ingot (Sibella 1996, 10; Pulak 1998, 194, 196). It is remarkable that among the 32 marks, there are some that appear on copper oxhide ingots found in Ayia Triadha in Crete, in San Antioco di Bisarcio in Sardinia and in Enkomi in Cyprus (Sibella 1996, 10). Unlike most of the oxhide ingots, from the Cape Gelidonya (Bass 1967, 52 and those found in various other Late Bronze Age sites such as the ones from Enkomi (Catling 1964, 267-8), Mycenae (Buchholz 1959, 36), Sardinia (Vagnetti, Lo Schiavo 1989, 225) and elsewhere, which bore impressed marks, the ingots from Uluburun all bore inscribed marks.

As stamped marks have to be produced when the metal has not yet fully hardened, it has been suggested that these must have been produced just after the casting of the molten metal, in other words at the place of production (Bass 1967, 72). There were, therefore, termed “primary” marks by Bass (1967, 74). Inscribed marks, on the other hand are considered to be “secondary”, as they could have been produced either at the place of production, or at the point of export and even at the point of import. The question of the meaning of the primary and secondary marks had been extensively discussed by Bass (1967, 72-4), who suggested that the primary marks identified the source of copper, while the secondary marks, may have been incised by a person inspecting the material ready for export, by the merchant who received them or even by the merchant who had bought them. The excavators of Uluburun, where literally hundreds of inscribed ingots were recovered, also tried to address the same question (Sibella 1996, 10; Pulak 2000, 146). According to Pulak (1998, 196):

> *“That the Uluburun marks were all incised and not stamped during casting or cooling (as were many from Cape Gelidonya) leads to the belief that they probably were made at some point of receipt or export rather than at the primary production centre or centres. This supposition finds a basis in the form of a similar mark on a tin ingot from Uluburun. As tin and copper would have been mined in different geographical regions, it is highly unlikely that the same mark would have been incised on ingots of dissimilar metals and of diverse origins unless this was done at a centre that handled both ingot types during the distribution process.”*

Thus it is significant to assign the marks to a script as this may give us some clues regarding the point of manufacture of the metal ingots, as far as the primary marks are concerned, and the centres involved in the trade of metals as far as the secondary marks are concerned.

According to Sibella (1996, 10), the member of the Uluburun team who has been studying the ingots and their inscribed marks, of thirty marks identified so far, at least five belong to the Cypro-Minoan script. Pulak´s (1998, 195; 2000, 46) only comment on the marks, however, is the following:

"The marks vary in shape from a simple cross to more complicated forms. It is of interest to note that an appreciable number are associated with the sea and ships: the fishhook in several forms, a trident, a fish, possibly quarter rudders and even a sailing boat". This suggests that the people who incised the marks were closely involved with the sea. Therefore, it is more likely that the marks were placed on the ingots at locations near the sea rather than inland".

This I believe is a very simplistic argument; especially if we take into consideration the fact that the so-called trident is one of the signs found not only in the Cypro-Minoan script but also in Linear A (Daniel 1941, 256; about Cypro-Minoan signs, see Masson 1974, 12-15). In fact, even someone who is not an expert on the Cypro-Minoan script can pick out more signs that may very well belong to the Cypro-Minoan script. One of the marks that have not been identified by Sibella as Cypro-Minoan, is the one found both on a copper ingot and a tin ingot[1] (Pulak 1998, 196). Yet this is a sign that belongs to the Cypro-Minoan script (CM 6, Masson 1974, 13 and that survives in the Cypriot Syllabary of the Iron Age representing the sound pa (Masson 1995, 66). The same mark is found stamped on an ingot from Cape Gelidonya (Bass 1967, 72), inscribed on Cypriot ceramics (Daniel 1941, 274), Mycenaean sherds from Ugarit (Hirschfeld 2000, 188) and Cyprus (Daniel 1941, 277), as well as, Cypriot ceramic loomweights (Smith 1994, 230, 232). The problem is of course that the same sign is found in other scripts such as Linear A and Linear B (Daniel 1941, 254). Nevertheless, Pulak does not even consider the slight possibility that the marks inscribed on the ingots belong to the Cypro-Minoan script.

This is, perhaps, the result of the general reluctance one detects in both Pulak and Bass to accept even the possibility that the ship could be a Cypriot one. The following statement by Bass (1991, 75) is I believe characteristic:

"If the Uluburun ship was Alasian, that would be strong evidence against the unproven identification as Cyprus, for there is no reason to believe that the ship was Cypriot, although much of its cargo was Cypriot: six tons of four handled copper ingots and several pithoi filled with unused Cypriot pottery (including Base Ring II Ware, White Shaved Ware, White Slip Ware, Bucchero Ware, unused lamps, and 'wall brackets')."

Although both often stress how difficult it is to identify the nationality of a ship (Bass 1991, 70; Pulak 1997, 252), they strongly support that the ship was of a Syro-Palestinian or Levantine origin (Pulak 1998, 218; 1997, 252). This in spite of the fact that when looked at closely the evidence presented is not conclusive: the anchors of the ship belong to a type common to Cyprus and the Syro-Palestinian coast (Pulak 1998, 218; Bass 1991, 74), the weights belong to a standard employed both in Cyprus and the Syro-Palestinian coast (Pulak 2000a, 259, 264), the wood (cedar) (Pulak 1998, 213) that was used to make the boat could have come either from Cyprus or the Syro-Palestinian coast, the type of bush (thorny burnet) used for dunnage in the bottom of the hold and below the copper oxhide ingots (Pulak 1998, 197) is common both in Cyprus and the Levant, etc. In the effort to identify the nationality of the boat they turn to the used, utilitarian ware found on the ship, as they believe that it would be characteristic of the region where the ship originated. However, the so-called "ship's galley ware", has not yet been identified and studied in detail (Pulak 1998, 216). The only supporting clue that remained was that among the two types of lamps that the ship was carrying, Cypriot and Syro-Palestinian, only the latter seemed to have been used (Pulak 1998, 218). I am not claiming that the ship is Cypriot, I am only noting that considering the difficulty in assigning nationality to a ship, to the ship's owner, to the ship´s crew, or to the person who perhaps chartered the ship to carry the cargo, I think we should leave this question open and suggest that both possibilities are equally probable. The nationality of the Uluburun ship, however, is not the subject of this paper. The trade of metals and the role of Cyprus is what concerns me and this is the reason why I have spent so much time looking at the marks on the copper and tin ingots.

We already knew that the copper oxhide ingots from various Late Bronze Age sites in the Eastern and Central Mediterranean were marked either with Cypro-Minoan stamped marks modelled on the still soft metal or inscribed after the metal had cooled down. The discoveries of tin ingots at Kfar Samir and at Uluburun have shown that the tin ingots are also inscribed and that most of the marks belong to the Cypro-Minoan script. Although we still cannot understand the significance of these primary and secondary marks they are still very important, because as suggested by Pulak (1998, 196) in the paragraph quoted above, the secondary marks probably relate to the people and the centre that was involved in the trade of these metals.

1. According to Pulak (1998, 196) the mark that is common to both the tin and the copper ingots is Number 4a in the table of incised marks (compiled by Sibella) that he reproduced in his paper. This mark, as stated above, is one that Sibella has not included in the group of Cypro-Minoan signs, although it is a well-known Cypro-Minoan sign. Sibella (1996, 11), on the other hand, writes that the mark common to the copper and tin ingots is no. 7 a in her table, and it is one that she did identify as Cypro-Minoan sign (Sibella 1996, 10). It is impossible to know whether this discrepancy is due to a typographical error, a mistake or because the two authors are referring to two different ingots and therefore, two different marks. One way or another, and which ever of the two statements is correct, as argued above both the marks belong to the Cypro-Minoan and, therefore, can be used to support the arguments I present in the paper.

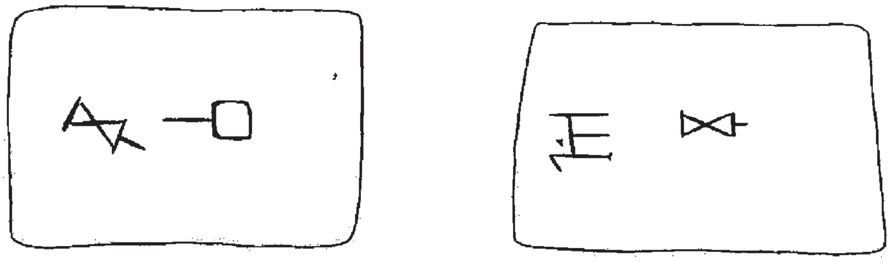

Fig.3. The two inscribed tin ingots discovered in Haifa (Wheeler, 1977: 25).

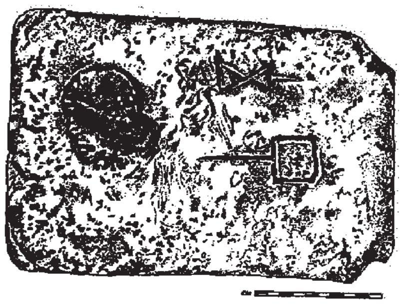

Fig. 4 Inscribed tin ingot with a moulded Head, from Haifa (Artzy, 1983: 53).

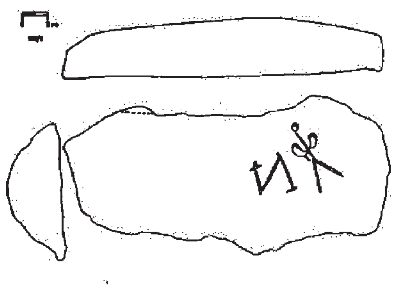

Fig. 5a. Inscribed tin ingot, from Hishule Carmel (Galili, et al. 1986: 29).

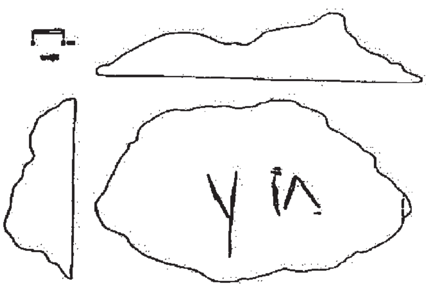

Fig. 5b. Inscribed tin ingot, from Hishule Carmel (Galili, et al. 1986: 29).

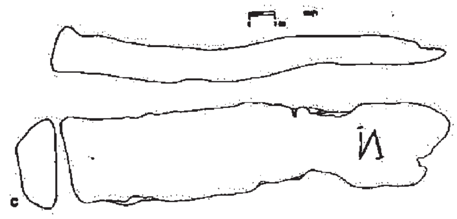

Fig. 5c. Inscribed tin ingot, from Hishule Carmel (Galili, et al. 1986: 30).

The strong possibility that the marks found not only on the copper but also on the tin ingots belong to the Cypro-Minoan script leads me to suggest, as indeed Maddin, Muhly and Stech (Maddin *et al.* 1977, 46; Muhly 1978, 45; Wheeler 1977, 24; Wheeler *et al.* 1979, 148) had suggested more than twenty five years ago, that this centre or centres (taking into consideration the number of LBA Cypriot urban centres on the coast, *i.e.* Enkomi, Kition, Hala Sultan Tekke, Maroni-*Tsaroukkas* etc) was located on Cyprus and that it was involved in the distribution of both metals around the Eastern Mediterranean.

Nevertheless, because I suspect that such a statement may not be easily accepted I will modify it slightly. I make this comment because even the possibility that a Cypriot international trade centre, such as Enkomi, may have been the Uluburun ship's last port of call is mentioned rather reluctantly, even though the largest volume of the cargo namely the ten tons of copper and the ten Cypriot pithoi filled with ceramics and comestibles originated on the island. Pulak (1997, 253; 1998, 215, 218), Bass (1997, 155) propose instead that the ship was loaded at Ugarit, where the Cypriot copper, the Cypriot *pithoi*, the 149 Canaanite *amphorae*, the tin and the rest of the cargo could be gathered from the various points of origin. Even if we accept this, it does not exclude the possibility of Cypriots, based in Ugarit, being involved or being in charge of the metals trade. After all, Ugarit is the only site outside Cyprus, where we find documents written in the Cypro-Minoan script (Masson 1995, 63; Masson 1974).

To support my argument I would like to draw a parallel between the inscribed ingots and the inscribed pottery of this period. Hirschfeld (1993; 2000; 2001) has been studying and recording Cypro-Minoan signs and inscriptions on ceramic vessels. The marks are inscribed on handles or other obvious locations after firing, which sets them apart from potters marks, which are usually at the bottom of the vase and are made before firing. The Cypriots commonly inscribed different types of their pottery both before and after firing (Hirschfeld 2001, 123). The practice of inscribing marks extended to imported pottery including Aegean Wares which are found in all the major Cypriot sites of the period, as well as, Near Eastern sites such as Ras Shamra, Minet el Beidha (in other words Ugarit and its port), Alalakh, Byblos, Beth Shan, and many more (Hirschfeld 1993, 312; Hirschfeld 2000). The fact that Cyprus has a long tradition of marking pottery, in contrast with the Aegean where the practice is very rare, in combination with the fact that large numbers of Aegean wares of a great variety of shapes marked with Cypro-Minoan signs are found on the island led Hirschfeld (1993, 313) to the conclusion that the incised marks point to a connection with Cyprus and to the following statement:

> *"This final observation supports the hypothesis that marking Aegean pottery with signs incised after firing is a specifically Cypriot practice. This in turn, implies that vessels with these signs on them have either been routed via Cyprus at some stage, or that they have been handled by people familiar with the Cypriot marking system".*

I believe it would not be unreasonable for me to borrow Hirschfeld´s ideas and to make a similar statement. In other words, marking of metal ingots, whether they are copper oxhide ingots, copper bun ingots, tin oxhide ingots or tin plano-convex ingots, indeed even lead ingots, seems to be a specifically Cypriot practice which implies that the ingots have either been routed *via* Cyprus or that they have been handled by people familiar with the Cypriot marking system.

It is quite possible that these people were based at Ugarit where the tin would arrive over land from somewhere in the east following a trade route that we know from earlier texts. Let us not forget the text from Mari (Mari text A 1270), which mentions the presence of Cretan merchants who had their elder and an interpreter in Ugarit, where they received shipments of tin from Mari (Heltzer 1989, 10). These texts date to the reign of Zimirlim, which corresponds to the first half of the eighteenth century (Heltzer 1989, 25). It is possible that a similar situation existed in the Late Bronze Age at the time of the Uluburun shipwreck and later. Instead of Cretan merchants, Cypriot merchants would have been based at Ugarit, as is witnessed by the presence of texts written in the Cypro-Minoan script found there (Masson 1974). These merchants would have been in charge of the import of Cypriot copper to Syria and Palestine. They also would have been in charge of receiving metallic tin coming from the East, which they brought back to Cyprus but also traded along with their copper to areas further west (Crete, the Aegean islands and mainland Greece) perhaps even to Egypt. This practice may be indicated in an Egyptian text (Papyrus Anastasi IV, 17.8-9) from the 19th Dynasty, which mentions ingots of copper and bars of tin being brought as presents to the pharaoh, on the neck of the children of Alashiya (Muhly 1973, 245). According to Muhly (1981, 48):

> *"Now Cyprus certainly has no tin, so this reference can only mean that tin came to Egypt through Cyprus".*

The involvement of Cypriots is shown by the inscriptions of Cypro-Minoan signs on the ingots a practice which parallels the practice of marking Aegean pottery, the trade of which has often been suggested was also in the hands of Cypriots, because Aegean Wares are usually found in the Near East in association with Cypriot wares (Muhly 1996, 52).

As pointed out again by Maddin, Muhly and Stech (1977, 46), the possibility that the Cypriots would trade tin, as well as copper need not surprise us. In order to produce bronze both copper and tin, are necessary. Tin, however, is not as readily available as copper and the identity of ancient tin sources create even today heated discussions among scholars. By including tin along with a shipment of copper, as was done in all three cases of the ancient wrecks dating to the Late Bronze Age, *i.e.* Uluburun, Kfar Samir and Cape Gelidonya, the Cypriots ensured that their own product would be consumed. Similarly, even if we are dealing with a trade system that is based on gift-exchange between royals a gift that included both tin and copper would have been much more valuable, and much more welcome than one which included only copper.

3.5. Conclusion

In conclusion, let me recapitulate the basic ideas of this paper. I believe that the emerging élites used the advent of tin bronze on the island to establish their position, by controlling the import and distribution of tin in the island. I further suggest that having understood the importance of tin and the control of the tin supply, Cypriot merchants took an active role in the trade of tin from the Syro-Palestinian coast, where it arrived over land routes from the East, to areas across the sea such as the Aegean, and perhaps even Egypt. Let me take the argument one step further. When the complex system of trading collapsed and Ugarit among many other places was destroyed, this eastern source of tin was cut off. This, however, became an incentive for the search of tin elsewhere. Perhaps this is the main reason why the Cypriots travelled west reaching and establishing strong trade relations with Sardinia, as witnessed by the presence there of Cypriot oxhide ingot (Lo Schiavo 1989; 1998; Kassianidou 2001), Cypriot pottery (Vagnetti, Lo Schiavo 1989, 219-21), as well as, Cypriot smithing tools and tripod stands (Lo Schiavo 1995, 49; Vagnetti, Lo Schiavo 1989, 227-231). In Sardinia, they would find tin coming from the island (although Prof. Valera´s paper in this volume will answer the critical question of whether tin deposits on Sardinia had indeed been exploited in the Late Bronze Age) but also from richer sources in Iberia. Current archaeological work has shown that they were already exploited in the Late Bronze Age (Rodriguez Dias *et al.* 2001).

The Bronze Age metals´ trade has been a subject of paramount concern to many scholars; even so many questions remain unanswered and there is clearly a lot that remains to be learned. I do believe that what is critically needed is a detailed study of the marks on all metal ingots, not just the ones from Uluburun but also those from Cyprus, Crete, Sardinia, and elsewhere, by an expert in very much the same way as it was done for pottery. I hope, and it is a hope that I have expressed to Joanna Smith who together with Nicolle Hirschfeld has been working on creating a corpus of the Cypro-Minoan script (Smith, Hirschfeld, 1999) that someone will take up this project and shed some light to some of the issues raised in this paper.

Note

V. Kassianidou, The trade of tin and island of copper, in "*Le problème de l'étain à l'origine de la métallurgie - The problem of early tin*" , Section 11, 2nd Colloquium, Acts of the XIV UISPP CONGRESS, University of Liège, Belgium, 2-8 Sept., 2001, A. Giumlia-Mair & F. Lo Schiavo eds., BAR I. S. 1199, 2003, 109-119.

Acknowledgments

I would like to thank Dr Fulvia Lo Schiavo and Dr Alessandra Giumlia Mair for inviting me to participate on this forum on the problem of ancient tin. I must admit that my initial reaction, one that I expressed immediately when the invitation was forwarded, was to state that I feared I would have nothing to say. After all, the one thing that we all know very well is that Cyprus has no tin. I am relieved that Dr Lo Schiavo did not accept this rush reaction and quickly reminded me that, of course there is tin in Cyprus, only it is in the form of bronze and, therefore, there would be something to say, even if it was just to explain when and how the tin came to the island.

As is often the case with other papers written on the subject of Late Bronze Age trade in metals, this one has benefited greatly by the work of the team of Robert Maddin, Jim Muhly and Tamara Stech-Wheeler who as pointed out above presented the same idea almost 25 years ago. I would like to acknowledge their work and express my thanks to them.

I would also like to thank Joanna Smith for her advice on issues regarding the Cypro-Minoan script, a subject I know little about. Special thanks to Michal Artzy for allowing me to reproduce the drawings of the inscribed ingots found in the area of Haifa.

Last but not least, I would like to thank Maria Iacovou and George Papasavvas for reading through and discussing this paper with me and offering valuable comments and suggestions for improvement, and Phryni Hadjichristophi for the translation of the abstract into French.

I hope that the final result will motivate someone to study systematically the primary and secondary marks on the metal ingots from all the sites in Central and Eastern Mediterranean, and shed some light on the burning issue of the metals´ trade.

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7.

THE FIRST IRON IN SARDINIA

Fulvia Lo Schiavo

1. The situation up to 1983

An attempt to assemble archaeological evidence on the first use of iron in Sardinia and to formulate some hypotheses on its chronological and historical framework dates to 1981 (Lo Schiavo 1981). The presence, established by R.B. Cooke and S. Aschenbrenner (1975) and by R. Tylecote (Tylecote, Balmuth, Massoli Novelli 1983 and 1984), of large quantities of iron and even of iron slag amongst the fragments and the planoconvex ingots of Sa Sedda 'e Sos Carros, Oliena (Nuoro), brought to the fore the problem of ironworking in nuragic Sardinia. Paul T. Craddock (1984) also turned his attention to the matter, with reference to the greater or lesser percentages of iron in finished bronze works as an indication of particular and distinctive working techniques.

As far as whole and fragmentary iron objects are concerned, mention must be made of:

1. an iron object between the front hooves of the ox and the manger in the nuragic bronze boat, known as “Noah's Ark” from the Tomb of the Duce di Vetulonia (Lilliu 1966, 432 no. 321);

2. an iron element, consisting of two small cylindrical rods with rings at the ends which forms a jointed fastening system which links the small bronze boat of the Circolo delle Tre Navicelle from Vetulonia to a pendant in the form of double ram's forequarters (Lilliu 1966, 400-401 no. 288);

3. many iron objects, specially arrows and a pin with an iron rod, from the nuragic complex of Sa Sedda 'e Sos Carros (Lo Schiavo 1981 fig. 288 bottom l; see Part III, chapter 1Hb1-43; archaeological file 31);

4. an iron clamp for repairing bronze basins from the small cavity of Su Benticheddu, Oliena (Lo Schiavo 1978) (fig. 1);

5. the fragments of a small iron boat from the small cave of Su Fochile at Urzulei (Nuoro) (Moravetti 1978; Lo Schiavo 1988 figs.1-2) (fig. 2);

6. a ribbon-shaped iron bracelet from the chamber of the giant's tomb of Bidistili at Fonni (Nuoro) (Lilliu 1982, 102);

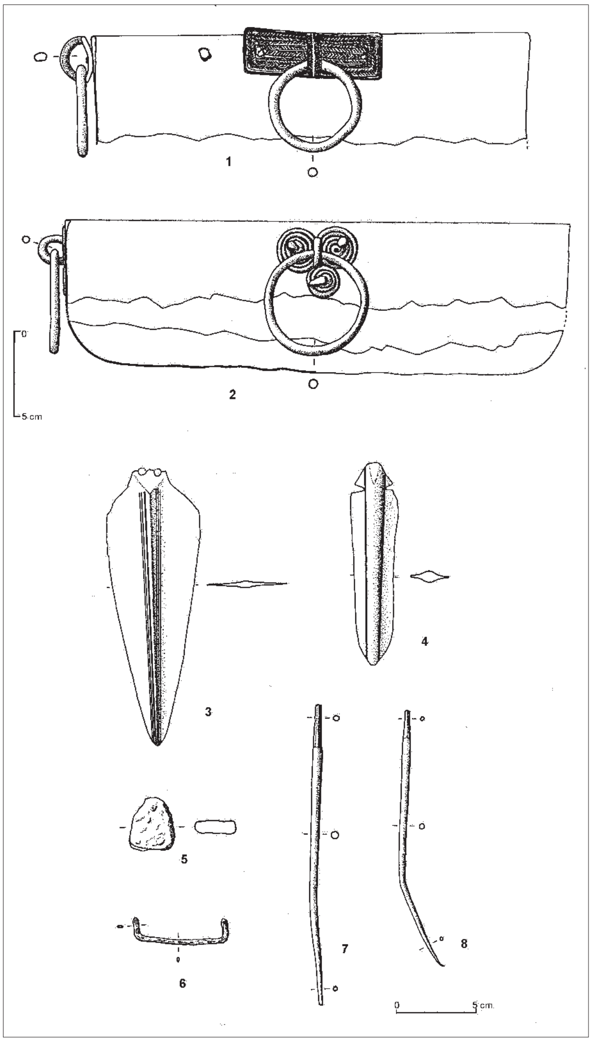

Fig. 1 – Hoard from Su Benticheddu, Oliena: 1. basin with corded decorated rectangular attachment; 2. simple-base dagger; 3. simple-base dagger; 4. short dagger made with a votive sword stump; 5. fragment of an ingot; 6. iron clamp for repair of bronze basins; 7-8. pins with mobile heads *(after Lo Schiavo 1976).*

7. a mysterious small object (*stiletto* ? “nilometre”?), 15,9 cm long and with openwork “hilt” or extremity in steatite, from the coffin collective burial (“*a poliandro*”) di

Motrox'e Bois, Usellus (Oristano) (Contu 1955-57, 173, tab. XIX, 21, XX; Lo Schiavo 1988 fig. 3)[1] (fig. 3).

8. many iron objects, including "...hooks for hanging up meat...." ("...*arpioni per tenere le carni appese*...") in tower E of the nuraghe Losa of Abbasanta, Oristano (Taramelli 1916, 246; Lilliu 1955, 119)[2];

9. "An iron axe, corroded and disfigured by rust" ("*Un'ascia di ferro corrosa e sformata dalla ruggine*") from the nuraghe Santu Antine of Torralba (Sassari) (Taramelli 1939, 69);

10. whole and fragmentary iron artefacts in the strata dating to phases C and D at Su Nuraxi at Barumini (Cagliari) (Lilliu 1955, 143 and foll.)[3] (figs. 4-7);

11. an iron spit from the nuraghe S. Pietro of Torpè (Nuoro) (see Archaeological file 30, p. 222) (Lo Schiavo 1976, 61, no. 376);

12. a large iron ring from the nuraghe Su Igante of Uri (Sassari) (Contu 1962, 298);

13. a hoard, with tools in iron and bronze, with handles in bone, discovered in 1982 by Maria Luisa Ferrarese Ceruti, hidden in a niche within the courtyard in front of the central tower of the nuraghe Sa Mandra 'e Sa Giua of Ossi (Sassari); Ferrarese Ceruti attributed the dating of the enlarging of the nuraghe to the Final Bronze Age (Ferrarese Ceruti 1985; Lo Schiavo 2004)[4];

14. An iron hook from the tomb of S. Cosimo at Gonnosfanadiga; the majority of the finds made there have been attributed to an advance phase of the Middle Bronze Age (BM2), otherwise known as "*di S. Cosimo*" or "*della ceramica metopale*" (Ugas 1981).

15. the presence of an iron item in a Final Bronze Age context is mentioned among the material found during the Bernardini excavations of 1989-1990 in some rooms of the village annexed to the well temple of S. Cristina at Paulilatino: "sole of bovine hoof" ("*plantare di zoccolo di bovide*") (Santoni 2001, 73).

16. for the recently-discovered "iron plaque" attached to a lead object found in the nuraghe Antigori at Sarroch, see Part III, chapter 1M5.

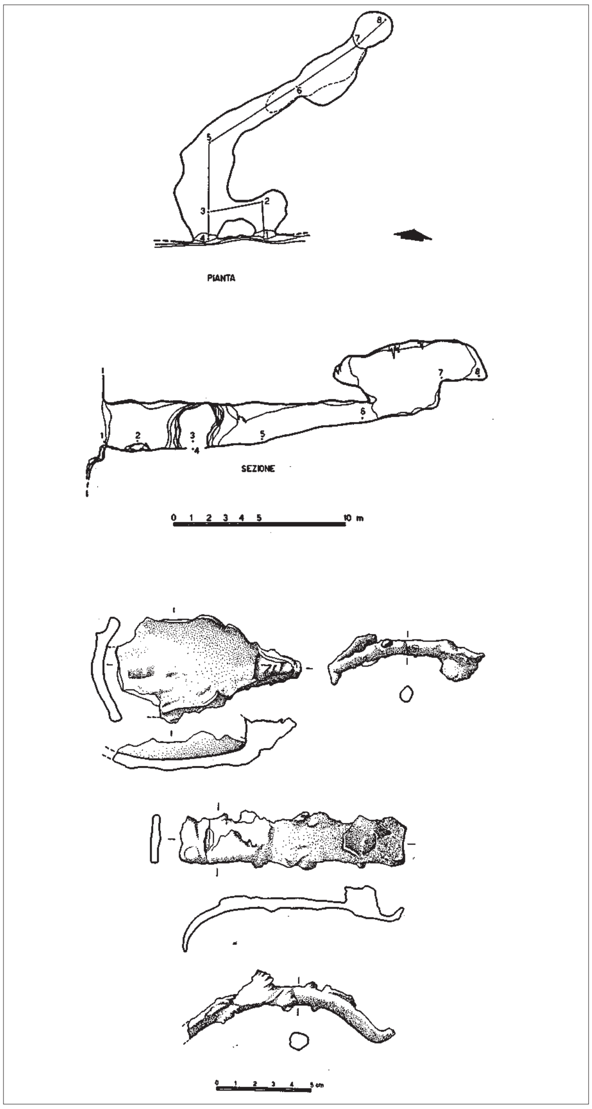

Fig. 2 – Small cavity of Su Fochile, Urzulei: 1. round plan and cross-section of the cavity; 2. fragments of iron *(after Lo Schiavo 1988).*

1. The object, of which all trace has been lost since the beginning of the 1970s, still remains mysterious (2003). In reply to a request for an opinion, Anthony Snodgrass courteously replied: "I have had a very careful search for parallels for this dagger hilt among the Egyptian and other oriental types, and I can find nothing in the least like it. I am almost sure that the reason is that the object is not really designed as a dagger hilt; as Contu suggested in the original publication, it really looks more like other objects, and it would certainly not make an efficient dagger hilt. I would guess that it had been copied in steatite from some imperfectly understood model. Incidentally I wonder whether the dagger was a real weapon at all? Now that it has disappeared, it will not be possible to tell whether the blade had sharp edges or whether it had been hardened in any way. But I will keep searching for related shapes, and let you know if I can find anything convincing." (Personal letter of 31 August 1981).

2. The nuraghe Losa has recently been widely and thoroughly re-examined, both from the architectural aspect and for the material found in past and recent excavations (Santoni 1994; 2001). Unfortunately the iron artefacts were presented in a group as "Metal finds", without specific indications as to the place of discovery and the associations (Serra 1994). The assumption is that most of them can be much younger than the nuragic period.

3. The nuraghe and village of Su Nuraxi di Barumini have also been re-examined from the point of view of the structure and of the material associations, which resulted in a proposal to attribute a considerably earlier dating: "It is interesting to register the presence of "fragments of iron", [in the context of Hut 36] in the same way as that attested by the author [G.Lilliu] for room 32, within the same nuragic II milieu: in both cases they are plausibly material contexts attributable to Nur. I and therefore corresponding to what has been established at Santa Cristina di Paulilatino" (*"E' di utile interesse registrare la presenza di "frammenti di ferro", [nel contesto della Capanna 36] alla stessa maniera di quanto l'A. [G.Lilliu] attesta per il vano 32, entro pari ambito Nur. II: in entrambi i casi si tratta plausibilmente di contesti materiali rapportabili al Nur. I Sup. e perciò in sintonia con quanto riscontrato a Santa Cristina di Paulilatino*") (see below no.15) (Santoni 2001a, 89). The same dating also applies to the "objects in bronze and iron" ("*oggetti di bronzo e di ferro*") from Hut 80, cited earlier (Santoni 2001b, 82).

4. The premature death of the scholar and incomparable friend deprived us of the complete edition of the excavation, which was already programmed and for which the Soprintendenza had already restored the material. It must be said, however, that the present progress in research on the characteristics and on the building phases of the complex nuraghi utterly confirms the intuition of Ferrarese Ceruti (Santoni 2001, 19; 2001a, 31; Cossu *et al.* 2003).

The data listed do not presume to be complete, but just to provide inspiration for research, and indicate the full nuragic period, within the Final Bronze Age, for the knowledge and first use of iron. The data is sufficient to clear the field of the widespread prejudice of the introduction of iron by the Phoenicians or Carthaginians to a Sardinia which is rich everywhere of deposits of this metal. The link between the working of iron and the production of bronze figures with the lost-wax technique is highlighted. The penetrating Cypriot influence in Sardinia, particularly in the metalworking sector, documented by the shape of the oxhide ingots, by the tools for working bronze, the shape of the double axes and the double-edged tools, by the tripods, by the cauldron fixtures and by other prestigious artefacts (see Part IV, chapters 3-4), make it very likely that both ironworking and the lost-wax technique were introduced very early, already by the Recent/beginning of the Final Bronze Age, and that from the island they spread to mainland Italy (Lo Schiavo, Macnamara Vagnetti 1985; Snodgrass 1982; Maddin 1982; Varoufakis 1982; Waldbaum 1980; 1982; Lo Schiavo 2004).

It is now unquestioned that Sardinia functioned as go-between for the transfer of Cypriot objects and influences towards the mainland, particularly to central Tyrrhenian Italy, as it also did, slightly later, for material from the Iberian peninsula. Therefore, it seems plausible that the impulse towards the working of iron in the Late Bronze Age in “mining” Etruria, where there are no extensive documents for periods parallel to the nuragic period, could have derived from Sardinia (Delpino 1981, 292-294; Delpino *et al.* 2004).

Although the documentary proof of this process is still occasional, it can be accepted without difficulty as a working hypothesis, in the expectation that new discoveries, which have become ever more frequent and interesting over the last twenty years, define the picture more distinctly (Lo Schiavo 1988)[5].

2. The fragment of iron from the nuraghe Antigori

In the meantime, a discovery confirms this hypothesis. It is a fragment of worked iron, about 3 cm long, corroded and rusted, perhaps belonging to the blade of a knife or of a dagger, from stratum 4 of tower c of the nuraghe Antigori at Sarroch (Cagliari), associated with a “wishbone handle” and under the level containing other fragments of Mycenaean pottery (Ferrarese Ceruti 1986, 10). With the full agreement of Maria Luisa Ferrarese Ceruti, the pottery fragment was illustrated and published before the publication of the excavation: as a result, L. Vagnetti classified it as a “Base-ring II ware”, attributable certainly to Cypriot production of the Late Cypriot II period (Lo Schiavo, Macnamara, Vagnetti 1985, 5, fig. 2,5).

Fig. 3 – Usellus (OR), Motrox’e Bois: iron *stiletto* with steatite handle *(after Lo Schiavo 1988).*

At the time, there was no place for comments, not least because the find spoke for itself. Later, the presence of a fragment of votive sword from stratum 3a of the same room was emphasized (Ferrarese Ceruti 1986, 184-5) (Lo Schiavo *et al.* in press, fig. 4, 1).

Therefore, the link between nuragic Sardinia and Cyprus is fully confirmed, principally manifested by the oxhide ingots, as we say above, and, together with them, by the arrival of the techniques of working copper and of new skills, such as that of working iron, known but not practised on a wide scale, and of lead, which, grafted onto a basis of knowledge and use dating back to pre-nuragic times, enjoys enormous popularity and very wide and almost excessive use.

3. Iron and the Phoenicians in Sardinia

The presence not only of many iron artefacts in Phoenician cemeteries, but also of places for the working of iron and of slag in the settlements has been long known; for that reason we will not dwell on the matter, but just make brief reference to it (Acquaro, Ingo 1996; Angelini, Bianco, 1996; Ingo 1993; Ingo, Bultrini, Chiozzini 1995; Bultrini 1995; Acquaro *et al.* 1996; Bernardini 1997, 61).

In the oldest Phoenician tombs are found bronze and iron artefacts, which reproduce the traditional typologies of previous generations, a phenomenon already known for some ceramic forms typical of the full nuragic period (Bartoloni 1985/1989). In parallel, at a S. Imbenia di Alghero, some nuragic shapes going back to the Final Bronze period turn out to be produced with the fast wheel (Bafico, D'Oriano, Lo Schiavo 1995, 89).

There are repeatedly pins with mobile head in bronze and shaft in iron in the apparels from the *necropolis* of Bithia, together with daggers, tanged spearheads, iron butts (Bartoloni 1997, files 136, 149, 158; Artizzu *et al.* 1997).

5. Up to this point the text of the report presented at the Congress “*Il Primo Ferro nel Mediterraneo*” held at Populonia and Piombino in October 1983 has been reproduced almost in its entirety, except for the addition of some notes and the completion of the bibliographical references. When, several years later (1988), the Acts were published, it was only possible to give the news of the discovery of the fragment of iron in the nuraghe Antigori in the form of a note (Lo Schiavo 1988, 83).

The same pins with mobile heads in bronze and shaft in iron are also to be found in the Collezione Pischedda at the Antiquarium Arborense of Oristano, coming from Cabras, Santu Marcu, probably from the northern *necropolis* of Tharros, and at Othoca (Zucca 1997, 96 file 202; Nieddu, Zucca 1991, 175), thereby documenting a custom that was widespread in Phoenician Sardinia.

On the other hand, a bronze dagger found in tomb 160 of the *necropolis* of Bithia is decidedly different from the nuragic ones, even if it imitates their shape (Bartoloni 1997, file 170). An analogous phenomenon may perhaps be observed in the small "votive quivers", some of which reproduce handles of daggers which are stylized and rigid in profile, similar to imitations rather than to the real nuragic forms. This observation must be supported by far-ranging typological analysis, however, particularly in view of the fact that many of these objects come from Tharros and are held in museums and private collections (Zucca 1987).

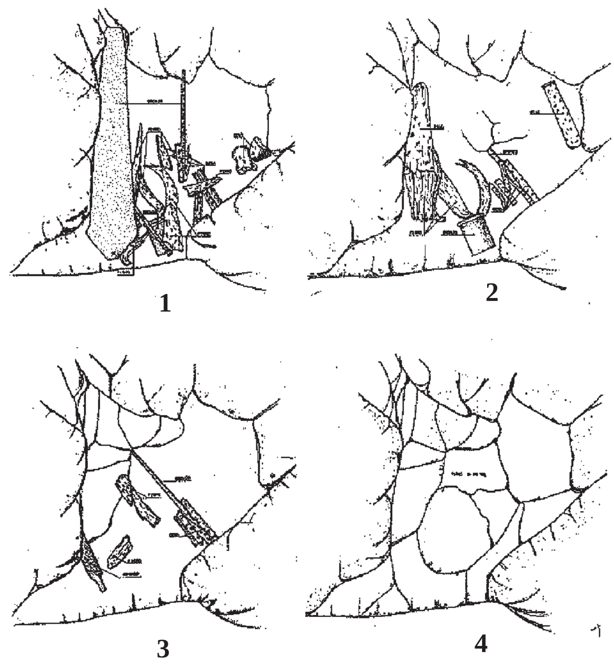

Fig. 4 – Ossi (SS), Sa Mandra 'e Sa Giua: hoard with artisan's tools from the niche of the courtyard: US1, US2, US3, US4 *(after Lo Schiavo 2004).*

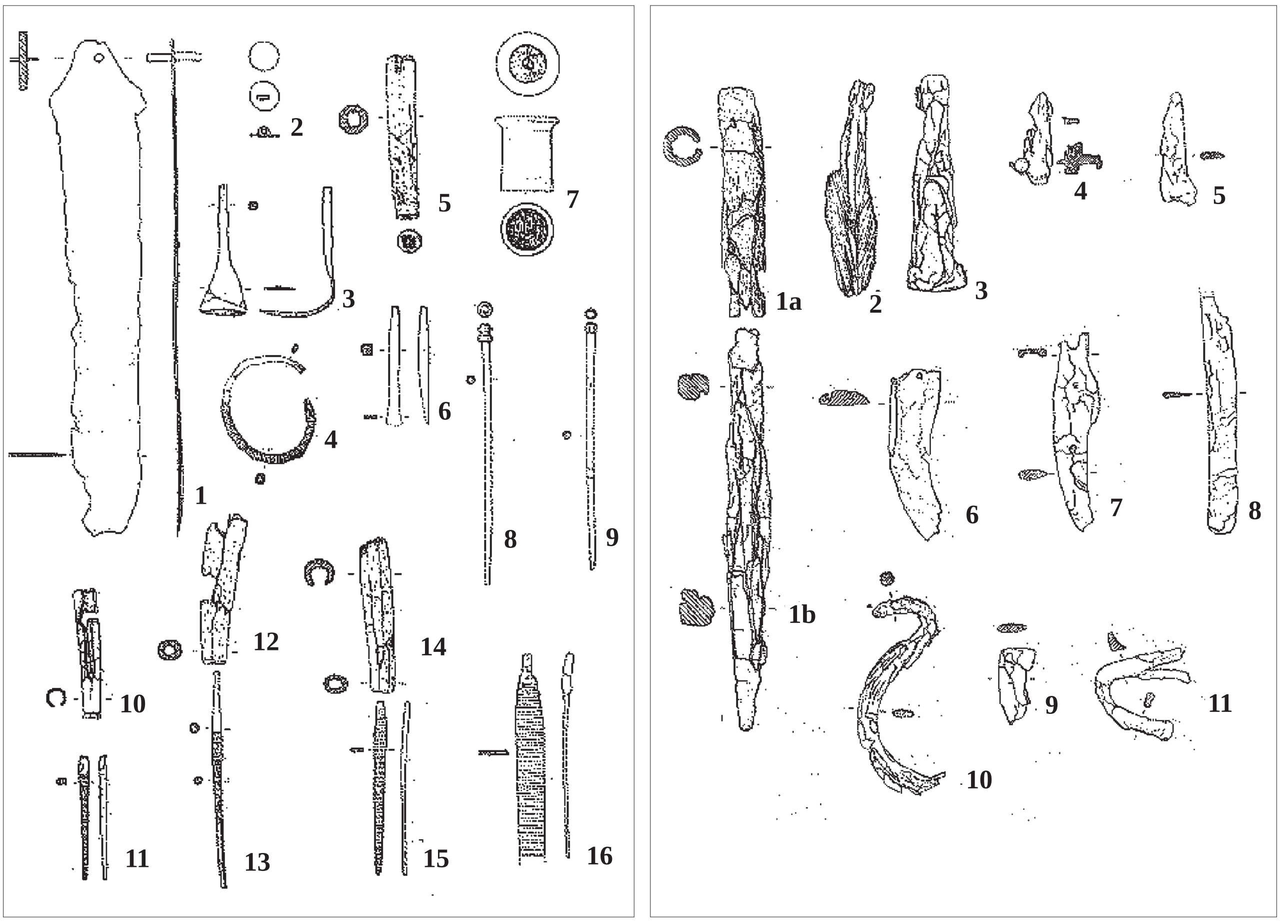

Fig. 5 – Ossi (SS), Sa Mandra 'e Sa Giua: tools in the hoard (after Lo Schiavo 2004): a. Bronze: 1. *spatula*; 2. small disc with an eyelet; 3. small spoon-shaped spatula; 4. ring-curved square cross-section file; 6. small chisel; 7. cylinder trunnion handle; 8. ribbed-head drift; 9. poligonal-head drift; 11. small square cross-section file; 13. thin round cross-section file; 15. square cross-section file; 16. rectangular cross-section file. Bone: 5. octagonal cross-section handle; 10. round cross-section handle with moulded extremity; 12. oval cross-section file; 14. oval cross-section file. b. Iron: 1. long trunnion handled drift (?); 2. short tanged knife; 3. flat tanged knife; 4. fragment of tanged knife; 5. fragment of a flat tanged knife; 6. curved bladed knife; 7. curved bladed knife; 8. straight bladed and round tipped tanged knife (?); 9. fragment of a curved bladed knife; 10. handle fragment; 11. fragment of a twisted rod.

4. Conclusions

Our present scarce knowledge specifically about Sardinia, united to a first geological assessment of the widespread presence of deposits of iron in the island, even if not always “interesting” from the point of view of the prehistoric operators (see Part II, chapter 2), must be compared to, and set against, the much more advanced research which has for long been carried out on the Near East and Mediterranean.

Whereas there is debate about the attribution of the primacy of the discovery and of the working of iron in the 5th millennium, between Samarra in northern Iraq and Tepe Sialk in northern Iran, and whereas ever more up-to-date lists evolve which extend in time and space the discovery and use of meteoric iron, there has long been no doubt about the widespread knowledge and use of iron in the 2nd millennium (Waldbaum 1980; Giumlia-Mair, Maddin 2004).

On this basis, there is again no reason to maintain that the nuragic peoples were ignorant of this metal and of its characteristic properties; on the contrary, the evidence in our possession proves the opposite.

Added to the difficulty of finding, preserving and analyzing iron artefacts, which is the cause for a large part of the gaps in the data, there seems anyway to have been little interest in iron in nuragic times, whereas at the same time the widespread preference for the production and working of bronze is evident.

As a result, the arrival of the Phoenicians and the foundation of the cities would bring epoch-making changes in the economic and social order, of which the obvious consequence was the adoption of the new metal and the direct management of the sources of supply and of the specific technologies, relegating the working of copper and bronze to the ritual sphere and that of tradition, almost an antiquarian phenomenon.

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8.

Concluding remarks

Fulvia Lo Schiavo

In this work the archaeological part has deliberately, just for once, been made almost "subsidiary" to that of geology and mineralogy and archaeometry. It is evident that the term is inexact both in this usage and in its original one, when the other sciences which in the mind of the user were supposed to provide support for the reading, interpretation and then for the preservation of the archaeological data, were defined as "subsidiaries of archaeology". The undeniable merit at the time was that of putting the specialists face to face with each other, and to give maximum emphasis to the needs of the archaeological inheritance. Today a new need is felt very pressingly, and it is not just that of following the path of research, but of formulating its objectives together, of carrying out investigations in parallel, and of meeting frequently and happily for the assessment of the results, both during the work and in the concluding phases.

An integrated and interdisciplinary procedure of this sort is rich in positive aspects, first of which is to have given a vague measure to what is known with respect to what is unknown. In the present case, just by gathering together the information and the bibliography for the compilation of the files, just by working out an archaeological interpretation for the artefacts analysed, the queries have multiplied and with them the desire to proceed much further.

It would take too long to list the highly interesting aspects which have just begun to show through and which merit a more thorough reply.

There is an almost utter lack of analyses of the artefacts from the most ancient "Prenuragic" phases in Sardinia and of the appearance of the phenomenon of metal-working, at least from the Neolithic to the Early Bronze Age periods, from at least *ca.* 3000 -1700 BC, a long period in which very varied cultural and historical, archaeological, technological and metalworking phases evolve.

Sufficient analyses for the Bronze Age are also lacking, that is to say for the nuragic Civilization itself over the whole span of its evolution, during the Early, Middle and Late Bronze Age, to the beginning of the Iron Age, between *ca*. XVI and X/IX centuries BC.

In contrast, if we look at the nuragic Civilization, the very high technological level it reached is now proved, for instance in hydraulic engineering: the catching and channelling of the springs, the planning and construction of perennial or seasonal wells, careful drainage using sophisticated solutions, etc. The level reached in their construction skills was also extraordinary; it is now ascertained that the erection of towers 27/30 m high was not exceptional, an enormous height when we consider that they were buildings in dry stone or just using natural binding agents. It has recently also been shown how many nuraghi with complex ground plans were built with the utmost mastery from the initial architectural plan and throughout following phases of construction.

As for metalworking, it has been shown that lead and bronze were used lavishly, while the distribution of the processes, of the artefacts, of the types and models is homogeneous and comprehensive throughout the whole span of the nuragic period, apart from, as far as we can see, the localization of the internal and/or external sources of supply.

In synthesis:

1. It has been hypothesized that the first experiences of research and working of metals spread *via* the routes of the obsidian trade, but there is still no direct proof;

2. It has been asserted that pre-nuragic metalworking is characterized by local experiences, which display principally western influences, but the proofs are still very scarce;

3. The first phase of nuragic metalworking dating to the first phases of the Middle Bronze Age (*ca.* XVI-XIV centuries BC), shows western and mainland influences together, but the proofs are still very scarce.

4. On other hand, it can be considered proven that nuragic metalworking of the Recent Bronze Age phase (*ca.* XIII-mid-XII centuries BC) shows a decidedly Cypriot influence, from which an extraordinary and original local production sprang almost immediately; the system of supply, distribution and first working of the metals, including the very terms of the trade, are completely unknown.

5. Equally proven is the superabundant nuragic metalworking production of the Final Bronze Age and the beginning of the Iron Age (mid-XIII-X/IX centuries BC), a veritable explosion of local production, accompanied by the acquisition of models from the Iberian peninsula (Monte sa Idda-type swords), and by the strong influence of local models on the Iberian peninsula (Monte sa Idda-type swords in iron); the fact is certain, but the terms of the trade are still not well defined. There is also the strong influence of local models on Tuscany, where they may have given a strong push to the start of mining and metalworking activities; here we have clues, but await further proof.

6. For all the periods, both pre-nuragic and nuragic, all that concerns the activity of mineral research, the technology of smelting, the sites where the activities of transformation were carried on, as well as, as we have already said, the systems of supply and trade, remains insufficiently documented.

Analysis of all metal finds should become the established practice, useful not only for knowledge, but also for the correct conservation. Unfortunately, from this point of view, archaeology has the deplorable primacy in the accumulation - often indiscriminate and in the worst conditions, easy prey, drawing on the well-known biblical expression, of "thieves who steal and rust that doth corrupt" - of exceptional material and extraordinary data. As has been repeated several times in the course of this work, the amount of unpublished material on the archaeology of Sardinia has reached catastrophic proportions in the full sense of the word, to the point of causing concern over the impossibility of future recognition and restoration of historic documents.

Is then the conclusion negative ? Absolutely not. On the contrary, it is critical and contains a proposal.

Given the highly urgent task of researching, getting to know and safeguarding, and given a field for investigation which is almost limitless, instead of continuing to proceed at the mercy of chance, as in the past, we now have many and fascinating questions which, formulated and debated together, will be the guidelines for future research.

CONCLUSIONS AND SUGGESTIONS FOR FUTURE RESEARCH

Ulrico Sanna,
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The combination, for the first time without limitations of space and preconceived ideas, of three facets of the science of archaeometallurgy - ore deposit geology, materials technology and archaeology - in addressing the subject of metallurgy of pre-nuragic and nuragic Sardinia, produced interesting results and in general, provided a measure of the work that remains to be done, by pursuing both parallel and convergent paths.

The time span covered, within the framework of this research project, has been considerably extended and goes back to the beginning of metal usage in Sardinia, while in the past research was confined to certain aspects of the height of the nuragic Age. Whole new classes of previously locally unknown materials have been studied, from the archaeometric and metallurgical standpoints, in particular pure copper, copper-arsenic alloys but also silver, gold-silver alloys, and iron.

For the first time, the geological environment has been involved and analysed in detail, by using current information. However, in the interpretation of the geological data we also took into account, as far as possible, how ancient populations presumably went about in the process of procuring the raw materials, essential for dealing with every aspect, be it primordial, of everyday life. By using this approach we were able to distinguish which georesources were minable, and to what extent. In particular, we described the resources that abounded in Sardinia as a function of the reserves actually minable at the beginning of the exploitation activity. Moreover, by using advanced instrumental analytic methods we also evaluated the possibility that the island might have been a prime source of important metals such as lead, copper, and tin.

The original outcrops of the huge galena-bearing ore deposits of Cambrian age in the Iglesiente region, in particular at Monteponi, contained tens of thousands of cubic metres of oxide and sulphide ores. Lead and silver were easily obtained from these orebodies, whose discovery and exploitation probably started very early. Lead isotope determinations, performed on dozens of archaeological finds indicate largely a Sardinian provenance, as the ratios closely match the Iglesiente Cambrian ores. Unfortunately, it is no longer possible to produce major evidence of early metallurgical activity in this area. The hundreds of thousands of tons of lead and silver-rich slag, accumulated over the centuries, especially in Roman and Medieval times, but which in all likelihood were stratified on more ancient slag heaps, were systematically reworked in the years between 1858 and 1872.

It is highly unlikely that the silver worked by early man was extracted from native silver deposits, which were only discovered on the island after the XVII century (silver deposit of the Sarrabus region). Thus the only source of silver available were the silver-bearing galena ores, from which early metalworkers extracted the metal by means of cupellation.

Numerous copper occurrences exist in Sardinia, often inappropriately referred to as “ore deposits” in the non-specialized literature. The mineralizations, which are likely to have attracted the interest of primitive man are listed in the volume, accompanied by observations that allow to judge their usefulness in terms of mineral concentration. Those mineralizations for which it is possible to estimate the greatest extent of primitive outcrops and alteration products, including native copper, comprise those at Calabona, Funtana Raminosa and Sa Duchessa.

The only true occurrence of tin-bearing ore, in the Fluminimaggiore area, is to be considered no more than a mineralogical rarity (for Sardinia). There is no evidence suggesting that it gave rise to the formation of a small placer deposit. On the other hand, the recent hypothesis enthusiastically supported by some researchers, that this occurrence is a true tin ore deposit is to be discarded as it stems from a gross misunderstanding about the interpretation of some residues left by a short modern exploration activity. Similar considerations are true also for gold. Only recently has Sardinia been recognized as a gold metallogenic province. Only advanced technology (cyanidation) enables the recovery of minor amounts of gold (a few g/t - so finely disseminated that it is often defined invisible gold).

Regarding the metallic archaeological objects, besides the essential classification based on bulk chemical composition, their microstructure was also studied. The microstructure was often found to be profoundly altered, particularly in the case of the numerous pre-nuragic silver artefacts and intrinsically thin work-hardened objects, such as copper and arsenical copper blades. Unfortunately the greatest part of the earliest finds analysed were in fact blades. This work has not provided any conclusive evidence as to the important issue of provenancing pre-nuragic metallic objects, but it does at least lay the foundations for future research, in the event that different classes of archaeological objects are made available and new analytical methods are developed.

Information on the important group of finds, consisting of hoards of pieces of copper ingots, especially oxhide ingots, has now been complemented by the series of data from the Baradili site. In this regard each copper fragment was systematically double-sampled. The results confirmed the copper generally to be of good quality, typical of this kind of ingot, which circulated widely throughout the Mediterranean. The lead isotope ratios determined for the ingots indicate once again a Cypriot type source for the metal ores.

Throughout this project, the only reliable indicator of metal provenance was found to be lead isotope ratios, determined by means of ICP-MS. In spite of the fact that this technique is inherently limited to determinations carried out on objects such as primary copper ingots - as many artefacts were fabricated by using a mixture of metals from different sources, especially tin and even lead - it is currently irreplaceable and should actually be extended to the isotope determination of other elements.

In interpreting the data we usually employed terms such as “Cypriot type”/”Sardinian type” rather than attempting a definite provenance assignment. At this stage of the research, it seems wise to proceed cautiously, especially because of the need to procure additional material for the comparative database so as to include new geographical areas and more information, possibly with the contribution of a larger number of research groups, and cross checking the results of different laboratories.

Slag deserves special attention as this material provides important indicators for recognizing and characterizing the extent of local metallurgical operations, especially whether they concerned primary or extractive metallurgy. The small amount of slag analysed during this project, though only representing part of the material identified up to now, reflects a scarceness, that borders on non-existence. In some cases this can be explained by that fact, that slag was reworked in historical times, and this, as mentioned above, is well documented in the case of lead. The current lack of slag, produced by the extractive metallurgy of copper and its implications, deserve consideration. Some pieces of slag, discussed in this work, can certainly be defined as intermediate product of roasting chalcopyrite, the most common copper mineral. However these finds are sporadic and none of them were recovered from actual slag deposits.

By contrast, metallurgical activity associated with the melting and casting of various objects in sites dated to the height of the nuragic Age is well documented and indisputable. In this project particular attention was focused on the site of the Santa Barbara nuraghe at Bauladu, where numerous remains of crucibles and casting moulds have been unearthed. We also studied a number of remains of smelting activity from the sites of Genna Maria, Santu Antiogu-Villanovaforru and Sa Sedda 'e sos Carros-Oliena. The analysis of twelve bronze figurines housed in the Archaeological Museum of Cagliari begun to cast light on this important page of metallurgy and local cultures.

In spite of the fact that, added to the archaeological finds already analysed, during this project around three hundred objects, as well as dozens of mineral samples, have been characterised, the need for further, even more systematic and comprehensive research, carried out also by study area, forcefully emerges. The enormous disparity between the number of recovered finds and the number of objects actually studied, compells the authors to tread carefully, and therefore to refrain from claiming to be able to draw conclusions. These can be only provisional conclusions and limitedly to partial aspects (working hypothesis based on partial archaeometric data) of the complex archaeology of Sardinian metallurgical production over a period of time, covering, we should recall, several millennia.

Experience gained during this project has provided a lesson as to method and approach to the scientific work: a few isolated, albeit formally correct data, whatever scientific area is being studied, may be useless or even misleading if a multidisciplinary approach is not adopted for their interpretation.

Concerning the metallurgical analyses of the archaeological specimens, in the past, the nature, typology, age, context and provenance of ancient objects, the problems and fitting them into a broader context were totally disregarded. By contrast, in this context, we have attempted to demonstrate, how all this information gives three-dimensionality to the object, enhancing its intrinsic value.

The analysis of all metal finds in the state of their discovery and prior to conservation treatment, should become common practice: indeed, analysis, following suitable and recognized protocols, along with graphic and photographic documentation, nowadays speeded up with the advent of digital cameras, should be conducted before any other action is taken. Obviously an ancient find needs to be scientifically studied before any kind of protective treatment can be carried out, be it first aid or conservation treatment (both defined as “restoration”). This too is an entirely interdisciplinary activity and for some time now not only conservation specialists but, depending on the nature of the site, also anthropologists, archaeozoologists, archaeobotanists and other specialists are involved in archaeological excavations.

INDEX OF THE ARCHAEOLOGICAL FILES

The file numbers indicate the chronological sequence of the finds and their context. The chronological table is in Part IV, chapter 2 (p. 279, fig. 1).

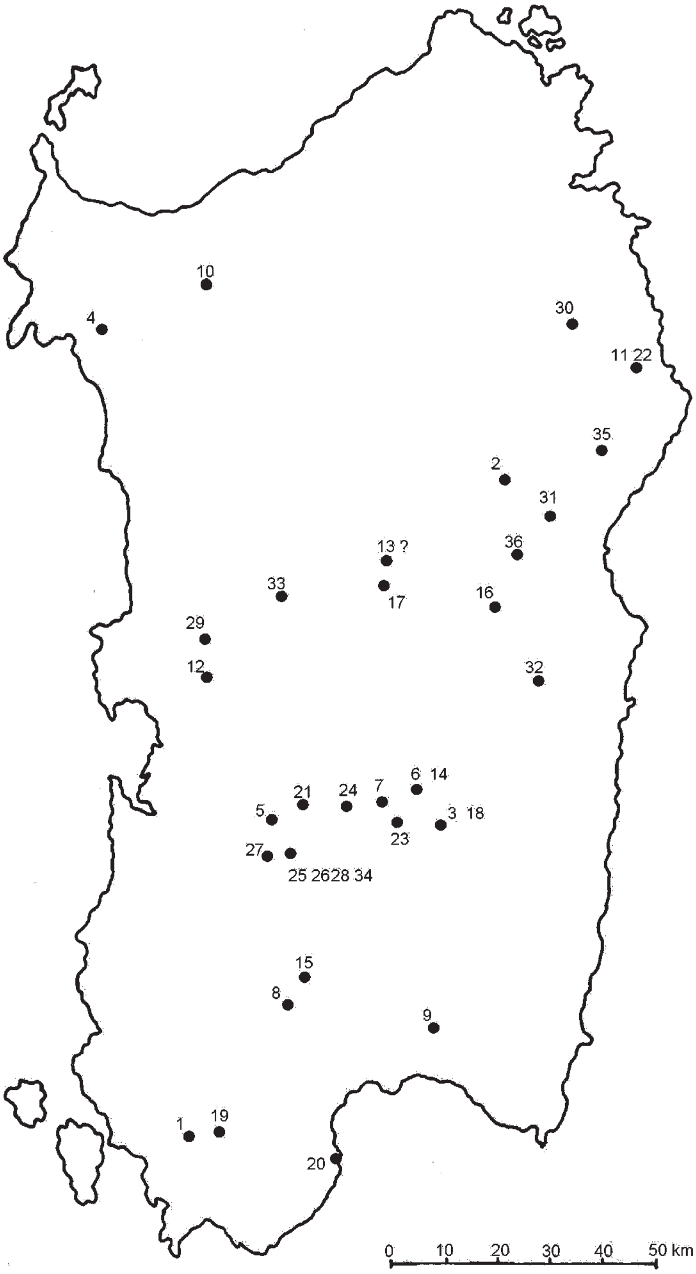

Fig. 1 – Sardinia’s map with the geographic location of the sites mentioned in the archaeological files.