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Pantelleria Island as a centre of production for the Archaic Phoenician trade in basaltic millstones: New evidence recovered and sampled from a shipwreck off Gozo (Malta) and a terrestrial site at Cádiz (Spain)

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ABSTRACT

New discoveries of flat Archaic querns recovered from the cargo of a Phoenician shipwreck at a depth of 110 m in Xlendi Bay (Gozo, Maltese Islands) dated to ca. 7th century BC and millstone fragments found at Cerro del Castillo (Cádiz, Spain) from Phoenician material between 7th and 6th century BC share the same petrographic texture and geochemical composition. The four samples consist of vesicle-rich grey basaltic lavas with a moderate porphyritic index and a microcrystalline intergranular groundmass. Major and trace elements distributions of the investigated artifacts highlight a provenance from Pantelleria Island, which is located in the Mediterranean Sea between Sicily and Cape Bon (Tunisia). This rules out other important widespread sources of basic volcanic rocks that were also used for millstones in ancient times, such as Etna volcano, Iblei Mountains and the Levant. Due to its barycentric position in the Sicily Channel, Pantelleria Island could therefore have represented one of the main supplying area of volcanic millstones for the Phoenicians. The provenance from Pantelleria was already documented for other volcanic millstones in Phoenician sites and Carthaginian settlements of Sicily (e.g. Motya and Entella) and Tunisia (e.g. Utica and Carthage) and those found in the shipwreck of El Sec (off the coast of Mallorca), dated to ca. 4th century BC. The new millstones from Pantelleria discovered in (i) an older shipwreck cargo (i.e. Xlendi Bay) and (ii) the most westerly Phoenician settlement of Gadir (nowadays Cadiz, ca. 1500 km far from Pantelleria) point to widespread Phoenician trade in Pantellerian basaltic rocks in the Archaic Period. Pantelleria Island can therefore be considered as a nodal point for trade in volcanic millstones, many centuries before the Hellenistic people and the Romans would largely exploit the basaltic lavas from Etna and Iblei Mountains for the same purpose.

1. Introduction

Most of the millstones for grinding cereals discovered in archaeological sites throughout the Mediterranean area are made of volcanic rocks (Williams-Thorpe and Thorpe, 1991, 1993; Williams-Thorpe et al., 1991; Renzulli et al., 2002; Antonelli and Lazzarini, 2010; Santi et al., 2013, 2015; Gluhak and Schwall, 2015; Di Bella et al., 2016, 2018). Lavas, generally characterized by wear resistance, are therefore particularly suitable for milling because of their abrasive property and rough vesicular surface (Peacock, 1980; Williams-Thorpe, 1988) providing good grinding capacity (Moritz, 1958; Santi et al., 2004). However, the selection criteria for the choice of raw materials used in the past for grain-milling artifacts (independently from the technology of millstones) were constrained by the accessibility of rock outcrops which necessitated the development of a commercial network for the transport of these objects.

Since the Late Palaeolithic Period, grinding stones occurred in settlements and quarries in a variety of shapes: oval/suboval, rectangular, triangular and other irregular shapes which were primarily used as base-stones (Williams and Peacock, 2011). A small, roughly squared hand-pebble of hard stone was then used to grind the material, causing many of the base-stones to have a smooth concave surface (Bloxam, 2011 and reference therein). Saddle and flat querns became widespread throughout the Mediterranean during Bronze and Iron Ages (i.e. Cyprus and Israel; Elliott et al., 1986). In the early 7th century BC, saddle querns underwent some refinements in their shape and in the method of working the upper stone (Curtis, 2001). Starting from the 5th century BC, a great innovation in grain milling took place somewhere in Greece

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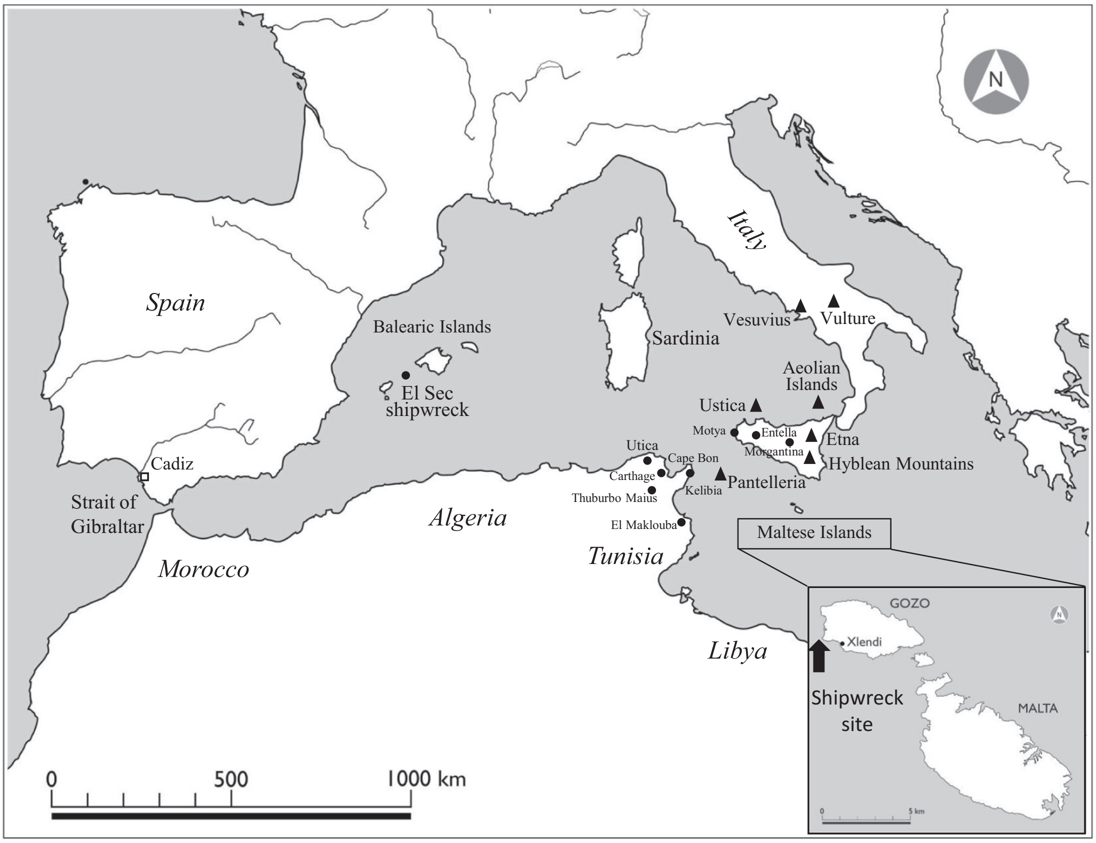

Fig. 1. Map of the Western and Central Mediterranean with several archaeological sites where millstones from Pantelleria were already found (full circles), also comprising the shipwreck millstone cargo of El Sec. Full triangles indicate the main volcanic sources for millstones in Central-Western Mediterranean (from literature). A close up (inset) of the Maltese Islands, with the location of the Xlendi Bay shipwreck cargo (black arrow) is also emphasized.

with the development of the so-called hopper-rubber mills (Olynthian type; Frankel, 2003). These operated on reciprocal motion, as did the querns, but with the upper stone widened with a cut into its circular cavity. This cut was large enough to receive a larger quantity of grain (Moritz, 1958; Curtis, 2001). From the 4th–3th century BC, rotary hourglass millstones were then used. Initially these consisted of the smaller Morgantina-type followed by the widespread and larger Pompeian-style during the Roman Period (Childe, 1943; Moritz, 1958; Curtis, 2001; Williams and Peacock, 2011).

Although some evidence from the Neolithic exists, most of the data for volcanic millstone trade in antiquity largely deal with Hellenistic Greek and Roman trade (Peacock, 1980, 1986; Williams-Thorpe, 1988; Williams-Thorpe and Thorpe, 1990; Santi et al., 2015). On the other hand, less data are available for the supply of volcanic rocks during the Phoenician and Punic Periods. In an attempt to address this dearth of information, we present petrographic and geochemical studies of two representative rock artifacts recovered from the shipwreck cargo at a depth of 110 m in Xlendi Bay (Gozo, Maltese Islands; Fig. 1) dated to ca. 7th century BC (one flat quern and one oval upper part) and two millstone fragments from Cerro del Castillo (Cádiz, Spain; Fig. 1) of similar age (between 7th and 6th centuries BC). All four samples can be considered of paramount importance for the investigation of millstone supply and exchange throughout the Central-Western Mediterranean during the Archaic Period. This is a period of Mediterranean history when three cultures, the Greeks, the Etruscans (Long et al., 2002; Hodos, 2015) and Phoenicians (Aubet, 2001; Gascón et al., 2015; Bernardini, 2016) all participated in thriving maritime trade. It is worth noting that, in the Archaic Period, Greeks made introads into various parts of the Mediterranean. They did this through the foundation of colonies along the coasts in various areas that stretched from the Ukraine in the Black Sea to Spain in the western Mediterranean (Malkin, 2011). In addition, Etruscan maritime power lasted at least, until 474 BCE, when Hieron I of Syracuse destroyed the Etruscan fleet off Cuma (Haynes, 2000).

2. The finds in the context of Phoenician trade

Originally referring to themselves as Canaanites, relatively little is known of the peoples often referred to as Phoenicians. The word 'Phoenicians' derives from the word used by the Greeks to describe them: *phoinikes*, red people. This was in direct reference to the coveted purple cloth which the Phoenicians produced and traded. What is certainly known is that they inhabited coastal cities such as Tyre and Sidon, cities perched on the narrow strip of land that runs along the coast of the Levant in present-day Lebanon and south-western Syria. Due to the topography of the landscape, the inhabitants looked seaward for economic prosperity. Maritime trade flourished and they developed into some of the most renowned sailors in the ancient world. The Phoenicians ventured beyond the Pillars of Hercules (Strait of Gibraltar) in search of trading partners, as testified by their westernmost colony of Gadir (Cádiz) in the Atlantic Ocean, southwestern Spain (Fig. 1).

Besides purple cloth the Phoenicians traded in metals, wine, timber and jewelry. In order to sustain this trade network, they sought to establish a number of colonies throughout the Mediterranean and even in the Atlantic. Between the 9th and 6th centuries BC the Phoenicians chose strategic locations in North Africa, Sicily, Spain as well as on small Mediterranean islands such as Malta and Gozo. This enabled them to secure raw materials, foodstuffs and valuable goods as well as safe havens where their ships could call in (Ciasca, 1999). To date, Phoenician trading patterns remain a complex puzzle. Much of what we know comes to us from the archaeological record on land, and this is fragmented at best. As yet, we have limited knowledge as to exactly how the Phoenicians loaded their ships, what cargoes filled their holds, or the exact routes they sailed (McGrail, 2001).

2.1. The shipwreck cargo in Xlendi Bay (Gozo)

In 2007, during a systematic archaeological survey of the seabed on the outer reaches of Xlendi Bay in Gozo (Maltese Islands), an anomaly was detected. After an in-depth study of the sonar data and verification with a remotely operated vehicle, the anomaly was recognized as the remnants of a well-preserved Phoenician shipwreck dating to the 7th century BC. The visible part of the site consists of the upper layer of cargo lying exposed on the seabed at a depth of 110 m. Data from a Sub Bottom Profiler survey point to the presence of approximately two meters of archaeological deposits buried in the sediments. An overall description, analysis and evaluation of the various underwater technologies and methodologies used to investigate this site is reported in Gambin et al. (2018). Like most ancient shipwrecks in the Mediterranean, the Xlendi wreck is identified by the presence of its cargo rather than the wooden remains of the ship itself, with the upper parts having almost certainly been eroded by the marine environment. It is however reasonable to assume that, buried beneath the sediment, parts of the ship's structure, such as wooden elements of the hull, survive intact (Gambin, 2011). The cargo is formally divided into three sections, the two extremities are dedicated to the stowage of querns whereas the central part is taken up by ceramic objects (Fig. 2). Approximately 120 ceramic pieces and 30 querns were visible at the time of the site's discovery. The querns, mainly basal flat stones and to a lesser extent oval upper stones, were clearly visible in various shapes and sizes (Drap et al., 2015; Renzulli et al., 2016; Fig. 2). Between 2014 and 2017, the site was subject to in-depth studies using state of the art subsea technologies as well as by diving archaeologists. During this period, a number of objects were recovered including a flat quern lower grinding stone and an oval upper grinding stone (GW1 and GW2 respectively; Fig. 3). The ceramic objects of the cargo consist of more than seven typologies mainly amphorae from the Tyrrhenian region of Italy and others from western Sicily. Some of them were previously unknown in the archaeological record (Gambin and Woods, 2017).

Ongoing petrographic studies of the ceramics point to the presence of urns made of Gozitan clay suggesting the ship was leaving the Maltese Islands when it sank (Gambin and Woods, 2017). This substantiates the argument that the Maltese Islands were part of the Phoenician maritime trading network, a theory that was previously backed solely from terrestrial evidence (Vidal Gonzalez, 1999). Although hundreds of Roman shipwrecks are known, some of which have been studied in great detail, the Xlendi site is just the eighth Archaic Phoenician shipwreck to be located in the Mediterranean (Abdelhamid, 2015). The importance of this site is not just its excellent state of preservation, but also because of its mixed cargo, the first of its kind to be found intact. The Xlendi site may be considered as one of the best preserved submarine archaeological area in the central and western Mediterranean dating to the Archaic Phoenician Period.

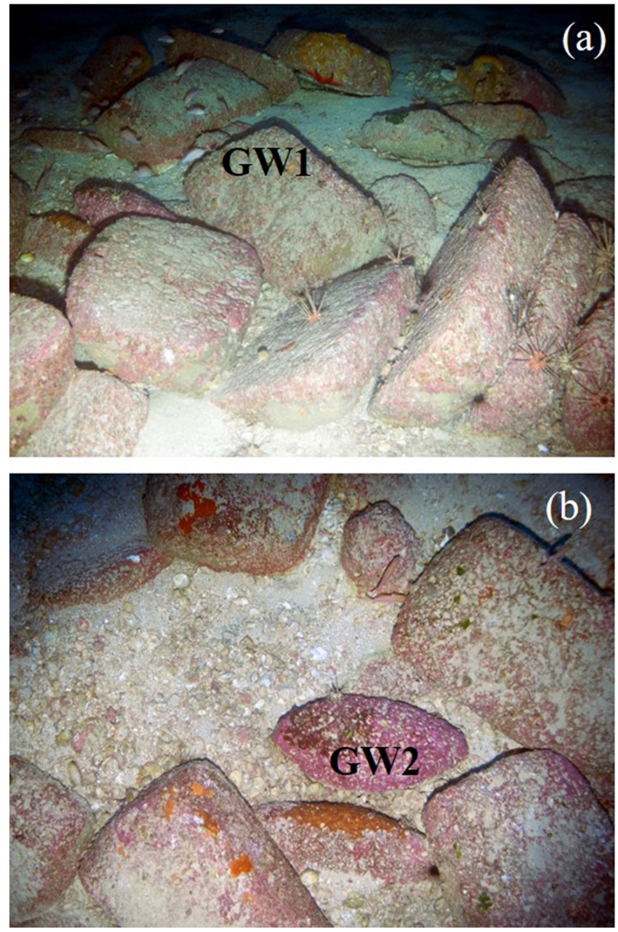

Fig. 3. The two recovered and investigated querns from the Xlendi shipwreck cargo; a) the basal (GW1) and b) the oval upper (GW2) stone.

2.2. El Cerro del Castillo (Chiclana de la Frontera)

Cerro del Castillo is a coastal hill (29 m above sea level, town of

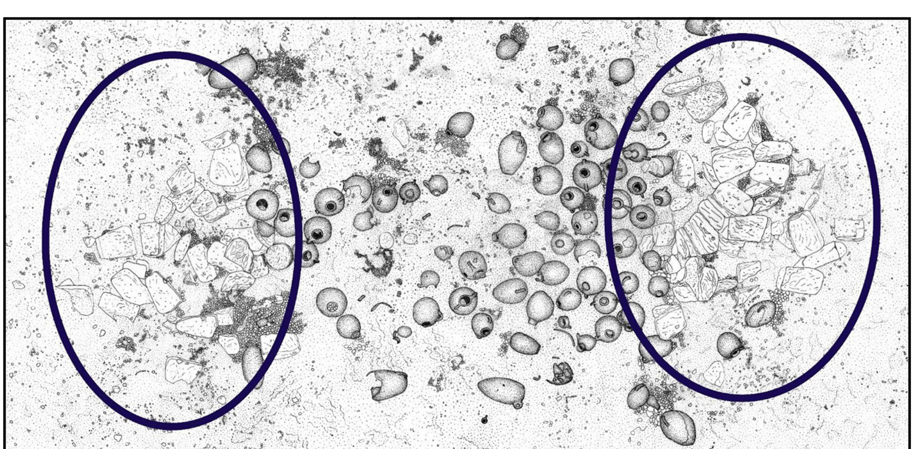

Fig. 2. High resolution archaeological illustration of the main cargo (amphorae and querns) of the Xlendi Bay shipwreck, based on the 2014 orthophoto (modified after Gambin et al., 2018). The stowage of querns (both basal and upper stones) was at the two extremities (outlined) whereas the central part was taken up by ceramic objects. The shipwreck size (rectangle) is about 12 × 5 m.

Chiclana de la Frontera) located ca. 15 km to the south west of the town of Cádiz, on the Atlantic Ocean (south eastern Spain). Palaeogeographic studies indicate that Chiclana de la Frontera was next to the mouth of the Iro River in the ancient Bay of Cádiz (the Phoenician *Gadeiras* and *Gadir* i.e. the ancient Cádiz). Several archaeological findings and historic documents emphasize the presence of a Phoenician temple dedicated to *Melqart* in the framework of an important Phoenician-Punic settlement at Cerro del Castillo (Bueno Serrano and Cerpa Niño, 2008). In this settlement, the beginning of the Phoenician coloniziation of the whole Bay of Cádiz was clearly identified on the basis of distinct archaeological levels and a fortified fence. The oldest settlement is defined by a 4 m wide fortification wall, domestic spaces and warehouses paved with red clays (Bueno Serrano et al., 2013). Few materials were found in the oldest archaeological levels, represented by handmade ceramics spanning from the Late Bronze age to Iron age I and few fragments of Phoenician ceramics with polychrome decorations (Bueno Serrano, 2015). During 7th–6th centuries BC, the settlement extended downwards along the slopes of the Cerro del Castillo. In this period, domestic spaces were characterized by several features including kilns, hearths and water drainage structures. Several Phoenician ceramic vessels were found in these archaeological levels. These include dishes, bowls, lamps, *boca de seta* jars, *pithoi*, urns and *Cerámica Gris de Occidente*. In addition, metal objects were also discoved, mostly iron knives (Bueno Serrano, 2015). The most recent period in the Cerro del Castillo is represented by the Punic phase (5th–3th centuries BC), characterized by wide edifices with large walls, most likely warehouses, indicating a change of use for the area from a domestic settlement into an area of food production and processing. In these archaeological levels iron smelters, together with several ceramic vessels were found, including the imported Greek grey varieties and the black varnished Ionian-types (Bueno Serrano, 2015).

The two lava fragments investigated in this study (Fig. 4) are representative of millstones found at Cerro del Castillo (Bueno Serrano, 2018). For some millstone fragments an origin from the Olynthian rectangular-type can be recognized. This is however not the case for the two millstone samples investigated in the present work, which refers to the Archaic Period; the hopper-rubber millstones had not been invented then. The millstone fragment labeled AV.RC (Avenida de Reyes Católicos) was found within the alluvial sands linked to the mouth of the Iro River, together with a Phoenician red *engobe* dish which can be dated between 7th and 6th century BC. The millstone fragment BN/11/1 (Barrio Nuevo) occurred inside one of the domestic spaces dated to the 6th century BC (Fig. 5).

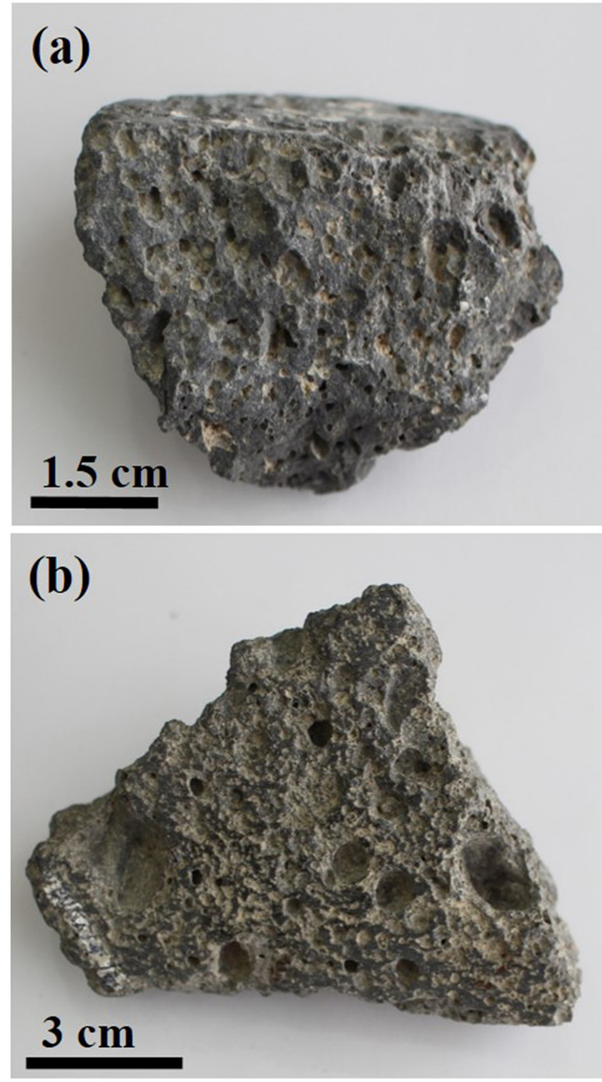

Fig. 4. Macroscopic view of the two millstone fragments from Cádiz (Cerro del Castillo): the sample datable to 7th–6th century BC (a; AV.RC) and that referred to the 6th century BC (b; BN/11/1).

3. Analytical methods, samples and results

In order to determine the provenance of the volcanic raw material, four samples of ≤ 1 cm^3 from each of the millstones (two from the Gozo shipwreck cargo and two from Chiclana de la Frontera) were collected using a chisel. From the Xlendi site samples, alterations and the external patinae on the querns caused by the long exposition of about 2700 years of the shipwreck cargo on the seabed, were mechanically removed (by brushing). Thin section modal mineralogy and petrographic texture (using a polarizing optical microscope) represent the classical and fundamental scientific approach to investigate the volcanic rock samples. However, this method has to be coupled with major-trace element determinations in order to unravel the magmatic series and the volcano or the volcanic province of the raw material from across the Mediterranean region. To define whole-rock chemistry, the samples were crushed and powdered in an agate mortar to limit contamination. Major (wt%) and trace (ppm) element concentrations were then determined using ICP-OES and ICP-MS techniques, respectively, at the Activation Laboratories Ltd. (Ancaster, Ontario, Canada) using the Lithogeochemistry Package WRA-ICP Code 4 Litho. Fusion is performed by a robot at Actlabs, which provides a fast fusion of the highest quality in the industry. The resulting molten bead is rapidly digested in a weak nitric acid solution. The fusion ensures that the entire sample is dissolved. Duplicate analyses were performed on the same sample. For most of these elements the 2σ values of the errors are calculated using a series of certified natural rock standards and are similar to the differences between the duplicates.

3.1. Petrography

The four volcanic rock samples share similar modal mineralogy and texture. They consist of basaltic lavas with partially seriate porphyritic texture (Porphyritic Index from 10 to 25%) and relatively high content of vesicles (from 15 to 20% of the volume) with irregular shapes (Fig. 6). Vesicles of the two sampled querns recovered from the shipwreck cargo of Gozo are generally filled by micritic cement and numerous carbonatic shells. In order of decreasing abundance, euhedral to subeuhedral phenocrysts consist of (i) plagioclase, locally with sieve texture, up to 3 mm in size (Fig. 6c, d, e); (ii) clinopyroxene of augitic composition with maximum size of 1.5 mm (Fig. 6d, f); (iii) olivine, partially iddingsitized, with size up to 1 mm (Fig. 6g). The groundmass of the investigated lava samples is mainly microcrystalline and characterized by an intergranular texture (Fig. 6a, e, h). Glomerophyres of the same phenocrystic minerals can be also present (Fig. 6d, f, h).

Fig. 5. The millstone fragment BN/11/1 (indicated by a white arrow) of Cádiz, found at Cerro del Castillo inside an household whose archaeological levels of settlement refer to the 6th century BCE.

Microlites are represented by plagioclase laths, clinopyroxene, olivine and opaque minerals (Fig. 6a, c). These latter are represented by both equigranular Ti-magnetite (often rounded in shape) and elongated ilmenite laths with acicular shape (Fig. 6b). Although a chemical classification is needed (see next section), the modal mineralogy of the investigated samples indicates a clear basaltic composition. The absence of modal orthopyroxene and the presence, also in the groundmass, of olivine and the Fe-Ti oxide pairs (i.e. magnetite and ilmenite) strongly suggest these basaltic rocks belong to alkaline/transitional magma series.

3.2. Chemistry (major and trace elements)

In order to achieve a correct chemical classification of the investigated lava millstones we plotted, on anhydrous basis, compositional data (Table 1) on the Total Alkali ($Na_2O + K_2O$) vs. Silica (SiO_2) diagram (TAS; Le Bas et al., 1986; Fig. 7), according to the IUGS recommendations (Le Maitre et al., 2002). All the samples show a basaltic composition. The alkaline affinity of the four samples is inferred from the $Na_2O + K_2O$ values (between 4.0 and 4.5 wt%; Table 1) at SiO_2 contents between 43.8 and 48.0 wt%. At these values of alkalis and silica, volcanic rocks are considered as belonging to the alkaline series according both to Kuno (1968) and Irvine and Baragar (1971) parameters. The alkaline character can be considered sodic as according to IUGS recommendations Na_2O (2.9–3.4 wt%) minus 2 remain always > K_2O (0.9–1.1 wt%) for all the analysed samples. All the other major elements are very similar among the investigated samples: Al_2O_3 15.1–16.1 wt%, Fe_2O_3 12.2–13.1 wt%, MgO 5.6–7.4 wt%, CaO 10.6–11.6 wt%, TiO_2 2.6–2.9 wt%, P_2O_5 0.6–0.7 wt%. The Mg# (Mg number; Table 1) of the analysed rocks ranges between 59.8 and 66.9 which are values indicating the origin from relatively primitive basalts, slightly affected by fractional crystallization.

Similarity and alkaline affinity of the magmas erupted to form these lavas is also suggested by the normative compositions (C.I.P.W. Norm, Table 1) with the absence of normative quartz and/or hypersthene and the presence of normative felspathoid (nepheline) between 1.1 and 6.1 wt% (Table 1) which is a clear feature indicating the basalts belong to a sodic alkaline series.

Basalts with the above petrochemical features, emphasizing an alkaline sodic affinity, generally have a within-plate origin (Ocean Island Basalts, OIB), characterizing many volcanoes and volcanic provinces throughout the Mediterranean. We can instead rule out a provenance from all the island-arc basalts (IAB) of subduction related origin (calcalkaline, high-K calcalkaline) which are also very widespread in the eastern (Hellenic arc, e.g., Santorini, Nisyros), central (e.g. Aeolian Archipelago and western Thyrrenian border of central-southern Italy) or western (e.g. Betic Cordillera, south-eastern Spain) Mediterranean region. A subduction-related (orogenic) fingerprint for the four investigated samples can be also ruled out by the normalized multi-element pattern of Fig. 8a. It is here clear that key elements such as Ta, Nb and Ti do not show the characteristic negative spikes of the subduction related volcanic rocks.

The Rare Earth Elements (REE) pattern of the four millstones are almost coincidental, with a moderate fractionation of Light REEs (La and Ce are ca. between 70 and 100 times the chondritic values) with respect Heavy REEs (Yb and Lu slightly above 10 times the chondritic values), with no Eu negative anomaly (Table 2, Fig. 8b). These REE patterns, characterized by La/Yb ratio ranging from 13.6 to 15.4 (Table 2), are common of alkaline OIBs.

3.2.1. Unravelling OIBs of the Central Mediterranean as millstone source

Among the OIB volcanoes of the Central Mediterranean, those exploited in antiquity for the manufacture of millstones are located in Sicily (Etna and Iblei Mountains; Williams-Thorpe, 1988; Gluhak and Schwall, 2015; Santi et al., 2015). There are however, smaller OIB volcanoes that are widespread in the Sicily Channel (e.g. Pantelleria and Linosa) and in the Southern Tyrrhenian Sea (e.g. Ustica). Many of these within-plate OIBs from Mediterranean volcanoes were already recognized by several authors as providing the raw material for millstones for the period covering the 4th century BC to the Roman Period (Williams-Thorpe, 1988; Williams-Thorpe and Thorpe, 1990, 1991; Santi et al., 2015).

However, the high TiO_2 content (2.6–2.9 wt%) of the four investigated basaltic millstones defines a chemical fingerprint of OIBs that allows us to rule out Etna and Ustica basalts, which are all characterized by a TiO_2 content ≤ 2.1 wt% (Peccerillo, 2005). This can be also seen in the binary diagram TiO_2 vs. Rb where the two querns from the shipwreck of Gozo and the two millstone fragments from Cádiz only overlap the basalts from Pantelleria and Iblei (Fig. 9a). In this diagram, samples from Ustica have Rb contents comparable with the investigated samples, but $TiO_2 < 2$ wt%. In order to discriminate between Pantelleria and Iblei, we utilised the binary correlation Nb vs. TiO_2 (Fig. 9b) where all the basalts from Iblei Mountains can be definitively excluded as the millstone source. Among the OIB volcanoes of the central Mediterranean, an additional constraint for the Pantelleria Island as the best provenance candidate of the investigated querns, is given by the La/Yb vs. Sm/Yb diagram (Fig. 9c) where Etna, Iblei, Ustica and Linosa lavas can be all excluded as sources. By contrast, when updated literature data (e.g. Peccerillo, 2005) entered in other binary diagrams commonly used to discriminate volcanic millstone provinces, such as Zr vs. V plot, firstly proposed by Williams-Thorpe (1988), no different compositional field among the OIBs of the Mediterranean area can be constrained. Good correlations and overlapping of the trace elements patterns of the Pantelleria basalts with those of the four investigated millstone samples is also reported for the incompatible elements and REEs, normalized to Primitive Mantle and Chondrite respectively (Fig. 8a–b).

4. Overall constraints for Pantelleria millstone trade

Pantelleria Island (83 km^2) is located in the Sicily Channel, ca 70

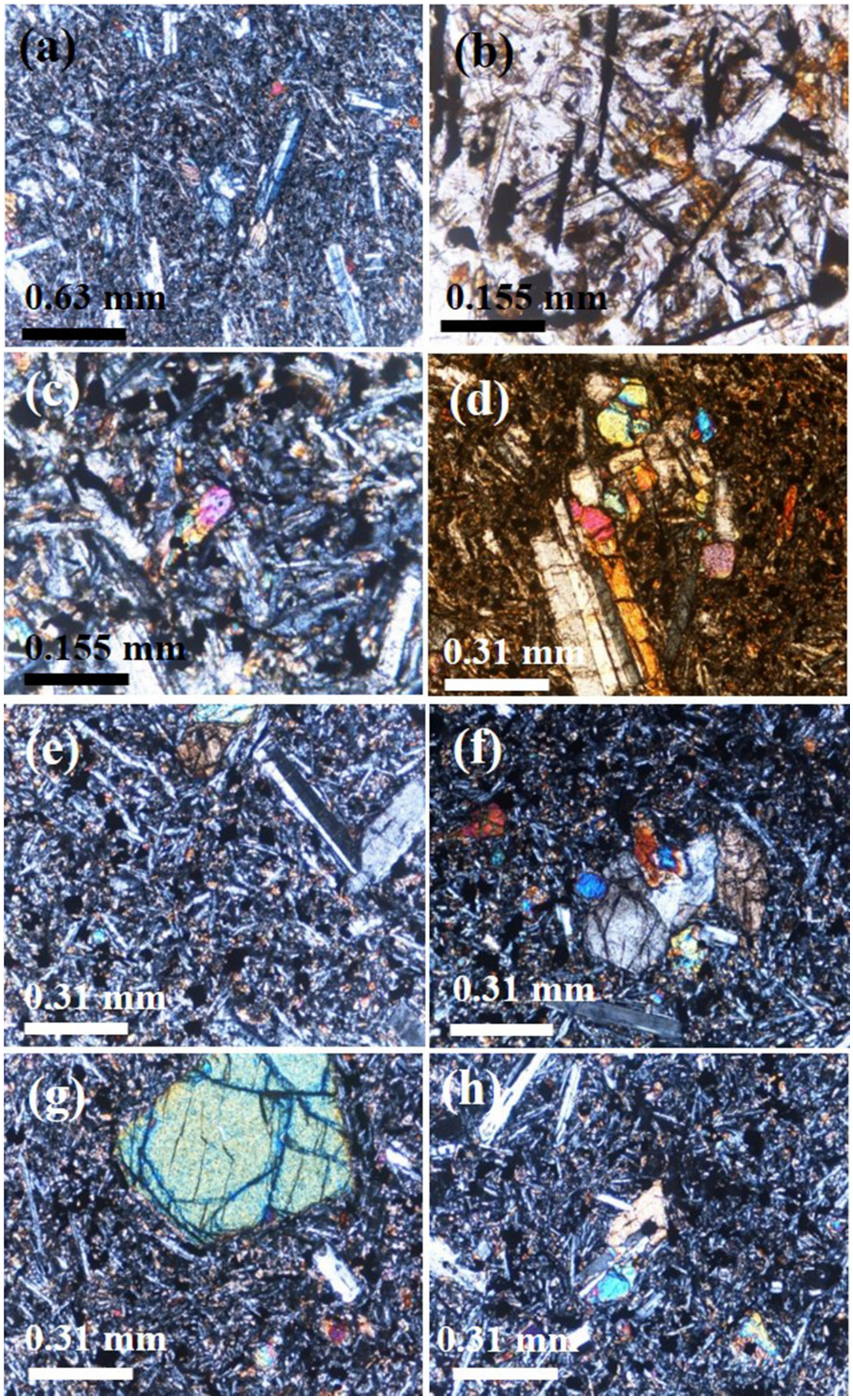

Fig. 6. Thin sections microphotos of the four investigated volcanic millstones (a–d: samples from the Gozo shipwreck cargo; e–h: samples from Cerro del Castillo, Cádiz).

Km ESE from Cape Bon (Tunisia) and ca 100 km SW from Cape Granitola (Sicily). Its height (836 m) makes it an excellent landmark for sailors in ancient times. It also has small but good havens from the prevailing North-West winds. These anchorages were however larger in ancient times (Arnaud, 2008; Baldassari and Fontana, 2002; Abelli, 2011). Although not attested in ancient written sources, it is highly likely that the Island of Pantelleria was involved in the development of the Phoenician expansion into the Central and Western Mediterranean. Textual evidence for Pantellerian history date to the Punic Period when the island is described in the *Pseudo Skylax* (Peretti, 1979) as an intermediate stop between *Hermania* (Cape Bon in Tunisia) and Lilibeo (present-day Marsala in Sicily).

The island is also known to have been a source of prehistoric obsidian, a volcanic glass which was extensively used to make sharp implements in the Neolithic and Bronze Age and that have been found across much of the Mediterranean area, up to several hundreds of

Table 1
Major elements (wt%) and C.I.P.W. normative composition of the four investigated querns and millstones. GW1 and GW2 were affected by some alteration due to the permanence on the sea bed for > 2500 years. This alteration, is pointed out by medium values of LOI (1.39 and 1.95 wt%) and mainly affects silica as the most abundant element oxide, in terms of relative depletion. Anyway, these LOI values do not preclude the use of major and trace elements for comprehensive geochemical comparisons.

	Gozo millstones		Cadiz millstones	
	GW1	GW2	AV.RC	BN/11/1
SiO_2	45,71	43,81	47,39	47,96
Al_2O_3	15,12	16,08	15,26	15,06
Fe_2O_3	12,34	12,48	12,19	13,15
MnO	0,18	0,17	0,18	0,18
MgO	6,02	7,39	6,17	5,57
CaO	11,14	11,59	11,38	10,60
Na_2O	3,06	2,92	3,24	3,40
K_2O	0,94	0,87	1,04	1,09
TiO_2	2,89	2,58	2,67	2,93
P_2O_5	0,68	0,64	0,63	0,71
LOI	1,39	1,95	-0,24	-0,18
Total	99,46	100,5	99,91	100,50
Mg#	63,60	66,90	63,80	59,80
C.I.P.W. Norm				
Orthoclase (Or)	5,7	5,3	6,2	6,5
Albite (Ab)	22,4	14,0	22,8	26,9
Anorthite (An)	25,5	28,9	24,2	22,7
Nepheline (Ne)	2,3	6,1	2,6	1,1
Diopside (Di)	22,0	21,0	23,4	21,0
Olivine (Ol)	11,9	15,2	11,4	11,7
Magnetite (Mt)	2,8	2,8	2,7	2,9
Ilmenite (Il)	5,7	5,0	5,1	5,6
Apatite (Ap)	1,7	1,6	1,5	1,7
Total (T2)	100	100	100	100

kilometres away from the island (Hallam et al., 1976; Acquafredda et al., 1999). Trade in Pantellerian obsidian was however of lesser importance when compared with Lipari (Aeolian Archipelago), from where considerable quantities of obsidian were transported to much of central and southern Italy and beyond (Tykot, 1996). As reported by Peacock (1985), the basaltic outcrops in the northwestern part of the island were certainly worked for querns during the Bronze Age. As a matter of fact, flat and saddle querns made of basaltic lava were found in the Bronze Age village of Mursia (Orsi, 1896, 1899; Marcucci, 2008). The compatibility of Pantelleria basalts with the four millstones studied for the purposes of this paper is not surprising. This because the provenance from this island was already documented for some volcanic millstones (Fig. 1) discovered at Phoenician sites and Carthaginian settlements of Sicily (e.g. Motya and Entella; Williams-Thorpe, 1988; Daniele, 1997) and Tunisia (e.g. Utica, Carthage, El Maklouba, Thuburbo Maius, Kelibia; Williams-Thorpe, 1988). Most of the basaltic hopper rubber millstones from the shipwreck of Sec (ca. 4th century BC) are also from Pantelleria (El Sec, off the coast of Mallorca; Williams-Thorpe and Thorpe, 1990).

4.1. Geology and petrology of Pantelleria

Pantelleria is a Late-Pleistocene volcanic system with a bimodal association of alkali basalts and peralkaline trachytic/rhyolitic rocks showing a large compositional gap at SiO_2 between 50 and 67 wt% (Civetta et al., 1998). Two groups of alkaline basalts are distinguished throughout Pantelleria: a high TiO_2 (> 3 wt%)-P_2O_5 (≥ 0.9 wt%) group, erupted before 50 ka BP, and a low TiO_2 (< 3 wt%)-P_2O_5 (≤ 0.75 wt%) group, that erupted after 50 ka BP separated by a caldera collapse (Civetta et al., 1998). Mafic lavas also include transitional basalts and hawaiites (Avanzinelli et al., 2004). Pantelleria is also the type locality of pantellerite, a type of leucocratic peralkaline rhyolite (Foerstner, 1881). Felsic lavas and tuffs, ranging in SiO_2 from ca. 62 to 72 wt% mainly consist of metaluminous/peralkaline trachytes and pantellerites (White et al., 2009).

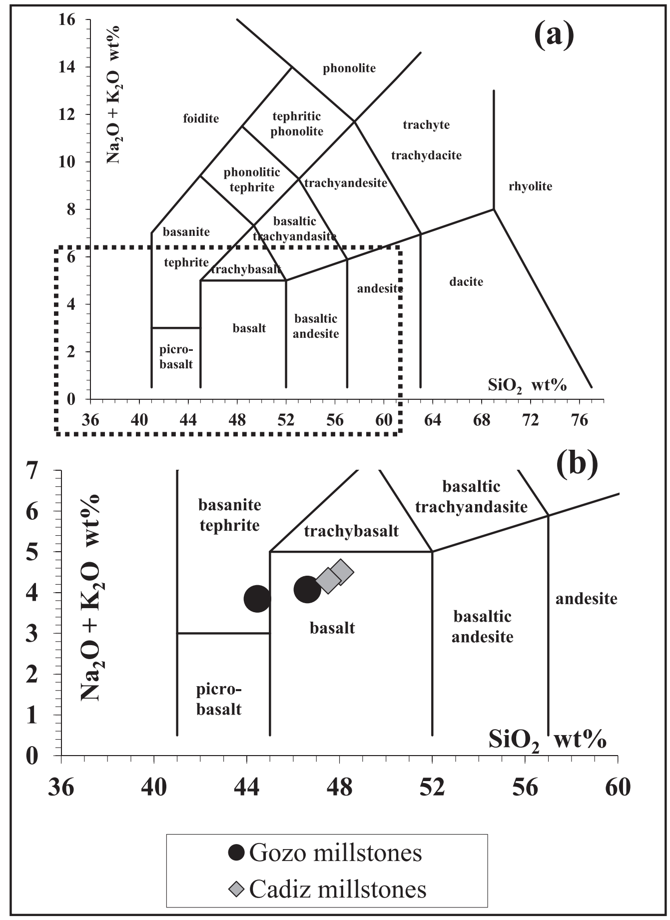

Fig. 7. Total Alkali-Silica classification diagram (Le Bas et al., 1986) for the four investigated lava millstones.

The high TiO_2-P_2O_5 basalt group has twice the trace element contents, including Sr, Y, Zr, Nb, Ba and light rare earth elements (LREE), relative to the low TiO_2-P_2O_5 basalts. All the geochemical features of the Pantelleria basalts emphasize within-plate, anorogenic (sodic) OIB petrogenetic features.

From a petrographic point of view, basalts (and hawaiites) from Pantelleria are weakly to highly porphyritic (5–20% by volume phenocrysts), with plagioclase > olivine > clinopyroxene ± Ti-magnetite, set in a microcrystalline groundmass consisting of plagioclase, olivine, clinopyroxene, ilmenite, Ti-magnetite and apatite (Civetta et al., 1998). In some cases, two types of groundmass can be recognized under the microscope. One appears dark, having abundant small Fe-Ti oxide grains. The other groundmass type has less abundant larger Fe-Ti oxide grains, thus appearing lighter than the former. Sometimes, both dark and light groundmasses can be present in the same rock at the micro-scale. Basalts outcrops are mostly present in the northern sectors of the island. On the basis of major and trace element comparisons with the four investigated millstone samples, the most likely manufacturing source area of Pantelleria Island had to be that of the low TiO_2-P_2O_5 (and low HFSE and LREE) group of basalts cropping out at Punta San Leonardo and nearby area, as already established by Williams-Thorpe and Thorpe (1990) as the provenance of the main group of the hopper rubber millstone (25 artifacts) of the cargo from the Greek shipwreck at El Sec (Mallorca).

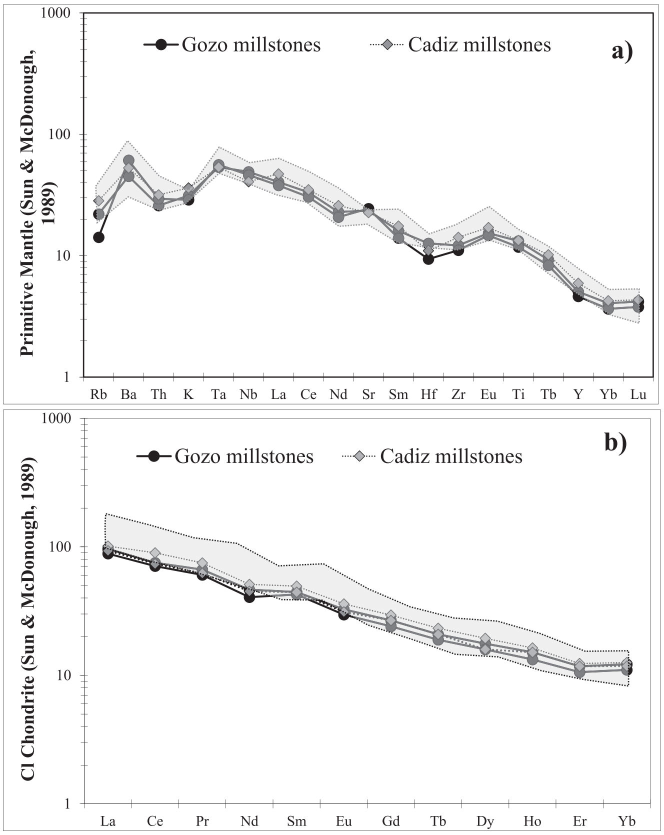

Fig. 8. Incompatible multielement (a) and Rare Earth Elements (b) diagrams normalized to Primordial Mantle (a) and CI Chondrites (b). Normalized values are from Sun and McDonough (1989). Pale grey fields represent the patterns of the Pantelleria basalts (data from Civetta et al., 1998; Avanzinelli et al., 2004; White et al., 2009). Uranium (U) is not reported in (a) as it could have been affected by leaching through water-rock interaction during the prolonged staying of the millstones under the sea (Thompson, 1983).

Table 2
Trace elements (ppm) composition of the four investigated samples.

	Gozo millstones		Cadiz millstones	
	GW1	GW2	AV.RC	BN/11/1
Be	1	< 1	< 1	1
Sc	30	30	32	31
V	286	277	273	299
Cr	100	140	140	100
Co	39	38	38	39
Ni	60	90	60	40
Cu	50	40	40	40
Zn	100	90	90	100
Rb	14	9	18	18
Sr	497	516	515	478
Y	23	21	23	27
Zr	136	124	137	159
Nb	35	33	30	29
Ba	315	427	463	369
La	27,8	26,1	27,2	32,4
Ce	59,1	54,2	57,1	62
Pr	7,15	6,73	7	8,54
Nd	31	28,2	29,1	35
Sm	7,1	6,2	6,9	7,8
Eu	2,58	2,47	2,57	2,87
Gd	6,7	6,1	6,4	7,4
Tb	1	0,9	1	1,1
Dy	5,3	4,8	5,3	5,9
Ho	1	0,9	0,9	1,1
Er	2,5	2,2	2,5	2,7
Tm	0,33	0,29	0,33	0,36
Yb	2	1,8	2	2,1
Lu	0,31	0,28	0,3	0,32
Hf	3,9	2,9	3,1	3,4
Ta	2,2	2,3	2,2	2,2
Pb	< 5	< 5	< 5	< 5
Th	2,2	2,5	2,5	2,7
U	0,4	0,4	0,8	0,8
La/Yb	13,9	14,5	13,6	15,4

4.2. *Comparisons ruling out a Levant source area*

Due to the Phoenicians coming from the Levant, it is necessary to perform comprehensive comparisons of the studied samples with the various basaltic rocks that are present in Israel, Jordan and Syria. In particular, those basaltic rocks that are petrographically and geochemically similar to those being investigated in the present study. In the Levant area, sources widely used in the ancient lithic industry and for the manufacture of millstones included outcrops in the Lake Tiberias area, the Golan Heights, the Jordan Plateau and Northern Syria (Xenophontos et al., 1988; Williams-Thorpe et al., 1991; Williams-Thorpe and Thorpe, 1993). Compositional data from the whole Levant region (Williams-Thorpe and Thorpe, 1990, and reference therein), or distinct updated literature data from Lebanon (Stein and Hofmann, 1992; Abdel-Rahman, 2002; Abdel-Rahman and Nassar, 2004), Syria (Mahfound and Beck, 1993; Demir et al., 2007; Lease and Abdel-Rahman, 2008) and Jordan (Ibrahim Khalil et al., 2003; Ibrahim Khalil and Al-Malabeh, 2006) point to the Levant basalts as generally having chromium contents ≫ 130 ppm (up to 495 ppm) and a widespread Sr compositional range (from ca. 300 to 2000 ppm). Chrome and strontium variations are too high with respect to the limited range of these elements (Cr 100–140 ppm; Sr 478–516 ppm) that are present in the four samples investigated for the present study. Most of the literature on geochemical data available for the Pantelleria basalts (Civetta et al., 1998; Avanzinelli et al., 2004; White et al., 2009) is outside the very widespread compositional field of the Levant basalts in the Sr vs. Cr diagram (Fig. 10). By contrast, this diagram illustrates that the four analysed millstones are well within the much more limited variation in Sr (ca. 410–530 ppm) and Cr (ca. 70–170 ppm) as are present in the Pantelleria basalts, also coinciding with the basaltic hopper rubber millstones recovered from the shipwrecked cargo of El Sec datable to the 4th century BC (already identified as Pantelleria Island millstones by Williams-Thorpe and Thorpe, 1990). In addition, if we group together both geological and archaeological (i.e. composition of volcanic stone artifacts) data of the Levant area (Syria, Jordan and Israel; Xenophontos et al., 1988; Williams-Thorpe and Thorpe, 1993) in the TiO_2 vs. Zr diagram (Fig. 11) we can definitively rule out a provenance of the two querns from the Gozo shipwreck and the two Cádiz millstone fragments from present-day Lebanon and its surrounding areas, i.e. the original lands of the Phoenicians.

5. Discussion

The Archaic Period in the Mediterranean is characterized by the interaction of cultures that transcended commercial ties and spilt over into social, religious and cultural aspects of everyday life (Hodos, 2015). To date, the majority of archaeological material from this period of intensive exchange originates from terrestrial sites that may be considered as “final destinations” for traded objects and materials (Gras, 1997). From the perspective of exchange, terrestrial archaeology provides a fragmented portrayal of how objects were grouped and transported. Gaining such knowledge is essential because it will contribute to a better understanding of interactions between Mediterranean regions and cultures. Such an understanding can be achieved through a detailed study of a well-preserved shipwreck and placing of results of such studies in a broader geo-economic landscape (Parker, 1992). The discovery of the Phoenician shipwreck off the Island of Gozo and

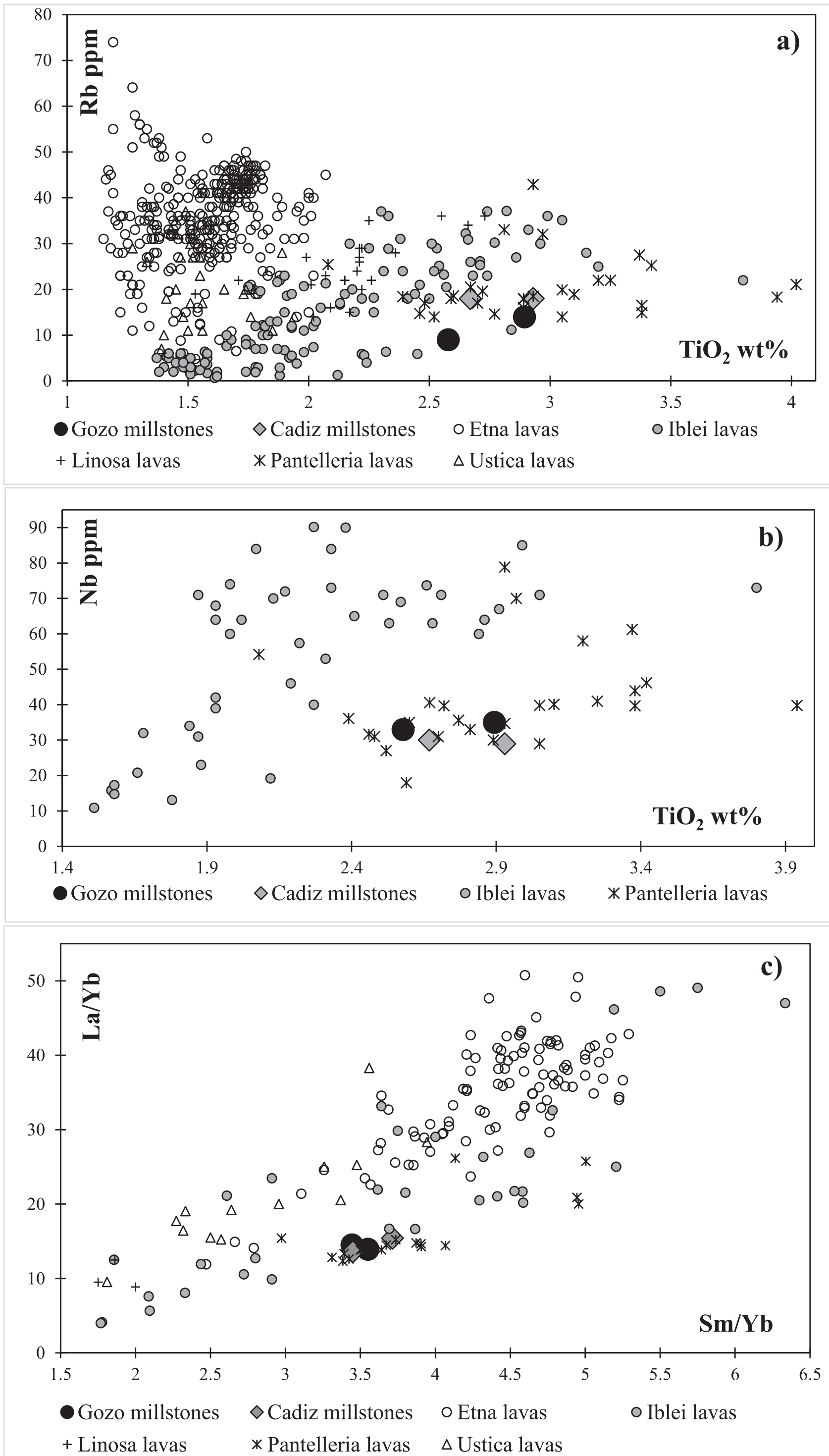

Fig. 9. TiO_2 vs. Rb (a), TiO_2 vs. Nb (b) and Sm/Yb vs. La/Yb (c) diagrams comparing the four investigated samples with selected basalts of within-plate origin (OIBs) from the Mediterranean: Etna, Iblei, Linosa, Pantelleria and Ustica lavas.
(Source: data from Peccerillo (2005)).

subsequent exploratory studies of two querns from its cargo have confirmed the unmistakable opportunities that this site provides. In addition, the terrestrial excavations of Cerro del Castillo (Cádiz) represent an additional opportunity to determine the provenance of representative millstones in the westernmost Phoenician colony.

Petrographic and geochemical investigations and comparisons of the studied samples with compatible volcanic rocks (i.e. basalts) from widely exploited areas known to manufacture millstones in ancient Mediterranean, rule out all the possible sources, with the exception of Pantelleria Island. As already reported by Peacock (1985), the basaltic outcrops from the northwestern sectors of the Pantelleria Island (the high TiO_2-P_2O_5 group supposed to be the source for millstones) could not have supported a viable industry during the Roman Period as these basalts are largely scoriaceous, dissected and with jointing, probably not suitable for large pieces of homogeneous lavas needed for the rotary hourglass millstones. By contrast, the basalts from Pantelleria were very

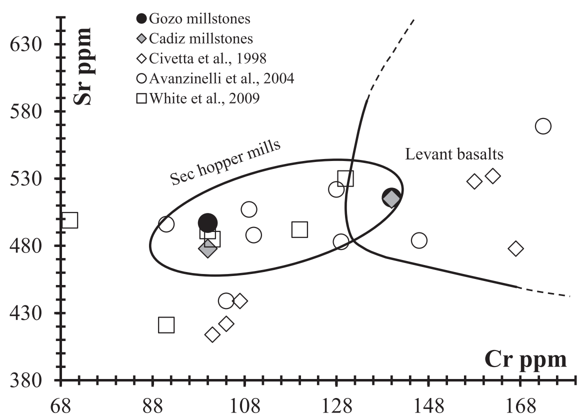

Fig. 10. Sr vs. Cr diagram as reported by Williams-Thorpe and Thorpe (1990) showing the right-hand side field of the Levant (Israel, Jordan and Syria) basalts. The whole Levant basalts field extend towards very high Cr (up to 495 ppm) and Sr (up to 2000 ppm) and also comprise updated literature from Lebanon (Stein and Hofmann, 1992; Abdel-Rahman, 2002; Abdel-Rahman and Nassar, 2004), Syria (Mahfound and Beck, 1993; Demir et al., 2007; Lease and Abdel-Rahman, 2008) and Jordan (Ibrahim Khalil et al., 2003; Ibrahim Khalil and Al-Malabeh, 2006). The compositional field of 25 hopper-rubber millstones of the El Sec shipwreck cargo (Williams-Thorpe and Thorpe, 1990) and the overall basaltic lavas of Pantelleria from the most recent literature data (Civetta et al., 1998; Avanzinelli et al., 2004; White et al., 2009) are also reported.

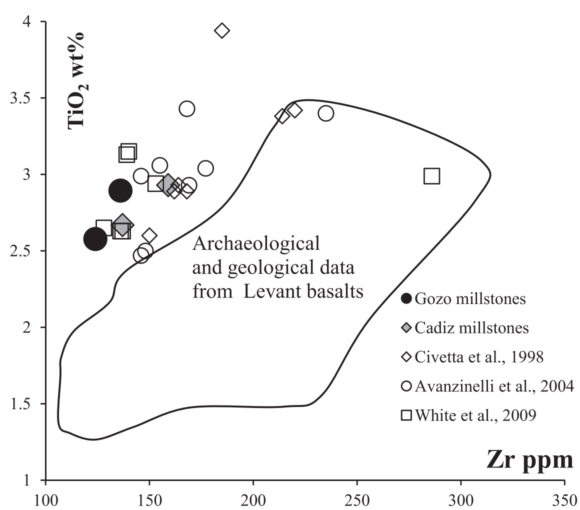

Fig. 11. TiO_2 vs. Zr diagram as reported by Williams-Thorpe and Thorpe (1993) showing the whole compositional field of the Levant basaltic lavas (Israel, Jordan and Syria) comprising both archaeological (lithic tools) and geological samples. The overall basaltic lavas of Pantelleria from the most recent literature data (Civetta et al., 1998; Avanzinelli et al., 2004; White et al., 2009) are also reported. Few Pantelleria basalts with Zr contents ≥300 ppm were not plotted, as they are not compatible with the low TiO_2-P_2O_5 group of Pantelleria basalts recognized as the source off the investigated millstone samples.

suitable for the small querns in the Archaic and Early Classical Periods (such as those present in Xlendi shipwreck) or the Hellenistic Greek medium-size Olynthian hopper rubber millstones (such as those from the 4th century El Sec shipwreck). On the other hand, the well-preserved cargo from the Xlendi shipwreck point to the important role played by the Maltese Islands in the Archaic maritime milieu. It is however clear that the querns loaded at Pantelleria were not all destined for the Maltese Islands and, together with the amphorae, the cargo was being transported to one or more destinations. The ship was in fact leaving the Maltese Islands when it sank, as testified by the presence in the cargo, of urns made of Gozitan clay. It is also interesting to note that during the 5th–6th century BC loose sands containing key-minerals of peralkaline trachytes such as anorthoclase (a feldspar) and aegirine (a clinopyroxene) from Pantellerian volcanic rocks were also used as temper for handmade pottery at Carthage (Peacock, 1985 and reference therein).

6. Concluding remarks

During the Archaic Period, Pantelleria Island represented a Phoenician landmark for the supply of volcanic millstones and their trade in the Central-Western Mediterranean, a role that continued up to the beginning of the Hellenistic Period. The central position of the island, in the middle of the Sicily Channel, could be considered strategic for the Phoenicians, from where basaltic mills could be loaded for transport to various destinations. The ship sank off Xlendi Bay when it was leaving the Maltese Islands and its next trading destination is of course unknown (Gambin and Woods, 2017). Williams-Thorpe (1988) and Daniele (1997) already established the presence of basaltic millstones from Pantelleria (Archaic querns and hopper rubber millstones) in Phoenician sites or Carthaginian settlements of Sicily (e.g. Motya and Entella) and Tunisia (e.g. Utica, Carthage, El Maklouba, Thuburbo Maius, Kelibia; Fig. 1). In addition, most of the basaltic millstone cargo of another shipwreck, off the coast of Mallorca (El Sec) dating to ca. 4th century BC (Williams-Thorpe and Thorpe, 1990) come from Pantelleria. El Sec is approximately 800 km from Pantelleria. The present study also emphasizes the presence of Pantellerian millstones in the westernmost Phoenician colony of Gadir (i.e. Cádiz), which is > 1500 km to the west from the island in the middle of the Sicily Channel. It is worth noting that sailing from east to west, towards the Strait of Gibraltar and finally reaching Gadir in the Atlantic Ocean, Pantelleria was the last westernmost volcanic island where Phoenicians could load basaltic millstones without calling into continental harbours. Although volcanic areas are also present in the southeastern Spain or northern Africa (Algeria and Morocco) these regions of the western Mediterranean could not assure lava millstone production and trade as was guaranteed by the Pantelleria Island.

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