THE PYLOS REGIONAL ARCHAEOLOGICAL PROJECT

PART II: LANDSCAPE EVOLUTION AND SITE PRESERVATION

(Plates 109–112)

HUMAN HABITATION PATTERNS are constrained by natural resources and processes. Any regional archaeological project must therefore first determine the primary resources provided by the natural setting, including the availability of fresh water, arable land, mineral deposits, building stones, and natural harbors, and, second, investigate the geological processes that may have distorted the original archaeological record, including erosion, deposition, tectonic movement, and coastal progradation and regression. Only when the quality and quantity of these factors are known will archaeological field projects be able to establish site size, function, and duration and reconstruct and interpret the historic interrelation between human habitation and landscape evolution.

When the Pylos Regional Archaeological Project (PRAP) was conceived to investigate the history of settlement and land use in western Messenia (Peloponnesos, Greece),[1] it was decided that physical sciences would comprise a major component of the study. This article represents the preliminary report of the principal natural scientists who participated in the fieldwork for PRAP between 1991 and 1995.[2] By employing an interdisciplinary team consisting of a geoarchaeologist (Eberhard Zangger), a soil scientist (Michael Timpson), a botanist and palynologist (Sergei Yazvenko), a geophysicist (Falko Kuhnke), and a hydroengineer (Jost Knauss), it was possible to reconstruct the environmental history of the landscape centered on the Palace of Nestor.[3] Among the main results of this study are a continuous vegetation history for the past 7,000 years, the discovery of the earliest artificial port in Europe, and the discovery of a magnetic anomaly indicating a massive artificial structure northwest of the Palace of Nestor.

Characteristics of Messenia

Western Messenia lies hidden in a far corner of the Greek mainland and is difficult to reach from the eastern Peloponnesos by land because three mountain ridges obstruct

[1] See Davis *et al.* 1993, 1994a, 1994b, 1995, and 1997 for a description of PRAP and for preliminary archaeological results. The full illustrated texts of preliminary reports for the 1993–1995 seasons are available on the WorldWideWeb at http://classics.lsa.umich.edu/PRAP.html, as is a complete gazetteer of all archaeological sites investigated by PRAP and a catalogue of representative artifacts from them. The physical scientific research was funded through PRAP by the Institute for Aegean Prehistory, the National Endowment for the Humanities (1992–1994 in support of fieldwork [RO-22441-92] and 1995–1997 in support of study for publication [RK-20170-95]), the National Geographic Society (1992–1994 in support of fieldwork [4798-92; 5004-93; 5227-94]), and by private donors. Full acknowledgments are included in Davis *et al.* 1997.

[2] For acknowledgments to individuals see p. 636 below.

[3] Strategies for interdisciplinary landscape reconstructions are described in Zangger *et al.* 1997 and Zanger *et al.*, in press.

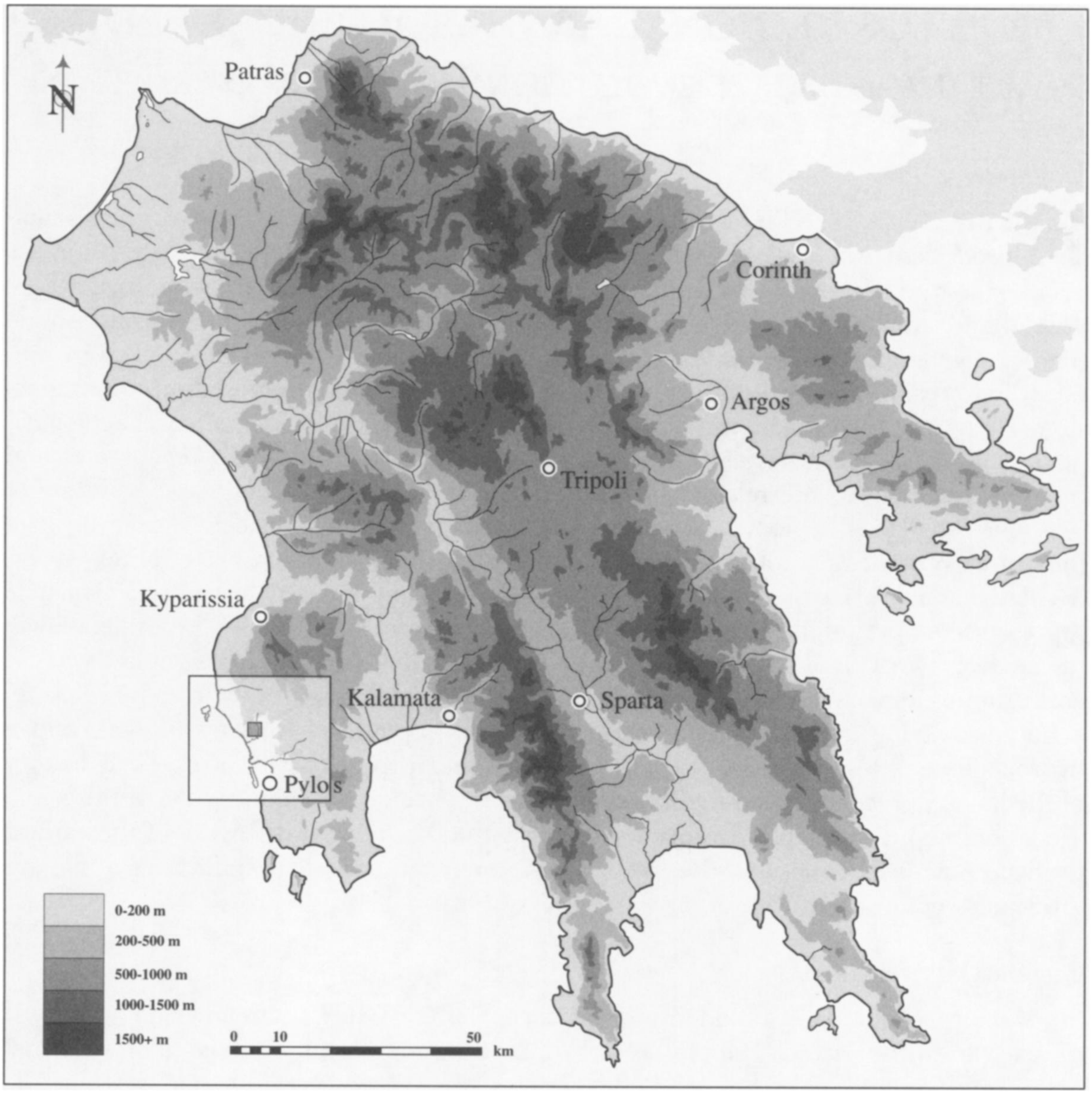

Fig. 1. Topographic map of the Peloponnesos showing the location of the study area in western Messenia (large square) and of the Palace of Nestor (small square) (Rosemary J. Robertson)

the route (Fig. 1). Although the Bay of Navarino (Figs. 2–4) offers the only large and safe harbor on the west coast of the Peloponnesos, this region is today rural and remote, with a low population density. The naval route around the Peloponnesos is notoriously dangerous and was used relatively little even in Classical times, when most of the east–west traffic passed through Corinth. The Palace of Nestor, half a dozen excavated tholos tombs, and numerous other archaeological sites, however, bear witness to Messenia's significance in the Mycenaean period. In addition to its remoteness from the eastern Peloponnesos,

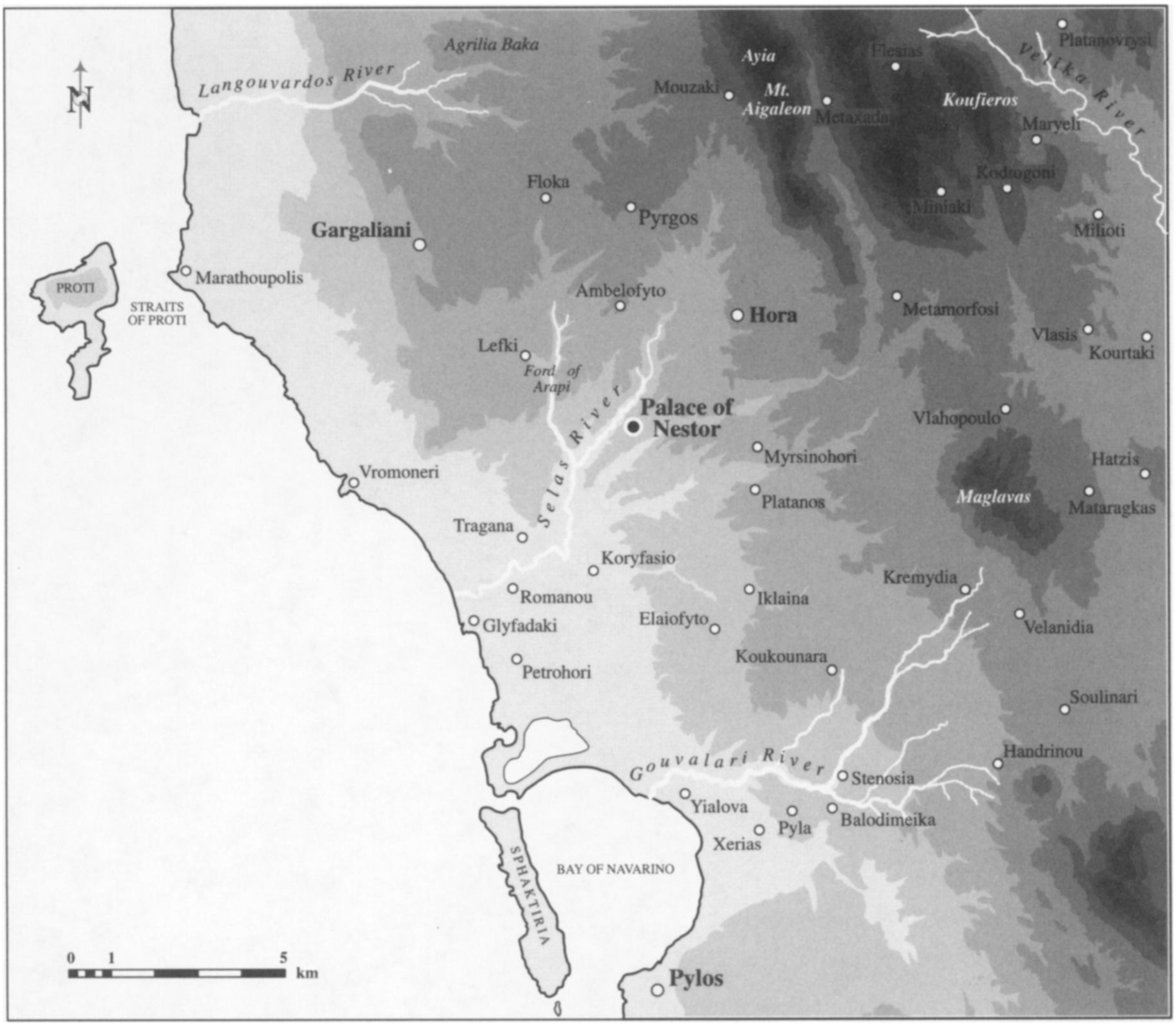

FIG. 2. Topographic map of the study area indicating important place names (Rosemary J. Robertson)

other characteristics of Messenia are recent crustal movements, which have produced one of the steepest subaquatic slopes on earth, just west of Messenia,[4] as well as textbook examples of Pleistocene marine terraces. Hence, Messenia seems to be characterized by opposites: desolate today yet once a cultural center; extreme remoteness from the Argolid or Lakonia yet with the potential to be a gateway to the west; subsidence and uplift.

Observations made during the initial season, in combination with research in the literature, provided further clues about the environmental setting. We noted early on that the abundant Pliocene and Pleistocene marl deposits north of the Bay of Navarino are highly prone to erosion. Their instability is caused by a number of factors, including their

[4] Philippson 1959, p. 400.

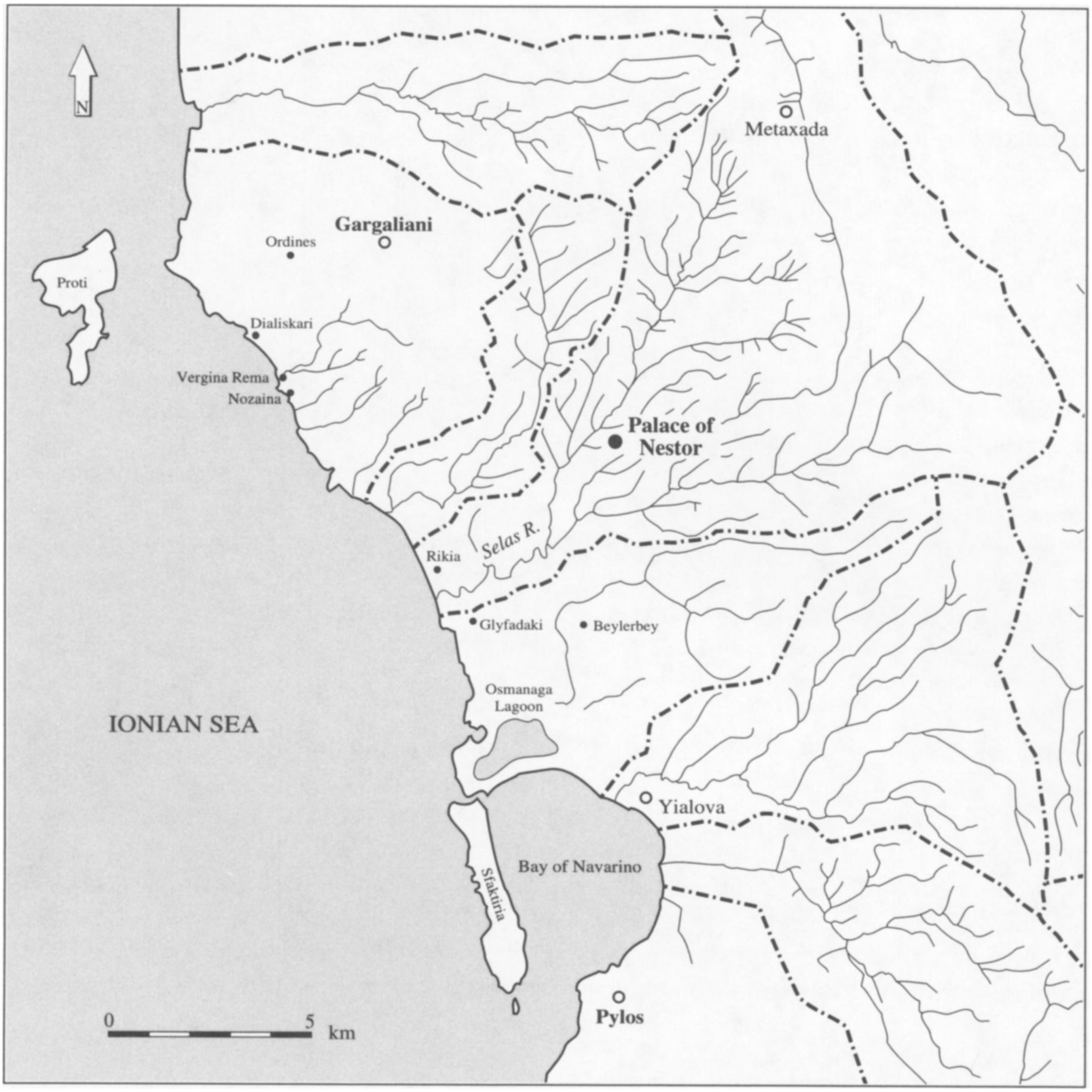

FIG. 3. Drainage systems in the study area north of the Bay of Navarino (Eberhard Zangger)

relatively young age, lack of consolidation, and the tectonic uplift. Eroded surface material was redeposited near the coast, where it has been filling up lagoons and floodplains. Archaeological sites in the uplands may therefore have suffered from erosion, while others near the coast might have been concealed under recent deposits. Another phenomenon deserving close attention is the unusual course of the Selas River flowing past the palace (Figs. 2, 3). During a previous investigation of the Holocene depositional history of western Messenia, it was suggested that the river was probably artificially diverted during the Late Bronze Age.[5] The precise character, function, date, and purpose of this suspected hydraulic engineering feat, however, remained obscure.

Aims

All these phenomena, and several others, became focal points of the fieldwork conducted by the physical-science team of PRAP. As stated in the introductory paragraph, the principal aims of the scientific fieldwork were to (1) determine the primary natural resources in the study area, (2) investigate the geological processes that may have distorted the original archaeological record, and (3) reconstruct the historic interrelation between human habitation and landscape evolution. Further dividing these main objectives, the science team was expected to address the following specific subjects and tasks:

Primary Resources

- Bedrock: Provide an inventory of the bedrock of the survey area that could be used as a base for the natural scientific and archaeological studies.
- Geomorphology: Investigate geomorphological factors that are likely to have influenced human settlement choice in the past.
- Natural resources: Determine the availability of natural resources such as water, mineral deposits, building stones, and raw material suitable for the production of stone tools.
- Soils: Describe the nature of the present soils and landforms, determine the agricultural potential of each area, and estimate the degree of soil erosion throughout the study area.

Secondary Processes

- Tectonics: Establish the character and extent of tectonic uplift and subsidence in the study area to estimate the rate of erosion.
- Erosion: Find out how erosion has affected the preservation of archaeological sites and the perception of the archaeological record in the present.
- Coastline changes: Determine the amount of coastal progradation and regression that may have buried or destroyed archaeological sites.
- Deposition: Investigate Holocene deposits to determine the thickness and chronology of stratified sediments containing or concealing artifacts.

Coevolution of Landscape and People

- Vegetation: Determine the vegetation history and the patterns of past land use.
- The Palace: Assess the lateral and vertical extent of buried prehistoric construction remains at the Palace of Nestor and other extensive sites.
- Tumuli: Illuminate the precise character of the many Bronze Age tumuli in the survey area.
- River diversion: Resolve the purpose and date of the redirection of the Selas River.

The methodology required to address these issues calls for a different arrangement of the subjects, one that follows more closely the frontiers of the disciplines involved in the study. In the conclusions, however, we shall return to the set of initial aims listed above.

[5] Kraft, Rapp, and Aschenbrenner 1980, p. 194.

Previous Studies

A number of natural scientific studies have been carried out in Messenia, often in conjunction with archaeological research in the area.[6] The University of Minnesota Messenia Expedition (UMME), supported by botanists, agronomists, soil scientists, archaeometallurgists, and geophysicists,[7] made the first systematic study of the area after the descriptive geographic reports of the 19th century.[8] In addition, William G. Loy produced a thesis entitled "The Land of Nestor: A Physical Geography of the Southwest Peloponnesos," in which he attempted to reconstruct the history of the Late Bronze Age landscape.[9] More recently, John C. Kraft and his coworkers conducted a detailed analysis of the Holocene stratigraphy and depositional history of the Bay of Navarino and its surroundings.[10] Finally, Joan J. Carothers wrote a doctoral dissertation on "The Pylian Kingdom," in which she dedicated ample space to the discussion of environment and archaeology.[11]

The purpose of our work was neither to repeat nor to summarize the observations and interpretations of these previous studies; rather we aimed to build on the knowledge accumulated by earlier research and acquire new data and observations. Physical scientific work on archaeological field projects often runs the risk of being split up into the components produced by the individual disciplines of the participants. To prevent this fragmentation, we summarize our preliminary results in this joint article, not to serve as a substitute but to complement subsequent detailed reports.

BEDROCK, TECTONICS, AND GEOMORPHOLOGY

The survey area lies in the southwest corner of the Peloponnesos on the western side of Messenia, north of the Bay of Navarino, between the modern towns of Yialova and Gargaliani, and from the coast inland to the Velika River valley (Fig. 2). This region possesses the most favorable climate of the Peloponnesos[12] and is blessed with an affluence of water that was noted by Strabo.[13] Three basic physiographic units can be distinguished in this area (Fig. 4).[14]

Mountains and Natural Resources

From the Mesozoic through the middle Tertiary, a marine basin extended over much of central and western Greece. The sediments that accumulated in this basin were

[6] Here we review natural scientific research conducted in the area. For a brief overview of previous archaeological work, see Davis *et al.* 1997.

[7] McDonald and Rapp 1972.

[8] Gell 1817; Dodwell 1819; Leake 1830; Curtius 1851; Philippson 1892.

[9] Loy 1970.

[10] Kraft, Rapp, and Aschenbrenner 1980.

[11] Carothers 1992, pp. 39–74.

[12] Philippson 1959, p. 409.

[13] Strabo 8.3.22.

[14] Loy 1970, p. 53 and fig. 3.

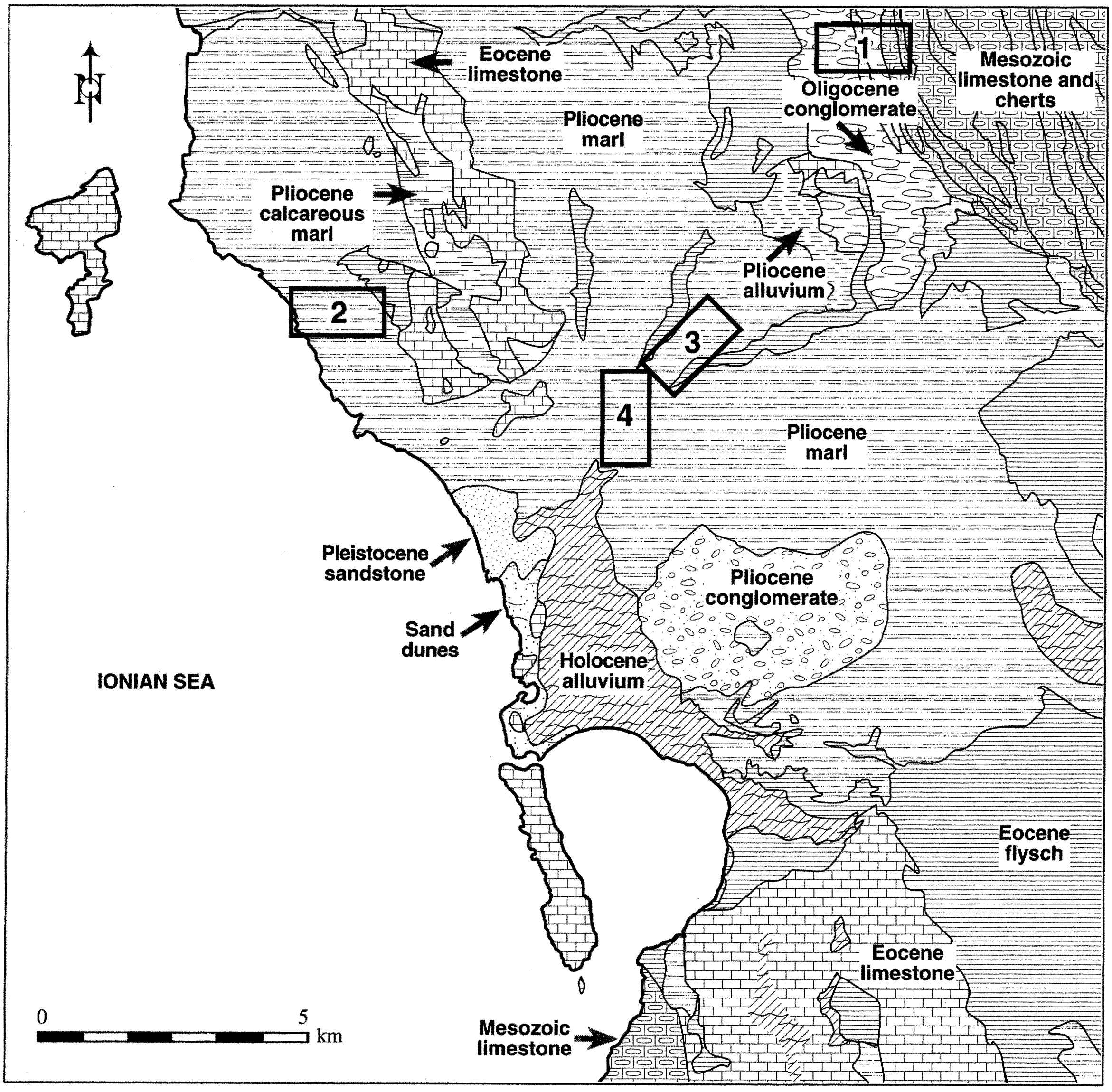

FIG. 4. Bedrock geology in the study area. The four rectangular boxes indicate the location of the subareas (2 × 1 km) used for soil studies: 1. Metaxada; 2. Dialiskari; 3. Upper Englianos; 4. Lower Englianos (Rosemary J. Robertson)

uplifted and folded in a pattern of north-northwest–south-southeast striking areas during the Alpine orogeny.[15] At that time the steep Aigaleon ridge in the northeast part of the survey area was formed (Fig. 2). It consists primarily of Mesozoic limestones and cherts. One of its main geological units is a thinly bedded black, red, and white chert of a Jurassic to Cenomanian radiolarite series containing limestone lenses and limestone

[15] Jacobshagen *et al.* 1976, p. 357.

interstratification. This chert is characterized by calcite-filled fissures perpendicular to bedding. The radiolarite series is in contact with a Jurassic limestone series consisting of partly microbreccious beds containing volcanic tuffs. During the lower and upper Cretaceous and the Eocene a thick sequence of the so-called Ionian flysch accumulated in front of the mountain ridge. It consists of deformed, thinly bedded alternating sandstones and sandy shales and is now revealed at the bottom of incised streams.

There are no known mineral resources in western Messenia, and even material suitable for building stones is rare. Apart from a few quarries for the production of road gravel, the only rock in the area that is commercially used is the Eocene limestone around Gargaliani. Today, it is mined for cement; in the past two hundred years it has been used for the production of lime in kilns. Many shallow quarries in the hills around Gargaliani resulted from this industry. Raw material suitable for the production of stone tools is only available in the form of pebbles of low-quality chert in streambeds.

Neogene and Quaternary Terraces

During the Neogene, topographically lower areas, including the west Messenian peninsula, were covered by the sea and accumulated marine deposits. Subsequently, uplift and subsidence during the Pliocene and Quaternary revitalized this area in the form of en-bloc movements combined with local fault tectonics.[16] During the Quaternary, uplift exposed the shallow Neogene marine deposits. Between Gargaliani and Hora they now form a degradational platform that is several kilometers wide. In the geological literature this unit is referred to as *kampos*, after the Greek word for plain. It consists of cohesive but soft, light yellow silt and marl and covers more than half the surface of the survey area. Near Hora the marl contains rhythmic sequences of lacustrine, brackish, and marine deposits reaching a thickness of several dozen meters. Its nannoplankton contents yield an early Pleistocene date.[17]

Western Messenia now forms a domelike structural uplift zone, bordered by a major east–west fault north of our study area.[18] Some outstanding examples of the effects of recent tectonic activity can be found along this coastal stretch of the Peloponnesos. Since the formation of the *kampos* at the beginning of the Pleistocene, its deposits have been uplifted approximately 400 meters, thereby producing pronounced marine terraces. The two youngest marine terraces, Eu- and Neo-Tyrrhenian in age, indicate continuous vertical movements throughout the late Pleistocene and Holocene.

Like most of the areas of Quaternary uplift, the Ionian coast has a steep continental slope practically without shelf. Offshore, two kilometers from the Sphaktiria ridge, the Ionian Sea drops to 200 meters. A trough up to 5,121 meters deep lies just seventy kilometers southwest of the Bay of Navarino. The uplift on the continent evidently represents a compensation for the concurrent sinking of these marine basins.[19] The combination of unconsolidated bedrock, recent high-magnitude tectonic uplift, and intensive agriculture

[16] Kelletat *et al.* 1976, p. 449.
[17] Fytrolakis 1971.
[18] Kelletat *et al.* 1976, p. 453.
[19] Fabricius *et al.* 1985, p. 300.

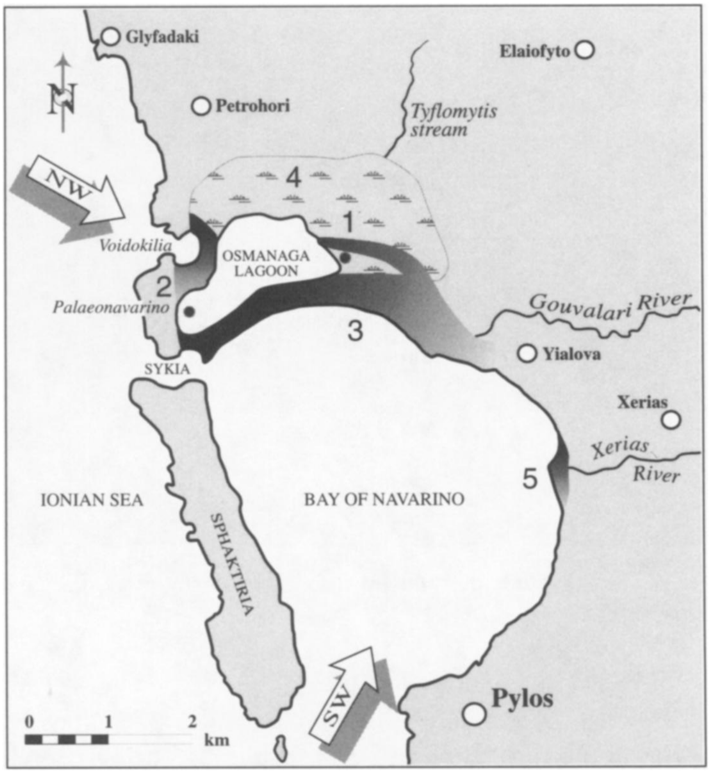

FIG. 5. Development stages of the beach barriers in the Bay of Navarino: 1. Incipient beach barrier north of Yialova; 2. Closure of channel at Voidokilia; 3. Formation of sand spit from Yialova to Palaeonavarino; 4. Formation of Osmanaga lagoon; 5. Incipient formation of a new barrier at the mouth of the Xerias River. The black dots on the west and east margins of Osmanaga lagoon indicate pollen core sites (Eberhard Zangger and Rosemary J. Robertson)

favors erosion and, of course, transport and redeposition of eroded material. Most of the eroded sediment was washed down into the streams and thence into the sea.

Alluvial Floodplains and Coastline Changes

The Bay of Navarino consists of a gulf up to sixty meters deep extending over ten kilometers from north to south and four kilometers from west to east, a shallow lagoon, and several sand spits. This embayment was invaded by the sea about 9,000 years ago. Because the bay is largely protected, its currents are controlled by strong winds from the north, west, and southwest, which enter the gulf through the channels at Sykia, Voidokilia, and Pylos (Fig. 5). The Sykia channel served as a major ship entrance to the gulf until the 16th century after Christ. Following the battle of Lepanto in 1571, however, the Ottoman admiral ordered that a line of ships be sunk across the channel to block it, because with

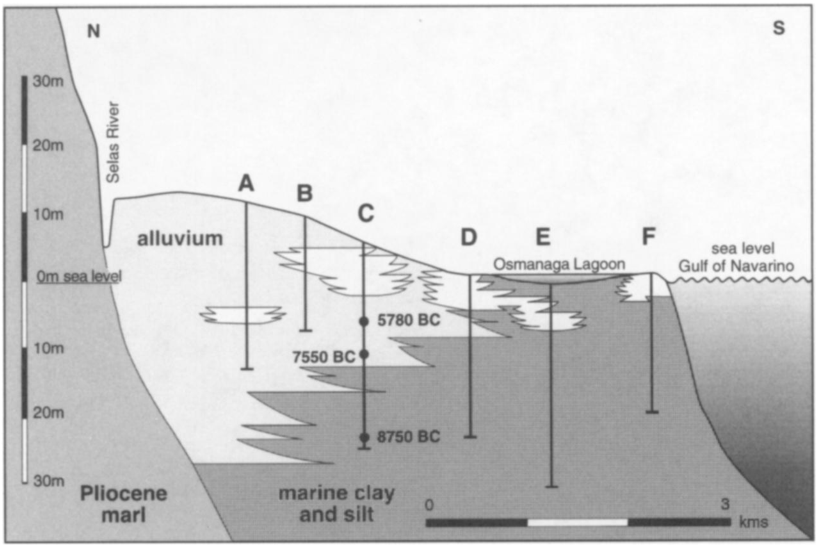

FIG. 6. Drill-hole cross section through the alluvial floodplain north of Osmanaga lagoon, after Kraft *et al.* 1980 (Rosemary J. Robertson)

only one entrance the gulf would be more defensible.[20] Today, the channel is still open, but the wrecks serve as a sediment trap and render it unnavigable.

The second gap in the coastal ridge, called Voidokilia, is now segregated from the Bay of Navarino by a large dune field. When the gap was still open the waves created by the north winds refracted at the sharp points of the peninsulas. The combination of narrow outflow, high waves with frequencies of several tens of meters, refraction of these waves, and ensuing loss of energy caused the deposition of sand around the channel at Voidokilia.[21] A semicircular dune field formed, eventually blocking the whole channel. The dune field is wider at its southern end because most of the sediment came from the southeast (Fig. 5).

As long as the gap at Voidokilia was open, only a rudimentary beach barrier existed in the gulf (Fig. 5:1).[22] Once the gap was closed (Fig. 5:2) the sediment in the northern half of the gulf was trapped. A slight counter-clockwise longshore drift generated by winds from the southwest caused the formation of a spit, which is now approximately three kilometers long and 400 meters wide (Fig. 5:3). It stretches in a broad arc projecting westward from the Yialova River to Voidokilia. A Hellenistic settlement and cemetery in its central portion yield a minimum date for its formation. A MASCA-corrected radiocarbon date of 2745 B.P. from the marine sediments under the barrier, obtained during an earlier study,

[20] Bory de Saint-Vincent 1834.
[21] Haralambous 1959, p. 93.
[22] Haralambous 1959, p. 95.

suggests that the spit formed after 800 B.C.[23] An extensive shallow back-barrier lagoon called Osmanaga (Fig. 5:4) covers the area north of the beach barrier. The shape of the lagoon varies with the amount of freshwater input and evaporation.[24]

At the northern end of the Bay of Navarino, between the villages of Romanou and Koryfasio, lies the most extensive alluvial floodplain in the study area. The Holocene depositional history of the floodplain north of the Bay of Navarino was investigated by Kraft and his coworkers, who drilled six holes to a maximum depth of 30 meters (Fig. 6:A–F). The stratigraphy showed interfingering marine silts and fluvial deposits at the beginning of the Holocene, when the Bay of Navarino extended about five kilometers farther north. Massive deposition during the early Holocene subsequently produced an alluvial floodplain with deposits up to 24 meters filling in the northern part of the gulf and forcing the coast to regress.[25]

SOILS

Soils form the basis for agriculture and provide a surface and materials for building construction. The preservation of archaeological sites and monuments is directly related to the condition of the soils surrounding them.[26] If the soils are well preserved, there is no reason to assume that archaeological sites have been destroyed by erosion. If, however, the soils themselves are eroded, settlements sitting on those soils will have been affected by erosion also. In other words, a lack of surface finds in erosional environments does not necessarily mean there were no settlements there in the past. Hence, the relationship between soils and landforms, on the one hand, and sites[27] and artifact distribution, on the other, must be known in order to understand the impact of landscape change on the accuracy of the archaeological surface record.

A number of studies in Greece have shown that soil morphology yields essential information for the reconstruction of archaeological landscapes.[28] In the southwestern Peloponnesos, in particular, the integration of soil studies and archaeological investigations is well established. Loy presented a reconstructed picture of the Late Bronze Age landscape of an area covering approximately 3,800 square kilometers.[29] He concluded that the alluvial slopes would have been the best-quality land available during the Bronze Age; that second-quality land was located on the Pliocene marine terraces;

[23] Kraft, Rapp, and Aschenbrenner 1980, p. 199: Nav No. 1; I-7306. Recalibration using CALIB 3.03 yielded an almost identical date of 2735 B.P.

[24] Kraft, Rapp, and Aschenbrenner 1980, p. 194.

[25] Kraft, Rapp, and Aschenbrenner 1980, p. 197.

[26] For general summaries of soil studies on archaeological sites in Greece and of the principal methods and terminologies employed, see Zangger 1992a and 1992b and references cited therein.

[27] In the present study use of the term "site", as it has traditionally been employed in archaeological survey, was replaced by the term POSI ("place of special interest") in the internal records of PRAP. See Davis *et al.* 1997 for a complete explanation.

[28] E.g., Pope and van Andel 1984; Timpson 1992; Zangger 1993.

[29] Loy 1970.

and that third-quality land consisted of soils found in the hill land, on the *kampos*, and on mountain shoulders of the region. He further suggested that human activity had not significantly altered the soil pattern of the southwestern Peloponnesos over the last three millennia.

In another study, four major groups of soils were identified: residual soils on consolidated rocks, soils on fine-grained Tertiary marine deposits, old alluvial soils, and recent alluvial soils, the latter usually occurring below twenty meters above sea level (20 masl).[30] Parts of the Nichoria ridge were found to have been disturbed by anthropogenic activity, primarily building construction. Post-Roman deposits in the floodplains turned out to be only 0.6–1.0 m thick, suggesting that climate and vegetation, two of the main soil-forming factors, had not changed significantly during the last few thousand years.[31]

During the early fieldwork for PRAP, *in situ* soils were identified on the Pleistocene alluvium north of Hora and on the Pleistocene sandstones west of Tragana. In both instances the soils consist of well-developed *terra rossa*-like red beds (Alfisols), with a reddish hue in the 5YR Munsell range, caused by enrichment with iron oxides. Very few examples of well-developed soils were observed on the extensive Pliocene marl. Owing to its silty texture, the bedrock itself, when broken up by plowing, provides a suitable substrate for agriculture. Its physical properties are almost ideal, and today the lack of fertility can be compensated for with fertilizers. Farmers in the survey area do not appear to be unduly concerned about soil erosion because most soils have already been denuded and the bedrock properties will not change appreciably if plowing and erosion continue.

To meet the goals of the project with respect to soil studies we chose four subareas within the PRAP survey region as targets for soil-landform maps. These subareas form rectangles, each two kilometers long and one kilometer wide. They were chosen to represent the major bedrock materials that occur in the survey region: Mesozoic limestone and flysch (Fig. 4:1), Pleistocene marine terraces (Fig. 4:2), and Pliocene marl (Fig. 4:3, 4). The surface covered by these subareas represents twenty-five percent of the total area that was intensively surveyed by the field-walking teams. Observations made during the subarea studies can thus be extrapolated to similar parts of the study region. In addition, site-specific investigations were carried out at individual locations throughout the project area to supplement the information gathered from the subareas.

Topographic maps of 1:10,000 scale were used as the basis for preparing the soil-landform maps. In each of the subareas, map units were established by determining the underlying bedrock and the major landscape forms, measuring the slope of the landscape, and examining the primary soil bodies. In inaccessible areas, aerial photo reconnaissance, landscape position, and parent material were used to infer the nature of the soils. The general results and conclusions of the soil studies presented below provide a basis for future detailed analysis of the interrelation and distribution of soil and artifacts to be conducted by interdisciplinary teams of PRAP.

[30] Yassoglou and Nobeli 1972, p. 171.

[31] Mineralogical characteristics of some late Quaternary alluvial soils from northeast Crete also implied little climate change in the last few thousand years (Timpson *et al.* 1996).

METAXADA/KALOPSANA

Much of the western side of the Metaxada valley consists of conglomeratic limestone with dark red (2.5YR 3/6), clay-rich soils that are interspersed with gravel, cobbles, and boulders (Fig. 7; Table 1, p. 627). Deep, loamy-textured soils with excellent water-holding capacities occur in gently sloping cove positions where flysch bedrock crops out in isolated patches. Only a few isolated nose slopes, however, are flat and large enough to be used for crop production. At the highest elevations soils vary from shallow Entisols in steeply sloping positions to moderately deep Alfisols on gentler slopes and in cove positions (Table 2, p. 628). The chemical properties of these soils are quite suitable for agriculture, but their landscape position, rock content, and clayey textures make them droughty and difficult to farm. Today, these slopes support lush macchia dominated by prickly oak, holm oak, evergreen maple, ash, and wild olive. Isolated remnants of abandoned agricultural terraces indicate that even the steep slopes (50–85%) were used for agriculture at some time in the past.

Soils on the eastern side of the valley developed from crystalline limestone and flysch deposits. Flysch-derived soils are loamy in texture, contain 30–40% gravel, and occur on slopes of 20–50%. Their agricultural potential is moderate to good, depending on available water. Terracing increases the thickness of these soils and their water-holding capacity and is therefore a suitable and widely used means to improve soil productivity. The flat, blocky nature of the flysch favors the construction and maintenance of terrace walls. The slopes above *ca.* 520 m are steep and dominated by bedrock outcrops, primarily limestone (Fig. 7: upper backslopes). The agricultural potential of these higher slopes is low, although pockets of suitable soils do occur. Terraces on higher portions of the landscape (Fig. 7: upper backslopes) are now abandoned because their maintenance is no longer profitable. Only on the lower portions of the hillside are agricultural terraces still actively farmed (Fig. 7: lower footslopes). Owing to the terraces, soil erosion on the east side of the valley is generally minimal.

The valley bottom is covered by Holocene alluvial deposits with interspersed bedrock knolls (e.g., Fig. 7: POSI A3, Metaxada *Kalopsana [3]*). The floodplain is well suited for agriculture, and soil erosion is only slight to moderate. The modern stream is incised up to two meters into the floodplain, which is covered by silty-textured Inceptisols and Entisols.

DIALISKARI

The second subarea for soil studies is located just south of the primary archaeological site of Dialiskari (POSI G1) on an east–west transect from the coast toward the low Eocene limestone hills south of Gargaliani (Figs. 4, 8). This subarea includes four distinct marine terraces with deep, clayey-textured soils (Table 3, p. 628), used at present for large, irrigated olive groves and interspersed vegetable gardens. Subdued topographic relief and a lack of major ephemeral streams have left these terrace surfaces between Tragana and Marathoupolis largely intact, perhaps for as long as 100,000 years. As a result, well-preserved soils on marl still exist along the coast and artifact distributions are likely to be relatively undisturbed.

Across all four terraces surface-soil properties and agricultural potential are approximately equal (Table 4, p. 629). On the younger terraces, closer to the coast, the soils

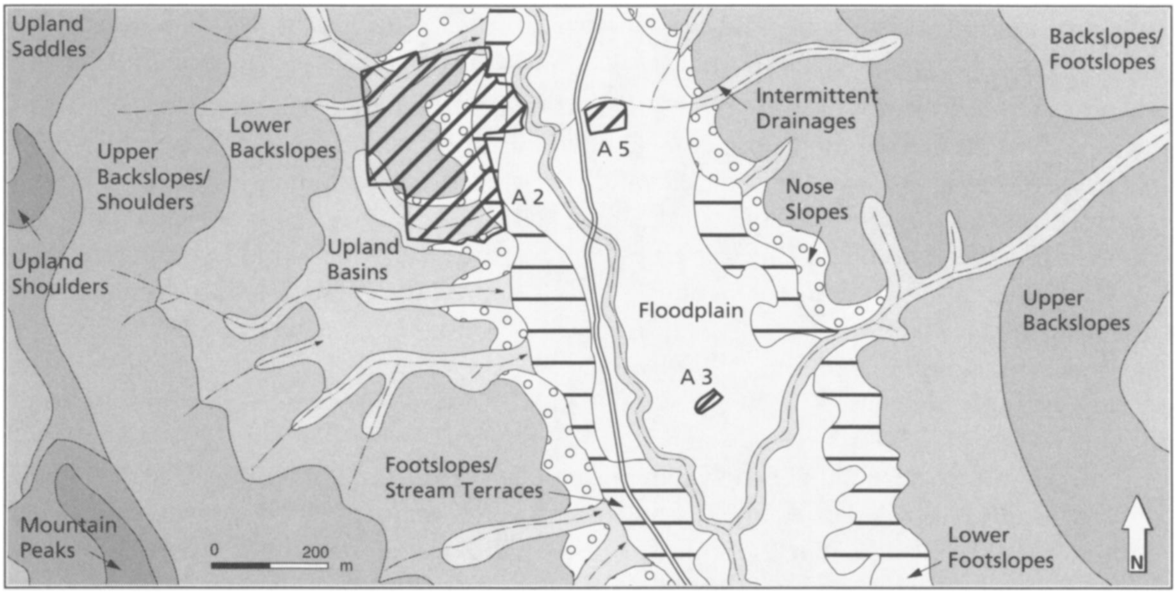

FIG. 7. Soil and landform map for the Metaxada subarea. POSIs A2, A3, and A5: Metaxada *Kalopsana (1)*, *(3)*, and *(2)* (Michael E. Timpson and Eberhard Zangger)

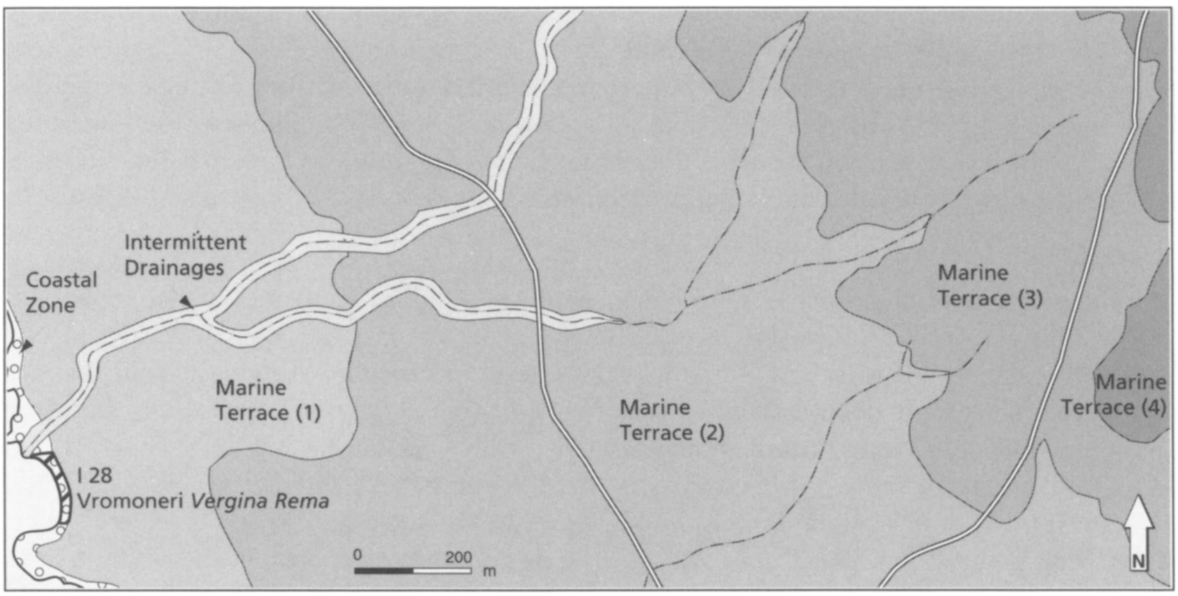

FIG. 8. Soil and landform map for the Dialiskari subarea. POSI I28 (Vromoneri *Vergina Rema*) is located near the coast (Michael E. Timpson and Eberhard Zangger)

may not be as acidic as those on the older terraces; on the other hand, sea spray carried inland during winter storms may cause some undesirable additions of salts.[32] In general, soils throughout this subarea are suited for agriculture. Without irrigation, however, they are best used for early-season crops because most of their moisture is strongly bound to the clay particles and therefore not available to plants. Hence, these soils do not readily support shallow-rooted agricultural crops through the basically rain-free Mediterranean summer. Erosion is pronounced along the steep side slopes of streambeds and in areas with little vegetation. Some soils near the coast are also severely eroded and consist of remnant B horizons sitting directly on bedrock. Farther inland, however, soil erosion is generally slight to moderate.

At POSI I28 (Vromoneri *Vergina Rema*), located along a low cliff near the present coast, PRAP teams recovered a number of Palaeolithic stone tools (Figs. 3, 8).[33] Both this site and nearby I20 (Vromoneri *Nozaina*; Fig. 3), just south of the mapped area, rest on Pleistocene, sandy, fossiliferous limestones. The soil profile at Vromoneri *Vergina Rema* is carbonate-free and contains a well-developed argillic horizon[34] that extends to bedrock (Table 5, p. 629).[35] Carbonate removal and clay translocation indicate substantial age for the soil, but the sharp lower boundary of the soil hints at redeposition. A better-preserved profile also containing a stone-tool assemblage and probably representing the landform on which these soils originally formed was identified farther south along the coast at Romanou *Rikia* (POSI I18; Fig. 3). The soil properties at Romanou *Rikia* (Table 6, p. 630) are very similar to those at Vromoneri *Vergina Rema*.

Upper Englianos

The Palace of Nestor and its surroundings (Fig. 9: POSI B7) are located on a relatively narrow interfluve that forms a steep ridge between the Selas River to the west and streams emanating from the Metaxada valley to the east. These perennial rivers possess the largest drainage basin in western Messenia, including the entire ridge of Mount Aigaleon (Figs. 2, 3). Englianos is located on a wide expanse of Pliocene marl deposits that are highly susceptible to erosion (Table 7, p. 630). Headwardly eroding channels dissect the ridge from both sides (Pl. 109:a), resulting in steep side slopes covered by weakly developed soils. In addition, multiple landslide scars on Englianos and other nearby ridges are indicative of intermittent, large-scale landscape instability.

Today the fields on Englianos are used for olive groves, and in many areas the fragility of the landscape has been increased by modern agricultural practices, including plowing, tractor-mounted rotary cultivation, and bulldozing, which is used for terrace construction.

32 Such salt additions have been noted in soils within one kilometer of the northeast coast of Crete (Timpson 1992) and along the coast of Israel (Yaalon *et al.* 1966).

33 For an archaeological description of the finds see Davis *et al.* 1997.

34 Argillic horizon = zone of pedogenic clay accumulation.

35 The profile was situated on top of the coastal cliffs at the southernmost limit of POSI I28. The parent material is Pleistocene bioclastic sandstone. Terrestrial snail shells occur in the rock. Clay films in the R/CBk horizon were located on the weathered faces of joints in the bedrock. Clay films in the argillic horizons were well developed but discontinuous in nature, perhaps indicating incipient breakdown. Secondary carbonates formed vein fills in the weathered bedrock.

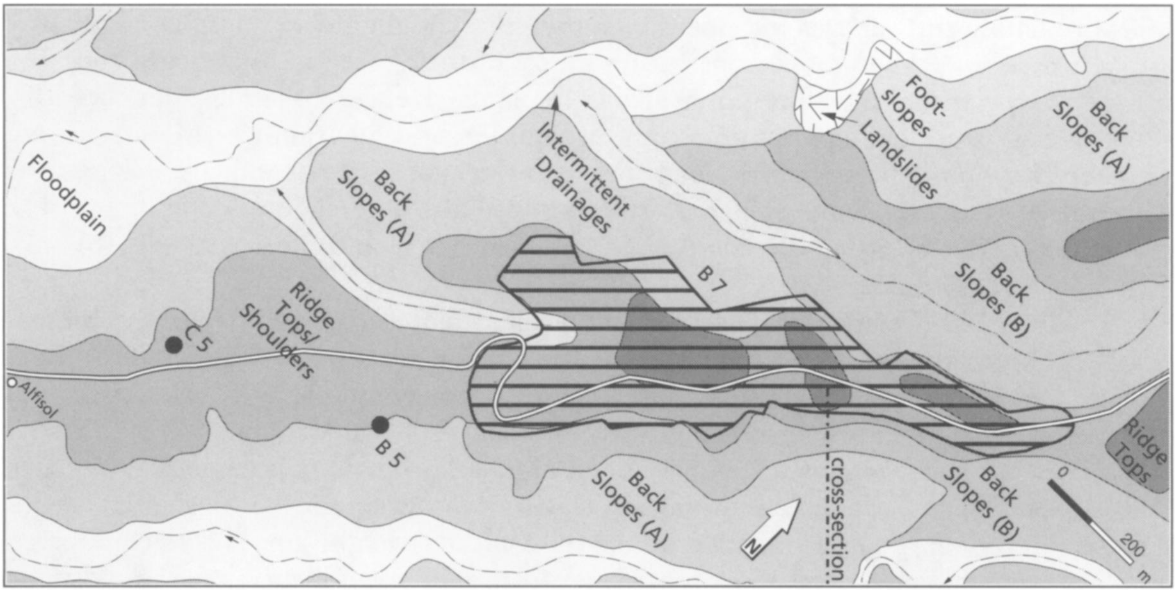

FIG. 9. Soil and landform map for the Upper Englianos subarea. POSI B5: Palace of Nestor chamber tombs; B7: Palace of Nestor Lower Town; C5: Kato Englianos tholos tomb. The dashed line labeled "cross section" marks the location of the profile shown in Figure 10 (Michael E. Timpson and Eberhard Zangger)

Consequently, the majority of the soils are severely disturbed, often to the point that bedrock crops out at the surface in many areas. Very few locations in the Upper Englianos region still contain intact soils. Only one small area of uneroded Alfisols (*ca.* 30 m^2) still exists on the ridge crest near the southwest margin of the subarea (Fig. 9: Alfisol). The proximity of an old field house may have prevented excessive deep plowing of this soil, thereby preserving the surface. Dramatic differences exist between the soil morphology of intact Alfisols developed from the marl and the eroded soils identified in many of the mapping units in both Englianos areas (Table 8, p. 631).

Soils in the olive groves surrounding the Kato Englianos tholos tomb (Fig. 9: POSI C5) consist mainly of thin A horizons that result from plowing and rotary cultivation of the bedrock. Isolated remnants of less eroded soils with minimally developed, cambic B horizons occur in this area. More substantially eroded soils are found in the area of the Palace of Nestor chamber tombs, POSI B5 (Fig. 9), where slopes range from 10% to 55%. As a result of both natural and accelerated erosion these slopes bear immature soils exhibiting A/C horizon sequences.

Prior to the impact of accelerated erosion, the agricultural potential of the soils on the upper slopes of Englianos would have been quite good. Thick soils with substantial water-holding capacity and reasonable fertility would have been the norm (e.g., the uneroded soil in Table 8). Present conditions (shallow soils and pulverized bedrock) result in extremely low water-holding capacities and poor soil fertility. Hence, agricultural exploitation today depends on irrigation and fertilizers.

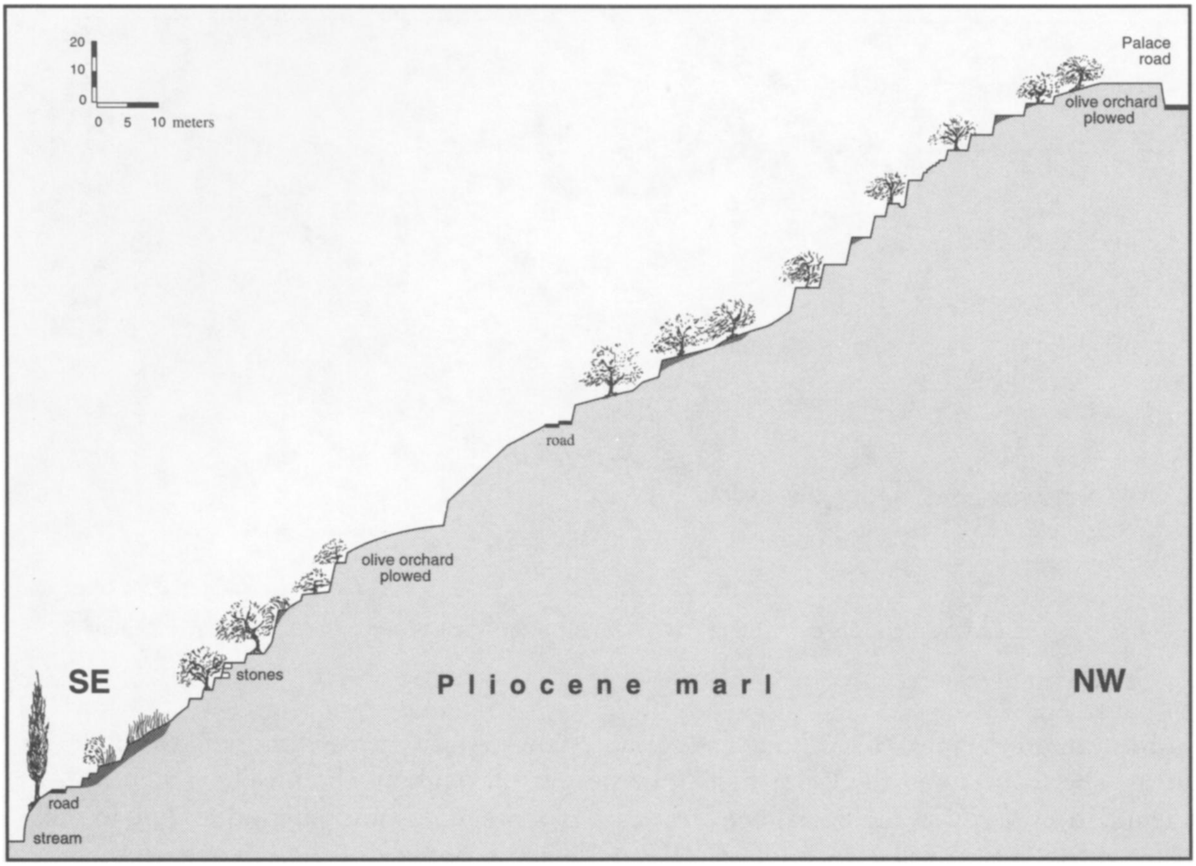

FIG. 10. Cross section illustrating the topography of the Englianos ridge east of the palace (Eberhard Zangger, Michael E. Timpson, and Rosemary J. Robertson)

Trial auger cores of the steeply sloping soils along the southeast side of the upper Englianos ridge showed that the marl bedrock lies only decimeters below the surface on the ridge top and, in fact, crops out in much of the area farther downslope. A topographic cross section shows the typical microrelief of the slopes on the Englianos ridge (Figs. 9, 10) and illustrates the degree of disturbance caused by the bulldozing that dissects much of the slope into terraces 4 m wide and 4–5 m high. The topographic section also shows that artifacts found on this slope (Fig. 9: back slopes A) were most probably not *in situ*, since the marl bedrock crops out along almost the entire profile. Only a small area near the middle of this transect contained remnants of a soil. Although artifacts from this particular area may have been *in situ*, it is more likely that they represent displaced material from higher areas.

A vertical profile of debris flow and slump deposits containing numerous (>100) Late Bronze Age pottery fragments lies *ca.* 200 m north of the topographic cross section (Fig. 11). The exposure is in a particularly steep part of the ridge, where an unpaved field road, running approximately perpendicular to the slope, crosscuts the deposit. The entire profile is about 30 m long and 3–4 m high. Approximately two-thirds of the exposure

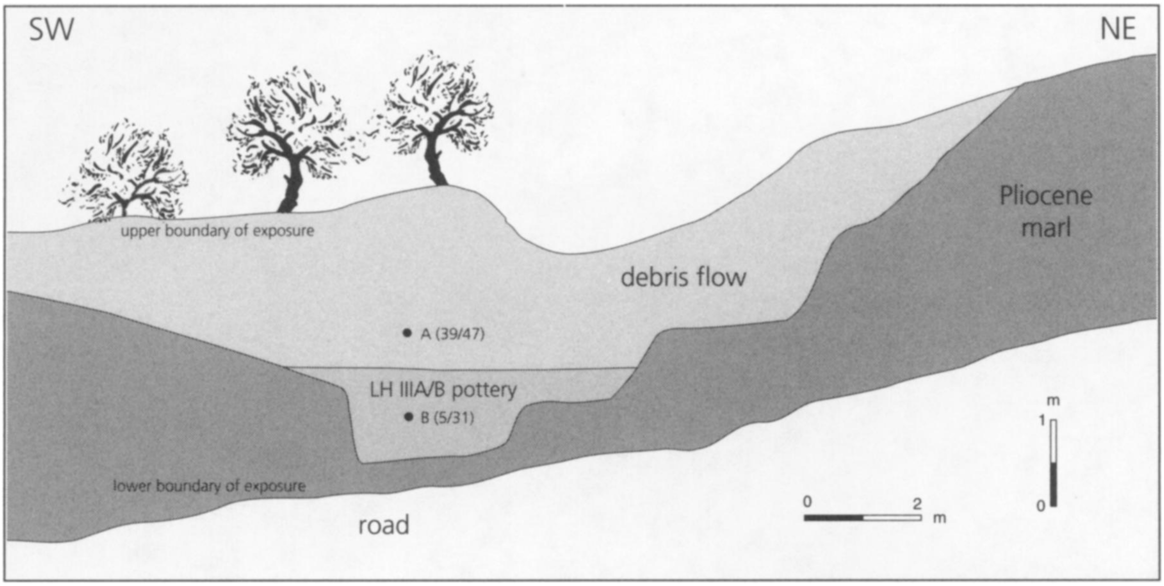

FIG. 11. Debris flow deposits containing Mycenaean pottery east of the palace (Eberhard Zangger)

is illustrated in Figure 11. Although the gravity-flow deposits are unstratified, the majority of the sherds occur in the lower half. The pottery throughout the profile is identical, as identified by Cynthia Shelmerdine: a mixture of storage jars and painted and plain table ware belonging to LH IIIA and LH IIIB, with some pottery of the latter date showing signs of burning. This is the only instance where we were still able to find a large quantity of Late Bronze Age pottery that had moved from its original site of deposition.

LOWER ENGLIANOS

The fourth and final subarea explored is also located on Pliocene and Pleistocene marl, but this time a valley was chosen to contrast with the ridge top of Upper Englianos (Figs. 4, 12). The slopes on both sides of the valley consist of eroded marl covered by olive groves (Table 9, p. 631) and are thus identical to the surface on the adjacent area of Upper Englianos. Some intact soils on the marl are preserved in depositional areas (Fig. 12: colluvial footslopes). Headward erosion along portions of the lower Englianos ridge has dissected the side slopes and produced steep areas that are covered with weakly developed soils. Similar processes dominate the higher portions of the Tragana ridge just west of the mapped subarea. The present agricultural potential of the lower marl slopes is the same as that in the Upper Englianos area.

The floodplain, now used for irrigated vegetable gardens, vines, and olive groves, represents a depositional environment containing in its center at least four meters of alluvium with little stratification. Auger cores into the floodplain deposits terminate on gravel layers at the present level of the river bottom, approximately 4–5 m below the

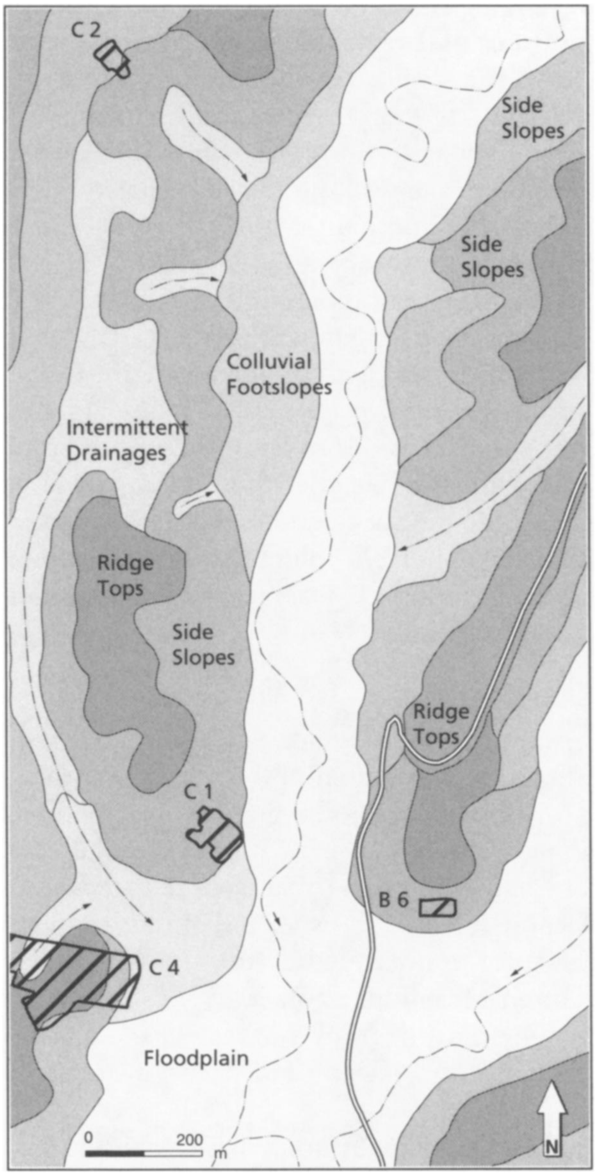

FIG. 12. Soil and landform map for the Lower Englianos subarea. POSI B6: Pisaski; C1: Alafinorema; C2: Aladina; C4: Hasanaga (Michael E. Timpson and Eberhard Zangger)

surface. Unlike the valley slopes, agricultural potential is still high in the floodplain, and erosion is minimal.

In valley areas in general, two types of depositional environment occur: fluvial sediments accumulate in the floodplain itself, while sediment gravity flows pile up in footslope positions at the bases of the valley sides. Since the floodplain deposits are unstratified, deposition appears to have been sufficiently continuous to prevent intervening soil formation. In this subarea artifacts were recorded by survey teams as a light background scatter with well-defined concentrations representing settlement sites (Fig. 12: POSIs B6, C1, C2, C4) ranging from the Classical to the Early Modern period. In order to determine whether portions of the sites and of the former surface are buried, five auger cores were taken at POSI C1, a small site with both prehistoric and historic components, located between the modern villages of Tragana and Koryfasio. The cores were aligned at ten-meter intervals, perpendicular to the slope. One of these cores, located two meters upslope of a one-meter-high terrace wall, produced a buried unit at 0.7–1.3 m depth that was much disturbed, rich in organic matter and charcoal, and contained some minute pottery fragments. This obvious anthropogenic impact on the soil could not be traced in adjacent cores. The paleosurface was apparently buried during the terrace construction and only preserved in an area stretching downslope less than twenty meters.

The dominance of historic sites in this subarea might well be due to the fact that prehistoric settlements have endured even more erosion, to the extent that they have vanished. Thus, even low sherd densities might represent the remains of previously high concentrations of artifacts. One example is POSI C3 (Tragana *Voroulia*), where excavations of a small Early Mycenaean site produced a large pottery deposit.[36] It is located just west of the mapped subarea on the upper portion of the Tragana ridge. Owing to soil erosion that has occurred during the past thirty to forty years, the site is now nearly unrecognizable without prior knowledge of its location.

Extrapolation of Subarea Studies

Extrapolating the results of the subarea studies to the remainder of the project area with respect to the preservational potential of these surfaces leads to the following results (Table 10, p. 632): (a) The Mount Aigaleon region, represented by the Metaxada subarea, consists of steeply sloping terrain stabilized by substantial forest or well-maintained agricultural terraces. The habitation pattern and off-site artifact distribution are currently not disturbed much because erosion is usually slight to moderate. (b) The emergent marine terraces near the coast, represented by the Dialiskari subarea, have the potential of preserving Paleolithic and Mesolithic artifacts *in situ*, although redeposition may have appeared there, too. (c) The marl bedrock surfaces in the center of the study area have changed significantly as a result of natural landscape instability and anthropogenically accelerated erosion.

In conclusion, the soil and landform studies in the subareas have shown that enhanced erosion and redeposition are likely to have removed a substantial portion of the evidence of early habitation where marl forms the bedrock, not only on the slopes but also in the floodplain, since standing monuments and high concentrations of pottery fragments may now be concealed by relatively recent deposits.

SOIL EROSION

A glance at the central survey area from an elevated ridge such as Englianos reveals that erosion and soil erosion are actively occurring over much of the area (Pl. 109:a). Almost

[36] McDonald and Hope Simpson 1961, pp. 239–240 (site 45); McDonald and Rapp 1972, p. 266 (site 12).

everywhere, exposed white bedrock shines through the olive orchards. A closer look confirms that *in situ* soil on marl is preserved virtually nowhere on the uplifted *kampos*.

According to several previous investigations in southern Greece, the erosion of marl surfaces appears to be responsible for the disappearance of archaeological sites. In the coastal plain of Elis, Constantine Raphael carried out a geomorphological/archaeological survey and found unusually high rates of erosion and redeposition since Classical and Roman times.[37] In Messenia, Dieter Kelletat and his coworkers noticed that the present extension of Neogene sediments is determined by erosion,[38] while Charles Higgins dedicated an entire article to the "Possible Disappearance of Mycenaean Coastal Settlements of the Messenian Peninsula."[39]

As early as the pilot season, the working hypothesis was formulated that some settlement sites, sitting on the marl and siltstone surfaces, may have been removed through post–Bronze Age soil erosion, while burial sites, placed under the surface, merely became truncated by erosion. This notion obtained further support from Carl Blegen's observations at Ano Englianos. During excavations outside the palace, he and his coworkers noticed that "erosion and the looting of stone had taken a generous toll . . . and too little was left to determine exactly just when these structures [south of the palace] were built and what purpose they served."[40]

Once the soil is gone, it is difficult to measure quantitatively how much material has been eroded. An examination of exposed bedrock makes it virtually impossible to tell whether only the soil mantle was removed or whether several meters of surface material have disappeared too. On the marl surfaces, however, a variety of observations offer an opportunity to measure the amount of post–Bronze Age erosion quantitatively. Examination of the olive groves provides one estimate. The bases of trees, where the roots start, are easily identified. They mark the land surface when the trees were seedlings, because the root system stabilizes the soil in the immediate area of the tree. In some parts of the Englianos ridge, with slopes of 18–20%, as much as one meter of soil has been removed from around the bases of olive trees estimated to be twenty-five to fifty years old (Pl. 109:b). J. Hutchinson made similar observations in the area of Agios Georgios in Epirus.[41] He noted erosion of 0.6–1.0 m in areas under cultivation. In natural forest areas, erosion was only 25–30% of these values. It is important to note that Hutchinsón's observations were made before the widespread use of deep plowing and rotary cultivation.

South of the palace, at Kato Englianos (Fig. 13), and east of the palace, at Zoodohos Piyi (POSI B4; Fig. 14), we examined the remains of chamber tombs cut into the marl bedrock. In both instances only the rear wall and less than one meter of the chambers themselves were left; in all cases stomion and dromos had been completely eroded. Such tombs normally have a chamber 2.5–4.5 m deep and an additional stomion and dromos 4–9 m long. Hence, a complete chamber tomb would extend into the marl 6.5 to 13.5 m, which

37 Raphael 1973, 1978.
38 Kelletat *et al.* 1976, p. 448.
39 Higgins 1966.
40 Blegen *et al.* 1973, p. 50.
41 Hutchinson 1969.

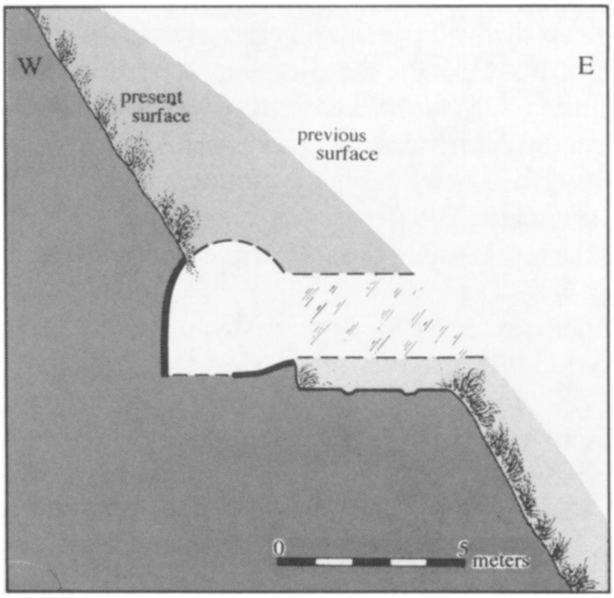

FIG. 13. Eroded Late Bronze Age chamber tomb (POSI B5) on a marl slope at Kato Englianos (Rosemary J. Robertson)

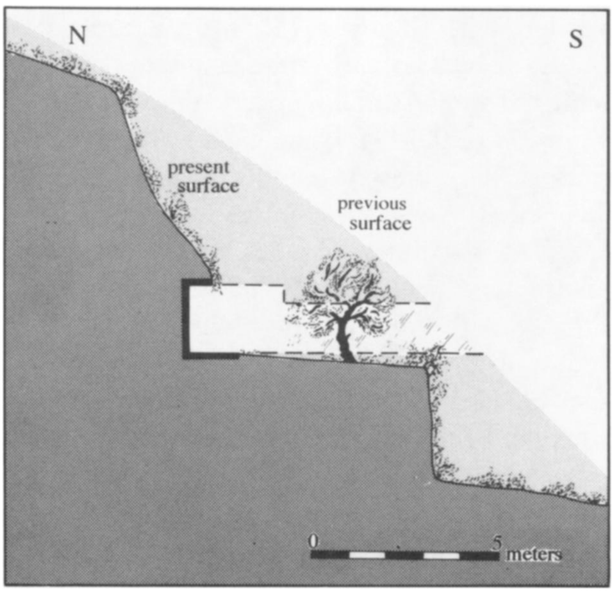

FIG. 14. Eroded Late Bronze Age chamber tomb (POSI B4) on a marl slope at Zoodohos Piyi (Rosemary J. Robertson)

means that a few vertical meters of surface material have been removed by post–Bronze Age erosion and agricultural activities.

Several archaeological sites in the survey area were found to be associated with conspicuous, well-defined knolls usually three to five meters high and several meters wide (Figs. 15–17). The combination of well-defined topographic elevation and archaeological site has frequently been interpreted as a tumulus or covering for a tholos tomb.[42] Our reconnaissance, however, indicated that these knolls often consist of undisturbed marl bedrock. Their surfaces are level and overgrown by grass and bushes, while their walls are usually vertical. Some of the mounds bear trigonometric stations (Fig. 15), some ancient graves (Fig. 7: POSI A3), some both (Figs. 16, 17). Natural erosion can be excluded as the cause for the drop in the surface, first, because the position on a flat ridge top would argue against above-average erosion and, second, slope wash and soil creep would have removed the entire surface and not left such peculiar formations. Apparently these mounds have been spared from plowing and bulldozing because they contain trigonometric stations or burial sites. All that remains of the former surface are these "leftovers". The surfaces surrounding them have been lowered considerably by extensive, sometimes excessive, plowing. The small size of the brush on the "leftovers" and of the olive trees surrounding them argues for a surface destruction within the last few decades.

A typical example of a "leftover", crowned by a trigonometric station and sitting in the middle of an olive grove, was found at Koukouyera (Fig. 15). The pillar was erected in 1953 and evidently predates the erosion. The olive trees on the surrounding lowered surface, however, are about twenty-five to thirty years old. The entire episode of agricultural destruction, which removed about two vertical meters, therefore occurred rapidly and was most likely generated intentionally.

In order to document these observations, a number of "leftovers" were drawn and measured in 1993. Among them was the mound at Pyrgaki *Tsouka* (POSI I19; Fig. 16), which bears a trigonometric station dating from 1965. Shortly after it was drawn, it was further reduced in size (Fig. 17).

Much of the destruction that led to the formation of "leftovers" seems to have occurred 30–40 years ago, after the trigonometric stations were installed but before the olive trees were planted on the eroded surfaces. After their first encounter with archaeologists, some landowners, possibly fearing future restrictions and perhaps expropriation, appear to have intentionally damaged sites on their fields by extensively plowing the soft marl. Such deliberate destruction by landowners, who balance the rise in land value with the increased cost caused by excavation on private property, has been observed elsewhere in Greece.[43]

If post–Bronze Age soil erosion occurred throughout the survey area, the tholos tombs on ridges may well have suffered from it too. Today, 30–50% of most tholos tombs in the area remain buried, but when constructed, 60–70% may have lain below the surface (Figs. 18, 19). How they appear today seems to depend on the amount of erosion and

[42] E.g., McDonald and Hope Simpson 1961, p. 237. See the appendix to Davis *et al.* 1997 (pp. 485–488) for a discussion of tumuli and tholoi.

[43] Runnels 1981, p. 92.

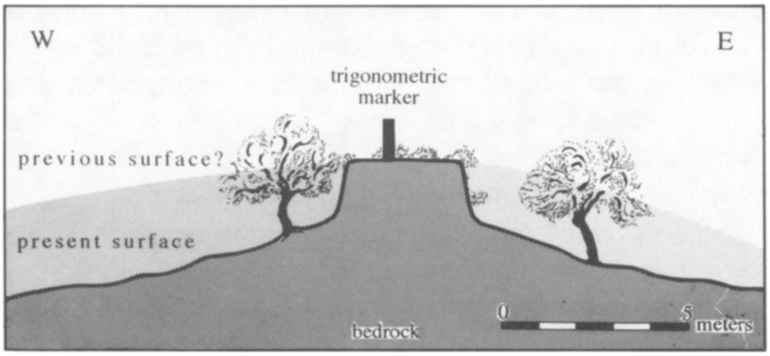

FIG. 15. "Leftover" marl bedrock around a trigonometric marker at Koukouyera (Rosemary J. Robertson)

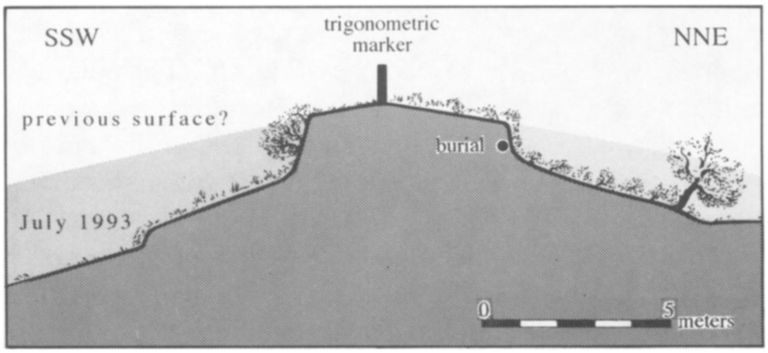

FIG. 16. "Leftover" marl bedrock with trigonometric marker and burial site at Pyrgaki *Tsouka* (POSI I19) in July 1993 (Rosemary J. Robertson)

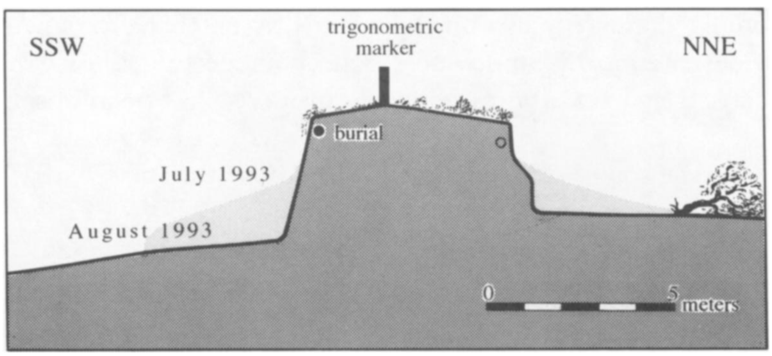

FIG. 17. The same "leftover" bedrock at Pyrgaki *Tsouka*, considerably reduced, in August 1993 (Rosemary J. Robertson)

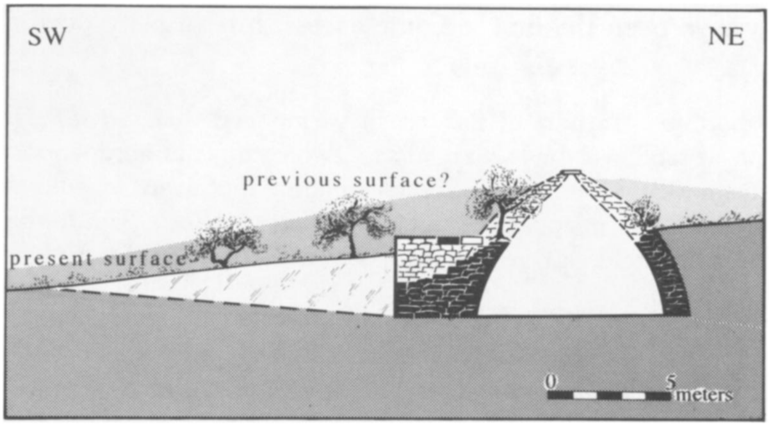

FIG. 18. The tholos tomb at Kato Englianos (POSI C5) and the possible level of the surface at the time of construction (Rosemary J. Robertson)

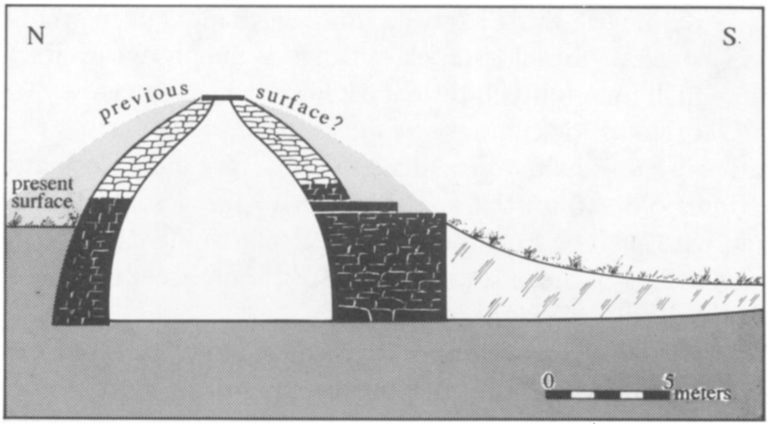

FIG. 19. The tholos tomb at the palace and the possible level of the surface at the time of construction (Rosemary J. Robertson)

deposition that occurred around them. Only one tholos tomb, the one at Koryfasio *Haratsari*,[44] was placed in a depositional environment, in this case the alluvial fan of Typhlomytis Creek. Not surprisingly, the six-meter-high tomb is now completely covered by gravelly stream deposits. Most likely its complete burial is simply due to geological processes.[45] In the vicinity of the tholos tomb there are olive trees with stem diameters characteristic of ages between 500 and 1,000 years. If this tomb was buried during a phase of landscape instability, this phase must have occurred some time ago.

[44] Also known as the "Osmanaga tholos", or POSI I2.
[45] John C. Kraft, personal communication 1992.

Another interesting phenomenon related to the preservation of archaeological monuments was the discovery of systematic rock cuttings in consolidated bedrock. Again, Blegen seems to have been the first to come across this curiosity during his work at the palace:[46]

> On the very bottom of a part of the trench we noticed that the *stereo* [bedrock] had obviously been worked over by human effort. Two cuttings in hardpan sloped one from east and one from west, meeting in an area descending southward in a direction aiming at the Englianos hill. Their purpose was not clear to us; perhaps a path to the center of the hollow, whatever that held, or possibly the bedding for the walls of some kind of structure.

During the fieldwork for PRAP, rock cuttings of this kind were found at Hasanaga and Gargaliani *Ordines* (Pl. 109:c, d). At Hasanaga a ditch 40 cm wide and 15 cm deep was cut into the bedrock to form a rectangle 10 m long and 4 m wide. At Ordines similar ditches exist, again 40 cm wide and about 20 cm deep. In addition, there are numerous artificial rock cuttings all over Ordines. Unnaturally level rock faces, most often vertical, appear to describe the shape of rooms. Apparently the rock was quarried for building stones, and in the process the quarry itself was shaped so that it could be used for foundations or walls. A number of clues provide a rough date for these structures, especially since we are able to compare them with Early Modern quarries that occur in great numbers around Gargaliani. The surface of the older rock cuttings is deeply weathered and completely covered by lichen, which means much time must have passed since they were first exposed. The quarries at Gargaliani look almost fresh, although they are as many as 200 years old. Hence, weathering and lichen growths by themselves indicate that the rock cuttings must be several times older than the Early Modern quarries. Often, Late Bronze Age sites are associated with such bedrock outcrops and quarries (e.g., at Megas Kambos), and the general craftsmanship of these features is indeed reminiscent of the Late Bronze Age quarrying below the citadel at Tiryns.[47]

Modern rock cuttings were also found at Ordines, a few hundred meters south of the site. In this case, the cuttings simply belong to currant-drying floors. They are easily distinguished from the cuttings at Hasanaga, for instance, because the ditches are much shallower (about 5 cm deep), their faces are not vertical but at 30- to 60-degree angles, and their width is 80 cm rather than 40 cm. In addition, ditches in currant-drying areas are spaced at five-meter intervals, whereas some of the older rock cuttings at Ordines have parallel ditches only one meter apart. Finally, the modern ditches are neither weathered nor overgrown.

Considering the places where we found ancient rock cuttings at Pylos, Blegen's suggestion that these ditches might represent the beddings for walls appears quite conceivable. While Ordines, according to the surface scatter, must have been an extensive Mycenaean settlement, Hasanaga had no prehistoric pottery. The existence of nothing but rock cuttings at a site would imply that all other evidence for human habitation or other use has either disappeared or was never present.

[46] Blegen *et al.* 1973, p. 65.
[47] Zangger 1992c, pp. 116–117.

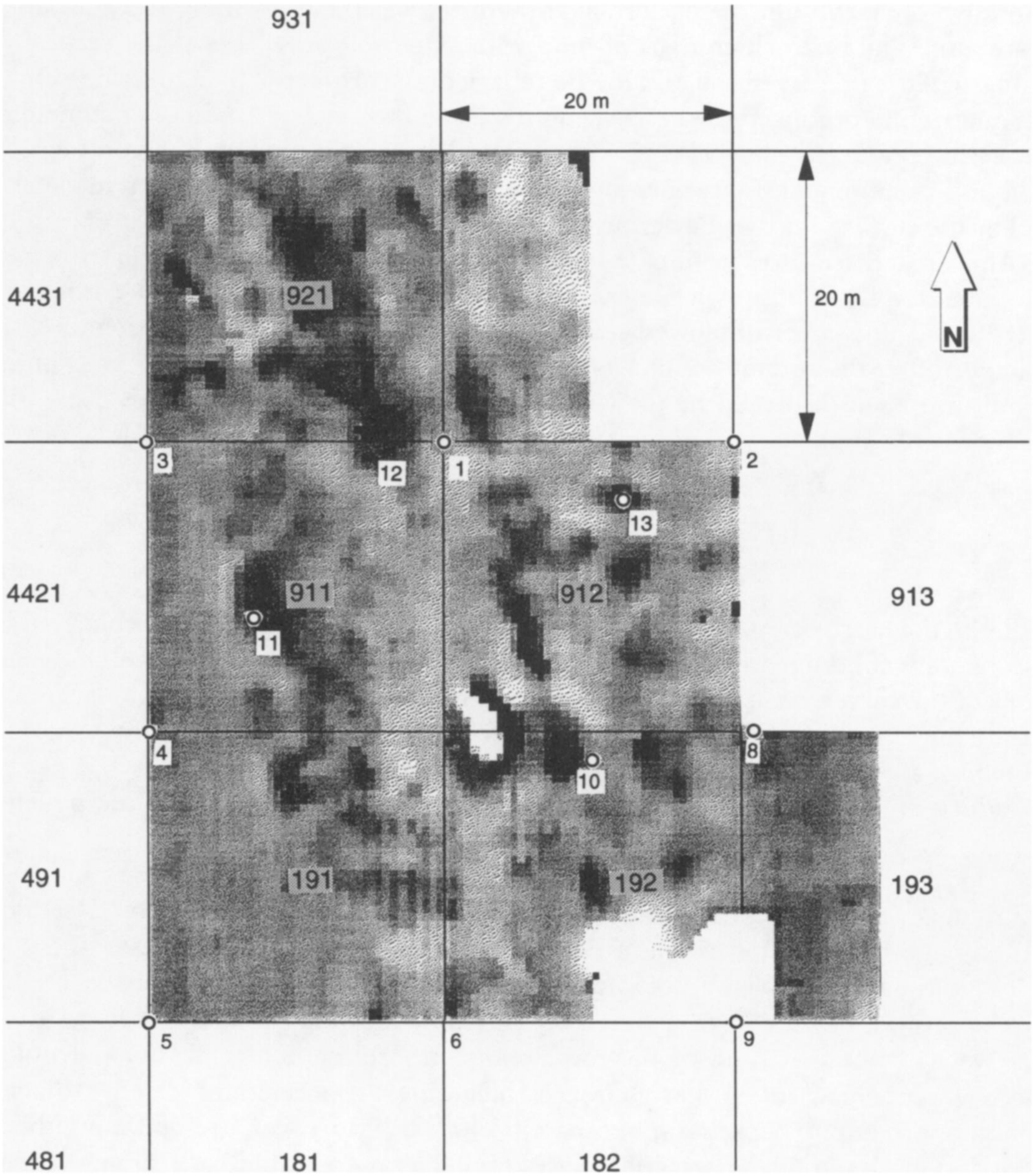

FIG. 20. Auger-core locations at Beylerbey (POSI I1) placed on a magnetometry plot (Hans Günther Jansen and Eberhard Zangger)

Those settlement sites that still do exist in the survey area obviously deserve closer attention. One of the most extensive sites of this kind is Beylerbey, where much painted Mycenaean fine ware, and even a sealstone, was found.[48] In 1960, architectural structures

[48] See Davis *et al.* 1997.

and probably graves were still visible.[49] In 1992 the site was gridded and collected and, in 1993, examined by the physical-science team. It sits on a gentle west slope and is covered by an olive orchard. On the eastern side there is a steep cliff forming the cut bank of a dry stream. The bedrock consists of marl with some soil preserved at the surface. The boundary of the preserved soil and the boundary of the artifact scatter coincide. On those grid squares that produced the highest count of Late Bronze Age artifacts a magnetometer survey was conducted in 1993 (Fig. 20). No evidence for buried architectural structures was found. Subsequently, twenty-eight auger cores were taken in order to determine whether the surface finds at Beylerbey might represent the uppermost layer of a stratified site. Almost all these cores terminated in marl bedrock only 20 to 50 cm below the surface. Therefore, despite its impressive lateral extent, the archaeological site of Beylerbey merely represents a thin veneer of plowed soil interspersed with artifacts and resting on a sharp, erosional, often discordant contact boundary with the underlying bedrock. The entire soil unit has been disturbed by plowing, possibly many hundreds of times over. With a little more erosion, all record of human habitation will be erased completely.

VEGETATION HISTORY

Parallel to the earth-science studies described above, botanical and paleoecological investigations were conducted to provide a record of the current environment and a vegetation history of the survey area. In particular, we intended to

- study the Holocene pollen record at a site with continuous sedimentation,
- establish a reliable radiocarbon chronology for the pollen sequence,
- produce an inventory of the current vegetation communities around the pollen-core site,
- develop a multifaceted reconstruction of the environmental history by examining pollen, Foraminifera, mollusks, and a number of physical properties of the cored sediments, including organic matter, carbon, nitrogen, C/N ratio, and stable isotopes.

The ultimate goal of the botanical research was a reconstruction of the vegetation history from the beginning of widespread agriculture to the present. At the end of our study we had obtained one of the most complete sedimentological and palynological Holocene sequences in southern Greece, including an accelerator-dated radiocarbon chronology stretching back to approximately 7400 B.P. Moreover, by combining the study of past and modern pollen vegetation, we obtained a rare quantitative estimate of the past vegetation.

Pollen analysis is one of the most important and most useful methods in paleoecology. It is based on the fact that every year plants release large amounts of pollen and spores, which are then dispersed by wind, animals, or insects. If the pollen falls on land, it is quickly destroyed by a combination of chemical oxidation and microbiological decay.[50] Only under permanently wet or permanently dry conditions, where oxidation is limited, is

[49] McDonald and Hope Simpson 1961, p. 242.
[50] Havinga 1984, pp. 543–545.

pollen preserved. Permanently wet conditions, which are most important for paleoecology, occur in the sea and in lakes, marshes, swamps, and mires. In stratified sediments, the percentages of preserved pollen can be used as a tool for estimating the past vegetation cover. A site suitable for taking pollen cores therefore requires a low-energy environment where organic sediments (peat, gyttja) or clay accumulate in stratified layers. These deposits are cored with devices that leave the stratigraphy undisturbed.[51] Subsamples taken from those cores are then processed using a series of acids and bases to remove minerals and unwanted organic particles.[52] Under ideal circumstances only pollen will remain in the subsample after processing. From each sample 400–500 pollen grains are used to determine pollen types and their relative percentages of the total pollen count under the microscope. The result is a list of pollen types (in most cases corresponding to plant taxa) with relative abundances for each pollen sample. The final pollen diagram is a two-dimensional graph showing the pollen counts of all samples. In this diagram the vertical axis represents depth and therefore time, and the horizontal axis represents the percentage of each individual pollen type or group. The pollen diagram reflects the change in preserved pollen assemblages over time.

An accurate reconstruction of the vegetation history, however, requires more than just a pollen diagram. To determine how plant communities are recorded in pollen assemblages, quantitative comparisons must be made between the composition of pollen in modern surface samples and its source vegetation. Moreover, the processes affecting the pollen between dispersion and retrieval from sediment (such as transport by wind and water, deposition and redeposition, destruction by chemical and biological agents) should be taken into consideration.[53] Owing to these selective processes, the percentages of pollen represented in a core may not reflect the percentages of plants that made up the past vegetation cover. Hence, any attempt to determine past vegetation communities and their evolution has to begin with the examination of the modern vegetation that is deemed similar to that recorded on the pollen site.[54]

Present Vegetation

The present vegetation in the PRAP survey area consists of a patchwork of typical Eu-Mediterranean plant communities, cultivated land, coastal vegetation, and pastures (see Pls. 110–112).[55] The human impact on the vegetation is so pronounced that virtually no natural vegetation communities are found. In the vicinity of Osmanaga lagoon, however, the coastal vegetation is quite diverse. The Palaeonavarino promontory contains salt-tolerant maritime plant communities that include scattered rock samphire (*Crithmum maritimum* L.), southern birdsfoot-trefoil (*Lotus creticus* L.), sea rocket (*Cakile maritima* Scop.), and golden samphire (*Inula crithmoides* L.). The area of sandy beaches and dunes around Voidokilia even ranks as one of the classic botanical sites of the Mediterranean. Scattered on the

[51] Wright 1972, 1991.

[52] Bryant and Holloway 1983; Berglund and Ralska-Jasiewiczowa 1986, pp. 456–459.

[53] Jacobson and Bradshaw 1981; Yazvenko 1992, pp. 12–17.

[54] Bradshaw 1981a, 1981b.

[55] See also Shay and Shay 1978, pp. 42–46 for an excellent account of the present vegetation around Nichoria, *ca.* 20 km southeast of the PRAP study area.

beach are sea spurge (*Euphorbia paralias* L.), yellow-horned poppy (*Glaucium flavum* Crantz), sea medick (*Medicago marina* L.), and sea holly (*Eryngium maritimum* L.). The dunes support grasses and sedges, sparse trees of Phoenician juniper (*Juniperus phoenicea* L.), mastic tree (*Pistacia lentiscus* L.), and shrubs of thyme (*Thymus capitatus* [L.] Hoffmans. and Link).

Genuine forests are virtually nonexistent in the PRAP study area. Patches of seminatural shrub vegetation (macchia, or maquis), on the other hand, occur throughout the survey area below about 600–800 masl. The macchia community around Pylos can be divided into two broadly defined classes.[56] The first one is characteristic of somewhat warmer and dryer conditions; it includes, among others, mastic tree (*Pistacia lentiscus* L.), wild olive (*Olea europaea* L.), carob (*Ceratonia siliqua* L.), and Kermes, or prickly, oak (*Quercus coccifera* L.). This kind of vegetation can be found on parts of the eastern slope of the Palaeonavarino ridge (Pl. 110:a). The second class of macchia is characterized by the prominence of evergreen oaks, viz., prickly oak and holm oak (*Quercus ilex* L.), often with a substantial admixture of deciduous oaks, mostly downy oak (*Quercus pubescent* Willd.) and valonia oak (*Quercus macrolepis* Kotschy; Pl. 110:b),[57] shrubs, and small trees, including myrtle (*Myrtus communis* L.), terebinth tree (*Pistacia terebinthus* L.), tree heath (*Erica arborea* L.), strawberry tree (*Arbutus unedo* L.), and mock privet (*Phillyrea latifolia* L.). Examples of this community are found on the lower slopes of the Englianos ridge. Both these types of macchia survived mainly on steep, inaccessible slopes (Pl. 110:a), often in various stages of degradation toward another kind of plant community, called phrygana (or garrigue), a light, open, shrub-plant community 0.5–1.0 m in height. Phrygana tends to look patchy because certain areas are often dominated by only one plant species, with sheep trails and bare rock occurring in between. Phrygana could be dominated, for instance, by thorny burnet (*Sarcopoterium spinosum* [L.] Spach), rockroses (*Cistus* spp.), Greek spiny spurge (*Euphorbia acanthotamnos* Boiss.), tree spurge (*Euphorbia dendroides* L.), Jerusalem sage (*Phlomis fruticosa* L.), and thyme. This community covers dry, sun-burnt, eroded slopes with thin soil and heavy grazing pressure. Owing to substantial soil loss and degradation of the habitat, phrygana is not always able to recover into macchia after grazing discontinues. Various types of phrygana are scattered throughout the study area. They cover parts of the Palaeonavarino ridge, the degraded slopes between Osmanaga lagoon and Romanou, and large areas around modern Pylos. In the spring, phrygana virtually explodes with white, yellow, pink, and blue flowers, creating one of the major botanical attractions of the Mediterranean. By late June to July, however, it becomes burned and dull until the next spring.

Grazing, trampling, and cutting may suppress shrubs to the extent that the plant community degrades even further (Pl. 111:b). In such areas pseudo-steppe herb communities develop. They are dominated by grasses, umbellifers, and the mint family and are rich in bulbous plants of the lily, daffodil, and iris families, such as asphodels (*Asphodelus* spp., *Asphodeline lutea* L.), St. Bernard's lily (*Anthericum liliago* L.), hyacinths (*Hyacinthus* spp.), daffodils (*Narcissus* spp.), and crocuses (*Crocus* spp.). Such communities occur, for

[56] Zohary 1973, pp. 505–515.

[57] An open woodland dominated by deciduous valonia oaks with abundance of spiny broom and asphodel (*Asphodelus aestivus*) is shown in Plate 110:b.

instance, around the villages of Romanou and Koryfasio and on the western slope of the Palaeonavarino ridge.

Most of the land in the PRAP survey area is under cultivation. Olive orchards constitute the dominant feature of the landscape, while other crops include grapes and currants, corn, cereals, fodder, figs, citruses, etc. (Pl. 112:a). Olive orchards and other cultivated lands used to harbor a rich flora of weeds, which abundantly flowered during the springtime. Since widespread application of herbicides began, most of these plants have virtually disappeared, while a few annual weeds have become extremely abundant (Pl. 112:d).

Quantitative Study of Modern Pollen and Source Vegetation

A number of studies have been conducted to relate quantitatively the pollen assemblages sampled from the ground to the modern source vegetation surrounding the sample site.[58] It is assumed that the relation between modern pollen and plant assemblages may be applied to estimate the relation between fossil pollen assemblages and past plant cover.[59] Until now, most of these quantitative studies have been conducted in the temperate regions of Europe and North America. In the eastern Mediterranean, all palynological studies have been qualitative comparisons between modern pollen and source vegetation.[60] Purely qualitative estimates, however, make it difficult to discriminate between vegetation units such as oak forest and intensively grazed oak macchia, because these ecosystems can have the same dominant taxa,[61] although they behave quite differently under human pressure. Deciduous oaks are not resistant to grazing and usually decline when human population increases. As soon as grazing drops, however, they have the competitive advantage of faster growth and may therefore quickly recover.

In order to provide more accurate reconstructions of vegetation history, the relationship between modern pollen and plant cover must be determined quantitatively. There are two principal approaches to be employed; both rest on the assumption that present pollen-to-vegetation relationships may be extrapolated into the past. Both also require collecting surface pollen samples (usually from moss polsters, surface soil, or plant litter) and recording the source vegetation surrounding the sampling site. The vegetation is assessed either at the local scale, in plots of 10 × 10 m to 40 × 40 m, or at the regional scale, using forest- and land-survey data or aerial photographs.

The first approach is usually called the method of modern analogs. It uses large reference collections of modern pollen samples, including matching descriptions of the source vegetation. Fossil pollen assemblages from cores are compared with the samples

[58] Andersen 1970; Webb 1974; Webb *et al.* 1981; Bradshaw 1981a; Heide and Bradshaw 1982; Bradshaw and Webb 1985; Jackson 1990; Yazvenko 1991.

[59] See, for example, Bradshaw 1981b. The merit of this approach is controversial. See Parsons and Prentice 1981, pp. 128–133; Overpeck, Webb, and Prentice 1985, pp. 90–92; Prentice 1986, pp. 803–805; Delcourt and Delcourt 1987.

[60] Wright, McAndrews, and Van Zeist 1967; Van Zeist, Timmers, and Bottema 1970; Wright 1972; Bottema 1974, 1980, 1994; Van Zeist, Woldring, and Stapert 1975; Bottema and Barkoudah 1979; Jahns 1990, 1991, 1993.

[61] Bottema 1974, p. 59.

in the reference collection to find the best match (the "modern analog").[62] This technique is easy to use but not quite quantitative, since it does not imply any specific mathematical model of the relationship of pollen to vegetation. However, it has been widely and successfully used for exploratory purposes. As long as the modern reference collection is large enough to contain close analogs for most fossil pollen samples, this technique works well. In a severely disturbed landscape, however, there may not even be close analogs of the undisturbed primeval vegetation.[63]

The second approach, sometimes called the method of transfer functions, does not depend on reference collections, since it aims to relate the absolute abundance of a species around the pollen sampling site and the amount of its pollen in the sample. This is a truly quantitative method, supported by a number of mathematical models that try to approximate or predict the absolute quantity of released pollen of any given species in relation to the absolute abundance, or biomass, of the source plants.[64] If both the biomass and the absolute pollen number for a species are known, a regression function can be established to relate the two parameters. The resulting equation can be employed to transfer the pollen counts from fossil samples into estimates of biomass of the past source plants. Since it would be too time consuming to obtain absolute numbers of the modern pollen and the plant biomass they represent, usually percentages of pollen types in the pollen samples and estimates of relative abundance of the plants are used instead.[65] Previous studies have established numerical equations to relate the pollen of many plant species to the biomass (or percentage of plant cover) of the respective species. It was found that plants such as pine (*Pinus*), alder (*Alnus*), and birch (*Betula*) are overrepresented in the pollen record,[66] whereas oak (*Quercus*), elm (*Ulmus*), spruce (*Picea*), and beech (*Fagus*) have approximately proportional pollen representation. Maple (*Acer*), basswood (*Tilia*), and insect-pollinated herbs produce little pollen and therefore tend to be underrepresented in the pollen record.

Applying the pollen record of Osmanaga lagoon to an environmental reconstruction requires knowledge of the extent of the pollen source area, that is, the area from which the majority of pollen (60–70%, according to Jackson 1990) originates. The size of the area from which pollen is derived depends on pollen abundance and transportability and varies for different species. Pine pollen travels far and is ubiquitous in pollen samples, while corn pollen drops almost vertically from flowering plants, and grape pollen may not be recorded in surface samples collected only a few meters away from vineyards. Pollen transport in the air depends on physiography, air mass movements, weather patterns, and other factors that are difficult to quantify. In addition to air-transported pollen, at Osmanaga lagoon

[62] Numerical models to determine similarity and dissimilarity of assemblages have been developed for this technique. For theory and discussion see Prentice 1980, pp. 81–88; Parsons and Prentice 1981, pp. 128–135; Overpeck, Webb, and Prentice 1985, pp. 90–104.

[63] Parsons and Prentice (1981), Overpeck, Webb, and Prentice (1985), and Yazvenko (1992) discuss other limitations of the modern analog approach.

[64] Webb *et al.* 1981, pp. 271–278; Heide and Bradshaw 1982, pp. 18–21.

[65] Webb *et al.* 1981, pp. 275–278.

[66] Andersen 1970, 1973; Bradshaw 1981a, pp. 60–62; Bradshaw and Webb 1985; Jackson 1990, p. 73; Yazvenko 1992, pp. 76–88.

some pollen is likely to have been transported by water in which turbulences could well have caused an uneven distribution of different pollen types.

Nevertheless, some observations indicate that the source areas for most pollen types found in the Osmanaga samples may have been limited to the area stretching from the Palaeonavarino ridge in the west to the rolling hills around Yialova in the east and from Englianos in the north to the Sphaktiria ridge in the south. For instance, ever since pine was eliminated from the vicinity of the lagoon, the Osmanaga pollen record has contained low and relatively stable proportions (2–5%) of pine pollen, representing long-distance input, which is not affected by landscape changes in the survey area. This suggests, first, that the conditions for pollen transport may have been fairly steady through time and, second, that for the majority of pollen, even of the most easily transported type, the source area was not as far away as modern Pylos. Less well dispersed types of pollen, including oaks, olive, heaths, and terebinth/mastic, are therefore likely to be derived from an area of the same or a smaller size.

In the Pylos region, we examined a broad range of different seminatural and agricultural plant communities to determine quantitatively the relationship between modern surface pollen and source vegetation. In thirty-four plots 25 × 25 m in size, the vegetation was quantitatively described. In each of these plots we estimated the relative percentages of trees, shrubs, and herbs.[67] For tree species with trunks of more than 30 cm circumference at breast height, the absolute basal area was determined, since previous studies have shown that it is closely related to the biomass of the tree and its pollen production.[68] The abundance of shrub and herb species was estimated using a modified Braun-Blanquet 6-point rank scale of relative coverage for each species under consideration.[69] The scale included class (0) for no plants, class (1) for less than 1% coverage, (2) for 1–5%, (3) for 5–20%, (4) for 20–50%, and (5) for more than 50%. Thus the descriptions of the modern vegetation are quantitative for trees and semiquantitative, or ranked, for shrubs and herbs. In the thirty-four plots, surface pollen samples were collected from moss polsters wherever possible, since pollen tends to be better preserved in moss than in soil or decaying leaves.[70] To relate the pollen percentages to the vegetation cover, least-square linear regressions were developed for the pollen types encountered in a sufficient number of pollen samples and vegetation descriptions. These include pine, deciduous and evergreen oaks (Fig. 21), olive (Fig. 22), tree heath, mastic tree and terebinth (combined), and asphodel.[71] The pollen found in the moss polsters is assumed to relate to the surrounding vegetation of the 25 × 25 m plot. In practice, however, a substantial proportion of the pollen originates outside the plot, which complicates interpretation of the results. The proportion of such long-distance pollen is higher for the open areas and lower for closed woodlands and

[67] For methods see also Yazvenko 1992.

[68] Andersen 1970; Bradshaw 1981a, pp. 51–52.

[69] Mueller-Dombois and Ellenberg 1974, pp. 59–60.

[70] Bradshaw 1981a, p. 50; Yazvenko 1992, p. 43.

[71] The merit of this approach is disputed (Andersen 1970; Bradshaw 1981b; Prentice 1986; Yazvenko 1992), but within its limits it does have the advantage of yielding numbers that in many cases proved to be quite accurate (Webb *et al.* 1981, pp. 283–294; Delcourt, Delcourt, and Davidson 1983; Jackson 1990, pp. 59–69; Yazvenko 1992, pp. 76–88).

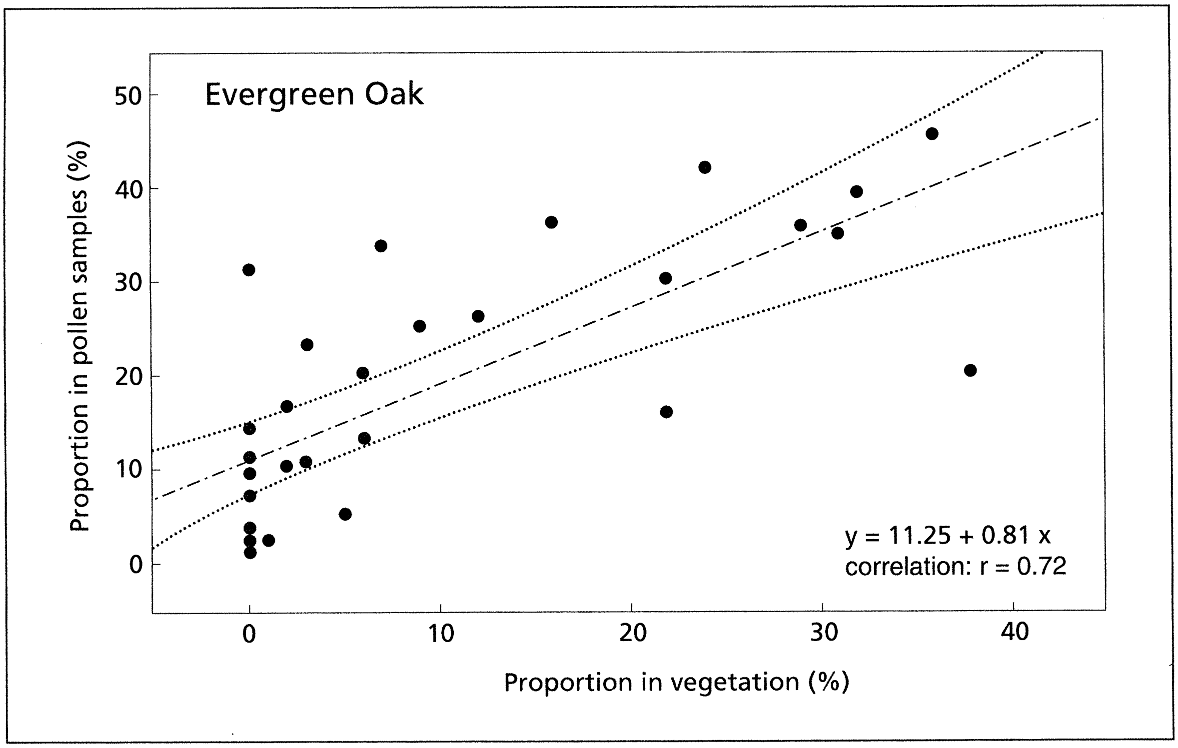

FIG. 21. Modern pollen samples of evergreen oak versus the source vegetation in the subarea (Sergei Yazvenko and Eberhard Zangger)

shrubs. Nevertheless, even in cases when most of the pollen derives from outside the plot, the local pollen may still accurately reflect patterns in present vegetation.[72] The resulting regressions can therefore still be used to convert the counts of fossil pollen from the cores into past plant compositions.

Previous Research at Osmanaga Lagoon

During the Minnesota Messenia Expedition several marshes, lakes, and coastal lagoons in the Peloponnesos were visited and probed, and two cores from the Osmanaga lagoon at the northern end of the Bay of Navarino were systematically analyzed for pollen. These two cores produced similar pollen curves, including a pronounced peak of olive[73] followed by an oak-pollen maximum and another smaller olive peak. Based on the radiocarbon dates, the absolute olive maximum would have occurred during the Dark Age (1100–700 B.C.), a period of low population density and light agriculture. The interpretation of the fossil pollen record from Osmanaga lagoon was enhanced by sampling of surface pollen along an altitudinal transect. This permitted the identification of principal pollen assemblages

[72] Yazvenko 1991; Jackson and Wong 1994; Jackson, personal communication, 1994.
[73] At 160 cm below sediment surface in core 30 and at 200 cm in core 15 (Wright 1972, p. 194).

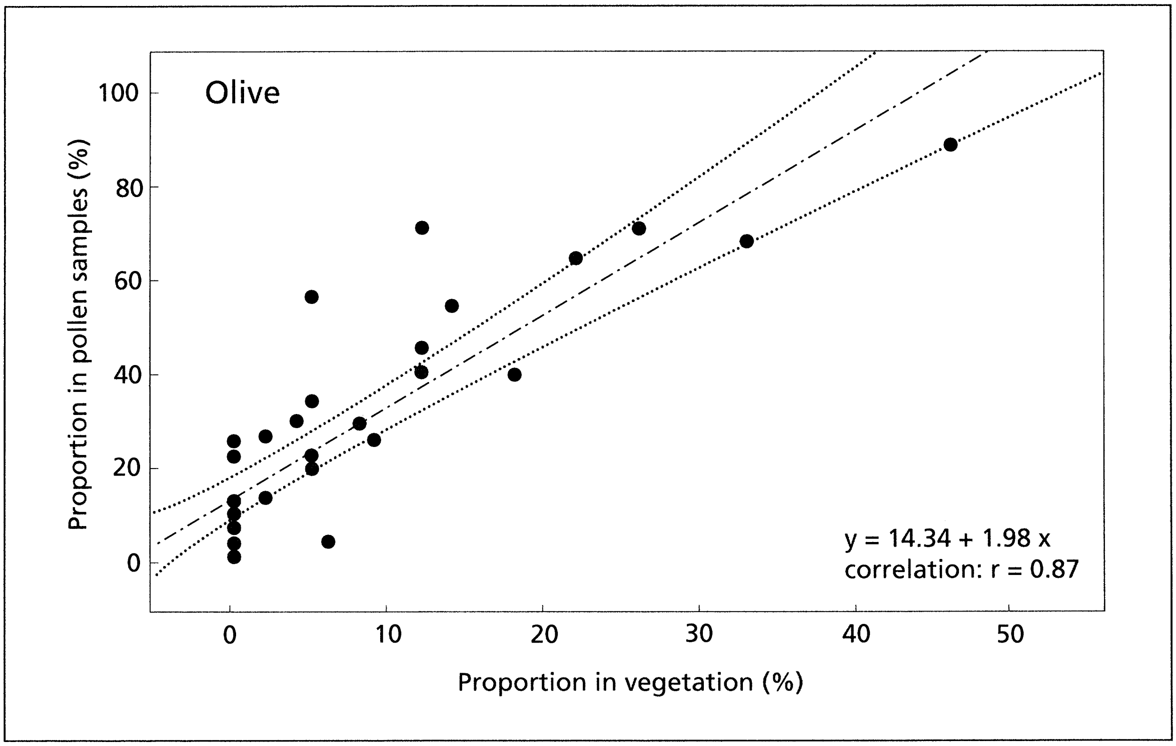

FIG. 22. Modern pollen samples of olive versus the source vegetation in the subarea (Sergei Yazvenko and Eberhard Zangger)

corresponding to broad vegetation units in the Peloponnesos, including coastal pine groves, open dunes, oak-dominated macchia and deciduous woods, and montane pine forests.

The previous pollen work at Osmanaga, however, should be regarded as a pilot study that left a number of questions unaddressed and made follow-up investigations highly desirable. First, too few pollen samples were analyzed (eleven from core 15 and sixteen from core 30). The resulting temporal resolution of 200- to 400-year intervals between adjacent pollen levels is too coarse for a detailed documentation of the vegetation changes. Second, only six dominant pollen types (oak, pine, olive, pistachio, heath, and grasses) were documented, and many other indicative types (walnut, cereals, plane, common vine, carob, ribwort plantain, thorny burnet, etc.) were not included in the study. Third, pollen of evergreen oaks was not distinguished from that of deciduous oaks, which may create ambiguity because the ecology of the two groups is quite different and in some respects antithetic. Fourth, by focusing on pollen analysis and disregarding physical and chemical properties of the sediment, fundamental changes in the depositional system were overlooked, including the drastic change in depositional regime below the large olive peak. Finally, quantitative studies of modern pollen deposition and its relation to the source vegetation were not included. The presentation of the results was somewhat ambiguous, too: in the text describing the pollen diagram, Wright refers to an olive-pollen value of more than 40% at its peak,[74] but in the diagram the maximum olive-pollen value is only 20%. Adding the pollen percentages for any given sample produces figures around 50%, rather than 100%. Thus, the scale on both pollen diagrams seems to have been misprinted; the percentages must probably be multiplied by two to yield accurate values. Nevertheless, the palynological studies of the Minnesota Messenia Expedition provide valuable information about the vegetation history of this region. The time has come, however, to address issues that were previously neglected.

Core Analysis

During the course of the Pylos Regional Archaeological Project we resurveyed the Peloponnesos in search of suitable pollen sites. Since many wetlands have been drained in the past two decades, Osmanaga lagoon remains one of the few locations suitable for a systematic palynological investigation.[75] The lagoon is more than one kilometer wide but at most places less than one meter deep. It is separated from the Ionian Sea by the Palaeonavarino ridge (Fig. 5). A few small streams emanating from the hills to the northeast carry their suspended load to the lagoon (Fig. 3). The winter floods of these rivulets constitute the principal water source of the lagoon, although marine water may seep through the beach barrier between Osmanaga and the Bay of Navarino.[76] Evaporation during the summer lowers the water level in the lagoon and increases the salinity. The deepest part of Osmanaga lagoon, on the western side adjacent to the Palaeonavarino ridge, however, is unlikely to have ever fallen dry. Wright's study showed that the pollen preservation in this part of the lagoon is quite suitable for pollen cores.

We collected a total of fourteen cores from Osmanaga lagoon, using Russian and modified Livingstone coring devices.[77] The length of these cores varied between 372 cm and 468 cm. The cores were taken as overlapping pairs of two cores one meter apart: one core running from a depth of 0–100 cm, 100–200 cm, etc., and the other core running from 50–150 cm, 150–250 cm, etc. Two of these core pairs (D-2 and D-4) were used for pollen analysis, radiocarbon dating, and sedimentological and paleontological studies. The others were stored as archives. Samples for pollen analysis were taken at different intervals between 5 and 20 cm. In lower parts of the cores, several samples contained too few pollen grains to be counted and were excluded from the pollen diagram. Only 3 cm^3 of sediment were used for pollen analysis, and so the entire sample horizon was limited to less than one centimeter of cored sediment.[78] The samples were processed in the laboratory using standard techniques.[79] The residue was preserved in silicone oil and

[74] Wright 1972, p. 195.

[75] Another example is the recently studied Lerna marsh (Jahns 1990, 1991, 1993).

[76] Wright 1972, p. 192.

[77] Wright, Mann, and Glaser 1984, pp. 657–659; Wright 1991, pp. 37–49.

[78] Methods of pollen sampling and analysis are described in detail in Wright 1972, pp. 189–190; Bryant and Holloway 1983; Berglund and Ralska-Jasiewiczowa 1986, pp. 456–459; Horowitz 1993.

[79] Berglund and Ralska-Jasiewiczowa 1986, pp. 456–459. The idea of processing is straightforward. Mineral particles consist mostly of silicates, carbonates, and sulfides. Silicates are dissolved in fluoric acid, carbonates in hydrochloric acid, sulfides in nitric acid. Unwanted organic particles are oxidized (acetilated) in a strong oxidizer called acetolysis mixture, a solution of concentrated sulphuric acid and acetic anhydride. Clay, which is chemically resistant, was eliminated by using the 10-mm nylon sieve combined with a vibrator (Cwynar, Burden, and McAndrews 1979).

kept in sealed plastic vials. A droplet of residue was analyzed under an optical microscope, and more than 400 pollen grains were counted in each sample except for some samples with particularly low pollen concentrations, in which case only 100 to 200 grains were counted. The basic sum used in all calculations did not include obligate aquatic taxa, sedges, chenopods, or grasses, for reasons detailed by Wright.[80]

Although no volcanic ash layers (tephra) were recognized macroscopically, pieces of volcanic glass were counted under the microscope along with other mineral particles of the same size class.[81] Two-milliliter subsamples were taken at 20-cm intervals to determine wet density, dry density, and loss-on-ignition at 550°C as a measure of sediment organic content.[82] Organic carbon, total nitrogen, $\delta^{13}C$, Foraminifera, and mollusks were determined in a number of collaborating institutes.[83] Twelve samples were submitted to BETA Analytic, Inc. for ^{14}C-accelerator mass spectrometry dating (Table 11, p. 633).[84] One of these samples consisted of charred terrestrial plants, five were individual bivalve shells, and six were bulk-sediment, including two from the level of the shells and one from the charred terrestrial plants. One bulk-sediment sample was dated conventionally. All radiocarbon ages have been calibrated using the CALIB 3.03 program.[85] The date derived from charred terrestrial plants in core D-4 at 387 cm is 560 years younger than the date of the bulk sediment at this depth. This age difference is presumably caused by a combination of the hard water and reservoir effects. The former occurs in areas where old carbon from limestone and marl rocks results in older-than-expected radiocarbon dates. The latter effect occurs in areas with significant upwelling, where ocean currents transport ^{14}C-depleted water to the surface.

To correct the bulk sediment and shell dates, we substracted 560 years from each before calibration. Essentially all dates obtained this way appear plausible; for the uppermost 250 cm the sedimentation rate is nearly linear (Fig. 23). Only two samples (at 281 cm and 344 cm) produced questionable dates and have therefore been rejected. The deviation of these dates could be the result of deposition of older material. They fall into the period of the first widespread soil erosion, a time that is often accompanied by anomalous radiocarbon dates because old organic matter from mature soils is deposited on top of younger sediments. When the mature soils have been largely eroded, this old organic matter has presumably disappeared too and the dates become accurate again.[86]

[80] Wright 1972, p. 193 (for sedges and chenopods).

[81] For procedure see Bennett *et al.* 1992, p. 245.

[82] For procedure see Bengtsson and Enell 1986, pp. 425–427.

[83] See p. 636 below.

[84] Dates provided by BETA Analytic are reported as RCYBP (radiocarbon years before present, "present" = A.D. 1950). By international convention, the modern reference standard was 95% of the ^{14}C content of the National Bureau of Standards' Oxalic Acid and calculated using the Libby ^{14}C half-life of 5,568 years. Quoted errors represent 1 standard deviation (68% probability) and are based on combined measurements of the sample, background, and modern reference standards. Measured $^{13}C/^{12}C$ ratios were calculated relative to the PDB-1 international standard, and the RCYBP ages were normalized to –25%.

[85] Stuiver and Reimer 1993.

[86] Reversals and anomalies in radiocarbon ages in England and northern Europe often coincide with the pollen record of widespread forest clearance (Pennington 1991, p. 21, and references therein) and with an increase in carbon content of the sediments. These widely reported anomalies were attributed to intensified

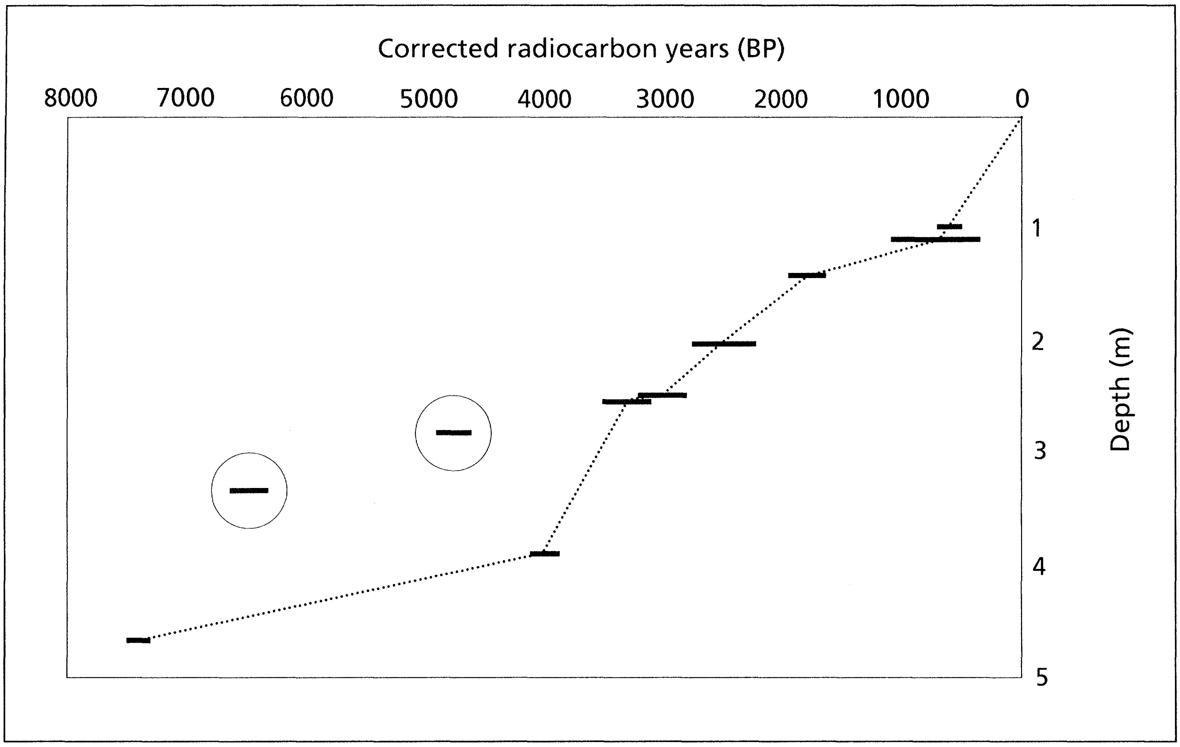

FIG. 23. Radiocarbon dates from cores D-4 and D-2 from Osmanaga lagoon (Sergei Yazvenko and Eberhard Zangger)

RESULTS AND INTERPRETATION

The sediments and pollen assemblages from Osmanaga lagoon provide a consecutive record of the environmental evolution of this area for the past 7,400 years. The pollen diagram (Fig. 24) shows that the plant cover experienced several dramatic changes during the past several millennia. In order to discuss the different stages of the vegetational and environmental history, we divided it into seven distinct chronological phases.

The Period 7300–5500 B.C.

The dunes at Voidokoilia and the beach barrier isolating Osmanaga lagoon from the Bay of Navarino did not exist during this period.[87] The present lagoon was therefore part of the bay and connected to the open sea. Extensive sandy beaches and Late Pleistocene dune fields covered the coastal zone north of modern Romanou. Because the pollen record in the cores taken during the Pylos Regional Archaeological Project begins around 5500 B.C., for a record of earlier events we must refer to pollen data collected by Judith Gennett from core 3, taken in the northern part of Osmanaga lagoon in the study

soil erosion and significantly increased input of organic matter from the catchment area after extensive deforestation.

[87] Kraft, Rapp, and Aschenbrenner 1980, p. 199.

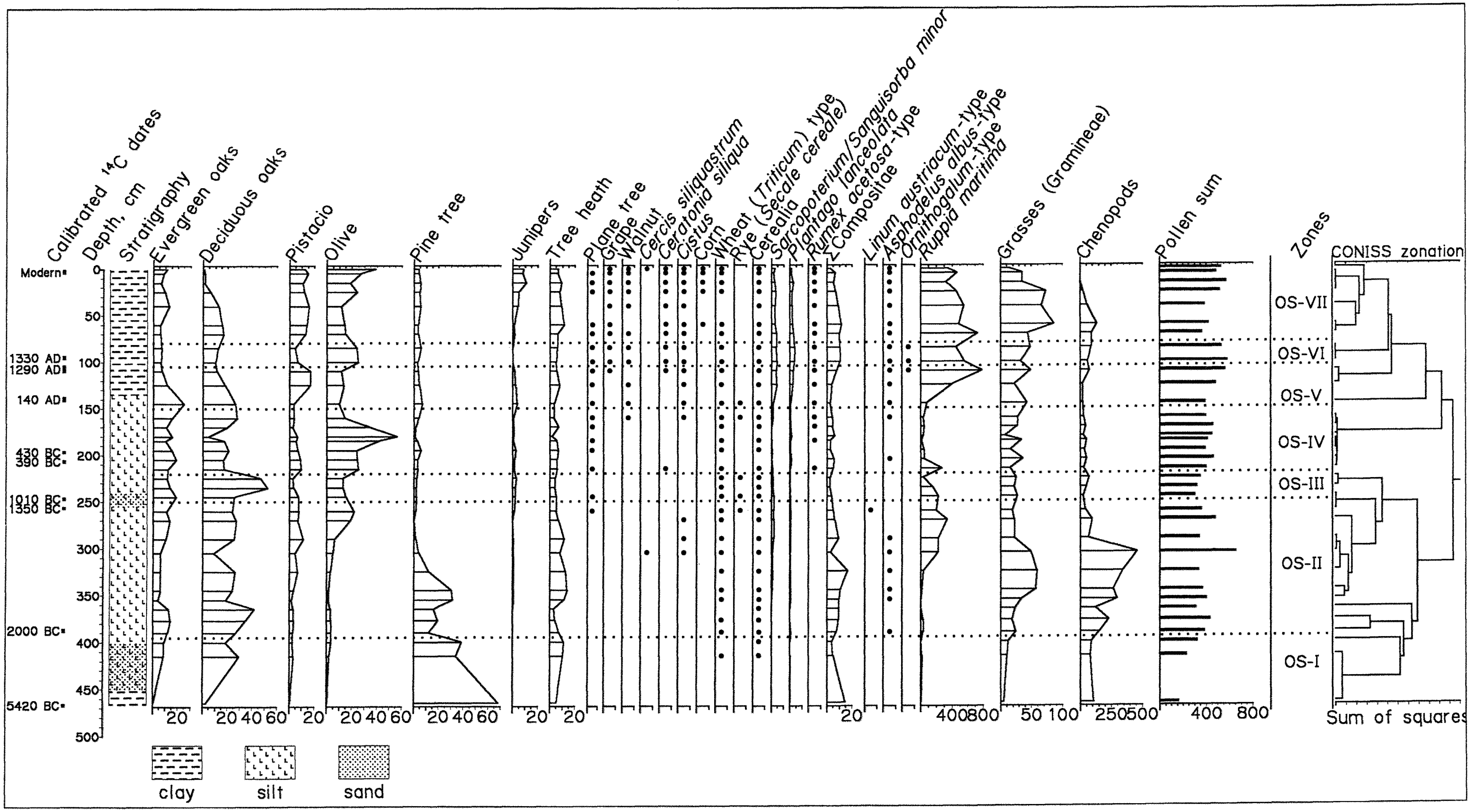

FIG. 24. Selection of the most important pollen types from core D-4 (Sergei Yazvenko)

conducted by Kraft and his coworkers.[88] In these samples, pollen of herbs dominated the record between *ca.* 7300 and 6000 B.C. The daisy family, chenopods, and, surprisingly, asphodels comprised most of the pollen. Many pollen types of the daisy family, chenopods, and probably of asphodel are highly resistant to decay.[89] Considering this composition and the prevalence of sandy sediments, generally unsuitable for pollen preservation, it appears likely that selective destruction of the pollen has occurred, apparently increasing the relative abundance of more resistant types. At *ca.* 6000–5500 B.C., a peak (35%) of pollen from hop-hornbeam or, more likely, eastern hornbeam (*Ostrya-Carpinus orientalis*) occurred, with pollen from oaks (20%) being important. After *ca.* 5700–5500 B.C. pine pollen peaked at 50–80%. The pollen record obtained during this earlier study ends around 3000 B.C. owing to low pollen concentrations in the sediments.[90]

The Period 5500–2000 B.C. (465–390 cm)

The pollen record of this period starts with a rapid expansion of pine (*Pinus*), which dominates the pollen assemblage with 40–70% of the total pollen. Pine tends to stand out in fossil pollen samples because it produces abundant pollen that is also rather resistant to weathering. Nevertheless, considering these very high values, pine must have been one of the dominant species of vegetation during the Neolithic period and Early Bronze Age. At that time pine forests probably covered the marl slopes near Koryfasio, much as Aleppo pine (*Pinus halepensis* L.) today grows in many coastal areas of the Peloponnesos, for example, near Kyparissia. Probably, most of the pine pollen in Osmanaga lagoon was also produced by Aleppo pine. Between 5000 and 2000 B.C. the proportion of pine pollen decreased, while that of deciduous oaks increased (Fig. 24). The sediments deposited at that time were rather coarse and therefore unsuitable for pollen accumulation. In water and air, pollen behaves like any other physical particle and usually is deposited together with other particles of equal size (10–100 μm). Besides, coarse sand, indicative of a high-energy depositional environment, tends to destroy pollen mechanically. These factors contribute to the poor pollen preservation below 415 cm. The record from these levels may not be accurate, and for the period before 2000 B.C. we can only say that pine was prominent.

A sharp transition occurred just before 2000 B.C. At that time pine dropped to 15–20% in pollen samples and probably to even lower figures in the plant cover. Deciduous oaks benefited from the decline of the pines, and a number of other pollen types either appear for the first time or increase in percentages. These include thorny burnet (*Sarcopoterium*), ribwort plantain (*Plantago lanceolata* L.), yarrow (*Achillea*-type), and asphodel (*Asphodelus*). These developments argue in favor of increased human impact on the landscape. Although sandy soils covered by pine woods do not rank as the best land for farming, the woods might have been cut or burned.[91] Husbandry may not have been very intensive at this stage, because deciduous oaks, which are intolerant of grazing, still dominate the

[88] Kraft, Rapp, and Aschenbrenner 1980, pp. 204–208.

[89] Bottema 1992, p. 23.

[90] Kraft, Rapp, and Aschenbrenner 1980.

[91] In the Middle East, Aleppo pine was also in all probability more widespread in the past but has been mostly cleared for fuel, farming, and pasture (Zohary 1973, p. 523).

vegetation. With the decrease of the pine forests, sedimentation rates accelerated sharply and remained high until the Early Iron Age.

More information about the human impact on the landscape around 2000 B.C. was derived from the physical properties of the sediment (Fig. 25). Fluctuations in C/N ratio usually correlate with the varying input of terrigenous organic matter and the productivity of the basin.[92] Marine organic matter has low C/N ratios (usually < 10) because plankton is relatively enriched with proteins and DNA and, hence, with nitrogen. The bulk of the biomass of terrestrial plants, on the other hand, consists of lignin and cellulose, which contain no nitrogen. Thus, high C/N ratios tend to reflect high input of terrestrial biomass. The twofold increase in the C/N ratio at 390 cm (*ca.* 2000 B.C.) therefore reveals a considerable increase of input of terrestrial organic matter. A concurrent, 15 cm thick, charcoal-enriched layer records widespread fires around the lagoon. Since this charcoal layer coincides with the decrease in pine forests (which are highly prone to fires), as well as with the increase in sedimentation and terrestrial biomass input, it seems to reflect the first wave of massive human impact on the landscape. Natural forest fires by themselves could not have had the same effect, because the change in vegetation communities indicates a significant increase in grazing. Moreover, fires are unlikely to trigger a phase of soil instability that would last for an entire millennium, unless, of course, they were followed by overgrazing.[93] Recent synoptic studies of the Holocene interrelations between people and landscape in Greece have argued that the first deforestation on hillslopes caused the most devastating soil erosion of the entire Holocene.[94] In Messenia this phase occurred later than elsewhere in Greece,[95] probably because the region lies far from the areas most densely inhabited during the Early Bronze Age and was therefore less intensively exploited than, for instance, the Argolid.

The Period 2000–1100 B.C. (390–250 cm)

Between 1800 and 1600 B.C. pine was able to recover partially, reaching 25–30% of the pollen count, possibly indicating less pressure on the landscape or a change in land-use patterns. The C/N ratio and carbon content dropped to low levels, which would also argue for increased landscape stability. Subsequently, however, between 1600 and 1400 B.C., the pines were destroyed completely and deciduous oaks dropped to half their previous values. At the same time *Asphodelus*, *Cistus*, and *Plantago lanceolata* increased, indicating expansion of a steppe and phrygana environment, perhaps as a result of grazing. Utilizing the observations of modern pollen-to-vegetation relationships, we were able to determine that about 40% of the total land surface may have been covered by steppe and phrygana communities (Fig. 26). Between 1400 and 1200 B.C. the pollen of steppe and phrygana plants dropped again, while olive reached a first peak of 23% after the middle of the second millennium B.C. Olive is a strong pollen producer and is usually overrepresented in fossil assemblages. Nevertheless, 20–25% olive pollen suggests that about 10% of the total surface was used for olive cultivation during the Late Helladic III period.

92 Anderson and Arthur 1983, p. 90.

93 See also Jahns 1993.

94 van Andel, Zangger, and Demitrack 1990; van Andel and Zangger 1990; Zangger 1992a.

95 In Thessaly, 4500–4000 B.C.; in the Southern Argolid, *ca.* 2500 B.C.

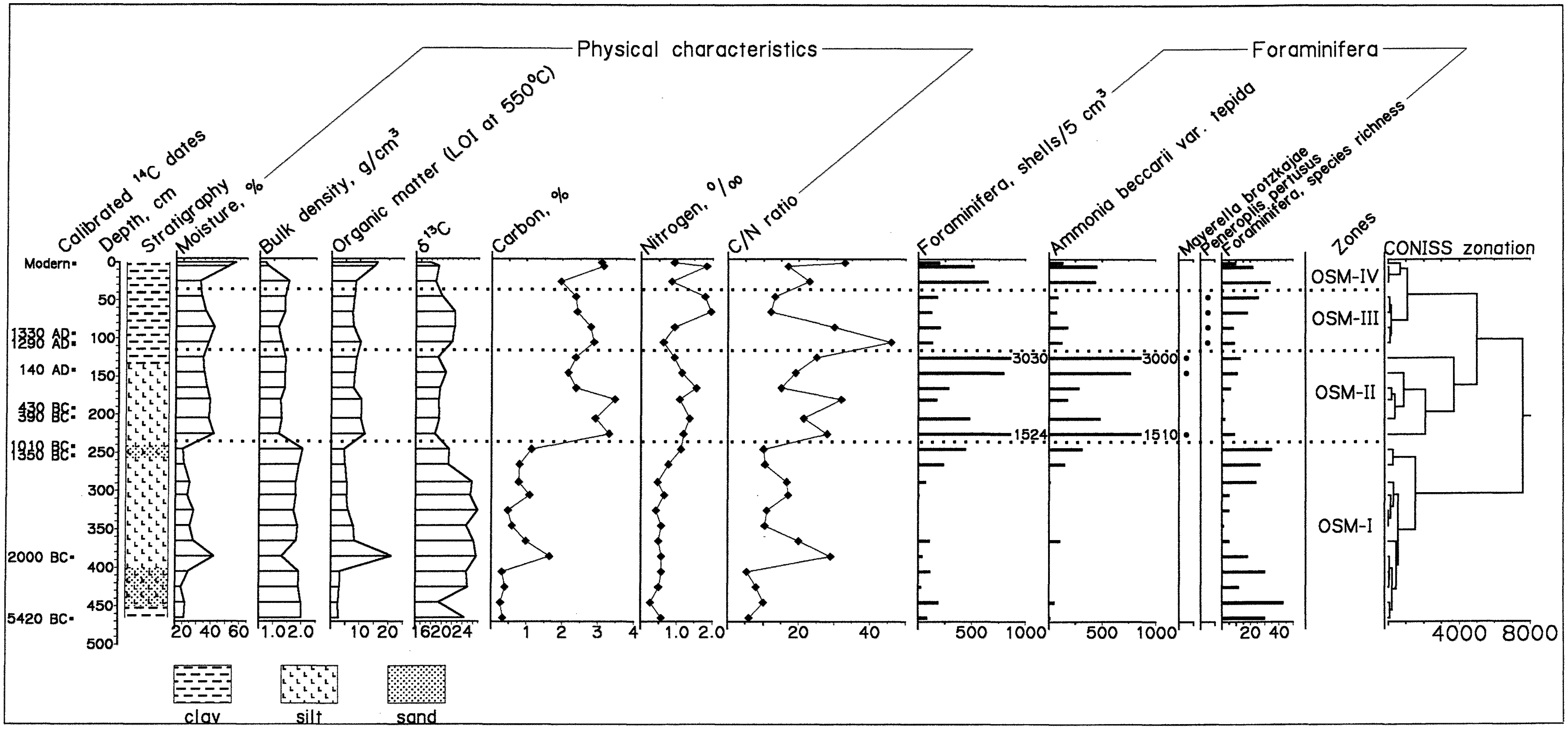

FIG. 25. Physical characteristics and fossil contents of cores D-4 (0–425 cm) and D-2 (445–465 cm) (Sergei Yazvenko)

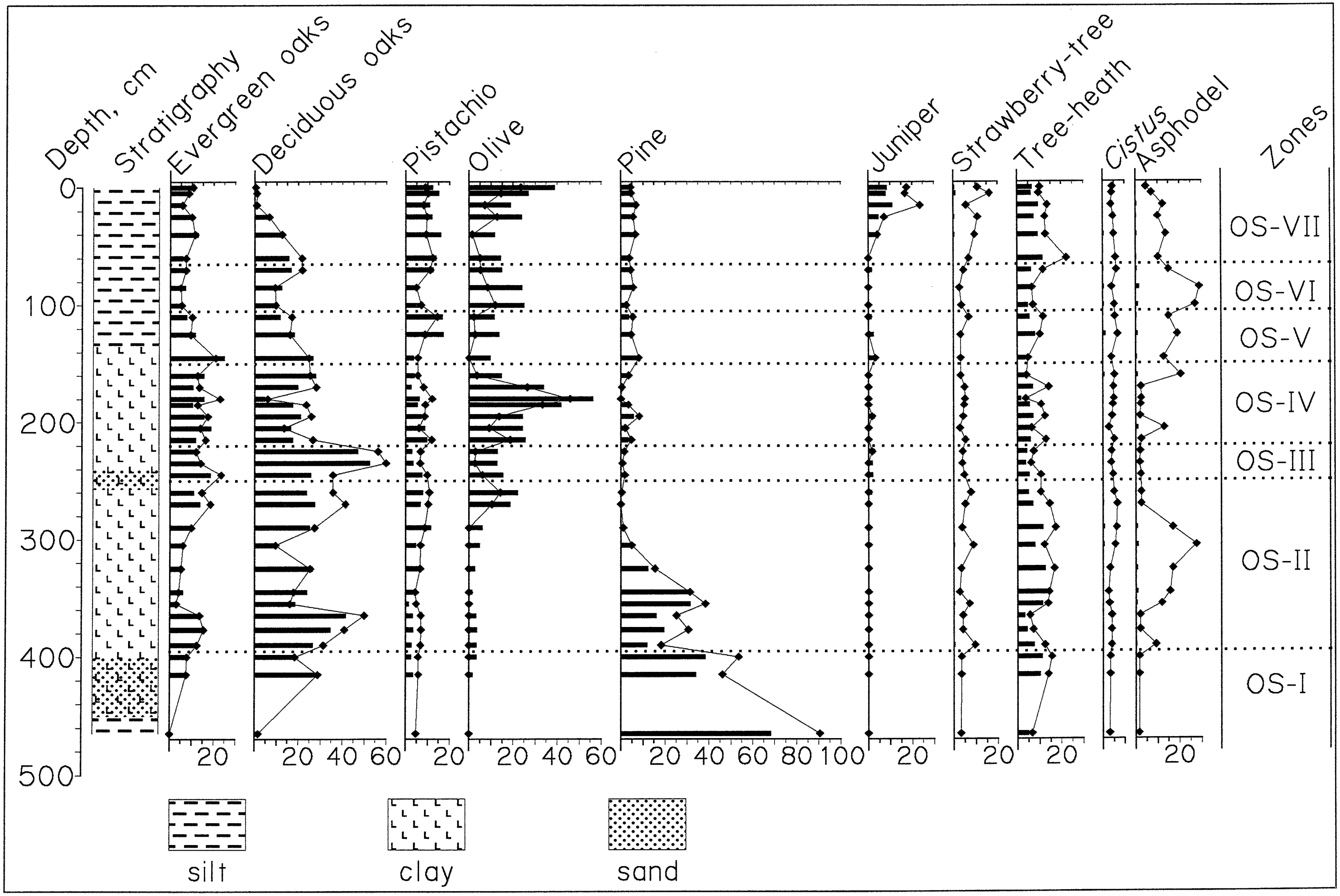

FIG. 26. Quantitative reconstruction of the vegetation around Osmanaga lagoon (Sergei Yazvenko)

Between 1400 and 1200 B.C. several pollen grains of rye (*Secale cereale* L.) appear. Rye is extremely rare at European prehistoric sites and might not have been introduced to Greece as a crop before Roman times. It may have been spread over Europe by the Celts during their migrations.[96] Susanne Jahns reports solitary questionable pollen grains of rye from Bronze Age deposits at Lake Lerna.[97] Based on these individual pollen grains it is impossible to establish the importance of rye in the Bronze Age economy. Perhaps it was an admixture, or a tolerated weed, of barley or wheat rather than a specifically cultivated crop. If rye was indeed cultivated, one would expect pollen counts on the order of a few percent. There is no discernible increase of Cerealia pollen at 1400–1200 B.C. Wheat and barley, unlike rye, are self-pollinated plants and produce so little pollen that it would hardly be recognized within the Cerealia pollen group, which consists mainly of wild grasses with similar types. New species appearing between 1400 and 1200 B.C. include plane tree (*Platanus*), walnut (*Juglans*), and Judas tree (*Cercis siliquastrum*). Pollen of flax (*Linum*) was also found. Since it belongs to the *Linum austriacum*-type rather than to the cultivated *Linum usitatissimum*-type it is likely to have been a wild form.

Around 1600 B.C. the C/N ratio increased twofold, only to drop, around 1400 B.C., to its previous level. At about 1400 B.C. the $\delta^{13}C$ values decreased too. Both these changes indicate a significant drop in terrestrial input. The peak of the Late Bronze Age civilization in the Pylos area was therefore accompanied by unusually low rates of sedimentation and terrestrial input into Osmanaga lagoon. This observation might well argue in favor of landscape stability achieved by a sophisticated control system that included terraces. It might also reflect an interference with the Selas River, which thus far had been the largest source of terrestrial input into Osmanaga lagoon. The physical characteristics of the cores taken from Osmanaga lagoon strongly argue in support of a date between 1400 and 1200 B.C. for an initial redirection of the river.

The $\delta^{13}C$ fluctuations provide more arguments supporting a significant change in the depositional environment during the Late Bronze Age. Two main isotope zones appear in the core, with their boundary at 265 cm (around 1400 B.C.). In the lower zone the $\delta^{13}C$ values oscillate around –24% to –25% (with one exception at 445 cm), whereas in the upper zone they are closer to –20%. The lower $\delta^{13}C$ values seem to be derived from planktonic organic carbon, usually ranging between –23% and –25%, and terrestrial material with average values around –27%.[98] The relative proportions of these two components are hard to discern from the isotopic record itself, and the C/N ratio hints at complex and dynamic relations between them. It is clear, however, that terrestrial input must have decreased toward the end of this period. This observation supports the argument of a redirection of the Selas River during the Late Bronze Age.

The Period 1100–500 B.C. (250–220 cm)

Between 1200 and 700 B.C. olive decreased to about 10–12% of pollen counts, reflecting about 5% of surface coverage—higher than the expected natural background of

[96] Sencer and Hawkes 1980.
[97] Jahns 1991, p. 116; 1993, pp. 199–200.
[98] Spiker 1981, pp. 86–90.

1–2% surface coverage. The gradual nature of the decrease of olive may have been caused by the long life span of this tree and its continuous pollen production after abandonment. At the same time, deciduous oaks increased, to the extent that they may have covered over half the total surface. Deciduous oaks are much less resistant to grazing than evergreen oaks, but with the withdrawal of husbandry they have the advantage of faster growth. Their success, combined with the decrease of olive and mastic/terebinth pollen, are clear signs of diminished human activity in terms of both cultivation and grazing. During the Early Iron Age the landscape experienced the least intensive human impact of the last 4,000 years. The two regional archaeological studies in Messenia (UMME and PRAP) show that population density dropped sharply after the Late Bronze Age.

The physical characteristics of the sediments in Osmanaga lagoon demonstrate how the entire character of the depositional system changed between 800 and 500 B.C. (at 230 cm). The sedimentation rate dropped further, and a completely different depositional and trophic regime developed. The productivity of the basin, reflected in carbon content, increased many times, and the subaqueous flora and fauna changed even more dramatically. Foraminifera, most of which indicate full salinity,[99] disappear almost entirely, except for *Ammonia tepida*, a euryhaline species abundant in brackish coastal lagoons, which increased a hundredfold. Concurrently, mollusks appear in great numbers, including *Hydrobia acuta* as the dominant species. All these developments indicate a significant decrease in salinity and wave pressure as well as an increase in organic productivity, with much of the organic matter being derived from subaquatic plants such as *Ruppia maritima* (marine ditch grass). A radiocarbon date[100] and a Hellenistic cemetery in the central part of the sand spit between Yialova and the Palaeonavarino ridge, as reported by the Minnesota Messenia Expedition,[101] indicate that the barrier closed during the first half of the first millennium B.C. The separation from the Bay of Navarino caused the salinity to drop and produced the changes in the depositional environment recorded by the physical properties described above. After the closure of the barrier the influence of the reservoir effect on the radiocarbon dates could have become smaller, while the effect of old carbon would have remained the same. The correction factor of 560 years may therefore be slightly too high for dates of samples above 230 cm depth. The influence of the reservoir effect, however, may not have been significant in the first place, because the $\delta^{13}C$ values of mollusk shells do not change significantly above 230 cm. This suggests that the ratio of carbon isotopes in the water remained fairly stable.

The environment in the lagoon changed fundamentally after the closure of the beach barrier. Prior to that, fine particles and colloidal and dissolved terrigenous matter may have been washed out into the sea without being used by local biota. After the closure, the organic productivity inside the lagoon must have increased many times. More important, the closure produced the stable, low-energy environment that offered a suitable habitat for aquatic macrophytes and a whole new trophic net in the ecosystem.

[99] Boucot 1981, p. 125.

[100] Kraft, Rapp, and Aschenbrenner 1980, p. 193.

[101] McDonald and Rapp 1972, p. 310 [site #401].

The Period 500–100 B.C. (220–160 cm)

After 800 B.C. olive cultivation increased sharply, reaching an all-time peak about 230 B.C. (Fig. 26), provided the sedimentation rate between the dates at 200 and 140 cm was constant. But error margins associated with radiocarbon dates have to be taken into account, too (Table 11, p. 633). Over 50% of the pollen belongs to olive, which may have covered up to a quarter of the total surface. At the same time, pollen of deciduous oaks dropped from 50% to 7–20%. During this period carob (*Ceratonia siliqua*) appears in the Osmanaga core, although it has not been found in pre-Roman pollen samples from Greece before our sample. Cereals and grapes are likely to have been important cultivated plants but are hard to track in fossil pollen assemblages. Surface pollen studies conducted during PRAP and by Sytze Bottema[102] demonstrate that even within 10 to 50 m of modern vineyards only solitary pollen grains of grapes are found at the surface.[103] Low values of daisy (*Compositae*) and other indicators of grazing imply that the emphasis of land use rested on farming rather than on grazing.

The palynological data argue for a dense population and a high level of agricultural production during the Classical/Hellenistic period. Human control of the landscape seems to have reached its maximum at that time, with a strong emphasis on olive cultivation at *ca.* 500–100 B.C. (220–160 cm). The peak of olive pollen coincides with a high C/N ratio, which indicates increased erosion due to higher pressure on the landscape.

The pollen cores taken during the Minnesota Messenia Expedition exhibited olive maxima that were dated to the Dark Age between 1100 and 700 B.C.[104] It appears more than likely that these olive peaks actually correspond to the maxima in our cores and therefore should be dated to the Classical/Hellenistic period. This discrepancy is evidently due to the fact that Wright used bulk-sediment samples for radiocarbon dating, without calibrating and correcting them for old carbon and reservoir effects, whereas we deducted 560 years from such samples because this is the empirically determined age difference in comparison with genuine organic matter. If Wright's dates are corrected by the same factor and calibrated, his olive maximum would fall into the period between 540 and 140 B.C. and would thus coincide with our data.

The Period 100 B.C.–A.D. 1200 (160–110 cm)

This interval, comprising the Roman and most of the Byzantine period, is compressed and fairly uniform in the pollen record. Olive dropped to low levels of around 10% pollen, which would argue for about 5% land coverage. At the same time, deciduous oaks increased again. The sedimentation rate slowed down by a factor of three, and only clay accumulated in the lagoon. The productivity of the lagoon decreased. Between A.D. 600 and 700 oak dropped in abundance while pistachio picked up again, arguing in favor of increased husbandry. In general, the vegetation history during this stage indicates

[102] S. Bottema, personal communication 1996.

[103] In a recent palynological study at Nemea, in the northeastern Peloponnesos, a rich deposit of organic material recovered in excavation was identified as grape pips, but no pollen of grape was found in the corresponding levels (Atherden, Hall, and Wright 1993). Macrofossil data indicate that the cultivation of grapes in southern Greece may have begun in the Early Bronze Age (Hansen 1988, p. 48).

[104] Wright 1972, p. 195.

diminished human land use. This period of barbaric raids and later of Slavonic invasions probably saw agricultural activity on a much-reduced scale.

The Period A.D. *1200–1500 (110–80 cm)*

During the period A.D. 1290 to 1420 (Table 11, p. 633) olive reaches another small peak of about 25% in the pollen samples, corresponding to 10% of land coverage. Decidous oaks and pistachio decrease in abundance and grape pollen appears for the first time. It would be plausible to assume that the correction factor of 560 years used for bulk-sediment samples is too high for the period after the closure of the sand barrier, because the reservoir effect decreased after the lagoon was separated from the Bay of Navarino. Hence, the last pre-Modern olive peak might also be attributed to a slightly earlier period, possibly the time between A.D. 1000 and 1200. A visitor to Messenia of that time, the English pilgrim Benedict of Peterborough, considered Koroni to be the biggest olive-production site in the world.[105] Parallel to the olive peak, the C/N ratio reached its all-time record, while $\delta^{13}C$ increased. Terrestrial organic matter seems to have risen at that time, indicating increased erosion.

The Period after A.D. *1500 (80–0 cm)*

Around A.D. 1700, corn (*Zea mays* L.) began to spread in Greece and to show up in the Osmanaga core. The olive reached a final maximum at 40% of the total pollen. Deciduous oaks disappeared almost entirely, much as they did in some other areas around the Aegean.[106] This may imply unprecedented human pressure on the landscape. Alternatively, some of the pollen of deciduous oaks in the past record may have belonged to valonia oak (*Quercus macrolepis*). Its large acorn cups were widely used for tanning, while pigs were fed with acorns four centimeters long. Groves of valonia oak were carefully maintained by selective elimination of other trees (Pl. 110:b). With the recent decline in the demand for natural tannin, the value of the oak decreased, and pure groves have survived only in remote areas of the Peloponnesos, for instance, 10 km west of Gythion and on the Mani peninsula, 10 km north of the village of Itilo.

GEOPHYSICAL INVESTIGATIONS

Because archaeological surveys are limited to surface observations, remains of architectural structures and other archaeological features buried in the ground cannot be detected. To estimate how much archaeologically valuable information might be concealed under the surface, we decided to employ geophysical sensing techniques in selected areas. Almost thirty years ago the Minnesota Messenia Expedition first applied these techniques with the crude instruments available at that time.[107] Today, geophysical prospection is conducted successfully on a number of archaeological projects in the Aegean.[108]

105 Topping 1972, p. 66.

106 See, for example, Van Zeist, Woldring, and Stapert 1975, p. 136; Jahns 1990, p. 334.

107 Rapp 1970; Rapp and Henrickson 1972.

108 E.g., Papamarinopoulos, Sarris, and Pavlopoulos 1993; Karastathis and Papamarinopoulos 1994; Becker and Jansen 1994.

Four artifact-rich sites were chosen for these investigations: the Hellenistic building at Romanou *Glyfadaki*, the Late Roman villa complex at Marathoupolis *Dialiskari*, the extensive prehistoric and historic POSI of Ordines, northeast of Marathoupolis, and the area immediately south and west of the fence around the Palace of Nestor. The main geophysical methods to be applied at those sites were magnetic and geoelectric mappings. A set of different devices was employed because the most suitable method depends on the physical and chemical properties of the soil, which vary significantly between the four areas chosen. Table 12 (p. 634) provides an overview of the methodological principles, the instruments used, and the areas covered with each of these techniques at the four archaeological sites. Only successful and useful measurements are indicated in this table. At all four sites, 10 × 10 m grids were set up with wooden pegs. Within those grids, readings were taken consecutively at one-meter intervals; only the FM36 mapping was performed in half-meter intervals. Geoelectric profiles were established along straight lines (Table 12: two bottom rows). In this instance readings were taken several times from varying distances, if necessary.

Glyfadaki

The first area chosen for geophysical measurements lies on a flat and well-defined fallow field near the peninsula called Glyfadaki, on the coast at Romanou (POSI E1; Fig. 2). In this field, systematic grid collection of artifacts by the archaeological teams produced evidence of a small but well-defined Hellenistic site.[109] In order to determine whether architectural remains are still preserved in the ground, various geophysical techniques were tested at Glyfadaki. Since this field had little plant cover, it offered a perfect testing ground for the equipment.

Previous studies by our team have found that geoelectric sounding provides valuable results when used for archaeometric purposes. At Glyfadaki, however, it failed completely. Very high contact resistivities in the surface soil, on the order of 50 kiloohms (kΩ) at each electrode, and shallow bedrock with low resistivity resulted in very low electrode currents with voltages too small to detect. Therefore, all geoarchaeological measurements at Glyfadaki had to be done magnetically.[110]

Two different magnetometers were employed to survey the site. An Overhauser gradiometer GSM-19G[111] was used to map an area of approximately 1,600 m^2. The instrument measures the earth's total magnetic field at 1.57 m and 1.00 m above the surface and calculates the difference between the two collected values. The second instrument, a fluxgate gradiometer FM36,[112] was employed to survey an area of about 2,000 m^2, coinciding with and extending beyond the first area measured. The fluxgate gradiometer detects the vertical gradient of the vertical component of the earth's magnetic field at 0.9 m and 0.4 m above the surface. At Glyfadaki, these measurements were usually conducted on a one-meter grid, although occasionally the spacing was reduced to half-meter intervals.

109 For a description of the pottery finds from the site (Romanou *Glyfadaki*, POSI E1) see Davis *et al.* 1997.

110 Examples of successful geoelectric soundings in Mediterranean environments are to be found in Kuhnke and Weidelt 1989; Fieberg, Johnson, and Sacker 1995.

111 Manufactured by GEM SYSTEMS Inc., Canada.

112 Manufactured by Geoscan Research, England.

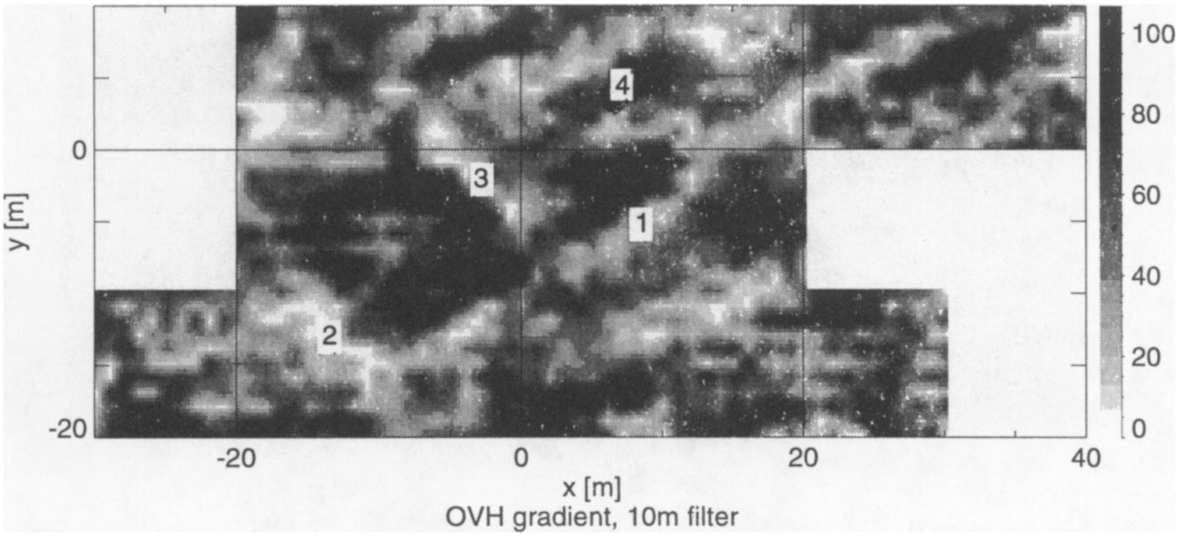

FIG. 27. Processed data of the magnetic gradient of the module at Glyfadaki, POSI E1 (Overhauser gradiometer GSM-19G) (Falko Kuhnke)

Archaeological remains typically cause gradients in the earth's magnetic field on the order of some nanotesla per meter (nT/m). The Overhauser's resolution of 0.01 nT and an accuracy better than 0.5 nT allowed for the detection of such buried remains. The fluxgate gradiometer, however, with a nominal resolution of 0.1 nT, showed strong drift and errors caused by misalignment of the sensors, which lead to heading errors. Since the accuracy of the fluxgate instrument is on the order of some nanotesla, which is also the magnitude of the signals expected from buried archaeological structures, the data collected with this device have to be corrected carefully to minimize the heading error caused by drift.[113] Corrected fluxgate measurements, however, are quite suitable for archaeometric purposes. The corrected and enhanced data obtained with both instruments are shown as dot density pictures in Figure 27, for the Overhauser magnetometer, and in Figure 28, for the fluxgate instrument. In principle, the images produced by the two techniques provide the same information. Because the Overhauser readings were taken at a greater height, however, its data plot appears smoother than that of the fluxgate. The sharper picture generated by the latter also contains more noise.

Since the area has been used as a vineyard and was therefore extensively plowed before it became fallow, we did not expect to find undisturbed architectural structures just below the surface. However, even magnetic signals of only 15 nT/m (Overhauser) or ±4 nT/m (fluxgate) produced clear and large patterns. We detected one linear structure over forty-five meters long, running at a 55° deviation from north (southwest–northeast), with two almost perpendicular lineaments attached to it (Fig. 27:1). The most prominent of these lineaments was at the western end of the investigated area and extended for

[113] Scollar *et al.* 1990.

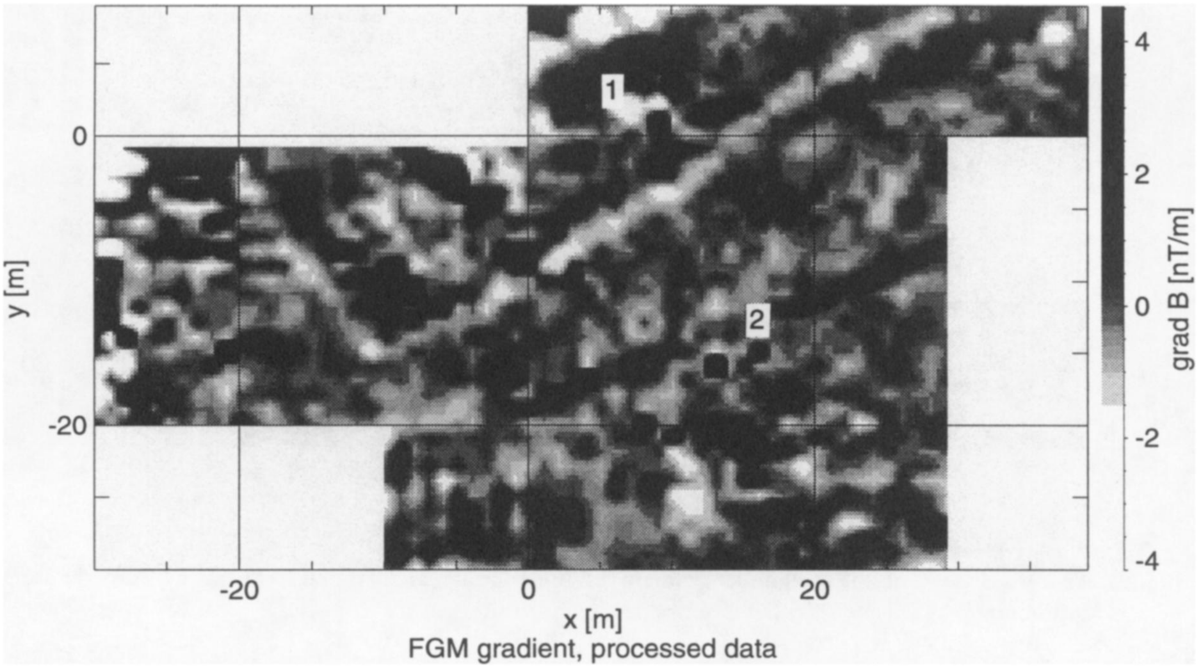

FIG. 28. Corrected and processed data of the vertical gradient of the magnetic field at Glyfadaki, fluxgate gradiometer FM36 (Falko Kuhnke)

approximately twenty meters (Fig. 27:2). It appears to reflect the outer walls of a large building of rectangular shape whose southwest corner shows up in the magnetometer plot. The second lineament, about fifteen meters east of the first, near the center of the chart (Fig. 27:3), seems to reflect an internal wall. A vague image of a third lineament appears another fifteen meters farther east and fades out to the north (Fig. 27:4). In Figure 28 this third line is interrupted by a big magnetic anomaly (Fig. 28:1). A second kind of lineament, approximately thirty meters long but opposite in magnetization, and therefore black (Fig. 28:2), was found running at a 68° deviation from north (southwest–northeast).

To be able to understand and interpret these magnetic lineaments, we carried out calibration experiments. In computer models we introduced bricklike bodies of different size and orientation with magnetic material of certain susceptibility and applied the ambient geomagnetic field of the location.[114] Subsequently, the true magnetic fields were calculated along certain lines crossing the model body at heights corresponding to the levels of the instruments. The results were compared with rearranged and median-filtered field data, and the control parameters were changed to achieve the best agreement between both data sets. The data were rearranged by squeezing or stacking most of them parallel to the anomaly. In other words, we calculated the perpendicular distance of all pixels from the lineament. Next, the new data set of distances and magnetic values was sorted with

[114] These model calculations were conducted with the kind support of Peter Weidelt and Fred Fieberg from the Institute of Geophysics and Meteorology at the Polytechnical University in Braunschweig.

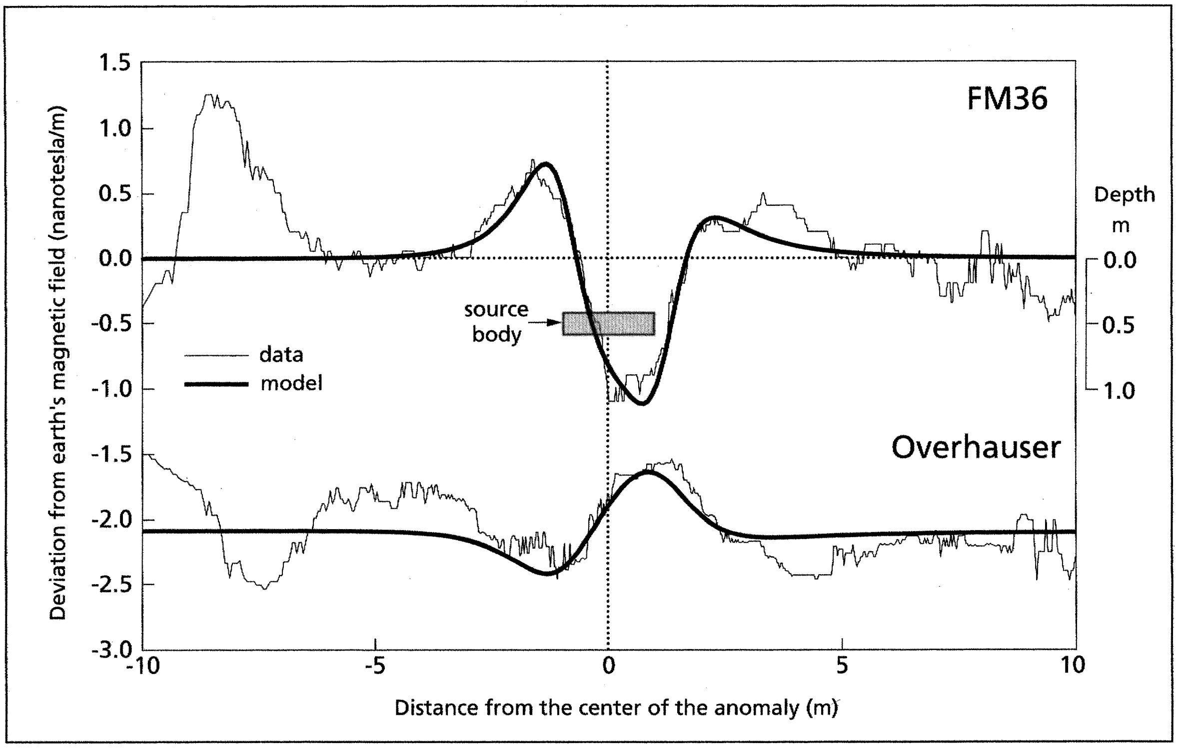

FIG. 29. Processed data across the white anomaly, including the results of model calculations (Fred Fieberg and Eberhard Zangger)

respect to the distance and afterwards median filtered with respect to the magnetic data. The filter length varied between ten and thirty elements. Using this approach, we were able to establish a model body showing the approximate dimensions and depth of burial of the source causing the anomaly.

The best models for the long white anomaly (Fig. 29) were achieved using only the induced magnetization. According to the computer model, the magnetized body is about 2 m wide and 30 cm thick, and its upper border appears to be approximately 0.4 m below the surface. Subsequently, shallow auger cores were taken at the maximum and minimum dimensions of the anomaly and in between the two, but no artifacts that would have explained the magnetic anomaly were found. Between 0.4 and 0.5 m, however, the plowed and incohesive brown topsoil (Munsell 5YR 3/3) changed into undisturbed red soil (Munsell 2.5YR 3/4), forming the Bt horizon of the typical clay matrix soils on the Late Pleistocene calcarenite dunes of this area. Passing with the FM36 gradiometer from the top to the bottom of the cores, we were able to detect a magnetization gradient at the soil boundary in 0.4–0.5 m depth on the order of 15 nT/m, measured at a distance of 0.1 m.

These observations are best explained by the previous agricultural use of the area. When the field was cultivated for vines, the uppermost 0.4–0.5 m was extensively plowed.

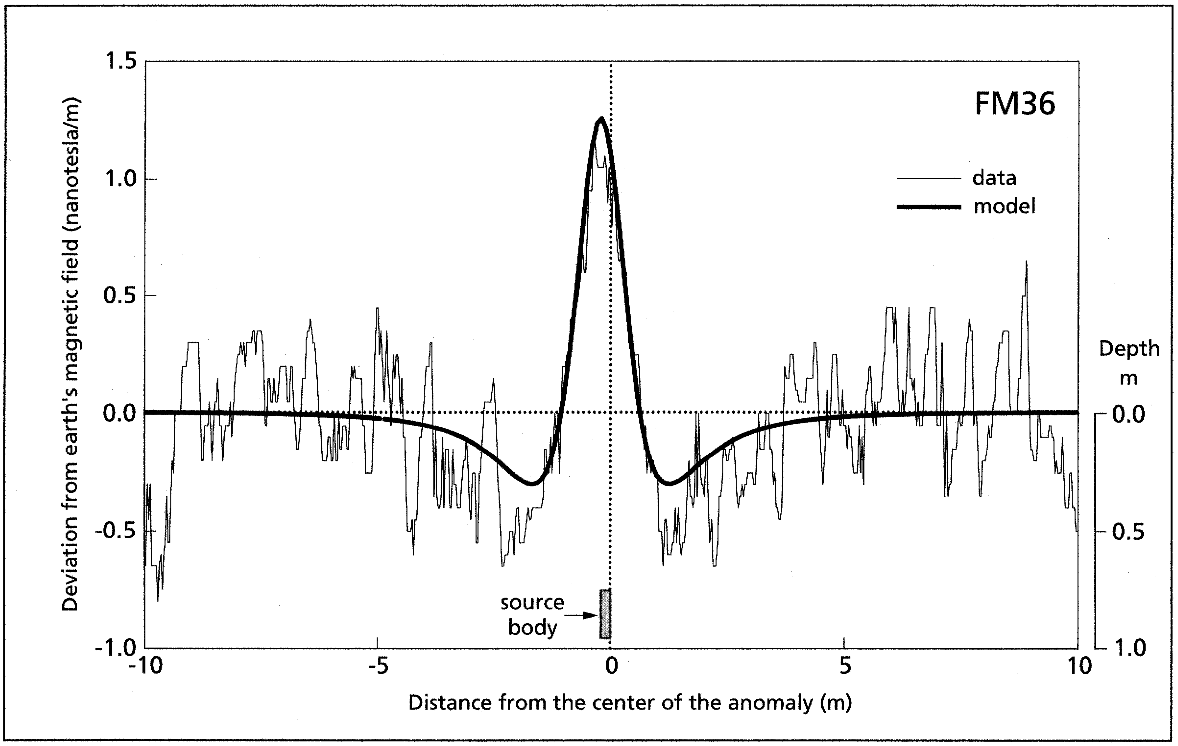

FIG. 30. Processed data across the black anomaly, including the results of model calculations (Fred Fieberg and Eberhard Zangger)

Below this layer, an induced magnetization remained undisturbed. Although we do not know the material that caused the magnetization, the red color of the soil argues in favor of hematite and other ferromagnetic minerals. The soil, including its magnetic minerals, was evidently compacted along the lineaments by the static pressure of the former building walls. While the stones of the walls have disappeared, probably because they have been reused elsewhere, the compacted soil below them remains.

The black lineament behaves completely differently in the computer models. Because it was most obvious in the FM36 record, we used only the data set obtained with this device for model calculations. A section across the anomaly (Fig. 30) produced symmetric curves on either side of the center of the anomaly. As induced magnetization would have caused a nonsymmetrical response in the magnetic record (as shown in Fig. 29), remanent magnetization has to be taken into account as the cause of the lineament. The remanent magnetic field of a source body of square cross section with 0.2-m-long sides, buried with its top edge 0.75 m below the surface and exhibiting a vertical magnetic moment of 0.3 ampere/meter (A/m), would match the field observations. Coring into the anomaly, however, produced the same geological sequence that was found in all the other cores from Glyfadaki. No buried structures were discovered.

Both types of lineaments at Glyfadaki seem to reflect images of architectural structures that used to exist there but whose building material has completely vanished. The magnetic differences picked up by the instruments apparently reflect soil diagenetic changes created by compaction below the formerly massive structures.

DIALISKARI

At Marathoupolis *Dialiskari* (POSI G1; Fig. 3), where a Roman hypocaust system is still partly preserved, a 46-meter-long and a 60-meter-long geoelectric profile were established in two consecutive years. Resistivity multiplexer measurements were conducted partly manually and partly automatically.[115] Using different electrode spacings in Wenner configuration,[116] we were able to produce a cross section with a maximum penetration depth of the apparent resistivity distribution of about five meters. To determine which features of appropriate resistivity best fit the measured values, the data were subjected to a two-dimensional inversion: a model calculation to identify the source of the anomaly (Fig. 31). In the resulting vertical profile, highly resistive areas stand out in black. The largest anomaly (Fig. 31:1) is a wedgelike high-resistive area beginning at 30 m and stretching to the end of the line, at 60 m. It probably reflects a change in the bedrock. A second anomaly (2) is superimposed on the previous one and seems to have been caused by an indentation in the adjacent terrace. The bedrock is covered by 2–5 m of sediment, which exhibits decreasing electrical resistivity with increasing moisture content. Near the center of the profile, between 18 and 30 m, we detected an anomaly in the uppermost meter, which seems to reflect caverns or preserved walls of the hypocaust system. Anomalies 3 and 4 are close to the surface. An electrode at 28 m hit an object within 0.15 m that may have been part of a wall causing anomaly 3. Anomalies 4 and 5 perhaps represent noncollapsed parts of the hypocaust system. Finally, the upper 0.30 m of the profile exhibits high electric resistivity because the topsoil has been loosened by plowing and dried in the sun.

Our reconnaissance at Dialiskari is a strong encouragement for the systematic three-dimensional tracing of hypocaust systems and similar architectural features on a two-dimensional grid, rather than along single profiles only.

MARATHOUPOLIS *ORDINES*

The site of Ordines (POSI K1; Fig. 3) lies about four kilometers north of Marathoupolis, on the top of a low hill. For the geophysical work we chose a fallow field that was mostly covered with grass and some bushes. A grid consisting of thirty-six 10×10 m squares was laid out and referenced to the center point (CP) and a second referenced point (2.P.), twenty meters distant, both of which were established during previous work by PRAP's archaeological team (Fig. 32). For convenience, we established a new center point for

[115] The geophysical fieldwork at Dialiskari in 1994 and 1995, as well as the analyses and computations of the results, were supervised by Axel Kampke from the Institute of Geophysics and Meteorology at the Polytechnical University in Braunschweig.

[116] In Wenner configuration, current electrodes (A, B) and potential electrodes (M, N) are set up in a sequence A-M-N-B.

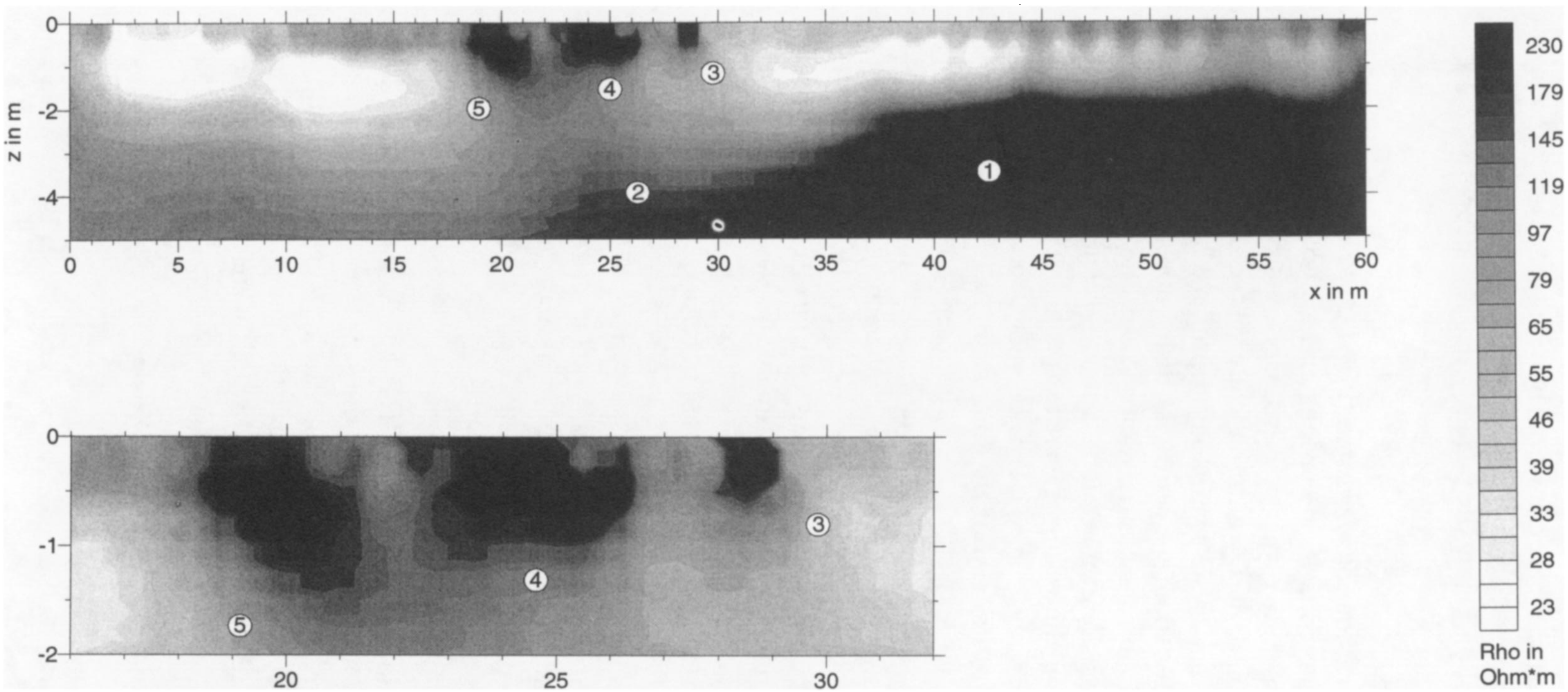

FIG. 31. 2D-inversion of the resistivity measurements across the Dialiskari hypocaust system (Axel Kampke)

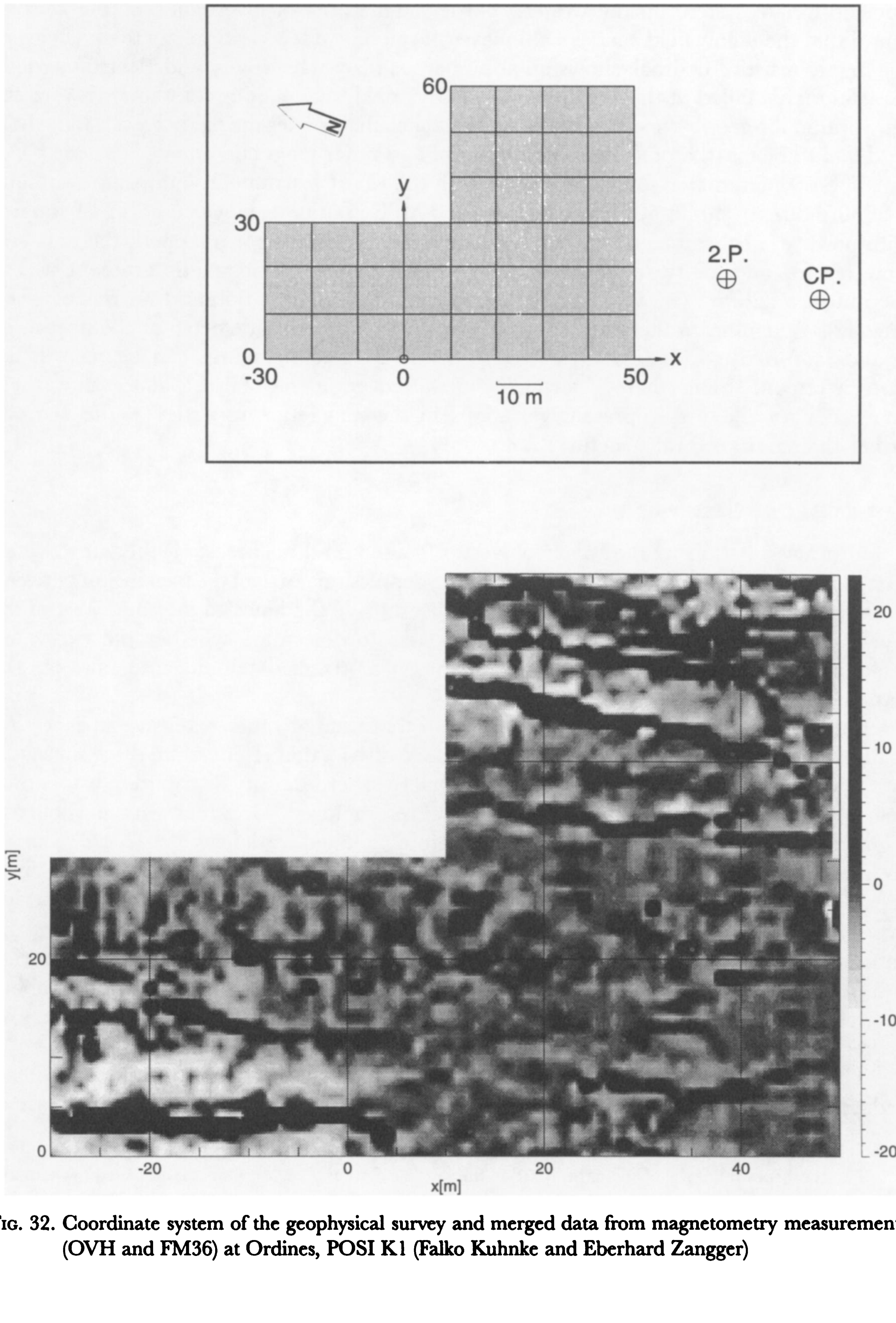

FIG. 32. Coordinate system of the geophysical survey and merged data from magnetometry measurements (OVH and FM36) at Ordines, POSI K1 (Falko Kuhnke and Eberhard Zangger)

our coordinate system on the western border of the area of investigation.[117] We soon found that the fallow field carries a thin layer of soil only a few centimeters thick. Because the highly resistive bedrock shows up at numerous places, resistivity and electromagnetic measurements failed at this location. As in Glyfadaki, magnetic measurements were the only option for geophysical prospection at this site. Before measuring, however, the whole field had to be cleared of shotgun ammunition and other magnetic litter.

The magnetometer survey was done with the OVH instrument within the rectangle [–30/0; –30/30; 50/0; 50/30], whereas the FM36 gradiometer was used in all squares with positive x-coordinates. In the area where the instruments overlapped, the data sets were leveled and afterward merged. In general, the vertical magnetic gradient was in the range of ± 20 nT/m, which yields a good signal-to-noise ratio and thus reliable data (Fig. 32). A significant anomaly approximately 35 m long was detected at the northwest boundary [–5/5] to [50/5]. More north–south-directed structures can be seen in the eastern region. Since there is virtually no soil covering the bedrock at this site, these anomalies are likely to represent variations in the magnetic properties of the bedrock rather than architectural structures.

The Palace of Nestor

Our investigations at the Palace of Nestor focused on three areas: (1) the unexcavated part on the plateau just east of the palace; (2) the depression north of the parking lot between the palace and the tholos tomb; (3) the area just outside the fence to the southwest of the palace. The purpose of these investigations was to determine whether the excavated building remains of the LH IIIB palace rest on a stratified tell site and how far the settlement remains extend laterally.

Our approach at the palace was similar to that used at other extensive surface sites in the study area. Except for the part of the palace district that is fenced in, these sites were first grid-collected by field-walking teams, so that the sherd-density distribution was known before geophysical and geological methods were employed. In areas with particularly high sherd counts, magnetometer surveys were conducted to determine whether buried architectural remains existed beneath the surface. In addition, hand cores were taken to provide more information about habitation layers in the subsurface. The initial working hypothesis for the coring campaign was formulated during the planning stage of the natural scientific research on PRAP: At least some cores can be expected to penetrate 2–3 m into cultural deposits, thereby providing valuable stratigraphic information about an area that is, first of all, untouched, and second, highly promising with respect to future archaeological excavations.

The auger cores showed, however, that on the plateau north of the palace the marl bedrock lies only 20–30 cm below the surface (Table 13, p. 635). This means the Palace of

[117] The centerpoint has the coordinates [0/0] in the x-y grid system (Fig. 31). Coordinates such as [–30/20] indicate the distance in meters from the center point. The first value corresponds to the x-axis, the second to the y-axis.

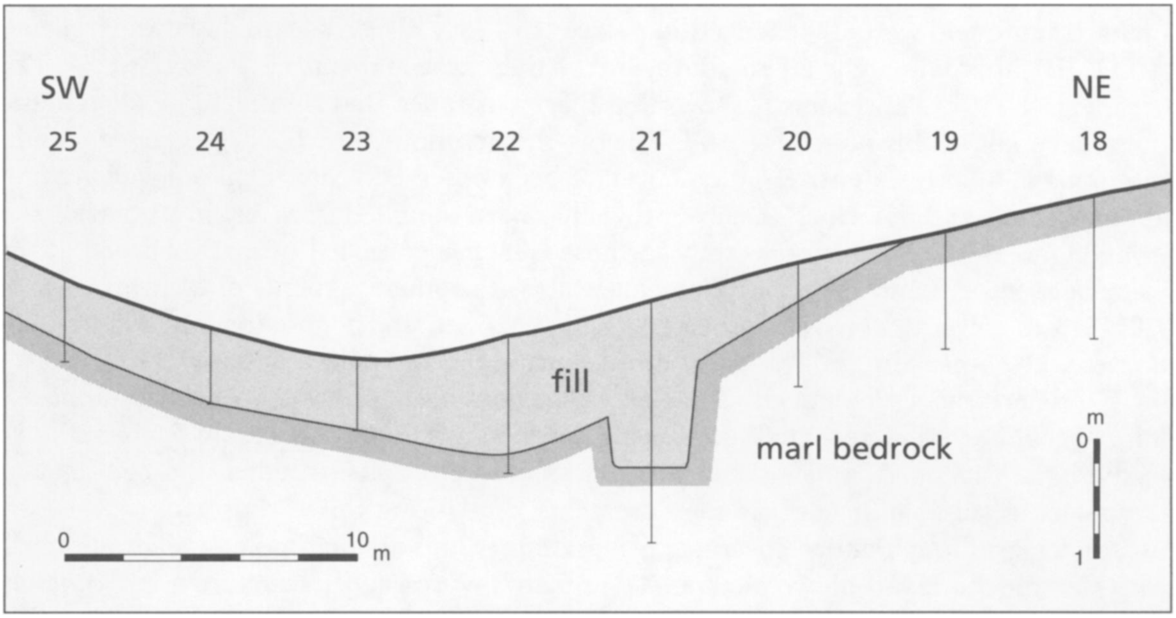

FIG. 33. Auger core traverse from the depression between the Palace of Nestor and the palace tholos (Eberhard Zangger)

Nestor is founded directly on bedrock and, therefore, is not a tell site; all significant structures seem to have been cleared by Blegen and his team of excavators. The ridge appears to have been leveled in the Bronze Age before the final building was constructed. Artifacts, or even foundation walls from earlier periods of habitation, are likely to be limited to pockets and depressions in the bedrock only. In Blegen's final publication of the site, it is frequently stated that *stereo* (bedrock) was encountered just below the plowed soil and that Bronze Age building foundations are restricted to former depressions in the surface.[118]

The situation is even more dramatic on the flat ground west of the main parking lot. There, eight auger cores were taken at five-meter intervals in a straight southwest–northeast cross section between the tholos tomb and the Late Bronze Age staircase to the palace (Fig. 33). In most places marl bedrock either cropped out at the surface or was encountered within the first meter of the bore holes, a finding that accords well with an observation made by Blegen and John Camp, who together conducted a sondage in this area in 1968. Camp found the bedrock at a depth of little more than 0.25 m[119] except for a deep hollow that was excavated to a maximum depth of 4.25 m but is now covered by the parking lot. One of our cores apparently hit their excavation trench, so that we encountered the marl at 1.4 m depth. The whole depression is filled with less than one meter of unstratified debris.

[118] Blegen *et al.* 1973, pp. 59, 61.

[119] Blegen *et al.* 1973, p. 65.

The So-called Lower Town

The third area of major interest for archaeological prospection is the terraced olive orchard south and west of the fenced-in palace. In 1959, Blegen's team dug three trenches (LT I–III) approximately 20 m southwest of the excavated palace buildings.[120] The acronym "LT" for "lower town" shows that Blegen assumed that a settlement belonging to the palace lay in this area. He said, "Below the acropolis on which the palace stands, remnants of a fairly extensive settlement have been observed. Almost all our information about the houses that formed the lower town has been obtained from exploratory trenches in many areas."[121] The stratigraphy in those trenches consisted of marl bedrock at the base, between 2.0 and 1.6 m, Mycenaean walls with some fragments of Minyan ware at 1.65–1.3 m, several LH IIIA stone walls at 1.3–0.6 m, and foundations of solidly built houses with some substantial rooms from the era of the late palace at 0.6–0.3 m.

To determine systematically the extent and continuity of structures in this area, we initially conducted a reconnaisance using an array of different geophysical methods, including a digital ground-resistivity meter,[122] to determine whether the soil around the palace is suitable for electric measurements.[123] During this early stage, we set up a two-meter grid to maximize coverage, using Wenner and dipole-dipole configurations[124] with electrode intervals of two meters. A dominant low-resistivity structure approximately five meters wide was picked up during the geoelectric measurements. We assumed that it was caused by an increase of moisture in the subsurface. Since there are no indications that this structure was generated in recent times, it might well have been produced in the past, for instance by compaction along a much frequented dirt road. However, geological processes cause similar resistivity anomalies too, and further measurements were required to establish the true nature of the lineament.

Between field seasons, the farmers had cleared the olive orchards of shrubs and bushes, thus offering an almost ideal ground for geophysical prospection. For the final measurements we established a grid of 10 × 10 m squares covering a total of 10,150 m^2, with a maximum northwest–southeast extension of 180 m and a maximum northeast–southwest extension of 90 m (Fig. 34).[125] The first device used at the palace was the FM36 vertical gradiometer, which provides sharp responses to buried anomalies because its sensors are close to the ground. To avoid time- and temperature-dependent deviation, the instrument was recalibrated after each grid. Additionally, all grids were surveyed twice in perpendicular directions to eliminate chessboardlike patterns. In the raw data collected by this instrument the biggest anomaly was produced by the metal fence around the archaeological site. This disturbance was subsequently filtered out during data processing.

[120] Blegen *et al.* 1973, p. 53 and fig. 312.

[121] Blegen *et al.* 1973, p. 47.

[122] GEOHM_3 manufactured by Gossen, Germany.

[123] A detailed description of this instrument can be found in Lehmann 1993.

[124] In dipole-dipole configuration, current electrodes (A, B) and potential electrodes (M, N) are set up in a sequence A-B-M-N.

[125] We are most grateful to Frederick Cooper and Michael Nelson for kindly providing us with digital and hard-copy versions of their map showing the architectural remains of the palace and the topography around it. Figure 34 is based on this information but has been modified.

FIG. 34. Coordinate system of the geophysical survey south and west of the palace (Falko Kuhnke, Frederick Cooper, and Eberhard Zangger)

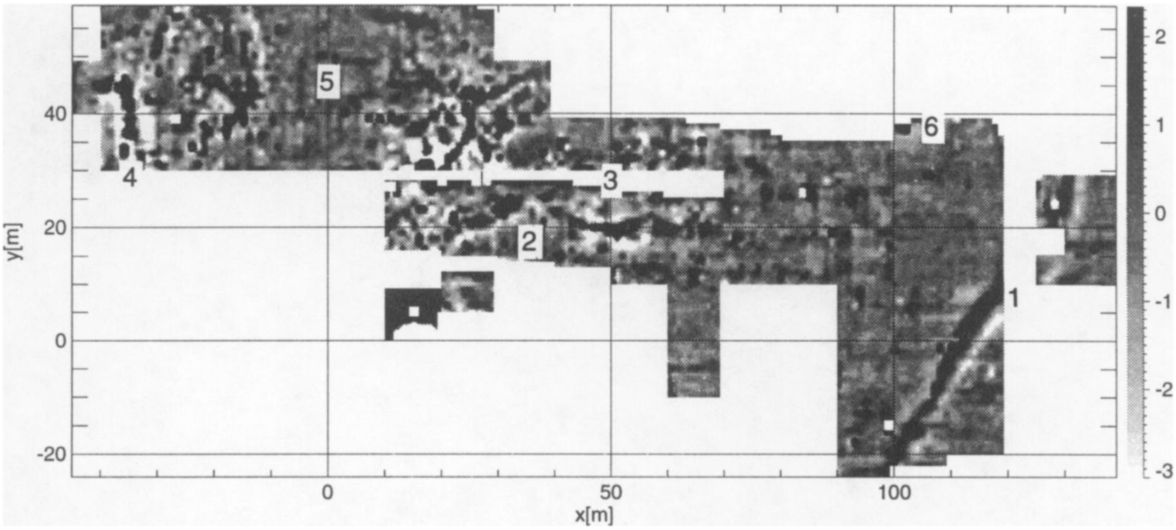

FIG. 35. Raw fluxgate gradiometer FM36 data south and west of the palace (Falko Kuhnke)

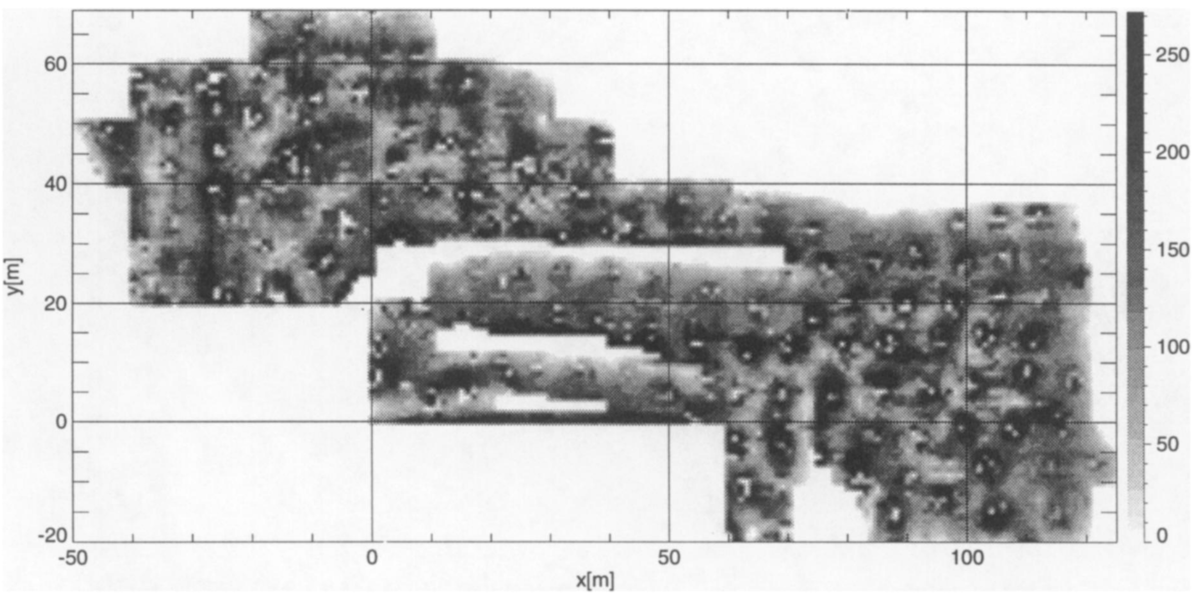

FIG. 36. Electromagnetic EM38 data: apparent conductivity (Falko Kuhnke)

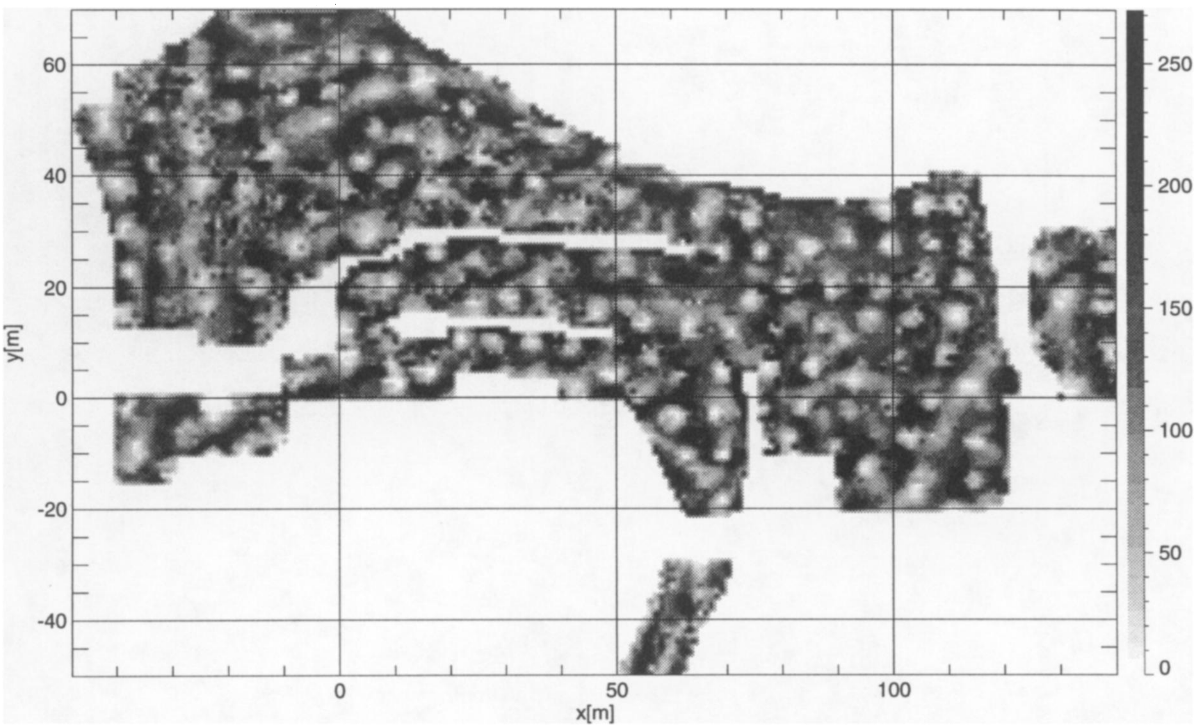

FIG. 37. Wenner and dipol-dipol resistivity measurements merged and locally filtered (Falko Kuhnke)

A genuine anomaly, 60 meters long and several meters wide, was found on the western side of the gridded area (Fig. 35:1). In addition, a rectangular structure (Fig. 35:2) shows up at [10/20], [20/20], [35/25], and [50/20]. The right part of this anomaly converges into a circular structure (Fig. 35:3) with a radius of about ten meters centered at [50/30]. Another prominent rectangular structure (Fig. 35:4) appears adjacent to the modern road at [–35/40]. Some faint rectangular features (Fig. 35:5) can be seen around [–5/ 40], [–5, 50], and [10/50]. Applying histogram filters to the raw data helped to emphasize small differences and to detect previously less visible structures, for instance another rectangular feature (Fig. 35:6) at [100/30], [112/30], and [112/40].

A completely different image was created using the EM38 instrument. The data plot produced a smooth background showing many dark patches with white spots (Fig. 36). This pattern is related to the olive trees and probably caused by high levels of soil moisture around the roots, creating above-average conductivity. Because the depth of signal penetration is approximately half a meter, the anomaly on the west side of the gridded area that was prominent in the FM36 data set was not picked up by this instrument.[126]

The third method used in this area was a resistivity survey. All the grids were measured twice, once in Wenner and once in dipole-dipole configuration. Afterward both data sets

[126] The alternative explanation, that the anomaly has no effect on the electric conductivity, seems less likely because of the distinct resistivity measurements.

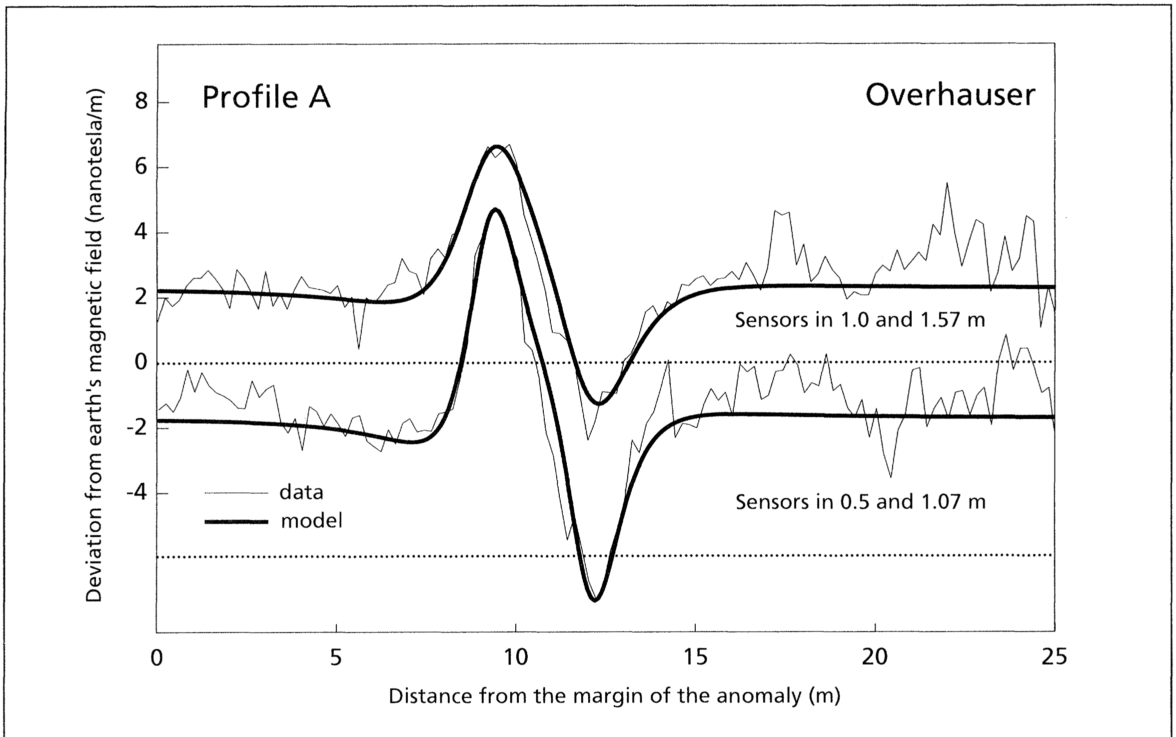

FIG. 38. Raw and model data along section A across the prominent anomaly (Fred Fieberg and Eberhard Zangger)

were combined to reduce noise. In the resulting locally filtered image, the apparent resistivity (the inverse of the conductivity) of the olive trees stands out as white spots (Fig. 37). Since the electrodes are spaced at one-meter intervals, the resistivity array of four electrodes is three meters long, which means subsurface information for the range of 1–1.5 m is collected. Hence, objects producing anomalies detected by this system can be expected to lie 1.5 m or less below the surface. Some anomalies that fell within this group were detected at [–10/50] to [20/55] and at [–20/10] to [-20/60]. Even the circular structure centered at [50/30] can be seen.

The fourth and final method, the OVH instrument, was used over the entire grid. In general the gradient of the total magnetic field was in the range of –5 to +16 nT/m. Strong magnetic anomalies show amplitudes of ~10 nT/m at [50/20], close to [0/20], in the region [20/30] to [29/49], and adjacent to the modern road at [–35/30] to [–35/50]. These anomalies may well reflect preserved parts of buried architectural remains.

The most distinct anomaly is the 60-meter-long lineament stretching from coordinates [100/–20] to [140/30] in the FM36, OVH, and resistivity measurements. A steeply sloping two-meter-high terrace caused a small data gap in this anomaly at approximately [120/10], but on both terraces the lineament appears to be identical in the magnetic and resistivity plots and thus seems to continue undisturbed. The eastern end of the

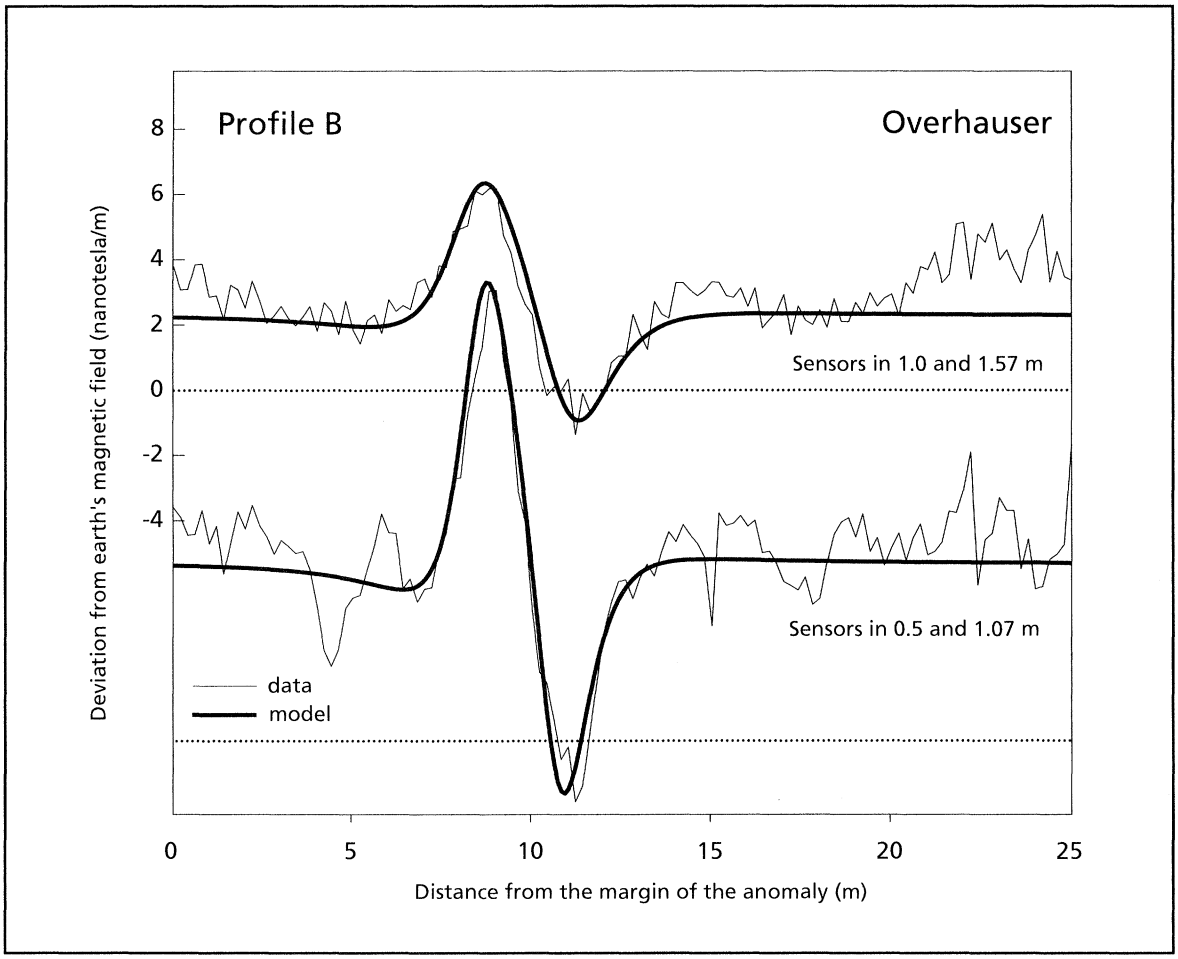

FIG. 39. Raw and model data along section B across the prominent anomaly (Fred Fieberg and Eberhard Zangger)

anomaly could be traced to the edge of the terrace, where the field breaks off in a steep, four-meter-long slope.

To determine the size and depth of the source causing the anomaly, Overhauser gradiometer readings were collected in two sections perpendicular to it. The first profile (A; Fig. 38) crossed the anomaly at approximately [109/–7], the second (B; Fig. 39), at [108/–9]. These profiles were two meters apart and parallel to each other. In each profile two different heights were used for the pair of sensors: 0.5/1.07 m and 1.0/1.57 m. The data collected from these profiles were used in computer simulations to calculate the response of a model magnetic body, which would aid in determining the dimensions and depths of the material causing the anomaly. The field measurements and the computed models coincide rather well, as do the model bodies determined for the two individual profiles (Figs. 38, 39). According to these computations, the upper boundary of the source causing the anomaly seems to be one meter below the surface and is certainly not deeper

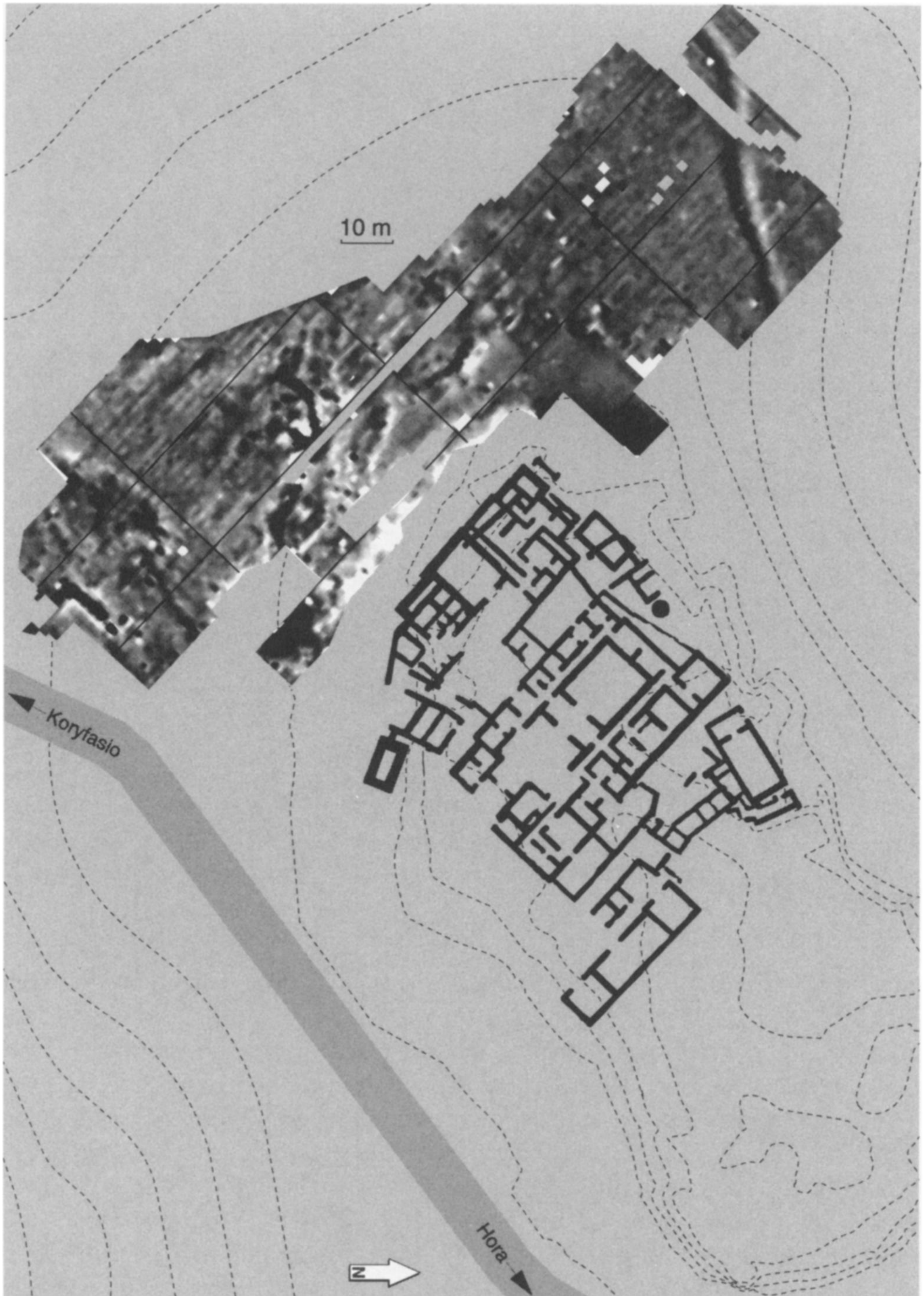

FIG. 40. Composite map of the Palace of Nestor showing architecure, topography, and processed Overhauser data (Falko Kuhnke and Eberhard Zangger)

than 1.5 m, results that confirm the depth values collected during the resistivity soundings. The width of the source appears to be approximately 2–2.7 m. Its vertical thickness cannot be accurately established, but the value provided by the computer model (0.5 m) seems to be a reasonable lowest estimate. The calculated strength of the magnetization is approximately 0.175 A/m. It appears unlikely that modern installations such as pipes or cables could cause this prominent anomaly. Without excavation it is impossible to establish its precise cause. Since the anomaly runs roughly parallel to the contours on the steep northwestern side of the ridge (Fig. 40), and since it continues beyond a modern two-meter-high terrace, it may well indicate the remains of a massive fortification.[127]

BRONZE AGE HYDRAULIC ENGINEERING

One of the most challenging problems associated with the landscape around Pylos is the possibility of an artificial stream diversion just north of Romanou. The topographic contour pattern of the coastal plain north of Osmanaga lagoon has the shape of an alluvial fan, suggesting that a massive amount of sediment was deposited there in recent times. Between Romanou and Koryfasio, where the coastal plain reaches elevations of 14–20 masl, Kraft and his coworkers found up to 24 m of early to middle Holocene floodplain deposits.[128] The existence of such massive deposits can only be explained if there was a river feeding fan and floodplain with sediment (Fig. 41). Today, however, the only large stream in the area, the Selas River, exits into the Ionian Sea, avoiding the alluvial plain north of Osmanaga lagoon (Fig. 42). The floodplain has even become inactive and is now an erosional rather than a depositional environment. Evidently, during the first half of the Holocene, when these large quantities of sediment were deposited, the stream must have used a different channel, one that ran south to exit into the Bay of Navarino. No later than 800 B.C., when Osmanaga lagoon formed, the Selas River must have changed direction and assumed its present course; otherwise, the lagoon would have long ago filled in.

That the Holocene change in riverbeds might well be due to anthropogenic interference was first suggested by Kraft and his coworkers: "At some time the river was diverted into its present flow pattern to the west. The authors consider it a possibility that man caused a diversion of the river by cutting a gap north of Romanou."[129] Kraft and his team suggested that this diversion was produced by Mycenaean engineers, whose goal may have been the removal of all major flood problems in the coastal plain in order to make the plain more habitable and to improve the agricultural potential of the floodplain.

Hydrology of the Selas River

During our investigation of the stream diversion we found that because of the relatively steep gradient of 5%, no more than 25–35% of the floodplain would have been under

[127] Further tracing of the anomaly during July 1997 confirmed the impression.
[128] Kraft, Rapp, and Aschenbrenner 1980, p. 197.
[129] Kraft, Rapp, and Aschenbrenner 1980, p. 195.

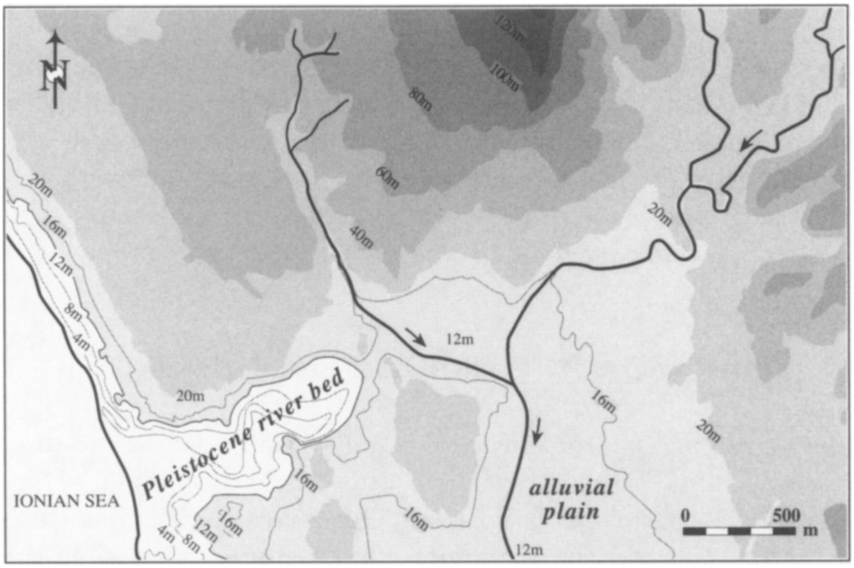

FIG. 41. Reconstruction of the course of the Selas River during the Early Holocene (Eberhard Zangger and Rosemary J. Robertson)

water even during major floods.[130] Hence, there was no real threat of flooding to anyone who might have lived in the floodplain. On the contrary, the inundations during the winter would have enhanced the agricultural value of the land. An artificial diversion of the river to prevent floods was therefore unnecessary.

Searching for clues that might explain the diversion, we focused on the new course of the Selas River, beginning where the stream takes a sharp westward turn toward the Ionian Sea. This bend is where the only road from Romanou to Tragana crosses the riverbed, by means of a wide concrete bridge. Beyond the bridge, the river follows a straight section 300 meters long, with a gradient of 7%. It then enters a small alluvial plain, where it bends in a pronounced meander (gradient 1.25%) and finally cuts through a steeply walled canal at the place marked "Ayios Dimitrios" in Figure 42. Stereoscopic aerial photographic interpretation shows that this canal dissects the highest part of a ridge, which could have been avoided by a small natural meander of less than two hundred meters. In the canal, large square conglomerate boulders with right-angle surfaces are falling from the banks. Although these boulders seem to be created by roots fracturing the bedrock, the original pattern of perpendicular fissures, cracks, and faults may have

[130] The drainage of the Selas River to the divide marked on Figure 46 comprises approximately 92 km^2. Its highest elevation is the top of Mount Aigaleon at 1132 masl, the lowest at 15.5 masl. The average elevation of the drainage is approximately 350 masl. The average annual precipitation at sea level is about 625 mm, equivalent to 900 mm across the entire drainage (N). The empirical value for maximum rainfall in 24 hours is 10–20% of N, thus 90–180 mm in this area (on December 2, 1905, a rainfall of 204 mm was measured in Kalamata). Average downpours usually reach 50% of the maximum value, equivalent to 2–4 mm per hour, or 50–100 mm per day. The maximum runoff of the Selas is 50–100 m^3 per second.

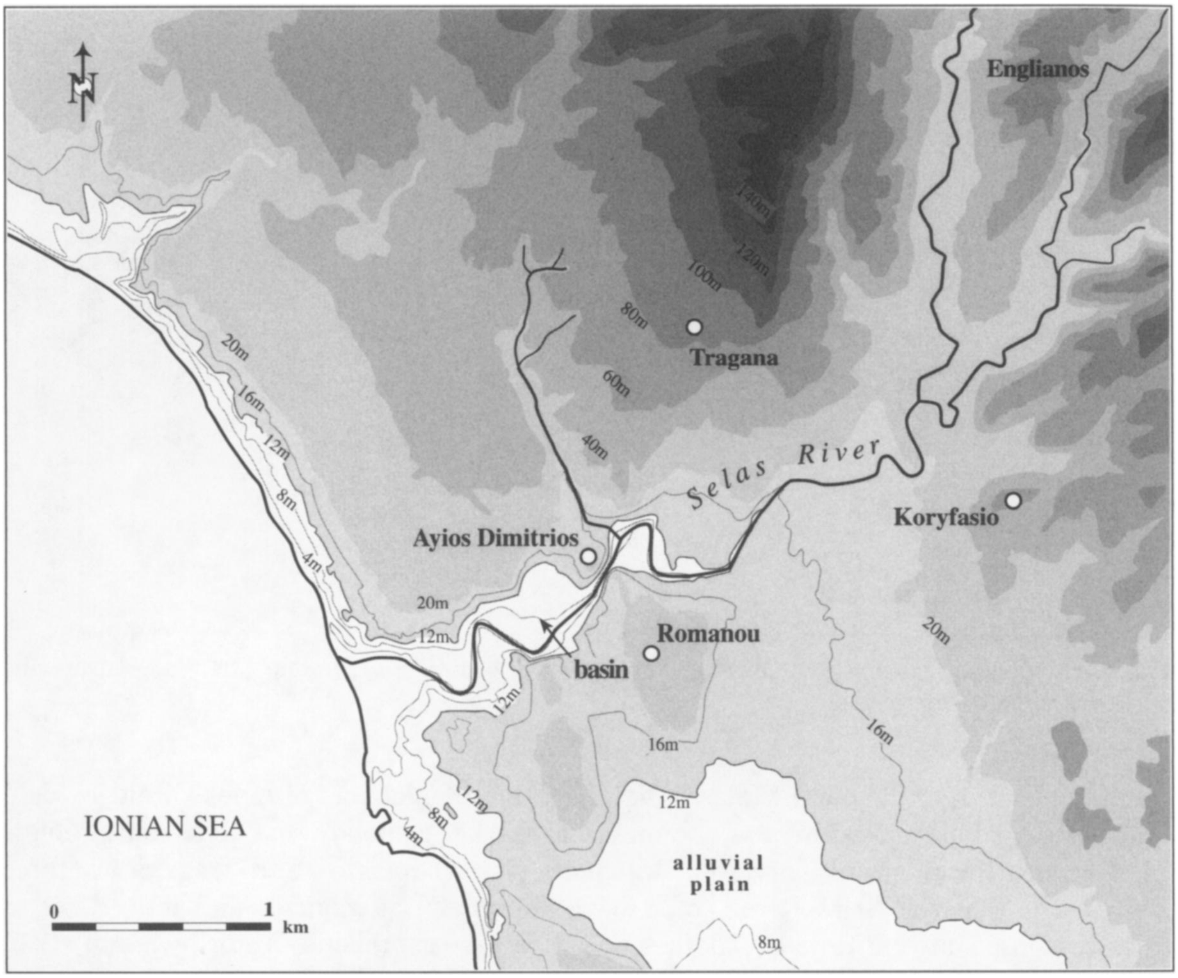

FIG. 42. Present-day topography between the Palace of Nestor and the Ionian coast (Eberhard Zangger and Rosemary J. Robertson)

been generated anthropogenically. In most places this canal is so densely overgrown that detailed investigation seemed impossible. We determined its width to be about 80 m at the top and 16.5 m at the bottom of the streambed. Its depth is 13 m. The lowest part of the incised bed is currently (in 1995) at 7 masl (Fig. 43).

That the canal did not form naturally is evident from a topographic profile extending from the valley flanks at Koryfasio in the east to those at Tragana in the west (Fig. 43). This profile shows two elevations, with the modern village of Romanou resting on the highest of these. The second is much smaller in size and height but is located right next to the deeply incised canal. Looking south from Tragana, this smaller elevation is easily recognizable because it is crowned by the now dilapidated former residence of the Kokevis family, to whom much of this area belonged until the 1970's (Pl. 112:b). The building is said to have been originally constructed as a station for a railway link to Kyparissia that was never

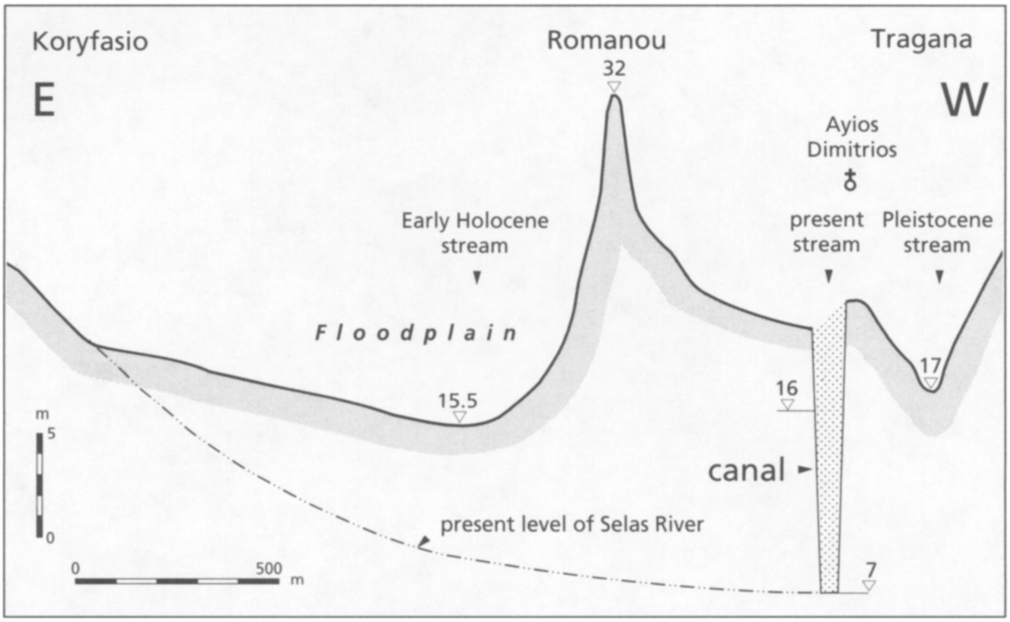

FIG. 43. Topographic section from Koryfasio to Tragana; vertical exaggeration 50x (Jost Knauss and Eberhard Zangger)

finished. Instead of the name Kokevis, however, the small chapel of Ayios Dimitrios right in front of the villa is used here as a toponym to mark the knoll on the maps and profiles.

Between the ridges of Koryfasio, Romanou, Ayios Dimitrios, and Tragana are three depressions that the Selas River could have chosen for its course, and indeed seems to have chosen at one time or another.[131] The first depression is northwest of Ayios Dimitrios, between the Kokevis villa and Tragana, and its saddle lies at 17 masl (Fig. 43). This depression seems to have been the bed either of the Selas or of its tributary, the Tsoukalorrema, during parts of the Pleistocene. The second depression, which seems to have been used by the stream for a few thousand years, is the present bed of the Selas, only 30 m southeast of Ayios Dimitrios. Finally, the third depression is the floodplain east of Romanou, where the lowest point of the divide lies at 15.5 masl. This course must have been used by the Selas during the first half of the Holocene, when most of the floodplain deposits formed.

The elevations of the lowest parts of the divide help determine the height of the saddle near Ayios Dimitrios at the time of the stream diversion. It must have been lower than 17 masl, for otherwise the Selas would have chosen a course through the westernmost gap. Since the original surface must have been between 20 and 21 masl, the initial canal had to be at least 3–4 m deep. Subsequent stream incision lowered the bed until it reached the present level of 7 masl.

[131] The course of the divide is indicated on the map in Figure 46.

The Basin

Beyond the canal at Ayios Dimitrios, the Selas passes through a well-defined rectangular alluvial plain that is about 330 m by 230 m and unusually flat at the surface (Fig. 42; Pl. 112:b, c). Although the surrounding bedrock consists of Tyrrhenian calcarenite, the surface of the alluvial plain is covered with a clayey soil. It appears to have been an inland water-filled basin that is now silted up.

In order to determine the character of the basin, we took five hand-auger cores from the floodplain southwest of Ayios Dimitrios, but all of them terminated in stream-gravel deposits before reaching the bottom of the Holocene sediments. In one core, reduced gley colors indicated deposition in a standing-water environment. Next, we hired a local well builder with a rotary drill rig to penetrate the gravel layers and to determine the entire Holocene stratigraphy (Fig. 44). Four power holes (Fig. 44:A–D) were placed in a straight cross section running diagonally through the plain. The holes were spaced at 80 m intervals, and their depths varied between 16 and 18 m. The lowest stratigraphic unit found in the holes is a bluish marine clay of Pleistocene age whose upper boundary is 12 to 15 m below the present surface. The driller indicated that this deposit continues at some places around Romanou for up to 200 vertical meters. In the two northern holes the marine clay is covered by several meters of calcareous sandstone, representing the bedrock on this side of the plain. In the southern half, a subaqueous deposit at 6 to 12 m depth confirms the existence of a silted-up basin.

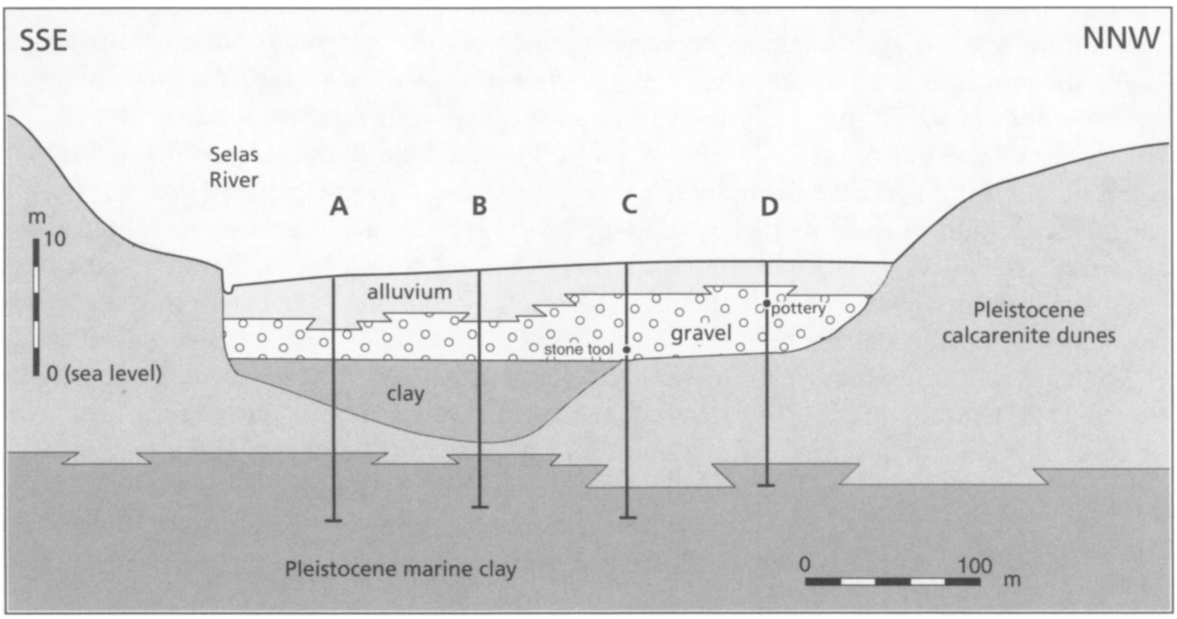

Fig. 44. Cross section through the basin west of Ayios Dimitrios showing locations of drill holes A–D (Eberhard Zangger)

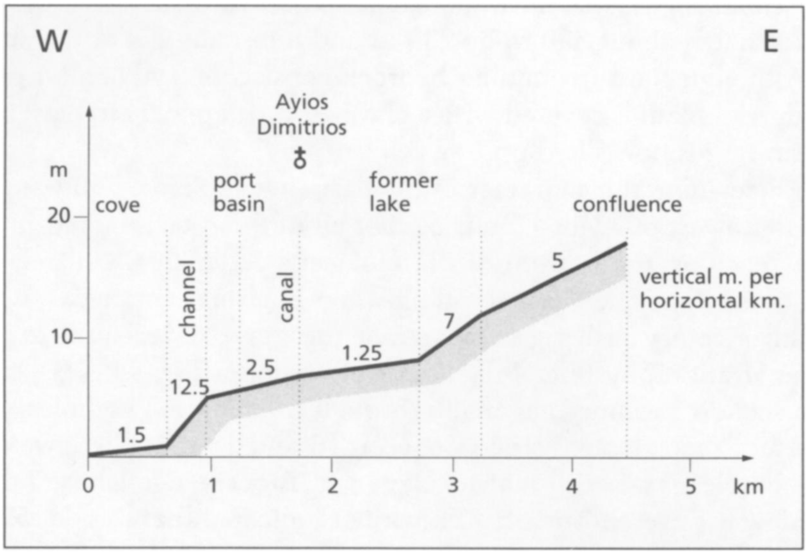

FIG. 45. Gradient of the Selas River before it exits into the Ionian Sea (Jost Knauss and Eberhard Zangger)

To determine the precise character of the subaqueous environment by microfossil analyses, samples were collected from the bore holes at one-meter intervals.[132] Most samples from the clay layer (A 6, A 8, A 9, A 10, B 7, B 9, B 10, B 13) were found to contain marine planktonic Foraminifera, including the genus *Globigerina* mostly in numbers >100, arguing in support of a subaqueous environment with considerable marine impact. These Foraminifera were accompanied by some ostracods from genera occurring in marine, brackish, and limnic conditions (e.g., *Aurila*, *Ilyocypris*, *Darwinula*, *Cypris*). Some samples contained fewer fossils, probably indicating temporary freshwater influences.

At the deepest location in the cross section (Fig. 44: hole B) the clay layer is about 6 m thick. The basin must have been open for a considerable period of time in order to permit the accumulation of this much clay. The top of the clay layer lies about one meter above sea level. If the water level in the basin corresponded to sea level, the area must have been uplifted by one or two meters since the basin was abandoned. Such a rate appears reasonable, considering the fast rise during the Pleistocene[133] and the steep gradient of the Selas River in its final section through the channel (Fig. 45), which might partly be the effect of tectonic uplift. Nevertheless, the vertical movement is one of several sources of error involved in this kind of investigation. Others are the unknown rate of eustatic sea-level rise (which we estimate to have been less than one meter since the end of the Bronze Age[134]) and the uncertainty about the precise level of stratigraphic boundaries in rotary drill holes (which also should be less than one meter).

[132] The sample processing and microfossil determinations were conducted by Dr. Thomas Jellinek and Doris Klein at the Senckenberg Institute in Frankfurt am Main.

[133] Kelletat *et al.* 1976, p. 448.

[134] Zangger 1993, p. 67.

The Port of Pylos

The rectangular shape and the steep walls of the basin argue in favor of an anthropogenic origin. Since there are no natural processes at this particular location that could create and maintain a marine basin half a kilometer landward of the coast, the sedimentological analyses also confirm the idea that the pond was at least in part created artificially. Evidently it represents a natural depression (Fig. 41) that was made deeper and wider. The fossil dunes surrounding the depressions are an ideal material for producing such a basin because they are soft enough to be quarried but also sufficiently well indurated to prevent steep walls from collapsing. Because the plain lies only 500 m inland of the coast, the most likely explanation for such an artificial basin would be that it was constructed to serve as a sheltered port.

The whole coastal indentation at Romanou consisted of three parts (Fig. 46): a funnel-shaped cove, a narrow and sharply turning channel, and the broad basin. The cove is now largely filled with beach sand, which blocks the river mouth during much of the year and renders it unnavigable. As this sand was most likely deposited after the diversion occurred, the cove would have been open while the Selas exited into Osmanaga lagoon. At that time, the cove would have offered a reasonably suitable natural harbor, quite likely the first one to be used by seafarers in this area. Later on, when engineering skills and

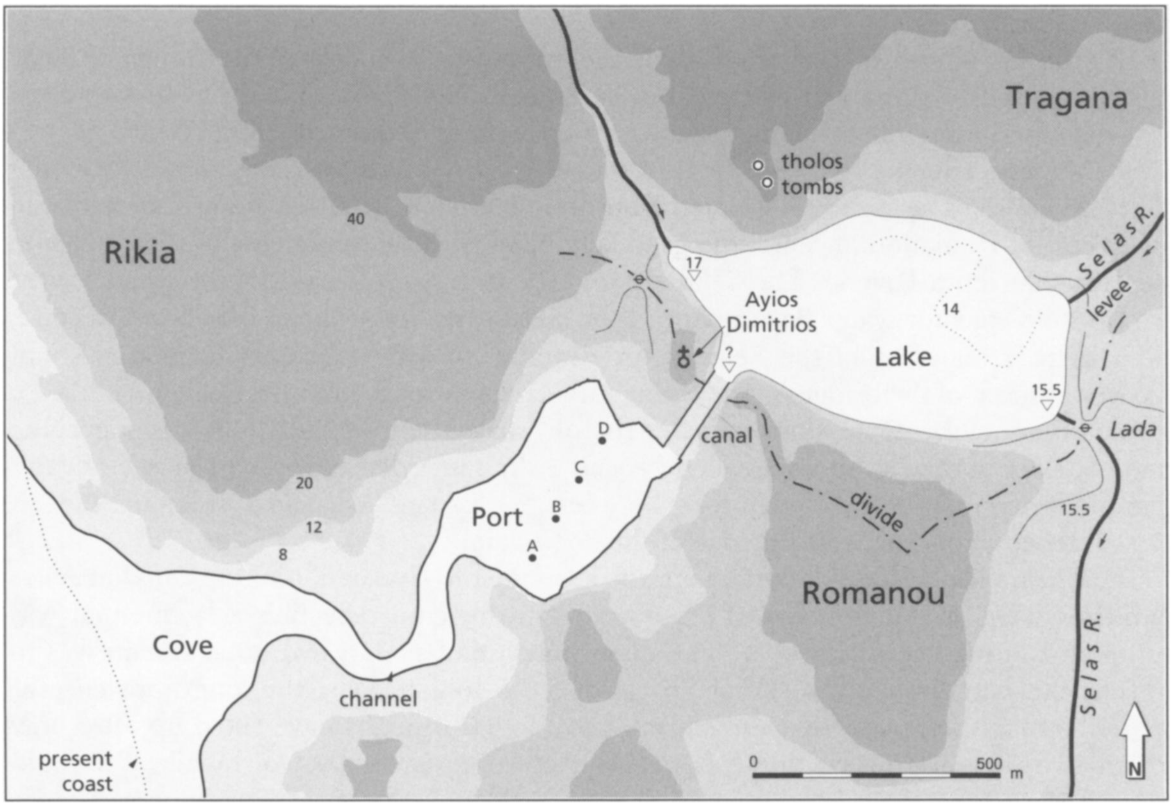

Fig. 46. Reconstruction of the Late Bronze Age port of Pylos, with location of drill holes A–D (Jost Knauss and Eberhard Zangger)

political power permitted, the indentation was artificially opened. After entering the cove, ships would have faced a narrow channel, only 40–50 m wide, that was easily controlled. A tidal range of half a meter may have helped ships navigate through this channel, although they could have been towed as well. A low topographic ridge forced the channel into a sharp turn and also offered the additional advantage of concealing the port basin and its entrance. Thus the port offered ideal protection not only from enemy attack but also from wind and waves.

Today, the most promising area to search for preserved port installations is probably on the northern side of the alluvial plain, where the knoll of Ayios Dimitrios intersects the basin. In this area, the edge of the basin follows perfectly straight lines. At the same time, it is so steep that the artificial shape of the topography becomes most obvious. Right where the road from the Kokevis estate meets the bottom of the plain, large conglomerate boulders crop out at the surface. Whether or not this conglomerate represents autochthonous bedrock is uncertain.

The Hydraulic System

Finding the port basin did not explain why the Selas River had been diverted. Redirecting the entire river through the basin does not make sense because the sediments carried by the stream would rapidly fill the basin. Yet, the artificial canal at Ayios Dimitrios was obviously related to the basin, assuming, of course, they were both constructed at the same time.

At the inner end of the canal we found extensive lake deposits forming a 150×150 m-wide terrace (marked by the 14-m contour in Figure 46): The original lake must have extended over 700×400 m, covering an area of approximately 180,000 m^2 between Romanou and Tragana (Fig. 46). Its level was at 15–15.5 masl, with high floods reaching 16–16.25 masl. The lake was isolated from the floodplain by either natural or artificial levees east of Romanou and became gradually filled with the sediments of the Selas and the Tsoukalorrema Rivers. The Selas entered the lake from the northeast. There were two possible exits for water flowing out of the lake: first, the artificial canal and, second, the original streambed of the Selas River running toward Osmanaga lagoon. About 120 m southeast of the bridge on the Romanou–Tragana road, in an area called "Lada", a distinct channellike depression indicates the old streambed on the 1:5,000 topographic map. Farther south, in an area called "Kelali", the same depression can be seen again. The old streambed was 3.25 km long between the former lake and Osmanaga lagoon and stretched along the western edge of the floodplain.

It appears likely that the port basin, the lake, the old riverbed, and the canal at Ayios Dimitrios were all components of one system, in this case reflecting a layout that was a standard in mediaeval Europe. The main purpose of such a hydraulic system was to prevent the port basin from silting up. Along the Ionian coast the longshore current carries so much sediment that the entrance to the basin might have silted up after only one or two years. Constructing a port basin, however, was only worthwhile if it could be used for a long time, ideally for several generations. Sediment therefore had to be prevented from entering the basin, and that meant preventing large amounts of sea water from entering it. The best way to achieve that is by flushing the basin with a small but permanent flow of clean water, thereby producing a steady stream flowing out into the sea. This clean water obviously had to be derived from the perennial Selas River. Since the Selas carries even more suspended and bed load than the longshore current, a sediment trap had to be installed first to clean the fluvial water. The lake was therefore an essential component of the system. When the sediment-rich river water entered the lake, it lost most of its energy and dropped its sediment. A small current of clean water from the upper-water layers in the lake was then directed through the artificial canal into the port basin, while the remaining water left the lake through the original streambed that exited at Osmanaga lagoon. During winter floods the entire stream may have been directed through the old streambed toward Osmanaga lagoon to irrigate and fertilize the fields in the floodplain. The port basin was then left to the erosional forces of the winter storms, which also brought in sea water and planktonic microfossils.

This system obviously demanded that somebody maintain control over when and how much clean water was directed into the basin and how much water was allowed to escape into Osmanaga lagoon. When this control was abandoned, the river was left to itself and permanently chose the shorter course through the canal at Ayios Dimitrios and the former port basin. The thick layer of apparently unstratified river gravel (Fig. 44) on top of the clay deposits indicates a sudden and drastic change in the parameters controlling the depositional environment. Spasmodic high-volume sediment supply could have been triggered by several processes, including sudden tectonic uplift, the abandonment of terraces, the collapse of the artificial hydraulic system, and landslides. The last possibility certainly is an important factor, because scars of at least a dozen large landslides are still visible on the western side of the Englianos ridge. Some of these are not overgrown and seem to have occurred only recently. Mass-balance calculations show that the volume of earth moved by those landslides could have been over 100,000 m^3, quite comparable in magnitude to the landslide that buried parts of the lower town of Tiryns in LH IIIB/C.[135] At Pylos, however, many such events occurred.

The Date of the Construction

When was this sophisticated hydraulic system constructed? Despite the crude rotary drilling technique, we were able to find a piece of worked chert in hole C at 7 m depth and a sherd in hole D at 4 m depth (Fig. 44). Unfortunately, neither artifact was closely datable. A number of observations, however, help in determining a relative date when the basin must have been open and filled with seawater. The discovery of pottery in the basin shows that it was built no earlier than 8,000 years ago, as common sense would have suggested, because Mesolithic or Early Neolithic people in Greece are unlikely to have moved a few hundred thousand tons of earth to open up an artificial port. In addition, the floodplain sediments along the previous course of the Selas, north of Osmanaga lagoon, have been radiocarbon-dated to the first half of the Holocene by Kraft and his coworkers. These sediments formed while the river was still using its original bed. Also, the lack of obvious soil horizons in the alluvia of the basin argues for deposition during the second half of the Holocene. On the other hand, the basin could not have been built very recently,

[135] Zangger 1994, p. 207.

because its surface exhibits some microtopographic relief, which probably required a few thousand years to develop. Furthermore, Kraft and his coworkers used the existence of Classical, Hellenistic, and Roman sites at or very near the surface at Osmanaga lagoon to argue that the diversion must have taken place before Classical times, or else these sites would have been buried more deeply by river sediments.

The new pollen cores from Osmanaga lagoon now provide an accurate date for the diversion. At a depth between 260 and 240 cm, the amount of organic matter, carbon, and the C/N ratio increased multifold, while $\delta^{13}C$ decreased. This combination of changes indicates a drop in terrestrial input, which evidently occurred when the Selas stopped depositing in the lagoon. Radiocarbon accelerator dates of 1350 B.C. and 1010 B.C. from this level of the core attest that the change in river courses falls into the Late Bronze Age or the period immediately afterward. Hence, the port basin was built during the Mycenaean era. It is therefore the first evidence for sophisticated, large-scale port installations in Mycenaean Greece and the oldest artificial port thus far discovered in Europe.

The magnitude of this construction is highly reminiscent of the domestic hydraulic feats known from Greece[136] and central and eastern Anatolia.[137] Until now, however, it was assumed that the knowledge of hydraulic engineering did not need to be applied to maritime installations in Greece, because Late Bronze Age vessels were simply pulled ashore on sandy beaches.[138] The discovery of fifty-foot merchant ships such as the one excavated off Ulu Burun,[139] however, is a strong indication that peaceful long-distance trade must have been eased by port installations, because this type of ship required at least a quay for loading and unloading. Since the Ulu Burun ship carried commodities from different places of origin, suitable naval installations are likely to have existed at several coastal cities.

Ponds similar to the one found at Pylos are indeed well known from Late Bronze Age/Early Iron Age port cities along the coasts of Syria-Palestine (e.g., Akhziv, Misrefot-Yan, and Tel Mikhmoreth),[140] Lebanon,[141] and Cyprus.[142] In Israel, where numerous prehistoric and early historic ports have been excavated in recent years, large numbers of stone anchors, quays, and docks were found, illuminating the level of technical achievement available at the end of the second and during the early first millennium B.C. Comparable in construction is the artificial port of Birket Habu in western Thebes, built during the 14th century B.C. under the rulership of pharaoh Amenhotep III.[143] With dimensions of 1 × 1.5 km, however, this rectangular basin is twenty times larger than the one at Pylos. Another basin of this type existed during the early second millennium B.C. at Serra Est in the northern Sudan.[144] In the Aegean, remains of constructions associated with

[136] Balcer 1974; Knauss 1987, 1989, 1990, 1991; Zangger 1994.
[137] Bittel 1984, p. 13; Neve 1993, p. 75; Emre 1993, fig. 1; Belli 1995, p. 22.
[138] Shaw 1990, p. 423; Schäfer 1992, p. 347.
[139] Bass *et al.* 1989.
[140] Raban 1985, p. 20; Raban in press.
[141] Raban 1981, p. 55.
[142] Gifford 1985, p. 48; Collombier 1988, p. 44.
[143] Blackman 1982, p. 92.
[144] Blackman 1982, p. 92.

possible prehistoric ports have been described from Minoan Crete[145] and Troy.[146] The construction of excavated ports became more widespread in Phoenician and Etruscan cities in Italy.[147] Artificial harbors from this period that were connected to the open sea by a narrow channel are often referred to as cothons, after the famous artificial port of Carthage. Unfortunately, no comprehensive catalogue or systematic investigation of such installations has been produced except for the list of Classical and younger ports compiled by Lehmann-Hartleben and published in 1923.[148]

A Late Bronze Age date for the construction of the port makes perfect sense, considering the role of Pylos as the only Mycenaean palatial center on the Ionian side of the Peloponnesos. The kingdom at that time had sufficient economic incentive, manpower, know-how, and political authority to justify and realize such a project. In 1942, William McDonald argued that it would be illogical for a maritime power that, according to Homer (*Iliad* 2.593), could provide ninety navy vessels not to locate its capital near the best harbor in the kingdom.[149] Reversing the argument would also make sense: it would be illogical not to build a harbor near the best place for the kingdom's capital.[150]

CONCLUSIONS

At the beginning we stated that the main issues to be addressed by the physical scientific work on PRAP were (1) the primary natural resources in the study area, (2) the geological processes that distorted the original archaeological record, and (3) the historic interrelation between human habitation and landscape evolution. Returning to these general objectives and the particular items specified under "Aims" we can draw the following conclusions.

Primary Resources

Bedrock: Two pre-Holocene geological units can be distinguished in the study area: (a) Jurassic to Tertiary marine limestones, conglomerates, and cherts folded in a pattern of north-northwest–south-southeast striking areas during the Alpine orogeny and forming the steep Aigaleon ridge; (b) shallow Neogene marine deposits that were uplifted during the Quaternary and now form the degradational platform called *kampos.* The distribution of these main geological units largely determines the topography of the study area, the availability of arable land, and the degree of erosion.

Geomorphology: The geomorphology of the study area is essentially controlled by the bedrock geology. In addition to the above units, (a) mountains and (b) Neogene and Quaternary terraces, we distinguished a third physiographic unit, (c) the alluvial floodplain

[145] Marinatos 1925–1926, p. 144; Guest-Papamanoli 1980, p. 99; Zangger 1995, pp. 88–89.

[146] Brückner 1925, p. 245; Zangger 1992c, p. 211; Kayan 1995, p. 223; Luce 1995, p. 211.

[147] Frau 1985, p. 96; Isserlin 1970, 1971, 1974.

[148] Lehmann-Hartleben 1923.

[149] McDonald 1942, p. 540.

[150] The port basin at Romanou is 5.5 km from the palace and would have been by far the closest possible beach access.

at the northern end of the Bay of Navarino, which consists of interfingering marine silts and fluvial deposits.

Natural resources: Mineral resources are absent from western Messenia, and even materials suitable for building stones occur infrequently. The Palace of Nestor, for instance, was built far away from a source of natural stones. The foundation stones for the palace walls had to be transported over a long distance, because the underlying marl is too soft to be used as building material. On the other hand, in comparison to other regions on the Peloponnesos, water abounds in western Messenia.

Soils: The soils in the study area can be divided into three main groups defined by bedrock geology and geomorphology: (a) those occurring on Mesozoic and Cenozoic limestone and conglomerate, (b) those on Pliocene and Pleistocene marl, and (c) those on Holocene alluvium. All these soils are relatively fertile and have moderate to good agricultural potential. Slopes on Mesozoic and Cenozoic bedrock, however, tend to be steep, allowing only small fields with stony soils and requiring terraces for stabilization. Traditional agriculture in the mountains is therefore labor intensive and is now being practiced on a reduced scale. The second group, consisting of soils on marl, can be subdivided into those occurring on the coastal terraces, where slopes are gentle and erosion is generally limited, and those in the uplifted interior, where streams are deeply incised and erosion is severe. The soils on the marine terraces are generally well preserved and fertile but require irrigation for maximum productivity. The soils in the interior, on the other hand, are eroded to the point that bedrock has become the substrate for farming in many areas. Finally, the Holocene floodplains have only experienced incipient soil genesis. The physical and chemical properties of the floodplain sediments make them the best areas for agriculture, provided there is sufficient water.

Secondary Processes

Tectonics: Uplift in the form of en-bloc movements combined with local fault tectonics exposed the shallow marine deposits of the *kampos* and produced outstanding examples of pronounced marine terraces raised by as much as 400 meters. Terraces from the latest interglacial indicate continuous vertical movements throughout the Late Pleistocene and Holocene. The fast uplift rate is one of the most important factors contributing to the unusual degree of erosion observed in the study area.

Erosion: The degree of erosion on the uplifted Pliocene/Pleistocene surfaces is extraordinary. Some of the former surfaces on the marl have been eroded by a few meters since prehistoric times, and soil *in situ* on marl is virtually nowhere preserved. This observation is of paramount importance to the archaeologists studying the area. Settlement sites that were placed on these surfaces may now have disappeared. In addition, surficial artifact distribution may no longer accurately reflect original depositional locations.

Coastline changes: The Bay of Navarino was invaded by the sea during the Early Holocene sea level rise about 9,000 years ago. While sea level was still 20 m below present, the coastline inside the bay extended four kilometers north of its present position. Subsequent sedimentation has filled in the northernmost part of the gulf and pushed the coast southward. Along the Ionian coast, progradation has been relatively minor—on the order of a few hundred meters for the entire Holocene. One coastal Early Bronze Age site (Vromoneri *Nozaina*, POSI I20), however, was clearly damaged by transgressional erosion.

Deposition: The only extensive floodplain in the study area stretches north of Osmanaga lagoon between the villages of Romanou and Koryfasio. Extensive Holocene deposits were formed during the first half of the Holocene. Possible Mesolithic, Neolithic, and Early and Middle Bronze Age sites in this depositional environment would now be concealed by alluvium. On both sides of the Englianos ridge, landslides have spasmodically contributed large amounts of sediment to the depositional system. At the same time, these slumps have destroyed ancient surfaces on the slopes as well as in the valley bottoms. Relatively little sediment has been deposited on top of the floodplain since the beach barrier between Yialova and Palaeonavarino closed between 800 and 500 B.C. Today, it is indeed an erosional environment, and most of the suspended and bed load of the rivers is carried to the sea.

Coevolution of Landscape and People

Vegetation: Our records begin at about 5000 B.C., when the extensive pine forests in the region gradually gave way to deciduous oaks. During the first phase of human-induced environmental changes, around 2000 B.C., the pine forests were reduced to a fraction of their former size. This period of rapid deforestation coincided with the introduction of widespread agriculture and triggered a phase of landscape instability that has lasted until the present day. More denudation seems to have accompanied the early phase of Late Bronze Age agriculture, between 1600 and 1400 B.C., when deforestation combined with overgrazing reduced the number of oak trees by half and completely wiped out the pines. Subsequently, between 1400 and 1200 B.C., relative landscape stability occurred and new species, including rye, walnut, plane tree, and Judas tree, appeared. The third phase of major environmental change coincided with the later first millennium B.C., when the olive reached an all-time peak (between 500 and 100 B.C.) and the number of deciduous oaks dropped significantly. After that, no major vegetation changes occurred until the modern period. Today, almost no examples of undisturbed natural plant communities can be found anywhere in the landscape. Natural forests have completely disappeared, and macchia has spread on those slopes that are not used for cash crops.

The Palace: After all these landslides, the soil erosion, the bulldozing, and the intentional site destruction, it is surprising that the palace itself is so well preserved. The foundations of the palace have in fact remained unharmed for a number of reasons. First of all, the palace is located on the flat top of a ridge, where there is little relief and therefore little natural erosion. Second, our auger cores have shown that the surface of the ridge was probably artificially leveled, and whatever relief there may have been was equalized in the process. Third, the foundations themselves prevented excessive erosion because they provide a dense grid of massive walls. Fourth, when the palace, consisting of at least two floors, collapsed, its foundations were preserved under the rubble. Fifth, the discovery of a large magnetic anomaly running parallel to the contours on the steep northwestern side of the Englianos ridge might indicate a massive artificial structure that could have helped stabilize the slope. Finally, the fence around the archaeological site protected the area during the most recent decades, when many other sites in the vicinity suffered destruction from modern agricultural techniques. The geophysical survey has shown that some foundations of buildings might still be preserved in the ground south of the palace. On the plateau north of the palace and on the level of the parking lot, however, the bedrock lies close to the present surface.

Tumuli: Several archaeological sites in the survey are associated with well-defined knolls usually three to five meters high and several meters wide. These have frequently been interpreted as tumuli or coverings for tholos tombs. Geological scrutiny has shown that these knolls often consist of undisturbed marl bedrock that was simply spared from plowing and bulldozing because it contained trigonometric stations or burial sites.

River diversion and port: A genuine surprise was the discovery of an inland basin near Romanou that must have served as the port for the palace. This port of Pylos is the earliest evidence for artificial harbor installations in Europe. To keep the artificial basin free from sediment it was integrated into a sophisticated hydraulic system with a clean-water flushing mechanism. The level of hydraulic expertise expressed in the engineering of this installation is matched by the many Mycenaean domestic meliorations known, for instance, from Gla, Tegea, and Stymphalos. At Pylos it was possible to show, for the first time, that this expertise was also applied to the construction of maritime installations.

In conclusion, the natural scientific work conducted during the Pylos Regional Archaeological Project has provided many clues about the landscape evolution of western Messenia and the current state of preservation of its antiquities. Contrary to William Loy's conclusions,[151] it appears that people have indeed had a severe impact on the pattern of soils and landscapes of the southwestern Peloponnesos over the past five millennia. In addition, the physical scientific work at Pylos has shown that we will have to look for new ways to reconstruct the past, even when almost all the evidence has been obliterated. If the results of this geoarchaeological project had to be summarized in one sentence describing their significance for reconstructing past settlement patterns on the basis of the preserved surface record, it would be, "The present is *not always* the key to the past."

[151] Loy 1970, p. 140.

Floodplain: Inceptisols and Entisols, 5-10% slopes, slightly eroded. These soils formed in alluvial deposits and exhibit A/Bw/C and A/C horizonation. Slopes are steep enough to allow a minor degree of erosion.

Intermittent Drainages: Entisols and rock outcrops, bouldery, 10-30% slopes, moderately to severely eroded. These soils formed in residuum and local alluvium and exhibit A/C horizonation. Flash floods have caused moderate to severe erosion and exposed bedrock in places.

Lower Footslopes: Inceptisols, slightly eroded, 20-30% slopes, 20-50% agricultural terraces. These soils formed in residuum and colluvium and exhibit A/Bw/C horizonation. They have been modified by agricultural terrace construction. Erosion is only slight due to terrace construction.

Footslopes/Stream Terraces: Inceptisols and Alfisols, 8-12% slopes, slightly eroded, 10-20 % agricultural terraces. These soils formed in colluvium and stream terrace deposits; they exhibit A/Bw/C and A/Bt/C horizonation and have been modified by agricutural terrace construction. Erosion is only slight due to terraces.

Backslopes and Footslopes: Inceptisols, 30-40% slopes, 50-70% agricultural terraces, slightly eroded. These soils formed in residuum from flysch or colluvium from flysch and limestone and exhibit A/Bw/C horizonation. They have been modified by agricultural terrace construction. Erosion is only slight due to terraces.

Nose Slopes: Inceptisols and Entisols, 30-40% slopes, 40-50% agricultural terraces, slightly to moderately eroded. These soils formed in residuum and colluvium from conglomeratic limestone and exhibit A/Bw/C and A/C horizonation. They have been modified by agricultural terrace construction. Where these terraces have been abandoned, erosion is moderate.

Lower Backslopes: Alfisols, bouldery, 30-45 % slopes, slightly to moderately eroded. These soils formed in residuum and colluvium from conglomeratic limestone and flysch and exhibit A/Bt horizonation. Boulders are dispersed on the surface and throughout the subsoil. Scattered, abandoned agricultural terraces are located on these slopes. Erosion is only slight to moderate due to thick forest cover.

Upper Backslopes/Shoulders: Alfisols and Inceptisols, bouldery, 45-60% slopes, slightly to moderately eroded. These soils formed in residuum and colluvium from conglomeratic limestone and flysch and exhibit A/Bt and A/Bw/C horizonation. Boulders are dispersed on the surface and throughout the subsoil. Erosion is only slight to moderate due to thick forest cover.

Upper Backslopes: Limestone outcrops and Entisols, 40-50% slopes, moderately to severely eroded. This unit consists primarily of rock outcrop. Soils, where they occur, likely formed in residuum and colluvium from dense, crystalline limestone and exhibit A/C horizonation. In places the remnant soils are agriculturally terraced.

Upland Saddles: Entisols, Inceptisols, and Alfisols, 60-80% slopes, slightly eroded. These soils formed in residuum and colluvium from conglomeratic limestone and flysch, and exhibit A/C, A/Bw/C, and A/Bt/C horizonation. These areas were probably never subject to much human disturbance, thus soil formation has kept pace with natural erosive processes.

Upland Basins: Inceptisols, Alfisols, Entisols,and rock outcrops, 8-12% slopes, 40-60% agricultural terraces. These soils formed in residuum and colluvium from conglomeratic limestone and exhibit A/Bw/C, A/Bt/C or R, and A/C horizons. They have been modified by agricultural terrace construction. Where the terraces are not maintained, erosion is slight.

Upland Shoulders: Entisols, greater than 80% slopes, slightly eroded. These soils occupy the shoulder positions below the highest summits. They formed in colluvium and residuum from conglomeratic limestone and exhibit A/C horizonation. These areas were probably never subject to much human disturbance, thus soil formation has kept pace with natural erosive processes.

Mountain Peaks: Rock outcrops, greater than 80% slopes.

TABLE 1. Soil mapping units in the Metaxada subarea (Michael E. Timpson)

Horizon	Depth (m)	Color (moist)	Color (dry)	Texture	Structure	Boundary	Consistency (moist-dry-wet)	Clay Films
A	0-0.10	10YR 3/2	10YR 4/2	L/SiL	1C sbk to 2F&M sbk	CS	vfr-fr-ss,sp	—
Bt1	0.10-0.34	10YR 3/3 10YR 3/4	10YR 4/3	CL	2C&M sbk to 3F sbk	CS	fr-h-s,p	2npo, pf
Bt2	0.34-0.53	10YR 4/6	10YR 5/6	gCL	1C sbk to 2F&M sbk	CW	fr-h-ss,sp	1npo, pf
BC	0.53-0.65	7.5YR 5/6	7.5YR 6/4	gL	2M&C sbk	CW	vfr-h to fr-ss,sp	1mt
Cr	0.65-0.75	—	—	gvL	1C sbk	AW	—	
R	0.75-	Coarse limestone conglomerate with carbonate cement			—	—	—	

TABLE 2. Soil profile description from the slopes of Mount Aigaleon in the Metaxada subarea. The soil is located in the saddle below a secondary peak of Mount Aigaleon on the western side of the Metaxada valley. The soil varied in depth and horizonation along the slope. Approximately three meters from the described profile the A horizon was up to 20 cm thick. Vegetation consisted of *Quercus coccifera*, bay, marjoram, grasses, and other, unidentified, shrubs (Michael E. Timpson)

Coastal Zone: Beaches, rock outcrops, and Alfisols, 0-2% slopes, slightly to severely eroded. This unit consists of beach deposits and rock outcrops including areas with Alfisols exhibiting A/Bt/R horizonation. Where soils occur, they are moderately to severely eroded.

Intermittent Drainages: No soils occur in this mapping unit. They consist of narrow, steep-walled channels.

Marine Terrace (1): Alfisols, 2-4% slopes, slightly to moderately eroded. These soils formed in Pliocene/Pleistocene marine terrace sediments and exhibit A/Bt horizonation. Soil erosion is probably slight in most parts of this unit. Isolated areas with steep slopes and little vegetation have been partly eroded.

Marine Terrace (2): Alfisols, 4-7% slopes, slightly to moderately eroded. These soils formed in Pliocene/Pleistocene marine terrace sediments and exhibit A/Bt horizonation. Soil erosion is slight for the most part, but isolated areas with steeper slopes and little vegetation have been eroded more.

Marine Terrace (3): Alfisols, 7-15% slopes, slightly to moderately eroded. These soils formed in Pliocene/Pleistocene marine terrace sediments and colluvium derived from higher areas of the same material. They exhibit A/Bt horizonation. Soil erosion is probably slight in most of this unit, but isolated areas with steeper slopes and little vegetation have been eroded more.

Marine Terrace (4): Alfisols, greater than 15 % slopes, slightly to moderately eroded. These soils formed in Pliocene/Pleistocene marine terrace sediments and colluvium derived from higher areas of the same material. They exhibit A/Bt horizonation.

TABLE 3. Soil mapping units in the Dialiskari subarea (Michael E. Timpson)

Horizon	Depth (m)	Color (moist)	Color (dry)	Texture	Structure	Boundary	Consistency (moist-dry-wet)	Clay Films
A	0-0.25	5YR 4/4	5YR 5/4	g L/CL	1M sbk to 2&3 F gr	CW	vfr-fr-ss,sp	—
BA	0.25-0.45	2.5YR 3/6	2.5YR 4/6	gCL/C	1C pr to 2C&M sbk	CS	fr-h-s,p	2mtk pf, po,pebs[a]
Bt1	0.45-0.80	2.5YR 3/6	2.5YR 4/6 2.5YR 5/6	gCL/C	1C pr to 2C&M sbk	CS	fr-h-s,p	2mtk pf,po,pebs
Bt2	0.80-1.00	2.5YR 3/6	2.5YR 4/6 2.5YR 5/6	gCL/C	1C pr to 2C&M sbk	CS	fr-h to vh-s,p	2mtk pf,po,pebs
Bt3	1.00-1.20	2.5YR 4/6 2.5YR 3/6	2.5YR 5/6 2.5YR 4/6	g C/CL	2M pr to 3F&M sbk	CS	fr-h-s,p	2mtk pf,po,pebs
Bt4	1.20-1.40	2.5YR 4/6	2.5YR 5/6	g C/CL	2M pr to 3F&M sbk	CS	fr-h-s,p	2mtk pf,po,pebs
Bt5	1.40-1.60	2.5YR 4/6	2.5YR 5/6	g C/CL	2M pr to 3F&M sbk	CS	fr-h-s,p	2mtk pf,po,pebs
Bt6	1.60-	2.5YR 4/6	2.5YR 5/6	g C/CL	2M pr to 3F&M sbk	—	fr-h-s,p	2mtk pf,po,pebs

a. pebs = pebbles in clay film boxes

TABLE 4. Soil profile description from the upper marine terraces in the Dialiskari subarea. The soil is located in the cut of a field road, approximately 0.9 km south of the main road from Gargaliani to the coast, and is situated at *ca.* 96 masl. The parent material was colluvial/alluvial fill from higher terraces. The B horizons contained common fine and medium iron/manganese concentrations. The A horizon was highly bioturbated by ants. The soil was noncalcareous throughout (Michael E. Timpson)

Horizon	Depth (m)	Color (moist)	Color (dry)	Texture	Structure	Boundary	Consistency (moist-dry-wet)	Clay Films
A	0-0.11	7.5YR 3/4	7.5YR 4/4	SL	1cscb	CS	fr-h-	—
Bt1	0.11-0.48	2.5YR 3/6	2.5YR 4/6	SL/CL	1mpr to 2msbk	CS	fr-h-	2mk pf&po
Bt2	0.48-0.70	2.5YR 3/6	2.5YR 4/6	SL/CL	2m&f sbk	AI	fr-h-	2mk pf
R/CBk	0.70-	—	—	—	0, Ma	—	—	1mt

TABLE 5. Soil profile description from Vromoneri *Vergina Rema* (POSI I28) in the Dialiskari subarea. The profile was situated on top of the coastal cliffs at the southernmost limit of POSI I28. The parent material is Pleistocene bioclastic sandstone. Clay films in the R/CBk horizon were located on the weathered faces of joints in the bedrock. Clay films in the argillic horizons were well developed but discontinuous in nature, perhaps indicating incipient breakdown. Secondary carbonates formed vein fills in the weathered bedrock (Michael E. Timpson)

Horizon	Depth (m)	Color (moist)	Color (dry)	Texture	Structure	Boundary	Consistency (moist-dry-wet)	Clay Films
A	0-0.20	7.5YR 3/4 7.5YR 4/4	7.5YR 4/4 7.5YR 4/2	LS	1M sbk	CS	vfr-fr-ns,np	—
Bt1	0.20-0.50	2.5YR 3/6	2.5YR 4/6	SL/SCL	2C to M sbk	CS	fr-eh-ss,ps	2npf
Bt2	0.50-0.70	2.5YR 3/6	2.5YR 4/6	SL	1C&M sbk	CS	fr-h-ss,pn	2vnpf
BC	0.70-1.00	2.5YR 4/4 2.5YR 4/6	2.5YR 4/6	lt. SL	1C sbk	CS	fr-h-ss,p	bridges and 1vnpf
Bkm	1.00-	7.5YR 5/4 7.5YR 5/6	7.5YR 6/4 7.5YR 5/6	cemented	0 Ma	—	vfi-eh-ns,np	—

TABLE 6. Soil profile description from Romanou *Rikia* (POSI I18). Note similarity with soil described in Table 5 (Michael E. Timpson)

Floodplains: Inceptisols and Entisols, 2-8% slopes, slightly eroded. These soils formed in alluvial deposits and exhibit A/Bw/C and A/C horizonation. Slopes are steep enough to allow a minor degree of erosion.

Ridge Tops: Entisols and Inceptisols, 2-5 % slopes, slightly to moderately eroded. These soils formed in residuum from Pliocene marls and exhibit A/C and A/Bw/C horizonation. Anthropogenic erosion has impacted these soils to a moderate extent.

Ridge Tops and Shoulders: Entisols and inceptisols, 10-25% slopes, 20 40% agricultural terraces, moderately to severely eroded. Soils formed in residuum from Pliocene marls and exhibit A/C and A/Bw/C horizonation. Bulldozer terraces comprise 20-40%; moderate and severe erosion. Thin A horizons, produced by agricultural tillage practices, overlie soft marl bedrock in most parts.

Back Slopes (A): Entisols and Inceptisols, 30-50% slopes, 50-70% agricultural terraces, moderately to severely eroded. These soils have formed in residuum and colluvium from Pliocene marls and exhibit A/C and AIBw/C horizonation; moderate to severe erosion. Bulldozer terraces comprise 50-70 %. The lower portions are covered by thin to moderately thick, relatively recent colluvial mantles that result from anthropogenically accelerated erosion. Entisols dominate this map unit.

Back Slopes (B): Entisols and rock outcrop, 55-65% slopes, 50 to 70% agricultural terraces, moderately to severely eroded. These soils have formed in residuum and colluvium from Pliocene marls, and exhibit A/C horizonation; moderate to severe erosion. Bulldozer terraces comprise 50-70%. Thin A-horizons, produced by agricultural tillage practices, overlie soft marl bedrock in most parts.

Footslopes: Inceptisols and Alfisols, 15-25% slopes, 20-40% agricultural terraces, slightly eroded. These soils formed in colluvium and residuum from Pliocene marls, and exhibit A/Bw/C and A/Bt/C horizonation. Approximately 20-40% of this map unit is composed of agricultural terraces.

Intermittent Drainages: Inceptisols and Entisols, 12-18% slopes, 20 40% agricultural terraces, slightly to moderately eroded. These soils formed in colluvium and local alluvium derived from Pliocene marls and exhibit A/Bw/C and A/C horizonation. Approximately 20-40% of this map unit is comprised of agricultural terraces.

Landslides: Rock outcrop and Entisols greater than 65 % slopes. This unit is composed of bare rock surfaces and thin Entisols where the slide scars have stabilized sufficiently to allow soil formation. When not vegetated, the scars are subject to severe erosion.

TABLE 7. Soil and landscape units in the Upper Englianos subarea (Michael E. Timpson)

Intact soil profile			*Eroded soil profile*		
Horizon	**Depth (m)**	**Color (moist)**	**Horizon**	**Depth (m)**	**Color (moist)**
A	0-0.1	7.5YR 3/4	AC	0-0.2	10YR 5/4
BA	0.1-0.3	7.5YR 4/6	Cr	0.2-	10YR 7/2
Bt1	0.3-0.6	5YR 4/6			
Bt2	0.6-0.9	5YR 4/6			
Bk1	0.9-1.15	7.5YR 4/6			
Bk2	1.15-	10YR 7/2			

TABLE 8. Simplified descriptions of an uneroded and an eroded soil on the marl bedrock on Englianos (Michael E. Timpson)

Floodplains: Inceptisols and Entisols, 2-5% slopes, slightly eroded. These soils formed in alluvial deposits and exhibit A/Bw/C and A/C horizonation. Slopes are steep enough to allow a minor degree of erosion in places.
Ridge Tops: Entisols and Inceptisols, 5-12% slopes, 5-20% agricultural terraces, moderately to severely eroded. These soils formed in residuum from Pliocene marls and exhibit A/C and A/Bw/C horizonation. Most of this map unit has been subject to moderate to severe erosion. Agricultural tillage practices and terracing have resulted in increased erosion.
Ridge Tops: Entisols and inceptisols, 12-20% slopes, 20-30% agricultural terraces, moderately to severely eroded. These soils have formed in residuum from Pliocene marls and exhibit A/C and A/Bw/C horizonation. Most of this map unit has been subject to moderate to severe erosion. Agricultural tillage practices and terracing have resulted in increased erosion.
Side Slopes (A): Entisols,18-25% slopes, 40-60% agricultural terraces, severely eroded. These soils formed in residuum from Pliocene marls and exhibit A/C horizonation. Bulldozer terraces comprise 40-60% of these slopes. Thin A horizons, produced by tillage practices overlie soft marl bedrock in most parts.
Side Slopes (B): Entisols, 25-45% slopes, 50-70% agricultural terraces, severely eroded. These soils formed in residuum from Pliocene marls and exhibit A/C horizonation. Bulldozer terraces comprise 50-70% of these slopes. Thin A horizons, produced by tillage practices overlie soft marl bedrock in most parts.
Colluvial Footslopes: Inceptisols, Entisols, and Alfisols, 10-18% slopes, 20-30% agricultural terraces, slightly to moderately eroded. These soils formed in colluvium and residuum from Pliocene marls and exhibit A/Bw/C, A/C, and A/Bt/Bk/C horizonation.
Intermittent Drainages: Inceptisols and Entisols, 6-16% slopes, 50% agricultural terraces, slightly to moderately eroded. These soils formed in colluvium and local alluvium derived from Pliocene marls, and exhibit A/Bw/C and A/C horizonation.

TABLE 9. Soil and landscape units in the Lower Englianos subarea (Michael E. Timpson)

Subarea	Present Soils		Agricultural Potential	Degree of Erosion
Metaxada	Uplands	Entisols, Inceptisols, Alfisols	moderate	low – moderate
	Floodplain	Inceptisols, Entisols	good	low – moderate
Dialiskari		Alfisols	moderate[a]	low – moderate[c]
Upper Englianos		Entisols, Inceptisols	moderate[b]	high
Lower Englianos	Uplands	Entisols, Inceptisols, minor Alfisols	moderate[b]	high
	Floodplain	Inceptisols, Entisols	good	low – moderate

a. Possible salt tolerance problems near the coast. The use of irrigation improves this rating to "good".
b. Due to the application of irrigation and fertilizers. With preserved soils, the water holding capacity and fertility of this area would have provided good support for most crops.
c. Except along coastal cliffs where it is "high".

TABLE 10. Variations in soils, agricultural potential, and degree of erosion among the four subareas (Michael E. Timpson)

Lab. No. AMS No.	Depth (m)	Sample mate-rial	$\delta^{13}C$	Conventional ^{14}C-age (years BP)	Calibrated age	Range (1σ)	Range (2σ)
BETA-77562 CAMS-16841	0.01	shell	-5.6	110±0.8%	post-1960	n. a.	n. a.
BETA-77563 CAMS-16842	0.95	shell	-5.4	1170±50	AD 1320 AD 1340 AD 1390	AD 1305 (0.73) 1360 AD 1380 (0 27)1405	AD 1290 (1.00) 1420
IEMAE-1824	1.05 -1.10	bulk deposit	-23.0	1270±160	AD 1290	AD 1160 (1.00) 1420	AD 950 (1.00) 1650
BETA-77564 CAMS-16843	1.40	shell	-3.2	2420±60	AD 140	AD 80 (1.00) 240	AD 20 (1.00) 400 BC
BETA-77565 CAMS-16844	1.98	shell	-2.7	3000±50	430 BC	760 (0.33) 680 BC 540 (0.67) 400 BC	770 (1.00) 400 BC
BETA-77566 CAMS-16845	2.02	bulk deposit	-19.2	2960±40	390 BC	760 (0.21) 700 BC 530 (0.79) 390 BC	770 (1.00) 380 BC
Above two samples combined	2.00	bulk/ shell	n. a.	2980±40	410 BC	760 (0.12) 710 BC 530 (0.88) 400 BC	770 (0.29) 630 BC 600 (0.01) 580 BC 560 (0.70) 390 BC
BETA-77567 CAMS-16846	2.48	shell	-2.9	3430±70	1010 BC	1120 (1.00) 920 BC	1260 (1.00) 840 BC
BETA-77568 CAMS-16847	2.49	bulk deposit	-21.8	3650±60	1390 BC 1340 BC 1330 BC	1420 (1.00) 1260 BC	1510 (0.02) 1480 BC 1460 (0.98) 1130 BC
BETA-77569 CAMS-16848	2.81	bulk deposit	-25.9	4800±50	2880 BC	2920 (0.46) 2860 BC 2810 (0.38) 2760 BC 2720 (0.16) 2700 BC	2930 (0.37) 2850 BC 2830 (0.63) 2620 BC
BETA-77570 CAMS-16849	3.44	bulk deposit	-27.1	6200±50	4460 BC	4530 (0.74) 4450 BC 4420 (0.26) 4360 BC	4580 (1.00) 4350 BC
BETA-77571 CAMS-16850	3.87	plant	-27.3	3660±50	2030 BC 2000 BC 1990 BC	2130 (0.31) 2080 BC 2050 (0.69) 1940 BC	2180 (0.01) 2160 BC 2140 (0.99) 1880 BC
BETA-77572 CAMS-16851	3.88	bulk deposit	-27.4	4220±50	2030 BC 2000 BC 1990 BC	2130 (0.31) 2080 BC 2050 (0.69) 1940 BC	2180 (0.01) 2160 BC 2140 (0.99) 1880 BC
BETA-77573 CAMS-16852	4.67	bulk deposit	-25.7	7460±60	5420 BC	5460 (1.00) 5350 BC	5510 (1.00) 5290 BC

TABLE 11. Radiocarbon dates from cores D-4 and D-2 from Osmanaga lagoon (Sergei B. Yazvenko)

	Methods	Instruments	Area (m^2) covered at: Glyfadaki	Dialiskari	Ordines	Palace
Magnetometry	Measurements of the module of the earth's magnetic field	Overhauser Gradiometer GSM-19G GEM SYSTEMS Canada	1600	750	2400	9550
	The vertical gradient of the module of the earth's magnetic field		1600	750	2400	9550
	The vertical gradient of the Z-component of the earth's magnetic field	Fluxgate Gradiometer FM36; Geoscan Research, England	2000		2400	6650
	Magnetic profile across anomaly					2 x (2 x 26 m)
Electro-magnetometry	Inductive measurements of the apparent coductivity	Ground Conductivity Meter EM38 GEONICS Ltd. Canada				8300
Resistivity	Wenner mapping with constant electrode spacing of one meter	manual Geohm and automatic Geohm_3 (earth resistance meter) GOSSEN GmbH Germany				10150
	Dipol-dipol mapping with constant electrode spacing of one meter					10150
	Geoelectric sounding on profiles in Wenner and/or dipol-dipol cinfiguration			1 x 60 m 1 x 46 m		2 x 26 m
	Cross-sections with multi-electrode line arrays	Electrode Multiplexer (selfmade)		1 x 60 m 1 x 46 m		

TABLE 12. Principal technologies, devices, and areas covered during the geophysical survey (Falko Kuhnke and Eberhard Zangger)

Core Number	Total depths (m)	Depth of marl (m)	Comments
Auger cores taken on the unexcavated plateau east of the palace.			
14	1.4	0.3	In 0.3-1.0 m possibly disturbed
15	1.2	0.3	Wet marl color in all cores 2.5YR 6/4
16	1.3	0.3	Wet color of top soil 10YR 3/3
17	0.8	0.2	
Auger cores west of the palace tholos on the level of the parking lot.			
18	1.2	Marl is exposed at the surface	
19	1.0	Marl is exposed at the surface	
20	1.0	0.3	
21	2.0	1.4	
22	1.1	1.0	Cores 20-25: unstratified silt (10YR 5/3) interspersed with undiagnostic potters.
23	0.6	0.6	
24	0.7	0.7	
25	0.6	0.6	
Auger cores on Englianos east of the palace road.			
26	0.1	Marl is exposed at the surface	
27	0.8	0.3	
28	0.8	0.4	Center of a magnetic anomaly, black horizon containing charcoal mixed into plowed soil at 0.1-0.3 m.
29	0.6	Marl is exposed at the surface	
30	0.9	Marl is exposed at the surface	

TABLE 13. Stratigraphy found in auger cores on Englianos (Eberhard Zangger)

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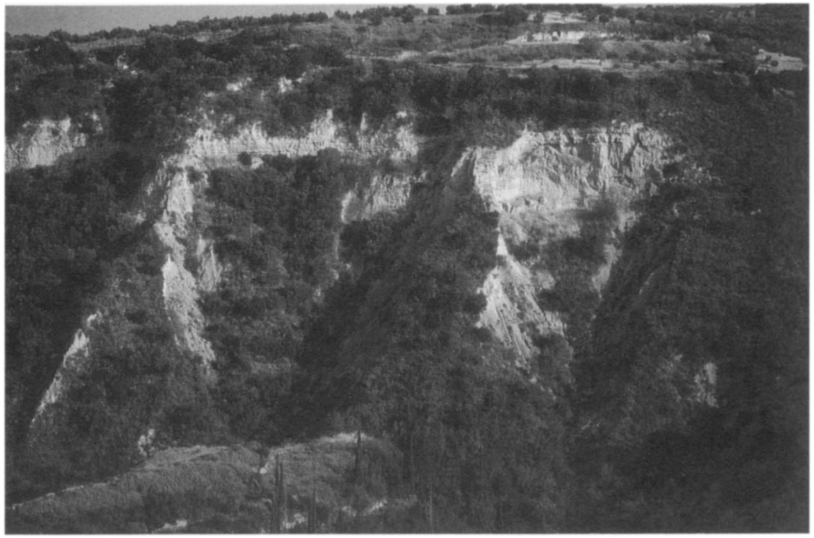
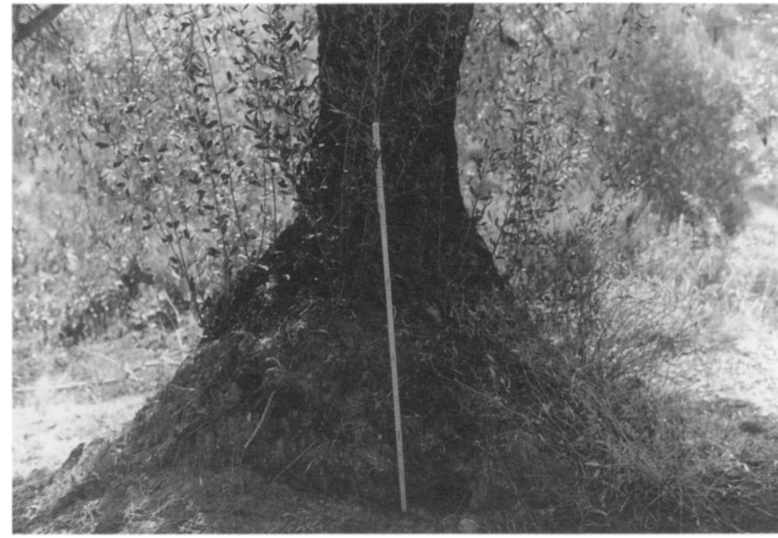
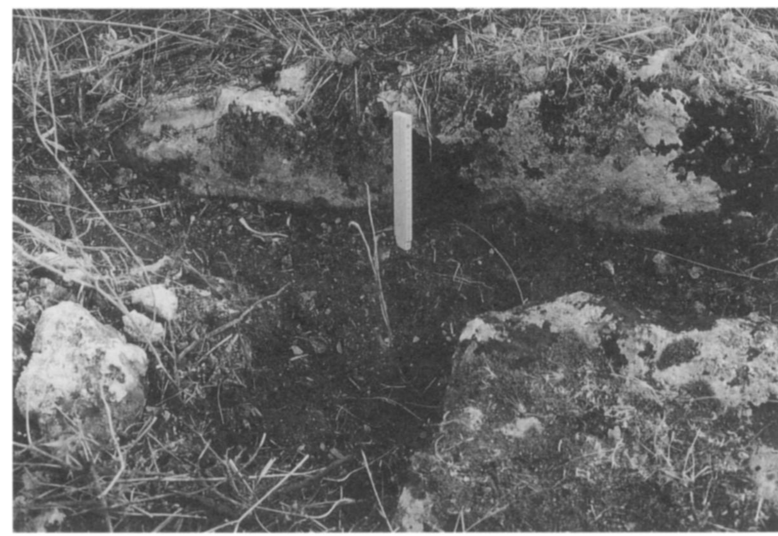


a. View from Englianos to the west, showing severe erosion of the marl slopes caused by tectonic uplift and stream incision, as well as human-made soil erosion on the flat ridge tops (Eberhard Zangger).

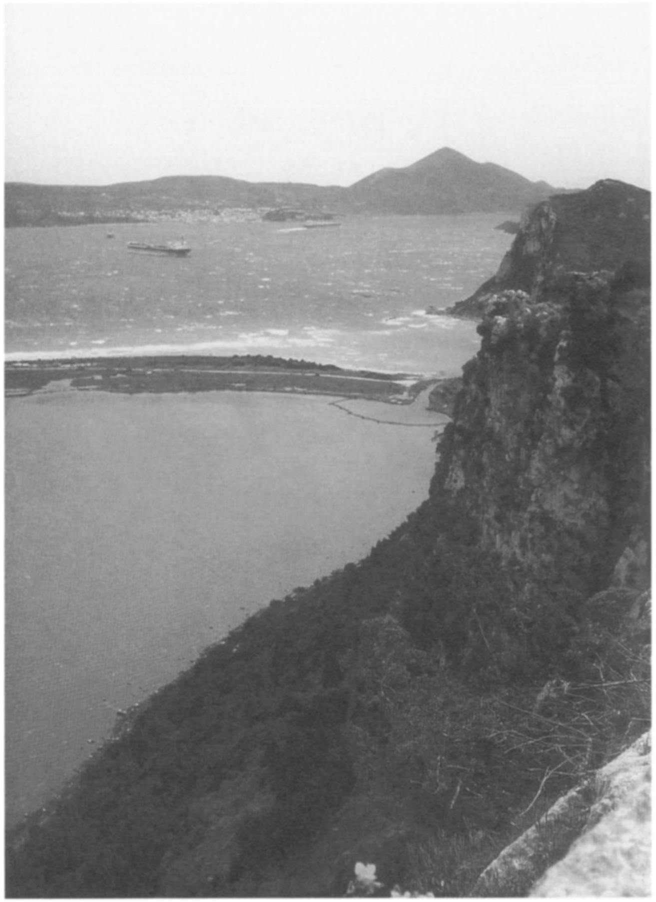


b. An olive tree with exposed base indicating recent soil erosion (Michael E. Timpson)

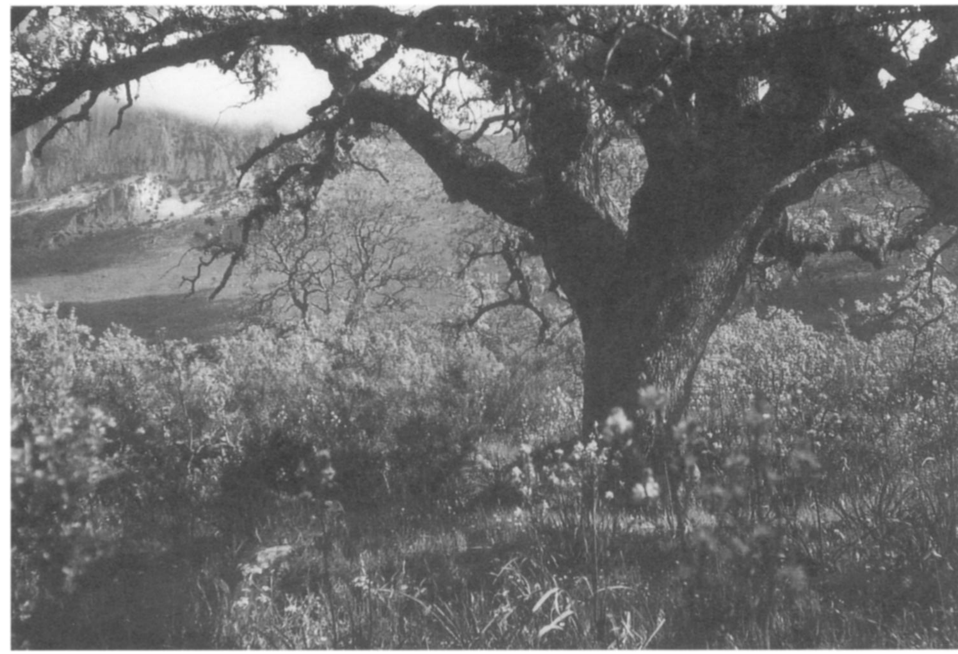
c. Artificial rock cuttings at Hasanaga (Eberhard Zangger)



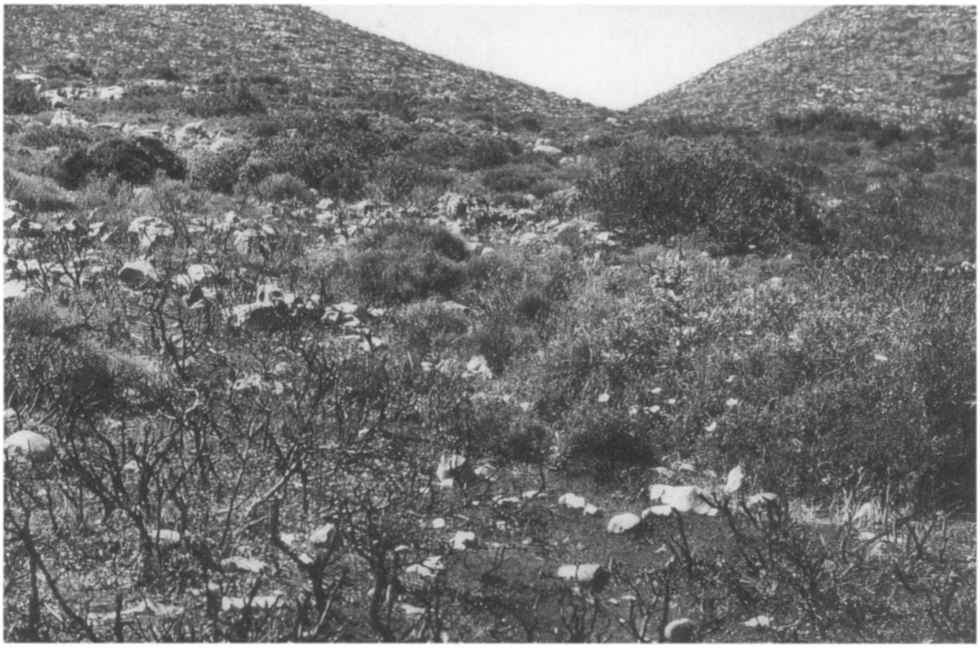
d. Artificial rock cuttings at Ordines (Eberhard Zangger)



a. View south from the top of the Palaeonavarino ridge toward Osmanaga lagoon and the Bay of Navarino, with coring site D2–D4 in the lower left corner (Sergei B. Yazvenko). The eastern slopes are covered with a macchia dominated by Phoenician juniper, holm oak, and Kermes, or prickly, oak, with mastic tree, tree heath, strawberry tree, myrtle, mock privet, spiny broom (*Calicotome villosa* [Poiret] Link), and other plants. Steep slopes below the summit support rocky flora of tree spurge, caper (*Capparis spinosa* L.), joint-pine (*Ephedra fragilis* Desf.), and sea lavender (*Limonium* spp.).

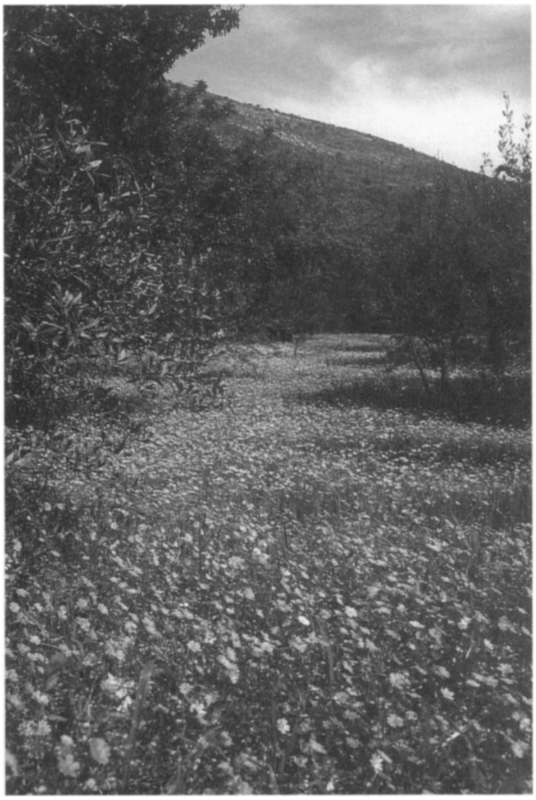


b. An open valonia oak woodland that was probably maintained for valuable tannin-rich acorn cups (Sergei B. Yazvenko)

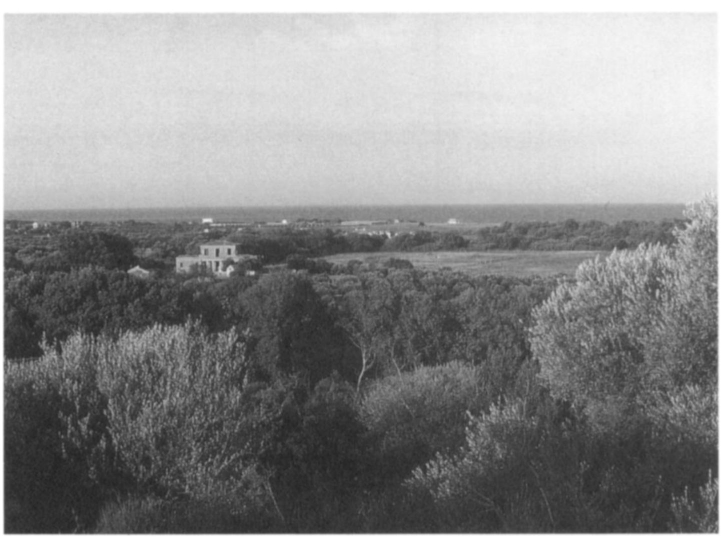


a. Overgrazed phrygana near Methoni with recently burnt bushes of prickly oak (foreground) and cushionlike patchy shrubs of prickly oak, thorny burnet, olive, Greek spiny spurge, thyme, and cistus (*Cistus incanus* L. and *C. parviflorus* Lam.) in the background (Sergei B. Yazvenko).

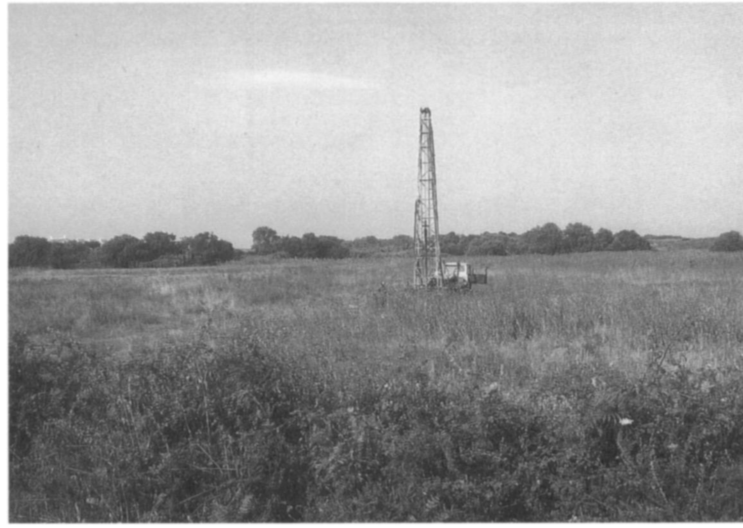
b. The severely grazed southwestern slope of the Palaeonavarino ridge with vegetation dominated by asphodel (*Asphodelus aestivus* Brot.) and grasses. Shrubs of mastic tree and Phoenician juniper are also present (Sergei B. Yazvenko).



a. An olive orchard in the valley of the Metaxada river in April, with dove's-foot cranesbill (*Geranium molle* L.) and grasses dominating the herb layer. A few weeks later, the application of herbicides and plowing will have completely removed the herb layer (Sergei B. Yazvenko).



b. The floodplain (former port basin) west of the Kokevis villa, as seen from the Tragana tholoi (Eberhard Zangger).



c. Investigation of the former port basin, using a rotary drill (Eberhard Zangger).

d. The Metaxada valley with cultivated olive orchards and vineyards occupying the floodplain. The hill slopes are covered by macchia, some of which was recently destroyed by a fire (Sergei B. Yazvenko).