FIVE THOUSANDS YEARS OF LAND USE AND ABUSE IN THE SOUTHERN ARGOLID, GREECE

GREECE is, in the main, a land of dry and barren mountains, poor in fertile, well-watered soil. Still, ancient authors refer repeatedly to the wooded hills and rich bottomlands of a remote past. Whether the disappearance of this lush landscape, if indeed it ever existed, was due to natural or to human causes has been debated with passion since Antiquity. Environmentalists of a pessimistic bent like to cite the eastern Mediterranean as a particularly horrifying example of what callous human disregard for the environment can bring about, while others have attributed the stripping of soil from the mountains to the severe climate of the Pleistocene.

The Argolid Exploration Project

In 1979, Stanford University initiated an intensive archaeological and environmental survey of the Southern Argolid (Ermionis), directed jointly by M. H. Jameson and Tj. H. van Andel. This project was designed to elucidate the prehistoric and historic evolution of a geographically well defined, environmentally diverse rural Greek region (Fig. 1); it built upon many years of exploration and some surveying in the Southern Argolid by Jameson and T. W. Jacobsen, as well as on excavations of Palaeolithic through Neolithic deposits at Franchthi Cave (Jacobsen, 1976, 1981) and at the Archaic and Classical polis of Halieis (Boyd and Rudolph, 1978; Jameson, 1969, 1974). A geological study of the late Quaternary landscape (Pope and van Andel, 1984) and a marine geophysical survey of the postglacial transgression and associated coastal environments (van Andel and Lianos, 1983, 1984) formed an integral part of the project.[1]

The geological study had two main objectives: 1) to determine the types of soils with which archaeological sites were associated and to assess the possible loss of sites due to erosion, burial by sediment, or inundation by the sea, and 2) to develop the history of soil formation, slope erosion, and valley and coastal plain alluviation in response to natural (e.g. climatic, tectonic, sea-level) and human factors, primarily agriculture and pastoralism.

Beginning in 1960, Claudio Vita-Finzi developed a general model of the late Quaternary alluviation history of the Mediterranean region. This model envisaged two stages of

[1] Besides M. H. Jameson who conceived the project and whose insight and encouragement were evident throughout, many colleagues participated in its execution. Without Anne Demitrack, Hamish Forbes, Timothy Gregory, Nick Kardulias, Susan Langdon, Dimitris Matsas, Mark Munn, Mary Lou Munn, Priscilla Murray, Kevin Pope, Daniel Pullen, and Susan Sutton the material for this paper would not have been prepared. We are deeply indebted to the Archaeological Service of the Greek Ministry of Culture and Sciences, especially to the successive Directors and members of the Argolido-Korinthia Ephorate in Nauplion, and to the Director and staff of the Institute of Geology and Mineral Exploration in Athens who supervised the study. The National Science Foundation, the National Endowment for the Humanities, the National Geographic Society, and many Stanford alumni have made the project financially possible, while some 50 students assisted in the fieldwork. The project was conducted under the auspices of the American School of Classical Studies at Athens. We thank all of them most warmly.

For the full form of the references, see the Bibliography following the text.

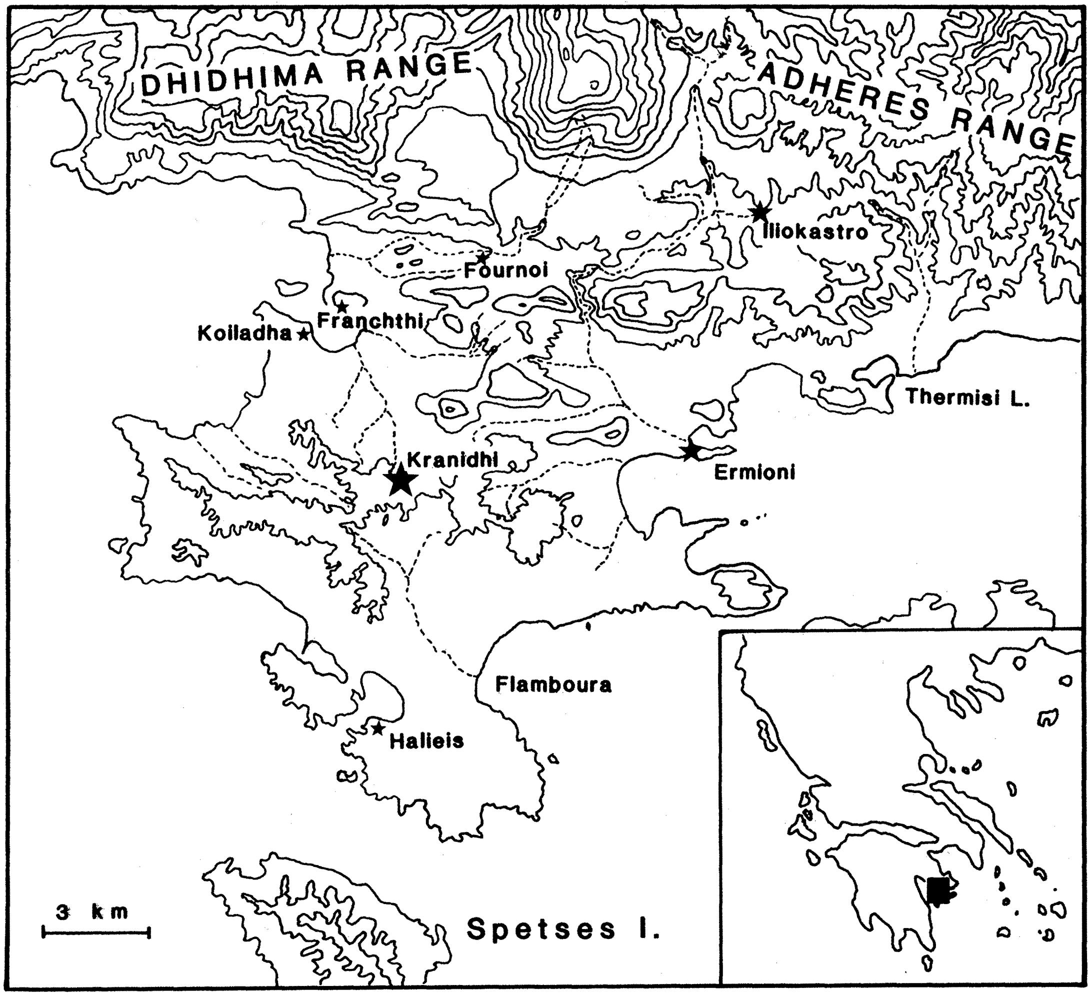

FIG. 1. The Southern Argolid in the Peloponnese, Greece (insert: black square). Streams are dashed. The topographic contour interval is 100 m. (from Greek topographic maps of scale 1:5,000)

alluviation, the Older and Younger Fills, each followed by a period of stream incision (Vita-Finzi, 1969). He placed the Older Fill, identifiable among other things by its full red color, late in the Pleistocene, and assigned the brown-gray Younger Fill to a late Roman (*ca.* A.D. 400) to early Modern date, attributing both to climatic causes. His model has been widely cited in Mediterranean archaeology but has lately drawn fire from studies that have shown the twofold alluviation scheme and the chronology to be too generalized to reflect reality or to permit a constructive analysis of the causes (e.g., Davidson, 1980; Raphael, 1973; and especially Wagstaff, 1981).

We therefore used the opportunity afforded by the Argolid Exploration Project to examine in detail the chronology of landscape stability and destabilization, the varying nature of the deposits, and possible correlations of both with the prehistoric and historic trends which emerged from the archaeological survey. We found a sequence and timing of events that differed significantly from the Vita-Finzi model, and the causes we deduced for the Holocene alluvia emphasize the activity of man more than that of climate. We note at the outset, however, that the conclusions elaborated below apply directly only to the Southern Argolid.[2] Detailed studies in areas with different human histories and environmental settings must assess whether there is more than local merit to our views.

The Archaeological and Geological Surveys

Field work was conducted during four seasons from 1979 to 1983 with the goal of investigating the changing patterns of human settlement and land use in the context of the history of the natural landscape, i.e., the human paleo-ecology of the Southern Argolid (Butzer, 1982). Details of the methods and results of the archaeological survey are discussed in Runnels (1981) and Runnels and van Andel (forthcoming) and in greater detail in Jameson *et al.* (in preparation).

The survey area approximately coincides with the eparchy of the Ermionis, an area of 225 sq. km. south of the Aderes and Didima ranges. Previous explorations and a reconnaissance survey in 1972 by an Indiana University and University of Pennsylvania team under the direction of T. W. Jacobsen, M. H. Jameson, and J. A. Dengate (University of Illinois at Urbana-Champaign) had revealed the presence of numerous archaeological sites; we verified as much as possible their locations, ages, and properties during the 1979–1983 survey.

The territory in its entirety was too large for complete coverage, and in any case some parts were not open to survey because of the destruction or inaccessibility of traces of the past in towns, industrial or resort areas, or on land of uncooperative owners (Fig. 2). Given the limits of our time and resources, it was necessary to restrict the intensive survey to about 20% of the total area. We rejected probabilistic approaches, although admittedly ideal in principle, as neither feasible nor taking proper advantage of pre-existing knowledge. Instead, we chose a sampling scheme guided by environmental considerations and a guarded use of previous information. We selected about ten separate tracts, emphasizing representative geomorphological and environmental settings, and avoided steep, barren slopes, although we inspected all ridge and crest areas. In addition, we paid special attention to the surroundings of the excavated sites of Halieis and Franchthi and explored to at least some degree each of the small drainages of the region. Altogether, about 44 sq. km. (*ca.* 20%) of the Ermionis were covered in an intensive manner, while the areas omitted from the intensive survey were inspected by special teams in a more extensive fashion.

Each survey tract was laid out on a Greek topographic map (scale 1:5,000) and surveyed by field-walking teams of at least five people spaced 5–15 m. apart. By this procedure

[2] Work in progress in the Argive plain in collaboration with the Deutsches Archaeologisches Institut in Athens appears to confirm some of our inferences but has not yet reached the final stage.

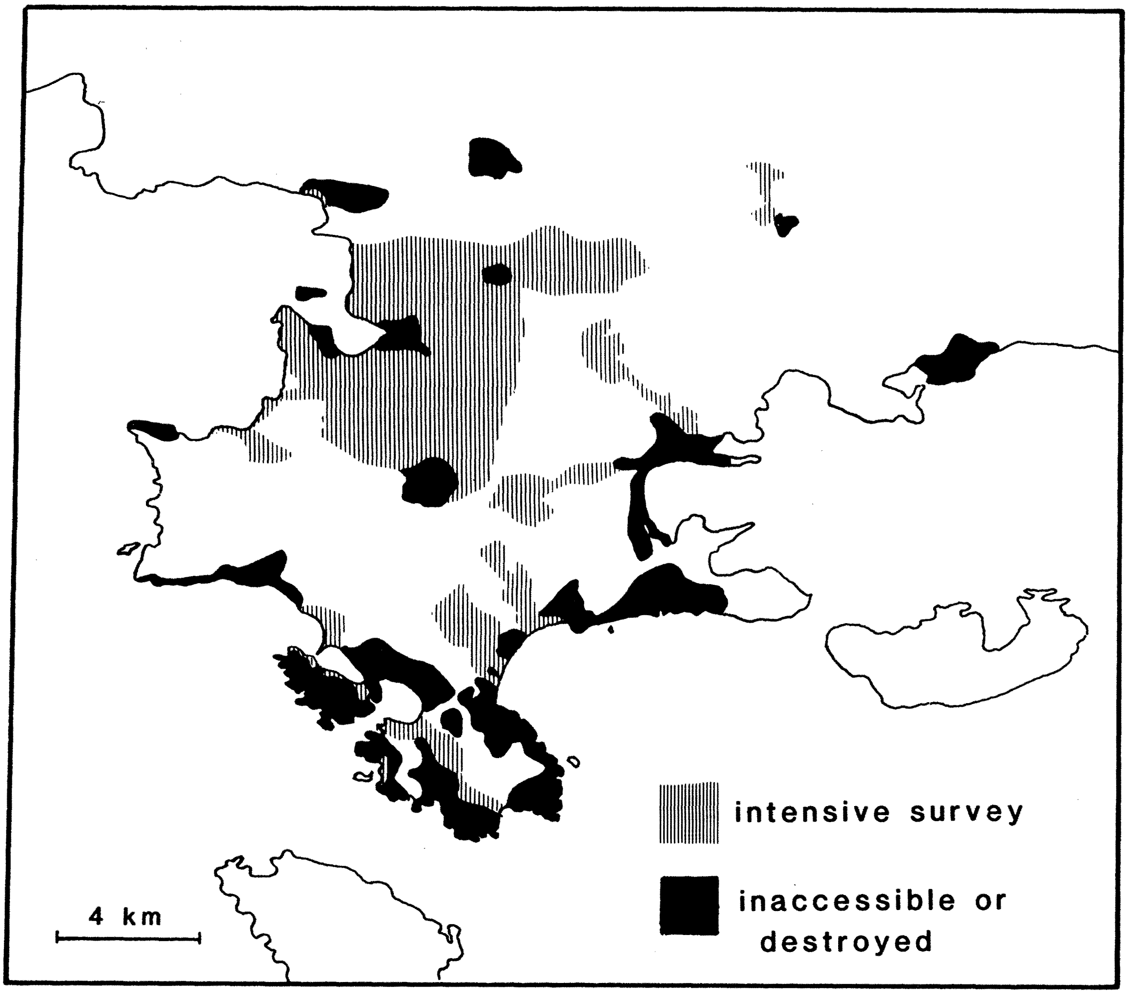

FIG. 2. Areas surveyed intensively and extensively during the Argolid Exploration Project

we detected sites as small as 12 sq. m. A site was defined as "a concentration of cultural materials with a recognizable boundary". Furthermore, in order to be considered "primary" the site had to show evidence that the cultural materials were coming from a buried context. Material from each site was collected by means of random sample squares or transects, as were all other diagnostic or "feature" artifacts. Approximately 319 sites were located and sampled.[3]

Discovery and identification of sites may be impeded by burial under later deposits, although erosion, plowing, and burrowing often bring cultural materials to the surface, but fortunately this is of small concern in our area. Less than 5% of the region is covered by

[3] A complete site register with ages, locations, and descriptions of all sites will be published in the forthcoming comprehensive report on the survey (Jameson *et al.*, in preparation).

Holocene alluvium, and those deposits tend to be thin and much incised. Much land exposed during the Upper Palaeolithic is now under the sea (van Andel and Lianos, 1983), but the postglacial rise of the sea has slowed, and a coastal zone measuring a mere 7% of the present land was inundated since the Neolithic.

The geological study, having for its objective the landscape contemporaneous with human settlement, was primarily oriented towards late Quaternary deposits and events. For practical purposes, those beds not affected by the last phase of tilting and faulting (Dufaure, 1965, 1977; Dufaure *et al.*, 1979) were assumed to constitute the late Quaternary sequence. Those deposits are restricted to narrow coastal plains and to the floors and lower slopes of the valleys in the many small drainages of the region (Fig. 3). We also examined and mapped all remnants of old soils, now found mainly on the rolling hills of the southern peninsula and in the Fournoi valley.

In the semiarid climate of the Southern Argolid, streams are seasonal except where fed by an occasional perennial spring. At present most are deeply incised in the deposits of earlier alluviation phases or in bedrock. Active deposition occurs in only a few places, such as the lower Ermioni valley and the few coastal lagoons.

The geological survey combined aerial photo analysis with a detailed field examination of all drainages to construct geological maps on a scale of 1:5,000 on which all archaeological sites identified by the survey teams were entered. In most valleys, several phases of alluviation could be recognized, but the discontinuous and highly variable deposits do not allow us to distinguish older and younger units with confidence unless they are superimposed, nor do they easily permit correlations from one valley to another (Butzer, 1980). Between phases of alluviation, however, soils formed (Fig. 4) whose properties depend on their maturity and so can be used to correlate across the region and to estimate the approximate age of the deposits (Birkeland, 1984, pp. 194–224; Harden, 1982; Morrison, 1976).

Using associations with buried soils, the characteristics of those soils, and such features as stream terraces and fan lobes, a sequence of deposits was established for each drainage, and the individual sequences were correlated across divides by means of paleosols. More precise age estimates than those based on soil properties were needed, however, to provide the fine chronological resolution demanded by our archaeological objectives. Artifacts contained in the alluvia, mainly potsherds, provided a date *post quem*, sites superimposed on them a date *ante quem* for individual stratigraphic units. Although both dates may differ considerably from the actual time of deposition, by good fortune several of the Argolid stratigraphic units were closely bracketed in time by means of archaeological data.

Units deposited prior to the Bronze Age usually lack artifactual material, nor do they contain in this area charcoal or wood suitable for radiocarbon dating. We succeeded in establishing the ages of some of them with thorium-uranium disequilibria determined on dense calcium carbonate nodules from the calcareous horizons of the paleosols (Ku *et al.*, 1979; Ku and Liang, 1983; Pope *et al.*, 1984). At the opposite end of the time scale, historical data have sometimes been helpful, especially the geomorphological features shown on Venetian cadastral maps of the early 18th century (Topping, 1976).

Although the chronological base (Pope and van Andel, 1984, table 3) is less ample than we would have liked, it is adequate to place the alluvial and soil units in a stratigraphic

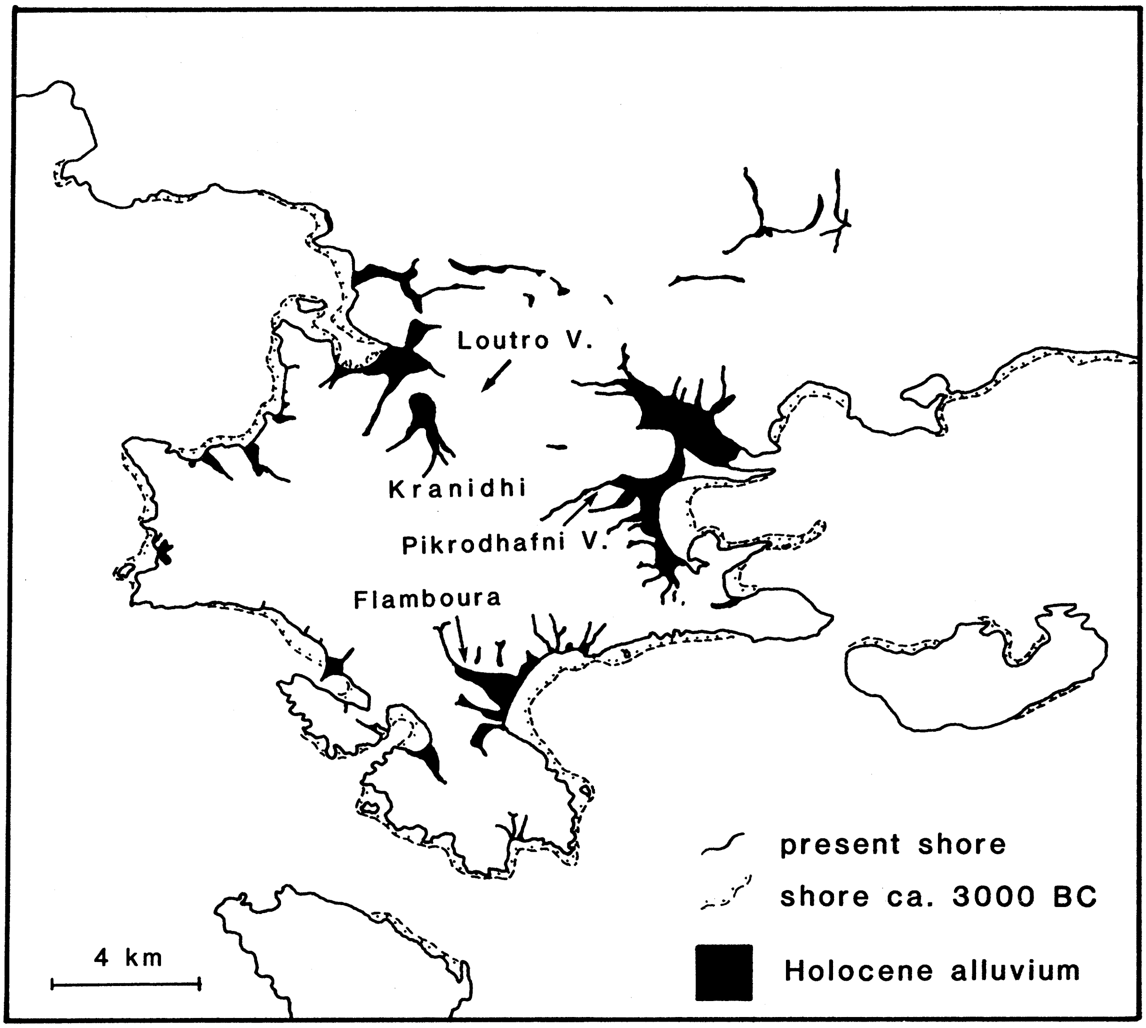

FIG. 3. Areas covered with Holocene alluvium (shaded). Between dashed and solid coastlines lies that part of the shore zone which has been inundated by the sea in the last 5,000 years. Place names indicate type locations of late Quaternary alluvial units (see Fig. 4)

scheme suitable for our purpose. The dates do not demonstrate perfect synchroneity between events in individual valleys, but, taken over the whole peninsula, they set useful limits on their onset and end.

Alluvial Deposits and Sequence of Events

Seven alluvial events can be recognized in the late Quaternary deposits of the Southern Argolid (Fig. 4). They are separated by intervals of landscape stability during which soils formed; only the last unit is too young to possess even an incipient soil.

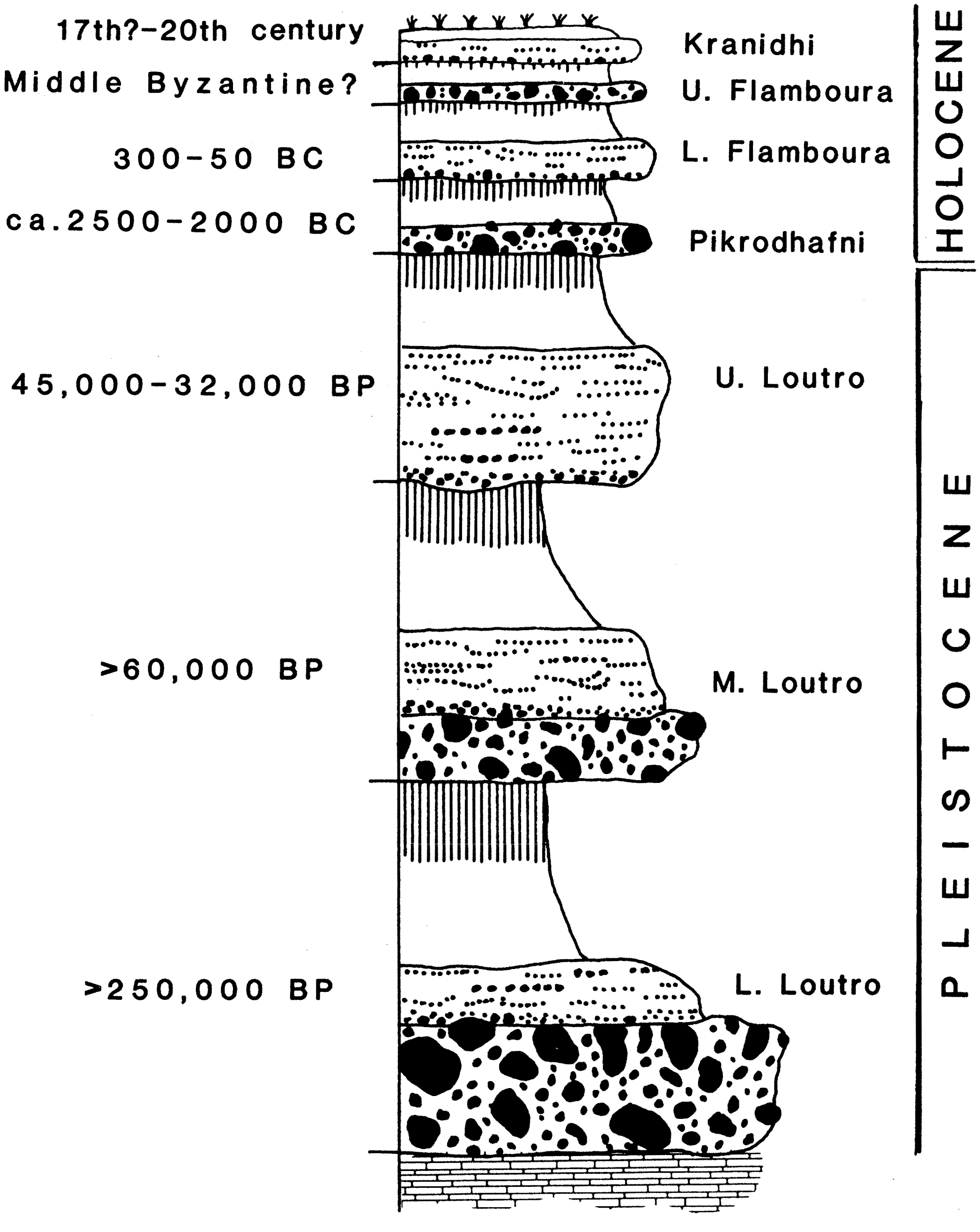

FIG. 4. Sequence of late Quaternary alluvial deposits and intervening soils with their approximate ages. Chaotic mass of large boulders represents debris flows; stratified gravels are stream-flood deposits. Intervening blank zones are overbank loams with soil profiles (vertical shading proportional in length to the degree of soil maturity). Units displayed in approximate proportion to their average thicknesses

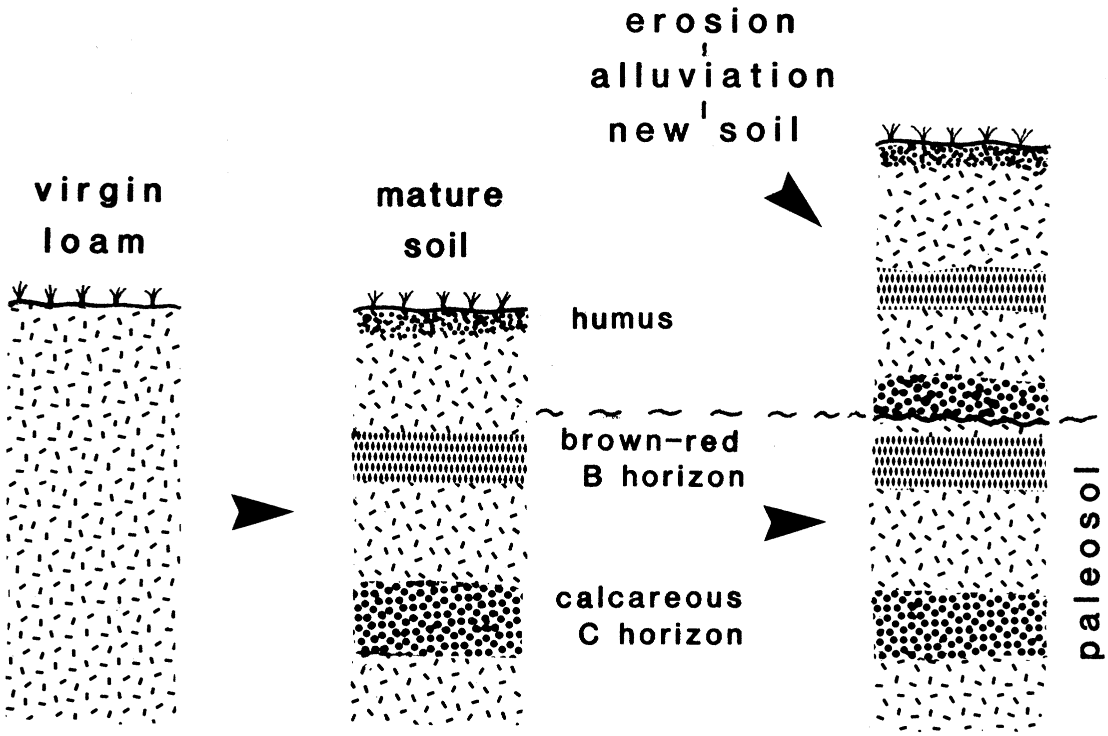

FIG. 5. Soil formation in a semiarid climate. Profile at extreme right shows erosion resulting in loss of top soil, followed by deposition of new alluvium and formation of another, less mature soil

Commonly only the B and C horizons (Fig. 5) of the old soils have been preserved. The B horizon is characterized by an intensification of color to reddish brown and red, by the deposition of pedogenic clay, and by the formation of a blocky soil structure (e.g. Birkeland, 1984, pp. 118–152). In the C horizon, calcium carbonate is deposited, beginning as scattered flecks but evolving to hard nodules and eventually massive calcareous banks (e.g., Leeder, 1975; Wieder and Yaalon, 1982). These processes are slow, and well-developed soils require thousands of years of landscape stability (Birkeland, 1984, pp. 194–224; Harden, 1982). Alluviation, on the other hand, is a quick process; local data allow a mere 250 years for the formation of the Lower Flamboura and a few decades for some examples of the Kranidi unit (Pope and van Andel, 1984). Evidently, the geomorphic history of the Southern Argolid has been one of long periods of tranquility irregularly broken by brief events of slope destabilization and valley alluviation.

With decreasing age, the alluvial units decrease markedly in thickness (Fig. 4), owing to a gradual reduction in slope mantle available for erosion and to an improved chance of preservation. This suggests that the sevenfold scheme may be incomplete and that some alluviation events, especially of Pleistocene age, may no longer be represented.

It also indicates that the denudation of the slopes of whatever soil mantle they may have possessed took place mainly during the Pleistocene, the volume of soil erosion having been relatively unimportant during the last 5,000 years. We have estimated elsewhere (Jameson *et al.*, in preparation) that postglacial erosion has removed a soil volume equivalent to a layer covering the whole area to a depth of less than 70 cm. A separate estimate for the southern peninsula which consists of softer, more easily eroded bedrock shows removal of about 100 cm., in contrast to less than 40 cm. for the hard limestone ranges in the north. Evidently, the barren aspect of this part of the Peloponnese[4] is largely due to the ravages of Pleistocene climate and sea-level changes and only to a lesser degree attributable to human carelessness.

The erosional and depositional processes that formed individual alluvial units can be inferred from the nature of the sediments themselves (e.g., Picard and High, 1973; Patton and Schumm, 1981). Three depositional types (Fig. 6) can be distinguished in the semiarid alluvial deposits of the Southern Argolid. The first are the debris flows, chaotic beds of ill-sorted, largely angular boulders, cobbles, and pebbles, surrounded and supported by a matrix of finer material (Bull, 1972, 1977; Hooke, 1967). Sheet erosion of weathered slope mantle forms debris flows which are often deposited catastrophically as thick, water-rich slurries (Innes, 1983). In the Southern Argolid, some debris-flow deposits blanket an entire valley floor with a single unit several meters thick. Sheet erosion becomes possible when the slope mantle is rendered vulnerable by a reduction in the plant cover due to prolonged drought, fire, or clearing.

Stream-flood deposits are formed during flood stages in braided channels and on bars (Rust, 1978; Miall, 1977). The stratified sediments consist of lenticular beds of fairly well sorted gravel and sand. In this case, it is increased runoff concentrated in gullies rather than sheet erosion that enhances down-cutting and sends a large sediment load downstream. One possible cause is an increase in precipitation not immediately compensated by a denser vegetation.

The most common alluvial deposit is a sandy overbank loam, often with thin pebble layers. This loam forms slowly and intermittently on valley floors and coastal plains during flood stages and also constitutes the distal parts of alluvial fans. All alluvial units in the Southern Argolid terminate in overbank loam which carries the soil of the postdepositional interval of stability.

In addition, the late Quaternary has extensive colluvium, i.e. slope-wash deposits, ranging from gravels to loam, and areas of old, deep soils formed on bedrock. Judging by their present distribution, these autochthonous soils formed mainly on the Cenozoic marls and shales of the southern peninsula and on an igneous complex known as ophiolites, common in, for example, the Fournoi valley and on the Iliokastro plateau. No remnants of these deep autochthonous soils have been found on the steep limestone slopes of the north, nor on the youngest Cenozoic mudstones and conglomerates in the extreme south where soil development was apparently thin. Although significantly eroded, enough remains of the old, deep soils to reconstruct their early and middle Holocene distribution, before extensive human use began (see, for example, Fig. 8).

[4] We believe that this conclusion applies to most of the Peloponnese and perhaps much of central Greece as well but have no quantitative evidence to support such a contention.

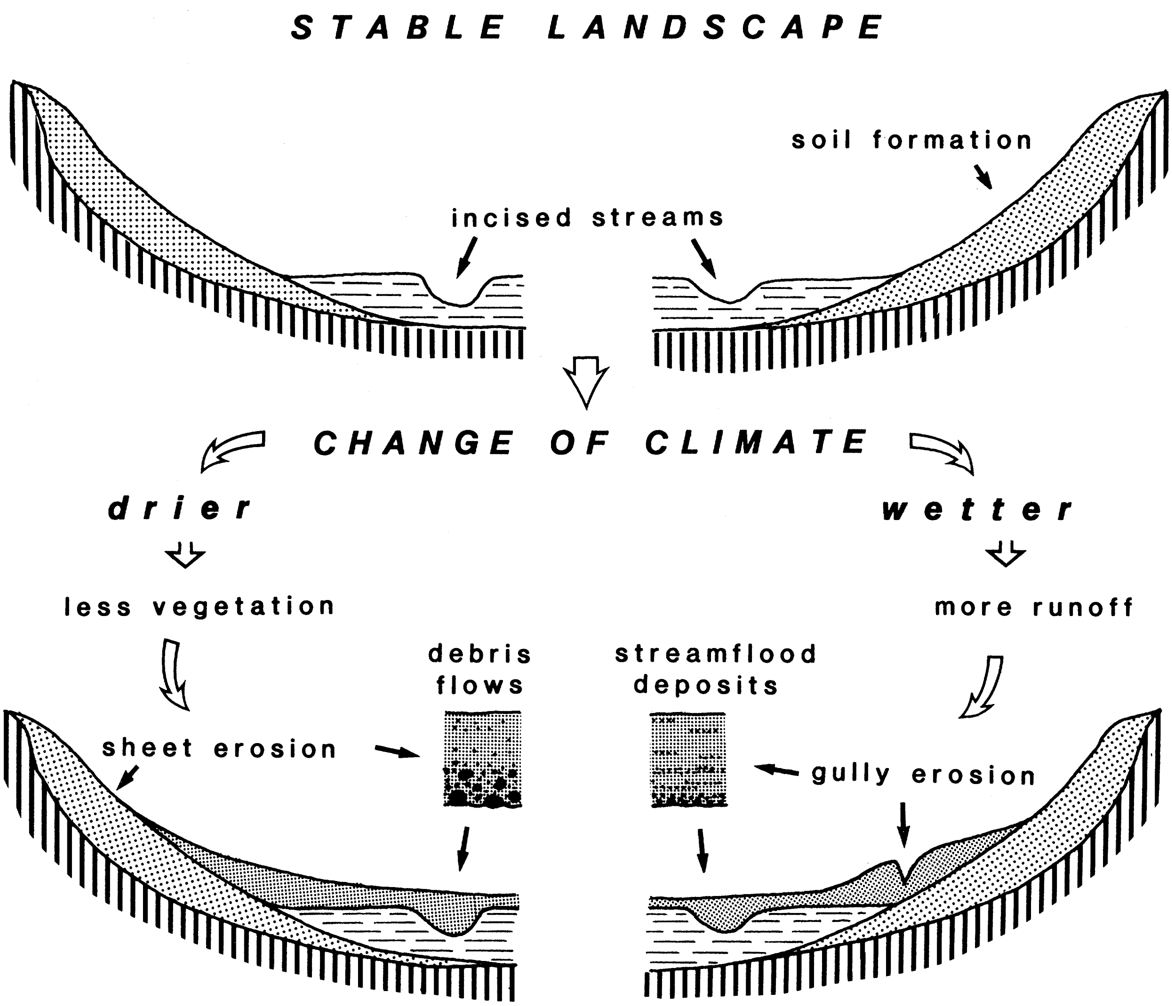

FIG. 6. Diagram of destabilization of slopes by climate change in a mature landscape where soils form and streams are incised. Drier climate leads to reduced vegetation (land clearing may do the same), sheet erosion of slopes, and the deposition of debris flows. A wetter climate (or neglect of existing terracing) leads to gully erosion, concentrates runoff, and produces stream-flood deposits

The three main alluvial facies occur in various combinations among the seven stratigraphic units. The Pikrodafni and Upper Flamboura, for example, are dominated by debris flows, whereas the Lower Flamboura and Kranidi are stream-flood deposits, thus demonstrating that the forces disturbing the stability of the landscape have varied with time.

The final Pleistocene alluviation (Upper Loutro: Fig. 4) was followed by long stability, the more remarkable because it spans the high glacial, the postglacial climatic optimum, and part of the subsequent gradual climatic deterioration. Then, about 4,000 years ago, began a series of thin but widespread alluvia separated by relatively brief periods of quiescence, the first arriving about a thousand years after the initial spread of settlement across the peninsula. While the causes of the Pleistocene alluviation events are undoubtedly to be sought in climate and sea-level changes (Pope and van Andel, 1984), the coincidence between the sudden Holocene increase in the frequency of alluviation events and the spread of settlement forces us to consider human causal factors.

Settlement Patterns, Soils, and Soil Erosion

The earliest traces of human occupation in the Southern Argolid date to about 50,000 B.P. (Pope *et al.*, 1984), and the Franchthi Cave site was settled at least since the Upper Palaeolithic (Jacobsen, 1976), but settlement elsewhere in the Southern Argolid remained exceedingly sparse (Fig. 7) until the Final Neolithic (FN) when, some time during the 4th millennium B.C., expansion across the peninsula began. The principal site at Franchthi was abandoned or left to shepherds and their flocks, and the number of sites, now scattered widely across the peninsula, rose from 2 confirmed ones in the Late Neolithic to between 7 and 13 FN sites, and to 28–32 by the Early Helladic (EH) II (Fig. 8). With few exceptions, the FN and EH sites cluster on or near the deep autochthonous soils, apparently avoiding areas where such soils are now, and probably always were, thin or absent.

Previously, these lands were probably covered with a moderately rich, open wood- or parkland of deciduous oak with hornbeam, beach, and holly (e.g. Rackham, 1983). Sparse pollen data from Thermisi lagoon in the Southern Argolid (Sheehan, 1979) suggest that remnants of this woodland still lingered in the area around the middle of the 3rd millennium B.C., even though much clearing would by then have taken place.

During the 4th and early 3rd millennia we encounter no evidence that the spread of settlements and clearing of the land had a destabilizing effect on the landscape, but ultimately damage was inevitable. The Pikrodafni alluvium, broadly dated by its content of EH I and II sherds and the presence of a Late Helladic (LH) site on top, has a soil-maturity level consistent with an age of about 4,000 years, and an analogous unit in the Argive plain is more narrowly bracketed by EH II material within and EH III sites on top. The Pikrodafni is found only in valleys where FN and EH I and II settlement was extensive, and its deposits consist mainly of debris flows. The individual flows formed essentially instantaneously but need not have been synchronous across the entire peninsula.

The EH III period brought a sharp drop from 28 confirmed sites to only 2, rising but slightly to 5 in the Middle Helladic (MH). A major expansion to 27 confirmed and 10 probable sites took place in the Mycenaean (LH) period (Fig. 9). It would be rash, however, to attribute the EH III decline to the soil erosion documented by the Pikrodafni, because political or economic disturbances were widespread at this time in the whole Aegean region (Caskey, 1960; Rutter, 1979). Moreover, although substantial damage was no doubt incurred, especially on some of the valley bottoms, the remaining deep soils continued for millennia to provide the principal local agricultural base.

What were the causes of such extensive erosion arriving so late during the first major agricultural expansion in the area? Destabilization of slopes accompanied by valley alluviation takes many forms (Butzer, 1974; Bell, 1982). Settlements themselves disturb

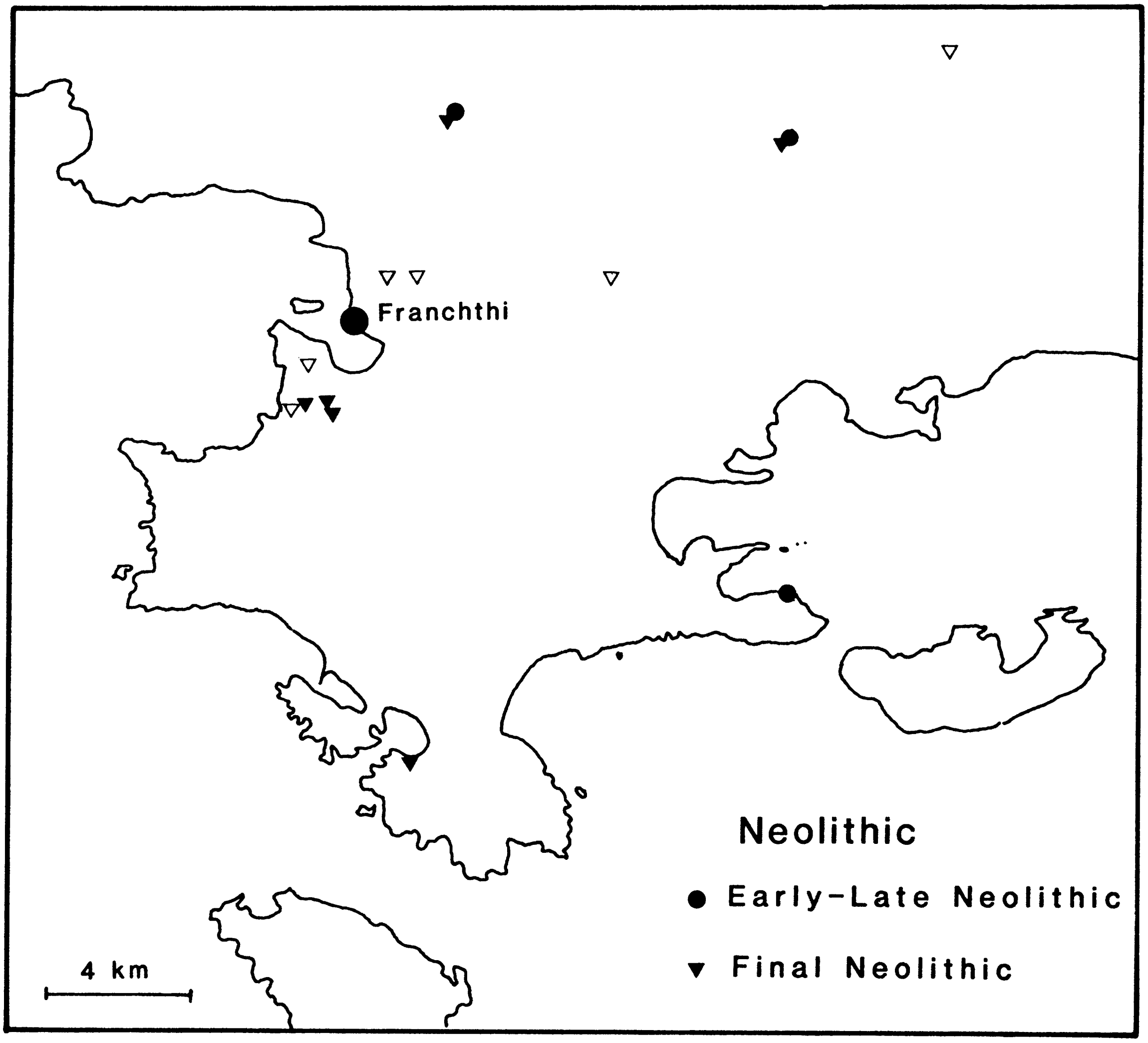

FIG. 7. Early through Late Neolithic sites in the Southern Argolid are few, but expansion into new lands begins in the 4th millenium B.C. Filled symbols indicate sites of confirmed age; open ones mark probable ones

vegetation and soil and concentrate rainfall and runoff, thereby accelerating erosion. Bare rocky slopes can be seen at present below such hilltop villages as Kranidi; the dislodged sediment forms a distinct apron in the plain. Prehistoric examples are provided by the row of EH I and II sites on the hills south of Koilada Bay; established to exploit the deep upland soils of the hill tops, the sites themselves are now on bare bedrock.

The soils of the gently rolling hill country of the southern peninsula and of the ophiolites of the Fournoi valley and Iliokastro plateau, mainstays of agriculture during the 4th through 2nd millennia B.C., are not especially vulnerable to erosion even without deliberate

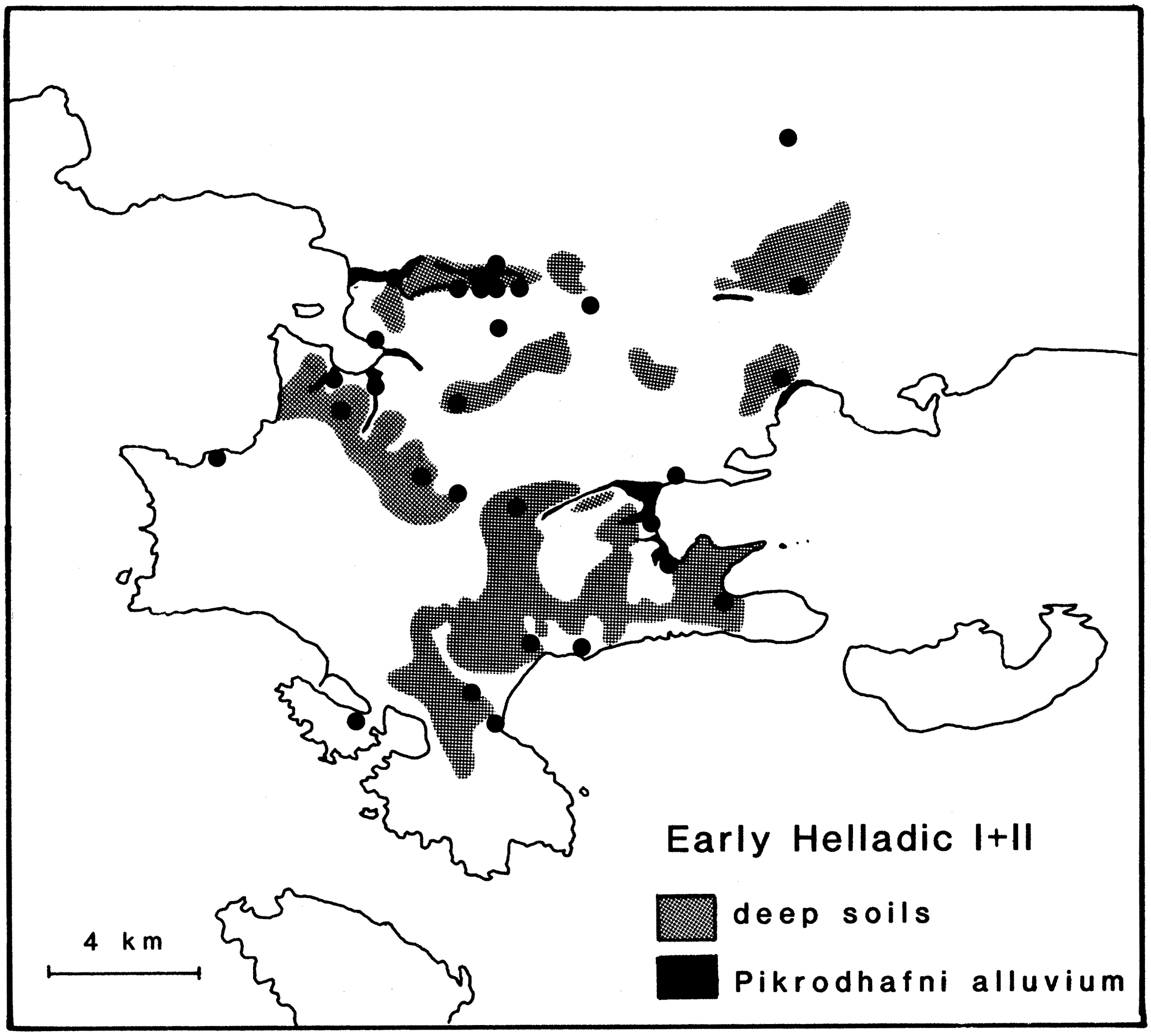

FIG. 8. Distribution of Early Helladic I and II sites relates closely to old, deep soils (shown here and in Figs. 9 and 10 in their reconstructed original extent). Pikrodafni alluvium of late 3rd or early 2nd millenium B.C. is found mainly downstream of clusters of sites and is attributed to catastrophic soil erosion resulting from intensified land use without soil conservation. Only sites of confirmed age are shown on this and all following maps

attempts at soil conservation. Evidence for this is the relatively large area of deep soil still remaining after 5,000 years of exploitation. In the semiarid climate of the eastern Mediterranean, landscape stability is naturally maintained by the vegetation (e.g. Naveh and Dan, 1973), and even after a major disturbance *maquis* and pine woods will quickly establish a protective cover provided that the disruption by burning, brush cutting, or

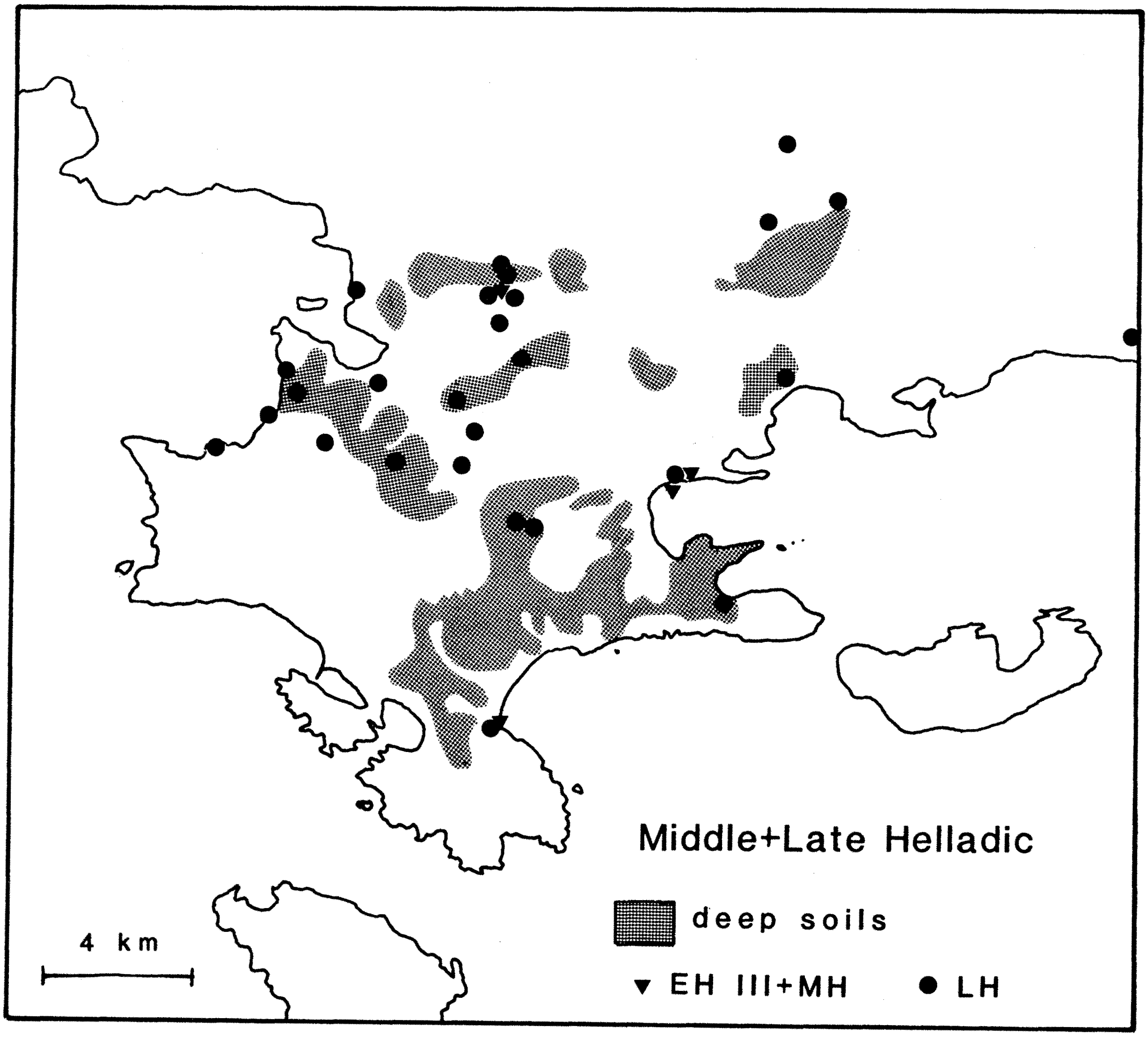

FIG. 9. Sparse Middle Helladic sites imply reduced pressure on land, but Late Helladic expansion returns to the old, deep soils exploited since the 4th millenium

overgrazing does not continue too severely. We have seen terraces bulldozed into steep slopes of shale which, having been abandoned after failure to deliver the expected yield, had become fully protected by a dense growth of *maquis* within a decade or so.

Therefore, a system of long fallow, with plowed fields scattered between larger areas left untended for many years, would present little risk of major soil erosion, because *maquis* would swiftly colonize fallow fields, as pollen data indeed indicate (Sheehan, 1979). Occasionally, a few years of exceptional rains in summer when the plant cover is most fragile might induce sheet erosion, but otherwise the risk of soil erosion would only gradually increase as growing population pressure led to shortening of the fallow and exploitation of progressively steeper slopes.

Whether caused entirely by increasing intensity of exploitation or aided by temporary shifts in the rainfall pattern (for which geological evidence would be hard to find), the Pikrodafni event demonstrates the eventual failure of EH agriculture to contain the loss of soil. That renewed expansion during the LH did not invite a similarly disastrous response, even though the same soils and slopes were exploited, demonstrates that the lesson had been learned well.

The traditional approach to soil conservation in the Aegean, and throughout much of the Mediterranean, is the construction of stone-walled terraces on slopes and stone check dams across gullies and small streams. The system is not only effective in reducing erosion but actively stores soil behind the terrace walls. Kept in good repair, terraces and dams virtually eliminate sheet and gully erosion, but the soil reservoir which gradually accumulates behind them is delicately perched and metastable. Once that reservoir is set in motion by any breaching of its walls, erosion is rapid and difficult to contain. Although an excellent soil conservation method, terracing exacts it price by the need for unceasing maintenance (Forbes and Koster, 1976).

Terrace walls appeared in the Levant during the later 2nd millennium B.C., associated with the culture of the olive (Gophna, 1979). In Greece, they have been used since at least Classical times, but few walls so old or older have been identified, and the date of introduction of the technique is not known. We have, however, seen behind an old terrace wall the occasional soil profile that appeared to be only slightly less mature than the Pikrodafni soil and hence might date to the 2nd millennium B.C. Mycenaean engineering, adept at the construction of fortresses, roads, bridges, and retaining walls, was certainly up to the task.

Whatever the soil conservation techniques may have been (although terracing appears to us the only plausible candidate), they were eminently successful, because no further trace of alluviation is found for the entire period of Mycenaean prosperity. Not even the collapse at the end of this period and the subsequent major abandonment of the area shown by the apparent absence of 11th- and 10th-century sites have left any mark on the landscape. The reason must surely be the rapidity with which, upon abandonment of large tracts of land, the natural vegetation takes over. Kermes oak, pistachio, wild pear, broom, and other shrubs normally edge all but the most meticulously kept terraces, and their roots hold the mass of soil firmly in place after the stone walls themselves have fallen away. Terraces long deserted but perfectly preserved by this means can be seen all over the Argolid. Moreover, *maquis* colonizes the terrace surfaces within a few years, impeding serious erosion.

The first resettlement of the Southern Argolid dates to the 10th century B.C. or after, but the recovery was slow and did not accelerate until the later 8th century. Settlement reached a maximum of 78 confirmed and 32 probable sites in the later 4th century B.C. (later Classical and early Hellenistic periods). First reoccupied were the old deep soils, mainstay of traditional cereal agriculture, but with the 5th century a major expansion began onto the thinner, stonier, and often steeper soils of the Pleistocene Loutro alluvium, as well as onto the late Cenozoic conglomerates and mudstones of the southernmost peninsula (Fig. 10). Many small sites were placed near steeply sloping land that could not have been used without terracing, thus providing further evidence that this had become the common mode of soil conservation. Elsewhere we have argued (Runnels and van Andel, forthcoming) that the

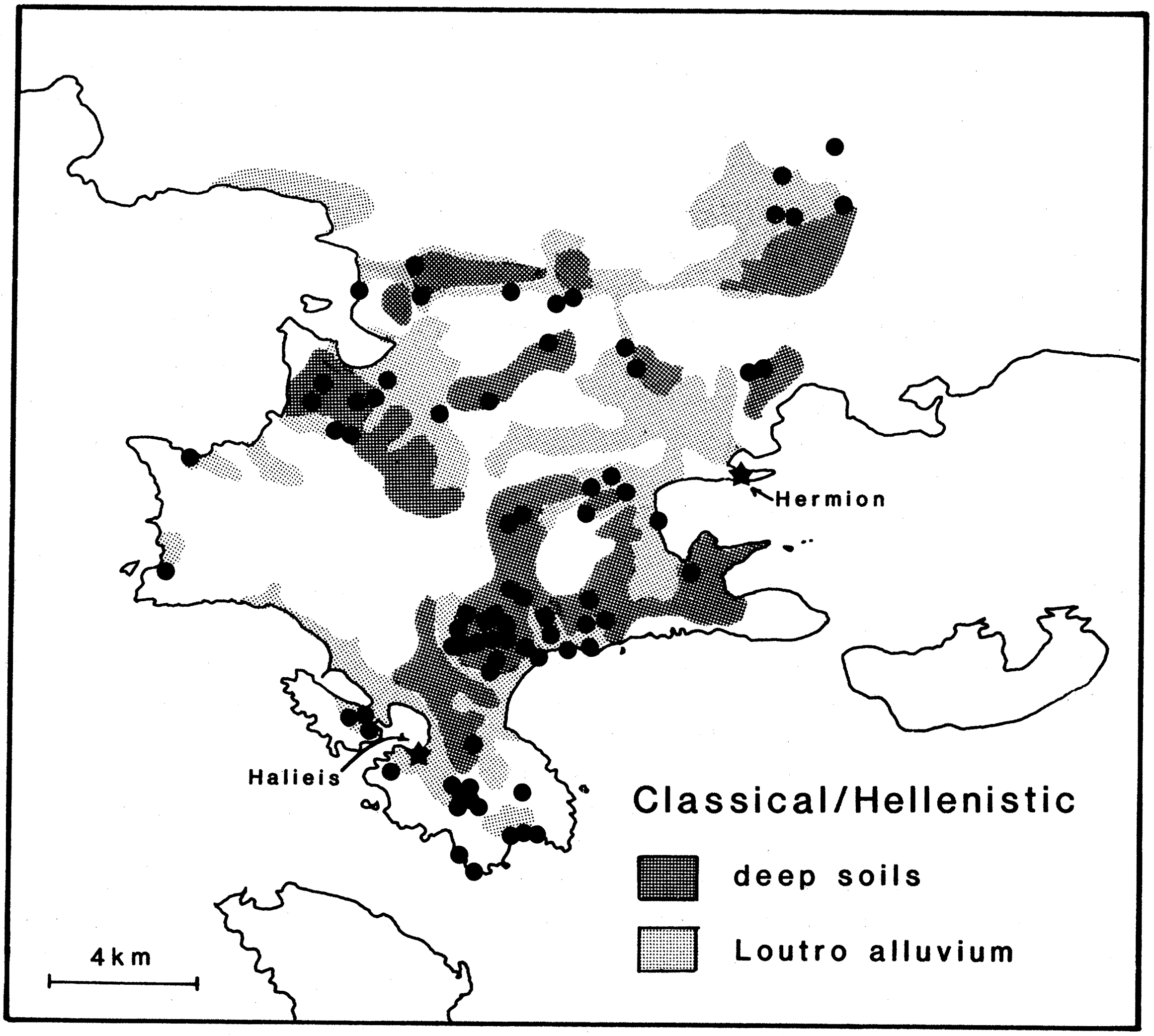

FIG. 10. Large expansion of Classical and Classical/Hellenistic sites continues to exploit old, deep soils but also extends to coarser, less favorable Loutro alluvium (lighter shading)

main force behind this expansion onto more marginal lands was an increase in cash cropping, especially of olive oil, for external markets.

This development carried with it a high environmental risk, and the consequences were not long in coming. Beginning in the 3rd century B.C., the Greek and Aegean worlds experienced a lengthy economic decline, and settlement in the Southern Argolid was sharply reduced, remaining thin until the 3rd century after Christ (Fig. 11). Wholesale abandonment of fields in the Hellenistic and Early Roman periods is reflected in a major increase of *maquis* pollen in the sediments of coastal lagoons (Sheehan, 1979) and in soil erosion which

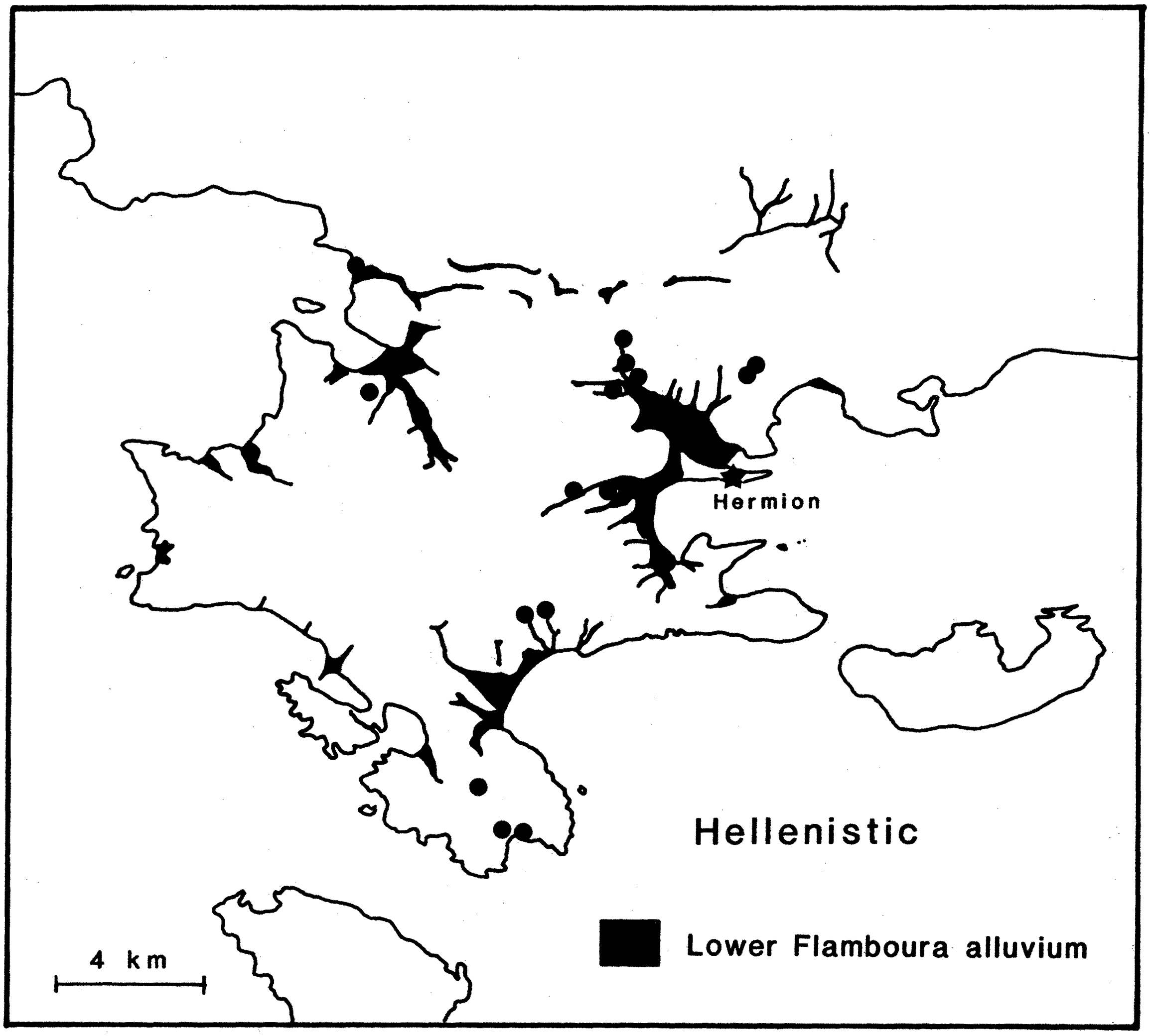

FIG. 11. Considerable reduction in number of sites due to economic adversity takes place during Hellenistic and Early and Middle Roman periods. Neglect of terrace walls is thought to account for the deposition of the extensive Lower Flamboura stream-flood deposits late in the 1st millenium B.C.

produced the extensive deposits of the Lower Flamboura. Evidently, as regards soil conservation a depressed rural economy may be far more damaging than total economic collapse.

During an economic downturn, the upkeep of agricultural terraces, especially when distant and on marginal soil, is seen as not cost-effective over the short term (Jameson, 1977–78), and the farmer will tend to redirect his efforts to better, more centrally located fields. A small continuing benefit may, however, be extracted by harvesting some olives and especially by turning the fields over to grazing by sheep or goats. This practice, common in the off-season in times of prosperity also, requires considerable effort by the shepherd to insure that terrace walls and land are not damaged, an effort less likely to be made when the interest of the landowner has so obviously lessened.

When the shepherd ceases to control his flock with brush barriers and no longer repairs any damage they may have done to the walls, two things happen that are serious and eventually fatal to the soil accumulated for centuries behind the walls. Sheep and goats wander across those walls, kicking down stones and creating trails soon excavated by the winter rains into gullies, which branch within the deposits behind the walls and rapidly remove the soil. The increased and concentrated runoff swells the small streams and spills across check dams, undercutting them until they collapse. Very rapid vertical erosion is the result. We note that, unlike the fine quality of prehistoric hydraulic engineering seen in some other parts of the world (e.g. Donkin, 1979), check dams in the Southern Argolid tend to be poorly constructed without proper spillover rims and splash basins. Moreover, owners appear to prefer the freedom to schedule work that comes from repairing rather than preventing damage and to accept the limited soil loss that normally results.

The consequences of neglecting maintenance while pastoralism continues are swift. In a small valley south of Koilada, intact terracing is evident on aerial photos taken in 1961. In 1979, few walls remained, slopes were strewn with boulders, soil erosion was obvious from exposed tree roots and fallen trunks, and 40 cm. of alluvium had accumulated in the bottom of the valley. Today, this process, observable elsewhere in the area, is usually not due to economic stress from, say, lost markets but rather to a redirection of the landowner's interests away from subsistence agriculture and towards tourist industry or sale of the land, but the results are the same.

Gully erosion concentrates runoff and increases stream flow, thus enhancing the deposition of stream-flood sediments which make up the Lower Flamboura. Of course, the same stream-flood deposits could have formed if runoff had been increased by a change towards a wetter climate. The unit is narrowly dated to the Hellenistic period, however, by Classical and Hellenistic sherds within the deposits and Hellenistic and Late Roman sites on top (Pope and van Andel, 1984, table 3), and there is no independent evidence for a climatic change at that time. Neglect of soil conservation thus appears to be the best explanation of the event.

We are fortunate that the alluvial history of the Southern Argolid contains more than one example of each of the postulated relations between land use and soil erosion or stability, thereby presenting us with a partial test of our reasoning.

Beginning in the 3rd century after Christ a strong economic recovery took place in parts of Greece, including the Southern Argolid, a recovery which continued into the 5th and 6th centuries. Sites of this date are numerous (Fig. 12), many of them reoccupying abandoned Classical and Hellenistic sites. The preference for old, deep soils, for Loutro alluvium, and for the southernmost peninsula also harks back to Classical and early Hellenistic times. The alluvium deposited during the time of retrenchment apparently held little attraction, perhaps because it was not yet old enough to possess adequate soil development, something which holds true for the Kranidi alluvium today.

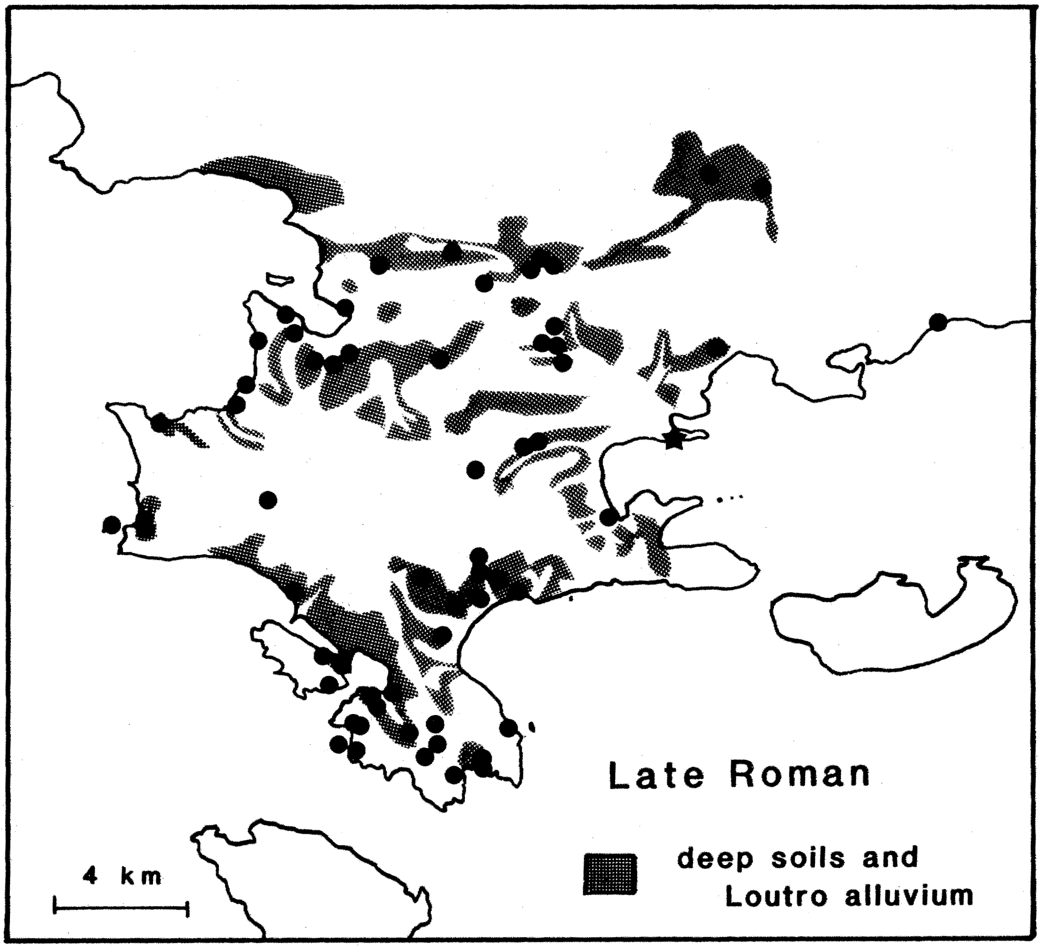

FIG. 12. Renewed expansion, beginning in the 3rd century after Christ, had no impact on slope stability and alluviation, being apparently accompanied by adequate soil-conservation measures. Deep, old soils (shown here in their present extent because of the severe losses during the Lower Flamboura erosion) and Loutro alluvium drew most sites

The expansion also involved lands not cultivated before, including some steeper slopes of the headwaters of the Ermioni and Fournoi rivers, but the pace of development must have been deliberate, and care was taken with soil conservation, impeccably restoring old terrace walls and dams and constructing new ones, because the landscape remained perfectly stable throughout.

Unfortunately, prosperity did not last long, because the barbarian invasions, beginning already in the 3rd century, increased markedly towards the end of the 6th and upset the economic stability of much of the Eastern Roman Empire. We have no evidence for sites in the area after the early 7th century, and once more pine and *maquis* become evident in the pollen spectra of coastal lagoons (Sheehan, 1979), protecting the soil effectively against erosion.

Not until the 9th century after Christ or later was Byzantine authority restored in the area, allowing settlers to return. They built their small hamlets and chapels in the headwaters of such valleys as those of Ermioni and Pikrodafni (Fig. 13) but shunned the shore. Kranidi on its ridge was probably founded at this time, with an excellent view of the sea but safely away from the coast. The exception was the former Classical town of Hermion (modern Ermioni), rebuilt and fortified to provide an outlet to the sea and the external world. The southernmost part of the peninsula was left uninhabited.

The new farmers, perhaps not familiar with the methods of soil conservation traditional to the area, were much less careful than their Roman predecessors. Extensive deposits of Upper Flamboura alluvium in the valleys below the clusters of Middle Byzantine sites (Fig. 13) bear witness to considerable erosion of the newly cleared lands. The age of the Upper Flamboura is not well constrained; nothing later than 6th-century Roman sherds has been found in it, and Venetian cadastral maps show houses on top of it, but its location downstream from the major Middle Byzantine/Frankish settlements suggests contemporaneity with them. Debris flows make up the bulk of the deposits as they did for the Pikrodafni, pointing to similar causes: rapid clearing of steep, thin soils without sufficient erosion control by terracing.

A period of quiescence separates the Upper Flamboura with its incipient but recognizable soil from the Kranidi alluvium which has none. The Kranidi alluvium is thin and sparsely distributed throughout the area (Fig. 14). Its age and history vary from place to place, but unfortunately its chronology is not well established, and neither are we well informed about the Frankish, Venetian, and early Modern history of the area.

The oldest Kranidi alluvium is found in the Fournoi area, but the landscape appears to have stabilized soon, probably because of prosperity brought about by the olive culture which has been successful in this valley since at least the 18th century (Gavrielides, 1976). Other Kranidi sediments are much younger; deposition in the lower Ermioni valley began about half a century ago,[5] but the large though thin Kranidi fans below the town of that name and in the Flamboura area on the southeast coast may be somewhat older. Deposition in all three areas, as well as in many smaller ones, continues to the present time.

The Kranidi alluvium consists entirely of stream-flood sediments, implying once again, as for the Hellenistic and early Roman case, a neglect of terrace-wall maintenance, now not so much because of economic adversity as because of a reorientation towards truck gardening on the better lands or towards the tourist industry. This neglect is evident in many places and directly associated with erosion and the emplacement of the alluvium.

[5] The lower strata there contain plastics.

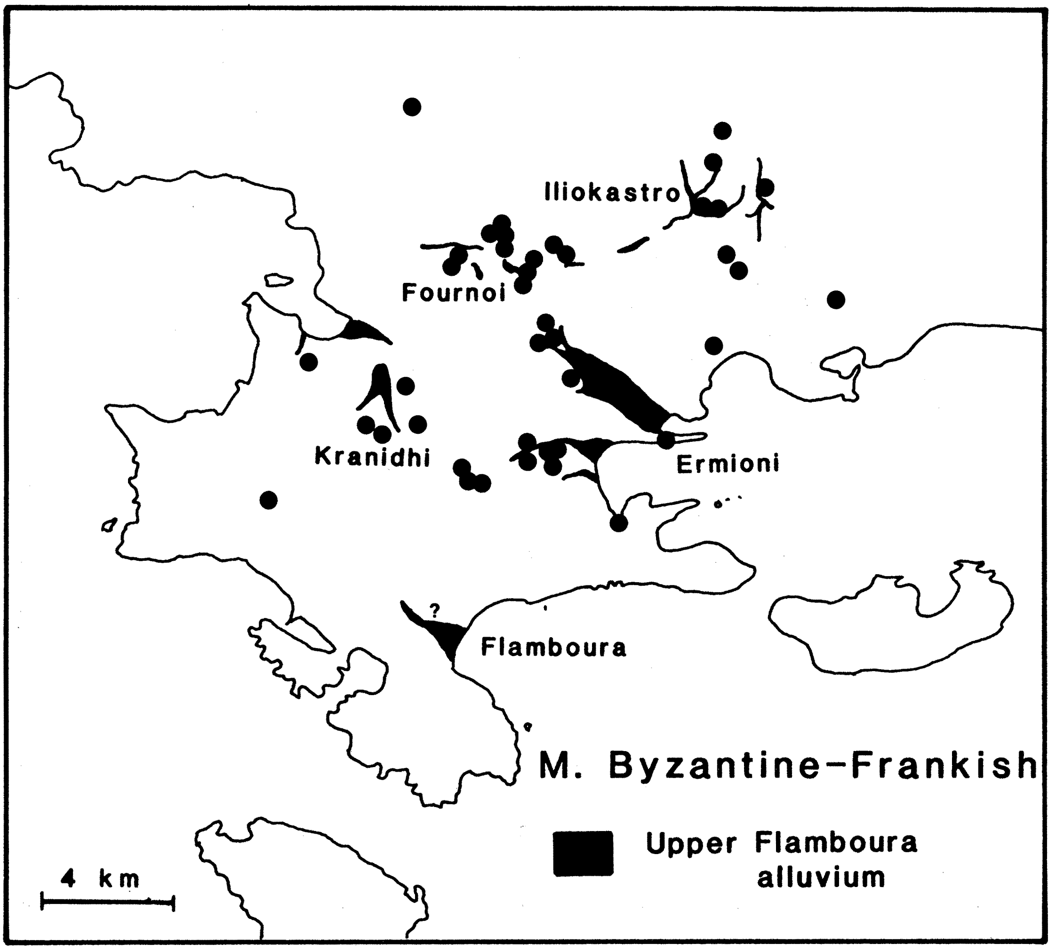

FIG. 13. Middle Byzantine/Frankish resettlement took place largely in secluded headwaters of streams. Rapid clearing of lands unoccupied since the 7th century appears to have produced much soil erosion demonstrated by Upper Flamboura debris flows in the valleys downstream from Middle Byzantine/Frankish site concentrations

Alternatively, some Kranidi deposition might be attributed to a climatic change which brought increases in rainfall and runoff, but once again there is no independent evidence for such an event. During the 16th through early 19th centuries, the Little Ice Age did indeed bring colder, wetter weather to northern and western Europe (e.g. Lamb, 1982, pp. 201–231), but most Kranidi deposits are not that old, and whether the Little Ice Age had any impact in the eastern Mediterranean, and if so what, is wholly unknown.

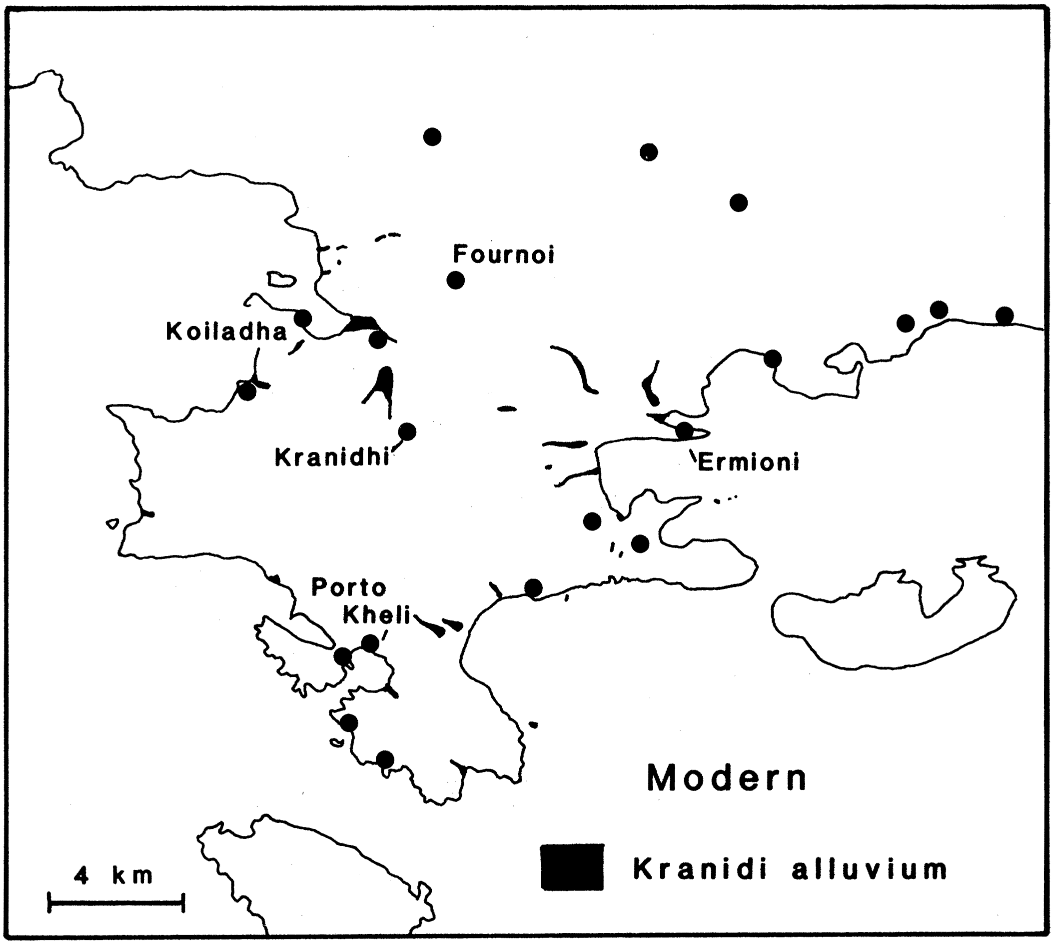

FIG. 14. The Kranidi alluvium, though widely scattered, is small in volume. Except for the Fournoi valley deposits, stabilized for several centuries, deposition generally dates back no more than a century and continues today in many places. Black dots indicate present settlements

CONCLUSIONS

For the past few 100,000 years, the landscape of the Southern Argolid has been mostly stable, its streams incised, its soils intact, sedimentation restricted mainly to the coastal zone. Only during three, probably rather brief intervals in the middle and later Pleistocene did a climate change alter the vegetation, increase runoff and erosion, and cause the deposition of beds of gravel and loam now conspicuous because of the bright orange red of their mature soils. The climate changes that induced erosion and alluviation remain somewhat

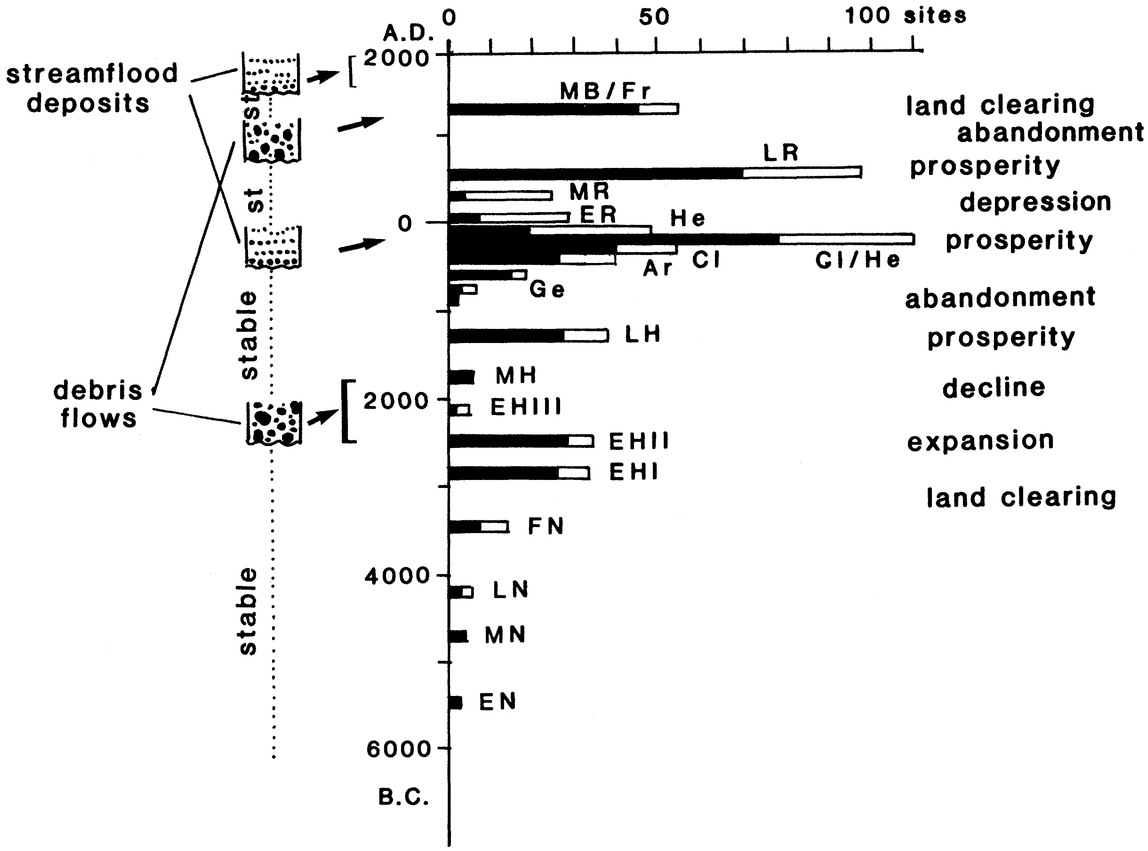

FIG. 15. Summary of erosion and alluviation events in the context of changes with time in numbers of sites. At extreme right, inferred rural economic history is related to alternating stability and destabilization of the landscape. Black columns in histogram count confirmed sites, white the probable ones

mysterious; during the height of the last glacial period and the subsequent climatic amelioration the landscape remained perfectly stable. Palaeolithic, Mesolithic, and Neolithic settlements, few in number and widely dispersed, also had no discernible impact (Fig. 15).

A new sequence of erosion and alluviation events began about 4,500 years ago, a thousand years after clearing of the Southern Argolid for agriculture started in earnest. Two of the four events brought debris flows and are therefore probably due to sheet erosion of slopes. We have interpreted those as the result of gradual shortening of long fallow produced by increasing settlement density or of rapid clearing of steep, marginal soils. In both cases, soil erosion control by terracing seems to have been unknown or neglected.

The other two events laid down stream-flood deposits. In the absence of independent evidence for increased precipitation and runoff and for other, circumstantial reasons, we have attributed those to neglect of a well-established system of terraces and gully check dams, with the inevitable vertical erosion, soil removal, and increased flooding of streams that such neglect entails.

Two modes of land stabilization thus exist and, we believe, existed in the Southern Argolid: terracing and dam construction and, ironically, the complete abandonment of the land which allows *maquis* and pine to resettle the fields very rapidly. Two modes also exist of destabilization: careless clearing or fallow reduction in times of prosperity, and the neglect of soil conservation combined with pastoralism in times of economic depression.

Having arrived at this conclusion for the Southern Argolid, we await with considerable interest what analogous, sufficiently detailed studies elsewhere in Greece might yield to test our hypotheses. We have attributed a great deal to the shifting successes and failures of rural economies, but have we perhaps underestimated other factors, including climatic change? Even if we should be in essence correct, can one indeed commonly read as much in the sequence, timing, and nature of alluvial deposits as we have attempted to do in the Southern Argolid?

BIBLIOGRAPHY

Bell, M., 1982, "The Effects of Land-use and Climate on Valley Sedimentation," *Climatic Change in Later Prehistory*, A. Harding, ed., Edinburgh, pp. 127–142.

Birkeland, P. W., 1984, *Soils and Geomorphology*, Oxford.

Boyd, T. D., and W. W. Rudolph, 1978, "Excavations at Porto Cheli and Vicinity, Preliminary Report IV: The Lower Town of Halieis, 1970–1977," *Hesperia* 47, pp. 333–355.

Bull, W. B., 1972, "Recognition of Alluvial-fan Deposits in the Stratigraphic Record," *Recognition of Ancient Sedimentary Environments* XVI, K. J. Rigby and W. K. Hamblin, edd. (Society of Economic Paleontologists and Mineralogists, Special Publication 16), Tulsa, Oklahoma, pp. 68–83.

— 1977, "The Alluvial Fan Environment," *Progress in Physical Geography* 1, pp. 130–148.

Butzer, K. W., 1974, "Accelerated Soil Erosion: A Problem of Man-land Relationships," *Perspectives on Environment*, I. R. Manners and M. Mikesell, edd., Washington, D.C., pp. 57–78.

— 1980, "Holocene Alluvial Sequences: Problems of Dating and Correlation," *Timescales in Geomorphology*, R. A. Cullingford, D. A. Davidson, and J. Lewin, edd., New York, pp. 131–142.

— 1982, *Archaeology as Human Ecology*, Cambridge.

Caskey, J. L., 1960, "The Early Helladic Period in the Argolid," *Hesperia* 29, pp. 285–303.

Davidson, D. A., 1980, "Erosion in Greece during the First and Second Millennia B.C.," *Time Scales in Geomorphology*, R. A. Cullingford, D. A. Davidson, and J. Lewin, edd., New York, pp. 143–158.

Donkin, R. A., 1979, *Agricultural Terracing in the Aboriginal New World* (Viking Fund Publications in Anthropology 56).

Dufaure, J.-J., 1965, "Problèmes de néotectonique dans le Péloponnèse," *Revue de géographie physique et de géologie dynamique* 7, pp. 235–252.

— 1977, "Néotectonique et morphogenèse dans une peninsule mediterranéenne: Le Péloponnèse," *Revue de géographie physique et de géomorphologie dynamique* 19, pp. 27–58.

Dufaure, J.-J., B. Bousquet, and P.-Y. Pechoux, 1979, "Contributions de la géomorphologie à la connaissance du Quaternaire continental grec en relation avec les études de néotectonique," *Revue de géomorphologie dynamique* 21, pp. 29–40.

Forbes, H. A., and H. A. Koster, 1976, "Fire, Axe and Plow: Human Influence on Local Plant Communities in the Southern Argolid," *Annals of the New York Academy of Sciences* 268, pp. 109–126.

Gavrielides, N. E., 1976, "The Impact of Olive Growing on the Landscape of the Fournoi Valley," *Annals of the New York Academy of Sciences* 268, pp. 143–157.

Gophna, R., 1979, "Post-Neolithic Settlement Patterns," *The Quaternary of Israel*, A. Horowitz, ed., New York, pp. 319–321.

Harden, J. W., 1982, "A Quantitative Index of Soil Development From Field Descriptions; Examples from a Chronosequence in Central California," *Geoderma* 28, pp. 1–28.

Hooke, R. L., 1967, "Processes on Arid Region Alluvial Fans," *Journal of Geology* 75, pp. 438–460.

Innes, J. L., 1983, "Debris Flows," *Progress in Physical Geography* 7, pp. 469–501.

Jacobsen, T. W., 1976, "17,000 Years of Greek Prehistory," *The Scientific American* 234, pp. 76–87.

— 1981, "Franchthi Cave and the Beginning of Settled Village Life in Greece," *Hesperia* 50, pp. 303–319.

Jameson, M. H., 1969, "Excavations at Porto Cheli and Vicinity, Preliminary Report I: Halieis, 1962–1968," *Hesperia* 38, pp. 311–342.

— 1974, "The Excavation of a Drowned Greek Temple," *Scientific American* 231, pp. 110–119.

— 1976, "The Southern Argolid: The Setting for Historical and Cultural Studies," *Annals of the New York Academy of Sciences* 268, pp. 74–91.

— 1977–78, "Agriculture and Slavery in Classical Athens," *The Classical Journal* 73, pp. 122–145.

Jameson, M. H., C. N. Runnels, and T. H. van Andel, in preparation, *The Southern Argolid: A Greek Countryside from Prehistory to the Present*, Stanford, California.

Ku, T.-L., W. B. Bull, S. T. Freeman, and K. G. Knauss, 1979, "230-Th/234-U Dating of Pedogenic Carbonates in Gravelly Desert Soils of Vidal Valley, Southeastern California," *Bulletin of the Geological Society of America* 90, pp. 1063–1073.

Ku, T.-L., and Z.-C. Liang, 1983, "The Dating of Impure Carbonates with Decay Series Isotopes," *Proceedings, Seminar on Alpha Particle Spectrometry and Low Level Measurement*, Harwell, England.

Lamb, H. H., 1982, *Climate History and the Modern World*, London/New York.

Leeder, M. R., 1975, "Pedogenic Carbonates and Flood Sediment Accretion Rates: A Quantitative Model for Alluvial Arid Zone Lithofacies," *Geological Magazine* 112, pp. 257–270.

Miall, A. D., 1977, "A Review of the Braided River Depositional Environment," *Earth Science Reviews* 13, pp. 1–62.

Morrison, R. B., 1976, "Quaternary Soil Stratigraphic Concepts, Methods, and Problems," *Quaternary Soils: Papers from the 3rd Symposium on Quaternary Research*, W. C. Mahaney, ed., pp. 77–108.

Naveh, Z., and J. Dan, 1973, "The Human Degradation of Mediterranean Landscapes in Israel," *Mediterranean Type Ecosystems: Origin and Structure*, F. Castri and H. A. Mooney, edd., New York, pp. 373–390.

Patton, P. C., and S. A. Schumm, 1981, "Ephemeral Stream Processes: Implications for Studies of Quaternary Valley Fills," *Quaternary Research* 15, pp. 24–43.

Picard, M. D., and L. R. High, 1973, *Sedimentary Structures of Ephemeral Streams*, Amsterdam.

Pope, K. O., C. N. Runnels, and T.-L. Ku, 1984, "Dating Middle Palaeolithic Redbeds in Southern Greece," *Nature* 312, pp. 264–266.

Pope, K. O., and T. H. van Andel, 1984, "Late Quaternary Alluviation and Soil Formation in the Southern Argolid: Its History, Causes, and Archaeological Implications," *Journal of Archaeological Science* 11, pp. 281–306.

Rackham, O., 1983, "Observations on the Historical Ecology of Boeotia," *BSA* 78, pp. 291–351.

Raphael, C. N., 1973, "Late Quaternary Changes in Coastal Elis, Greece," *Geographical Review* 63, pp. 73–89.

Runnels, C. N., 1983, "The Stanford University Archaeological and Environmental Survey of the Southern Argolid, Greece: 1979–1981," *Archaeological Survey in the Mediterranean Area*, D. R. Keller and D. W. Rupp, edd. (*BAR*, International Series 155), Oxford, pp. 261–263.

Runnels, C. N., and T. H. van Andel, "Settlement Pattern Change in the Southern Argolid, Greece: An Economic Explanation," forthcoming.

Rust, B. R., 1978, "Depositional Models for Braided Alluvium," *Fluvial Sedimentology* V, A. D. Miall, ed. (*Memoirs Canadian Society of Petroleum Geologists* 5), pp. 605–625.

Rutter, J. B., 1979, "Ceramic Change in the Aegean Early Bronze Age. The Kastri Group, Lefkandi I, and Lerna IV: A Theory Concerning the Origin of Early Helladic III Ceramics," (*Institute of Archaeology Occasional Papers* 5), Los Angeles.

Sheehan, M. C., 1979, *The Post-glacial Vegetational History of the Southern Argolid, Greece*, diss., Indiana University.

Topping, P., 1976, "Premodern Peloponnesus: The Land and the People under Venetian Rule (1685–1715)," *Annals of the New York Academy of Sciences* 268, pp. 92–108.

Van Andel, T. H., and N. Lianos, 1983, "Prehistoric and Historic Shorelines of the Southern Argolid Peninsula: A Subbottom Profiler Study," *IJNA* 12, pp. 303–324.

— 1984, "High-resolution Seismic Reflection Profiles for the Reconstruction of Post-glacial Transgressive Shorelines: An Example from Greece," *Quaternary Research* 22, pp. 31–45.

Vita-Finzi, C., 1969, *The Mediterranean Valleys: Geological Change in Historical Time*, Cambridge.

Wagstaff, J. M., 1981, "Buried Assumptions: Some Problems in the Interpretation of the 'Younger Fill' Raised by Recent Data from Greece," *Journal of Archaeological Science* 8, pp. 247–264.

Warren, P., 1980, "Problems of Chronology in Crete and the Aegean in the Third and Earlier Second Millennium B.C.," *AJA* 84, pp. 487–499.

Wieder, M., and D. H. Yaalon, 1982, "Micromorphological Fabrics and Developmental Stages of Carbonate Nodular Forms Related to Soil Characteristics," *Geoderma* 28, pp. 203–220.

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