Rocks, views, soils and plants at the temples of ancient Greece

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This study explores bedrock geology, topographic setting, compass orientation, soil profile and plant cover at 84 temples of Classical (480-338 BC) mainland Greece, several Aegean islands and Cyprus. A striking pattern emerges: the soil and vegetation matches the dedications to particular deities, suggesting an economic basis for particular cults.

Keywords: Greece, temples, soil, land-use, geobotany, archaeological geology

Introduction

Libation, or the pouring of wine or blood on the ground, was an important element of religious practice in ancient Greek religion (Burkert 1985), indicating reverence for soil. Homer (*c*. 750 BC, *Iliad* 14.347) sang how *'divine soil* [χθών δîα] *made fresh-sprung grass to grow, and dewy lotus, crocus and hyacinth'*. A similar epithet 'sacred soil' ['ιερὸν πέδον], which includes the root word for pedology (soil science), was used by Sophocles (*c*. 445 BC, *Ajax* 859) and Apollonius of Rhodes (*c*. 248 BC, *Argonautica* 1296). Plato wrote in *c*. 350 BC *'Some districts are ill-conditioned or well-conditioned owing to a variety of winds or to sunshine, others owing to their waters, others owing simply to the produce of the soil, which offers produce either good or bad for their bodies, and equally able to effect similar results in their souls as well'* (*Laws* Book V, Bury 1947: 389).

Ancient Greek writers also had technical understanding of soils, classifying them according to colour-texture (Xenophon and Theophrastus), fertility (Plato and Strabo) and medical considerations (Hippocrates and Theophrastus), and into categories corresponding to modern Andisols, Mollisols, Vertisols, Aridisols, Spodosols, Alfisols, Entisols and Inceptisols, as well as aquic and salic conditions (Bech Borràs 1999; Soil Survey Staff 2000).

This study of soils and vegetation explores relationships between the religious and scientific perceptions of soil at 84 temples of Classical (480-338 BC) mainland Greece, several Aegean islands and Cyprus (Figure 1). The main question to be addressed is why are the temples where they are? Can this be determined by detailed examination of bedrock geology, compass orientation, topographic setting, soils and vegetation at the various sacred sites of ancient Greece? Or are they just accidents of history, where individual founders had profound

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Received: 2 January 2008; Accepted: 27 February 2008; Revised: 11 March 2008

ANTIQUITY 82 (2008): 640–657

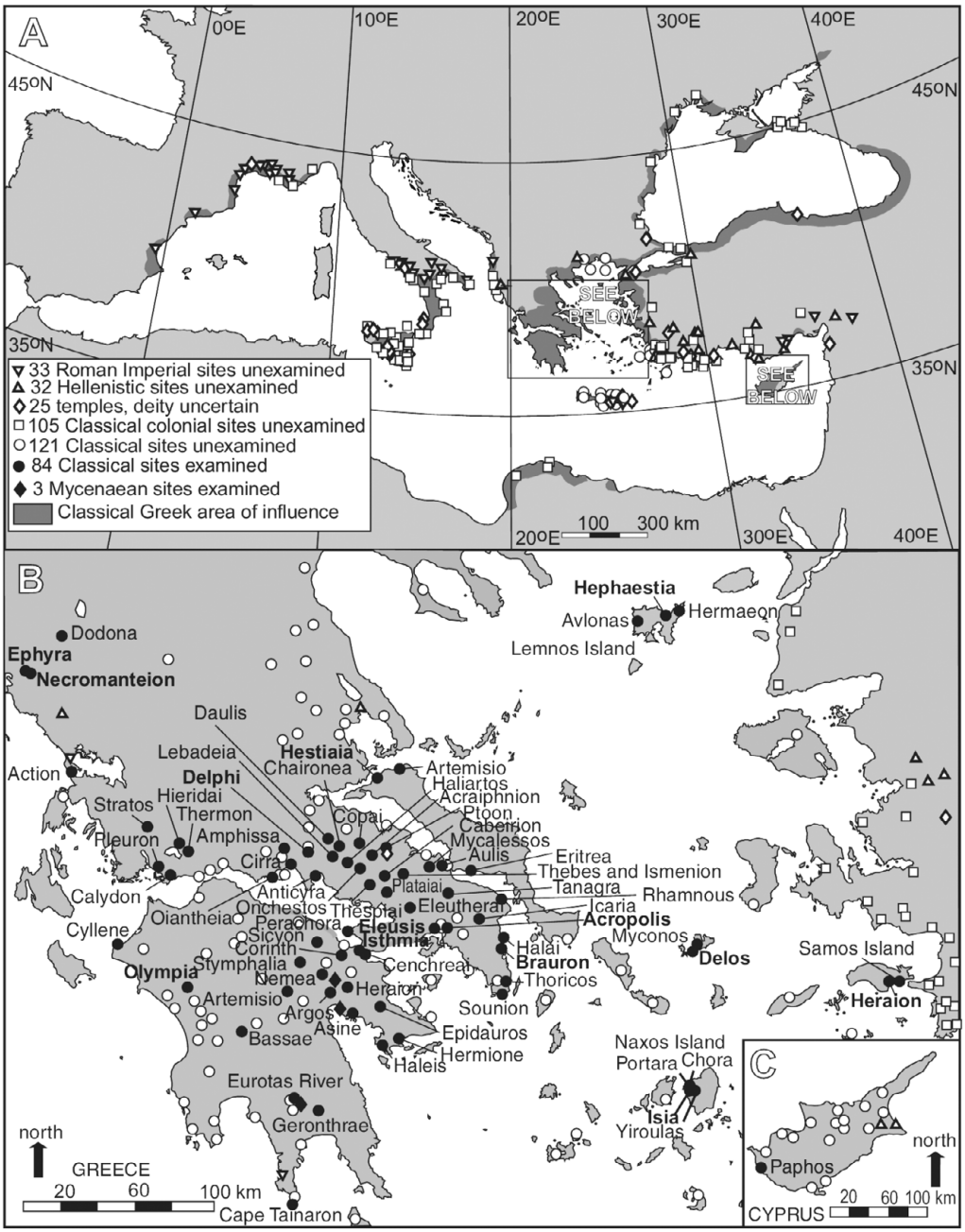

Figure 1. Location of Classical Greek (480-338 BC) temples visited for this study (closed circles), together with other sacred sites worthy of further investigation (open circles), and a variety of other sites of marginal relevance because of differing age or colonial influences. Names of sites, their deities and ages are listed in supporting material online.

religious experiences, or did sites of long prior occupation reach a threshold of affluence to afford large investments of labour and capital?

Background to soils and vegetation of Greece

Soil formation in Greece is limited by mountainous topography, with 29 per cent of the country above 800m, and 49 per cent of the surface area sloping at a declivity greater than 10 per cent (Kosmas *et al*. 1998). This relief is maintained by active tectonism of the Hellenic subduction zone and regional crustal extension, which makes Greece the most seismically active region of Europe. Active volcanism is restricted to Aegean islands (Higgins & Higgins 1996).

The climate of Greece is Mediterranean, with most rain and snow falling during a cool autumn and winter (January means 4 to 13°C from north to south) and little rain during a hot summer (July means of 25 to 29°C from north to south). Mean annual precipitation varies from arid (<400mm) in coastal regions of eastern Greece and some Aegean islands, to subhumid (800-1000mm) in mountainous western Greece (Kosmas *et al*. 1998). The native vegetation of Greece was probably grassy woodland of evergreen oak (*Quercus ilex*), carob (*Ceratonia siliqua*) and pine (*Pinus halepensis*), with coastal heath and alpine fellfield (Polunin 1980). The native soils of Greece are limited in variety: largely Entisols (Fluvents, Orthents, Psamments), Inceptisols (Xerepts, Andepts, Anthrepts), Alfisols (Xeralfs), Mollisols (Xerolls), Vertisols (Xererts) and Andisols (Food and Agriculture Organization 1981). Small-scale variation in soil and vegetation proved critical at the scale of temple precincts (Figure 2). Limestone mountains for example have thin rocky soils (Orthents) under alpine shrubland grading downslope into open woodland (on Xerepts) and gardens (on Anthrepts). Thick clayey soils of toeslopes and high alluvial terraces (Xeralfs) may have formed originally under oak woodland (Pope & Van Andel 1984) but have long been deforested and used for pasture. Some Xeralfs were converted to olive and citrus orchards, with the ready availability of plastic irrigation piping in the twentieth century. Loamy soils of low floodplains (Fluvents) are the most productive soils for market gardening and other crops. The most valued soils for grain and vegetable production are small areas of valley grassland soils (Xerolls).

A second soilscape is on rolling downs of Miocene and Pliocene sandstones and shales (Higgins & Higgins 1996). These soft sediments of ancient Thessaly, Elis and Messenia weathered to grassland (Xerolls) and cracking-clay soils (Xererts), and remain the principal agricultural resource of Greece. These lowland terrains also include some rocky soils on local limestones formed largely of fossil seashells and soils with flint, tile and brick of human occupation extending back 9000 years (Van Andel & Runnels 1995).

A third soilscape of Pleistocene coastal terraces in arid coastal Corinthia, Achaia and Cyprus, has soils which accumulate salts such as carbonate in soft masses ('havara' and 'panchina' of Calcids) distinct from bedrock limestone (Soteriades & Koundounas 1969; Higgins & Higgins 1996). Most coastal terrace soils are dry, gravelly or excessively drained, so are difficult for agriculture, which is confined to loamy floodplain soils (Fluvents) of narrow coastal creeks (Van Andel & Runnels 1987).

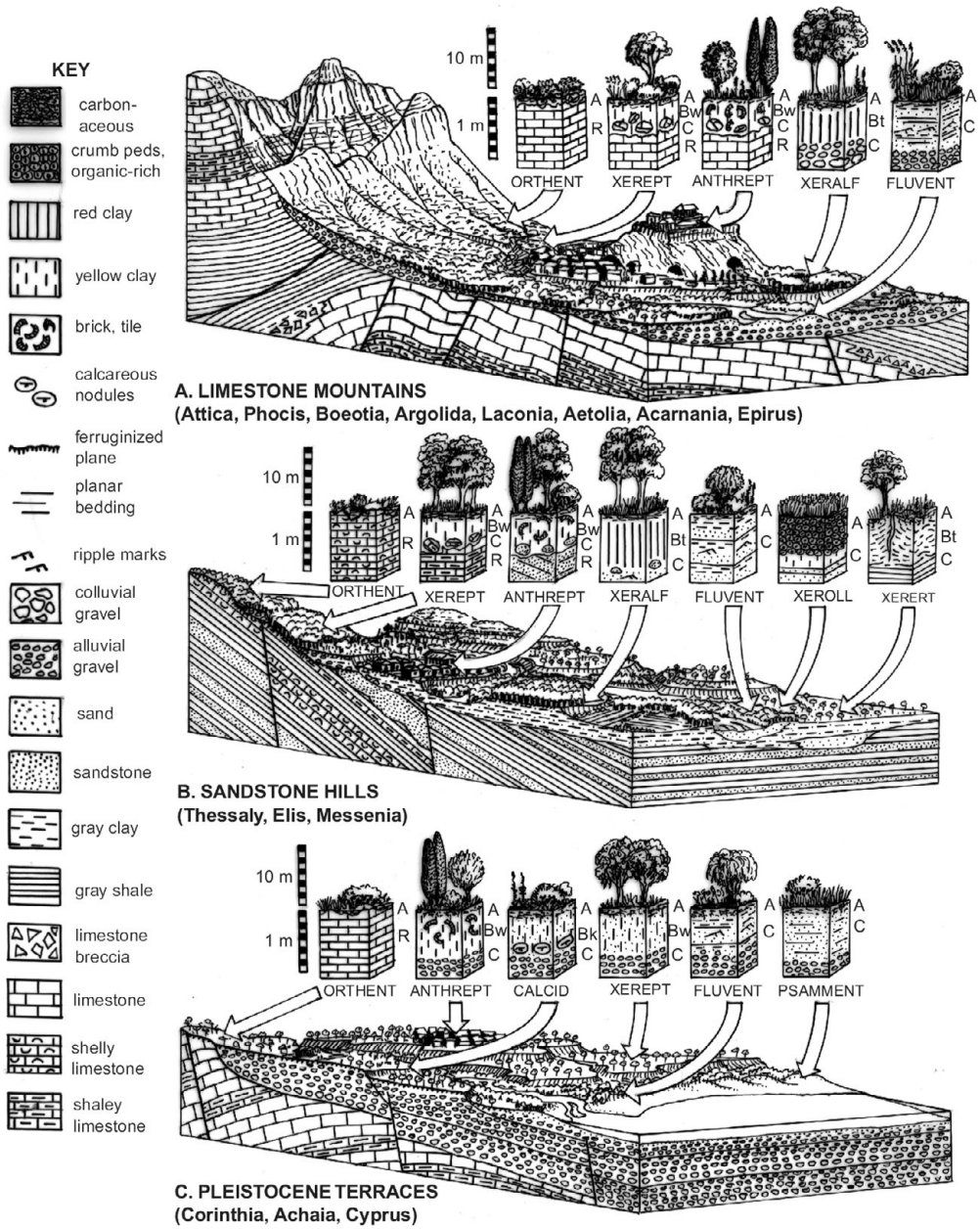

Figure 2. Three common geological and topographic settings of ancient Greek temples showing local similarities and differences in soilscapes.

Materials and methods

Although the number of ancient Greek temples is limited (Figure 1), this study was further limited geographically and temporally. The sample of 84 sites included only sacred sites

of Classical age (480-338 BC) in the Greek homeland, Aegean islands and Cyprus, as documented by literary sources (Table 1). Especially valuable in identifying the sites were the travelogues of Pausanias written in AD 194 (Jones & Ormerod 1926; Jones 1931; 1935; 1939), Strabo writing in AD 23 (Jones 1927; 1950) and Diodorus of Sicily writing in about 39 BC (Oldfather 1939).

Some temples have no information on the deity worshipped there and were therefore eliminated from the study (Stillwell *et al.* 1976). Also excluded on grounds of uncertain deity was Acrocorinth, which Pausanias (Jones 1931: 258) attributed to the Titan Helios; its later dedication was to Aphrodite, but the female temple statue bore weapons more like those of Athena. Also excluded on the basis of non-Classical date were Mycenaean Therapne, Hellenistic Cassiope and Phillipi and Roman Imperial Nicopolis and Diocaesarea. Further excluded were colonies, such as Greek outposts in modern-day Spain, France, Italy, Libya, Romania, Ukraine, Georgia, Russia and Turkey (Figure 1), where there was a strong indigenous influence (Stillwell *et al.* 1976). The cult of Persephone as a goddess of spring harvest in Sicily according to Diodorus (Oldfather 1939) and Artemis as a fertility goddess in Ephesus (Strelan 1996) were distinct in iconography and practice from mainland Greek concepts of Persephone, the victim, and Artemis, the virgin huntress (Olalla 2002).

The principal investigations undertaken in the field at each site were the documentation of a soil profile, using a milliner's tape, Munsell soil colour chart and acid bottle, and the identification of all current species of plants using field keys (Polunin 1980). All soil profiles were taken from pre-existing excavations for roads or archaeology, or in creek banks. Special attention was paid to stoniness of the soils, as a major impediment to ploughing, by measuring the depth (in cm) in the profile from the surface to the occurrence of stones greater than 5cm in diameter. Also assessed was the degree of development of the soils, expanding to 100 the 5-point scale of Retallack (1997; 2001). This is pegged to 50 for the acquisition of a diagnostic argillic or calcic horizon or histic epipedon (in the taxonomy of the United States; Soil Survey Staff 2000), which was also used to classify the soils. Soil classification was supported by whole rock chemical analysis of the B or lower A horizon of each soil, recording major element oxides, and phosphorus by X-ray fluorescence, and testing for organic carbon by acid digestion of carbonate. The location of each sacred monument and of the available soil exposures were recorded using a hand-held 12-channel Garmin GPS unit. The full chemical analysis, list of plant species and locality details for each of the 84 sites examined are given in the online supporting information at http://www.antiquity.ac.uk/ProjGall/retallack/index.html.

Soil and vegetation at the temples

The principal result of this study is the surprising pattern that temples of particular deities are consistently found on particular kinds of soils (Figures 3-5) and, less obviously, correlate with vegetation type and land-use (Table 2). The soil-deity relationship is best illustrated by a plot of depth-to-stones *versus* soil development, in which soils associated with particular deities separate into distinct fields (Figure 3a). The depth in a profile of stones larger than 5cm was measured because stones of this size within the upper 20cm were a significant obstacle to the Classical ard (Sallares 1991). Negative depth in this plot represents rock protruding from the

Table 1. Geology, topography, soil and vegetation at the temples of ancient Greece.

Deity	Location	Facing	Geology	Topography	Soil	Vegetation
Aphrodite	Cenchreai, Corinthia	Unknown	Pleistocene gravel	Coastal terrace	Calcid	Littoral
Aphrodite	Hieridai, Acarnania	Unknown	Triassic limestone	Hillside meadow	Calcid	Garden
Aphrodite	Oiantheia, West Locris	Unknown	Pleistocene gravel	Coastal terrace	Salid	Maquis
Aphrodite	Paphos, Cyprus	East	Pleistocene gravel	Coastal terrace	Calcid	Cultivation
Aphrodite	Samos Island	South	Pleistocene gravel	Coastal terrace	Calcid	Maquis
Aphrodite	Rhamnous, Attica	South-east	Miocene marble	Coastal hillside	Calcid	Maquis
Apollo	Action, Epirus	Unknown	Pleistocene conglomerate	Coastal terrace	Orthent	Littoral
Apollo	Argos, Argolida	North-west	Cretaceous limestone	Rocky hillside	Orthent	Pine wood
Apollo	Asine, Argolida	South-east	Cretaceous limestone	Rocky hilltop	Orthent	Olive grove
Apollo	Bassae, Arcadia	South	Cretaceous limestone	Mountain ridge	Xerept	Oak wood
Apollo	Chaironeia, Boeotia	North	Cretaceous limestone	Rocky hillside	Orthent	Garden
Apollo	Cirra, Phocis	Unknown	Pleistocene conglomerate	Marine terrace	Xerept	Garden
Apollo	Corinth, Corinthia	North-east	Pleistocene conglomerate	Marine terrace	Xerept	Garden
Apollo	Delphi, Phocis	North-east	Cretaceous limestone	Mountainside	Xerept	Phrygana
Apollo	Delos Island	East	Miocene granite	Hill toeslope	Xerept	Phrygana
Apollo	Epidauros, Argolida	North-east	Triassic tuff	Hill toeslope	Xerept	Pine wood
Apollo	Eretria, Euboea	South-east	Miocene mica schist	Hill toeslope	Orthent	Garden
Apollo	Haleis, Argolida	East	Neogene fanglomerate	Coastal terrace	Xerept	Maquis
Apollo	Ismenion, Boeotia	Unknown	Pleistocene fanglomerate	Low hilltop	Orthent	Garden
Apollo	Portara, Naxos	East	Pleistocene fanglomerate	Low sea stack	Orthent	Littoral
Apollo	Ptoon, Boeotia	West	Cretaceous limestone	Steep hillside	Orthent	Phrygana
Apollo	Sicyon, Corinthia	East	Pleistocene gravel	Marine terrace	Xerept	Pasture
Apollo	Thermon, Acarnania	East	Triassic limestone	Hillside meadow	Orthent	Garden
Apollo	Thespiai, Boeotia	Unknown	Pleistocene fanglomerate	High ridge	Xerept	Garden
Ares	Geronthrae, Laconia	Unknown	Holocene alluvium	Creek bank	Fluvent	Riparian
Ares	Eurotas River, Laconia	Unknown	Holocene alluvium	River bank	Fluvent	Riparian
Artemis	Artemisio, Euboea	Unknown	Raised shingle beach	Coastal terrace	Xerept	Olive grove
Artemis	Artemisio, Arcadia	Unknown	Cretaceous limestone	Mountainside	Orthent	Phyrgana
Artemis	Aulis, Boeotia	South	Pleistocene fanglomerate	Bayside ridge	Orthent	Maquis
Artemis	Avlonas, Lemnos	Unknown	Porphyritic tuff	Coastal ridge	Orthent	Maquis
Artemis	Brauron, Attica	East	Holocene colluvium	Rocky footslope	Xerept	Phrygana
Artemis	Calydon, Acarnania	East	Paleogene flysch	Coastal terrace	Xerept	Olive grove
Artemis	Chora, Naxos	Unknown	Miocene granite	Coastal ridge	Orthent	Maquis
Artemis	Glyphada, Samos	South	Miocene limestone	Salt marsh	Orthent	Littoral
Artemis	Halai, Attica	East	Pleistocene conglomerate	Coastal terrace	Xerept	Maquis
Artemis	Stymphalia, Corinthia	Unknown	Holocene colluvium	Rocky footslope	Xerept	Phrygana
Athena	Acropolis, Athens	North-east	Cretaceous limestone	Rocky hill top	Anthrept	Garden
Athena	Amphissa, West Locris	Unknown	Cretaceous limestone	Rocky hill top	Anthrept	Garden
Athena	Argos, Argolida	North-west	Cretaceous limestone	Rocky hillside	Anthrept	Pine wood
Athena	Daulis, Phocis	Unknown	Cretaceous limestone	Rocky hill top	Anthrept	Pine wood
Athena	Haliartos, Boeotia	East	Cretaceous limestone	Rocky hill top	Anthrept	Phrygana
Athena	Pleuron, Aetolia	East	Cretaceous limestone	High hill top	Anthrept	Phrygana
Athena	Stymphalia, Corinthia	East	Cretaceous limestone	Rocky hill top	Anthrept	Phrygana
Demeter	Cabirion, Boeotia	Irrelevant	Holocene alluvium	Open plain	Xeroll	Cultivation
Demeter	Copai, Boeotia	Unknown	Cretaceous limestone	Hill in plain	Xeroll	Garden
Demeter	Corinth, Corinthia	East	Cretaceous limestone	Hill footslope	Xeroll	Pasture
Demeter	Eleusis, Attica	East	Cretaceous limestone	Rocky footslope	Xeroll	Pasture
Demeter	Mycalessos, Boeotia	Unknown	Pleistocene alluvium	Low hill	Xeroll	Pasture
Demeter	Thebes, Boeotia	Unkown	Pleistocene fanglomerate	Low hill	Xeroll	Pasture
Demeter	Yiroulas, Naxos	South	Miocene mica schist	Rolling hills	Xeroll	Pasture
Dionysos	Acraiphnion, Boeotia	Unknown	Cretaceous limestone	Low ridge	Xeroll	Garden
Dionysos	Chora, Myconos	Unknown	Miocene granite	Upland plateau	Xeroll	Pasture

Table 1. (Contd.).

Deity	Location	Facing	Geology	Topography	Soil	Vegetation
Dionysos	Eleutherai, Attica	East	Pleistocene alluvium	Alluvial fan	Xeroll	Pasture
Dionysos	Eretria, Euboea	West	Holocene gravel	Creek floodplain	Xeroll	Pasture
Dionysos	Icaria, Attica	North	Holocene gravel	Narrow valley	Xeroll	Pasture
Dionysos	Isia, Naxos	East	Holocene sand	Coastal plain	Xeroll	Cultivation
Dionysos	Samos Island	Unknown	Miocene limestone	Hillside	Xeroll	Garden
Dionysos	Sicyon, Corinthia	North	Pliestocene gravel	Marine terrace	Xeroll	Pasture
Dionysos	Tanagra, Boeotia	Unknown	Miocene marble	Hill footslope	Xeroll	Pasture
Dionysos	Thoricos, Attica	South	Holocene alluvium	Creek terrace	Xeroll	Pasture
Hades	Necromanteion, Epirus	East	Cretaceous limestone	Rocky hill top	Rock	Rock crevice
Hades	Cape Tainaron, Laconia	Irrelevant	Mesozoic marble	Sea caves, cliffs	Rock	Rock crevice
Hephaestos	Hephaestia, Lemnos	Unknown	Holocene alluvium	Coastal plain	Fluvent	Pasture
Hera	Heraion, Argolida	South-east	Pleistocene fanglomerate	Rocky footslope	Xeralf	Citrus orchard
Hera	Heraion, Samos	East	Holocene alluvium	Coastal plain	Xeralf	Olive grove
Hera	Perachora, Corinthia	East	Pleistocene gravel	Marine terrace	Xeralf	Littoral
Hera	Plataiai, Boeotia	East	Pleistocene alluvium	Alluvial terrace	Xeralf	Pasture
Hermes	Cyllene, Elis	Irrelevant	Pliocene sandstone	Seaside hill	Xeralf	Pasture
Hermes	Hermaeon, Lemnos	Irrelevant	Eo-Oligocene sandstone	Hill footslope	Xeralf	Pasture
Hestia	Hestiaia, Euboea	Unknown	Holocene alluvium	Coastal plain	Fluvent	Riparian
Hestia	Olympia, Arcadia	Unknown	Pleistocene river silt	River terrace	Fluvent	Riparian
Persephone	Eleusis, Attica	East	Cretaceous limestone	Deep cave	Rock	Rock crevice
Persephone	Ephyra, Epirus	Unknown	Cretaceous limestone	Rocky hilltop	Rock	Rock crevice
Poseidon	Anticyra, Phocis	Unknown	Cretaceous limestone	Coastal terrace	Calcid	Maquis
Poseidon	Hermione, Argolida	East	Paleogene limestone	Coastal head	Calcid	Pine wood
Poseidon	Isthmia, Corinthia	East	Pleistocene beach gravel	Coastal terrace	Calcid	Olive grove
Poseidon	Onchestos, Boeotia	Unknown	Cretaceous limestone	Low hill	Calcid	Pasture
Poseidon	Sounion, Attica	East	Miocene schist	Sea promontory	Calcid	Littoral
Zeus	Acraiphnion, Boeotia	Unknown	Cretaceous limestone	Ridge in valley	Anthrept	Maquis
Zeus	Dodona, Epirus	South-east	Paleo-Eocene limestone	Ridge in valley	Anthrept	Garden
Zeus	Lebadeira, Boeotia	North-east	Cretaceous limestone	Prominent hilltop	Anthrept	Garden
Zeus	Nemea. Argolida	North-east	Holocene gravel	River floodplain	Anthrept	Garden
Zeus	Olympia, Arcadia	East	Pleistocene colluvium	Footslope of hill	Anthrept	Garden
Zeus	Stratos, Acarnania	East	Cretaceous limestone	Low hill top	Anthrept	Garden

soil, as in rocky cliffs and caves sacred to Hades and Persephone (Table 1). Soils of Hera and Hermes were cultivable only with difficulty, because their degree of development proceeded to the differentiation of a subsurface horizon of pedogenic clay, which is particularly resistant to the plough during the long dry summer. Soils of Athena and Zeus overlap in this plot with those of Artemis and Apollo, but are distinguished by abundant brick, tile and other cultural debris, or other evidence of long, high-density human occupation. This distinction is also made clear in soil taxonomic classification (Soil Survey Staff 2000), which recognises human-modified soils as a separate suborder (Anthrepts) from otherwise comparable soils (Xerepts, Figure 3b).

Preferences of plant species for particular soils and temples are less differentiated (Figure 3c), and although soil-ecosystem linkages are apparent (Table 2), no definitive indicator species were found. Many native trees are very widespread, such as olive *(Olea europea,* 38/84 sites), funeral cypress (*Cupressus sempervirens*, 29/84), evergreen oak (*Quercus ilex*, 21/84) and Aleppo pine (*Pinus halepensis*, 21/84). Also widespread are indigenous agricultural

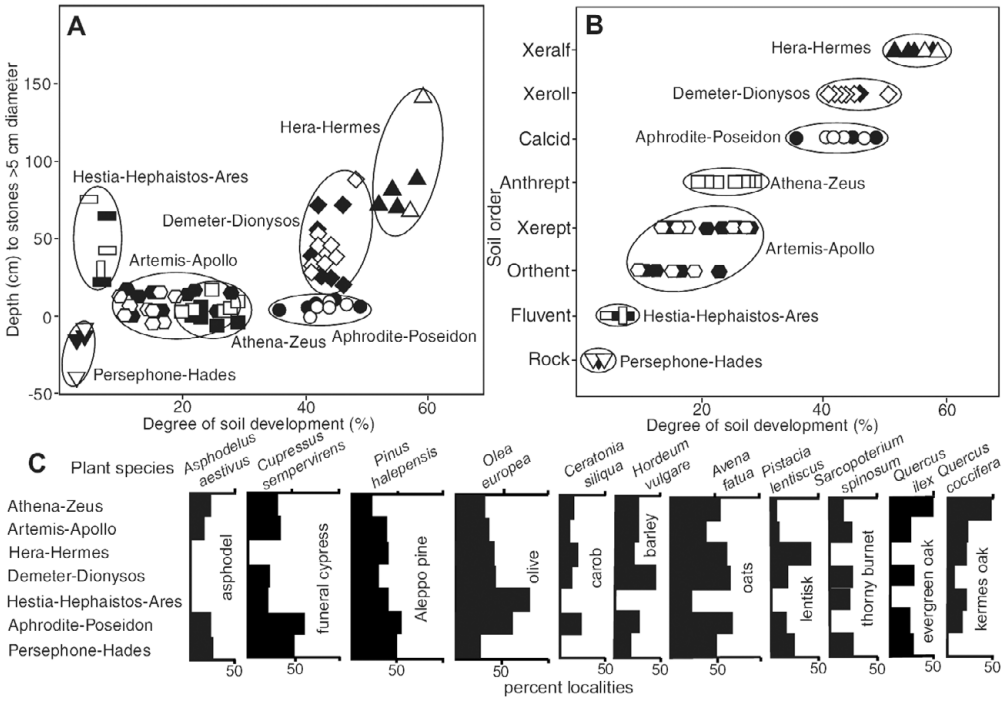

Figure 3. Discrimination analysis for 84 soils studied at the temples of Classical Greece: (a) depth to stones reflects ease of ploughing, with negative depths for stones protruding from the ground. Degree of development is related to time available for soil formation (Retallack 2001), and is also a consideration in soil classification (Soil Survey Staff 2000); (b) sites related to types of soil and degree of soil development. Filled symbols are female and open symbols male deities of the following pairs Athena-Zeus (squares), Artemis-Apollo (hexagons), Demeter-Dionysos (diamonds), Hera-Hermes (triangles), Hestia-Hephaistos-Ares (rectangles), Aphrodite-Poseidon (circles) and Persephone-Hades (inverted triangles); (c) the plant assemblages at the sites today.

Table 2. Characteristic plants and soils at the temples of ancient Greece.

Deities	Soil	Modern vegetation	Interpreted native vegetation
Zeus-Athena	Anthrept	Garden and park	Broadleaf oak forest
Apollo-Artemis	Orthent, Xerept	Montane phrygana	Montane fellfield
Hermes-Hera	Xeralf	Citrus orchard, olive grove, pasture	Grassy oak woodland
Dionysos-Demeter	Xeroll	Pasture, market garden, vineyard	Lightly wooded grassland
Ares-Hephaistos-Hestia	Fluvent	Market garden, vineyard	Riparian woodland
Poseidon-Aphrodite	Calcid	Coastal heath and maquis	Coastal heath
Hades-Persephone	Cliff, cave	Cliff flora	Cliff flora

weeds such as wild oats (*Avena fatua*, 44/84 sites), bent grass (*Agrostis gigantea*, 35/84), spiny asparagus (*Asparagus acutifolius*, 28/84), oriental thistle (*Jurinea mollis*, 27/84) and barley (*Hordeum vulgare*, 25/84). The temple of Artemis at Glyphada on Samos now has

halophytic plants of the intertidal zone, and the submerged harbour at nearby Pithagorion indicates subsidence by at least 50cm over the past 2500 years (Higgins & Higgins 1996). Many ancient sacred sites, such as Acraiphnion, Athenian Acropolis, Amphissa, Anticyra, Cirra, Corinth, Daulis, Eleusis, Geronthrae, Heiridai, Hestiaia, Necromanteion, Lebadeia, Perachora, Ptoon and Yiroulas, are now, or were historically, Eastern Orthodox Christian churches, landscaped and adorned with garden ornamentals. These modern plants are very different from those forming the soils.

Soils of city dwellers (Athena, Zeus)

Temples of Athena are consistently sited within high rocky fortresses, whereas those of Zeus are on flat portions of narrow valleys near commanding knolls, but all are united by soils with profound human modification (Anthrepts) (Soil Survey Staff 2000). This is most obviously revealed by fragments of brick, tile and other artefacts in the soil profile (Figure 4). Their subsurface horizons are weakly developed, with modest accumulation of pedogenic clay or iron stain. This degree of soil development (Bw or cambic horizon) takes as little as 900 years in south-western Greece (Haidouti & Yassoglou 1982). Large stones and bedrock outcrops in soils near temples of Athena and Zeus are evidence that such sites were chosen for strategic, rather than agricultural reasons. A role for soil in such choices was suggested by Cyrus the Great (580-529 BC), as reported by Herodotus (485-425 BC): *'Soft soils breed soft men; wondrous fruits and valiant warriors grow not from the same soil'* (*Histories* IX.122, Godley 1924: 301).

Soils of hunters (Artemis, Apollo)

The most numerous of Classical temples are dedicated to Artemis, the virgin huntress, and her twin brother, radiant Apollo (Table 1). Their temples were built on a wide array of rocks ranging from granite to gravels, and in sites ranging from the mountains to the sea. What they all share are thin rocky soil profiles (Figure 4), bright (high Munsell value and chroma) red to yellow colours, low organic carbon and a strong sense of wilderness, set apart from villages and cities. Most of these temples are on residual soils on bedrock, dark red with iron stain and clays from the chemical dissolution of limestone. Others are on less deeply weathered colluvium and gravel. None have strongly developed profiles, varying from simple organic-weathered (A-C profiles or Orthents) to organic-discoloured-weathered (A-Bw-C profiles or Xerepts). Some of these soils have been degraded from Xerepts to Orthents by sheet wash on their steep slopes (Pope & Van Andel 1984). Because of abundant stones and steep slopes, these soils were unsuitable for ploughing. Their thin profiles and residual clays and oxides favour shrubs such as kermes oak (*Quercus coccifera*) and thorny burnet (*Sarcopoterium spinosum*), typical of montane phrygana and coastal maquis, rather than vigorous grass growth, and their use for grazing is thus limited. Such soils would have been suited to hunting and gathering before the advent of agriculture in Greece (Pope & Van Andel 1984), and still are used for the gathering of salad greens after spring rains. The erosion of hill soils was lamented by Plato (*c*. 380 BC): *'in comparison of what then was, there are remaining only the bones of the wasted body . . . all the richer and softer parts of the soil*

having fallen away, and the mere skeleton of the land being left', and *'there are some mountains which now have nothing but food for bees, but they had trees no very long time ago*' (*Critias*; Bury 1952: 273). Thucydides (*c*. 400 BC) implied that such stony soils distinguished the character and history of Athenians with their democratic and philosophical ideals, from Boeotians and Thessalians. *'For the greater power that accrued to some communities on account of the fertility of their land occasioned internal quarrels, whereby they were ruined, and at the same time they were exposed to plots from outside tribes. Attica, at any rate, was free from such internal quarrels from the earliest times by reason of the thinness of the soil, and therefore was inhabited by the same people always*' (Thucydides I.2, Smith 1954: 5).

Soils of herders (Hera, Hermes)

Both Samians and Argives claimed that their imposing temples of Hera were at the birthplace of the queen of heaven (Olalla 2002) and at both sites, soil is thick, clayey and high in alumina (Xeralf) compared with other soils. Hermes' 'rock of Lemnos' ('Ερμαῖον λέπας Λήμνου) mentioned by Aeschylus (*Agamemnon*, 281) as the site of a relay beacon warning Clytemnestra of the return of Agamemnon from Troy, was probably a hill near the modern radio station west of Panagia, on Lemnos. The site has thick clayey soils (Xeralfs), with subsurface horizons stiff with illuviated clay (Bt or argillic horizon). In north-west Greece, such differentiated soil horizons take 24 300-19 600 years to form on stable toeslopes and terraces under forest and woodland (Vikos unit of Woodward *et al*. 1994). By Classical times, most native forests of evergreen oak had been cut down (Pope & Van Andel 1984). The clayey Xeralf soils remained a challenge to the plough because of their stiff dry clay and were better suited to rough pasture for cows and sheep. Trees have returned to these soils now in the form of citrus orchards and olive groves made possible by irrigation using plastic pipes. Following Neolithic to early Archaic land clearance these soils were most suited to pastoralism, as befitted *'Hermes the ram-bearer'* ('Ερμης φέρων κριόν of Pausanias' *Description of Greece* 9.22.1) and *'ox-eyed queen Hera*' (βοωπις πότνια 'Ηρή of Homer, *Iliad* 4.50).

Soils of family farmers (Demeter, Dionysos)

The most celebrated ancient sanctuary for Demeter was at Eleusis, now on the outskirts of the metropolitan area of Athens, where the goddess introduced the cultivation of grain to Attica, according to Diodorus of Sicily (*Library of History* 5.68.1-5. 69.2, Oldfather 1939). Similarly the sanctuary of Dionysos near Icaria, in the hills north of Athens, is where the god introduced wine-making to Attica (Olalla 2002). Both sites, and others sacred to these agricultural deities, have soils with distinctive crumb-structured, thick (>18cm), dark brown, organic-carbon-rich surface horizons (mollic epipedon) of grassland soils (Xerolls, Figures 4 and 5). Amid the rocky hills of Attica, such grassland soils are limited in area, within narrow valley bottoms. These fertile, well-structured soils are more widespread on the rolling plains and basins of Thessaly, Epirus and Elis (Figure 2), and have always been an important agricultural resource of Greece. Some of these toeslope soils were severely eroded in Classical times, again as noted by Plato in *c*. 380 BC, *'in place of moorlands* [φελλεύς,

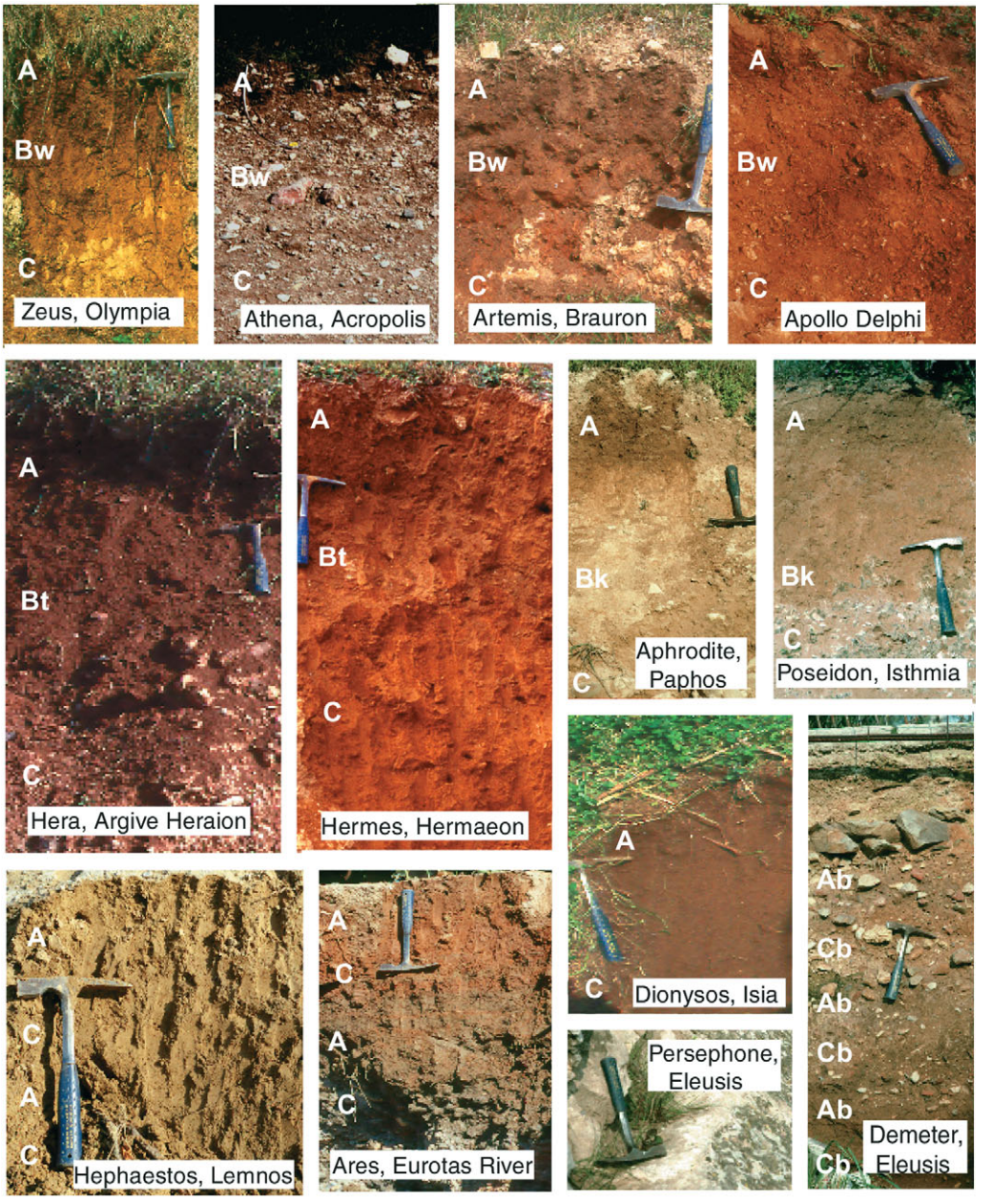

Figure 4. Colour photographs of examples of soil profiles at temples of ancient Greece (hammer, for scale has handle 25cm long).

or rocky fell] *as they are now called, it contained plains of rich soil'* (*Critias*; Bury 1952: 273). Xerolls are ideal for grain cultivation celebrated by festivals of Demeter. Once the sod is broken, their stable structure and natural fertility (high concentrations and good balance of alkalis and alkaline earths) are suited to cereal crops, as well as market gardening of fruits

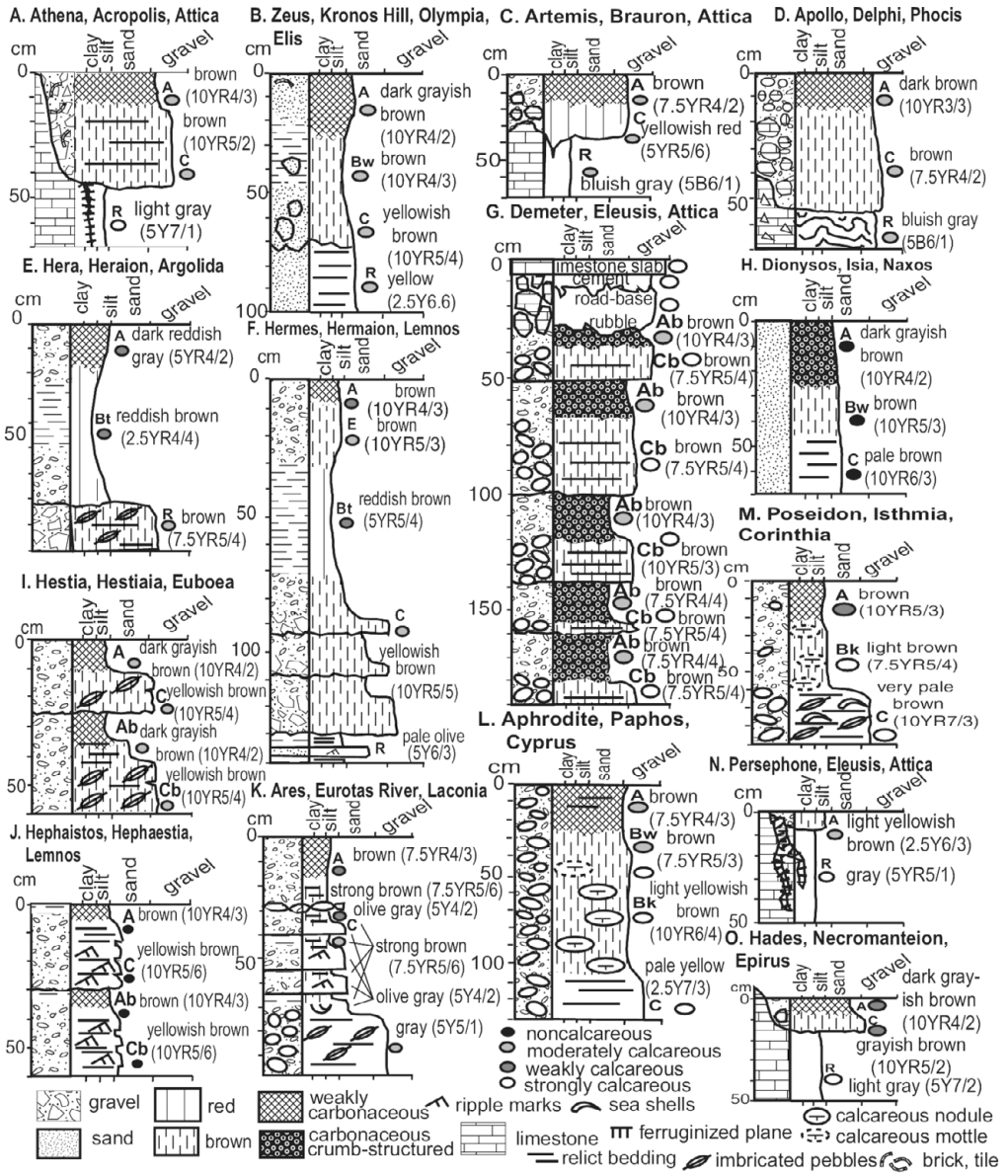

Figure 5. Summary of soil profiles at temples of ancient Greek deities. Individual soil profiles, locality details and vegetation of all 84 sites examined are in online supporting information.

and vegetables. Such calcareous and fertile soils are not ideal for complex, dry wine that suits the modern palate, but wines drunk in honour of Dionysos were sweet and potent, and taken with a water chaser (Olalla 2002). As Homer sang, *'For among the Cyclopes, the earth, giver of grain, bears the rich clusters of wine, and the rain of Zeus gives them increase; but this is a draught from a stream of ambrosia and nectar'* (*Odyssey* IX.355, Murray 1994: 1, 343).

Soils of estate farmers (Hestia, Hephaestos, Ares)

No archaeological sites are known to be sacred to Ares, the god of war, despite excavation at likely sites (Catling 1998). Pausanias (*Description of Greece* 3.19.7 and 3.22.6) mentions a temple and grove in Geronthrae, and a sanctuary near the Eurotas river on the road to Therapne. Both areas are within the ancient Spartan state, and have silty to sandy alluvial soils (Figures 4 and 5). Sites sacred to Hestia, goddess of the hearth, and Hephaestos, artisan of the gods, also were not marked with large monuments, but at towns named for these deities, there also are alluvial soils (Figures 4 and 5). These are all Fluvents (Soil Survey Staff 2000), formed by deposition of sand, silt and clay by flooding on broad flat floodplains. Their distinguishing features are ripple marks, bedding planes and other sedimentary structures little disturbed by roots and other soil-forming agents. These soils were not eroded but continually building. Such soils are fertile with freshly eroded minerals, moist with shallow water table and easy to plough because uncemented by pedogenic minerals (Van Andel & Runnels 1995). Before the advent of the mouldboard plough, agricultural mechanisation and upland irrigation techniques, floodplain soils were the principal agricultural resource (Sallares 1991). Aeschylus, writing in *c*. 470 BC, understood the importance of *'rivers that pour their gentle draught and give increase of children, with their fertilizing streams soothing its soil'* (*Suppliant Maidens* 1025, Smyth 1922: 101).

The distinction between the family farm and corporate agriculture, so politically sensitive today, was also apparent in ancient Greece (Hanson 1995). The family farm was a voting unit in the Athenian democracy because only men with household means to afford the hoplite panoply of arms to defend the state were entitled to vote. In contrast, corporate agriculture in the ancient world was run by the despotic irrigating civilizations of Mesopotamia, or, closer to home, the Spartan state on the plains of the Eurotas river in Laconia and their conquered lands in the plains of nearby Messenia. Young Spartan men of means lived in communal militaristic messes until marriage and kept order on large agricultural estates worked by an enslaved local population (helots).

Soils of fishers (Poseidon, Aphrodite)

Aphrodite, the goddess of love, and Poseidon, the earth-shaker, were closely linked in myth and iconography with the sea (Olalla 2002). Their temples also have good views of the sea or large lakes such as Lake Trichonida and Lake Copai, the latter subsequently drained for agriculture (Higgins & Higgins 1996). Soils of Aphrodite and Poseidon were unsuited to agriculture by reason of silty to sandy texture, free drainage and excess salt and carbonate (Figures 4 and 5). These soils and sites are also largely in climatically arid regions of eastern Greece and Cyprus, and are Calcids (Soil Survey Staff 2000), with subsurface accumulation of carbonate nodules (Bk) or salts (By). Soils of Poseidon and Aphrodite offered lifestyles like those in Iasos, now in Turkey, where Strabo noted *'it has a harbour, and the people gain most of their livelihood from the seas, because the sea here is well supplied with fish, but the soil of the country is rather poor'* (*Geography* Book XIV, Jones 1950: 291).

Soils of hermits (Persephone, Hades)

Sites sacred to the king and queen of the underworld, Hades and Persephone, are marked by much bare rock. Cape Tainaron, at the southernmost point of mainland Greece, was noted by Strabo (*Geography* 8.5.1, Jones 1927) to be the site of a cave leading to the underworld. The cape is at the southern end of the Mani, a barren rocky land where hillsides are a maze of high rock walls stacked by ancient Laconians. Free of Spartan persecution in this mountainous stronghold they scratched a living from unproductive rocky soil (Burford 1993). Twin caves at Eleusis in Attica were the site of the rape of Persephone according to Pausanias (*Description of Greece* 1.38.5, 2.35.7, 6.21.1, 9.31.8, Jones 1931) whereas Diodorus of Sicily thought her abduction was near Enna, in Sicily (*Library of History* 5.2.3-5.5.1, Oldfather 1939). Rivers around Ephyra and Necromanteion in Epirus were used by Homer (*Odyssey* X.513) as a model for the underworld, so dismal was this swampy area in antiquity (Olalla 2002). The rocky headlands of Tainaron, caves of Eleusis, and formerly swamp-girt hills of Ephyra and the Necromanteion are all places of retreat and hermitage.

Discussion: competing explanations for temple sites

Could the pattern of deity-specific soils be an artefact of post-Classical erosion, climate change, land subsidence or other modifications? Significant human-induced erosion began with Neolithic deforestation (Pope & Van Andel 1984) and has made many upland soils (Xerepts) rocky and thin (Orthents). Yet deep ferruginised cracks remain to distinguish these soils of Artemis and Apollo from cliffs and caves of sites sacred to Persephone and Hades. While the 2500 years separating us from Classical Greece is a long time in human history, Xeralfs (Figure 5e-f) and Calcids (Figure 5l-m) require 2 to 10 times that length of development (Pope & Van Andel 1984; Woodward *et al.* 1994). Other kinds of soils such as Fluvents (Figure 5i-k), Xerolls (Figure 5g-h), Anthrepts (Figure 5a-b) and Xerepts form at millennial time scales (Haidouti & Yassoglou 1982), but there is evidence from buried soils at Hestiaia (Figure 5i), Hephaestia (Figure 5j), Eleusis (Figure 5g) and Nemea and Olympia (supplementary information online) that comparable soils formed again and again at the same site after catastrophic burial by floods and landslides, extending back well before Classical times. Climate change is not apparent within the last 2500 years of pollen records in Greece, although some change is apparent in the mid-Holocene (4000 years ago) and marked changes during the last ice age (Pope & Van Andel 1984). Land subsidence has affected temples at Action and Pithagorion on Samos and many temples were rebuilt and gardened as Christian churches. These changes have altered vegetation at the sites since Classical times, but have had less effect on the slow pace of soil formation. Post-Classical weeds, gardens and agriculture have considerably obscured the link between soil and vegetation in natural Mediterranean ecosystems (Grove & Rackham 2001) but patterns of soils persisted (Figure 3).

Geological explanations for temple sites include Piccardi's (2000) argument that the temple of Apollo at Delphi was located over a fault trace, producing vapours of hydrocarbons responsible for the oracle-inducing trance of the priestess of Pythian Apollo. Volcanic tuffs

and ochre-rich spring deposits of the island of Lemnos have long been associated with the god of the forge, Hephaestos (Georgiades 1947). Ammonites, like petrified snakes, in pink Triassic limestones at the entrance to the sacred precinct of Apollo, Artemis and Asclepios in Epidauros (Jacobshausen 1967) may have attracted attention to that site of ancient healing, with its emblem – the snake-encoiled caduceus (Olalla 2002). These are all special cases, not widely applicable (Table 1). Temples of Poseidon at Isthmia and Sounion are both built on Calcid soils, but their bedrock is very different: Pleistocene coquina-conglomerate and Miocene schist, respectively. Temples of Artemis all have comparable rocky shallow soils, but their bedrock varies from granite to marble, porphyritic tuff, limestone, sandstone, conglomerate and colluvium.

Scully (1979) proposed that the temples of ancient Greece were located in particularly scenic locations, with good views of especially suggestive topographic features, such as the illusion of a reclining woman on the ridgeline of Salamis as viewed from Eleusis. Bassae, Delphi and Perachora are all in breathtaking topographic settings but other temples, such as Dodona, Nemea, Olympia and the Samian Heraion, are in surprisingly prosaic locations. There is little consistency to the topographic setting of ancient Greek temples (Table 1).

Both Scully (1979) and Richer (1994) have argued that Classical Greek temples were calendrical devices oriented so that the sanctuary was illuminated on certain sacred days. This view is falsified by the wide scatter of temple orientation (direction from cella to pronaos in Table 1). Richer (1994) also suggested systematic arrangement of temples around Delphi as the navel of the known universe, in a terrestrial reflection of astrological divisions. No such symmetry is apparent from the distribution of known sacred sites (Figure 1).

Temples were founded when influential individuals had transformative religious experiences and built when cities attained sufficient affluence for large public works, but were their locations also accidents of history? Pausanias (*Description of Greece* 2.19.3-8, Jones 1931) explains how Danaus founded a temple of Apollo Lykeios (wolflike) in Argos as a monument to his own wolfish cunning in his rise to power. Similarly, Diomedes founded a temple of Athena Oxyderkes (far-sighted) near Argos because he thought the goddess lifted a veil of mist from his eyes while fighting at Troy (*ibid.* 2.24.2). While no great monuments are created without a will or a way, the idea that the sites for temples of ancient Greece are only historical accidents is challenged by the soil groupings (Figure 3). Despite the record of inspirational moments, it can be argued that legendary founders like Danaus and Diomedes had inherited a concept from pre-existing religious tradition of where a deity would feel at home, choosing a rocky slope for Apollo and a commanding view for Athena. In other cases, the sacred sites, not just the concepts, preceded temple construction, such as oak groves sacred to Zeus at Dodona and Nemea, springs sacred to Apollo at Delphi and Ptoon and the cave of Hades at Necromanteion and of Persephone at Eleusis (Olalla 2002). Temple sites were thus not entirely accidents of history but reflect ancient concepts of land use and divinity.

Conclusions

This study of sites of 84 temples of Classical (480-338 BC) Greece found no clear relationship of their sites with geological or topographical setting, or with compass orientation but there

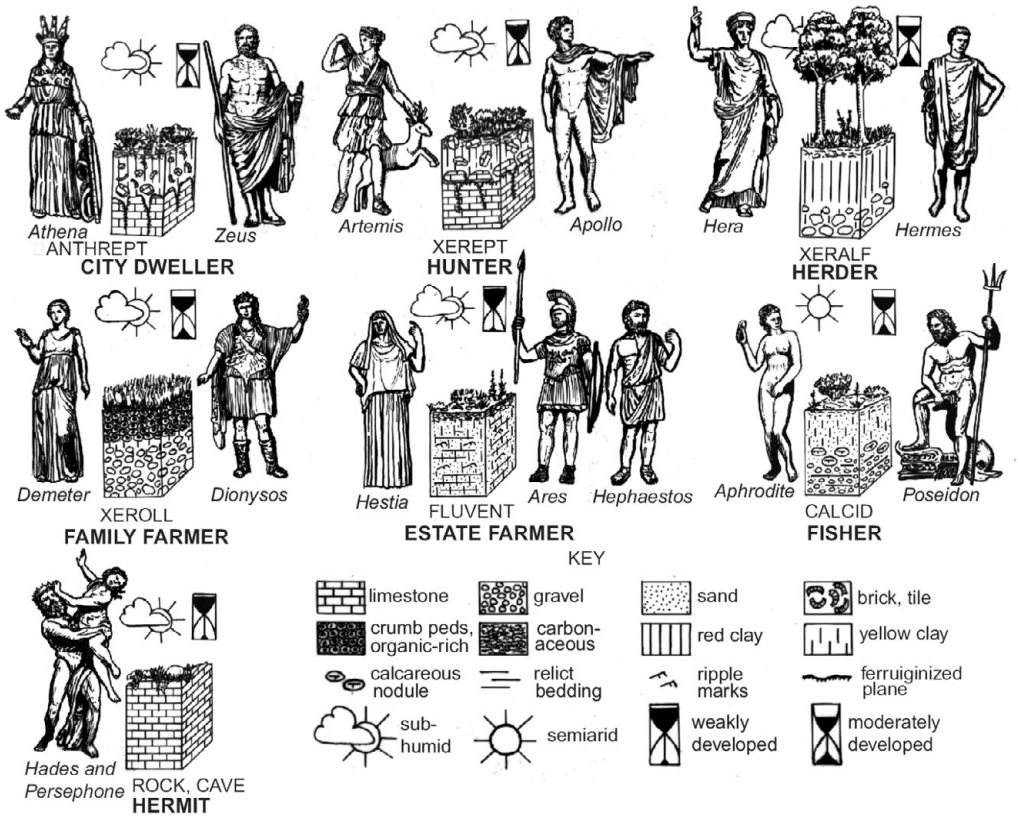

Figure 6. Model of the deities of ancient Greece and their associated soils and vegetation. Climate (sun–cloud) and degree of development of the soils (hourglass) are also indicated by symbols. Soil horizon terminology follows Soil Survey Staff (2000).

was a consistent correlation of soil type with particular deities (Figure 6). Temples to Athena and Zeus on soils of citadels (Anthrept) contrast with those of Artemis and Apollo on rocky soils (Orthent, Xerept) of wilderness. Hera and Hermes were worshipped on clayey soils (Xeralfs) suited to cattle grazing. Sanctuaries of Demeter and Dionysos are on fertile soils (Xerolls) suitable for mixed farming, whereas alluvial soils (Fluvents) of large farming estates were sacred to Hestia, Ares and Hephaestos. Temples of Aphrodite and Poseidon are on arid soils (Calcids) near fishing harbours, but caves were sacred to Persephone and Hades.

Such deity-specific land-use near the major monuments of ancient Greece support a multicultural view of ancient Greek polytheism, in which concepts of divinity from tribes of different economic heritage came together with different emphases within different city states (Sourvinou-Inwood 2000). In Athens, for example, the founding tribes of Ion (*c*. 1050 BC) were ‘Οπλητος (warrior), Γελέοντος (farmer?), Αιγικόρεος (shepherd) and Αργάδεω (husbandman?), each with their own cults and festival calendars (Herodotus 485-425 BC *Histories* 5.66). Other mixes and emphases of economic-religious tribal groups prevailed in other cities, in accord with local soil resources.

Acknowledgments

This research owes much to my classics masters Adrian Kent, Ronald West and Michael Smee. Funding came from the Center for the Study of Women in Society at the University of Oregon, through a Rockefeller Foundation grant for a seminar on 'Science, Gender and the Sacred'. Stephen Franks facilitated a field season by sponsoring a short course at ARAMCO, Dahran, Saudi Arabia. For much useful discussion I thank Lynn Fessenden, Irene Diamond, Himanchia Hernandez, Brinda Rao, Edrie Sobstyl, Evelyn Krull, Carolyn Phillips and Jeff Hurwit.

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