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Abstract: This paper uses the results of recent excavations of the city of Stymphalos and environmental studies on the floor of the Stymphalos polje to examine the role of both the lake and springs in the history of the classical city. Associated with Artemis and famed for Herakles' sixth labour (killing of the Stymphalian birds), the city has a rich (geo)mythology. While this narrative has been associated solely with the lake, it is argued here that this geomythology was part of the city's relationship to environmental unpredictability and the relationship between water supply and water loss. Seen in this context, the construction of the Fountain-house above the contemporary lakeshore is symbolic of the importance of springs to the foundation and sustainability of the classical city during both the Greek and Roman Periods. Through these archaeological and environmental analyses, we seek to illustrate the complimentary, but complex nature of archaeological, hydrogeological and palaeoenvironmental data that intersect in the geomythological landscapes of Mediterranean antiquity.

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3/05/2016

Dear Editors,

Please accept our submission entitled “Archaeology, Hydrogeology and Geomythology in the Stymphalos Valley” This paper is founded on original fieldwork and data. The argument is based on the results of recent excavations of the city of Stymphalos and environmental studies on the floor of the Stymphalos polje to examine the role of both the lake and springs in the history of the classical city.

Yours,

Kevin Walsh and Tony Brown
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08/03/2017

Dear Editors,

Our response to the reviewers comments
We have dealt with all points and accept each recommendation and we have adjusted the manuscript accordingly.

Reviewers 1 made minor comments and recommendations for minor additions – we have dealt with all of these.

Reviewer 2 made more substantive comments
i) We agree that the concept of geomythology required a more nuanced and developed discussion – we have dealt with this.
ii) observations on physical geography and remarks on mythology are arbitrarily mixed in single paragraphs. We have dealt with this and edited accordingly.
iii) the link between mythology and geomorphology should rather be argued for than automatically assumed – we agree and have developed our argument accordingly.
iv) At various point the article is fairly loose with archaeological chronology. We have dealt with this, especially in the final discussion.
v) We have developed our discussion of sanctuaries and approaches to classical landscapes and have employed much of the literature referred to by the referee.

Yours,

Kevin Walsh and Tony Brown
....

*Highlights (for review)

Highlights for review

- A new study of the "geomythology" of the Stymphalos polje to examine the role of both the lake and springs in the history of the classical city.
- This site is associated with Artemis and famed for Herakles' sixth labour (killing of the Stymphalian birds)
- The palaeoenvironmental work (lake cores) demonstrates how the lake level and the lake characteristics have varied over time
- The geomythology was part of the city's relationship to environmental unpredictability and the relationship between water supply and water loss.
- The paper argues that the construction of the fountain-house above the contemporary lakeshore is symbolic of the importance of springs to the foundation and sustainability of the classical city during both the Greek and Roman Periods.

Archaeology, Hydrogeology and Geomythology in the Stymphalos Valley

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Abstract
This paper uses the results of recent excavations of the city of Stymphalos and environmental studies on the floor of the Stymphalos polje to examine the role of both the lake and springs in the history of the classical city. Associated with Artemis and famed for Herakles' sixth labour (killing of the Stymphalian birds), the city has a rich (geo)mythology. While this narrative has been associated solely with the lake, it is argued here that this geomythology was part of the city's relationship to environmental unpredictability and the relationship between water supply and water loss. Seen in this context, the construction of the Fountain-house above the contemporary lakeshore is symbolic of the importance of springs to the foundation and sustainability of the classical city during both the Greek and Roman Periods. Through these archaeological and environmental analyses, we seek to illustrate the complimentary, but complex nature of archaeological, hydrogeological and palaeoenvironmental data that intersect in the geomythological landscapes of Mediterranean antiquity.

Introduction

The social memories associated with different landscapes are co-constructed via a complex intersection of monuments, natural features, stories and myths, to name but a few elements that constitute social memory (Van Dyke, 2008). While it has been long recognised that natural features, such as rock outcrops or rivers, are imbued with cultural meaning (Bradley, 2000), relatively little palaeoenvironmental (palaeoecological and geoarchaeological) research explicitly engages with the question as to how certain complex environmental processes may underpin the development of myths and memory in Mediterranean landscapes.

Many places are imbued with layers of meaning that are cumulative and mutable (Van Dyke, 2008: Kindle Location 10205). Such is the case of Stymphalia, best known as the site of Herakles' killing of the man-eating birds, but also associated with Artemis, who in turn may have deeper (Minoan-Mycenaean) antecedents that lay with Potnia, a female figure associated with the natural world (Thomas and Wedde, 2001). The figures and myths referred to above are all associated with wetlands, and such stories and deities exist scattered across time and space within the Mediterranean, and indeed, globally. Despite their importance, climate and hydrogeological conditions are a critical but often under-researched environmental combination in the archaeology of the Mediterranean region (Butzer, 2011; Rosen, 2007), and there is hardly any palaeoenvironmental research that addresses the development of these particular cultural aspects of past landscapes. Much of the palaeoenvironmental work that has taken place in Mediterranean wetlands has understandably focused on the description and explanation of environmental changes with people considered a driver of certain environmental processes (e.g. vegetation clearance, erosion) (Dusar et al., 2011; England et al., 2008; Woodbridge and Roberts) and also at the mercy of certain natural processes (e.g. earthquakes, storms). In some cases, projects have also considered resource potential, and the relationship between site distribution and wetland characteristics (Benjamin R et al., 2011; Farinetti, 2009; Karkanas et al., 2011; Perlès, 2001). Meanwhile, certain classicists or ancient historians have considered the cultural role and perceptions of wetlands. Here, the emphasis is often placed on how ancient writers, such as Herodotus, Thucydides, or Aristotle characterised wetlands vis à vis their economic value (e.g. medicinal plants), the risks that they posed to health, or even their strategic military role (Châtelain, 2007). In addition, archaeological projects have revealed detailed evidence relating to the physical characteristics and chronologies of certain temples. For example, in the Hellenistic town of Lousoi (Arcadia), Artemis' temple was expanded at c. 300 BC, indicating the start of a period of activity running through to the first century AD (Mitsopoulos-Leon, 2011). Most recently, a synthesis of archaeological and palaeoenvironmental research from across the Peloponnese has assessed possible links between past environmental changes in developments in settlement and economy from the Neolithic to the Medieval Period and found overall a lack of correspondence (Weiberg et al., 2016), but this is not surprising given the problems of site visibility and survival and the relatively poor temporal resolution of both datasets. As they suggest the key to understanding societal change was local socio-political processes (ibid.) and this includes culture and mythology. From the mythological perspective, scholars have considered the distribution of sanctuaries and their relationships with environmental features, including springs (Jost, 1996) or even soils (Retallack, 2008). While others have assessed the specific nature of rites associated with different sanctuaries and deities (e.g. Rougement, 2011), or the heterogeneity of rites and the variation in the roles and interpretations of deities and sanctuaries across Ancient Greek urban and rural spaces (Osborne, 1987). None of these approaches has employed palaeoenvironmental evidence with the explicit aim of assessing the relationship between wetlands and wider issues of ideological, cultural and mythological processes, and the manner in which these influenced human perceptions of, and thereby, interaction with these environments (see table 1 for examples of some key Mediterranean wetland projects).

Background: Stymphalos, archaeology, environment and mythology

Constructing geo-mythologies

Over many years, archaeologists have studied the remains of the mountain city of Stymphalos situated on the lake edge (Gourley, 2005; Gourley and Williams, 2005; Williams et al., 2002). Although the precise location of the first early city (*c.* 700-375 BC) remains unknown, logically it should have been close to a permanent water supply, the most obvious candidate being the lake. The later classical city has been the object of much research, which is summarised below. However, the nature of the physical and cultural relationships between the lake, the city, and the valley floor and slopes are poorly understood. Indeed, we had no data regarding the extent of the lake at the time when the city flourished before the research presented in this paper.

The site of Stymphalos (modern Stymfalia) situated in the Arkadian mountains, is 41 km south-west of the town of Kiato on the Corinthian Gulf (Fig. 1). Although many Mediterranean landscapes have been subject to landscape survey, the landscape around the lake at Stymphalos has seen relatively little research. Moreover, the environmental history and the management of natural resources in this area during the Classical Periods are poorly understood. Consequently, a landscape and environmental project was designed to investigate the palaeoenvironmental characteristics of this landscape. This research is required in order to enhance our understanding of the ways in which protohistoric societies engaged with, and mythologised both this enigmatic landscape and environmental change.

Some ancient historians claim that only texts provide precise information on the nature of ancient religion, in particular, the specifics of certain rites (Rougement, 2011). Although this is true vis a vis attitude of those who produced the texts, we also require interdisciplinary approaches that combine archaeological, palaeoenvironmental and historical evidence if we are to understand the origins of certain rites and sanctuaries and their possible relationships with wider natural and socio-economic processes. Such approaches can elucidate the origins and development of ritual-landscape hybrids; processes that are rarely articulated in ancient texts.

Although Pausanias' fusion of history and mythology can cause confusion, his accounts reveal how toponyms were often constituted via associations with deities whose stories were usually associated with one or more element in the natural world (Saïd, 2011). Mythology and geomorphology connect as societies develop interactions with different parts of a landscape and develop forms of environmental knowledge which, although different from modern post-enlightenment scientific understandings, are in their own way internally consistent, offering explanations for processes that might be only partially or poorly understood. Climate and hydrogeological conditions are an implicit, or even explicit, part of the mythological comprehension of natural phenomena or 'geomythology' (Vitaliano, 1973). These two discourses are both particularly evident in relation to the valleys of the northern Peloponnese and Lake Stymphalos; famous as the place where Herakles carried out his legendary sixth labour of killing the Stymphalian birds (Bulfinch, 1856). Employing a Durkheimian view of religion, we would agree with Kopaka in that religion, and in this context, that many deities, including Potnia (a deity considered to be Artemis' antecedent, with possible Mycenaean/Minoan origins), are part of a religious phenomenon that "defines, encodes and orders the actual, physical structures, attitudes and experiences of the human groups it represents" (Kopaka, 2001: 15).

Potina's powers, including the ability to change animals into men, all suggest "civilising power over both nature and mankind" (*ibid.* 23). Moreover, as Osborne observed for the Classical period, "…Greek religion can validly be seen as 'problem solving'. By his religious actions man reconciled himself to the natural and human environment" (1987: 166).

Apart from the Stymphalian birds, the lake was also known for its unpredictable changes in level, from suddenly filling the entire valley floor to disappearing entirely. This problem was recounted by the Romanised Greek traveller Pausanias (b. 120 AD) who was known for his documentation of the human and natural geography of Greece between AD 145 and AD 180 (Clendenon, 2010). Pausanias recounts at least two occasions when the sinkhole ('chasm mouth', see Fig. 1) became blocked, and the lake flooded the valley floor followed by almost instantaneous drainage. The narrative of both events, the flooding and the drainage, involves the swallowing up of a deer and a hunter into the 'underworld' which was the general mythological conception of the karstic subterranean realm (Clendenon, 2009a). In an earlier 4th century BC narrative recounted by Strabo, Iphicrates, an Athenian general, besieged the city and tried to flood the area by blocking the sinkhole with a large quantity of "sponges" but gave up when Zeus sent an omen from the sky (Clendenon, 2009b). It is hardly surprising that stories of such dramatic changes in a landscape contributed to the creation of myths of supernatural forces related to the subterranean world before the understanding of karstic hydrology in the 18th century (Biswas, 1972). These stories and their contribution to the social memories of this landscape need to be scrutinised via reference to archaeological and palaeoenvironmental evidence that facilitate the assessment of landscape processes that could well have provided the foundations for these stories or mythological narratives.

Hydrological context

Lake Stymphalos, as a body of water, is enigmatic as both a natural and cultural feature; this is as true today as it was in the past. The waxing and waning of the lake have been controlled by a complex series of natural processes as well as technological interventions, including management of the sinkhole on the southern edge of the lake. It is known that by the 2nd century AD the lake level was controlled through the construction of the Hadrianic aqueduct, which provided lake water to the major city of Corinth 45 km to the northeast, and this suggests that significant fluctuations in the water level occurred before this date. An important hydrological research question relates to the links between the Stymphalos, Scotini and Alea poljes (Fig. 1). Their outflow occurs at the Kephalovryso and Douka Vryssi springs and in the Inachos River Valley (Morfis et al., 1985). Such discharges can be highly variable in the Mediterranean climate and are rarely well-understood (Crouch, 2004). However, one major hydrogeological study of the NE area of the Peloponnese in the 1980s included research on the Stymphalos basin (Morfis et al., 1985) and provides some hydrological data as well as useful contextual information.

The current wetlands at Stymphalos are an artefact of centuries of human manipulation and management. Moreover, their modern characteristics might lead us to believe that water has always been bountiful, accessible, easy to manage and that agriculture in this landscape has always been a relatively straightforward enterprise. The fact that the Romans drew water from the area supports such a notion. However, water exploitation and management in the area is a far more complex issue. The presence of adequate water on the steep slopes surrounding the wetland/lake would not always have been guaranteed as it is almost entirely spring derived.

The first stage of this environmental project was to elucidate the characteristics of the wetland area and assess how it has changed over time, and more importantly to consider its utility as a proxy-archive for the wider landscape history around the basin. The primary aims of the project thus far have been; to date the lake, trace its former extent and establish its relationship to the city (including ceremonial sites), which is now partly submerged by lake sediments, and the economy of the valley. Below, we present an overview of archaeological work in the area followed by an assessment of the nature of the lake/wetland, and how this has changed over the last five millennia. This part of the research is based on a series of cores undertaken during the summer of 2009; these results are then considered in conjunction with a broader landscape/environmental survey conducted in 2007 supplemented by contemporaneous studies by Heymann et al. (2013). In the final part of the paper, we consider the results of the environmental research and their implication for our understanding of the built remains at Stymphalos and wider landscape processes.

Stymphalos archaeological history and Excavation History

Archaeological studies at Stymphalos have concentrated on the Classical city, and relatively little is known about the surrounding landscape. A landscape survey of the nearby Sikyon area does provide some useful contextual information (Lolos, 2007), and a study of the Hadrianic aqueduct provides detail on this other important landscape element (Lolos, 1997). Relatively little is known about the prehistory of this area, largely because there has been no concerted prehistoric research. However, there are stone axes from Stymphalos dated to the 3rd millennium BC, and a small amount of Mycenaean pottery from the excavations in the Classical settlement implies a Bronze Age presence at the site (Williams, 2010). Consequently, we can infer from the few known sites, and recent research in the Sikyon area (Lolos 2007), that Stymphalos would have seen Mycenaean activity. Richard Hope Simpson in his gazetteer of Bronze Age sites in Greece noted Mycenaean sherds on the acropolis (Simpson, 1979). Fortifications in the Lavka area may be Bronze Age, along with tholos tombs over the Wolfsen Pass in the next valley on the way to the Peloponnesian Orchomenos. Earlier peoples, as represented by rare finds of earlier prehistoric material (Williams, 1983), were undoubtedly present in the area, but the precise nature of their settlement and economic strategies are unknown.

The Classical period city, which has been under investigation since the early 1980s, is situated on the modern northern shoreline of the lake. This settlement was not the first city of Stymphalos; an earlier settlement situated at an unknown location probably existed during the fifth century BC. It is important to note that the late fourth century BC town at Stymphalos included fortifications, and was thus part of a militarised or defended landscape where access to water and its control would also have been critical (Gourley and Williams, 2005). Finally, a watercourse to the north is assumed to have provided another natural defence augmenting the substantial city walls (Fig. 2). Although most of the city was located on the bedrock knoll, parts of the city extended down to what is today lake edge, in particular, the Pheneos that runs south into the lake reeds. Other than Roman settlement evidence, the most important Roman feature of the Stymphalos area is the aqueduct that supplied water to Corinth. The aqueduct takes the springs at Tsepi, near Driza just to the northeast of the lake, as its source, these being the springs that would normally feed into the lake (Lolos 1997).

Geological, Climatic and Hydrogeological Processes in the Stymphalos Valley

Stymphalos lies in a structural basin (polje) on the south side of the Mt Kyllini limestone massif in the north-eastern Peloponnese (Fig. 1). It is a montane internal drainage basin ranging in altitude from 2257 m asl (Mt Kyllini) to the valley floor at 600 m asl. It is orientated WSW-ENE along the strike of the limestones which dip to the south in a series of thrust-nappe structures. This makes the basin asymmetrical, with steep scarp slopes on the southern side of the basin and more gentle dip slopes on the north side. At the base of the northern slopes is the major E-W fault which defines the basin, upon which the ancient city was located (Morfis et al., 1985). Although entirely underlain by Upper Trias and Lower Cretaceous limestones, the northern slopes are covered by Cenomanian, Senonien and Maastrichtian bioclastic limestones and dolomites, Pliocene conglomerates and Quaternary breccias. On the southern side of the basin, there is a marked alternation of steep valleys with large alluvial fans, bedrock spurs, benches of schists, as well as limestone and cemented breccias. Underlying the divide-gap at 700 m asl on the southern watershed is a zone of milonitised laminated Upper Trias-Lower Cretaceous limestone under which the Roman and 19th-century water tunnel and aqueduct were constructed carrying water into the adjacent Asapos/Scotini basin and eventually to Corinth. As this implies, the geology of the basin is critical in the hydrology of the catchment and lake.

The Stymphalos polje lies between the 800 mm yr^{-1} and 1000 mm yr^{-1} isohyets and calculations adjusting for altitudinal variations produce a mean annual precipitation 1090 mm yr^{-1} (Morfis et al., 1985). This precipitation is strongly concentrated into winter and spring, with highest discharges (Souri channel) occurring February to May because of combined snowmelt and rainfall. The yearly average temperature of the Stymphalos region is 10^{o} C and using both local and regional data Morfis et al. (ibid.) calculated an average water balance for the whole catchment of:

$$237.5\ (P) = 126.2(ET) + 52.7(R_s) + 58.6(R_u)$$

Where P is precipitation, ET is evapotranspiration, R_s is surface runoff, Ru is underground discharge, and all figures are expressed as 10^6 m^3. A discrepancy between this estimated R_u and a value calculated from stream flow (of 11 x 10^6 m^3) is ascribed to underground inflow to the Stymphalos polje from the northern Ziria mountain block outside the morphological catchment area (i.e. an inter-basin transfer). Morfis et al. (1985) believe that the spring at modern Stymfalia is one of the springs fed by this inter-basin transfer. Measured surface runoff also shows that on average the maximum discharge has a three-month delay from the maximum precipitation - a factor that greatly facilitates highly productive spring-fed agriculture. These variable delays, which we understand today through our understanding of hydrogeology, in the past would have been understood through the personality and associated deity of the sacred spring (Mather, 2016). However, these figures hide large year-to-year variations as well as spatial variations within the basin. Using water chemistry, temperature and stable isotopes Morfis et al. (1985) were able to divide the springs into five groups draining aquifers in different lithological units (Table 2). Hydrograph analysis revealed different residence times for each aquifer, with the Olonos-Pindos springs (draining impermeable flysch) showing a significant variation in discharge (short residence time) whereas the Tripolis limestone water shows much smaller variations (longer residence times). On the north side of the valley, several springs, including those under the ancient city of Stymphalos and the modern village of Stymfalia, have high discharges and low residence times. These springs discharge underground water from the northern slopes along the bedding planes of the Ziria limestone block (including the inter-basin transfer component) to the valley floor where it recharges the alluvial fan aquifers and emerges as perennial springs (Fig. 3). The springs occur at a wide range of altitudes above the valley floor and up to 1200 m asl due to karstification of the limestone (Fig. 3). However, they increase in discharge and become perennial at lower altitudes. It is noticeable that three villages in the 19th century used clusters of springs at the headwall of valleys at altitudes of 800-900m asl. The water from the lowest springs at the modern village of Stymfalia is now directed across the valley for agriculture, with the excess water draining into the lake. In the past, a distributary channel network led the water over low-angle fans to the valley floor lake.

There are few springs on the south side of the basin due to the dip of the limestones and the valley floor which abuts the steep southern scarp face slopes. However, at one location (37°50'23.03'' N 22°26'45.47''E) there is a large natural sinkhole in the Mesozoic limestone that would have naturally drained the lake into the regional limestone aquifer, including the resurgences in the Asapos/Scotini and Nemea valleys. Much of the steeper basin slopes and the valley floor are covered by large alluvial cones and fans, which although stable and now under agriculture, do show evidence of past torrential flows along steep channels onto the valley floor. The hydrogeology of the basin is complex as the lake is fundamentally (i.e. naturally) a groundwater-fed through-flow lake, which also receives significant overland flow during the snowmelt season due to the altitude. This implies that the level of the lake before abstraction and regulation of the outlet (tunnel) would have been controlled by the influx of snowmelt on the northern massif (via the underground conduit system), the rate of evaporation of the lake, and the discharge through the sinkhole. The last of these parameters is the most difficult to estimate and may not have remained constant due to blockage by sediment. Since the 19th century, and probably since the Roman period or even earlier, the sinkhole has been managed, and thus the tunnel determined normal lake level. However, the whole valley floor is known to flood, with discharges exceeding the tunnel capacity, and outflow probably occurring through the sinkhole, which since the 19th Century has been isolated from regular flows. It is also known that in the recent past the lake has completely dried and even used as a landing strip. That the pre-modern drainage of the lake and associated wetlands were more extensive can be gauged from the area over which there is an arterial drainage system. This system covers an area of approximately 12 km^2, which is three times greater than the current lake area (3.8 km^2).

Whatever the status of the lake, as far as human settlement and economy is concerned, the key hydrological component of the valley is the abundant and perennial supply of high-quality water from the springs on the north side of the basin, which given their occurrence at heights up to 900 m above the valley floor (e.g. Drosopigi), are ideal for gravity-fed irrigation systems. Indeed, at Bouzi the slopes either side of the road to the upper village of Stymfalia are covered with an abandoned terrace system at least some of which is Roman in age on the basis of abundant Roman pottery exposed as part of a terrace fill exposed by a collapsed terrace wall.

Field and Laboratory Methods

The stratigraphic record of the lake was investigated by coring at selected locations (Fig. 1). Coring employed a range of coring devices, including open gouge corers (4cm and 8cm diameter), a fixed-chamber Russian-type corer and screw auger for resistant horizons. The stratigraphic methods reported here are standard and described in Jones *et al.* (1999). Likewise, analytical methods (loss on ignition, mineral magnetics, pollen analysis) used standard techniques and can be found in standard manuals such as Berglund (1986). Sediment description follows the Troels-Smith system, as modified by Aaby (1986). Organic content and carbonate were assessed using combustion. Pollen and spore analysis used 0.5 ml of sediment (Moore et al., 1991) from a sample thickness of 5 mm. Standard processing methods were used, the samples being sieved (180 microns and 8 microns) and mounted in silicone oil. Identification was at X400 and X1000 for critical grains. The University of Southampton reference collections were used for critical identifications. Standard pollen floras were supplemented by European pollen floras such as Punt and Clarke (1980) and Erdtman *et al.,* (1963), and studies of key genera including Cannabaceae, Moraceae, Urticaceae and Oleaceae (Liphschitz et al., 1991; Punt and Malotaux, 1984). A pollen sum of 500 land pollen grains was used excluding aquatic types and spores. In theory, the pollen catchment area for the site should be large, as it is a function of the basin size, which in this case is approximately 2200m in its shortest dimension (N-S). Work on pollen catchment areas by Jacobsen and Bradshaw (1981), and more recently modelled by Hellman *et al*., (2009) would suggest that the airborne catchment area of a site of this size would be regional - from the surrounding hills and valleys. However, the water that entered the lake would have run through soils, the conduit system and areas of thick marsh vegetation and/or intensive agriculture. Under such conditions, it is highly likely that a substantial component of the pollen could be waterborne as is the case in many lakes fed by rivers (Brown et al., 2007).

For XRF analysis continuous measurements were made from the top 940 mm of core LSC3 with an ITRAX core scanner on the sediment in the U-channels. The distinctive feature of the ITRAX core scanner is the generation of a flat X-ray beam, measuring a rectangular window rather than a single spot. In this way, grain-to-grain variances are averaged across the horizontal core axis. For the Stymphalos sediment a 20 x 0.1 mm rectangular beam was used, with a step-size of 60 mm, a count time of 4 s, a voltage of 30 kV, a current of 30 mA and a Mo X-ray tube. It is standard practice to ration elements to Ti, however, in this case, this was not done in order to assess the clastic/non-clastic component in the core as a proxy for lake level.

Sediment cores were inspected and material sieved to search for suitable plant macrofossils for ^{14}C AMS dating. However, organic-rich horizons were highly humified and so AMS dating was undertaken on bulk samples from the levels with the highest loss-on-ignition. AMS dates have been calibrated using INTCAL 5 (Stuiver et al., 1998).

Results

The Fountain-house and Nearshore Stratigraphy

A core transect was undertaken from the fountain-house extending 75 m into the lake. The transect (Fig. 4a) revealed three main stratigraphic units out from the fountain house into the lake and then separate more complex stratigraphy in certain areas. For example, along the causeways a black organic dump stratum was recorded, while dark soil and concentrations of broken roof tiles appeared along the walls. In addition, in a few locations off the transect, a dark to black cultural layer containing large quantities of pottery, bone, stone from the walls, broken roof tiles and other artefacts was encountered. The depth of this layer varied depending on its location on the site. Given the relationship between the sedimentary units in Fig. 4a and the depth of building and other cultural debris, the accumulation of at least the upper 2 m postdates the fountain-house and associated walling. This confirms that during the construction and use of the fountain-house, the lake must have been at some distance from this area. This is consistent with the use of the space on the lake-side of the Acropolis as a running track (Williams et al., 2002). There is, therefore, no functional, nor necessarily cultural link between the fountain-house [clickable-link here for the 3D model of the fountain house: https://skfb.ly/NNtT] and the lake other than the overflow of spring water that would have drained down to the lake shore (*ibid*.).

The Lake and Environmental Reconstruction

A bathymetric survey was undertaken in 2008, designed to establish the existence of a depocentre with organic-rich sediments in the lake. This survey revealed a remarkably constant depth with an average of only 1.08m and a maximum depth of 1.25m. Coring also showed that the lake bottom was entirely composed of clay under a shallow layer of decaying reeds and organic mud. This indicates that the lake has in recent or Classical times filled to capacity, and has almost certainly dried up completely in the recent past. The height of the present fill correlates with the outlet tunnel dug in the Roman period; it is likely that the lake has been in this state at least since that time. By coring from a raft a maximum of only 2.18 m of sediment was obtained, and this consisted entirely of silty clay (Fig. 4a, LSC1). Consequently, we concentrated coring from the dry ground at each end of the modern lake.

Although five core holes were made at the NE and SW ends of the lake, only two were sampled, and these provide data on the lake history. At the north end of the lake, core C3 (37°51'573'' E 22°28'708'' N) yielded 5.86m of stratified silts, clay and marl (Fig. 4b). The occurrence of organic fragments of reeds, shallow fresh-water gastropods, and a palaeosol at 3.39-3.81m illustrates the long-term ephemerality of the lake with phases of shallow aquatic vegetation and wetland soils being formed in dry phases. The main core at the south end of the lake (37°50'818'' E 22°27'162'' N, C2) only yielded 5.51 m but included a marl unit (1.85 - 3.53 m) and an abrupt change in sedimentation below this level. The marl reflects the spring-fed origin of the water and the shallow water with abundant aquatic vegetation. Radiocarbon dating bracketing the palaeosol in LSC2 produced two dates in the range 7326-7582 BC.

Previous attempts to extract pollen from the sediments at Lake Stymphalos have been unsuccessful (Atherden pers. comm.). However, through the use of large samples and triple sieving, enough pollen was extracted from the levels 4.43m to 4.51m of core C2 (Fig. 5). The eight levels counted all show approximately 50% of tree pollen dominated by *Quercus* sp. (oak) with smaller amounts of *Pinus* (pine), *Abies* (fir), *Betula* (birch), *Carpinus* (hornbeam), *Alnus* (alder) and *Corylus* (hazel). The herbaceous pollen is dominated by Poaceae (Poaceae/grasses) and Lactucoideae (dandelion types) with a consistent representation of *Bidens* t. pollen (daisy types). Aquatic pollen are dominated by *Myriophyllum* (water milfoils) and there is a minor presence of Pteridophytes (ferns). There is some stratigraphical variation, making it possible to divide the diagram into an upper and lower pollen assemblage zone across which there is a fall in Lactucoideae and a rise in Poaceae and *Myriophyllum*. This suggests that much of the Poaceae could be derived from marginal aquatic or wetland grasses (e.g. *Glyceria*). Cereal type pollen is recorded in every count, and therefore, there is little doubt that there was arable agriculture nearby. However, given that the surface water entering the lake will have flowed through areas of cultivation, it is quite likely that this high representation is derived from the aquatic pollen input from the northern valley slopes. Cereal pollen is known to be well represented in aquatic pollen load from arable catchments (Brown et al., 2007).

The ITRAX analysis reveals significant changes in the upper unit of core S3. Based on the presence of pottery and extrapolation of the lower dates, and the nearby dates Heymann et al. (2013), this upper unit covers the Classical and post-Classical period with an estimated date for its base of *c.* 2000-2050 cal BP (Fig. 6). Whilst Al remains constant, Cu Zn and Fe decrease systematically above 72 cm depth. This is also the case with Ti, and the similar trends in these three elements illustrate a decrease in clastic sedimentation from the base of the core upwards. This is compensated for by the rise in Ca, the source of which is $CaCO_3$. This is interpreted here as a strong indication of the lake becoming shallower and at least this area drying out repeatedly after c. 300-350 AD (using both LS3 dates and Heymann et al. dates at 0.72m depth. Before this date, the lake was permanent as illustrated by the shell-rich silts below. These data strongly suggest that the lake was at its pre-drainage maximum extent during the Classical period. This is in agreement with an increase in log(Rb/Sr) values in early Hellenistic times at Asea in the Central Peloponnese (Weiberg et al. 2016).

Discussion

The archaeological and stratigraphic investigations at the Fountain-house (Figs 7 & 8) and in the lake basin confirm that a shallow lake and marsh environment has existed at Stymphalos over at least the last 9,000 years, and certainly throughout the Classical Period when it appears to have been larger, deeper and probably permanent (i.e. non-seasonal). The reduction in sand content and increase in organic material and marl dated here to *c.* 7,600-7,300 BC marks a change to deeper water alternating with drier wetland phases. This is likely to be the result of the wetter early Holocene climate known from many other studies in the Mediterranean (Brown et al., 2015; Roberts et al., 2011; Walsh, 2014) and the blockage-prone nature of the sink-hole outlet. At the wider regional scale, work at Tenaghi Philippon (northeast Greece) suggests the development of dry winters and wet summers at *c.* 8,200 cal. BP (Peyron et al., 2011). After the 8.2 kr event (from c. 7,800-5,000 cal. BP), Tenaghi Philippon indicates continued wet conditions with a drying trend beginning sometime later *c.* 5,000 cal BP. From the sedimentary research undertaken by Unkel *et al*. (2011) and Heymann et al. (2013), carbonate influx and changing rubidium/strontium ratios at Stymphalos also suggests a post 8,200 cal. BP change in precipitation with the polje becoming wetter *at c.* 7,500 cal. BP. Given the high mean annual temperatures maintained in the central Mediterranean during the mid-Holocene, this must have been the result of increased precipitation which would have facilitated spring-fed slope agriculture. It is also possible that an increase in sediment supply from the slopes to the lake correspondingly increased the likelihood of outlet blockage. These characteristics and processes produce beneficial conditions for agriculture on the lower slopes and around the lake, as suggested by the pollen evidence presented here for early farming. These processes also created the increasingly erratic fluctuations in lake levels. It is suggested that it is this scenario that may have prompted the ascription of narratives and deities to the site and eventually, attempts to control the lake levels.

Relatively few archaeological data exist for the Mesolithic, Neolithic and Bronze Age in the Stymphalos area. There is little doubt that hunter-gatherers would have been attracted to the Stymphalos landscape with its wide range of aquatic and terrestrial resources. The Mesolithic is represented across parts of the Peloponnese, especially in the Argolid area to the south-east (Runnels, 2009; Runnels et al., 2005) and, towards the coast to the west around Kastro (Chavaillon et al., 1969). A small number of find spots of Neolithic material are known from the areas around Stymphalos, including Kionia on the south-western edge of the lake (Howell, 1970) as well as in the Nemea Valley area just to the east (Cherry et al., 1988). The palaeoecological evidence allows us to postulate agricultural activity in the area (or lake catchment) from the Early Neolithic onwards – this fits with our understanding of wider regional processes (Bintliff, 2012: chapter 3; Weiberg et al., 2016). We can also complement Bintliff's observation that the south-east of Greece did not necessarily see much in the way of early farming settlements due to the dominance of arid zones; it is apparent that the wetland areas, with the possibility of exploiting water-fed slopes, were attractive to early farmers. The presence of some nitrophilous plant species might suggest some pastoral activity. Whatever the extent and intensity of any arable and pastoral activity, it is likely that much of this activity took place within relatively open woodland along the wetland edges and the small plateaus and slopes that constitute the lake catchment. One of the best understood Neolithic landscapes, Thessaly with its patches of humid and fertile zones, is renowned as a landscape that saw high levels of Early Neolithic activity across soils that were underlain by a relatively high water-table (Perlès, 2001). For the Bronze Age (or Mycenaean Period), there is little doubt that the landscape around Stymphalos witnessed reasonable levels of activity. However, the relative dearth of archaeological evidence prevents us from developing a clear assessment of the nature of human-environment interaction during this period. To the south-east, the Argolid comprises the core Mycenaean zone with a complex settlement hierarchy and evidence for extensive and intensive exploitation of the countryside (Jameson et al., 1995). As Unkel et al. (2011) and Heymann et al. (2013) suggest from their work at Stymphalos, a phase dated broadly to 3500 – 3000 cal BP (RCC 4) of rapid climate change (transition to a wetter environment) is inferred from carbonate influxes and changing ratios of rubidium/strontium, which coincides with the Late Helladic period. The work reported here suggests that this phase of higher lake levels did not end until *c.* 300-350 AD.

With recourse to the archaeology, sanctuaries, perhaps more than any other cultural feature, constitute a hybrid, or an intersection of economic, religious and environmental processes within a landscape. As Jost (1996) argues for Arkadia, "...certain places seem destined to be considered sacred, and certain types of landscape attract cults of one divinity rather than another". Springs are of particular importance, and there is no denying the influence that the distribution (across both and space) of water has on all aspects of life. Indeed, without springs in karstic areas of the Mediterranean, sedentary human settlement would be virtually impossible. However, as the hydrogeological analyses from the Stymphalos polje show, all springs are not alike as there are substantial variations in the quantities and timing of discharge which can be an individual signature or biography of individual springs. This inherent unpredictability (even today) would not only have driven the construction of cisterns but also given them distinct characteristics similar to human or superhuman (*herculean*) personalities. It is, therefore, not surprising that these personalities have such an important role in geomythologies, and hydrogeological variation is mirrored by the number and variety of Greek water deities, including the many Naiad nymphs (Naiades, Heleionomai, Krenaiai) and the Pegaiai, who were Naiad Nymphs of springs. Other minor deities were associated with sources of freshwater, including fountains, moist breezes and rain clouds (The Okeanides), rivers (e.g. Alpheus), lakes (The Limnatides) and water-meadows.

The plains of eastern Arkadia comprise a calcareous soil covered with clay and alluvium that does not drain well, and it is the limestone fissures (the *katavothra*), that provide a natural drainage system. Both springs and fissures are natural features that are managed from at least the early Classical period onwards (Jost, 1996: 219). The wet or poorly drained areas of the landscape are often associated with Artemis, a goddess associated with dampness, as well as Poseidon. Artemis was important as the goddess of the marshland at Stymphalos (Jost, 1996) and in her role as the patron goddess of fishing. The rites associated with Artemis were not homogenous across the Hellenic world, with variations across urban and rural sites (Osborne, 1987: 170-1), and place-specific rites that may well have been linked to associations with other mythological figures, in our instance, Herakles. It is also likely that Artemis (cf. Diana) maintained her importance during the Roman period at Stymphalos (Clendenon, 2009a). Both springs and sinks are prone to temporal variation in water flow driven fundamentally by inter-annual variations in precipitation, but also in the case of sinks, by periodic blockages by sediment (Fairchild and A., 2012) or deliberate obstructions. We can see this in the accumulation of deposits in the aqueduct channel suggesting there were quite lengthy periods when water flow was relatively low and unable to re-suspend and erode sediments (Biers, 1978). Knauss (1991) argues for ancient land reclamation designed to reduce the size of lakes within Arcadia. This reclamation would have been achieved through the construction of polders, and thus lowering of the maximum water depth of the lakes. These notionally Mycenaean works would have also comprised the construction of drainage canals. Such works also included irrigation facilities for settlements and agriculture as revealed by a survey of the Kaphyai plain just to the south-west of Stymphalos (Knauss, 1991). Knauss (ibid.) argues that similar remains in the Stymphalos area imply the existence of a similar hydraulic management initiative here. Therefore, it is possible that this pre-Classical landscape was also imbued with mythical and religious meaning. As noted earlier, the Mycenaean/Minoan goddess, Potnia is considered the predecessor to Artemis (Thomas and Wedde, 2001).

The importance of Stymphalos as a source of water was transformed during the Roman period when the Hadrianic aqueduct to supply water for Corinth was built. The manipulation of this plentiful water supply, more specifically the spring at Driza just to the north of Lake Stymphalos (Lolos, 1997) by Roman technology altered the very nature and meaning of water at Stymphalos. This does not mean to say that local people's engagement with the lake and surrounding springs and the springs' associations with sanctuaries and deities necessarily changed. Nonetheless, the capture of this source must have affected inputs into the lake and at least part of the hydrological system around Stymphalos. An aqueduct not only creates a physical link between the source and consumer of the water (in this instance Corinth), it may well have changed the nature of cultural and ideological links between the source area and the consuming city; symbolic of the loss of autonomy of the city under Roman rule. This change in a community's or society's relationship with water would have course been true in any landscape where such a feat of hydraulic engineering had been undertaken. In Greece alone there were *c.* 25 aqueducts plus a dozen more across the Greek islands (Lolos 1997).

While much has been made of the ideological aspects of the control of water in the Classical Mediterranean world (Purcell, 1996), relatively few Mediterranean landscape surveys devote much time to the analysis of natural and unmanaged hydrological systems. Although it is the lake that has been the object of mythologising, and which caused inconvenience, the lake and indeed ancient economy was dependent upon the springs from 300m up the slopes down to the Fountain-house on the lakeshore. Fundamentally the Greek myths recognise the city as important, and this importance is reflected in its architecture, particularly its public buildings, all founded upon a prosperous local agricultural economy. There is little doubt that drainage of the valley floor was a problem in the Stymphalos polje. This is part of the story of the mythological blocking of the lake's sink-hole by Artemis relates to her anger at the Stymphalians for ceasing to worship her, and because their use of the land had damaged the preferred habitat of the animals protected by her (deer and cypress, (Burford, 1993: 165)). As well as the association of Artemis with wild, untamed nature, she was also the goddess of childbirth and the bringing and relieving of disease in women. This mythology reflects hunting, fertility and health as much as the presence or vicissitudes of the lake that probably relates to an earlier period of lake instability.

Conclusions

At Stymphalos, the ready supply of spring water and gently sloping land with relatively fertile soils attracted agricultural settlement from early in the Neolithic, and despite a lack of archaeological data, probably continued throughout the Bronze Age. We suggest links between our chronology of key landscape changes and the development of the two key mythological/ritual characteristics or memes/myths associated with Stymphalos. Hydrological instability within the lake probably characterised the Bronze Age. The need to manage a complex wetland may well intersect with the story of Herakles' sixth labour. Despite the problems with the lake, this area would have provided rich agricultural land, and the wetland itself would have produced abundant floral and faunal resources. This richness can may well have created associations with Potnia (Thomas and Wedde, 2001), and then over time, Artemis emerged as the important deity when the lake was at its pre-drainage maximum extent. We should not forget, that for successful agriculture, it was not the lake itself that was important, but rather the springs that fed the lake. The presence of the fountain house and Artemis' temple in the area were in fact references the wider fertility.

From the foundation of the Greek city onwards, we can also consider the intersection of nature and environmental change with mythical-religious values associated with the fundamental importance of uncontaminated water for human, animal and agricultural use. While the waxing and waning of the lake were the visual and symbolic element of fluctuating nature, the variations in spring-flow would have had the greatest economic impact. In this context, mythological and water-based rites became increasingly formalised and structured, as represented by architectural and hydraulic features on the north side of the valley floor. The substantial evidence produced by recent excavations of the Greek city of Stymphalos have revealed a large, wealthy city both fortified and with substantial public buildings from the 4th to 1st Centuries BC. This city, along with the earlier city and the succeeding Roman city were dependent upon springs on the valley sides and the valley floor due to the enclosed (polje) nature of this valley, and its relative isolation from both the coast and any large rivers. This is symbolised by the construction of the fountain-house, which was an 'urbanised' springhead located beneath the city above the edge of the lake (Figs 7 & 8). The lake has been shallow and occasionally dry for the last 9,000 years due to the combination of variable water supply from the Kylene massif and the unpredictable behaviour of the sinkhole outlet. Certainly, during the Classical Period, it was no larger than it is today but was, however, marginally deeper.

Given its isolated location and lack of any known mineral wealth, its population and prestige must have been founded on local agricultural surpluses. The lower slopes could provide spring-fed terraces systems, and the lower low-angle alluvial fans provided high-grade agricultural land with a water supply. It is notable that the architecture clearly reveals the importance of the spring (e.g. the fountain-house) whilst the myths associated with the city are concerned with the erratic behaviour of the lake. This erratic behaviour is reflected in the stratigraphy of the lake sediments, as is the agricultural use of the lake area. However, and despite the fame of the lake even in Classical times, it is argued here that the key element in the existence, persistence and power of the City of Stymphalos stems from the water supply (springs) that supported the city and incidentally kept the lake full or the marshes wet. As is reflected by the Hadrianic engineering at least in the Roman period, the lake itself is not the valued resource but the water is. We firmly believe that the (Classical) landscape around Stymphalos was religious, in the sense that comprised "...all kinds of myths and [of] mythological traditions interweaved with the land and the polis" (Horster, 2010: 438). With this view in mind, the myth of the Herakles and Stymphalean Birds, or the narrative of the Athenian siege, can both be read as reflecting the problematic and demonic nature of Lake Stymphalos, rather than celebration of a natural wonder, whilst the archaeology points to the critical importance of springs, fountains and a reliable water supply.

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Figure captions

Figure Captions

Figure 1. A map of the Stymphalos Basin, the Stymphalos, Scotini and Alea poljes and an inset location map.

Figure 2. City plan produced via topographic survey. Red dots represent auger transect samples.

Figure 3. Hydrogeological cross-section across the Stymphalos polje with inset schematic tectonic map of the polje of Stymphalos with underground discharge directions within the Ziria block. Adapted from Morfis and Zojer (1986).

Figure 4. Plan of coring and stratigraphic cross-section into the lake from the Fountain-house (a) and the two cores at each end of the present lake (b).

Figure 5. Pollen diagram from levels 4.44 to 4.51 from core LSC3.

Figure 6. Itrax results from core LSC3.1 (0-1000 mm).

Figure 7. Photos of fountain-house area looking towards the lake (Kevin Walsh and Ben Gourley).

Figure 8. Photogrammetric model of the fountain house at Stymphalos (photos taken via kite-survey (Ben Gourley)). house [clickable-link here for the 3D model of the fountain house: https://skfb.ly/NNtT]

References

Aaby, B., 1986. Palaeoecological study of mires, in: Berglund, B. (Ed.), Handbook of Palaeoecology and Palaeohydrology Wiley, Chichester, pp. 145-164.

Bakker, J., Paulissen, E., Kaniewski, D., De Laet, V., Verstraeten, G., Waelkens, M., 2012. Man, vegetation and climate during the Holocene in the territory of Sagalassos, Western Taurus Mountains, SW Turkey. Vegetation History and Archaeobotanly 21, 249-266.

Benjamin R, G., A, F., William G, F., Stuart, C., Ian, B., David, K., Jane, R., Emma, T., 2011. From Site to Landscape Assessing the Value of Geoarchaeological Data in Understanding the Archaeological Record of Domuztepe, Eastern Mediterranean, Turkey. American Journal of Archaeology 115, 465-482.

Berglund, B.E., Ralska-Jasiewiczowa, M., 158B., I.G.C.P.P., 1986. Handbook of Holocene Palaeoecology and Palaeohydrology. J. Wiley.

Biers, W.R., 1978. Water from Stymphalos? Hesperia 47, 171-184.

Bintliff, J., 2012. The Complete Archaeology of Greece. John Wiley & Sons.

Biswas, A.K., 1972. History of Hydrology. North-Holland.

Bradley, R., 2000. An archaeology of natural places. Routledge, London.

Brown, A., Carpenter, R., Walling, D., 2007. Monitoring fluvial pollen transport, its relationship to catchment vegetation and implications for palaeoenvironmental studies. Review of Palaeobotany and Palynology 147, 60-76.

Brown, A.G., Bailey, G., Passmore, D., 2015. Environments and landscape change, in: Fowler, C., Harding, J., Hofmann, D. (Eds.), The Oxford Handbook of Neolithic Europe. Oxford University Press, Oxford.

Bulfinch, T., 1856. The Age of Fable; Or, Stories of Gods and Heroes. Sanborn, Carter, and Bazin.

Burford, A., 1993. Land and Labour in the Greek World. John Hopkins, London.

Butzer, K.W., 2011. Geoarchaeology, climate change, sustainability: a Mediterranean perspective. Geoarchaeology, climate change, and sustainability. Geol Soc Am Special Paper 476, 1-14.

Châtelain, T., 2007. La Grèce antique et ses marais: Percpetion des milieux palustres chez les Anciens. Universit, de Neuchatel and Université de Paris IV - Sorbonne.

Chavaillon, N., Chavaillon, J., Hours, F., 1969. Industries paléolithiques de l'Élide. II. Région de Kastron. Bulletin de correspondance hellénique 93, 97-151.

Cherry, J.F., Davis, J.L., Demitrack, A., Mantzourani, E., Strasser, T., Talalay, L.E., 1988. Archaeological survey in an artefact-rich landscape: A Middle Neolithic example from Nemea, Greece. American Journal of Archaeology 92, 159-176.

Clendenon, C., 2009a. Hydromythology and the Ancient Greek World: An Earth Science Perspective Emphasizing Karst Hydrology. Fineline Science Press, Michigan.

Clendenon, C., 2009b. Karst Hydrology in Ancient Myths from Arcadia and Argolis, Greece. Acta Carsologica 38, 145 - 154.

Clendenon, C., 2010. Ancient Greek geographer Pausanias as a qualitative karst hydrogeologist. Ground Water 48, 465-470.

Crouch, D.P., 2004. Geology and Settlement: Greco-Roman Patterns. Oxford University Press, New York.

Dusar, B., Verstraeten, G., Notebaert, B., Bakker, J., 2011. Holocene environmental change and its impact on sediment dynamics in the Eastern Mediterranean. Earth-Science Reviews 108, 137-157.

England, A., Eastwood, W.J., Roberts, C.N., Turner, R., Haldon, J.F., 2008. Historical landscape change in Cappadocia (central Turkey): a palaeoecological investigation of annually laminated sediments from Nar lake. The Holocene 18, 1229-1245.

Erdtman, G., 1963. An Introduction to a Scandinavian Pollen Flora. Almqvist & Wiksell.

Fairchild, I.J., A., B., 2012. Speleothem Science: From Process to Past Environments. Wiley-Blackwell, London.

Farinetti, E., 2009. Boeotian landscapes. A GIS-based study for the reconstruction and interpretation of the archaeological datasets of ancient Boeotia. Leiden University.

Gourley, B., 2005. Geophysical Survey at Ancient Stymphalos: 2005: Report on Preliminary Results

Gourley, B., Williams, H., 2005. The fortifications of Ancient Stymphalos. Mouseion 49, 213-259.

Hellman, S., Gaillard, M.-J., Bunting, J.M., Mazier, F., 2009. Estimating the relevant source area of pollen in the past cultural landscapes of southern Sweden—a forward modelling approach. Review of Palaeobotany and Palynology 153, 259-271.

Heymann, C., Nelle, O., Dörfler, W., Zagana, H., Nowaczyk, N., Xue, J., Unkel, I., 2013. Late Glacial to mid-Holocene palaeoclimate development of Southern Greece inferred from the sediment sequence of Lake Stymphalia (NE-Peloponnese). Quaternary International 302, 42-60.

Horster, M., 2010. Religious Landscape and Sacred Ground: Relationships between Space and Cult in the Greek World. Revue de l'histoire des religions 227, 435-458.

Howell, R., 1970. A Survey of Eastern Arcadia in Prehistory. The Annual of the British School at Athens 65, 79-127.

Iakovidis, S., 2001. Gla and the Kopais in the 13th Century BC. Library of the archaeological society at Athens.

Jacobson Jr, G.L., Bradshaw, R.H., 1981. The selection of sites for paleovegetational studies. Quaternary Research 16, 80-96.

Jameson, M.H., Runnels, C., van Andel, T.H., 1995. A Greek Countryside: Southern Argolid from Prehistory to the Present Day. Stanford University Press, Stanford.

Jones, A.P., Tucker, M.E., Hart, J., Association, Q.R., 1999. The description & analysis of Quaternary stratigraphic field sections. Quaternary Research Association.

Jost, M., 1996. The Distribution of Sanctuaries in Civic Space in Arkadia, in: Alcock, S., Osborne, R. (Eds.), Placing the Gods: Sanctuaries and Sacred Space in Ancient Greece. Clarendon Press, pp. 217-230.

Karkanas, P., Pavlopoulos, K., Kouli, K., Ntinou, M., Tsartsidou, G., Facorellis, Y., Tsourou, T., 2011. Palaeoenvironments and site formation processes at the Neolithic lakeside settlement of Dispilio, Kastoria, Northern Greece. Geoarchaeology 26, 83-117.

Knauss, J., 1991. Arkadian and Boiotian Orchomenos, centres of Mycenaean hydraulic engineering. Irrigation and Drainage Systems 5, 363-381.

Kopaka, K., 2001. A day in potnia’s life: Aspects of potnia and reflected “Mistress” activities in the Aegean Bronze Age. POTNIA: Deities and Religion in the Aegean Bronze Age, 15-27.

Liphschitz, N., Gophna, R., Hartman, M., Biger, G., 1991. The Beginning of Olive (Olea europaea) Cultivation in the Old World : A Reassessment. Journal of Archaeological Science 18, 441-453.

Lolos, Y., 1997. The Hadrianic Aqueduct of Corinth (with an Appendix on the Roman Aqueducts in Greece). Hesperia, 271-314.

Lolos, Y., 2007. Land of Sikyon: Archaeology and History of a Greek City-State. American School of Classical Studies, Athens.

Mitsopoulos-Leon, V., 2011. Pausanias VIII 18, 8 et les fouilles autrichiennes à Lousoi, in: Carlier, P., Jost, M. (Eds.), Paysage et religion en Grèce antique: mélanges offerts à Madeleine Jost. De Boccard, Paris, pp. 27-35.

Moore, P.D., Webb, J.A., Collinson, M.E., 1991. Pollen Analysis, 2nd ed. Blackwell Scientific Publications, Oxford.

Morfis, A., Zojer, H., Harum, T., Zötl, J., 1985. Karst hydrogeology of the Central and Eastern Peloponnesus (Greece), Steirische Beiträge zur Hydrogeologie. Kommission Springer-Verlag, pp. 1-301.

Osborne, R., 1987. Classical Landscape with Figures: The Ancient Greek City and Its Countryside. ACLS History E-Book Project, New-York.

Perlès, C., 2001. The Early Neolithic in Greece: The First Farming Communities in Europe. Cambridge University Press, Cambridge.

Peyron, O., Goring, S., Dormoy, I., Kotthoff, U., Pross, J.Ç., De Beaulieu, J.L., Drescher-Schneider, R., VanniÇùre, B., Magny, M., 2011. Holocene seasonality changes in the central Mediterranean region reconstructed from the pollen sequences of Lake Accesa (Italy) and Tenaghi Philippon (Greece). The Holocene 21, 131-146.

Punt, W., Malotaux, M., 1984. Cannabaceae, moraceae and urticaceae. Review of Palaeobotany and Palynology 42, 23-44.

Punt, W.C., G.C.S., 1980. The Northwest European Pollen Flora II. Elsevier, Amsterdam.

Purcell, N., 1996. Rome and the management of water: environment, culture and power, in: Shipley, G., Salmon, J. (Eds.), Human Landscapes in Classical Antiquity: Environment and Culture Routledge, London, pp. 180 -212.

Retallack, G.J., 2008. Rocks, views, soils and plants at the temples of ancient Greece. Antiquity 82, 640-657.

Roberts, N., Eastwood, W.J., KuzucuoŽYlu, C., Fiorentino, G., Caracuta, V., 2011. Climatic, vegetation and cultural change in the eastern Mediterranean during the mid-Holocene environmental transition. The Holocene 21, 147-162.

Rosen, A.M., 2007. Civilizing Climate: Social Responses to Climate Change in the Ancient Near East. AltaMira, Plymouth.

Rougement, G., 2011. L'Oracle de Delphes, les Sciences de la Nature et l'Archéologie, in: Carlier, P., Jost, M. (Eds.), Paysage et religion en Grèce antique: mélanges offerts à Madeleine Jost. De Boccard, Paris, pp. 175-182.

Runnels, C., 2009. Mesolithic Sites and Surveys in Greece: A Case Study from the Southern Argolid. Journal of Mediterranean Archaeology 22, 57-57.

Runnels, C., Panagopoulou, E., Murray, P., Tsartsidou, G., Allen, S., Mullen, K., Tourloukis, E., 2005. A Mesolithic Landscape in Greece: Testing a Site-Location Model in the Argolid at Kandia Journal of Mediterranean Archaeology 18, 259-285.

Saïd, S., 2011. Les Mythes Arcadiens dans le Livre VIII de la in: Carlier, P., Jost, M. (Eds.), Paysage et religion en Grèce antique: mélanges offerts à Madeleine Jost. De Boccard, Paris, pp. 175-182.

Simpson, R.H., 1979. A gazetteer of Aegean civilization in the Bronze Age. Astrom, Göteborg

Stuiver, M., Reimer, P., Bard, E., Beck, J.W., Burr, G.S., Hughen, B.K., McCormac, G., van der Plicht, J., Spurk, M., 1998. INTCAL98 radiocarbon age calibration, 24,000-0 cal BP. Radiocarbon 40, 1041-1083.

Thomas, C.G., Wedde, M., 2001. Desperately Seeking Potnia. Potnia. Deities and Religion in the Aegean Bronze Age. Aegeaum 22, 3-14.

Unkel, I., Heymann, C., Nelle, O., Zagana, E., 2011. Climatic influence on Lake Stymphalia during the last 15 000 years, in: Lambrakis, N., Stournaras, G., Katsanou, K. (Eds.), Advances in the Research of Aquatic Environment. Springer Berlin Heidelberg, pp. 75-82.

Van Dyke, R.M., 2008. Memory, place, and the memorialization of landscape. Handbook of landscape archaeology, 277-284.

Vermoere, M., Bottema, S., Vanhecke, L., Waelkens, M., Paulissen, E., Smets, E., 2002. Palynological evidence for late-Holocene human occupation recorded in two wetlands in SW Turkey. The Holocene 12, 569-584.

Vitaliano, D.B., 1973. Legends of the Earth: Their Geologic Origins. Indiana University Press.

Walsh, K., 2014. The Archaeology of Mediterranean Landscapes : Human-Environment Interaction from the Neolithic to the Roman Period. Cambridge University Press, Cambridge.

Weiberg, E., Unkel, I., Kouli, K., Holmgren, K., Avramidis, P., Bonnier, A., Dibble, F., Finné, M., Izdebski, A., Katrantsiotis, C., Stocker, S.R., Andwinge, M., Baika, K., Boyd, M., Heymann, C., 2016. The socio-environmental history of the Peloponnese during the Holocene: Towards an integrated understanding of the past. Quaternary Science Reviews 136, 40-65.

Williams, H., 1983. Stymphalos: A Planned City of Ancient Arcadia. Classical Views 2.

Williams, H., 2010. Stymphalos.

Williams, H., Schaus, G., Gourley, B., Cronkite Price, S., Sherwood, K., Lolos, Y.G., 2002. Excavations at Ancient Stymphalos 1999-2002. Mouseion 46, 135-188.

Woodbridge, J., Roberts, N., Late Holocene climate of the Eastern Mediterranean inferred from diatom analysis of annually-laminated lake sediments. Quaternary Science Reviews.

Table 1

Tables

Site name	Region	Chronology	Nature of wetland	Research Theme	References
Gla	Boeotia, Greece	Mycenaean	Wetland/marsh	Settlement in, and management of landscape	(Iakovidis, 2001)
Multi-site	Boeotia, Greece	Archaic – Late Roman	Mix of wetlands, valleys	GIS analyses of site distributions and landscape	(Farinetti, 2009)
Pontine	Central Italy	Roman	Wetland/marsh	Settlement in and management of landscape	(Attema and de Haas, 2005; Walsh et al., 2014)
Sagalassos	SW Turkey	Roman-Medieval	Lake & marsh	Human exploitation of landscape, vegetation change	(Bakker et al., 2012; Vermoere et al., 2002)
Domuztepe	SE Turkey	Holocene	Alluvial landscape with wetland/marsh	Landscape change, relationship between environment/resources/settlement location	(Benjamin R et al., 2011)
Dispilio	Nth Greece	Neolithic	Lake	Site, lake environment and economy	(Karkanas et al., 2011)
Multi-site	Thessaly	Neolithic	Wetlands	Landscape change, relationship between environment/resources/ settlement location	(Perlès, 2001)

Table 1: Some examples of typical research in Mediterranean wetlands

Table 1

Spring Group	Spring group name	Predominant aquifer lithologies	Water qualities
I	Olonos-Pindos	Debris & Olonos-Pindos limestone	Normal earth alkaline predominantly hydrocarbonatic
II	Tripolis water	Tripolis limestone (with gypsum)	Normal earth alkaline predominantly hydrocarbonatic sulphatic
III	Lime gravel waters	Neogene conglomerates	earth alkaline predominantly hydrocarbonatic
IV	Tyrol waters	Tyrolis nappe limestone	earth alkaline predominantly hydrocarbonatic with increased alkali content
V	Waters from the PQ unit	Phyllite-Quatrzite unit	earth alkaline predominantly hydrocarbonatic with increased alkali content

Table 2. Classification of springs in the Stymphalos area from Morfis and Zojer (1986).

Figure 1

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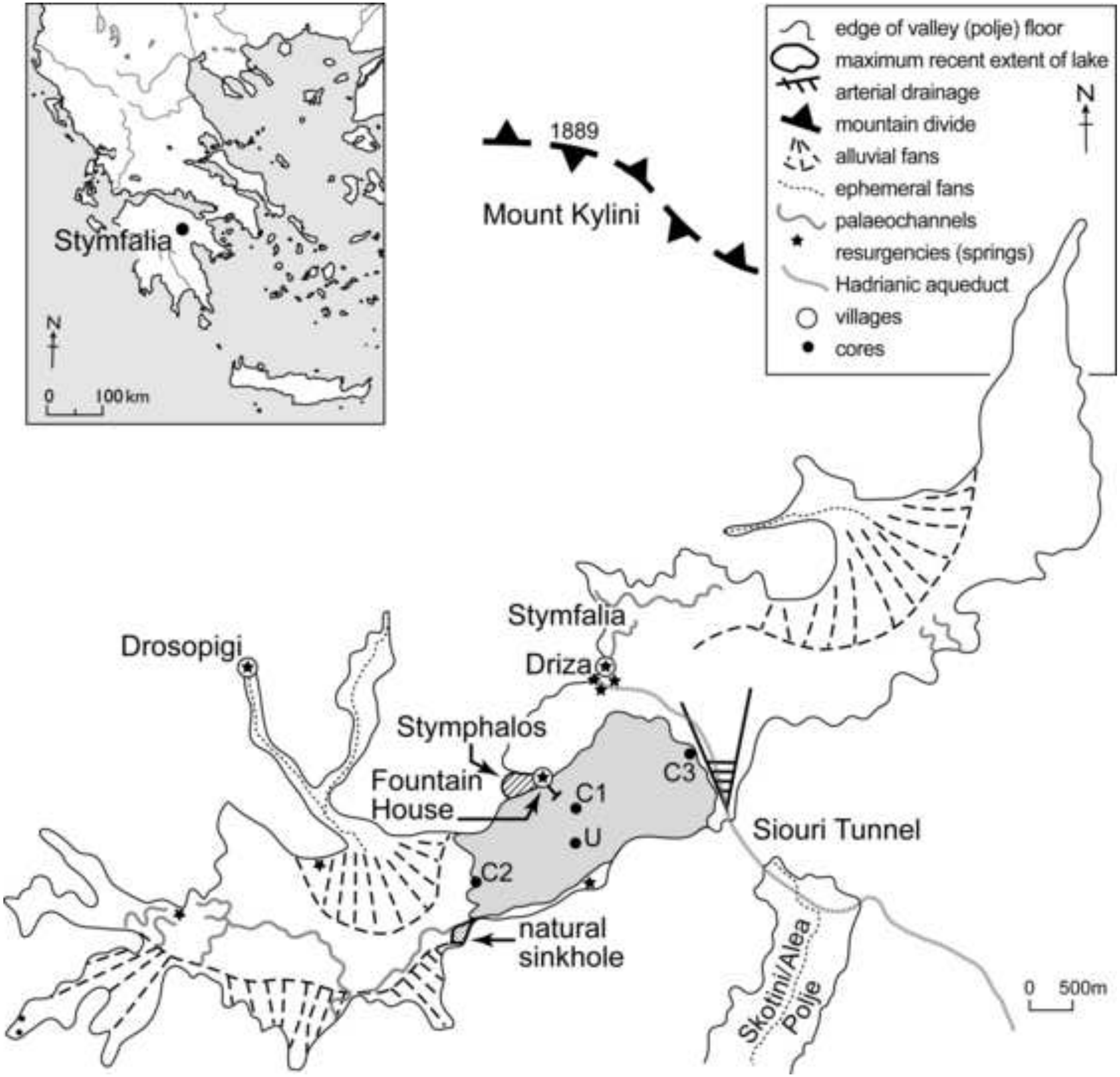

Figure 2

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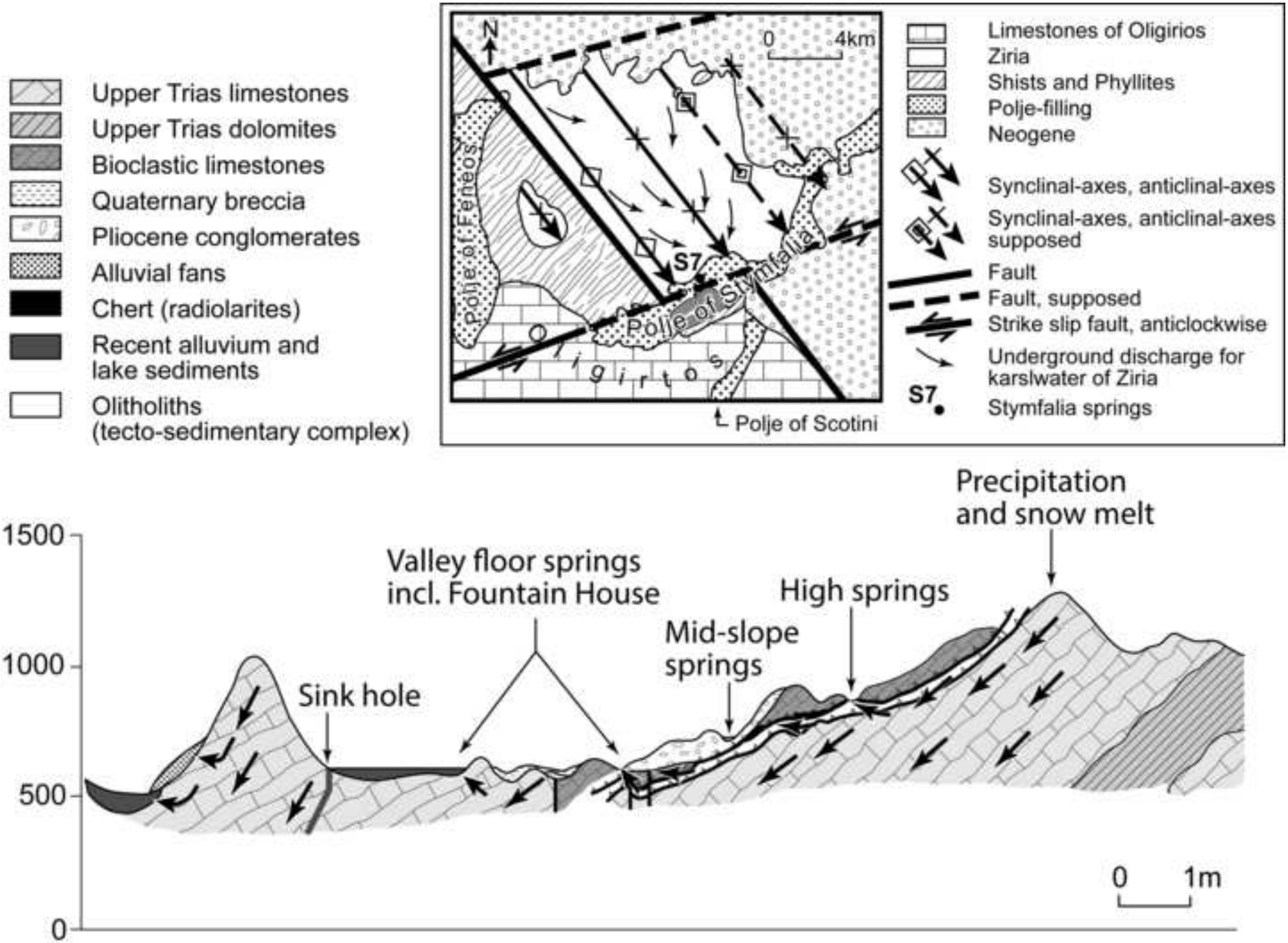

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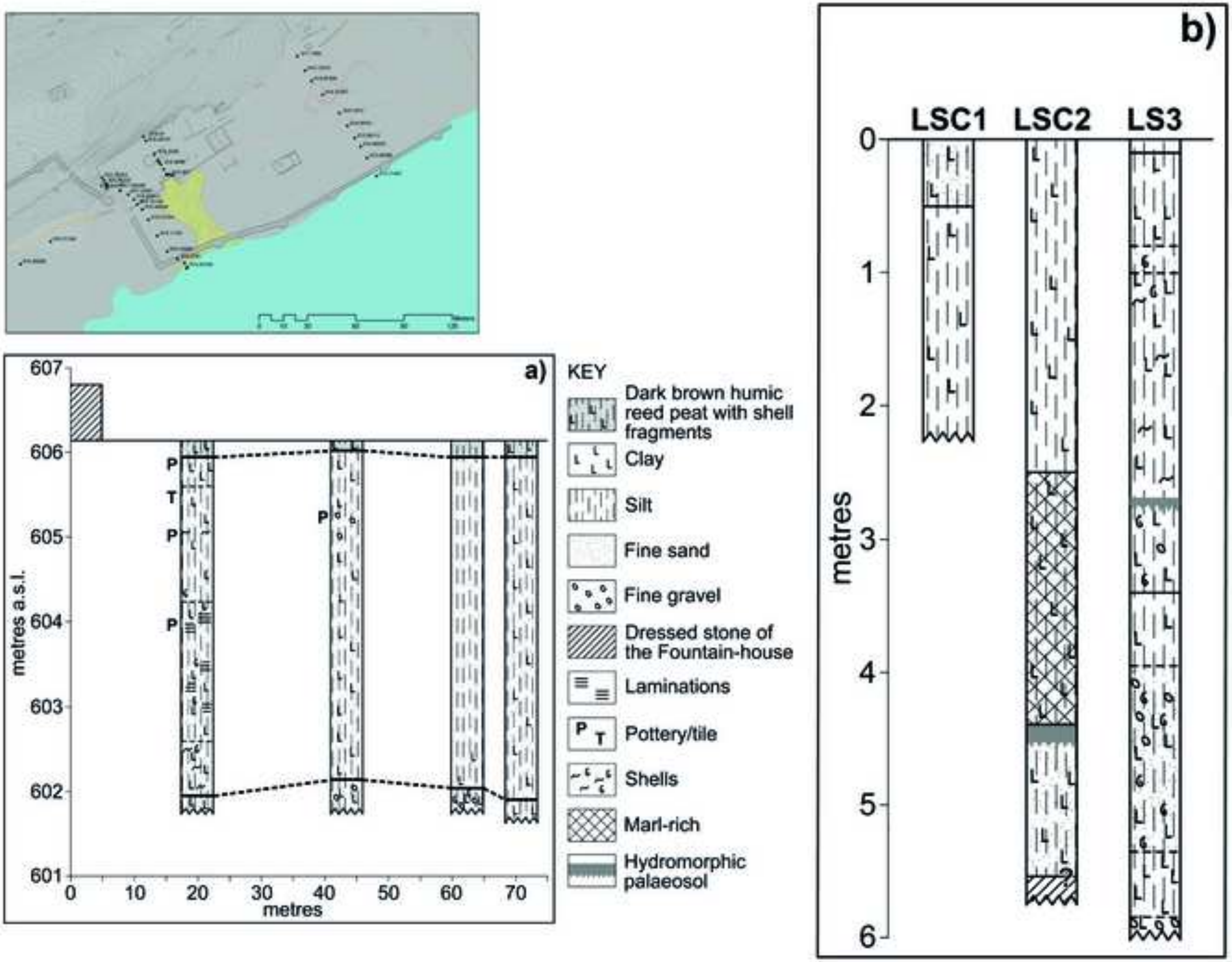

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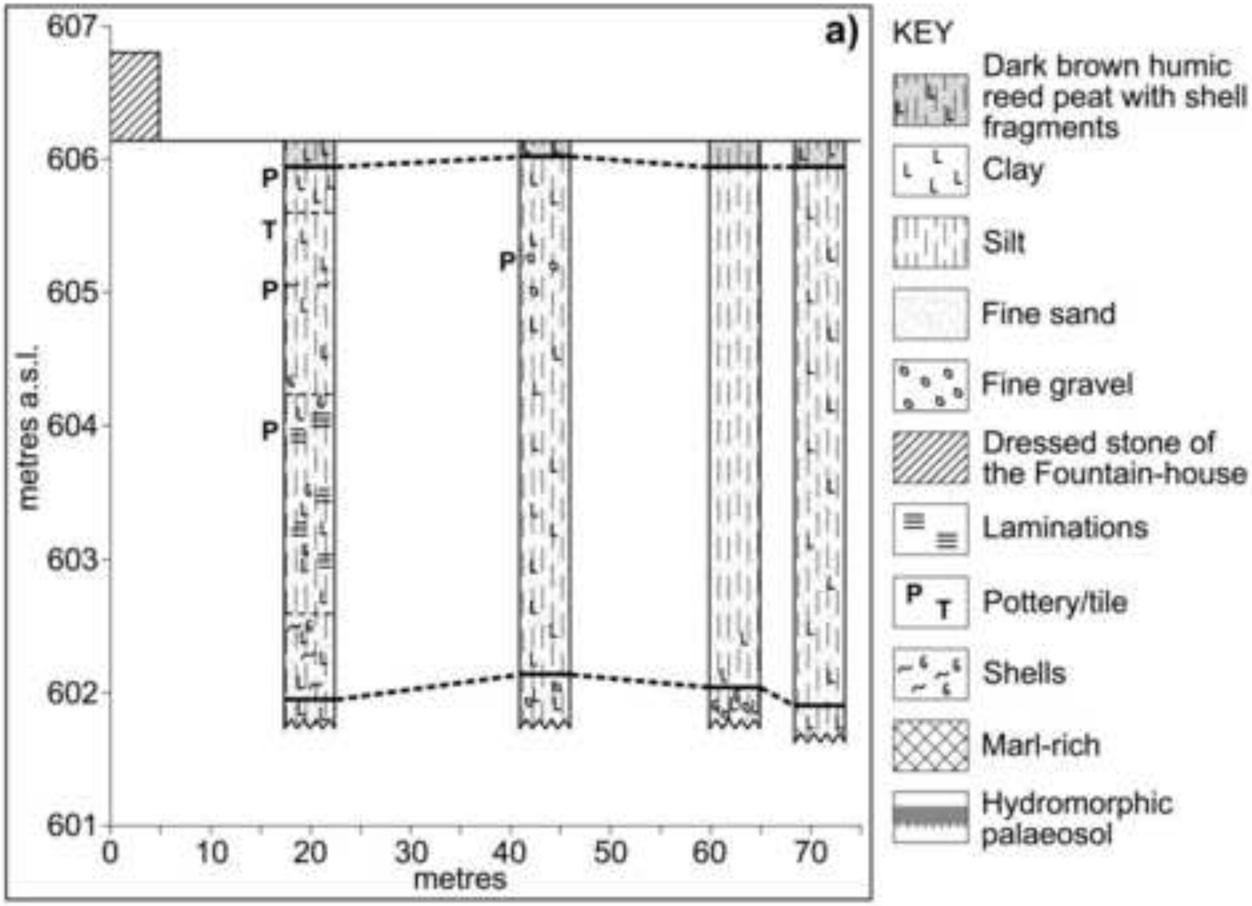

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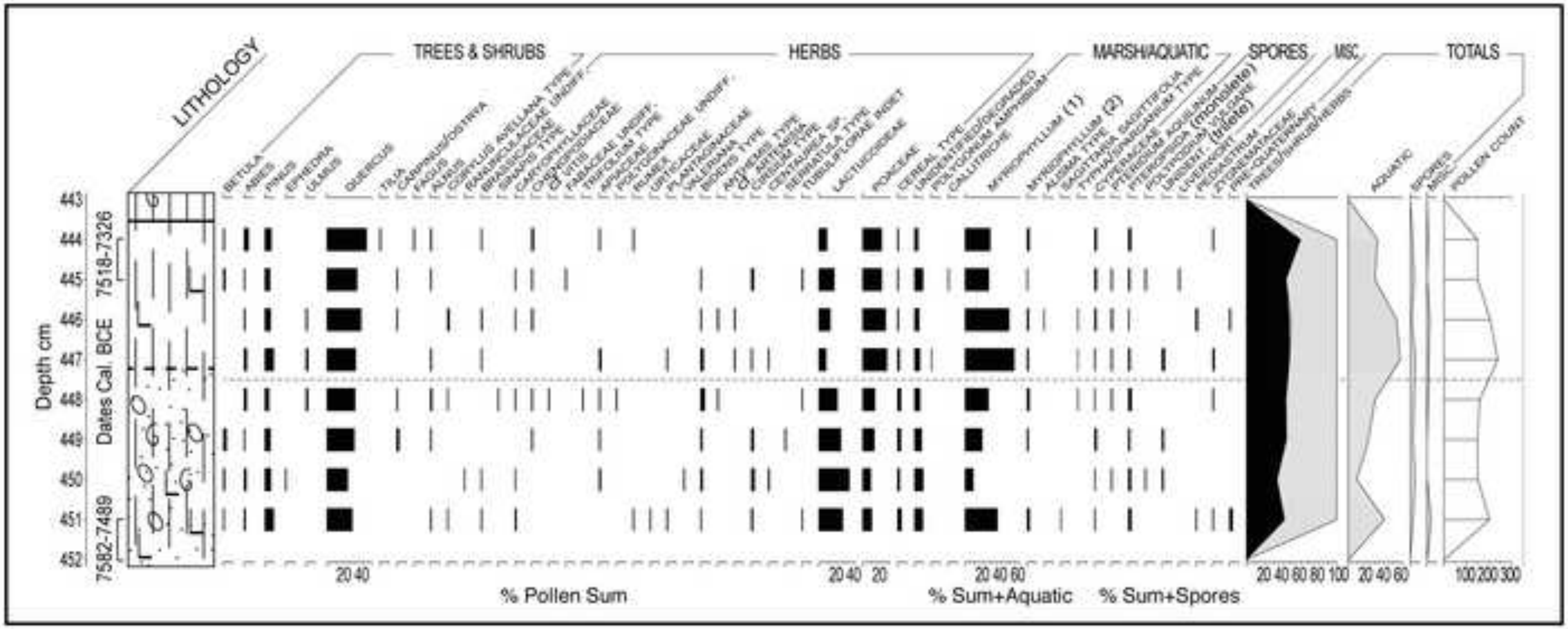

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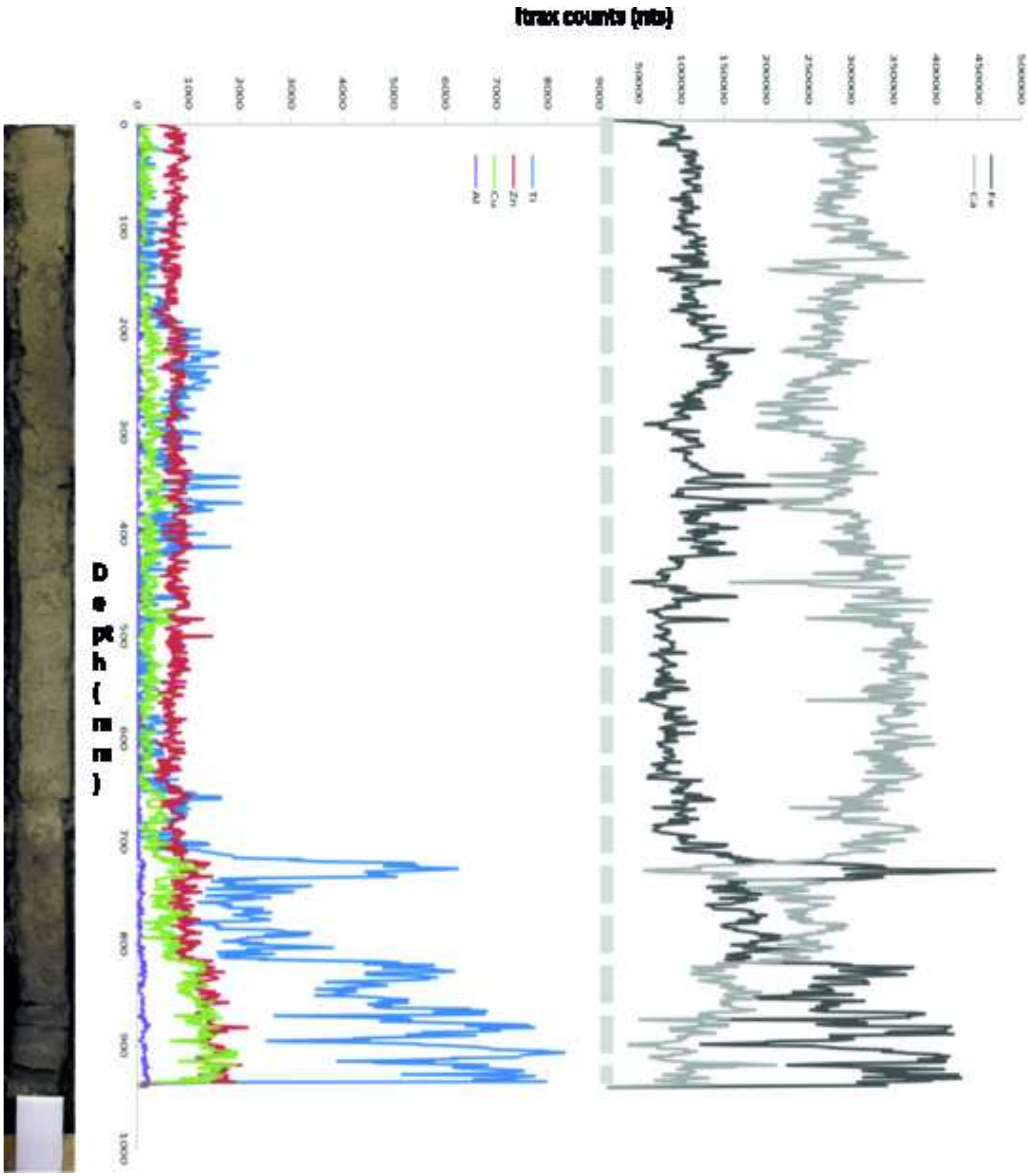

Figure 7
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