Investigations of past erosional and sedimentological process at the Roman and Byzantine site of Sparta

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Introduction

On-site environmental archaeology in Greece has mainly focused on the reconstruction of past economies through the analysis of assemblages of charred plant remains (e.g. Jones 1987) and bones (e.g. Halstead 1987) rather than past environments. The time period on which these investigations have been carried out has also been restricted to pre-Classical (Table 1) cultures, in part caused by the belief that vegetational and land-use changes are well documented in written accounts for periods subsequent to this. Techniques of palaeo-environmental, -erosional and -depositional reconstruction have mostly been applied at an off-site level, in an attempt to solve large scale problems of vegetational and depositional change that occur over long time periods (e.g. Greig and Turner 1974; Davidson *et al.* 1976; Bintliff 1977).

However, recent theories have demonstrated the importance of analysing and reconstructing formational processes of archaeological sites, even if for no other reason than understanding why a particular sedimentological unit does, or does not, contain particular types of artefact or ecofact (Stein 1985; Schiffer 1987). In the case of archaeological investigations in Greece, there are only a very few cases where this type of approach have been adopted and techniques of sediment analysis have been applied to answer site specific problems (e.g. Davidson 1973; Stein and Rapp 1978). Furthermore to the authors knowledge, not one of these are from sites of the historic period. To some extent this can be attributed to the way archaeological investigation is carried out in Greece, with very few sites being excavated in comparison to the many regional surveys that take place.

This latter type of investigation requires knowledge of how sedimentological processes operate at a regional scale and over a long time period, rather than localised changes within a site. Therefore the chance to apply a series of sedimentological techniques in order to answer specific site formational problems relating to a site dating from the Hellenistic and later periods, presented the opportunity to test various sedimentological techniques currently used in northern Europe and to see how useful they are in the Mediterranean environment. The site in question was the acropolis at Sparta, in the Laconia province of the Peloponnese, where excavations have been conducted under the auspices of the British School at Athens since 1989 (Waywell and Wilkes in prep.).

The site and its environment

The Spartan acropolis sits on one of a series of Neogene hills, scattered at the northern end of the six kilometre wide, sixty kilometre long Evrotas valley (Fig. 1). The valley is a huge tectonic trough formed during, or prior to, the Upper Pliocene, whilst the limestone massifs that surround it (the Taygetus range to the west and the Parnon range to the east), were uplifted as the valley sank (Philipson 1959; Bintliff 1977).

During the Tertiary and Quaternary epochs these contrasting processes continued to operate so that the Taygetus crest line is now some 2200 m above the valley floor. Besides the processes of uplift and valley depression, another major reason for the large height differential between the Evrotas valley and the surrounding mountains was massive erosion of the Neogene deposits that once filled the valley, by sustained fluvial activity. Today the Neogene only exists as a surface deposit on small hillocks in the centre of the valley (an example of which is the acropolis hill), or as outliers at the base of the two mountain ranges (Fig. 2) (Philipson 1959; Richard and Phillippakis 1969). During the Pleistocene the valley filled with flood plain alluvium of several distinct types, collectively termed 'Older Fill' (Vita-Finzi 1969), as the River Evrotas has changed course.

Deposition of alluvium has also occurred during the Holocene, termed 'Younger Fill' (Vita-Finzi 1969), although in recent times a process of river down cutting and net erosion has led to the loss of a great deal of material, causing a delta to be formed where the Evrotas meets the Laconian Gulf (Bintliff 1977; Bintliff 1982). There has been a constant debate as to whether this Holocene erosion was caused by climatic change at various stages (particularly in the Late Roman and Medieval period) (Vita-Finzi 1969; 1976; Bintliff 1975; 1977; 1982), or whether man's agricultural activities and their intensification are to blame (Butzer 1974; Davidson 1980; Wagstaff 1981). Recently it has become largely accepted that the latter argument is the more likely, although climatic change may have intensified the process (Bintliff 1992).

Period	Other Titles	Begins	Ends
Palaeolithic		pre 100.000 BC	10.000 BC
Mesolithic		10.000 BC	6000 BC
Neolithic		6000 BC	3000 BC
Early Bronze Age	E. Helladic (mainland), E. Cycladic (Cyclades), E. Minoan (Crete)	3000 BC	2000 BC
Middle Bronze Age	M. Helladic (mainland), M. Cycladic (Cyclades), M. Minoan (Crete)	2000 BC	1600 BC
Late Bronze Age	L. Helladic (mainland), L. Cycladic (Cyclades), L. Minoan (Crete)	1600 BC	1100 BC
Proto-Geometric and Geometric	Dark Ages	1000 BC	700 BC
Archaic and Classical		700 BC	400 BC
Hellenistic and Roman		400 BC	700 AD
Byzantine		700 AD	1453 AD
Turkish		1453 AD	19th cent. AD

Table 1 Summary of time period classification for Greece

Very little information is available as to contemporary environments in the Sparta region in the Roman and Byzantine periods, although it has always been assumed that the climax oak woodland of the early Holocene had been cleared for agricultural purposes (Bintliff 1977). This dearth of information is due in no small way to the lack of pollen studies in the Laconian region. Wright (1972), using pollen evidence from the Messenia area to the west of Sparta, considers that forest clearance had occurred from the Bronze Age onwards in the valleys, although the hills may have remained wooded (Greig and Turner 1974). It is possible that even these had been cleared of forest by Roman times, although it should be considered that a pollen diagram from a site 60 km away may have little relevance to the Evrotas valley. Nevertheless indications of Roman and Byzantine agricultural activity argue for a largely open environment (Bintliff 1977; Peña-Chocarro 1990) in this period, although olives may have been a (major crop (Renfrew 1973).

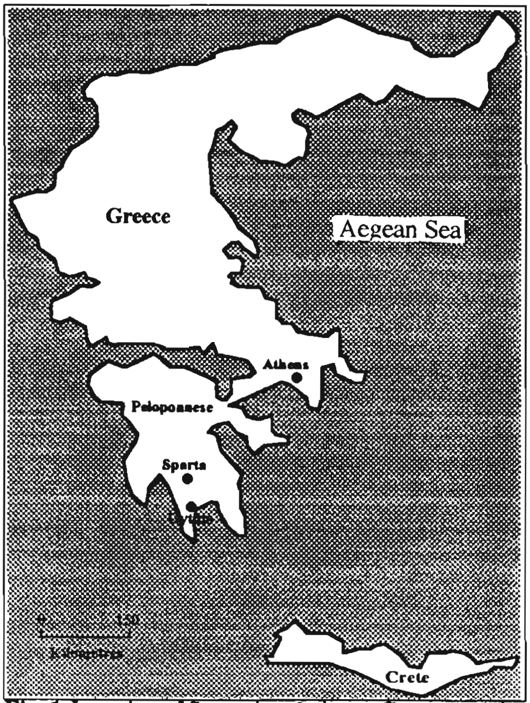

Fig. 1 Location of Sparta in relation to Greece and the Aegean

Sparta is probably best known as the major protagonist facing Athens in the Peloponnesian wars of the middle first millennium BC. The town relating to this period lies to the south of the acropolis hill, and is now thought to be buried between several metres of alluvium (Bintliff 1977). The site on the acropolis hill dates to the Hellenistic period (Table 1), although most features seen today are of Roman date. Perhaps the most impressive of these are the Theatre and the Stoa (Fig. 3), which have been the subject of excavation since the end of the last century, although major investigations have only been carried out in the early 1900's (B.S.A. 1906; 1907; 1909; 1910), 1920's (Woodward 1925; 1927) and more recently since 1989 (Waywell and Wilkes in prep.). During these excavation programmes, extensive evidence for Byzantine occupation and activity has also been found, mainly of material relating to the period following the collapse of Rome, and prior to the construction of the fortified citadel of Mistra by the Franks in 1249 A.D. (Runciman 1980).

Sediment source and depositional processes affecting the Spartan acropolis

The Evrotas valley was extensively studied by Bintliff in the 1970's (Bintliff 1977), and although many of the conclusions which he made (see above) are now thought to be incorrect (cf. Wagstaff 1981), the original data a re still useful. Although primarily concerned with prehistoric erosion, Bintliff (1977) noted that most of the 'Younger Fill' alluvium deposited around the Neogene hillocks is of Roman and Byzantine date. This is based on the fact that these sediments contained pottery of these periods, and that in one place they covered part of the Sanctuary of Artemis Orthia, a Hellenistic structure (B.S.A. 1905). For this depositional process to occur the River Evrotas would need to have been subject to flooding, and been continuously altering course. Deposition of alluvium is thought to have ceased prior to the Turkish period, possibly caused by irrigation reducing water levels in the Evrotas to an extent where it was no longer able to flood. Indeed irrigation has today led to a situation where the flow of water is only seasonal.

Holocene alluvial material has not been found within 500 m of the acropolis hill, but the fertile agricultural land which it produced would have been a major source of food resources to the inhabitants of the Roman and Byzantine towns. Indeed in recent work on material found in Byzantine rubbish pits on the acropolis, it has been concluded that most of the crop species are likely to have grown in such an environment (Hather *et al.* in press; Peña Chocarro 1990).

Sedimentary deposits found on the acropolis hill are largely derived from the Neogene gravels from which the hill is formed. These Neogene deposits are conglomerates composed of rounded river pebbles bonded by a calcareous concretion. As the concretion is relatively susceptible to physical and chemical erosion, breakdown occurs readily, and therefore many of the sediments found on the hill include small rounded pebbles (which should therefore not be used as evidence of deposition by fluvial means!). The organic components of the sediments are largely derived from contemporary soils that have eroded from the hill crest, on the south side of which both the Theatre and the Stoa have been cut (Fig. 3). As this slope is steep (in excess of 20% in some places) the majority of material contained within these features is presumably of colluvial origin due to slope destabilisation, caused by human activity on the crest and major storm events.

A further source of sediment has been in the decay of mud brick buildings, built at some point in the Byzantine period. This has led to the deposition of approximately 2 m of material in the western end of the Stoa. Within the colluvial deposits Byzantine occupational horizons have been found, defined by ash lenses and artefact scatters. As these appear to have suffered little truncation it can be assumed that sedimentation was rapid, implying intensive human activity throughout the Byzantine period. However, it is uncertain whether agriculture was taking place, although it is likely after the abandonment of the site in the thirteenth century. If so it is probable that a pastoral economy was being practised as the large stone constructions on the hill top would have made ploughing almost impossible. Recently it has been noticed that over grazing by herds of domestic herbivores can cause large scale erosion through the destruction of plants that stabilise the slopes (Evans 1992).

As previously stated, sections exposed in the Stoa have demonstrated that there are between 3 and 5 m of sediment resting on the Stoa floor. The ceramic evidence indicates that although some accumulation occurred in the Late Roman period, the majority occurred in the Byzantine phase. The sedimentary sequences exposed in the Stoa sections are extremely complicated, which when combined with the height of the stratigraphy makes interpretation very difficult in terms of cause, source and relative date of sedimentation.

Material found in the Theatre mostly relates to the Byzantine period (the Theatre itself dates to the Roman, and perhaps even the Hellenistic period), although it has not been exposed in section as excavation has largely been carried out within the remains of standing buildings. Several phases of occupation have been recognised, but as in the Stoa the stratigraphic sequence is complicated and difficult to date owing to problems of ceramic residually. Moreover excavations in the Theatre have demonstrated that great spatial variation exists in deposition, in addition to the stratigraphic variability.

At present the acropolis is almost entirely owned by the state, and the only erosion is caused by the many tourists who visit the site and by exceptionally violent storms (see below). The cultivation of olive trees has also helped to stabilise the slopes, so very little material has been deposited in the Stoa or Theatre in this century.

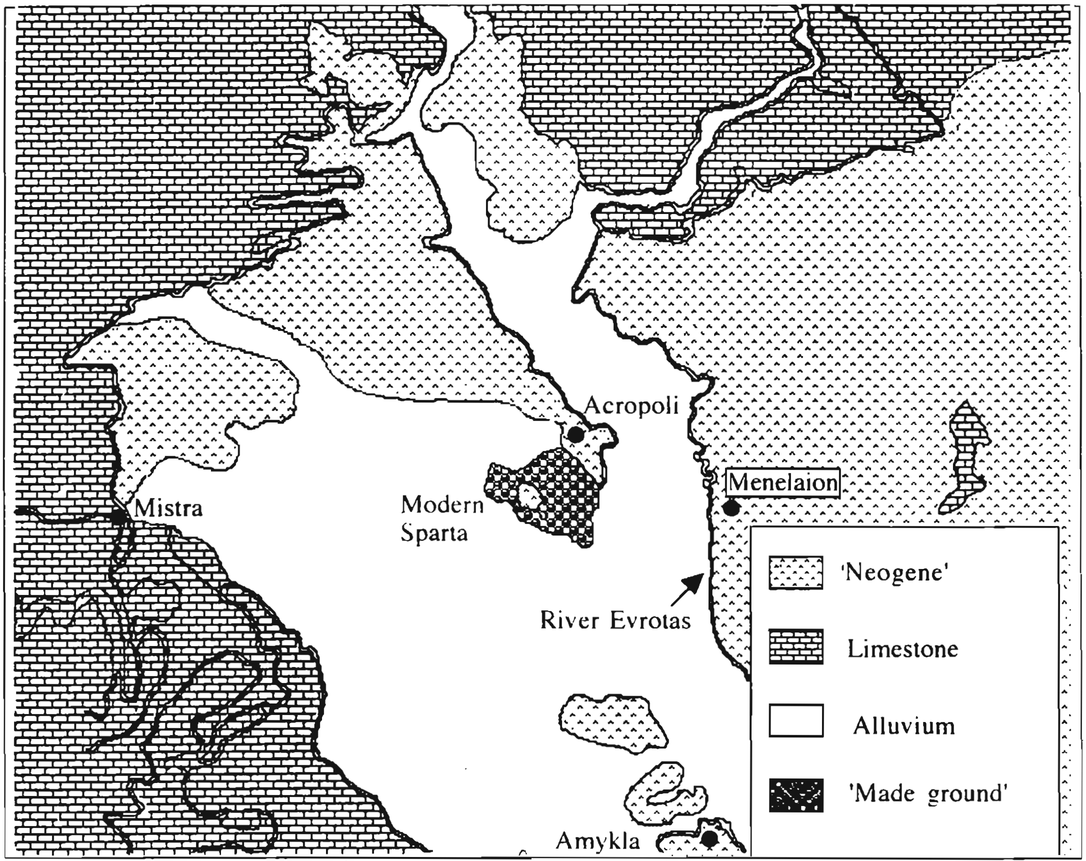

Fig. 2 The geology of the Sparta region. The lines within the limestone division represent different limestone strata

Objectives and methods of sediment analysis at Sparta

The main objective of sediment analysis at Sparta is to determine the cause of deposition and source of particular sedimentary contexts. In addition, as a total of nine trenches have so far been excavated, a secondary aim is to identify sedimentary units that appear in several trenches, and that can subsequently be used as marker horizons. The overall objective of the work is to produce a model of erosional and depositional regimes at various time in the past, and to see how this correlates with occupation of the site.

The extremely complicated spatial and stratigraphic sequences of occupational and erosional sediments found at the Spartan acropolis have much in common with sequences of urban deposits found in western Europe. Although preservation is obviously affected by different determinants, taphonomic processes operate at different rates and in different ways, and erosion takes place by different mechanisms, the fact remains that the principle of accumulation as a result of many phases of occupation and abandonment remains the same. If this observation is correct it is possible that techniques of sediment sampling and analysis developed on western European urban sites since the 1970's could also be applicable to deposits at Sparta.

The simplest approach to solving problems of cause and mode of sedimentation is by detailed description of each sedimentary unit using standard descriptive techniques and colour determinations. In this way units appearing in more than one trench can readily be recognised, and those with obvious modes of formation (e.g. wall collapse) can be characterised. Where more detailed analysis is required samples need to be taken for various forms of analysis.

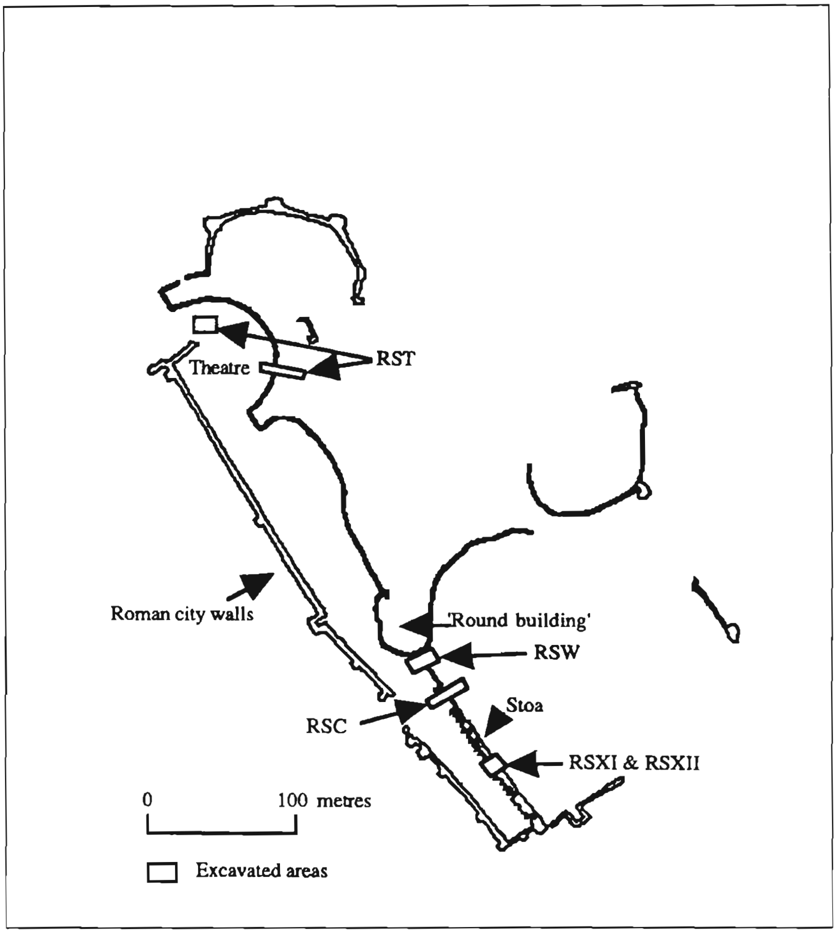

Fig. 3 Plan of Sparta's Acropolis made prior to the discovery that the Stoa continues westwards to the Round Building

The main method of sampling used at Sparta for sedimentological purposes is with 'column samples'. This consists of taking consecutive samples, each of approximately 1 kg, from a section at predetermined intervals, although they are never taken across stratigraphic boundaries. Each sample is separately bagged and given a unique number that is recorded in a computer database along with information about the context, site co-ordinates and site datum. Samples of this type can then be used for particle size analysis, phosphate tests and magnetic susceptibility measurement.

The other major sampling technique used is by 'monolith'. This requires a tin of stainless steel measuring 50 x 5 x 5 cm to be pushed into a section and cut out when full to preserve the exact stratigraphy. This technique has been used when an area of a section contains a particularly complicated stratigraphy. On arrival at the laboratory these monoliths can be drawn and described under controlled conditions, and sampled at very fine intervals for further analysis (e.g. particle size and phosphate tests). If a plastic insert (made from a half section of drainpipe) is placed within the tin prior to sampling, this can later be used to extract the sediment from the tin (whilst still retaining the stratigraphy), allowing X-radiography and magnetic susceptibility measurement to be carried out - techniques that would otherwise be hampered by the metallic tin.

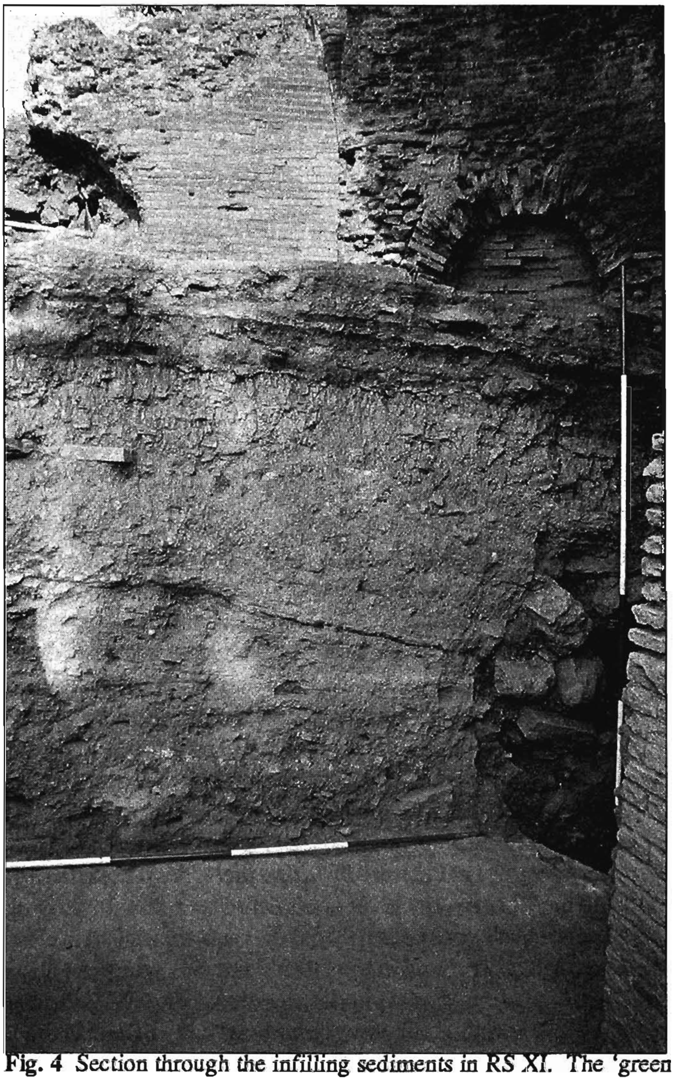

Fig. 4 Section through the infilling sediments in RS XI. The 'green layer' is defined by ash lenses towards the bottom of the profile

In practice taking monolith samples in such a dry climate as that found in Sparta can cause problems, particularly when pushing the tin into the section. This can be overcome by thoroughly soaking the section with water and covering it with a plastic bag to allow it to 'sweat' for half an hour prior to taking the sample. Use of this technique has the advantage of softening the sediment whilst still retaining its structure. Additional samples for magnetic susceptibility measurement are taken by pressing 10 cc pots into the section at predetermined intervals (normally 5 cm) throughout a sedimentary profile.

Particle size analysis used a combination of dry sieving (for material greater than 63 microns) and pipette (for material less than this) techniques (Avery and Bascombe 1974). Using the percentage data thus obtained, conclusions can be drawn as to source and likely mode of sediment arrival.

Magnetic susceptibility measurement has traditionally been regarded as a technique of investigating sediment source in lake sequences (e.g. Dearing *et al.* 1981). However, it has also been applied to archaeological deposits, mainly as a prospecting technique, but more recently also in the investigation of sedimentary sequences (Thompson and Oldfield 1986; Allen 1988). In the case of the latter it can be a useful indicator of phases of pedogenesis or burning, but is also useful in determining whether stratigraphic units are a result of man's activities (particularly is used in conjunction with phosphate analysis). Measurement is by use of a Bartington MS 2 meter with various probes depending on sample type. Column samples were sieved to 250 microns and material finer than this was placed in 10 cc pots and susceptibility measures using an MS probe. Monolith samples were scanned at 2 cm intervals using a MS loop, whilst 10 cc pot samples taken directly from the section were also measured using a MS probe.

Phosphate analysis is another useful indicator of human activity. Samples for this analysis were sieved to 2 mm and sub sampled so that 50 mg of material was used in the analysis. This was carried out using the Grundlach method (Eidt 1972) which is qualitative rather than quantitative, but is quick and yet still gives useful results (Bakkevig 1981).

In order to demonstrate how the use of these techniques have influenced the interpretation of sediment deposition and subsequent alteration, a case study will be used illustrating preliminary results from just one sedimentary unit.

The 'Green layer'

This deposit has been found in all areas that have been excavated since 1989, although it varies in thickness from over 1 m in the Theatre, to about 30 cm in the central chambers of the Stoa. To some extent it similarly varies in the north-south plain (in the Theatre area), being thicker in the north and thinning off southwards. Unsurprisingly it is a uniform bright green colour (Munsell value 2.5Y 5/4 Light olive brown) mottled by black patches that are the result of charcoal inclusions. Its stratigraphic position is similar in all locations, in that it appears near the very base of the sequences, almost directly resting on the floors of the former buildings. Therefore it is likely that it was deposited soon after the abandonment of these structures. The morphological appearance of the layer also varies only slightly between the various trenches, and the artefactual components within it seem to consist solely of charcoal and rounded sherds of late Roman pottery. This latter evidence would appear to indicate re-deposition (i.e. the sherds appear to have been eroded), and therefore it may date to after the late Roman period. In both the Stoa and the Theatre, the layer is bordered by a thin horizon of ash above it, whilst above this are colluvial (Theatre) and occupation (Stoa) deposits relating to the Byzantine period. This same deposit was also found by excavations in the 1920's and was interpreted as being deposited in a large marshy pond, as a result of a breakdown in the aquaduct system (Woodward 1925).

Several questions have been asked of this layer, which can only be answered by the application of certain of the sedimentological techniques discussed above. These are:

1. Do the deposits found in the various trenches relate to the same depositional episode?
2. How did the deposit form and what caused it?
3. How do the properties of the sediment vary spatially?
4. When did the deposit form?

In order to answer these and to provide further information on the properties of the deposit, a series of samples were taken from sections in the Theatre and the central section of the Stoa. Monolith, magnetic and column samples were all taken from these areas, but only the first two are dealt with in detail here.

The Stoa

Figure 4 shows the section sampled in the central area of the Stoa, marking on the actual position of the monolith samples. Figure 5 shows the sedimentary profile in one monolith and the results of a magnetic susceptibility analysis carried out on it. This demonstrates that in this particular area, the 'green layer' is bordered by burnt layers both above and below, and consists of four discrete horizons. However, magnetic susceptibility measurements show that these horizons are very similar in their magnetic properties, averaging only 20 SI units (x 10^{-6}). These values are distinctively low, especially when compared to those of the occupation layers above and below which have produced readings in excess of 150 SI units (x 10^{-6}). Therefore it is unlikely that the 'green layer' accumulated as a result of human habitation as concentrated human activity is thought to lead to high magnetic susceptibility readings (Thompson and Oldfield 1986). Neither is it likely that it was the result of deposition of material in a shallow 'pond' type environment as stated originally by Woodward (1925) (see above), as upon drying after prolonged submersion in water, iron mineral particles are thought to oxidise to a more highly ferrimagnetic state, and therefore lead to high magnetic susceptibility readings. Thus, it is likely that the 'green layer' formed under conditions where human activity was not *directly* the cause, and where there was no standing water.

Particle size analysis was carried out on 2 cm thick sub-samples of two monoliths including the 'green layer'. Results from these tests were used to calculate mean particle size, sorting and skewness (of the size distribution) (Fig. 6) (Folk 1959). These calculations demonstrate that material from the occupation deposits above the 'green layer', the 'green layer' itself and the deposits below it, had similar particle size distributions. There are differences, particularly in terms of mean particle size and skewness, but these do not seem to relate specifically to changes in morphological appearance. The fact that these similarities exist suggests that ultimately all the sedimentary units examined have a similar source, even if differential post-depositional processes have caused subsequent visual differences. All samples analysed were shown to be very poorly and extra poorly sorted, which again suggests that deposition did not occur under a body of standing water, as if this had occurred material would be sorted through the differential rate of sediment settling on the bed which is dependant upon particle size. The poor sorting is particularly indicative of colluvial deposition (Butzer 1982), and therefore its likely source is from material once lying on the top of the acropolis hill. Colluvial processes have been shown to operate in many ways (Allen 1991; Boardman 1992), and from the particle size data (as shown by the near symmetrical to coarsely skewed skewness ranges), predominantly coarse sediment was being deposited. This suggests that high energy erosion of the acropolis hill top occurred, leading to the swift deposition of colluvium (i.e. there is no banding within the deposit to suggest the occurrence of stand still phases).

The Theatre

The 'green layer' as present in the Theatre is very similar to that found in the Stoa, but as yet analysis of the material has not been carried out in detail. The main difference from the Stoa material is in thickness and in the quantity of charcoal recovered. Analysis of bulk samples by flotation showed the large amount of charcoal from the Theatre to be of twiggy material, in a relatively fresh condition. However, as there was again no banding, and no distinct 'charcoal rich' layers it is likely that the latter has been re-deposited. If this is the case it suggests that burning occurred just prior to erosion, and that rapid burial has lead to preservation. Stratigraphically there is also a slight difference in the position of the layer, as, unlike the Stoa, where further occupational deposits were found below the 'green layer', in the Theatre it rested directly on the seating blocks.

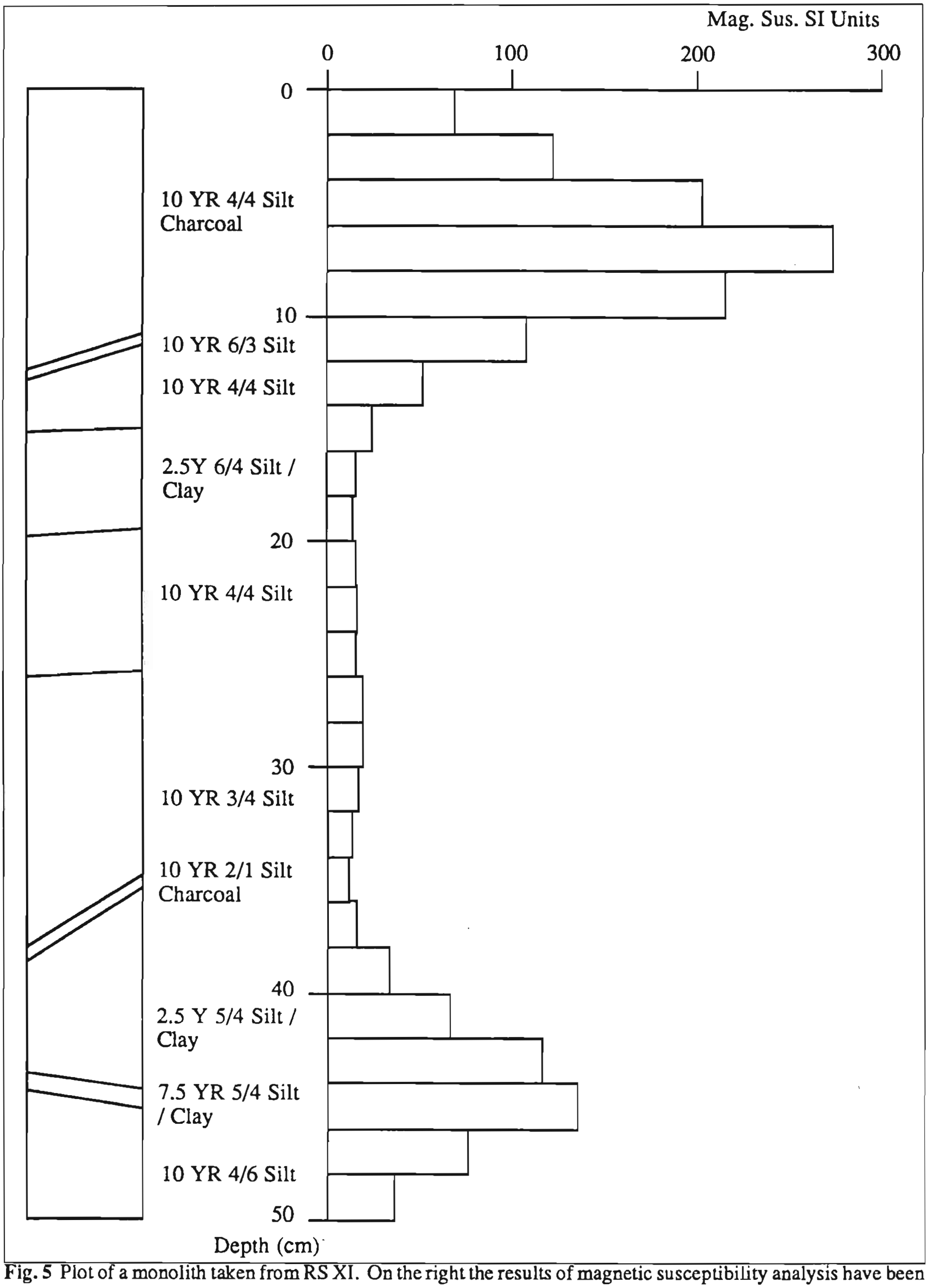

Fig. 5 Plot of a monolith taken from RS XI. On the right the results of magnetic susceptibility analysis have been placed

How did the 'green layer' form?

From the evidence presented above it is now possible to comment on the four questions originally posed:

1. It is not certain if material from the 'green layer' found in both trenches, relates to the same episode, but sedimentological properties are very similar, and nowhere else in any profile on the site does another similar deposit occur.

2. The deposit probably formed rapidly as colluvium, through a single (or series) of high energy erosional event(s). This 'event' could possibly even be associated with the breakdown of the aqueduct system as suggested by Woodward (1925), although it is very likely that this led to the formation of a large permanent body of water. However, the sudden release of large volumes of water would lead to the formation of rills and gullies in the hillside, from which even the largest particles would be moved (Boardman 1992). This could even explain the differences in the layers thickness between the Theatre and the Stoa, as the former was nearer to the position where the aqueduct met the acropolis hill and would therefore experience the greatest erosive force. It is equally likely that deposition was the result of several severe storms on agricultural soil on the top of the acropolis hill.

3. The properties of the sediment appear to vary very little spatially, except for the quantity of charcoal present.

4. The deposit seems to have formed in the Late Roman or Byzantine periods, as the occupation horizon below the 'green layer' in the Stoa dates to this period.

5. The colour of the 'green layer' is still a source of mystery. Indeed it was the greenish hue that first gave Woodward (1925) the idea that it was deposited under fluvial conditions (presumably through the reduction of iron minerals). However, as has been demonstrated, it is most unlikely that this process was the cause of deposition, and therefore the 'green' colour must have originated through some other mechanism. A possibility is through the oxidation of copper ions, as many of the Theatre fittings, the entire roof of a nearby building and more significantly some of the sheeting associated with the aqueduct, were of this material. In order to investigate this, analysis is currently taking place on sub-samples from the monoliths using an SEM LINK system and a microprobe, to calculate the proportionsof copper (as well as lead and zinc) ions in the 'green layer' as compared to other colluvial deposits from the site.

Conclusions

The task of this paper has not been to detail the results of investigation of a single deposit from one site, but to show the type of results that can be achieved using simple sedimentological techniques. Inevitably all questions cannot be answered using these, and indeed the analysis can even lead to the posing of more queries which would otherwise not arise! However, these are likely to be increasingly concerned with small details, rather than major issues, such as where the deposit originated and how it formed. The analysis of material from Sparta has demonstrated that interpretations based primarily on visual examination are often unreliable. For example the 'green layer's' re-interpretation is significant as it demonstrates that material contained within it is likely to have been re-worked or re-deposited (i.e. of a secondary nature) which has implications for both dating and contemporary site usage. Therefore it would be advantageous to apply similar techniques to other sedimentary layers that have previously only been interpreted from their visual morphology, and re-interpret them accordingly.

The sourcing and determination of likely mode of formation of sedimentological units on archaeological sites should be a concern of every field archaeologist, as it directly affects views on why certain classes of artefact are preserved in particular localities whilst others are not. Furthermore, re-deposition is a feature of many sites, and it is particularly important to know if, and to what extent this has occurred, as this can greatly affect site chronology (as for the 'green layer'). The study of formation

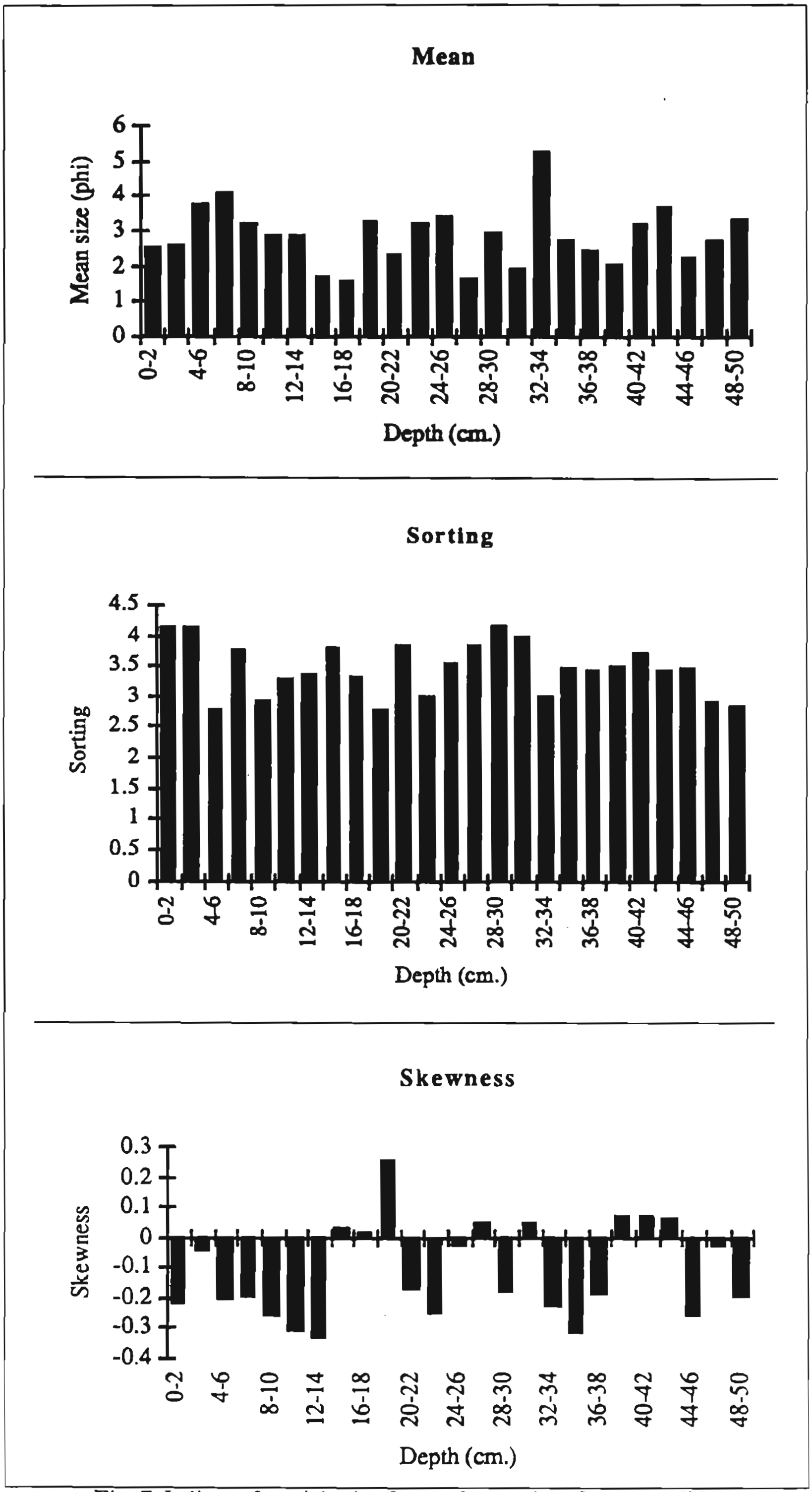

Fig. 7 Indices of particle size from sub-samples of the monolith

processes, particularly through the analysis of sedimentary structures, can to some extent alleviate the problems by helping to understand how the processes operate. It is important to frame questions about each deposit that is to be investigated in terms of: reason for formation, source, mechanism of formation, likely date and how inclusions (both cultural and biological) become incorporated, as then specific techniques can be formulated to answer these questions. Similarly the analysis of a site as part of a larger environment is desirable (as undertaken at Sparta - Waywell and Wilkes in prep.) in order to understand what resources would be available, and what processes are likely to have operated. For instance in the Evrotas valley the amount of fertile alluvial land found locally (to Sparta) would have been smaller than at present in Roman and Early Byzantine times as during this period the area occupied by alluvium is likely to have been smaller (Bintliff 1977). This argument has just as much relevance to the historic period as the prehistoric, as Classical and Roman authors in particular do not report in detail about the landscape that they travelled through. For example Pausanias (Levi 1971), in his travels through Laconia records details of the impressive buildings he visited and their relative locations, but does not mention the type of crops or the farming techniques being used.

The type of sedimentological and formational analysis detailed above has been slow to reach archaeological sites in Greece, in particular those of the historic period, and yet as illustrated in this paper, their use would greatly benefit the understanding of the post-constructional history of these sites.

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