Trace Metal Accumulations in Soils on and around Ancient Settlements in Greece

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Abstract

This paper describes recent studies of trace metal and magnetic enhancements in soils on and around ancient settlements in Boeotia, central Greece. The investigations were conducted as part of the Cambridge and Bradford Boeotian Archaeological and Geographical Expedition and the scientific data were collected with reference to archaeological sites originally identified as artefact scatters. Transects of soil samples were taken across the whole area under study to provide context for the site-related data. Elemental analysis of samples was conducted through AAS. The results indicate enhancement of lead, zinc and copper, but not nickel, in soils around known ancient sites. Detailed analysis of trace metal concentrations and magnetic enhancements, in relation to artefact distributions and geophysical data, provides indications of site function and morphology in several instances. The trace metals data also supports artefact collection data off-site, in areas where intense infield activity is proposed.

Introduction

Modern evidence suggests that wherever people live or work metal concentrations in nearby soils rise, the metals are bound in chemical forms which are often not susceptible to diminution by leaching, and the resultant accumulations can still be detected several centuries later. This suggests the possibility that much more ancient settlement could also be associated with unusual and localised accumulations of certain metals in soil. Other soil properties, notably soluble phosphorus content and magnetic susceptibility, are commonly studied as an aid in archaeological research, together with other changes in soil properties revealed by cropmarks visible in air photographs. The success of these methods suggests that changes which are imposed on the soil mantle can be identified many hundreds of years, even millennia later.

The objective of a recent investigation was to determine whether certain pre-Industrial archaeological sites in Greece were characterised by unusual accumulations of trace metals in soil. Several metals were selected. Copper and lead compounds have been used since later prehistory as has zinc when alloyed with copper (brass), even though metallic zinc was not known in Europe until the 15th century. Nickel is a modern metal and there is no reason to suppose it should have accumulated in ancient sites other than around copper ore workings. Manganese was used in the ancient world to bleach glass but the metal was not isolated until the 19th century; its soil chemistry suggests it is not a good candidate for an archaeological marker but it is a useful indicator of pedological conditions. However all of these elements may concentrate in animal and human faeces.

The samples were collected during the 1986 and 1987 field seasons of the Bradford and Cambridge Boeotian Expedition. Since 1979 the Boeotia Survey has systematically fieldwalked over 40 sq.km. of countryside in the central Greek province of Boeotia (Bintliff and Snodgrass 1988a). Ancient habitation sites have been identified from concentrations of surface artefacts (essentially pottery and tile) and by mapping 'offsite' background densities of ancient artefacts between these sites in order to trace past human activity such as field manuring and work stations in the cultivated landscape (see the sector mapped in Figure 1 with offsite density variations). It should be pointed out that our geomorphological researches suggest that the vast majority of this landscape has not been buried by eroded material since the time of the sites being considered in this paper, ie Hellenistic times; however it has generally suffered topsoil erosion into localised lowlying depressions. In other words we consider this to be a truncated relict landscape.

Regional Trace Metal Survey

In order to provide regional baseline data for trace metal analysis and to seek evidence for any long-distance trends, surface soil samples were collected along several long transects (Figure 2). Two east-west lines of transect were established, 500m apart but in parallel, and both ran for 4km west from the edge of the ancient city of Thespiae. At right-angles two further transects, running north-south, were set up, running for 2 and 5km respectively. Samples were taken at 200m intervals.

On Site Trace Metal Survey

A series of surface sites was chosen for each of which a grid of soil samples was taken for trace metal analysis.

They included the ancient city of Thespiae, the medieval village at VM4, and Greco-Roman rural villa sites at TPW2, PP17, PP27, VM64, VM89 and VM95. In most cases complementary information was available from geophysics (for structural evidence), magnetic susceptibility (reflecting habitation refuse and pronounced soil disturbance) and surface artefact patterning (indicating living, working and rubbish disposal areas).

Field and Laboratory Methods

Samples were collected using either a mild screw auger or a stainless steel garden trowel. After drying and chemical treatment metal contents were determined using conventional flame atomic absorption spectrophotometry.

Summary Results

Inspection of the results (Figure 3) indicates a general tendency for the lead, zinc and copper values from the specific archaeological sites to be greater than those from the regional transects, whereas the manganese values are smaller except at PP17. Nickel values vary widely above and below the regional mean.

There was no evidence for consistent accumulations of nickel at the archaeological sites and this is consistent with the initial hypothesis that pollution by this metal is essentially a modern phenomenon. As for manganese, the regional mean of 761 mg/kg is consistent with soil averages in the literature of c.1000. Except for PP17, site values are significantly below the regional mean. Whether the anomaly at farm PP17 could be the result of stockpiling manure remains to be investigated. The zinc values are variable, with the means at Thespiae and VM4 significantly higher than the regional mean, whereas at farm sites there can be both abnormally high as well as normal background values. This suggests that zinc may accumulate at village or urban sites where metal working and other industrial activities undoubtedly took place, but also and for unexplained reasons at many rural sites.

Copper and lead were identified at the start of the investigation as two of the elements most likely to be markers of vanished human occupance of the land. Davies and others (cf. Davies 1978) have demonstrated the ubiquity of soil contamination by copper and lead throughout the British Isles in garden soils of both city and country. For pre-Industrial times, an obvious source for this 'habitation effect' are metallic compounds used since later prehistory for coins, ornaments, glazes and pigments. However equally and possibly more relevant in rural archaeological contexts is the evidence from Classical written sources and pottery dispersal on and off site (cf.Bintliff and Snodgrass 1988b), that long-occupied agricultural landscapes and ancient farm and village sites may have zones of accumulation of human and animal waste products, especially in the form of manure, which may contain abnormal concentrations of these and other trace elements. Hence the hypothesis that soils associated with ancient habitation would contain residual accumulations of these metals. Only at site PP27 (where in any case we had low sample numbers), was there no evidence of an excess of copper over the regional background; lead was always elevated at the sites sampled.

Perhaps the most dramatic illustration of these effects can be seen at the ancient city of

Thespiae, where the sampling transect ran from the countryside across the ancient wall into the former town enclosure (Figure 4). Here metal values soar inside the walled area.

Detailed Analysis of Rural Farm/Villa Sites

However the potential of the approach and its problems are best seen in smaller rural sites, typical for field survey, and where the activities involved anciently are much less understood compared with urban or large village sites.

PP17

This site was located through surface finds of roof tiles and potsherds and identified as a small farmstead of Late Hellenistic to Early Roman times. Possible outlines of the collapsed farmhouse came from resistivity survey (Figure 5), together with additional features provisionally interpreted as farm enclosures and perhaps pits beyond. Contouring of the surface pottery (Figure 6) showed the highest concentration left of the farmhouse, within and beyond the suspected yard; the rooftile however was predictably focussed on the dwelling structure. Interpretation here as elsewhere suggests that domestic rubbish disposal is associated with but not peaking within the living structure.

The trace metal sample grid covered a much larger area beyond these archaeological and geophysical features defined as 'site' (Figure 7). The lead plot (Figure 8) and the copper (Figure 9) show values, even so, all well above the regional norm; all values shown are in excess of background (eg minimum lead is 22mg/kg compared to the regional norm of 6.6, copper minimum is 8.4 compared to 5.7). Clearly the trace metals are picking up a wider area of past human activity than the habitation zone proper. Indeed a further set of samples taken in 1987 found that high values continue for both metals tens of metres beyond these diagrams away from the 'site'. Now if we look at PP17 in terms of offsite pottery densities (Figure 10) we can see at once that there is indeed what we call a strong site halo of high discard extending at least 100m in all directions from the site focus. We interpret the combined evidence as showing intensive infield activity based at the farm, probably combining concentrated manuring, rubbish disposal and localisation of farm animals.

Further insights can be obtained if we look at a close-up of the site proper. The copper plot (Figure 11) shows a discrete high over the query two-roomed farmhouse, with a second major concentration on the left of the picture; the lead in clear contrast (Figure 12) forms a ring of high values around the farm but the actual structure is a pronounced trough of values. We seem to be picking up differential accumulation of the two metals across the site and in its halo, which should eventually shed light upon behavioural variations on this relatively short-lived site.

Apart from building-up a series of case-studies of farmsites like PP17 to improve our understanding of such phenomena, a further avenue we hope to explore is taking comparable suites of samples from the extraordinarily well-preserved Classical farmsites in nearby Attica (Lohmann 1983, 1985), where the structural evidence is still free-standing together with contemporary field systems and agricultural installations.

VM64

This is another small farm site (Figure 13), this time of Imperial Roman date. The pottery contours identify a neat concentration with a northward tongue, and a fringe area to the south on a higher terrace. The tile counts (Figure 14) identify essentially the same habitation focus, with a slight shift in peak values compared with the pottery peaks, yet also a northward tongue. For unexplained reasons at this site domestic discard broadly coincides with what seems to be the collapsed farmhouse. The geophysical interpretation (using an advanced Schlumberger array) (Figure 15), compared with the tile and pot counts may be picking up one massive end and perhaps another boundary of this farmhouse, but also further unidentified features in the very top left and right sectors. Immediately adjacent to the query house is what could be an untiled yard or shed.

Magnetic viscosity measurements (Figure 16) echo the rooftile closely, and the mysterious northward tongue. Magnetic susceptibility (Figure 17) has an almost identical distribution. So far then, the local separation seen at PP17, of main structure with tile from the main concentrations of refuse and human activity traces in the soil, is contrasted at VM64 where we see a closer association. This contrast continues with the trace metal data.

Lead for example (Figure 18) has a strong concentration over the main structure at this site, although we note immediately that as at PP17 high values appear in the upper sectors where only the geophysics had shown activity. As for copper (Figure 19) as at PP17 one peak sits discrete over the farmhouse, whilst the other peaks are in more peripheral sectors, often where other indicators apart from geophysics are absent. The northward tongue is a trace metal low in both cases.

Just as at PP17 these hints from the trace metals of a wider radius of past human activity can be followed into a wider halo, beyond the ostensible archaeological site with its structures and artefactual concentrations (Figure 20). Four transects were set up running 50 metres in the cardinal directions away from the site focus. Along each, soil samples were taken for magnetic susceptibility and trace metals. The South-North pair (Fig. 21) for magnetic susceptibility is here placed against the tile counts across the site proper; we see a good agreement within the site, yet the highest magnetic values are just offsite to the south. Likewise with the East-West pair of transects (Figure 22), a very nice match of tile counts and magnetic susceptibility occurs on site, but the largest peak is just off site.

The trace metal results are even more striking: for copper (Fig. 23a) we can note that all values are well above the regional mean of 5.7, but the site focus peaks are matched and exceeded by peaks around the site. Likewise for lead (Fig. 23b), and here we do see a closer parallel to PP17 with the site core as a relative trough compared to the immediate offsite zones. Note again that all values are above the regional mean of 6.6. Once again if we take a bird's eye view of the offsite pottery map (Figure 24) we see confirmation that VM64 has a well-developed discard halo, corresponding to heightened activity around the formal site being indicated by magnetic components and the trace metals.

TPW2

This is a much larger villa, typical for the Late Roman period. As may be seen from the regional sherd density map (Figure 25) this 3.4 hectare site lies in an area of extensive halo effects, in which its own substantial halo is merging with the gigantic halo effect of discard from the city of Thespiae nearby to the right of the picture.

Detailed analysis has only been made of a small hillock at the heart of the site. The tile count data for this sector of 60 by 40 metres (Figure 26) bring out two likely roofed structures and a lack of significant roofing to the left of the plot. The magnetic viscosity plot (Figure 27) picks out the same two peaks but introduces a lesser accumulation in the far left. As for magnetic susceptibility (Figure 28) we merely see the overall tendency mirroring the tile, to emphasize the right hand sectors versus the left on the sampled area. The resistivity plot (Figure 29) is only available for the bottom limb of the L shape, but does give strong results: a massive east-west wall, a lesser north-south wall crossing it and what may be the corner of a structure in the upper right. If we overlay geophysics with tile (Figure 30) it does look as if one roofed structure is defined by the lower enclosing walls, and the other roofed structure, seemingly larger, is defined by two walls running at right angles. It is quite likely that the isolated wall stump on the right marks one corner of the upper farm building. The upper left sector seems well defined as a separate enclosure, with just a thin trail of tile above the wall maybe suggesting a shed or similar feature built up against the wall; interestingly the magnetic viscosity plot picks out this query feature as well.

Now for the trace metals. The copper plot (Figure 31) picks out the lower roofed structure with a small peak, and larger ones for the upper roofed structure. But we also have a substantial accumulation in the neglected enclosure to the upper left. The lead plot (Figure 32) is peaking well over the lower structure, but peaks sit peripherally to the upper right structure and there is again accumulation in the upper left enclosure.

Comparing TPW2 with our other rural sites we see once more that copper picks out the roofed structures, whereas lead overlies some structures whilst accumulating around others. Both metals are also accumulating in parts of the site lacking obvious structural evidence or artefact peaks. Within the site core the remnant magnetism associates closely with the roofed structures, but can be expected to appear in additional peaks peripheral to the habitation features identified by archaeology and geophysics.

Conclusions

We clearly have been able to demonstrate our initial hypothesis, that trace metals accumulate at very significant excess levels on and around ancient sites (even if as at PP17 occupation may have lasted a mere 200 years), and furthermore that the patterning persists up to the present day. But is this going to be yet another example of the 'archaeometry paradox', where we produce scientifically satisfying analyses of archaeological data which nonetheless neither surprise the archaeologist, nor lead on to solve any important archaeological problems? No, in this case we would like to indicate some substantial implications of the research results just outlined:

(1) Firstly it has become clear that our concept of the 'site' should envisage on the one hand the traditional focus with buildings and peaks of artefactual refuse, but in addition a surrounding halo or infield of intense human activity, showing up from plateaux of offsite pottery discard and accumulations of magnetism and copper and lead that are often above site focus levels. Both zones have values all well in excess of the regional norm. The research frontier here will be to model ancient behaviour, and try to identify recurring suites of patterning, as well as to investigate accumulation patterns in modern farm contexts.

Site survey is a major archaeological tool. Only a tiny fraction of sites discovered will ever be excavated, so the application of this kind of battery of subsurface and surface approaches is a vital aid to interpretation of field survey data. In fact it is probable that excavation in the halo area would in any case find little or no structural evidence.

(2) Secondly, these results shed unexpected light on a major issue in landscape archaeology, the effect of soil erosion on the rise and fall of past complex societies. For Greece Van Andel (cf.Pope and Van Andel 1984) and other geomorphologists have shown that the cyclical collapse of prehistoric and Greco-Roman settlement can be associated with massive episodes of soil erosion that presumably ruined the agricultural economy. Our own work on relative densities of surface pottery (Bintliff and Snodgrass 1988b) shows a cline of ever greater amounts of surface pottery as one moves from England, through the Mediterranean, to Arabia, which we have interpreted as reflecting amongst other processes a cline of increased soil erosion.

Yet our Boeotian data allow us to set limits to the scale of these erosion processes. The pottery and tile peaks over site foci can of course remain even if the soil fines, their original context, have washed away, but the peak accumulations of remnant magnetic components and copper and lead within site foci and in the immediate halo can only be explained through the survival in situ of at least the original subsoil of the ancient sites. In support of this view Professor Van Andel has estimated that the total depth of soil lost on average in the last 5000 years in the southern Greek landscape is less than 1 metre (Van Andel et al.1986, p.111).

(3) The trace metals programme may well prove vital in shedding new light on past intensity of land use across the countryside. Already we have used the offsite pottery densities to suggest (cf.Bintliff 1988) that although field survey never finds all the ancient farm sites, the low numbers in the north of our survey area genuinely reflect less intensive land use. It should be possible (and we are already experimenting with area grid soil collection strategies in Yugoslavia and Greece to this purpose), to match trace metal accumulations with offsite pottery discard, if we are correct in our belief that much of the excess copper and lead reflect human and animal manure spread over the cultivated landscape.

Quite unintentionally our Boeotian regional trace metal transects, although designed as a control over anthropogenic accumulations at habitation sites, hint at the potential of offsite trace metal analysis for land use history. We must point out that the sample collection design could not have been less suitable for obtaining a picture of local manuring patterns, with tiny soil samples gathered at 200m intervals. Even so, if we note how the east-west transects run from lowish offsite pottery discard into higher levels nearing the city of Thespiae, undoubtedly reflecting urban infield manuring, so on the mean plots for copper and lead (Figures 33 and 34) we see a general trend of rising values towards the city. We can even say something about some of the peaks or hollows on these graphs, covering as they do 4 km of landscape: quite a few of the localised peaks mark sectors where soil samples were taken within site haloes (Figures 35 and 36).

Clearly we need to take many more closely-spaced soil samples for an accurate comparison with field-by-field offsite pottery density values, in order to test the usefulness of trace metal assay for past land use intensity. Trace metals should be much more firmly attached to the soil matrix than phosphates and their analysis could act as a complement and in many soils a replacement for phosphate analysis at the landscape level.

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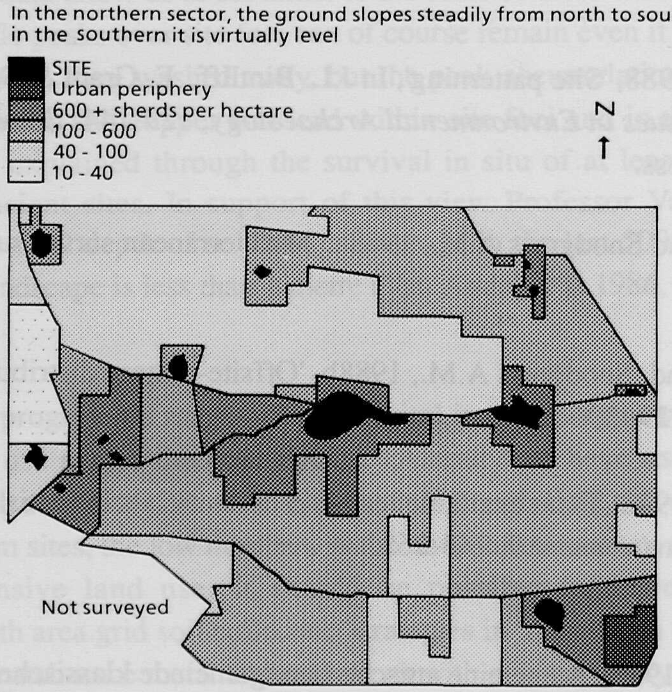


Figure 1 A typical Boeotian density plot.

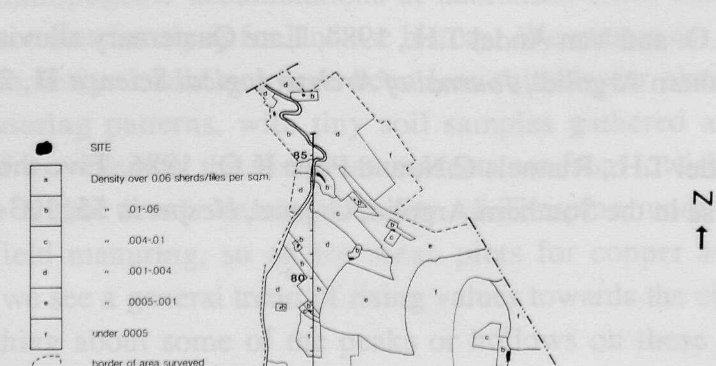


Figure 2 Regional trace metal survey transects.

	METAL				
	Pb	Zn	Cu	Mn	Ni
	SITE MEAN SOIL METAL (mg/kg)				
REGION	6.6	6.6	5.7	761	192
THESPIAI	13*	18***	19***	239***	113
PP17	53***	7.5	13***	1019***	69***
PP27	11*	5.0	6.7	171***	89***
TPW2	23***	49***	23***	478***	446***
VM4	20***	17***	21***	70***	89***
VM64	16***	65***	26***	624*	232
VM89	19***	55***	28***	604***	473***
VM95	15***	55***	21***	532***	254

Values different from the regional mean are shown at the following significant levels: *** 0.1%, ** 1%, * 5%.

Figure 3 *Mean concentrations of metals in soils at individual sites and of the region as a whole.*

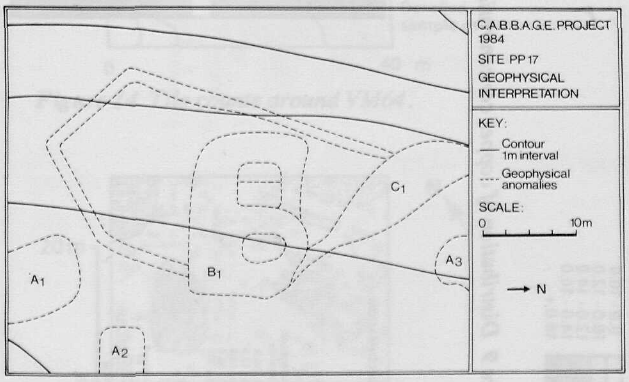


Figure 5 *Interpretation of resistivity survey anomalies at PP17.*

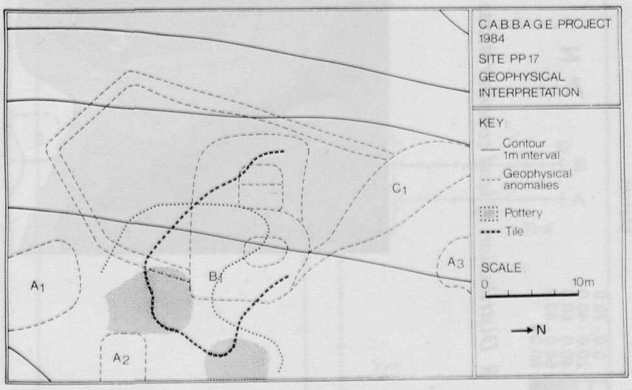


Figure 6 *Location of tile and pottery concentrations at PP17.*

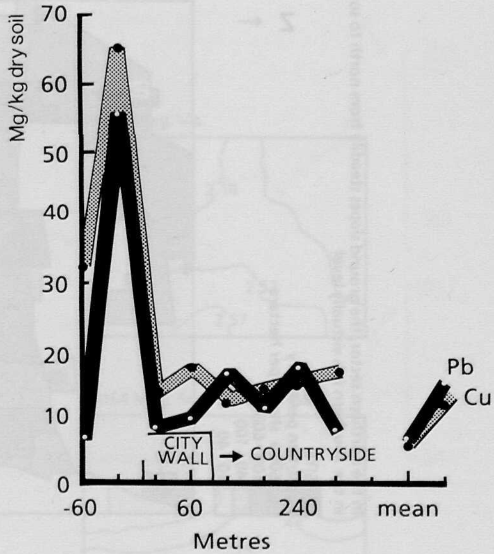


Figure 4 *Copper and lead concentrations in soil samples taken along a transect crossing the ancient city walls at Thespiai.*

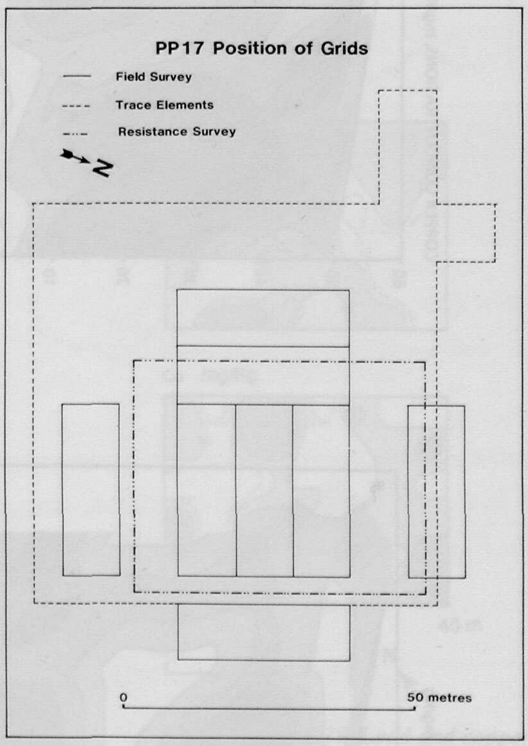


Figure 7 *Location of survey grids at PP17.*

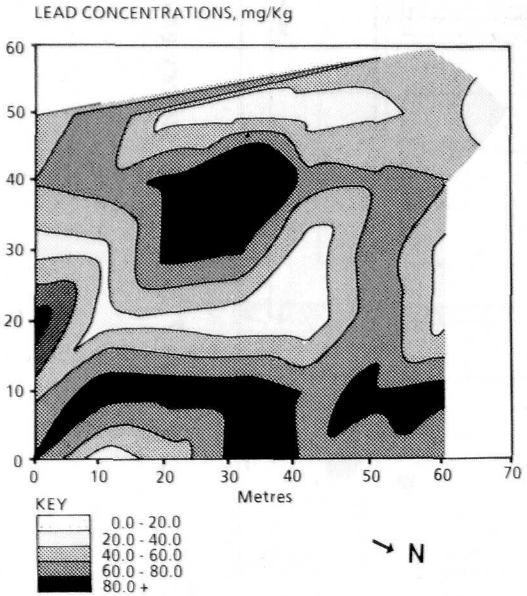


Figure 8 Distribution of lead concentrations around PP17.

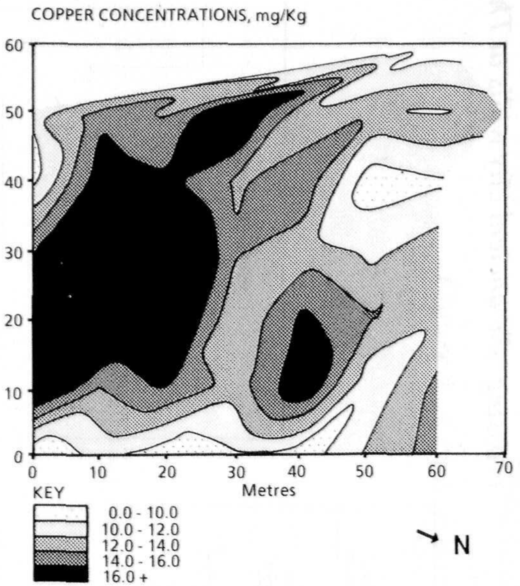


Figure 9 Distribution of copper concentrations around PP17.

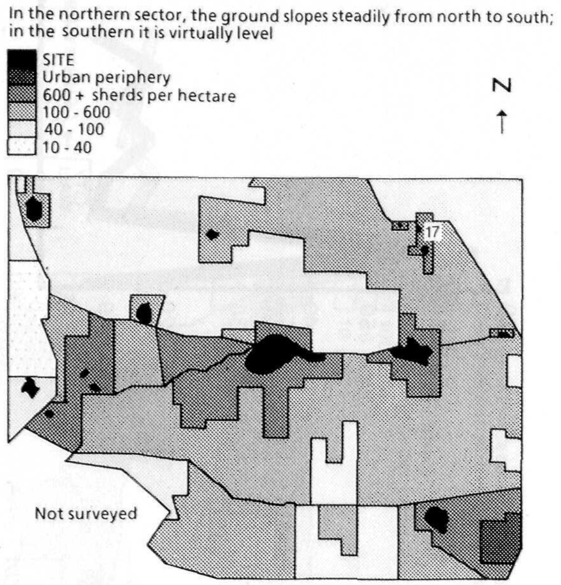


Figure 10 Pottery densities around PP17.

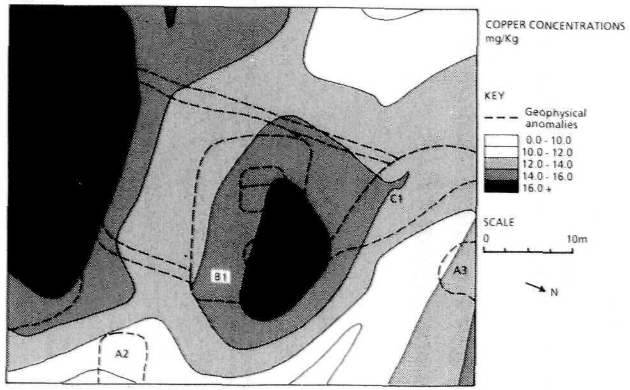


Figure 11 Copper concentrations and geophysical anomalies at PP17.

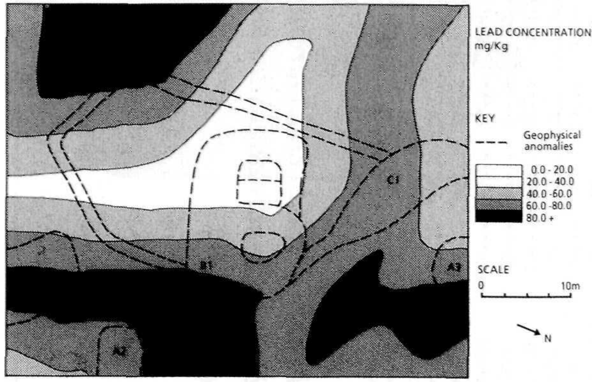


Figure 12 Lead concentrations and geophysical anomalies at PP17.

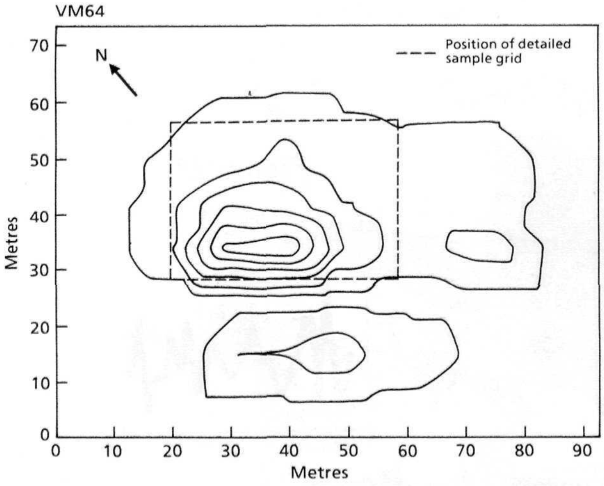


***Figure 13** Pottery concentrations around VM64.*

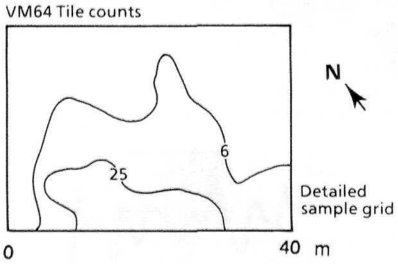


***Figure 14** Tile counts around VM64.*

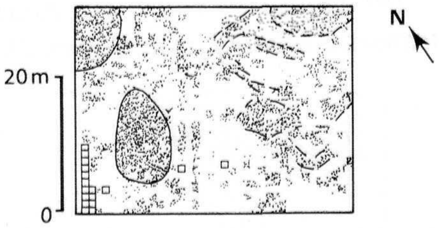


***Figure 15** Interpretation of resistivity survey over the detailed sample grid at VM64.*

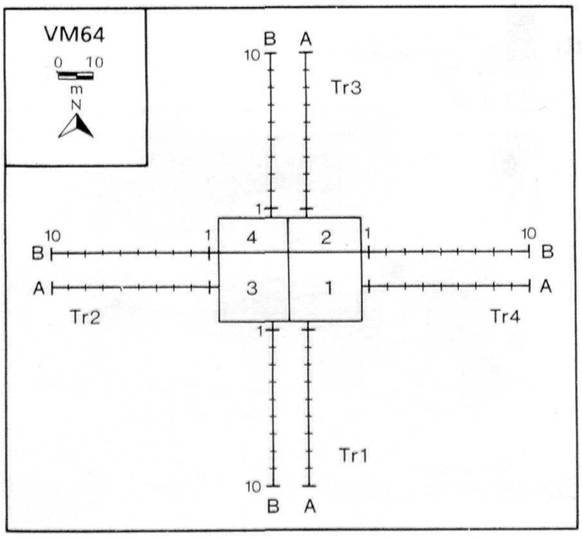
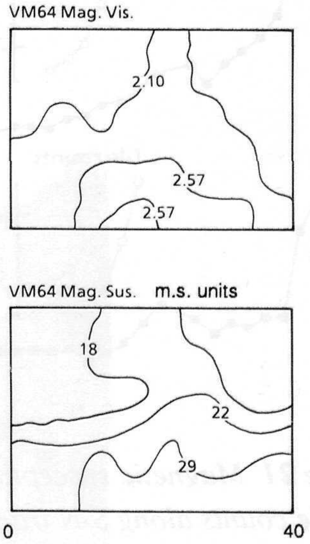
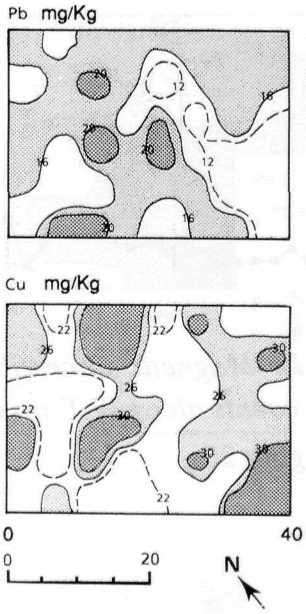


***Figure 20** Location of trace metal sampling transects around VM64.*



***Figures 16 and 17** Magnetic susceptibility and magnetic viscosity measurements over the detailed sample grid at VM64.*



***Figures 18 and 19** Lead and copper concentrations over the detailed sample grid at VM64.*

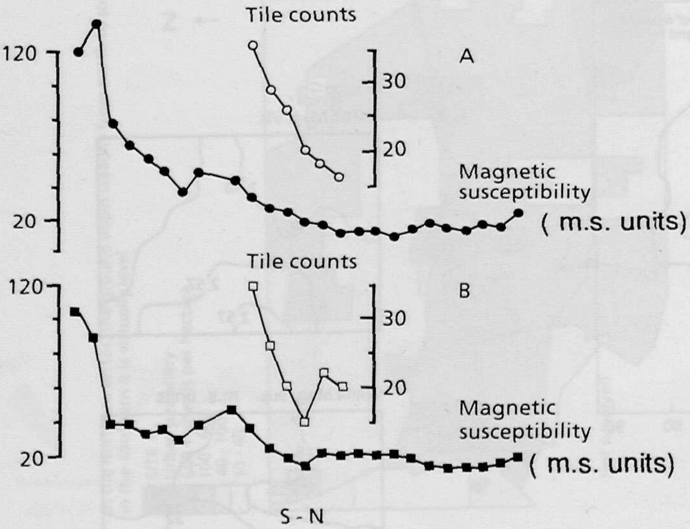


Figure 21 *Magnetic susceptibility measurements and tile counts along S-N transects, located as in Figure 20.*

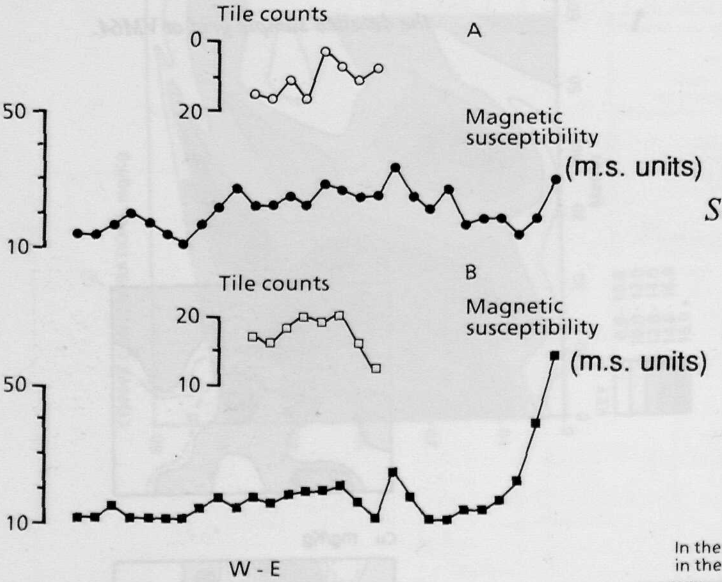
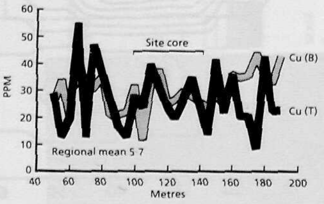
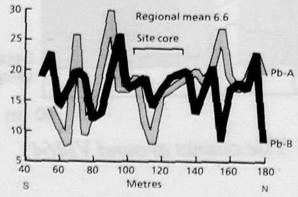


Figure 22 *Magnetic susceptibility measurements and tile counts along W-E transects, located as in Figure 20.*

Figure 23



(a) Copper concentrations along W-E transects located as in Figure 20.



(b) Lead concentrations along S-N transects located as in Figure 20.

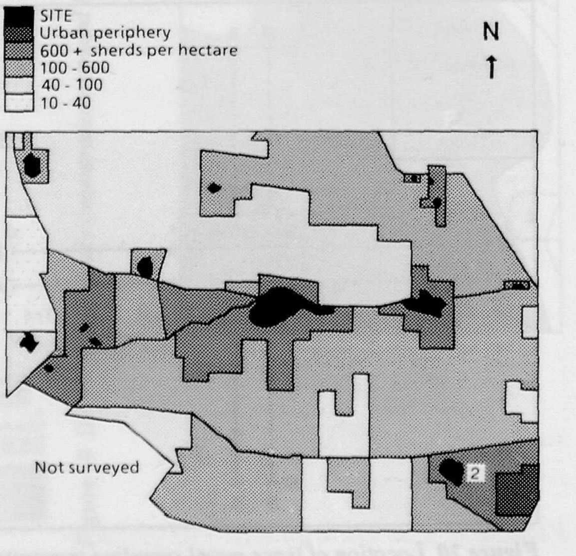

In the northern sector, the ground slopes steadily from north to south; in the southern it is virtually level

Figure 25 *Pottery densities aound TPW2.*

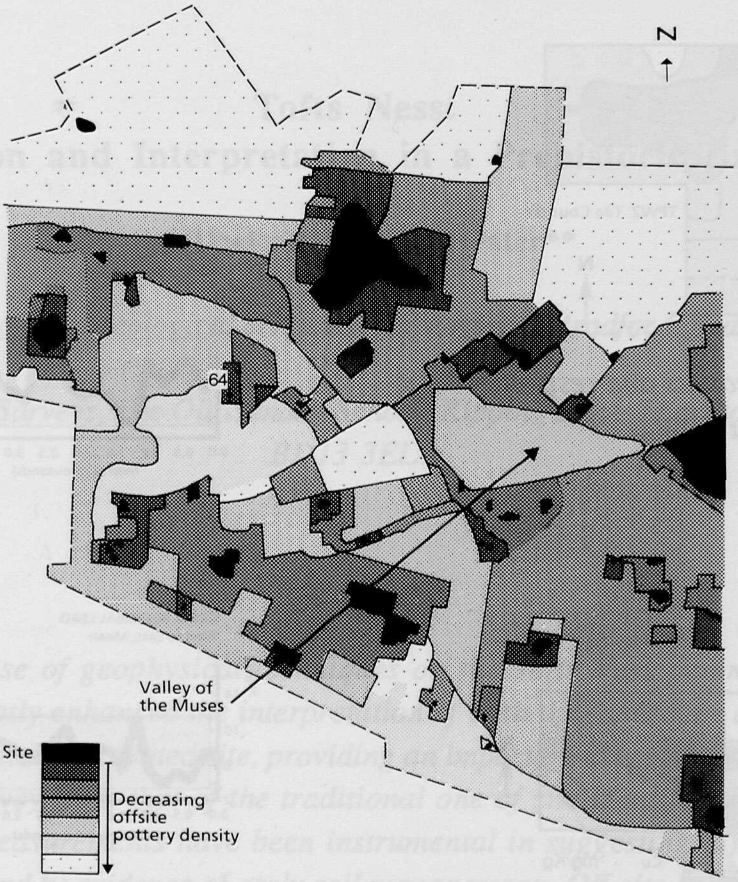
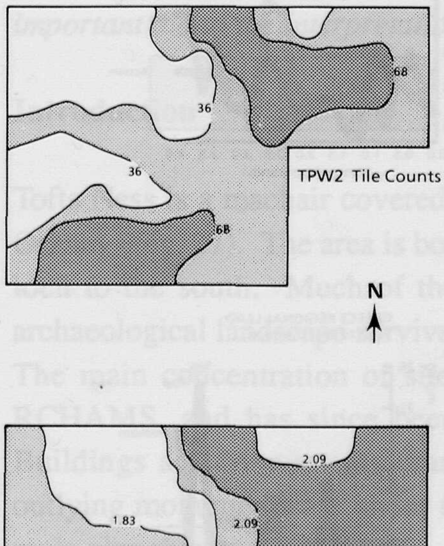
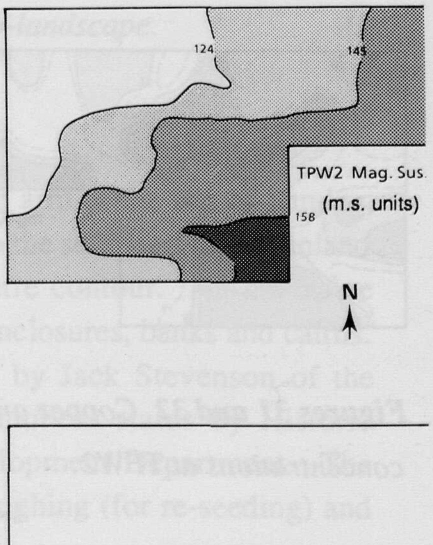


Figure 24 *Pottery densities around VM64.*



Figures 26 and 27 *Tile counts and magnetic viscosity measurements at TPW2.*



Figures 28 and 29 *Magnetic susceptibilit measurements and resistivity surve interpretation at TPW2*

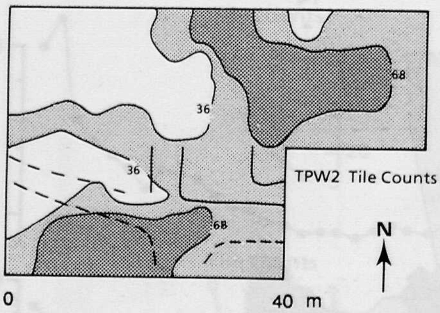
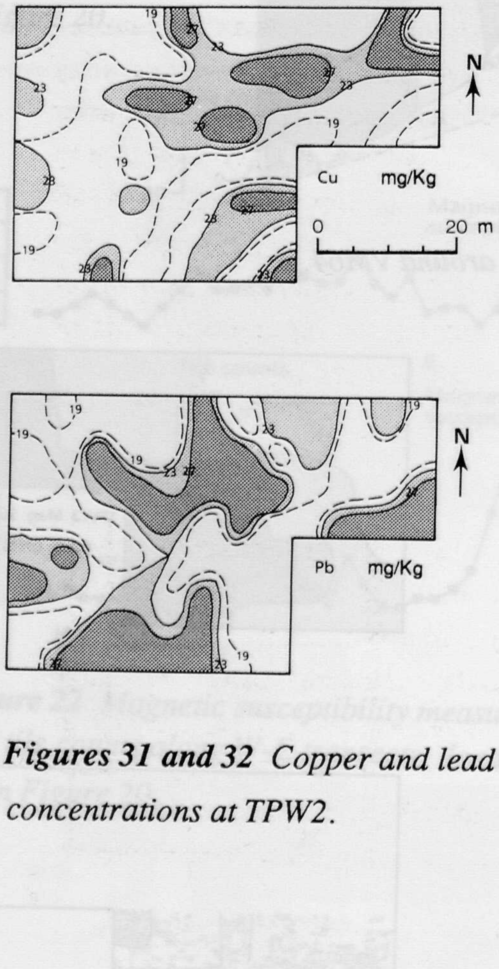
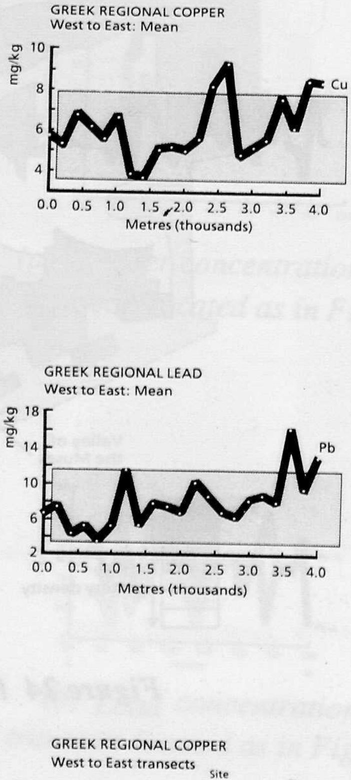


Figure 30 Tile counts and resistivity survey features at TPW2.



***Figures 31 and 32** Copper and lead concentrations at TPW2.*



***Figures 33 to 36** Copper and lead concentrations (measured and mean) along West to East transects located as in Figure 2.*