Reprinted from Trace Substances in Environmental Health-XXII, 1988.
A symposium, D.D. Hemphill, Ed., University of Missouri, Columbia.

Trace Metal Residues in Soil as Markers of Ancient Site Occupance in Greece

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ABSTRACT

Modern evidence shows that wherever people work or live the concentrations of heavy metals rise in nearby soils and these residues persist for many years. This paper reports similar accumulations of Cu and Pb in soils at sites of ancient occupation in Greece. It is proposed that such accumulations can act as markers of such occupation and complement evidence derived from other archaeological survey methods.

INTRODUCTION

In modern societies heavy metal contaminated soils are widespread in industrial areas and cities, including residential suburbs. Davies and Houghton (4) reported that the metal contents of garden soils in Birmingham declined progressively from the city centre towards rural Warwickshire and the concentration trends could be modelled by polynomial regressions. Private gardens show evidence of contamination by Pb and other metals in rural areas and the Pb content of the soil increases over time (3). Even in remote islands characterised by a general absence of petrol driven vehicles (Aran, Tory, Sark) and hence of petrol-derived Pb pollution, garden soils contain relatively high Pb contents (5). There is therefore a "habitation effect" in which both industrial and domestic site occupation give rise to heavy metal contamination of soils. The available evidence also suggests that metals deposited on soil are lost only very slowly by normal leaching (6,7,8) and metal residues therefore persist in soil over long periods of time.

This modern experience has suggested the possibility that much more ancient settlement could also be associated with unusual and localised accumulations of certain metals in soil.

The objective of this investigation was to determine whether certain pre-Industrial archaeological sites in Greece were characterised by unusual accumulations of trace metals in soil. This paper reports data for the metals Cu and Pb, compounds of which have been used by man since earliest times, for the study area generally and for two specific sites namely, a suspected farm site and an ancient walled city.

THE STUDY AREA

The samples were collected during the 1986 field season of the Universities of Bradford and Cambridge Boeotia (Greece) expedition. In the survey area ancient habitation sites have been identified by Bintliff and Snodgrass (1,2) from concentrations of surface artefacts (essentially pottery and tile fragments) and by mapping 'offsite' background densities of ancient artefacts lying between these sites.

In order to provide regional, baseline data surface soil samples were collected along four long transects. Two parallel east-west lines of transect were established, separated by 500 m, commencing at the western boundary wall of the site of the ancient city of Thespiai and running westwards for some 4 km. At a point 2 km west of Thespiai a third transect commenced, normal to it and running 5 km due north. A fourth transect was sampled 500 m west of transect No. 3 but this terminated after 2 km. Samples were taken at approximately 200 m intervals along each line and the total number collected was 77.

A small villa or farmstead of Late Hellenistic and Early Roman date (site PP17) had been identified through surface finds of roof tiles and pot sherds. It lies beside a tractor trail and possible outlines of the collapsed building had been established by geophysical surveys. An orthogonal grid for soil sampling for trace element analysis was established overlying the area suspected as comprising the collapsed building with its ancillary structures. The grid dimensions were 60 x 60 m and samples were taken at 10 m intervals. Forty five samples were collected.

Sample collection also took place across the collapsed city wall at Thespiai. This major Boeotian city of Greco-Roman and Mediaeval date occupies an area of agricultural fields below the modern villages of Thespiai and Leondari and at its maximum was some 100 hectares in extent. Two samples were taken at 30 m and 60 m into the city and the transect was continued for 300 m beyond the wall in a southerly direction (176^{o}.)

FIELD AND LABORATORY METHODS

Samples were collected to a depth of 15 cm using either mild steel screw auger or a stainless steel garden trowel. The samples were dried, gently disaggregated and sieved (<2 mm) and sub-samples were extracted with hot *aqua regia* ($HCl:HNO_3$, 3:1). Metal contents were determined by atomic absorption spectrophotometry. Accuracy was checked by certified reference materials and recoveries were satisfactory.

RESULTS AND DISCUSSION

The analytical data are summarised in Table 1. The arithmetic means of the data were generally larger than the medians and indicated skewed populations. Accordingly, the data were $\log_{10}$ transformed for statistical testing.

Frequency distribution curves (not shown here) for the log-transformed data from the regional transect indicated a very good accordance with normality and therefore these data could be used as representative of the local background values for soil trace elements. Inspection of the data indicated a general tendency for the Pb and Cu values from the specific archaeological sites to be greater than those from the regional transects. The geometric means for each site were therefore compared with the regional means using the conventional t-test and the results are presented in Table 1.

Classical sources are the indications from pottery dispersal on- and off-site suggest that long-occupied agricultural landscapes and ancient farm and village sites may have zones of accumulation of human and animal waste products derived from farmyard manure and household rubbish tips. Manures may contain abnormal concentrations of trace elements.

Both metallic Cu and Pb and their compounds and alloys have long been used as coins, jewellery, pipes, vessels, ceramic glaze pigments etc.

TABLE I. SUMMARY SOIL METAL CONCENTRATIONS (mg/kg). THE GEOMETRIC MEAN WAS DERIVED FROM A LOG 10 TRANSFORMATION OF THE DATA BUT IS IN ARITHMETIC VALUES WHEREAS THE GEOMETRIC DEVIATION IS NOT

	Site					
	Region		Thespiai		PP17	
N	77		8		45	
	Pb	Cu	Pb	Cu	Pb	Cu
Minimum	1.6	2.6	6.2	12	22	8.4
Maximum	25	15	55	65	130	21
Median	6.8	5.6	10	16	61	14
Mean	7.2	6.0	16	23	59	14
S. dev.	3.4	2.3	16	18	27	3.7
G. mean[1]	6.6	5.7	13*	19***	53***	13***
G. dev.	0.185	0.155	0.302	0.247	0.212	0.177

1 differences from regional mean: * $p<0.05$ *** $p<0.001$

These metals are likely to have been carried to the soil around a building during rubbish disposal or through accidental losses. It was therefore hypothesised that soils associated with ancient habitation might contain residual accumulations of these metals. Table 1 shows that the mean Cu and Pb concentrations of the soils at the two sites are significantly different from the regional baseline means and therefore these areas of ancient occupation are typified by an excess of Cu and Pb.

Further analysis of the data continued by examining the spatial relationships at each site for Cu and Pb. The data for the mean values of Cu and Pb for the two west-east transects combined together are plotted in Figure 1. In general these plots demonstrate apparently random fluctuations around the respective mean values. There is an indication that soil Cu might be anomalously high around 2500 m on the east-west transect since both curves rise together but the maximum concentration is within the 95% bound. Close to Thespiai at 4000 m soil Cu and Pb concentrations tend to rise which could be ascribed to a "city influence" (cf modern Birmingham in Davies and Houghton, 1984).

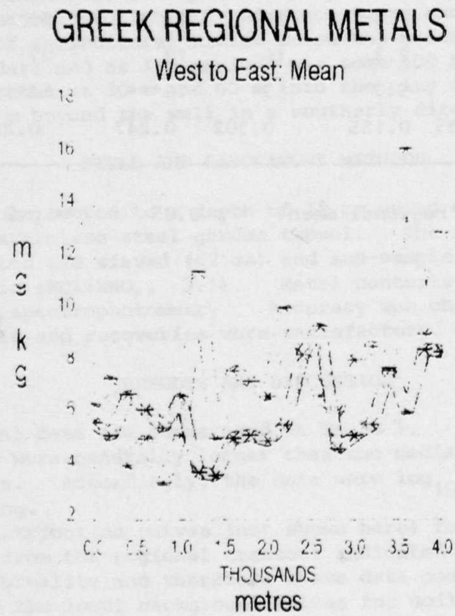


FIGURE 1 - PLOT OF THE Cu AND Pb CONCENTRATIONS IN SOILS SAMPLED ALONG THE WEST TO EAST REGIONAL TRANSECT.

The data for Thespiai are plotted in Figure 2. There is an indication here of a real difference between soil composition within and without the city wall while the trend beyond the wall is that of random fluctuations within background.

The villa site PP17 data are presented in Figure 3. Figure 3a depicts the geophysical interpretation of the site and Figure 3b shows the relationship of the soil survey grid to the other surveys. The isoline (contour) plot for Cu is shown in Figure 3d. The lowest Cu content on this site was 8.4 mg/kg compared with the regional mean and high of 5.7 mg/kg and 12 mg/kg, respectively. Plotting limits were set at 10, 12, 14, 16 and >16 mg Cu/kg soil. There is a marked accumulation of soil Cu centred on coordinates 20,40.

The minimum Pb content at this site was 22 mg/kg compared with the regional mean of 6.6 mg/kg and the 95% high value of 24 mg/kg. Five plotting limits were chosen, namely, <20, 40, 60, 80 and >80 mg Pb/kg. A zone of high Pb (Figure 3c) values borders the road and extends for approximately 20 m into the site. This is just conceivably explained by accumulations from Pb products in the exhaust fumes of modern vehicles using the road but its unsuitability for other than diesel powered tractors makes this unlikely. These and other areas of ccumulation are more safely ascribed to the habitation effect noted by Davies (3).

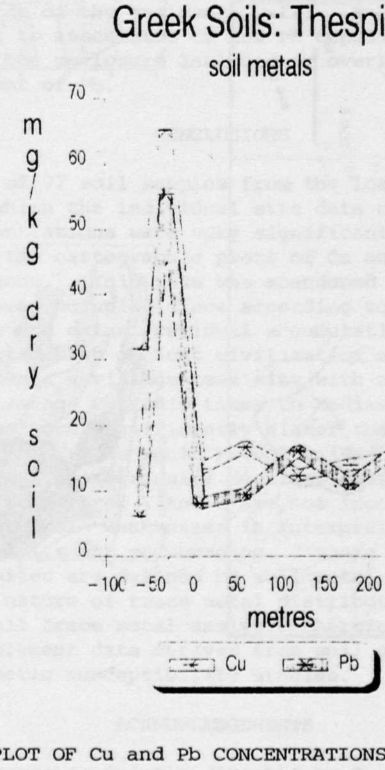
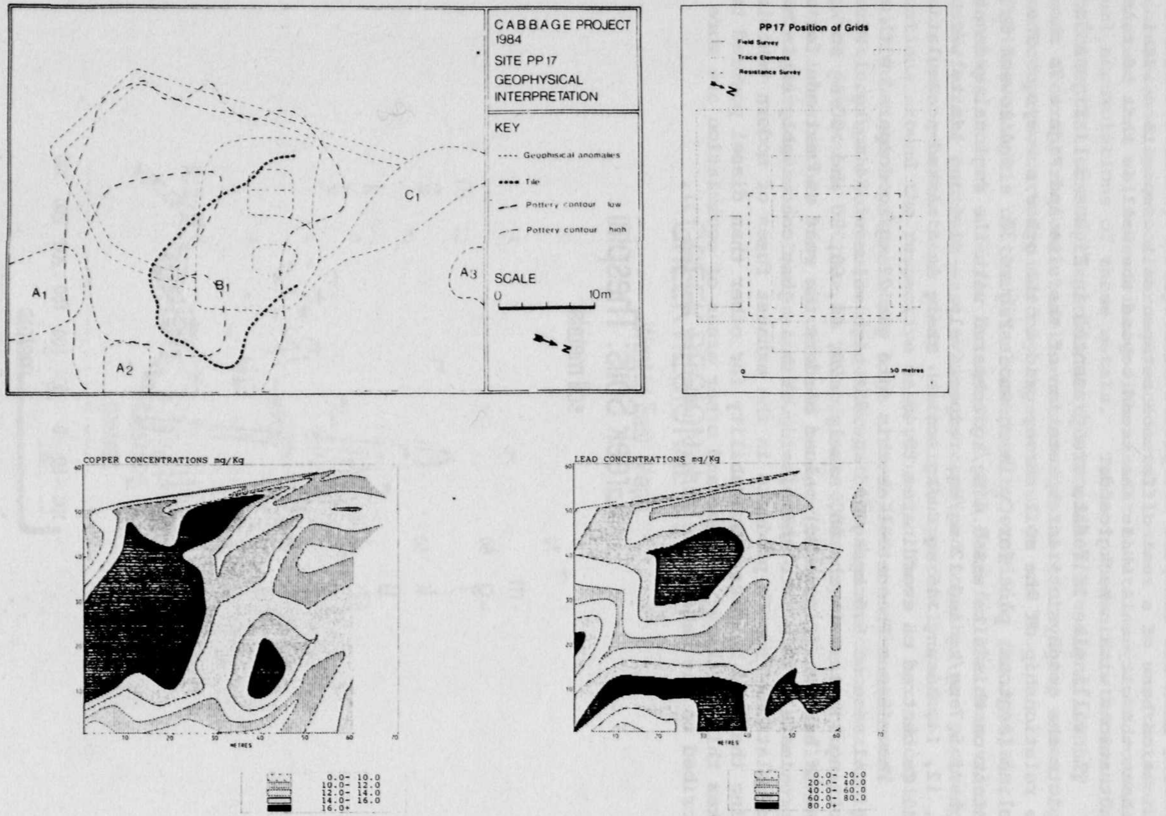


FIGURE 2 - PLOT OF Cu and Pb CONCENTRATIONS IN SOILS SAMPLED ALONG A TRANSECT FROM WITHIN THE CITY WALLS OF THESPIAI TO THE FIELDS BEYOND.

FIGURE 3 - FARMHOUSE SITE PP17: CLOCKWISE FROM TOP, LEFT: a - INTERPRETATION OF GEOPHYSICAL DATA; b - RELATIONSHIPS OF SURVEY GRIDS; c - ISOLINE PLOT OF SOIL Pb; d - ISOLINE PLOT OF SOIL Cu.



The area covered by the soil grid is far larger than that revealing the ancient farm and concentrated pottery debris. Nonetheless, the wider area appears to exhibit higher values for Cu and Pb than the regional norm, thus suggesting tentatively an outer halo of activity beyond the immediate focus of habitation. Comparison of Figure 3a-d and concentrating on the area of Figure 3a suggests that lead noticeably forms a halo of high concentration on three sides of the putative enclosure walls of the farmhouse. On the other hand, Cu rises in concentration to a maximum over the area identified as the farmhouse structure and declines over the enclosure to the south. On the larger scale Pb and Cu are similarly broadly complementary in distribution over the area sampled. It is tempting to hypothesise differing activities across PP17 and in its immediate surroundings, by the site occupants and their animals, producing: the distinct Cu anomaly over the farmhouse and south of the enclosure; the Pb anomalies surrounding but barely infringing on the farm enclosure - on the north, east and west; finally, the enclosed area south of the farm with notable low concentrations of both Cu and Pb.

If the distribution of non-tile pottery is included in the analysis (Figure 3a) additional complications emerge. The inner, higher value pottery contour has two parts, one within the south enclosure, the other to its east. Cu concentrations are lower in both, but the east high is associated with high Pb concentrations. A very speculative suggestion to account for these anomalies is to postulate different centres for pottery discard on either side of the enclosure wall. Enclosure discard involved activity not leading to associated Cu and Pb deposition, whereas discard immediately east of the enclosure included or overlapped with activity leading to enhancement of Pb.

CONCLUSIONS

The collection of 77 soil samples from the long transects provided baseline data with which the individual site data could be compared. At PP17 Cu and Pb concentrations were very significantly higher than the baseline values and the cartographic plots of Cu and Pb revealed marked, localised accumulations. This site was abandoned in the early Roman period and has not been occupied since according to the surface ceramic finds. Thus, there are extant residual accumulations of the trace metals most closely associated with ancient civilisation some 2500 years later.

Thespiai represents a village-town site with a long history of occupation from Bronze Age Helladic times to Mediaeval and later. The Pb and Cu concentrations were significantly higher than the regional baseline values. Similar modern sites would reveal raised metal levels in soils within the urban area and progressive declines towards the rural outskirts. The trends depicted in Figures 1 and 2 are not inconsistent with this.

Despite the inevitable weaknesses in interpreting data from a first, pilot project the results are encouraging. There is a strong suggestion that these ancient sites are defined by soil metal anomalies in a manner consistent with the nature of trace metal distribution in modern garden and city soils. Soil trace metal analysis therefore shows promise as another tool to supplement data derived from soil phosphorus analysis, resistivity and magnetic susceptibility studies.

ACKNOWLEDGEMENTS

The Boeotian survey is jointly directed by Dr. J.L. Bintliff and Professor A.M. Snodgrass of Cambridge University.

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