The use of soil analysis in the interpretation of an early historic landscape at Puxton in Somerset

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ABSTRACT

Soils samples taken from two adjoining fields close to the village of Puxton in the county of North Somerset, UK, were analysed in 1997 for heavy metals, phosphorus, magnetic susceptibility and loss on ignition as part of an archaeological investigation of the origins and development of a medieval settlement. It had been argued that an oval-shaped field next to the church was the nucleus of marshland reclamation during the early medieval period, though it was unclear whether the enclosure was occupied by a settlement or was simply an area of embanked agricultural land. Soil chemistry shows certain elements, including phosphorus and the heavy metals (Pb, Zn, Cd, Cu, etc), to be concentrated in a restricted part of the enclosure, which earthwork, resistivity and fieldwalking surveys suggest correlates with an area of human occupation associated with the dumping of midden material nearby (a hypothesis confirmed through excavation). This paper demonstrates the value of multifaceted soil chemistry, alongside a range of other survey methods, for characterising the nature of human activity on archaeological sites, and in the future may be used to locate previously unrecorded sites in more speculative landscape surveys.

KEYWORDS

North Somerset Levels, medieval settlement, soil analysis, soil chemistry

INTRODUCTION

The association of enhanced levels of soil phosphorus with abandoned settlements has long been recognised (Bethell & Máté 1989), the element being concentrated in domestic waste, particularly faeces, urine and wood ash, and accumulating in the soil as the result of its rapid fixation and long-term immobility. This process is paralleled by other elements, notably heavy metals, several of which similarly arrive on settlements through anthropogenic processes, resulting in zones of contamination around ancient farm sites. Other soil characteristics attributed to human activity, such as soil colour, accumulations of organic material, and increased magnetic susceptibility due, in part, to fires (kilns, ovens, etc) or the presence of burned material, are also measurable by independent processes and can provide corroborating evidence of human settlement or activity (Aston *et al.* 1998a; 1998b).

Puxton is situated on an area of reclaimed coastal alluvium, the North Somerset Levels, lying beside the Severn Estuary near Weston-super-Mare (Fig. 1). This low-lying land has been partly protected from tidal inundation by a belt of sand dunes extending from the limestone promontories at Uphill, in the south, north towards other bedrock outcrops at Worlebury and Middlehope. Recent observations at Weston-super-Mare have established that this natural coastal barrier was in existence by the Roman period, although there is no evidence that the dunes ever extended along the stretch of open coast between Middlehope and Clevedon (Rippon 1997). The presence of a wealthy late Roman villa on the banks of the Congresbury Yeo at Wemberham implies that during the Roman period the North Somerset Levels were free from tidal inundation, and this hypothesis has been confirmed by the results of recent palaeoenvironmental work on several Romano-British rural settlements at Banwell, Kenn and Puxton Moors (Rippon 2000). The wholly freshwater environment that can be reconstructed on these sites from the pollen, plant macrofossils, mollusca, beetles, diatoms and foraminifera suggests that the stretch of coast, not protected by natural sand dunes, must have been blocked by a man-made earthen embankment. The work at all three sites has also shown that the coastal parts of the North Somerset Levels were once again subjected to tidal inundation during the post-Roman period with a return to saltmarsh conditions: clearly the sea walls had been breached (*ibid.*). Place-names and documentary evidence indicates that a second episode of marshland reclamation on the North Somerset Levels was well underway by the eleventh century, though it is unclear

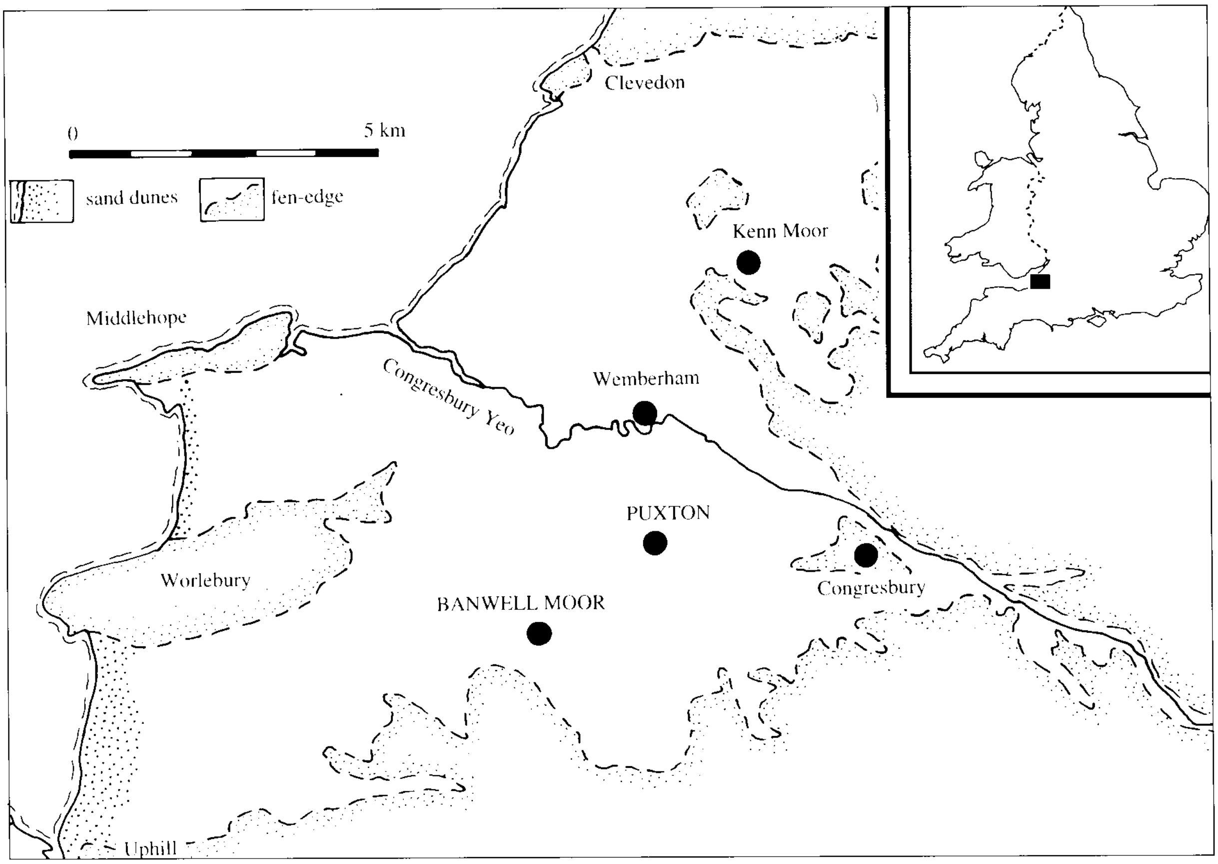


Fig. 1. Puxton, on the North Somerset Levels.

precisely when and how this early medieval phase of settlement expansion took place.

In order to answer that question a programme of survey and excavation was initiated at what appeared to be one of the earliest foci for the early medieval reclamation: one of a number of oval-shaped enclosures known as 'infields'. These features are not uncommon on the higher, coastal parts of the reclaimed saltmarshes on both sides of the Severn Estuary, and it has been argued that they represent the earliest stages of marshland reclamation, with the oval shape resulting from their having been enclosed in a relatively open landscape, thus being unconstrained by existing landscape features (Rippon 1997, figs 44 & 45). The sites have a number of common characteristics. They are often associated with field-names indicative of early medieval habitation (*e.g.* 'worth' and 'huish'), lie close to medieval churches/chapels, and have surface finds of medieval and/or Roman pottery. Many are also associated with extant farmsteads though, like the churches/chapels, these almost invariably lie towards the edges of the enclosed area.

The example chosen for detailed investigation was 'Church Field' in Puxton, 9 km east of Weston-super-Mare (Fig. 2). The site has now been subjected to earthwork, resistivity and fieldwalking surveys along with trial excavations (Fig. 3) which have yielded samples for palaeoenvironmental analysis (Rippon 1996; 1997; 1998; 1999). In addition, soil samples were also taken from the whole of the 'infield' together with a field to the south, and it is the results of the chemical analysis of these samples that are reported here. Although there is no evidence for an habitative field-name, Puxton otherwise conforms to the type description of an 'infield' with a church and hamlet located on its northern edge. When ploughed during the 1960s the field revealed Romano-British and medieval pottery, and though considerably denuded by recent ploughing there survive the earthworks of a coherent pattern of rectilinear platforms and enclosures suggestive of an area of abandoned settlement (Fig. 3).

The smaller but more pronounced platforms lay to the north/north-east of the 'infield' and are suggestive of house platforms, the highest of which lies immediately to the south-east of the church. When fieldwalked, this area produced the greatest amount of medieval building debris (stone, burnt clay/daub, etc) and kitchen refuse (animal bone, pottery, etc), and excavation (Trenches 2 & 12) revealed a deep sequence of occupation debris dating to between the tenth and thirteenth centuries. The enclosures in the southern and western parts of the 'infield' are larger and defined by slighter ditches, and are more suggestive of the paddocks that cluster around traditional farms even today, being used as gardens, orchards and yards for livestock. The

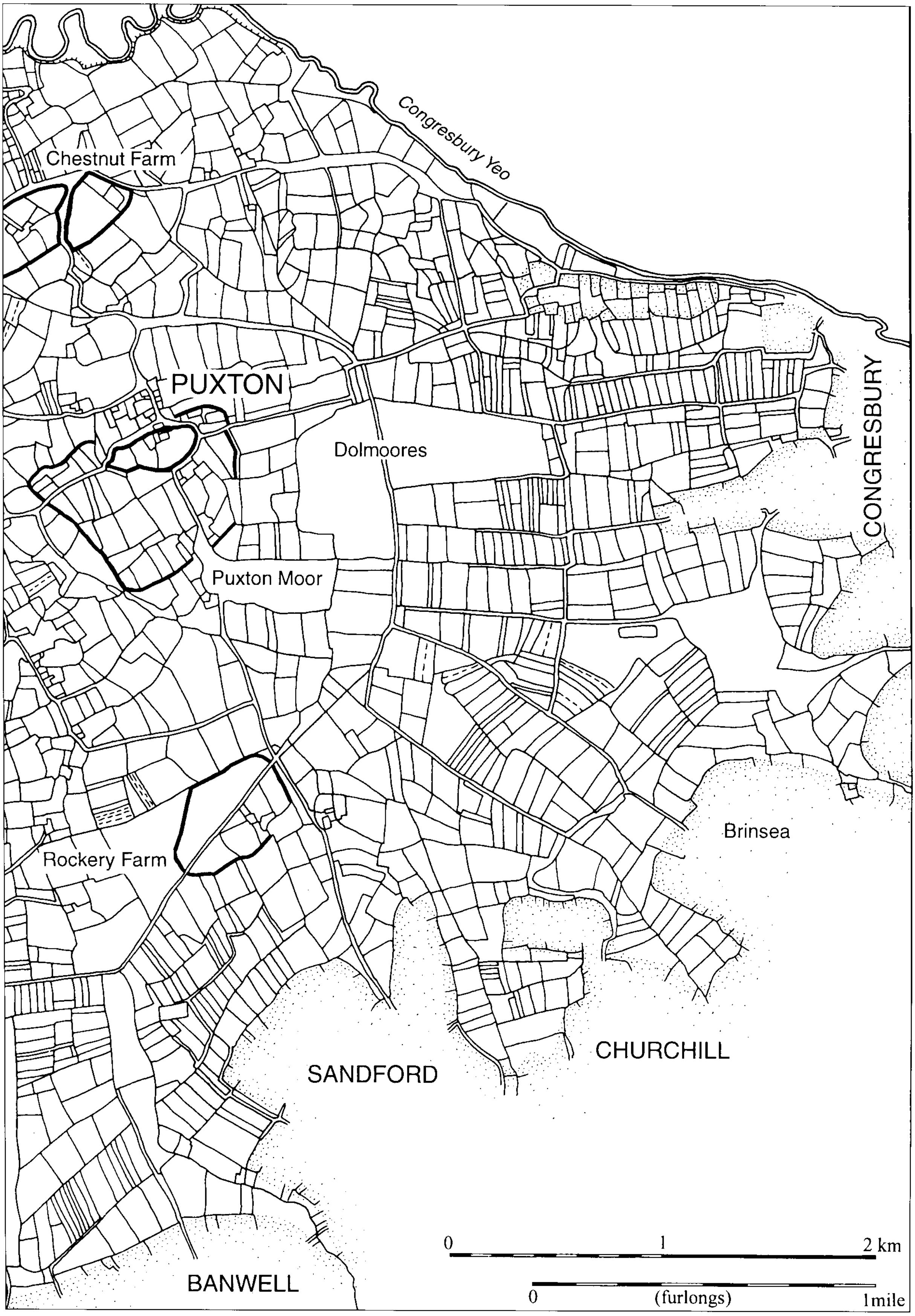


Fig. 2. The south-western part of the North Somerset Levels, with the early 'infield' enclosures highlighted. The inner enclosure at Puxton, and the field directly to the south are the subject of soil chemistry and fieldwalking surveys reported here.

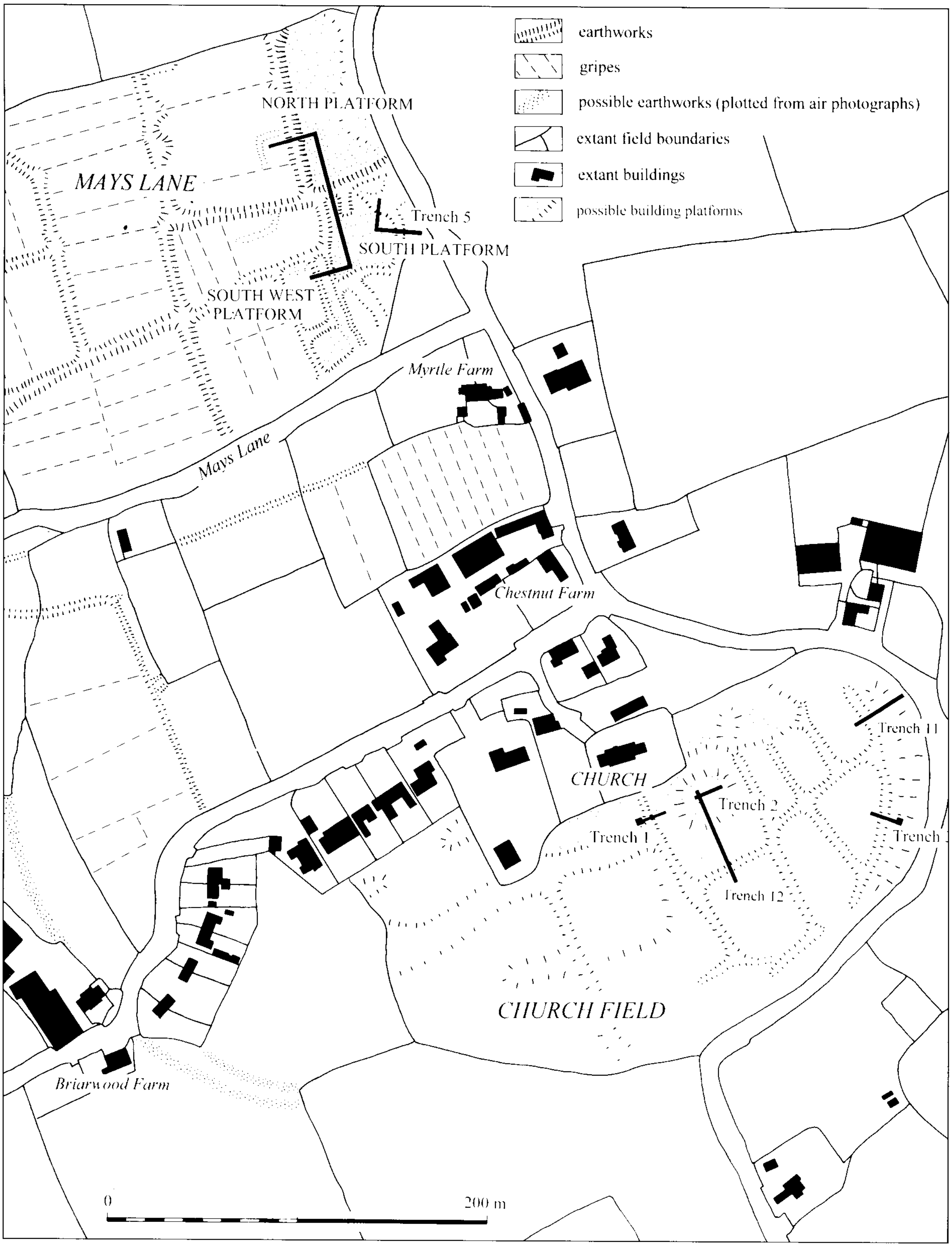


Fig. 3. Shrunken settlement earthworks at Puxton, and the location of excavated trenches.

fieldwalking survey produced a light scatter of medieval material (Fig. 16) suggestive of kitchen rubbish and farmyard manure being spread over the paddocks in order to increase fertility. To the south-west of the church there is a pronounced circular depression which, when fieldwalked, yielded large amounts of post-medieval material suggestive of a former pond that has been partly backfilled in recent times. The eastern, southern and western edges of the 'infield' enclosure are marked by an extant field drain, inside which there are traces of a concentric bank and inner ditch (sectioned in Trenches 3 & 11).

The fieldwalking survey also produced Romano-British and post-medieval pottery (Figs 15 and 17). The former was a very light scatter over much of Church Field, indicative of no more than the spreading of farmyard manure over fields. Larger amounts of post-medieval pottery were recovered, concentrated in the northern and north-western areas, indicative of manuring and the dumping of material over the ends of back gardens in the extant village. A very discrete concentration of post-medieval debris also occurred in and around the slight depression of a former pond and indicates its recent partial back-filling.

SOIL COMPOSITION AND HUMAN ACTIVITY

The survival of earthworks, and the presence of ploughing that allowed the systematic surface collection of artefacts, means that a considerable amount can be said about different activity zones within the infield, and this has now been confirmed through small-scale yet carefully targeted excavations. However, if the earthworks had been ploughed flat, and the site then returned to pasture, there would have been no evidence on the surface as to the nature of this site, or any indication of where to excavate. As geophysical survey is notoriously unsuccessful on alluvial soils, another method of prospection needs to be developed for use in such circumstances.

As described above, the Puxton data suggested that a number of discrete activity zones could be identified within the 'infield': an area of domestic occupation and midden dumping south-east of the church, the occasional manuring of small enclosures used for horticulture, orchards, and paddocks for stalling livestock elsewhere in the 'infield', and an area of recent dumping in the circular hollow. Based on this existing knowledge, the relatively untried technique of heavy metal analysis was used, alongside the well-established phosphate analysis and magnetic susceptibility, in order to test its success on a site where patterns of activity were already relatively well understood.

The elemental composition of soils is influenced primarily by the nature and weathering of the parent material and the incorporation of anthropogenic organic matter through bioturbation. Many other factors also affect or disturb that chemical composition, including the addition of agricultural fertilisers, cropping, and other past uses of the land. The hypothesis tested here was whether existing patterns of soil chemistry are linked to past human activity. The magnetic properties of topsoil can be affected by a series of processes, some physical, some biological. The magnetic nature of top soils may also be influenced by aerial contamination. Not all these processes are fully understood, but it is generally found that soils taken from the surface layers give stronger magnetic signals than those from the subsoil. Of more relevance to this study is the hypothesis that laboratory analysis of surface samples will give some indication of localised enhancements that may be attributable to burning, burned or otherwise oxidised material, or to topsoil/subsoil mixing (buried ditches, eroded banks etc) that has been rendered more magnetically susceptible.

Analysis of soils for phosphorus accumulations associated with sites of human occupation has been practised for many years since the pioneering work by Olaf Arrhenius in the late 1920s (Arrhenius 1929). Although such evaluations have been known in certain circumstances to give inconsistent results (*e.g.* shallow upland soils which vary markedly in depth and texture — see Crowther 1997), in the deeper and texturally more consistent lowland alluvial soils of North Somerset this would be unlikely.

It was initially considered that the measurement of organic carbon content of soils as an indicator of past human activity might be compromised by its usually high turnover rate in the soil. However, associations of areas of dark soils with ancient settlements (*e.g.* in field-names such as 'blacklands') have been shown to be connected with elevated levels of organic carbon (Aston *et al.* 1998b). Indeed, work at Rothamsted Experimental Station over twenty years ago (Jenkinson & Rayner 1977) gave credence to the longevity of residual levels of organic carbon in arable soils. The use of loss on ignition as a measurement of organic carbon was based on the improved methodology of Ball (1964).

The ways that soil heavy metal concentrations could have been altered by human activities in the past has been described elsewhere (Aston *et al.* 1998a; 1998b) and these include, as with phosphorus and organic carbon, enrichment of soils through urine and faeces in the form of refuse dumping, cess-pits, middens, stored produce and animal housing, along with the use of fires/hearths, metalworking and other processing such as leather making and crop processing (*e.g.* winnowing and retting). As far as food consumption is concerned it has been shown that the daily intake and excretion rates of a selected range of metals and phosphorus for an average human being are significant (Snyder *et al.* 1975). Four elements (phosphorus, zinc, manganese and copper) show very high rates of intake and excretion; nickel and lead show intermediate levels; while cadmium, chromium and cobalt show relatively low levels. The intake and excretion rates of the elements will, of course, vary with diet. There is evidence that ancient diets (Roman and medieval) contained a much higher lead content that those of the present day (Gilfilan 1965; Nriagu 1983). Aston *et al.* (1998a; 1998b) and Jackson (2001) have presented *ad hoc* calculations showing the relative effect of human faecal material on soil elemental composition and have shown the relative enrichment of soils based on average concentrations in 'normal' soils. In a similar way, burning of wood for fires used in various activities would have also resulted in an accumulation of wood-ash which, relative to soil, would be enriched in many metals originating from the normal chemical composition of plants used as fuel.

METHODOLOGY

In this survey, the 'infield' enclosure at Puxton (Church Field) was the main focus of attention, although a second field to the south that lay outside the enclosure was also sampled. The latter was included because it was felt important to sample an area wider than that of the main focus of interest in order to obtain a range of measurements that would be both active and inactive archaeologically. Samples from the field to the south would, it was hoped, provide an objective comparison with 'natural' or, at least, less disturbed, background levels of soil factors. There are no visible earthworks in the field to the south of Church Field and fieldwalking produced far fewer finds. No excavations were carried out.

A number of factors need to be considered before the use of heavy metal analysis of soils can be taken as a reasonable tool in archaeological research, some of which will influence choice of metals or analytical method, while others highlight alternative explanations of distributional patterns (see Jackson 2001). In this case study, one of these factors, variations in soil chemistry due to the underlying geology, is not a problem since the entire site at Puxton lies on a uniform estuarine alluvium. Nearly 300 soil samples were collected from the top soil on a 20-metre grid laid out over both fields. Organic carbon was estimated by loss on ignition and magnetic susceptibility measured in the laboratory on air-dried soil. Total phosphorus (spectrophotometry) and heavy metal assays (atomic absorption spectrometry) were made following digestion of sub-samples in nitric acid. Full details of the methodology employed and analytical procedures followed are described elsewhere (Aston *et al.* 1998a; 1998b).

RESULTS

The geographical variation over Church Field and the field to the south in soil concentrations of magnetic susceptibility,[1] percentage loss on ignition (organic matter), phosphorus, and eight individual heavy metals (mg per gram of soil), are presented below as isoline maps (Figs 4-14). Plots for the distribution of Roman, medieval and post-medieval pottery (number of sherds per 20-metre transect) recovered by fieldwalking are also illustrated (Figs 15-17). Spatial interpolation follows specifications in a standard statistical software — *Minitab 12 Contour Plotting*.

Magnetic susceptibility: the most noticeable enhancement of magnetic susceptibility lies *c.* 100 metres to the south-west of the church and coincides with the small circular hollow revealed by the earthwork survey (a former pond) and a marked concentration of post-medieval debris indicative of recent dumping (Figs 4 and 17). Otherwise there is a more generalised pattern over the two fields although there appear to be some parallels with copper and zinc.

Loss on ignition (used to estimate organic carbon): there are scattered peaks and troughs of organic carbon enrichment mostly in the central and eastern parts of the Church Field with an outlying patch to the north-west. Similar concentrations occur within the field to the south of Church Field although these diminish southwards (Fig. 5). Within Church Field, the soil samples that lost most organic carbon on ignition at 450°C were close to and just to the south of areas that the earthworks, resistivity survey, fieldwalking and excavation suggest correspond to the main focus of occupation. However, other peaks are located in areas considered to be outside the primary settlement area as such and may result from localised waterlogging in the winter months or where soils are naturally more peaty. They may, of course, arise from loci of, as yet, unidentified human activity.

Phosphorus: the highest concentrations of phosphorus are found on the raised platform to the south-east of the church which appears to have been the main focus of occupation. Concentrations in the field to the south of Church Field were relatively low (Fig. 6).

Lead: the highest levels of lead are found in the centre of Church Field and, like phosphorus, are mainly concentrated on the raised platform to the south-east of the Church. There are also small patches of lead-rich soil to the west and south of this central area and a larger patch of

Figure 4 **Magnetic Susceptibility**

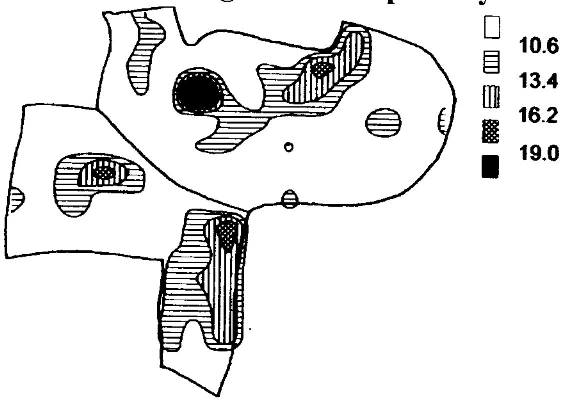


Figure 5 **Loss on Ignition (%)**

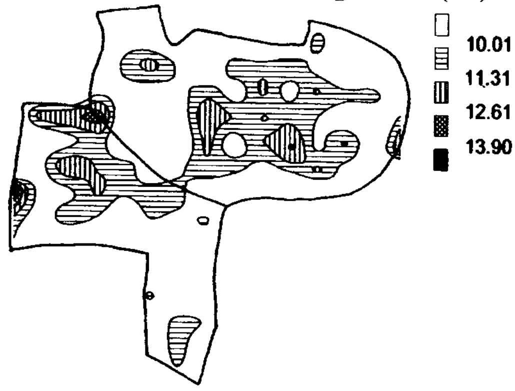


Figure 6 **Phosphorus**

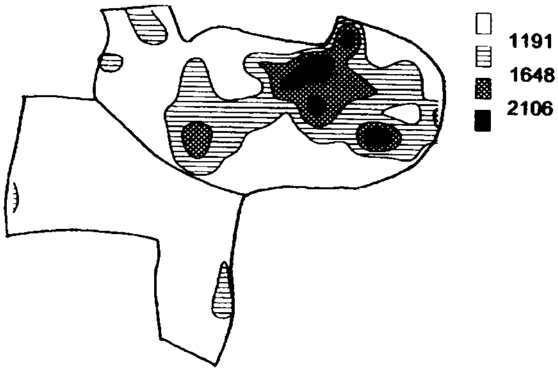


Figure 7 **Lead**

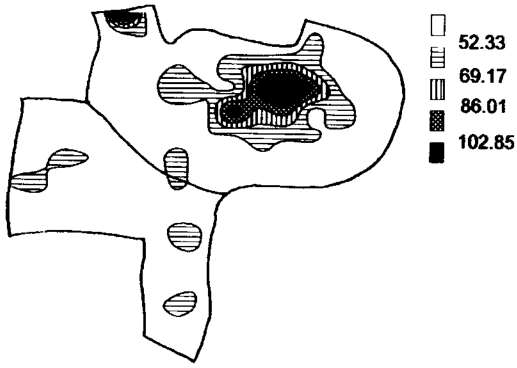


Figure 8 **Copper**

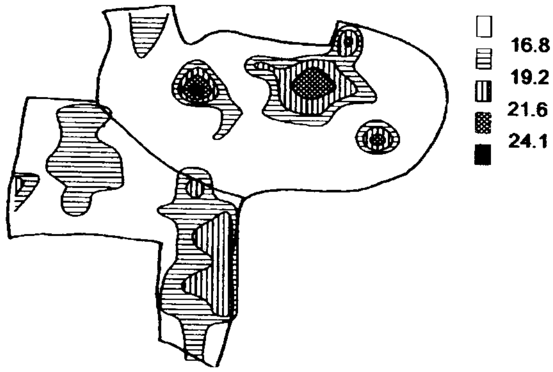


Figure 9 **Zinc**

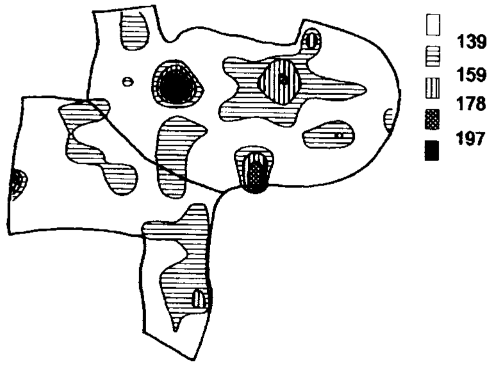


Figure 10 **Cadmium**

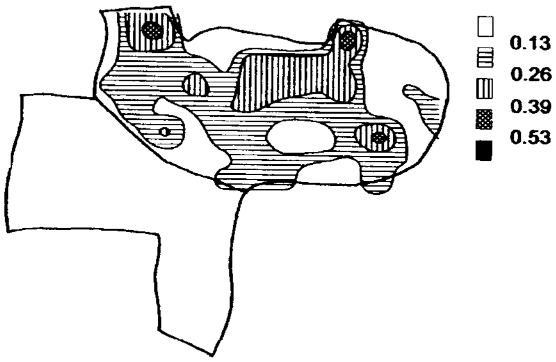
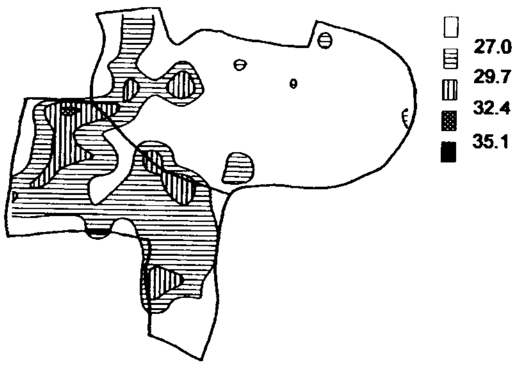
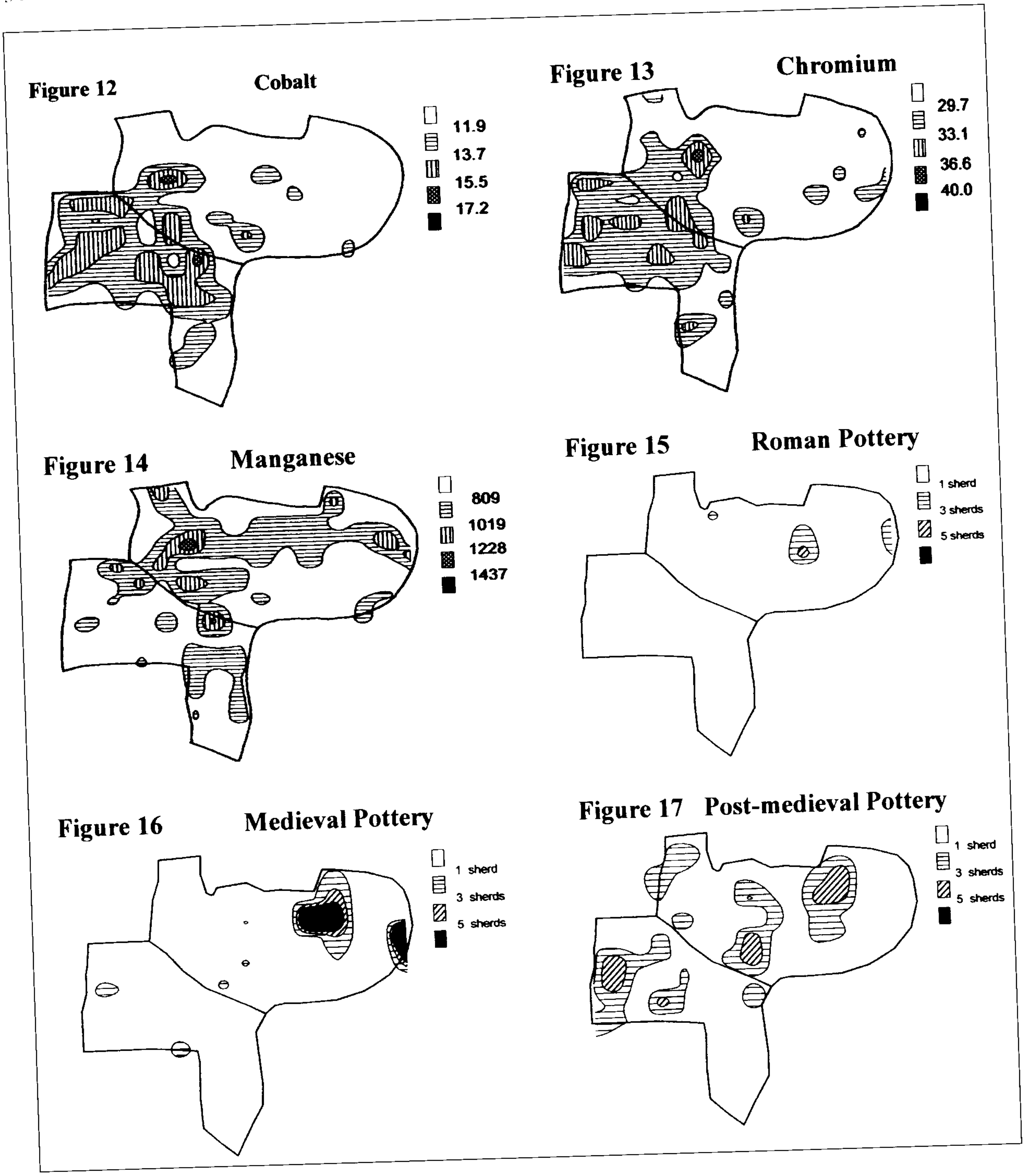


Figure 11 **Nickel**



Figs 4–11.



Figs 12–17.

enhancement to the north-west which does not appear to correlate with any indication of medieval occupation. The distribution of post-medieval pottery suggests that this was an area of rubbish dumping. Minor concentrations of lead also occur within the field to the south of Church Field, matching those of copper and zinc, though the levels are much lower than in Church Field itself (Fig. 7).

Copper: the levels of copper are not exceptionally high but higher concentrations can be found on the raised platform south-east of the church, and over the former pond. Lower concentrations are found in the field to the south of Church Field (Fig. 8). These areas of greater copper enrichment match those of lead, zinc and cadmium, and appear to relate to settlement-related activity, and the backfilling of the former pond.

Zinc: the pattern of zinc-rich soils is more dispersed than lead, but has a broadly similar distribution. There is a marked concentration *c.* 100 metres south-west of the church corresponding to the former pond with its high magnetic susceptibility and post-medieval debris (Fig. 9).

Cadmium: the distribution of cadmium-rich soils is confined to Church Field itself, although these levels, it must be said, are not particularly high (Fig. 10). The distribution is broadly similar to lead and zinc with concentrations on the raised platform south-east of the church, in the north-west of Church Field, and over the former pond.

Nickel (Fig. 11), *Cobalt* (Fig. 12) and *Chromium* (Fig. 13): the distribution of soils with higher levels of nickel, cobalt and chromium all concentrate in the western part of Church Field, including over the former pond, and over much of the field to the south of Church Field. This pattern appears to show a marked negative correlation with the distribution of phosphorus, lead, zinc, cadmium and copper, and the other indicators of medieval occupation. An explanation for this is suggested below.

Manganese: discrete patches of manganese-rich soil are dispersed widely over the sampled area with no strong correlation to any other elements or the known patterns of human activity (Fig. 14).

ANALYSIS OF DATA

Variation in the values of magnetic susceptibility, loss on ignition, heavy metals and phosphorus recorded in soils taken from Church Field and the field to the south of Church Field are presented below (Table 1). Some comparisons are presented between the settlement field (Church Field) and the relatively less disturbed field to the south. The data from Church Field are then considered in more detail.

Simple statistical analysis generally confirmed the patterns revealed in the isoline plots. Church Field contained greater mean soil concentrations of phosphorus, lead and zinc, whereas the field to the south was richer in nickel, cobalt and chromium ($p = 0.001$). In terms of localised elevated enhancements, those for magnetic susceptibility, phosphorus, lead, zinc and copper all occurred in Church Field, whereas those for nickel, cobalt and chromium were to be found in the field to the south (see kurtosis and skewness values in Table 2). Soil concentrations of organic carbon (as measured by loss on ignition) and manganese failed to demonstrate much in the way of a between-field variation.

TABLE 1. SOIL MAGNETIC SUSCEPTIBILITY READINGS, LOSS ON IGNITION (%), HEAVY METALS AND PHOSPHORUS VALUES RECORDED (MG/G) IN CHURCH FIELD, PUXTON, AND IN THE FIELD TO THE SOUTH

Measurement	*Church Field*			*Field to the south*		
	minimum	maximum	mean	minimum	maximum	mean
Magnetic Susceptibility	6	30	11	7	18	11
Loss on Ignition	7	13	10	7	15	10
Phosphorus	551	2672	1300	410	1476	828
Lead	32.0	154	55.9	39.0	76.1	47.0
Zinc	102	298	141	98	201	136
Cadmium	0.1	0.5	0.2	0.1	0.8	0.3
Copper	10.3	25.6	16.4	13.9	21.9	17.5
Nickel	20.6	33.4	26.0	23.4	34.4	28.4
Cobalt	8.3	16.4	11.2	9.1	17.3	12.9
Chromium	20.0	38.9	29.0	22.6	40.6	30.8
Manganese	273	1508	868	435	1493	766

TABLE 2. STATISTICAL DISTRIBUTION (KURTOSIS & SKEWNESS) OF HEAVY METALS, PHOSPHORUS, MAGNETIC SUSCEPTIBILITY AND LOSS ON IGNITION

Element	*Church Field*		*Field to the south*	
	kurtosis	skewness	kurtosis	skewness
Magnetic Susceptibility	12.03	2.92	2.09	1.45
Loss on Ignition	-0.12	0.20	0.66	0.46
Phosphorus	1.37	1.11	0.75	0.88
Lead	6.95	2.46	5.67	1.93
Zinc	22.20	3.51	1.29	0.68
Cadmium	-0.45	0.49	0.51	0.56
Copper	0.39	0.56	-0.60	0.34
Nickel	-0.11	0.36	-0.34	0.06
Cobalt	0.62	0.70	-0.18	0.40
Chromium	-0.02	0.15	-0.34	-0.23
Manganese	0.16	0.08	0.81	0.86

N.B. When the distribution is normal, *i.e.* without distortion due to abnormal readings, values will tend to zero.

TABLE 3. CORRELATION (PEARSON) ANALYSIS

	MS	LOI	Phosphorus	Lead	Copper	Zinc	Cadmium	Nickel	Cobalt	Chromium
LOI	-0.015									
Phosphorus	0.243	0.085								
Lead	0.261	0.170	**0.461**							
Copper	**0.433**	0.172	**0.338**	**0.467**						
Zinc	**0.452**	0.141	**0.399**	**0.398**	**0.641**					
Cadmium	0.161	-0.012	**0.690**	**0.398**	0.152	0.291				
Nickel	0.133	-0.162	**-0.327**	-0.134	0.281	0.177	-0.265			
Cobalt	-0.055	-0.107	**-0.395**	-0.140	0.095	-0.004	**-0.324**	**0.626**		
Chromium	0.046	-0.041	-0.231	-0.170	0.110	0.150	-0.211	**0.728**	**0.562**	
Manganese	0.112	**-0.355**	0.234	0.186	0.209	0.190	0.289	**0.347**	**0.357**	0.113

The apparent similarities between certain distributions can also be tested statistically. Correlation analysis of soils from Church Field (see Table 3) show a significant ($p = 0.001$) association of phosphorus with lead, copper, zinc and cadmium. Copper and zinc concentrations also correlated ($p = 0.001$) with the more magnetically susceptible soils. Soil concentrations of nickel, cobalt and chromium (and manganese) were all clearly associated ($p = 0.001$) but negatively correlated (not manganese) with phosphorus.

The cluster analysis dendrogram (Fig. 18) of the soils taken from Church Field graphically demonstrate these correlations.

This segregation into a phosphorus-dominant, site-positive group of soil factors and a nickel-dominant, site-negative group of soil factors has been evident in other archaeological soil investigations in the British Isles (Jackson 1997; 2001). Both groupings are argued to be anthropogenic in origin, the site-negative nature of certain soil factors being attributed to a dilution effect by more aggressively generated (or possibly more soil persistent) soil elements.

An unusual feature at the Puxton site is the relative ambiguity of the loss on ignition results. At most other sites investigated (Jackson 2001) soils rich in residual organic carbon were clearly site positive and strongly linked with phosphorus-rich soils. No explanation for this inconsistency at Puxton is as yet forthcoming.

Statistical analysis of soils from the field to the south of Church Field (not presented) show similar correlations. This is not surprising considering its proximity to the medieval settlement. Indeed, few soils in lowland Britain are likely unaffected by past human activities.

The essential nature of the technique, as it is presented here, is in its potential for site prospection and the identification of foci of past human activity, and hence it is the relative spatial distribution (as displayed in the isoline maps) of the measured soil properties that matters. Plotting site-positive data and site-negative data as aggregated isoline maps has proved a useful

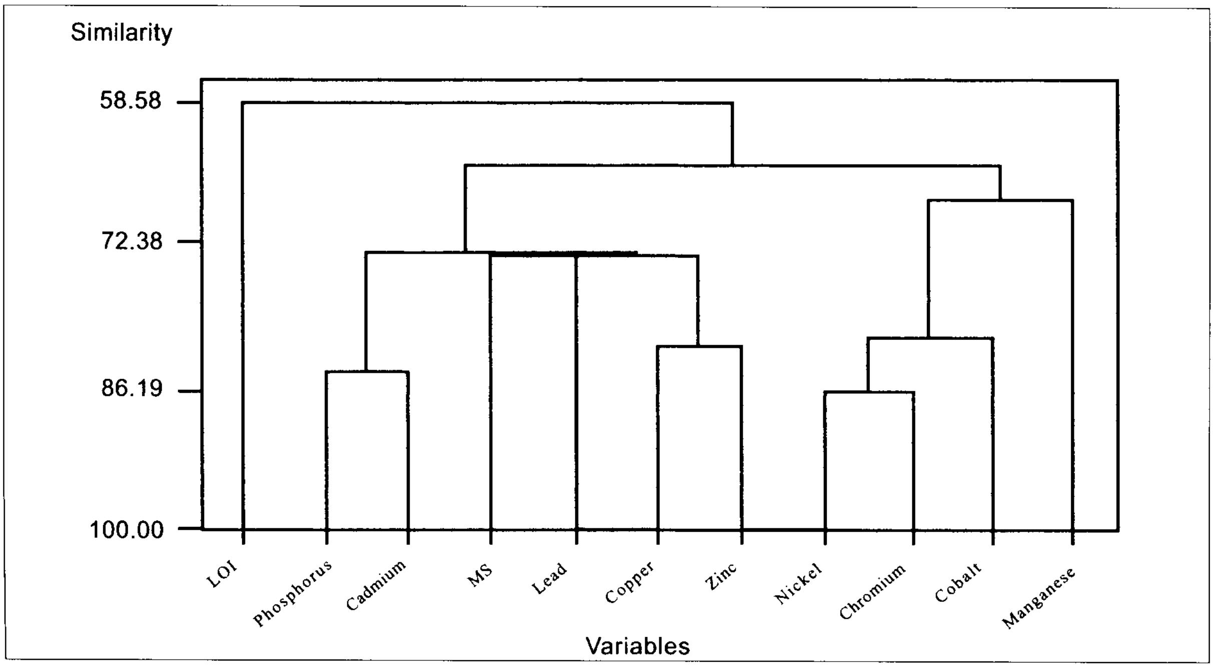


Fig. 18. Cluster analysis dendrogram.

means of locating, confirming or extending potential areas of archaeological investigation (Jackson 2001). Figs 19 and 20 illustrate this procedure applied at Puxton.

The interpretive potential of soil analysis data is not confined to prospection and some initial work on identifying the activities that may have contributed to the surviving residues has been reported elsewhere (*ibid.*). At Puxton, the geochemistry suggests zones of different activities and these are discussed below.

DISCUSSION

The programme of survey and excavation at Puxton allows the results of soil chemistry analysis to be compared with a wide range of other data in order to reconstruct a number of activity zones in and around a medieval settlement. Earthwork survey, fieldwalking and excavation suggests that the main focus of occupation within an oval-shaped enclosure lay on the raised platform some 50 metres south-east of the church, while during the medieval period the remaining parts of Church Field would appear to have been laid out as a series of small paddocks and enclosures that may have seen some manuring. The field to the south of Church Field lay outside the 'infield' and a lower intensity of human activity is to be expected at least in the earlier phases of the evolution of this landscape. Fieldwalking certainly produced far fewer artefacts and there are no settlement-indicative earthworks. The spatial distribution of soils enhanced with magnetic susceptibility, phosphorus, lead, copper, cadmium, and zinc (and, to a lesser degree, organic carbon), would support this hypothesis.

By contrast, soils comparatively rich in nickel, cobalt and chromium appear to be more concentrated in the southern and western parts of Church Field and outside the enclosure in the field to the south. This apparent enhancement in the area peripheral to human settlement is, it is argued, due to the relative dilution of these metals within the settled area by more rapidly accumulating amounts of site-positive soil factors. Soils with increased levels of manganese similarly showed a poor correlation with the known archaeology but did not fall comfortably into either of the above groupings. Manganese deposition is often associated with areas prone to waterlogging or a water retentive area.

Apart from the main focus of medieval settlement to the south-east of the church, there are two localised areas which produced relatively high readings for a number of elements. A small hollow to the south-west of the church appears to represent a recently backfilled pond. Large amounts of post-medieval debris were recovered through the fieldwalking survey, and the area had enhanced magnetic susceptibility (indicating the deposition of burnt material) and concentrations of copper, zinc, cadmium, nickel and chromium. The other area with relatively high values for a number of elements lay to the north-west of Church Field and appears to correlate with an area in which refuse has been dumped over the backs of gardens also during the post-medieval period.

It would appear, therefore, that both medieval occupation and post-medieval dumping can produce very similar chemical signatures in the soil chemistry, and that other survey techniques are required in order to distinguish the two. However, this work confirms that magnetic susceptibility and phosphorus indicate intense occupation and associated midden dumping, though now several heavy metals (lead, cadmium, copper and zinc) can be added to this list.

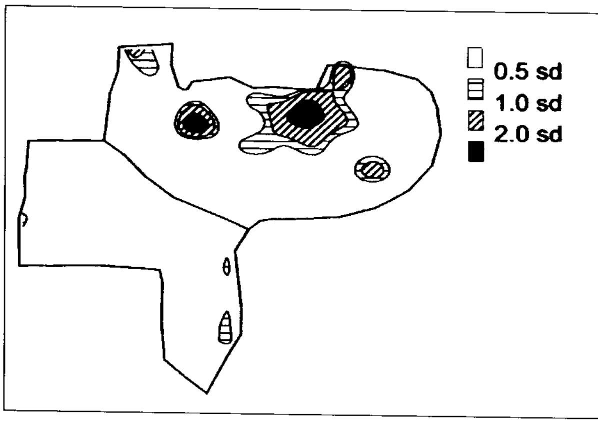


Fig. 19. Site-positive factors.

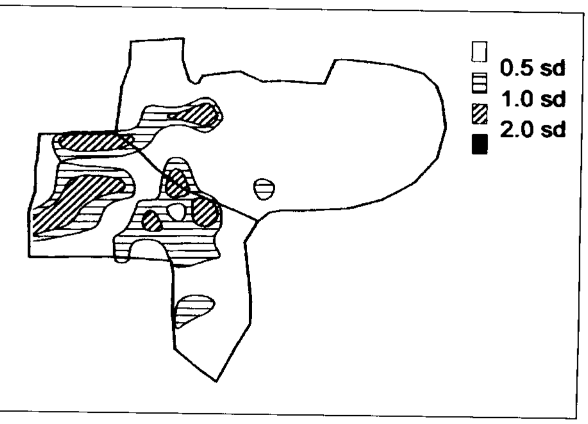


Fig. 20. Site-negative factors.

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NOTES

1. Measurements of magnetic susceptibility are comparative and therefore dimensionless.

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