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Report 53/92

RESEARCH INTO NATURAL AND ANTHROPOGENIC DEPOSITS FROM THE EXCAVATIONS AT FLIXBOROUGH, HUMBERSIDE

Matthew Canti

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Summary

Research has been carried out into the nature of the blown sand which underlies and covers the middle Saxon layers at Flixborough. The sand has a calcareous component which, combined with its constant accretion, has meant that some of the underlying ash and occupation horizons have never suffered acid leaching. For this reason, exceptionally good preservation of bone and other calcareous materials was recorded. Micromorphology was used to detail the taphonomy of the deposits and relate them to pH and particle size characteristics.

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RESEARCH INTO NATURAL AND ANTHROPOGENIC DEPOSITS FROM THE EXCAVATIONS AT FLIXBOROUGH, HUMBERSIDE

1. Introduction

Excavations were carried out at Flixborough, Humberside after sand quarrying began in 1988. Early finds centred around a number of middle-Saxon burials, but also revealed evidence of occupation deposits. A full excavation was then undertaken by the Humberside Archaeological Unit and supervised by Dave Tomlinson. This work, carried out during 1989-1991, revealed a large area of ditches, occupation surfaces and 14 timber halls. Evidence of iron working was common, and a profusion of everyday objects made from bronze, lead and iron were unearthed. Extensive ash and bone dumps were also found, the latter showing an unusually high degree of preservation. It was the understanding of this preservation that prompted the present study.

2. Geological Background

The site is on the west side of a north-south trending erosion scarp associated with the broad alluvial plain of the River Trent. The scarp is composed of a Lower Lias sequence of mudstones (Coleby and Scunthorpe) intercalated with bands of ironstone (Frodingham) and limestones. Extensive ironstone working and the subsequent dumping of waste have made geological investigation near the site extremely difficult, but a published cross-section is available for the scarp approximately 1.5 km to the south (B.G.S Sheet 80).

The scarp face is heavily mantled in blown sand, and the site is entirely founded on this material, rather than on the solid geology. From studies elsewhere in the region, the origin of the sand appears to have been late Devensian sandy lacustrine deposits, but subsequent redistribution of the material has occurred, possibly since the Bronze Age and including modern episodes (Gaunt et al. 1992).

3. Research Rationale

The research presented here is intended to throw light on two areas. Firstly, the nature of the blown sand and its relation to the extreme preservation of the bone; and secondly, the various dump and occupation deposits located during the excavation. To this end, samples were collected as follows:-

Blown sand

S1 Sand from the west facing side of the dune-bedded deposits in the quarry-trench to the west of the excavation. Probably more than 4m down from the pre-excavation land surface.

S2 Sand from 0.75m depth (from surface) in the deep capping deposit on the east face of the excavation area.

S3 Sand from the west facing side of the dune-bedded deposits in the quarry-trench to the west of the excavation. Probably more than 4m down from the pre-excavation land surface.

S4 Sand from the natural subsoil 0.6m depth exposed on the east-facing side of the quarry-trench to the west of the excavation.

S5 Sand from 0.5m depth on the east facing side of the deep pit around 100m to the south of the excavation.

Anthropogenic deposits

All samples consisted of undisturbed tins for micromorphology and a comparable bulk sample. Locations can be found on Figure 1.

Context	Designation	Grid ref
535	Dark soil	96.85/107.25 at 22.63m O.D.
779	Occupation	96.85/107.25 at 22.49m O.D.
6365	Dark soil	93.43/107.25 at 20.12m O.D.
6387	?Occupation	93.43/107.25 at 19.87m O.D.
6386	?Occupation	93.43/107.25 at 19.61m O.D.
3711	Ash dump	88.65/153.27 at 19.45m O.D.
5617	Bone dump	80.18/135.63 at 19.23m O.D.
3758/6235	Ash dump/soil	80.08/147.15 at 18.46m O.D.
5983	Ash dump	80.08/147.15 at 18.27m O.D.
2859	?Occupation	48.72/159.20 at 15.87m O.D.
2861	Base of ditch	48.40/158.96 at 15.23m O.D.

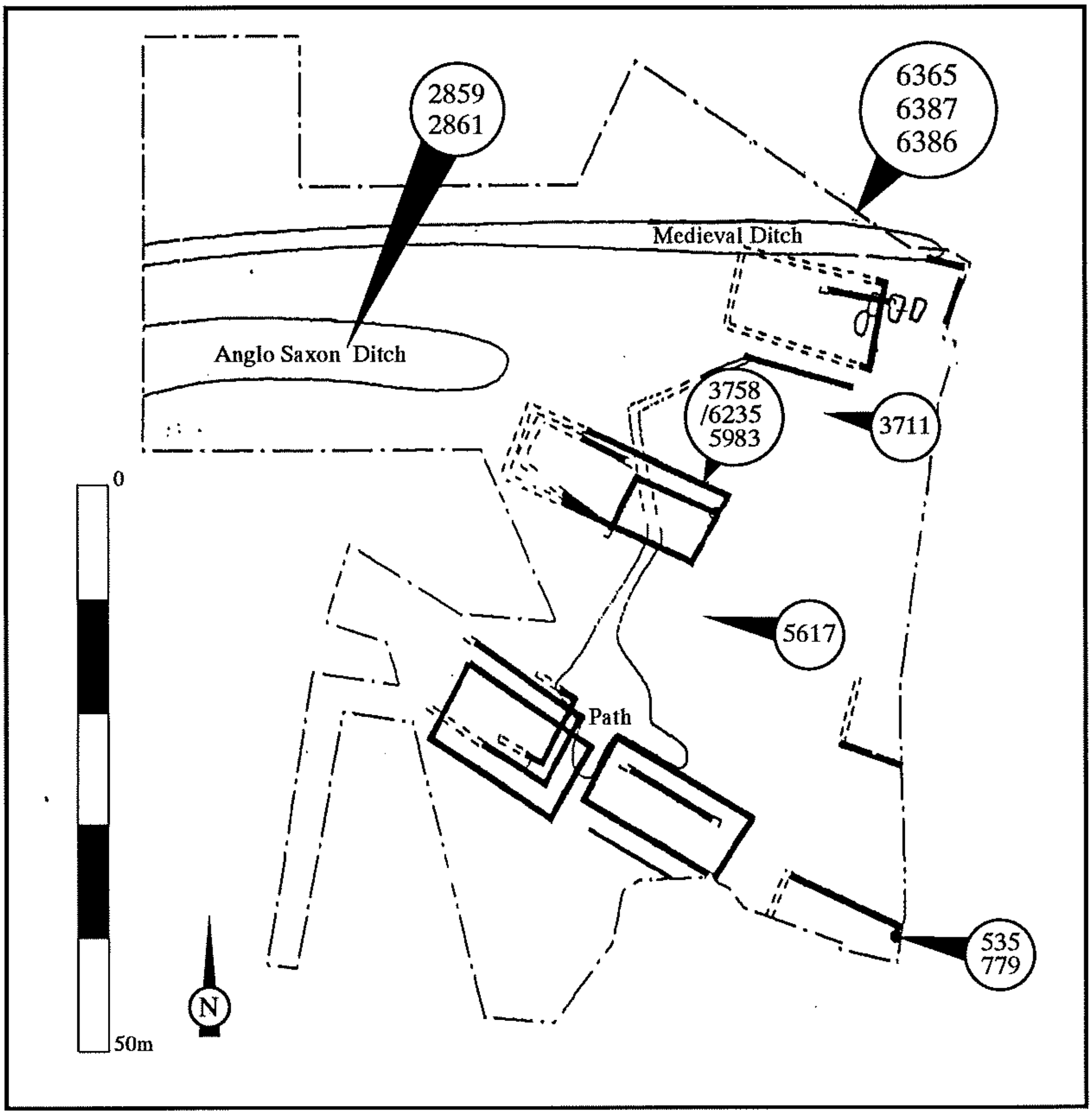

Figure 1
Map of the main features and soil sampling points

4. The Blown Sand

4.1 Introduction

The blown sand is an important element of the archaeological story since it forms the background to all the deposits and may, of itself, provide the basis for understanding the taphonomic conditions. Initial tests with HCl showed that it had a calcareous component - an unsurprising result in view of the fact that none of the local soils developed on it were podzolised. Since a high $CaCO_3$ content could be the cause of the bone preservation, it was decided to make a full study of the nature of the calcareous elements in order to further understand their dynamics.

4.2 Laboratory Studies

Particle-size analyses of the 5 sand samples were carried out using sieves and a Sedigraph 5000ET (see Fig 2). These curves are a standard representation of the full range of mineral particle sizes found in each sample, and a discussion of interpretation methods can be found in Canti (1991). It is immediately apparent that the materials are almost identical, despite the vertical and lateral variations in the sampling points.

Regular sieve fractions were examined and tested for their particulate $CaCO_3$ content. This was carried out by two means. The coarser fractions down to 45um were submerged in HCl and viewed reacting under the microscope. For fractions down to 400um, it was possible to do rough identifications of the grain type reacting and these are recorded on Figure 3. The finer fractions down to 20um were counted under polarising light, where calcite and calcareous materials are easily identified by their high birefringence and extreme variations in relief on stage rotation. Inherent differences in the two techniques were investigated in the 45 and 38um fractions of S3, but the errors were found to be only 2-3%.

The results for all the samples are shown on Figures 3 and 4. It can be seen that while both deep samples (Figure 3) and shallow samples (Figure 4) have increasing percentages of calcite below about 150um, only the deep samples show the increasing spread up to the maximum grain size of about 2.00 um. The difference between the types of calcareous materials is also highly significant. The coarse distributions on Figure 3 are made up of limestone, chalk calcareous sandstone, tufa etc. - clearly a detrital assemblage blown in with the original sand; the fine calcareous material in both shallow and deep sands, however, consists almost entirely of individual crystals. These latter are varied in shape but often consist of long or jagged grains, unlikely to survive a long phase of aeolian transport without wear (see Plate 1).

Two fundamental hypotheses can be put up to explain this pattern of distribution:-

1) The calcareous materials are part of an even distribution that was diluted by addition of the quartz-dominated sand. This would imply two original sources for the aeolian material, and is untenable if the fine calcite is authigenic. With the coarse quartz grains (>200um), travel by atmospheric suspension is only possible under extreme wind conditions (Catt 1988) and they would typically travel more by saltation. The fine calcite could not have undergone such a process and can, at most, have undergone only a light phase of suspended transport, perhaps simultaneously with the saltation of the coarse particles. These complications weigh against the theory, but it has the merit of clearly explaining the bowl-shaped distribution having its nadir at the point of maximum grain percentage i.e 200-300um.

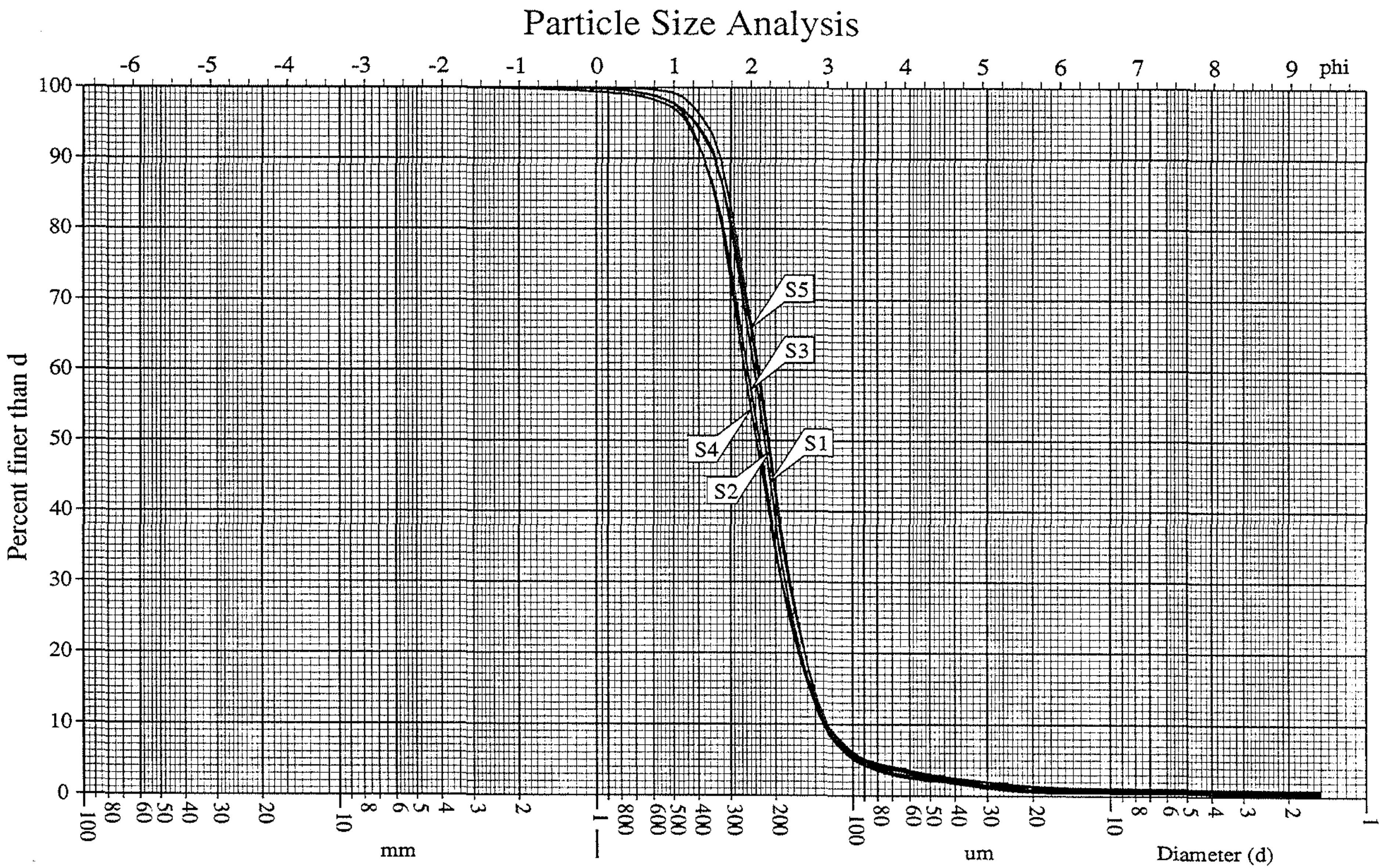

Figure 2.

Particle size analyses of all the blown sand samples.

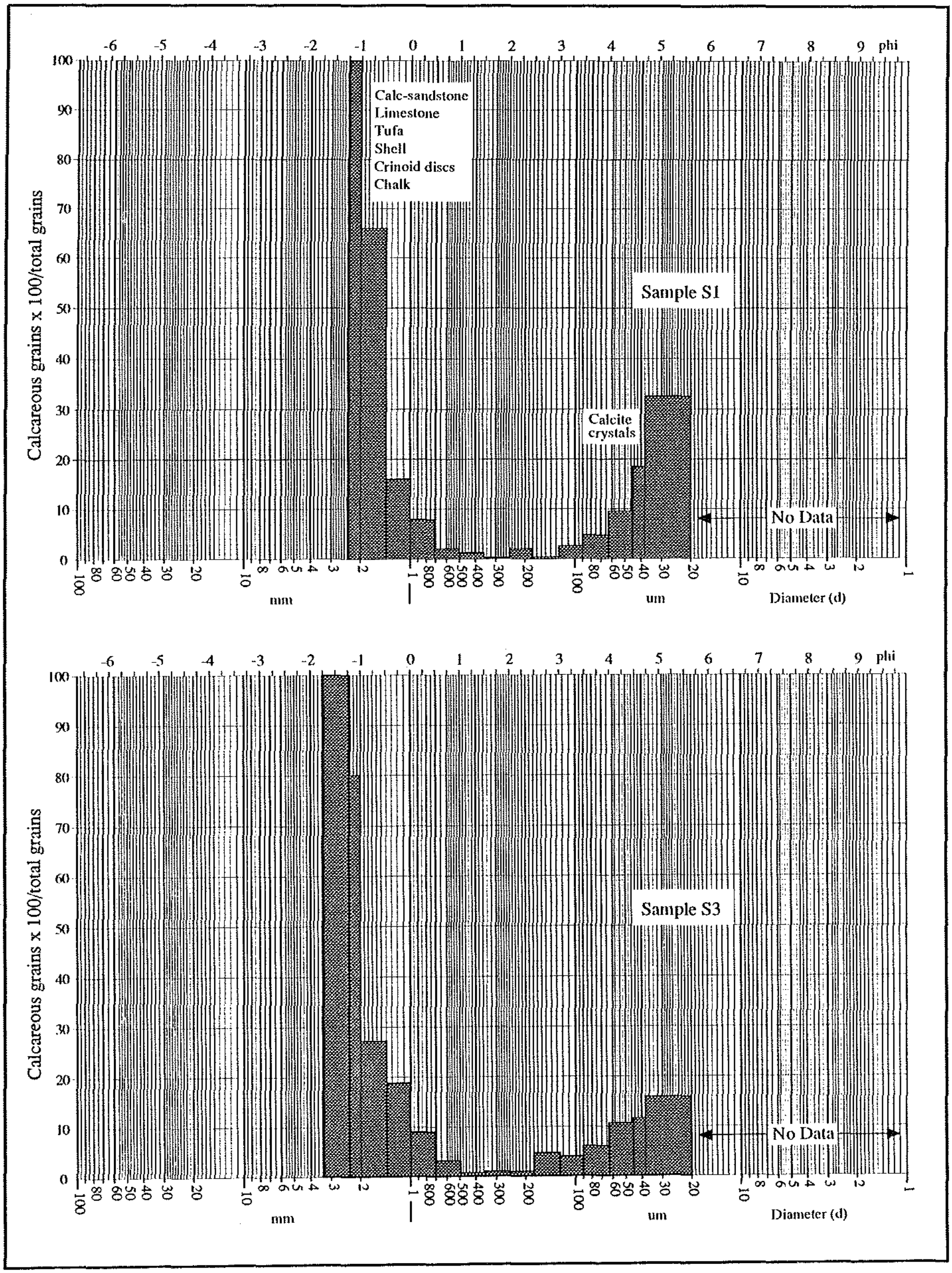

Figure 3
Percentage of grains found to be calcareous in samples 1 and 3.

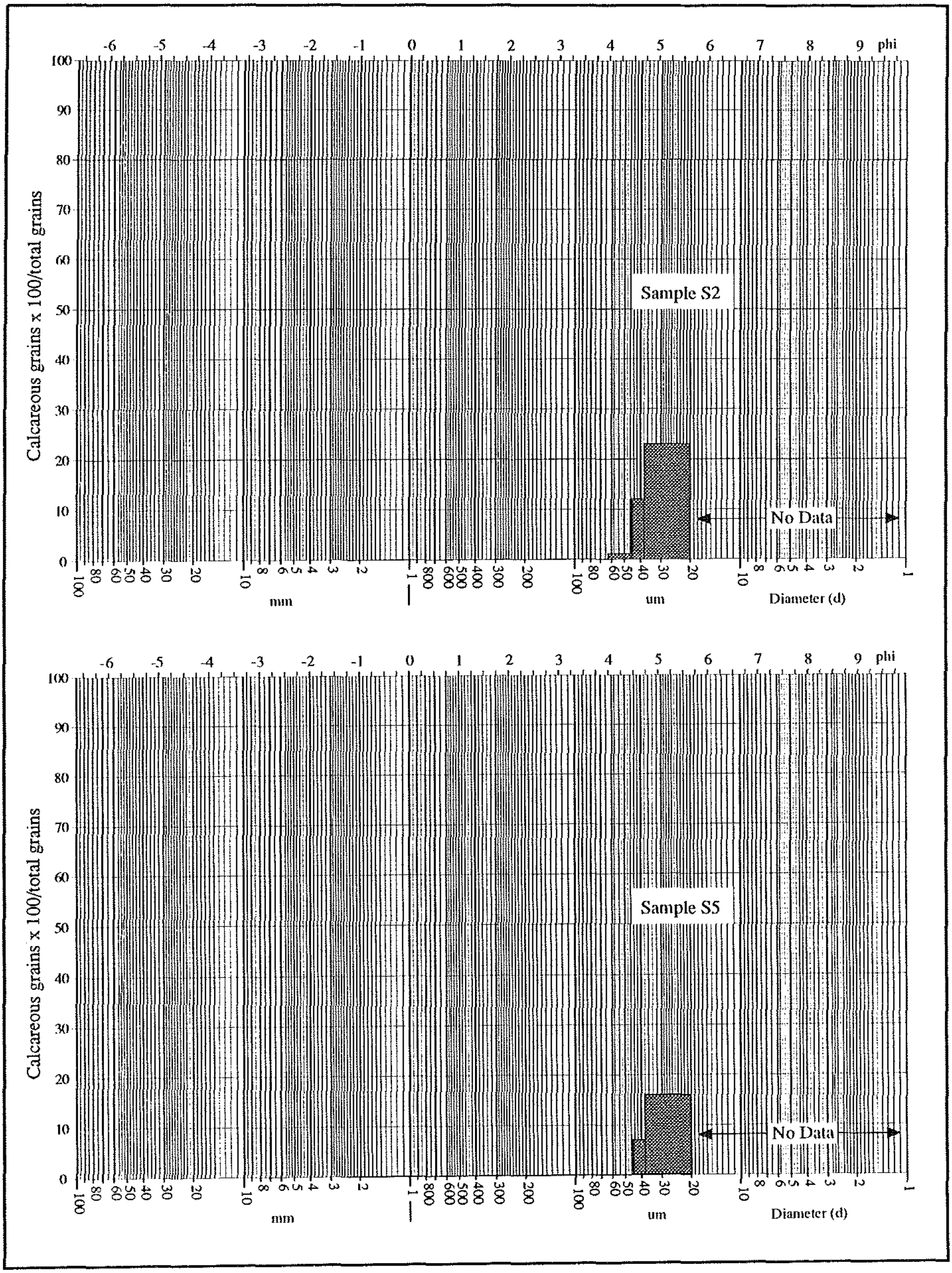

Figure 4
Percentage of grains found to be calcareous in samples 2 and 5.

2) The calcareous distribution is a function of dissolution dynamics. This hypothesis works well for the left-half of the distributions on Figure 3. Here, detrital calcareous components are getting smaller due to dissolution and have almost disappeared around 300um. On Figure 4, the detrital materials have completely dissolved, in keeping with their stratigraphic positions nearer the surface. The problem with this hypothesis is explaining the apparent growth of the fine calcite on the right-hand side of these diagrams. It is pertinent here to note that the interstitial spaces between the sand grains (assuming perfectly packed 300um spheres) would offer a maximum size for crystal growth of about 124um. No authigenic-type calcites were seen in the fractions above this size. Whether they truly grew in-situ or not, their presence cannot pre-date, or be contemporaneous with, the leaching of the detrital material, since the fine grains would obviously dissolve first in the leaching environment.

Neither hypothesis is completely satisfactory. There may be other factors at work, for example a difference in dissolution rates between the limestone, tufa etc and the tighter structured crystals. The other main possibility is that the shifting nature of the sand puts coarse and fine materials out of phase on a microscale, the detail being lost in bulk sampling. The pH values (see Fig 5) reflect accurately the broad concept of near-surface samples being more leached; those with no left-hand side to their distributions (Fig 4) are more acid ca. pH 6.6, while those with coarse calcareous components (Fig 3) are more alkaline ca. pH 7.6.

Sample	Type	pH
S1	Deep sand	7.6
S2	Shallow sand	6.4
S3	Deep sand	7.5
S4	Shallow sand	6.6
S5	Shallow sand	6.6
535	Dark soil	6.8
779	Occupation	6.8
6365	Dark soil	7.3
6387	?Occupation	7.8
6386	?Occupation	7.8
3711	Ash dump	8.2
5617	Bone dump	7.8
3758/6235	Ash dump/soil	7.5
5983	Ash dump	7.9
2859	?Occupation	6.7
2861	Base of ditch	7.4

Figure 5
pH values for all the samples (in distilled water).

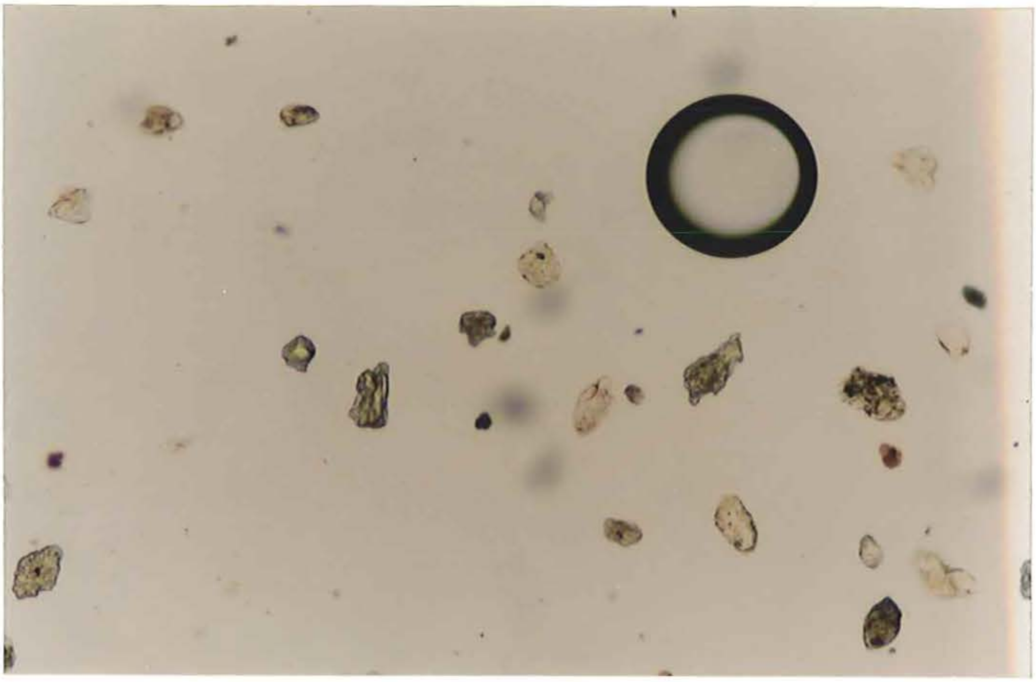

Plate 1 70um

Fine calcite crystals (darker grains near centre) from S1. Note sharp edges of grain beneath large spherical air bubble. Plain polarised light.

4.3 Summary

For the purposes of understanding the taphonomy at Flixborough, the sand can be seen as a weakly calcareous material, constantly undergoing leaching, but not yet having developed any significant acidity. The sand's accretion since Saxon times means that a constant supply of calcium carbonate has been added to the top of the profile at regular intervals. This has arrived in the form of hard limestones, soft limestones including chalk and tufa, shell and calcareous sandstone. At some stage, calcite appears to have grown in-situ, but very local derivation of these crystals cannot be absolutely ruled out.

It is the calcareous additions which are preventing the acidification that would otherwise be expected on such a coarse parent material.

5. The Anthropogenic Deposits

5.1 Introduction

The whole range of anthropogenic deposits at Flixborough includes purely man-made dumps through to semi-natural ditch fills. They have been studied chiefly through micromorphology which involves impregnating undisturbed samples with resin, sectioning them down to 30um thickness, and examining them under a petrological microscope. Particle-size analyses were also carried out for additional information on the make-up of the bulk materials.

5.2 Particle-size Analyses

The particle-size analyses of all the deposits are presented in bulk form on Figure 6. This enables gross comparisons of the types of mineral background in the materials. It can be seen that all of the deposits are strongly influenced by a blown sand content - chiefly represented by the steep part of the curve around 200-300um. The coarse ends (500um upwards) are rather variable due to stone, bone, mortar and slag mainly in 5617, 3711, 3758/6235 and 5983. At the fine end, the ash dumps (3711, 3758/6235 and 5983) have all received a large proportion (approx. 20%) of fine silt (15-2um) from the ash itself; this is also true, to a lesser extent, of the occupation horizon 6387. The soil on top of the Anglo-Saxon ditch (2859) and the uppermost soil layer (535) have received the least of these human inputs and their curves match the blown sand closely. What little variation there is appeared in both these samples to consist chiefly of finely divided bone powder. This material was found in most of the fine sieve fractions (125-45um) of all samples, and dominated the finest grades (63 and 45um) in many.

5.3 Micromorphology

The 11 thin sections produced are shown in colour or monochrome at about 2.5x natural size in Plates 7-17 see page 19. These images are intended as a reference for the discussion, a location for the colour plates, and to show the general trends of soil, dump, artifact and ecofact proportions in each one. As a rule, this suite has provided little <u>sequential</u> information, owing chiefly to the lack of fine fabric in most samples. Information from the objects found and (where possible) the fabrics they are found in will now be discussed on a slide-by-slide basis.

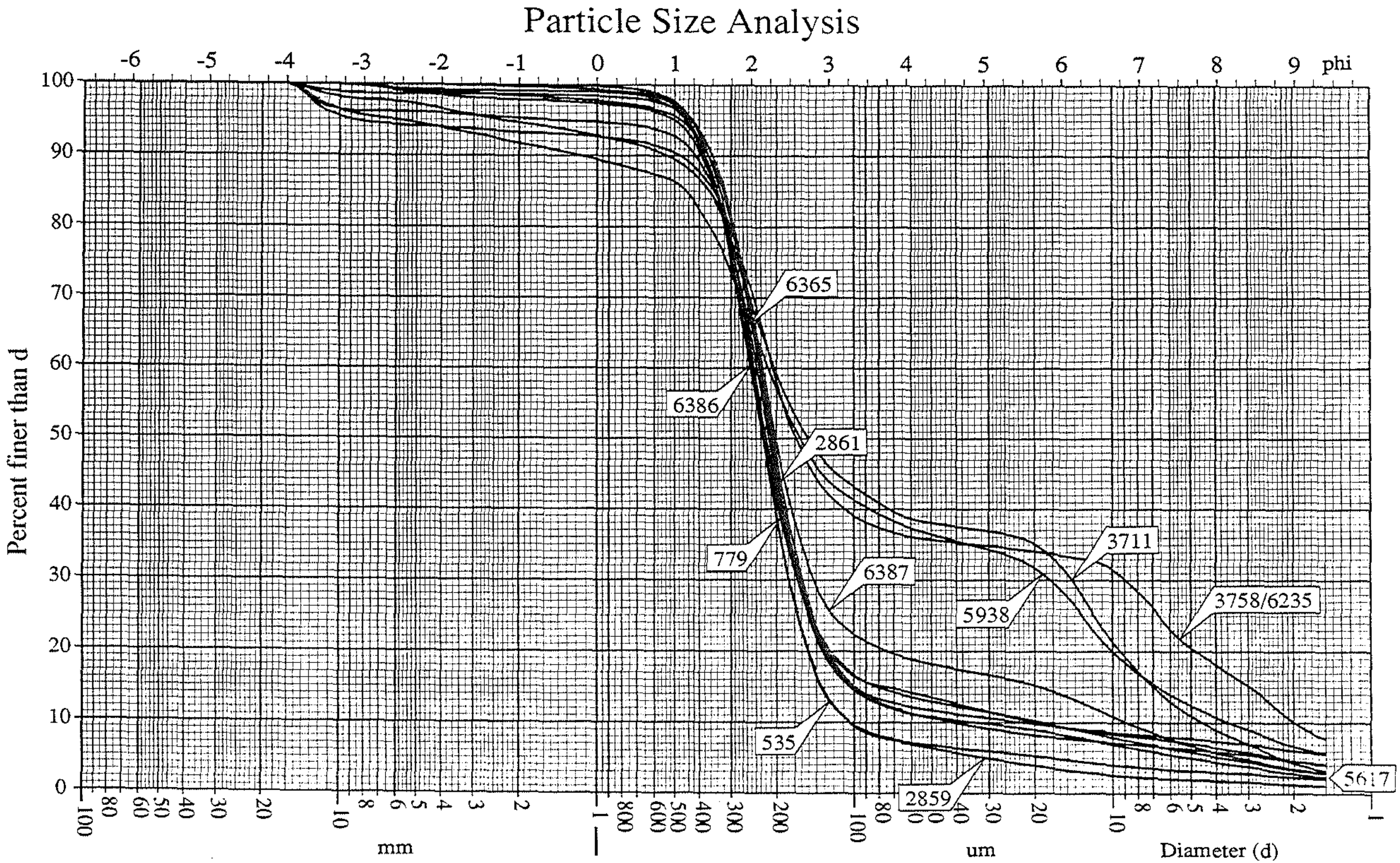

Figure 6.

Particle size analyses of all the anthropogenic deposits.

535 and 779 (Plates 7 and 8)

These two samples, from the eastern edge of the excavation are designated as occupation horizon (779) and overlying dark soil (535). The dark soil is overlain by the post-Saxon clean blown sand which builds up through one more modern soil layer before the current surface is reached around 1.8m above. Both slides are exremely low in anthropogenic material, although both contained at least one piece of highly weathered bone. The coarse sandy matrix is devoid of fine components, except in the case of a few soil fragments probably blown in from local sources. Neither slide contained any calcareous components, so it is possible that bone has weathered out from at least the upper soil (535).

2859 and 2861 (Plates 9 and 10)

These are from the Anglo-Saxon ditch on the North side of the site. 2859, the sealing soil is the most featureless of the samples taken. As was suggested by its particle size analysis, it contains no material other than blown sand and a weak humus content, not even the small amounts of charcoal typical of 535. In this context, it seems likely that the final stabilisation of the ditch fill occurred in the absence of human activity.

At the base of the ditch fill, the primary soil lining the sides (2861 Plate 10) is much richer. The basic fabric is non-calcareous sand, but many areas show individual grains having coatings of a clay-sized orange material. This has been found in patches in a number of slides and a clue to its possible origin is to be found in a highly weathered bone fragment in 2861 (Plate 2).

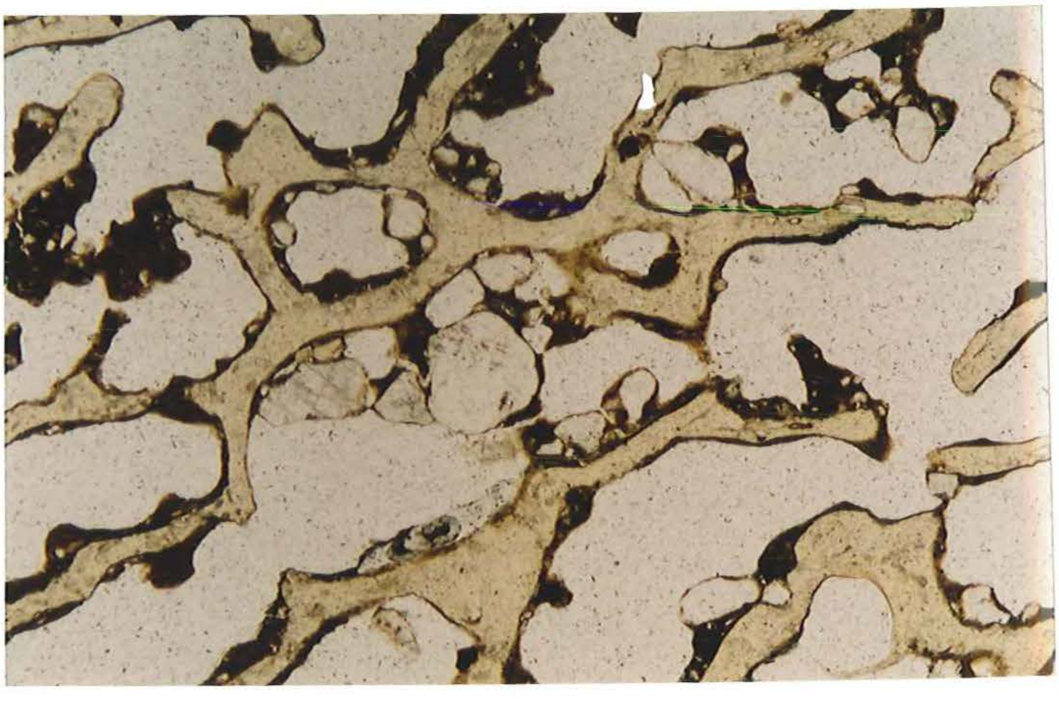

Plate 2

Highly weathered bone from 2861. Pale network=bone; dark adhesions = orange clay, possibly derived by weathering of the bone (see text); light background = voidspace. Plane-polarised light.

The orange material can be seen covering most surfaces of the bone, even the most internal enlarged pores. It seems possible that the clay-sized aggregates are breakdown products of the bone, perhaps forming clays together with iron and silica in the soil water. The clay is more thickly deposited inside this bone than elsewhere on the slide, suggesting perhaps that it is fairly mobile, but is being protected from translocation by being contained in the remaining bone structure. Once the bone had completely gone, the clay would then be free to be mobilised to form the coatings found elsewhere. This view cannot be certain, because the bone fragment may have been blown in after a period of burial in nearby heavy soils where it picked up translocating clay. It would also not be an explanation for all the mobile clay in the slide; there are other areas where clear examples of partially broken-down imported soil fragments can be found. However, the coatings produced by these are typically associated with a large proportion of silt grains, probably implying mudstone-derived or alluvial sources for the aggregates.

On the bottom right of the slide, there is a large intact piece of bone, also coated (although less thickly) in the orange material. The proximity between the highly weathered and the intact fragments may be due to the relative porosity of the bone types, but an implication could be that this context is acidifying only patchily. Although there is a general lack of calcareous elements, the occasional decaying shell or tufa fragment can be found, and this upholds the view that it was calcareous until relatively recently.

Little has been preserved that could elucidate the use of this ditch. Macromorphologically, the dark staining appears to have "soaked" into the surrounding sand suggesting that it was temporarily wet, but no microsedimentary structures have been preserved in the thin-section. The few fine fabric aggregates that do occur are not due to sedimentary sorting, but are lumps of local soil. Periods of bank collapse and refilling with sand appear to have occurred, alternating with dark bands suggestive more of dirty water than periods of soil development. If the sand was as erosive as it is today, little time would be available for plant establishment in such a ditch before it became refilled.

6365, 6387 and 6386 (Plates 11, 12 and 13)

With 6365 as a capping soil, 6387 and 6386 as possible occupation deposits, this sequence is comparable to 535 and 779 (previous page).

The upper soil 6365 consists of sand with very few of the orange coatings discussed above. Of three large bone fragments present, only one is slightly weathered; again it is the larger pores that are weathering out, and again the coatings are beginning to develop. The pH is similar to 2861 at ca. 7.5, and it is suggested that this context is at a similar stage of acidification. It is less advanced in this respect than its possible counterpart 535. It has been buried under a more clayey deposit in the cultivated area to the north of the dune and will therefore have generally received a more alkaline throughput. Two large limestone/calcareous sandstone fragments are present in the slide along with a small amount of charcoal.

6387 has a partially weathered woodash matrix denoting a status somewhere between the clean sands so far discussed and the ash dumps, as reflected in the particle size analyses. After leaching of the more soluble alkalis, woodash leaves a silty calcium carbonate residue which gradually dissolves under non-calcareous soil water conditions. Within this matrix there are many fragments of ceramic, charcoal, and limestone as well as a portion of bird's egg and decaying slug granules (calcareous excretions of the Roundback slugs - Arionidae). The top centimetre of the slide is dominated by thermally shocked quartz grains (Plate 3). This suggests some form of very rapid cooling, such as water poured on a fire.

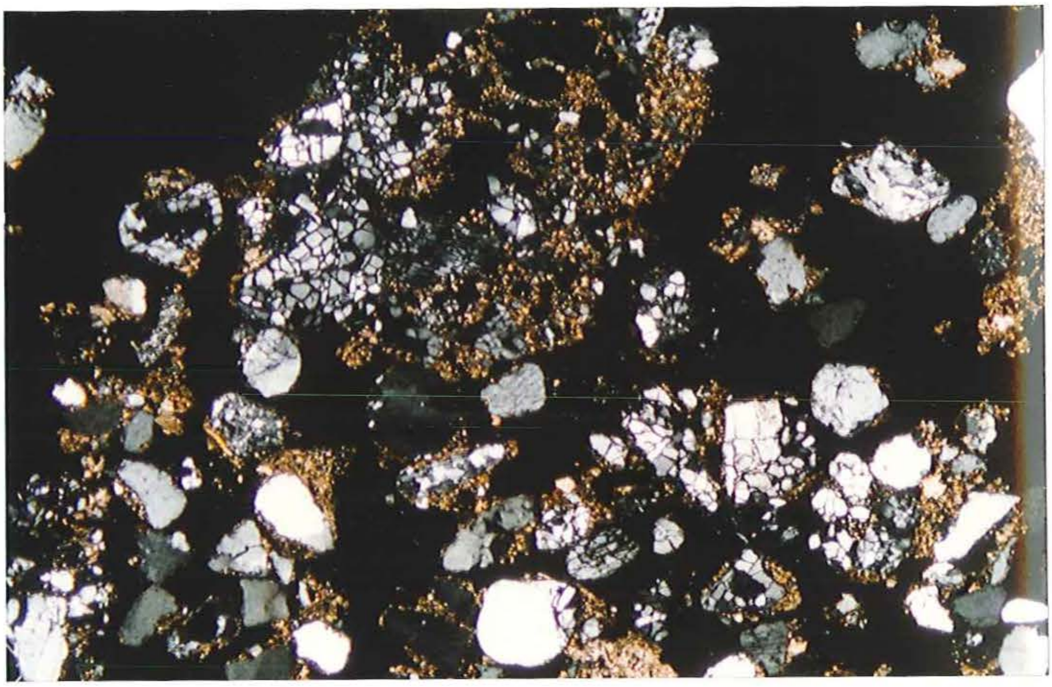

Plate 3 500um

Thermally-shocked quartz grains from the top of 6387. The affected grains are those with a network of fine cracks. The brownish fine matrix is CaCO3 ash-residue. Cross-polarised light.

6386 is a similar layer to 6387 in most respects. There appears to be a higher sand to woodash ratio in 6386, leading to its having a more regular blown sand-type of particle size curve. However, the thin section barely reflects this difference and all the same sorts of objects are found in the matrix. One unusual part is an area of fused wood or possibly grass ash on the left hand side of the slide, see Plate 4.

It is interesting to note that neither 6386 or 6387 contain any bone. The excellent preservation associated with ash in other samples means that, aside from chance, systematic removal is a possibility.

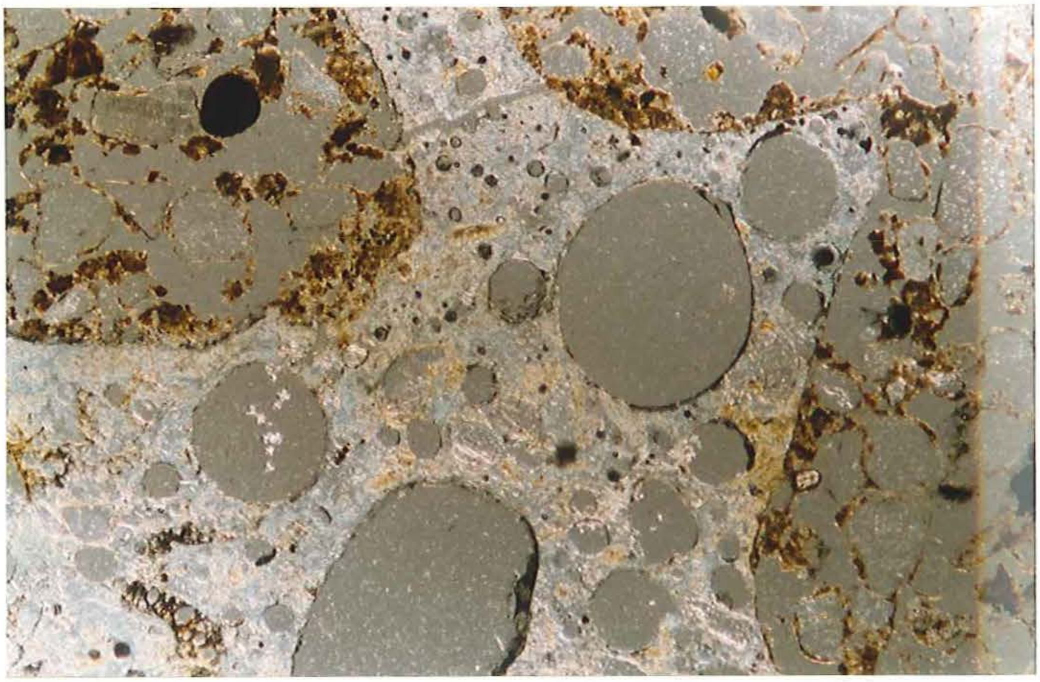

Plate 4 500um
Fused ash from 6386, showing characteristic vesicular structure. Shaded plane-polarised light.

Plate 5 500um
Bone fragment (Dark with faint pale streaks) in fine ashy matrix (pink -brown) of 3711. Compare with Plate 2 for preservation. Cross-polarised light.

3711 Plate 14

3711 was an ash deposit possibly from ovens to the north. The matrix (see Plate 5) is extremely rich in calcium carbonate from the ash along with charcoal, shell, sandstone, limestone, bone, and two pieces of shell-tempered pottery. All calcareous elements are near perfect in their preservation due to the calcareous matrix and high pH (8.2). Bone is, therefore, almost pristine and has none of the orange clay adhering to its surfaces.

3758/6235 and 5983 Plates 15 and 16

3758 was designated as an ash dump over a soil 6235; 5983 was the ash dump below this soil. Within 3758/6235, there should be a division between the two materials - this has not been found. Parts of the lower half of the slide are rich in dark fused masses of ash and finely divided charcoal, while the upper half is dominated more by a pale calcareous ash matrix, but it is not a strong division as can be seen on Plate 15. There is clearly no evidence of an underlying soil in this slide. The ash matrix contains large amounts of charcoal, micritic calcareous aggregates, tufa, sandstone, Arionid granules, fused ash and shell fragments. The large central charcoal can be positively identified as oak (Quercus spp.) and some of the upper fragments probably are as well (Carruthers pers.comm.). Only small quantities of bone are present and these show the same high degree of preservation as those in 3711.

5983 is considerably different to the other ash dumps in that its contents are nearly all fused. The ashes are mixed with both burnt and unburnt soil, as well as plant material, ceramic and stone. Bone preservation is generally good, but some of the bone is burnt, making comparison with other slides problematic. Much (but not all) of the fused area has fine orange-clay coatings similar to those found on the weathering bone (Plate 2); bone itself can still just be made out amongst the melted mass (Plate 6), but the extent of its proportions before heating cannot be assessed. The isotropy of the resultant glasses, and the low birefringence of whole bone are too similar optically for any sure identification. However, it is interesting to note that the bone fragment in Plate 6 cannot have been heated to more than 400-500 degrees C, as it has not developed the high birefringence associated with the mineral transformations that occur above this temperature (Courty et al. 1989).

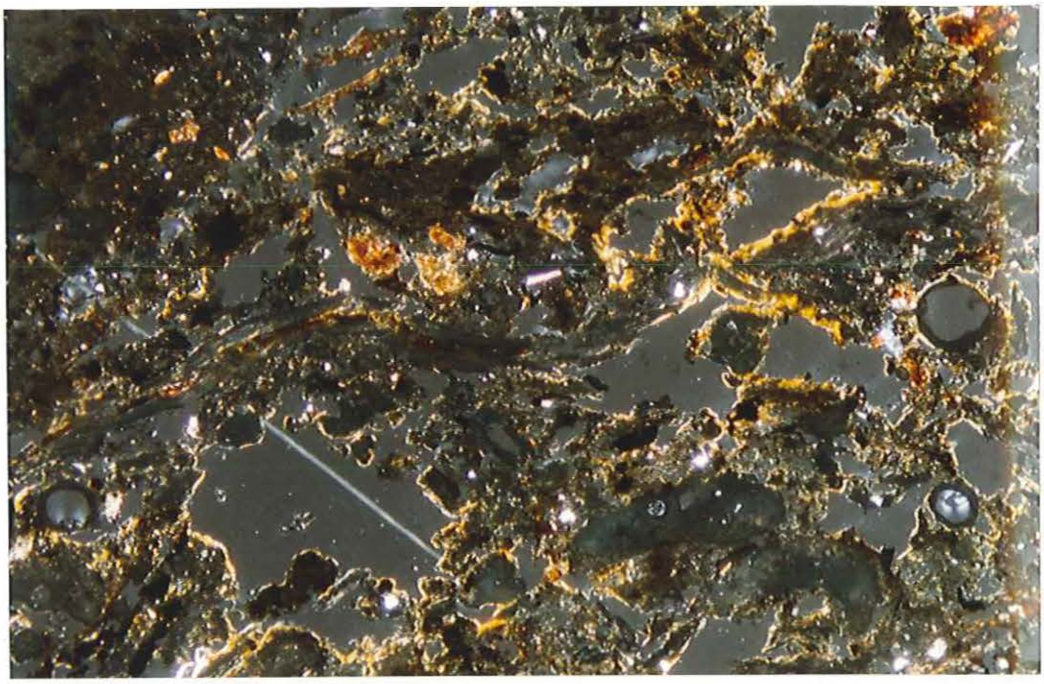

Plate 6 — 500um

Bone (Brown-cored linear feature undulating across centre left) in the fused ash of 5983. Note orange clay lining pores. Cross-polarised light.

5617 Plate 17

5617 is another sample with a weathered ash and sand matrix. Bone preservation is good and there are no clay coatings on the fragments. With the pH at 7.8, other calcareous materials such as slug granules are in a perfect condition. The slide contains moderate amounts of charcoal and soil aggregates as well as sandstone, chalk, flint and mortar.

5.4 Summary

The results from the study of the anthropogenic deposits show the clear effect of woodash in maintaining a high pH and thus promoting the preservation of calcareous components including bone. In this respect, both calcium carbonate (ash, limestone, chalk,tufa, Arionid granules, shell) and calcium phosphate (bone) are similarly affected by the soil water alkalinity. Phosphate itself has not been examined, since measuring its levels in soils consisting partly of bone powder, relative to the clean sand containing no collophane or other phosphatic components, would be pointless. There must be a bone preserving effect, amongst the lower stratigraphic layers receiving water that has picked up ions from the bone above; it will be less effective at high pH, however, because of the tendency of phosphate ions to form calcium phosphates and phosphate-carbonates under alkaline conditions (Limbrey 1975).

The nature of the clay-sized coatings found on weathered bone is beyond the scope of this study, but would be a useful area for further research. Specifically, if it is the result of bone decay, then its presence as grain coatings in 2861 may represent the products of large amounts of bone now vanished. This could relate to the phenomenon of soil silhouettes (Keeley et. al. 1977), where decaying bone appears to attract manganese from the surrounding soil.

6. Discussion

The issue of the bone preservation at Flixborough can now be seen as a coincidental relationship between two factors - the woodash itself, and the calcareous component of the blown sand. Constant accretion of the sand has meant that the residual calcium carbonate in the ash has never had to undergo the acid leaching that would be expected on such a substrate if it were pure quartz. This has slowed down its removal, even in layers relatively close to the surface, and allowed pH values as high as 8.2 (though more typically in the 7 - 8 range) to be maintained. The sheer volume of ash is therefore another part of the equation, as is the unknown factor of the speed of deposition. This latter question is important for its implications on open-air pre-weathering of the bone, which would presumably act to hasten its breakdown. There is no evidence in any of the slides for lengthy surface exposure of the ash layers. Rainfall and wind would be expected to create sorted layers and microsedimentation features (e.g crusts), which would survive burial as long as they were not disturbed by soil fauna. Site staff reported minimal earthworm activity, but moderate disturbance from animal burrows. This would be unlikely to destroy all evidence of sedimentary effects and it can reasonably be concluded that, in the sampled areas, the ash was laid down in deep layers rather than slowly accumulating. How the bone fits in to this pattern depends rather on its origin. If it was simply domestic waste, then it would have been sporadically thrown into the accreting dumps. If, however, it was an integral part of some process, the large quantities might have necessitated deliberate emplacement below the surface. Burial in what appear to have sometimes been very hot ashes (especially 5983), would also have discouraged scavenging animals, at least for some of the time.

The peculiarities of the waste dumps examined here have provided a snapshot of taphonomic conditions where leaching has been reduced to a minimum. Thus, we are effectively viewing a site whose condition, at least in some aspects, is more typical of a far shorter period of burial. It is worth considering how, in the absence of the sand, much of the detail would be lost to acidity and reduced to a series of mainly charcoal layers.

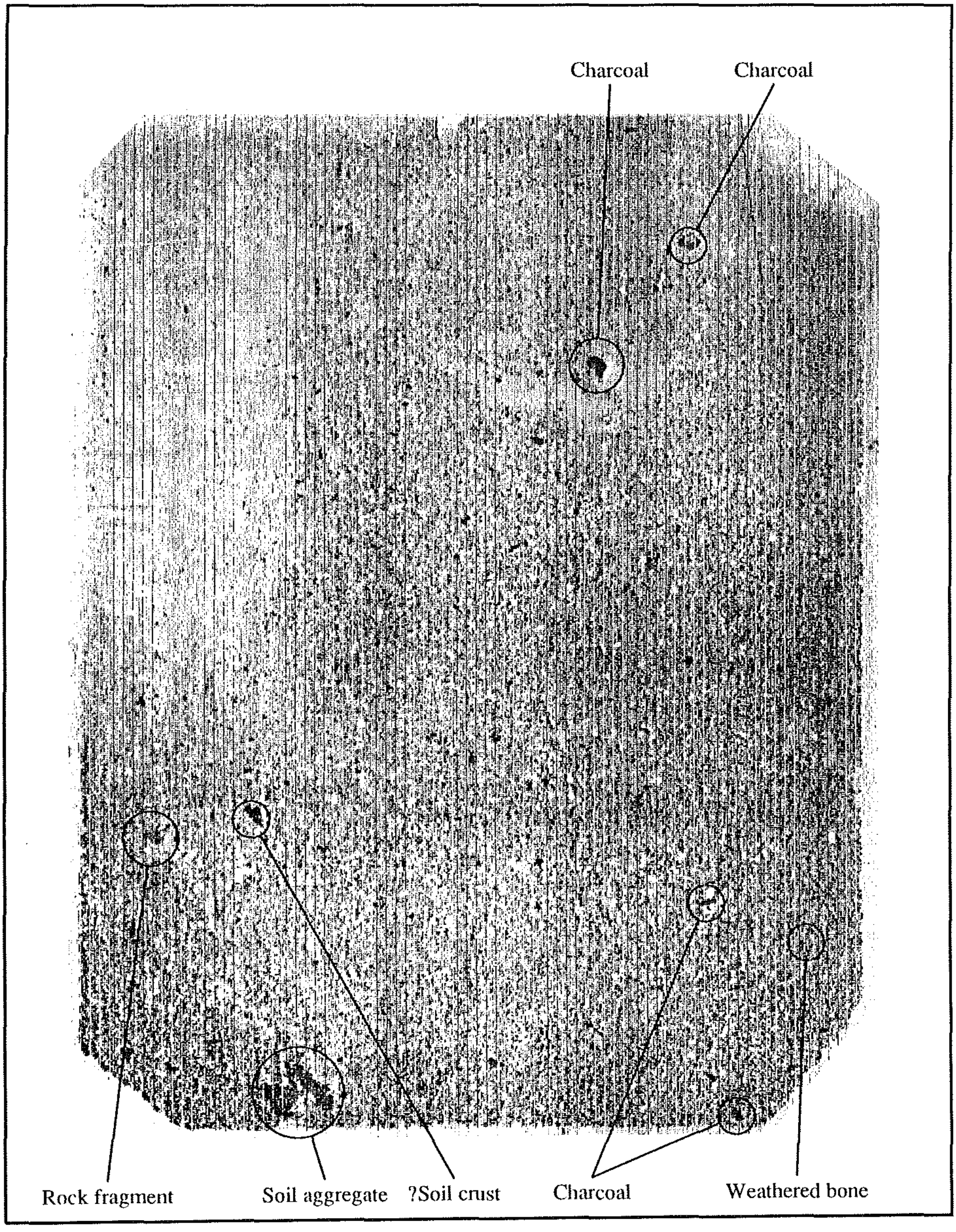

Plate 7
Whole slide of context 535.

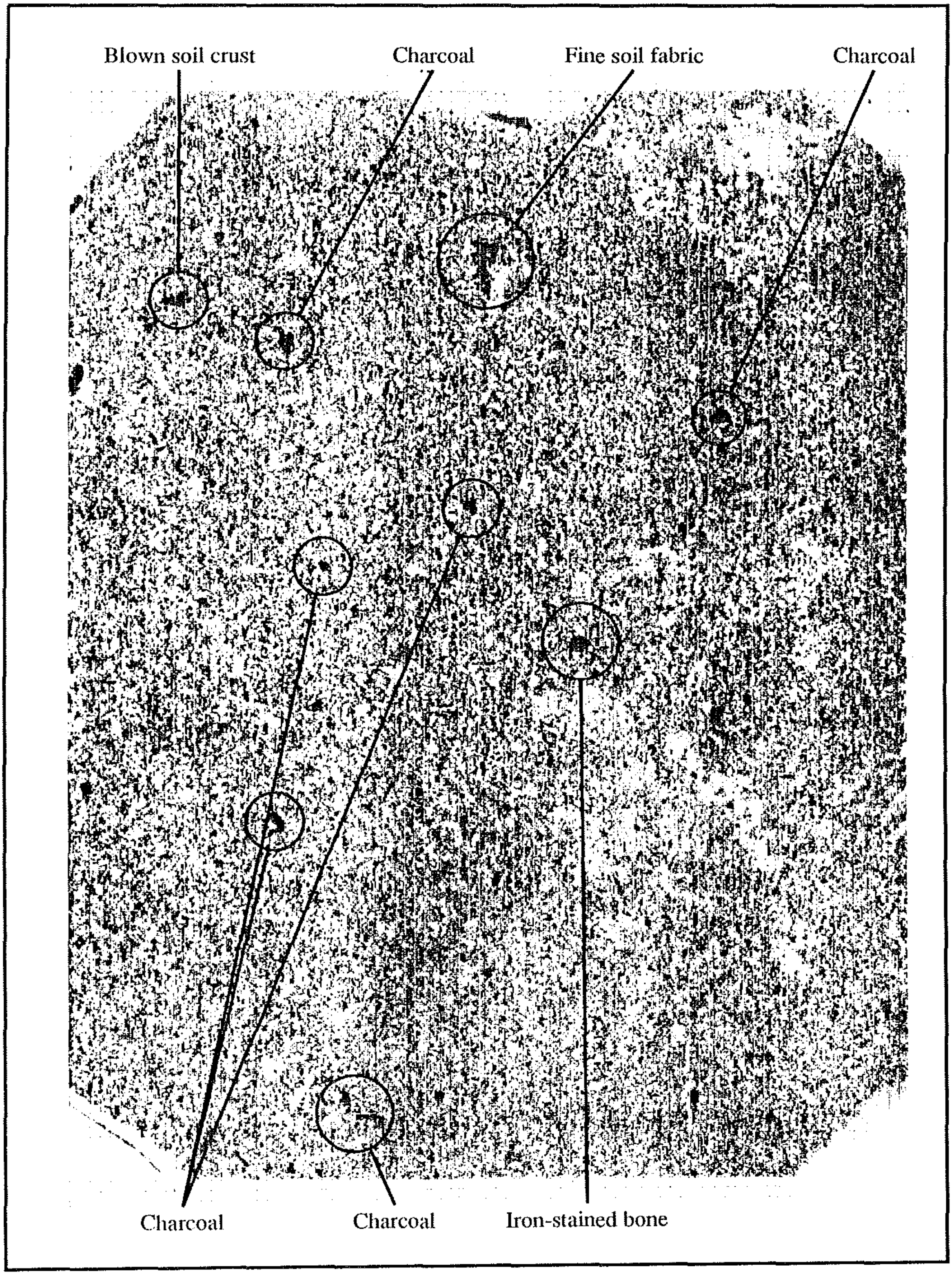

Plate 8
Whole slide of context 779.

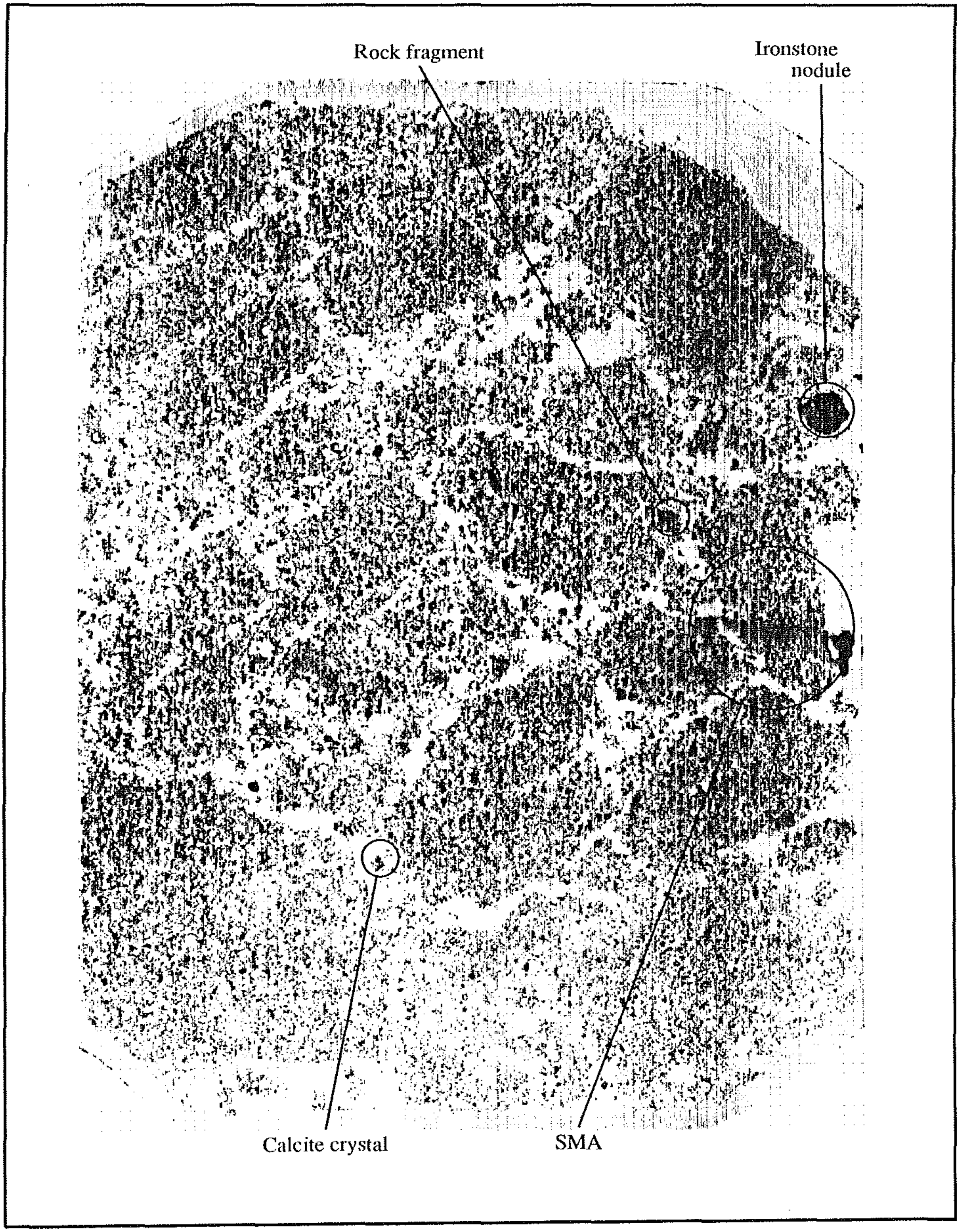

Plate 9
Whole slide of context 2859. SMA = Slide manufacture artifact

Acknowledgements

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APPENDIX 1

Particle Size Analyses.
Values are weight% finer than diameter in left hand column.

Diameter	535	779	2859	2861
16.00mm	100.00	100.00	100.00	100.00
11.30mm	100.00	100.00	100.00	99.08
8.00mm	100.00	99.85	100.00	98.70
5.70mm	100.00	99.39	100.00	98.66
4.00mm	100.00	99.24	100.00	98.67
2.80mm	99.96	99.19	99.99	98.67
2.00mm	99.89	99.13	99.91	98.65
1.40mm	99.86	99.09	99.89	98.57
1.00mm	99.79	99.01	99.79	98.42
707.10um	99.44	98.62	99.37	98.09
500.00um	97.77	96.73	97.21	96.83
353.60um	88.66	86.71	87.26	90.06
250.00um	62.10	59.42	59.43	68.25
176.80um	28.92	33.36	29.28	37.07
125.00um	12.92	19.64	13.17	19.34
88.40um	8.69	15.63	8.45	13.89
62.50um	7.29	14.40	7.12	12.35
44.20um	6.57	13.05	6.02	11.43
31.30um	6.02	11.67	5.03	10.70
22.10um	5.48	10.42	4.13	10.04
15.60um	4.82	9.40	3.33	9.36
11.00um	4.13	8.57	2.66	8.74
7.80um	3.62	7.95	2.24	8.28
5.50um	3.23	7.32	1.95	7.86
3.90um	2.94	6.44	1.74	7.38
2.80um	2.66	5.60	1.54	6.85
2.00um	2.28	4.61	1.25	6.08
1.40um	2.06	4.04	1.08	5.61

Textural Details
These values are the normal weight percent in each of the class groups. See Appendix 2 class details.

Coarse Sand	0.97	1.11	1.22	0.98
Medium Sand	60.04	57.34	60.25	51.34
Fine Sand	31.79	27.17	31.54	35.29
Total Sand (S)	92.80	85.63	93.01	87.61
Coarse Silt	1.89	4.18	3.10	2.42
Medium Silt	1.99	2.62	1.87	1.89
Fine Silt	1.03	2.92	0.77	1.92
Total Silt (Z)	4.91	9.72	5.74	6.23
Total Clay (C)	2.29	4.65	1.25	6.17
Texture	S	LS	S	LS

APPENDIX 1 contd.

Particle Size Analyses.
Values are weight% finer than diameter in left hand column.

Diameter	6365	6387	6386
16.00mm	100.00	100.00	100.00
11.30mm	100.00	100.00	100.00
8.00mm	100.00	99.82	99.79
5.70mm	100.00	99.24	99.07
4.00mm	99.97	98.93	98.47
2.80mm	99.88	98.69	98.12
2.00mm	99.73	98.42	97.89
1.40mm	99.59	98.17	97.71
1.00mm	99.34	97.78	97.39
707.10um	98.89	97.18	96.85
500.00um	97.41	95.66	95.11
353.60um	90.16	89.06	86.63
250.00um	66.46	68.17	60.46
176.80um	35.34	40.53	34.35
125.00um	18.78	25.66	20.21
88.40um	13.58	21.27	15.57
62.50um	11.48	19.07	13.76
44.20um	10.25	17.81	12.58
31.30um	9.25	16.83	11.59
22.10um	8.44	15.69	10.59
15.60um	7.80	13.91	9.44
11.00um	7.32	11.51	8.23
7.80um	6.85	9.23	7.16
5.50um	6.37	7.21	6.14
3.90um	5.86	5.70	5.14
2.80um	5.33	4.55	4.27
2.00um	4.61	3.45	3.31
1.40um	4.17	2.87	2.78

Textural Details
These values are the normal weight percent in each of the class groups. See Appendix 2 class details.

Coarse Sand	1.34	1.79	1.65
Medium Sand	53.50	48.24	55.15
Fine Sand	33.81	30.77	29.30
Total Sand (S)	88.65	80.81	86.10
Coarse Silt	3.10	3.67	3.40
Medium Silt	1.74	7.76	3.97
Fine Silt	1.89	4.26	3.14
Total Silt (Z)	6.73	15.69	10.52
Total Clay (C)	4.62	3.51	3.38
Texture	S	LS	LS

APPENDIX 1 contd.

Particle Size Analyses.
Values are weight% finer than diameter in left hand column.

Diameter	3711	3758/6235	5983	5617
16.00mm	100.00	100.00	100.00	100.00
11.30mm	98.52	96.21	97.11	96.82
8.00mm	97.82	94.70	95.58	96.17
5.70mm	97.58	94.27	94.92	96.17
4.00mm	96.59	94.00	93.92	95.99
2.80mm	95.48	93.64	92.87	95.59
2.00mm	94.65	93.29	91.74	95.31
1.40mm	93.86	93.08	90.71	94.97
1.00mm	92.80	92.72	89.51	94.75
707.10um	91.62	92.05	88.11	94.29
500.00um	89.55	90.50	86.44	92.80
353.60um	84.39	85.43	79.37	86.00
250.00um	69.13	70.98	66.11	64.16
176.80um	54.65	51.91	52.73	33.91
125.00um	46.08	41.97	43.89	18.27
88.40um	41.91	38.03	40.19	13.33
62.50um	38.86	36.23	37.56	11.37
44.20um	37.73	35.45	35.89	10.51
31.30um	36.99	34.90	34.52	9.89
22.10um	35.89	34.30	32.68	9.23
15.60um	31.78	33.50	28.45	8.32
11.00um	23.35	32.37	21.46	7.24
7.80um	16.79	28.04	16.67	6.21
5.50um	11.90	21.70	13.17	5.24
3.90um	8.83	17.89	10.61	4.37
2.80um	6.55	14.45	8.64	3.60
2.00um	4.31	10.12	6.69	2.76
1.40um	3.11	7.61	5.64	2.28

Textural Details
These values are the normal weight percent in each of the class groups. See Appendix 2 class details.

	3711	3758/6235	5983	5617
Coarse Sand	4.05	1.93	4.66	1.58
Medium Sand	33.48	36.09	33.19	52.97
Fine Sand	21.61	23.27	21.47	33.65
Total Sand (S)	59.13	61.29	59.31	88.20
Coarse Silt	3.47	2.19	5.84	2.36
Medium Silt	23.84	12.05	19.68	3.71
Fine Silt	9.01	13.63	7.88	2.85
Total Silt (Z)	36.32	27.86	33.40	8.91
Total Clay (C)	4.55	10.85	7.29	2.89
Texture	SL	SL	SL	S

APPENDIX 1 contd.

Particle Size Analyses.
Values are weight% finer than diameter in left hand column.

Diameter	S1	S2	S3	S4	S5
16.00mm	100.00	100.00	100.00	100.00	100.00
11.30mm	100.00	100.00	100.00	100.00	100.00
8.00mm	100.00	100.00	100.00	100.00	100.00
5.70mm	100.00	100.00	100.00	100.00	100.00
4.00mm	100.00	100.00	100.00	100.00	100.00
2.80mm	100.00	100.00	99.97	100.00	100.00
2.00mm	100.00	100.00	99.85	100.00	100.00
1.40mm	99.99	100.00	99.67	99.99	99.97
1.00mm	99.92	99.99	99.41	99.83	99.86
707.10um	99.44	99.90	98.92	99.34	99.46
500.00um	97.78	99.26	97.14	97.77	97.84
353.60um	91.25	93.37	86.75	86.37	90.77
250.00um	63.19	67.06	57.23	54.41	65.93
176.80um	26.94	30.85	24.97	25.43	29.73
125.00um	8.76	9.19	9.21	9.78	9.82
88.40um	4.11	4.23	4.66	5.02	4.15
62.50um	2.95	3.44	3.35	3.72	2.60
44.20um	2.02	2.72	2.29	2.63	2.01
31.30um	1.21	2.06	1.34	1.64	1.61
22.10um	0.63	1.52	0.69	0.95	1.33
15.60um	0.43	1.21	0.46	0.74	1.16
11.00um	0.42	1.03	0.44	0.74	1.09
7.80um	0.39	0.91	0.41	0.69	1.03
5.50um	0.37	0.82	0.39	0.64	0.99
3.90um	0.34	0.71	0.35	0.58	0.95
2.80um	0.31	0.62	0.32	0.53	0.90
2.00um	0.27	0.54	0.28	0.46	0.83
1.40um	0.25	0.49	0.25	0.42	0.78

Textural Details
These values are the normal weight percent in each of the class groups. See Appendix 2 class details.

Coarse Sand	1.11	0.29	1.50	1.16	1.07
Medium Sand	60.84	57.16	63.84	64.70	57.69
Fine Sand	35.21	39.20	31.43	30.54	38.72
Total Sand (S)	97.16	96.65	96.77	96.40	97.48
Coarse Silt	2.30	1.94	2.65	2.75	1.26
Medium Silt	0.16	0.56	0.18	0.19	0.27
Fine Silt	0.11	0.31	0.12	0.19	0.17
Total Silt (Z)	2.56	2.82	2.96	3.13	1.69
Total Clay (C)	0.27	0.54	0.28	0.46	0.83
Texture	S	S	S	S	S

APPENDIX 3

Particle size classes and textural assessment.

Size Classes :-

SAND (S) 2mm-60um
Coarse (CS) 2mm-600um
Medium (MS) 600um-200um
Fine (FS) 200um-60um

SILT (Z) 60um-2um
Coarse (CZ) 60um-20um
Medium (MZ) 20um-6um
Fine (FZ) 6um-2um

CLAY (C) <2um

Textural Assessment :-

Values for Sand, Silt and Clay are entered into the triangular diagram below.