Reports from the Environmental Archaeology Unit, York **95/42**, 26 pp.

Assessment of soils and sediments from and exploratory evaluation at Low Hauxley, Northumberland

by

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Summary

Soil survey and analysis were carried out on materials from a trench excavated in 1994 as part of an archaeological evaluation near Low Hauxley, Northumberland. The trench had been excavated following the discovery of two Bronze Age cairns and other Mesolithic and Bronze Age remains during an excavation in 1983. Earlier paleoenvironmental work associated with the 1983 excavation had suggested stratigraphic correlations between the cairn sites and a sequence of paleosols and peats buried under sand dunes.

The assessment of soils and sediments provides information on the relationships between the soil hydrological sequence, slope and waterlogging, and on the initial stages of sand burial. This has allowed the formulation of hypotheses on the stages of evolution of the landscape adjacent to the cairns.

The work shows that soil analyses (including micromorphological investigations, particle size analysis and diatom analysis on samples already available) has the potential to provide information for the definition of the paleo-groundsurface at the time of the construction of the cairns, to test the hypotheses of landscape evolution and highlight further paleo-environmental evidence.

Keywords: Low Hauxley, Northumberland, paleosols, paleogroundsurfaces, soil, sediment, micromorphology, Bronze Age, Mesolithic.

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18 July 1995

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Introduction and aims

Coastal erosion to the south of Low Hauxley (NU 284 018), at the North end of Druridge Bay, Northumberland, has exposed Mesolithic and Bronze Age archaeological remains, including burial cairns, cists, mammalian remains, midden deposits, artifacts and various layers of buried soils and sediments below more recent sand dunes.

In 1983, after a cist and an inhumation had been exposed by wind erosion to the South of Low Hauxley (NU 284 018), the Archaeology Department of Edinburgh University carried out an excavation which revealed two Bronze Age cairns, cists, cremations, inhumations and much earlier midden deposits containing shells of about 7000 BP, together with typical late Mesolithic flint artifacts, and mammalian remains (Bonsall, 1984). Associated palaeoenvironmental studies were carried out between 1983 and 1988 (Payton, Bonsall and Tipping, *in preparation*).

In 1993, the Archaeology Department of Tyne and Wear Museums carried out excavations on the same site which revealed a further cist (Tyne and Wear Museums, 1994). More details and the results of analytical work are yet to be published.

In 1994, the Lancaster University Archaeological Unit undertook an explorative evaluation with the aims of gathering together the results of the excavations and studies carried out in the area, and of establishing the potential for further work. The evaluation revealed Mesolithic to Bronze Age flints, a few animal bones and well preserved wood, including tree stumps in a trench sub-parallel to the shoreline, and human bones, flint fragments and wood along the cliff. Samples were collected for ^{14}C datings, thermoluminescence, pollen analysis and assessment of biological remains.

The aim of this assessment is to establish the potential of further work and analysis on soil/sediments for understanding palaeoenvironmental conditions and providing information that can be correlated with the archaeological evidence.

Site description

The excavation site was located on the coast in the sand dune belt approximately 1 km south of Low Hauxley behind a small headland at the north end of Druridge Bay. A description of the district, its geology, relief, climate and soils is given by Payton and Palmer (1990). The site is dominated by sand dunes overlying Devensian Boulder Clay. Below this is the Upper Group of the Upper Carboniferous Coal Measures, comprising interbedded sandstone, siltstone, mudstone, shale and coal. These rocks are also visible directly below the dune sand along this section of the beach.

Landward of the dunes, the Upper Carboniferous strata have been disturbed by extensive open-cast coal extraction and land reclamation. This has created an artificial, 'man-made', landscape, and has affected the entire area to the south of Amble and immediately west of Druridge Bay, as far south as a line lying approximately between Ulgham and Widdrington. Much of the former coal workings have now been reclaimed and the land restored to agriculture, or, locally, to a country park and a nature reserve.

Along the seaward dune face, an irregular and discontinuous succession of narrow organic-rich layers is visible within the dune sand sequence. Below the sand dunes a toposequence of buried paleosols is exposed for more than 800 m to the north of the cairn site, developed largely within weathered Devensian till and/or glacially disturbed bedrock. The paleosol toposequence extends down a gentle slope into a peat-filled depression. The buried peat is exposed along the cliff for more than 500 m.

Similar peat outcrops are found further north, near High Hauxley, and further South in outcrops at different depths near the village of Cresswell (Tooley, M.J., personal communication). Numerous other peat outcrops are exposed along the Northumberland coast between Berwick and Blyth, and further south on the Durham coast, including Hartlepool Bay. Similar lowland peat deposits (eutrophic reed swamp, grass sedge and humified peat) are relatively uncommon in the surrounding area (Payton and Palmer 1990, Burton and Hodgson 1987).

The archaeological evaluation by the Lancaster University Archaeology Unit included the excavation and sampling of an approximately N-S 50 m long trench (D1) sub-parallel to the coast line, a smaller trench (D2, abandoned at an early stage), auger borings, and the survey and sampling of various sections of the cliff face.

Previous palaeo-pedological studies

Palaeoenvironmental studies associated with the 1983 archaeological excavations were undertaken between 1983 and 1988 (Payton *et al.*, in preparation) as follows:

(a) studies of the subdune paleosols and geological deposits beneath and around the cairns, including soil morphology, soil thin section analyses; and soil chemical and physical analyses;

(b) studies of the subdune paleocatena of soils and geological deposits then exposed in the dune face extending northwards from the cairn site downslope into what was formerly a wet peaty depression, including lithostratigraphic analyses, soil morphology, classification and variability in relation to the paleo-landsurface; and soil sampling for chemical and physical analyses;

(c) the paleoenvironmental analysis of the buried peat at its thickest development in the former wetland depression 67.5 m north of the site, including lithostratigraphic analysis; pollen and diatom analyses, and ^{14}C dating.

Such previous work identified the presence of buried paleosols beneath and around the cairns and demonstrated that the Bronze Age cairns were built upon a low, well-drained rise or hillock with wetland depressions both to the north and south of the site and revealed a hydrological sequence of soils characteristic of undulating terrain with waterlogged depressions affected by fluctuating groundwater. The toposequence was developed in variable, thin glaciogenic deposits strongly influenced by the underlying Upper Carboniferous sandstones, siltstones and mudstones.

Progressive soil changes related to topographic site showed that well-drained brown earths on the convex hillock merged into imperfectly drained stagnogleyic brown earths on midslopes, then into seasonally waterlogged stagnogley soils on concave slopes marginal to the peaty marshland, and finally into very poorly drained humic gleys soils and eutro-amorphous peat soils in the lowest lying ground (soils classes according to Avery 1980).

The work also suggested that the pedological evidence for this buried hydrological sequence, together with evidence of incorporation of blown dune sand into the buried A horizon beneath cairn No. 2 (one of the two cairns described by Bonsall (1984) and thin layers of blown sand in the surface layers of the peat soils in the depression to the north suggested that the buried land surface beneath the same cairn was contemporaneous with the upper 20 cm of the peat.

Methods

The evaluation included the excavation of a 50 m NE-SW trench (D1), sub-parallel to the coast line, through the dune sand and into the paleo-landsurface running northward from the site of the 1983 stone cairn excavation as far as the peat-filled depression. Five soil profile pits (D1A, D1B, D1C, D1D and D1E) were located at different parts of the sub-dune slope to sample the soil changes related to topography. The evaluation also included a smaller trench (D2), auger borings, and a survey of the eroded dune cliff section.

The soil profile pits in trench D1 and section 14 in the cliff face were described according to methods in Hodgson (1976), and classified according to the Soil Survey of England and Wales system (Avery 1980). General field observations were also possible throughout trench D1 and at various points on the cliff face.

Undisturbed samples, including Kubiena boxes and soil columns, were collected following the sampling strategy described in Table 1.

Macro-morphological description of an undisturbed column monolith sample of profile D1E and of whole soil samples from profile D1B was carried out following the methods of Hodgson (1976), FAO (1977), and additional class groups, and results compared with the field descriptions.

Eighteen selected samples were impregnated with Crystic resin (following the methods of Bunn (1985) and Murphy (1986) and selected representative blocks were cut into nine soil thin sections for micromorphological analysis.

Thin sections were observed with a polarizing microscope under parallel and cross polarized light at various magnifications. Methods and terminology employed for thin section description are mainly those of Bullock *et al.* (1985), but some additional terms were also employed. Semi-quantitative descriptions were carried out using comparative tables from Bullock *et al.* (1985), and Hodgson (1976). Sorting was described on the basis of comparative figures in Pettijohn *et al.* (1973).

In order to identify the vertical variation of soil microfeatures, a full micromorphological description was made of all thin sections (Nos. 2078, 2079 and 2080) from soil profile D1A, the closest to the cairns discovered during the 1983 excavation, at the southern end of trench D1. The remaining thin sections from soil profiles D1B to D1E were briefly scanned and selected micromorphological characteristics recorded to establish the potential for further, more detailed analyses.

Results

Selected data and results from the sample analysis and field description are summarized in Figure 1 and in the text below. The full data set and thin section descriptions are reported in Appendix 1 and 2.

Profile No. D1A

Buried stagnogleyic argillic brown earth in fine loamy, very stony unsorted glacigenic deposits with some admixture of blown sand in buried A horizon.

Horizon sequence:
0-10cm bAh; 10-42cm Bw(g);
42-60cm Btg

This imperfectly drained brown earth contained common weathered soft sandstone and siltstones and contained decayed tree roots (1-4 cm diameter) in the less permeable, mottled subsoil horizons that experience slight seasonal waterlogging. It was unclear from field examinations whether these soils had developed clay-enriched argillic Btg horizons.

D1A		**D1B**		**D1C**		**D1D**		**D1E**	
context No	**tins or pack/s No**	**context No**	**tins or pack/s No**	**context No**	**tins or pack/s No**	**context No**	**tins or pack/s No**	**context No**	**tins or pack/s No**
144	***2078***	155	*2102*, P001, 2087, 2088	167	*2082*	171	*T004*	180	*2106* *2133*u
154	***2079***	156	***2103***, P001, T001 bulk, T002u	168	***2083u***	172	*T005*	183	*2107* *2133*u
166	***2080***	175	*2104*, P001, T002b	169	***2083b***	173	*T005* *2099*	186	***2108*** *2133*b
		187	*2105*, 2091	174	***2084***	182	*2100*	188	***2109*** *2133*b
				190		191	2101	189	2100 *2133*b

Table 1. Soil sampling strategy for trench D1. Italic numbers for tins or pack/s (packages of undisturbed samples) indicate that the sample has been impregnated in resin. Samples which have been cut into thin sections are underlined. Suffixes u and b indicate the upper or basal parts of a sample, respectively.

Thin section 2078 *(Context 144,Horizon bAh)*

The Related Distribution Pattern (hereafter RDP) of the fine and coarse material is mainly monic ([1]) in the upper part of the section, where moderately to well sorted fine sand (< 250 :m) is dominant, this suggesting addition of sand (probably wind-blown) prior to burial.

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(1) RDP classes are from Bullock et al. (1985). The terms used, however, are also listed in Appendix 3.

In the lower part of the section the RDP is mainly enaulic.

Flint fragments (observed were between 200 Φm and 1 mm diameter), quartz, rare alkali-feldspars, and lithorelicts are included in the coarse fraction. This (approximately 80%) includes 10-50% silt, 10-50% very fine sand and 10-50% fine sand.

The sand grains within sandstone lithorelicts often have clay coatings, frequently microlaminated, and/or by Fe/Mn textural pedofeatures, and/or by black/reddish haematite or other Fe/Mn.

The spatial pattern at the scale of the feature suggest that often Fe coatings are successive to clay coatings, though in rare cases an inverse order is also observed. No similar clay or opaque coatings were observed in the fabric of the groundmass around lithorelicts.

The b-fabric is mainly constituted by a brownish, often dotted, opaque or partly masked, undifferentiated fraction and, subordinately by brownish-red or dark brown to black undifferentiated fraction, including large amounts or organic matter. No peds or planes are visible.

Thin section 2079 (Context 154,Horizon bBg)

Gefuric and prophyric RDP between coarse and fine fraction.

Less than 20% area of the groundmass contains weakly developed, accommodated or not accommodated, <500 Φm subangular blocky peds and rare unclear or very weakly developed >500 Φm subangular blocky peds.

Frequent, randomly distributed and oriented and subordinately parallel, root channels of different sizes, observed from <40 Φm to 1-2 mm, intrapedal or arranged along weakly defined ped walls.

Rounded or subrounded flint fragments of variable size (examples were observed around 50 Φm, 100-200 Φm, 500-1000 Φm) and shapes are approximately <2% of the specimen. The coarse fraction and weathering products within lithorelicts are similar to those in the above horizon; likewise, no clay or opaque coatings similar to those within the lithorelicts were observed in the groundmass around the lithorelicts. Textural pedofeatures around voids and grains are rare.

Thin section 2080 (Context 166,Horizon Bt)

The fine fraction is mainly in a porphyric RDP with the coarse material. In some cases, surfaces of weakness (planes or bands of non-accommodated voids) define oblate areas, representing 3-5 mm subangular blocks or peds of other shapes. Rotten wood band and unsorted, heterogeneous coarse fraction, including gravels with dimensions up to 4 cm.

Sand-size flint fragments and, rarely, 2x3 mm fragments with 'salt/pepper' microcrystalline mosaic structure, are found. Grain sizes includes silt, very fine to coarse sand, and gravels, unevenly concentrated in different parts of the section - in approximately half of the section, the coarse fraction includes up to very coarse sand (2 mm) or gravels and occupies > 50 % of the area, whilst where the fine material is dominant, the coarse fraction is generally < 500 Φm.
Whilst only rarely the b-fabric is grano-striated, different types of textural pedofeatures are significantly represented with RDP and Related Orientation Pattern (hereafter ROP) parallel to grains and voids. Such pedofeatures include: (1) small to medium (< 10Φm to 150 Φm) typic clay coatings, hypocoatings and quasi-coating, in cases microlaminated; (2) medium to large (10 to > 150 Φm) black opaque typic coatings, hypocoatings and quasicoatings; (3) rare, medium silty textural pedofeatures. Such pedofeatures are almost always in the order:

- Soil Groundmass
- Clay coating
- Black coating
- Silty coatings
- Void.

Profile No. D1B

Buried typical stagnogley soil developed in fine loamy over clay stony glacigenic deposits strongly influenced by underlying Carboniferous sandstones and siltstones.

Horizon sequence: bAh 0-9cm; Eg 9-26cm; Btg 26-42cm; BCtg 50-70 cm+.

This surface water gley soil was, and is currently, affected by prolonged seasonal waterlogging within 40cm of the paleolandsurface due to slowly permeable subsoil horizons. Most stones are strongly weathered.

Evidence of the eluvial Eg horizons and clay coatings in the argillic Btg and BCtg horizons indicate that the soil was subject to substantial leaching and acidification prior to burial. The overburden of calcareous dune sand will have altered the soil pH to neutrality, so that post-burial clay translocation is unlikely. Coarser textured bAh horizon suggests additions of blown sand prior to burial.

Thin section 2103 (Context 156, Horizon Eg)

Presence of charcoal, fragments of textural pedofeatures, *in situ* rock-weathering. Mostly un-coated sand grains, with some areas of speckled b-fabric and rare clay coatings and fragments of colloidal textural (*'papule'*) pedofeatures.

Profile D1C

Buried humic gley soil developed in layered parent material consisting of blown sand over stoneless silty clay over slightly stony, fine loamy glacigenic deposits.

Horizon sequence: 0-9cm bAh; 9-16cm Eg; 16-25cm 2bAhg; 25-60cm 3Bg.

This very poorly drained soil has a very dark grey humose buried Ah horizons developed in blown sand that can be traced northward into a progressively thickening peaty topsoil (i.e. Oh1 horizon of Profile No. D1D). This confirms that the top of this horizon represents the buried landsurface.

The underlying white Eg is developed in blown sand and has been strongly depleted in iron oxides under waterlogged, reducing conditions. It buries a former gleyed topsoil developed in stoneless silty clay. This deposit would have been laid down in standing water ponded within the depression to the north prior to peat development. The underlying grey gleyed 3Bg was, and still is affected by prolonged saturation with groundwater.

Thin section 2083
(Contexts 168/189;Horizons Eg/2bAhg)

Context 168, Horizon Eg: Very well sorted dominantly rounded and subordinately angular un-coated sand grains, mainly quartz. Though visible in the field, mottles do not fall in the area of this section. Presence of probably present day root channels still containing root fragments. Absence of clearly pre-burial root channels. Flints were not observed.

Context 169, Horizon 2bAhG: Moderately to poorly sorted coarse fraction, mainly including quartz sand grains. frequent root channels of variable size. Abundant inter grain organic matter. Local sandstone lithorelicts. Flints were not observed. Root channel network. No mottles observed. Discontinuous silt channel infillings and hypocoatings, and wind blown sand bands increasing towards the Eg horizon above.

The characteristics of Contexts 168 and 169 are entirely different from those of the contexts below.

Thin section 2084 (Context 174, Horizon 3Bg)

Frequent excrement pedofeatures (< 500Φ to > 3 mm), root channels, mottles and Fe-Mn nodules, paleo-root channels with parallel RDP in relation to nodules. Unsorted, mainly angular sand. Numerous lithorelicts. Large, probably present day or very recent, root channels. Frequent silt coatings. Few small charcoal flakes. Differentiated but not speckled b-fabric with porphyric RDP.

Profile No. D1D

Buried humic gley soil developed in stoneless silty clay over fine loamy glacigenic deposits.

Horizon sequence:
0-10 cm bOh1; 10-17 cm Oh2;
17-23cm Eg; 23-64 cm 2BG;
64 cm+ 2CG.

This very poorly drained groundwater gley soil with a peaty surface occurred within a wetland depression and was permanently affected by a fluctuating groundwater table with long periods of saturation, as shown by the strongly reduced, bluish grey subsoil horizons that have gley morphology typical of this hydrological situation, with iron precipitation around former root channels.

The 2Eg horizon is developed in a thin stoneless silty clay deposited in standing water prior to peaty topsoil formation.

Thin section 2099 (Context 173, Horizon Eg)

Sandy horizon with uncoated grains and differentiated non-speckled b-fabric. Abundant root channels with preserved roots. Organic matter, opaque nodules and faint diffuse mottles.

Thin section 2100 (Context 182, Horizon 2BG)

Abundant weathered lithorelicts of different nature, coal, charred plants. Network of root channels of various size and random orientation.

Profile No. D1E

Buried humic gley soil developed in thin stoneless silty clay over fine loamy, slightly stony glacigenic deposits.

Horizon sequence:

0-20 cm bOh1; 20-28 cm Oh2;
28-45 cm Eg; 45-58cm 2Bg;
58-70 cm+ 2BCG.

This peaty groundwater gley soil has 28cm of humified, eutrophic amorphous peat at its surface overlying a grey, gleyed eluvial horizon developed in stoneless silty clay laid down in standing water prior to peat development.

The soil morphology indicates a permanently waterlogged environment affected by a high, seasonally fluctuating groundwater table. The peaty horizon thickens northward into eutro-amorphous peat soils of more than 40cm thickness similar to those described in the studies of the paleocatena by Payton *et al.* (in preparation).

The presence of distinct sandy laminae in the peaty Oh1 horizon of this soil indicates that sand had started to blow into the peaty wetland depression towards the final stages of soil development.

Thin section 2019 (Context 188)

Undifferentiated b-fabric. Mottles and dark impregnative pedofeatures around root channels.

Discussion and statement of potential

The discontinuous succession of narrow organic layers within the sand dunes exposed along the cliff represents former top soils (A horizons) related to a sequence of recent short cycles of soil formation that occurred during intervals between episodes of windblown sand deposition.

The paleocatena exposed in Trench D1 confirms the hydrological toposequence of buried soils formerly exposed in the dune face at the back of the beach originally described by Payton, Bonsall and Tipping in 1985 (Payton *et al.*, in preparation). The conclusions that can be drawn from the 1994 field investigations and thin section analysis, supported by the earlier work, are as follows.

Reconstruction of the paleo-groundsurface

Field descriptions and soil thin section analyses of the soils of the paleocatena exposed in Trench D1 have enabled the paleo-groundsurface to be defined more accurately than the 'OGS' as assumed in the reports of the archaeological team. It is apparent that the nature of the buried topsoil horizon changes substantially with position on the slope, mainly in response to changing soil hydrological conditions.

The soil investigations suggest that the paleo-groundsurface at the time of the construction of Cairn No. 1 (referred to by Bonsall, 1984) was within the peaty topsoil (Oh horizons) of Profile D1E and not at the organic-mineral soil interface 28 cm below the dune sand (Context 186), i.e. peat had started to accumulate in the depression before cairn construction.

Evidence for additions of wind blown sand to different parts of the soil catena during the time interval between the construction of the Cairn No.1 and Cairn No.2, suggests the hypothesis that the paleo-landsurface at the time of the construction of Cairn No.2 was then at the surface of the bAh horizon in Profile D1C, at the surface of the Oh1 horizon in D1D and near the surface of the Oh2 horizon in Profile D1E. The evidence for the initial phase of sand deposition is discussed below. Further detailed micromorphological work on Profiles D1C to D1E is required to confirm such hypothesis fully.

The soil environment immediately around the cairn site

The supposed Bronze Age cairns were constructed on leached brown earths occupying a well-drained hillock to the south of a peat-filled wetland depression. Trench D1 confirms findings of earlier work by Payton *et al* (in preparation), but did not include the freely drained typical brown earth found beneath the cairns. The closest profile to the cairn site was D1A. Both field descriptions of this profile and the micromorphology of soil thin sections showed clay coatings lining void walls and sand grains in Context 166, thin section 2080 (D1A, horizon Btg) confirming leaching and clay translocation. Leaching and clay translocation are regarded as pre-burial on the following evidence:

(1) The spatial pattern of horizonation of the illuviation clay coatings is not in agreement with post-burial leaching. Clay coatings are preferentially distributed in the Bt horizon suggesting pre-burial eluviation from the overlying A and Bw(g) horizons, as in present day soils, i.e. they are nowhere present in the buried A horizon.

2) There is no likely source of clay colloids within the overlying windblown sands for post-burial clay translocation.

3) Clay coatings occupy pre-burial root channels and voids or are arranged parallel to, or around them in the Btg horizon, but not in similar voids in the horizons above.

(1) to (3) above indicate that clay coatings formed during profile development before burial; this phase of soil formation must have lasted at least 3000-5000 years, the time generally required in lowland Britain to build up a significantly developed argillic horizon (colloidal clay coatings are in places up to 300 Φm thick).

Other pre-burial soil forming processes interpreted from soil thin section evidence include wetting and drying, biological processes and former soil structure development. Periodic wetting/drying is indicated by the fabric stress features (i.e. part of the b-fabric is grano-striated around voids and coarse grains).

Biological processes, including vegetation development, are indicated in thin section by pre-burial root channels associated with reddish-brown, limpid clay coatings, hypocoatings and, subordinately, quasi-coatings.

Evidence for structure formation, including biotic aggregates in the bAh horizon and weakly developed peds in the subsoil Bw(g) and Btg horizons, is given by Fe quasi-coatings, bands of non-accommodated voids and planes which define lines of weakness around former subangular blocky structure. Soil micro-structure could have been partly obliterated by post-burial compaction.

Alternatively, soil structure may have been limited or weak, even during the time of profile differentiation.

Evidence for a soil hydrological sequence determined by slope with variable waterlogging

The earlier work by Payton *et al.* (in preparation) indicated that soils surrounding the freely drained cairn site on the hillock were poorly or very poorly drained and unfavourable to any form of cultivation. They had undergone leaching and some degree of acidification prior to burial. Soil profile descriptions and micromorphological analyses from Trench D1 confirm and extend these observations.

In profile D1A, thin sections 2078 and 2079 (horizons bAh and Bw) there is strong micromorphological evidence for the segregation of iron and manganese under seasonally waterlogged conditions in the subsoil. This started at an early stage of pre-burial soil development and continued after leaching and the clay migration that formed the argillic horizon.

The micromorphological spatial relationships between ferro-manganese segregations/nodules or coatings and illuviation clay coatings suggests that iron and manganese mobilisation both preceded and followed clay illuviation. Field descriptions and soil thin sections show that the degree of soil waterlogging increases downslope.

These soils change first into seasonally waterlogged cambic stagnogley soils and then into more permanently waterlogged groundwater gley soils (humic gley soils). The latter initially possess an humose Ah horizon passing downslope into well-developed humic gley soils with a progressively thickening peaty topsoils (Oh horizon) once the main former wetland depression is reached. Deep peat soils > 40 cm thick were not encountered in Trench D1. Trees tolerant of waterlogged conditions were growing on the margins of the peaty depression (there is a need for further investigation of decayed roots which could provide material for dating the paleo-landsurface and further defining the paleo-ecological environment).

There is also field evidence for post-burial iron segregation caused by waterlogging of the dune sand that buries the lower part of the paleocatena discussed below.

Initial stages of dune sand encroachment and post-burial waterlogging

Evidence of additions of sand to the top of the buried profiles is found in section 2078 (bAh) from Profile D1A on the margins of the cairn site on the hillock, where the vertical variation of the RDP shows a higher proportion of sand grains in the upper part, with the top soil dominated by well sorted < 250 :m sand. This suggests a gradually increasing input of wind-blown sand during the later stage of profile formation.

Further sand additions to the top of the buried soil profiles D1A, D1B and the sand lenses interlayered in the upper parts of the peaty topsoil of Profile D1E, provide evidence that the buried land surface was affected by dune encroachment about the time that Cairn No. 2 of Bonsall (1984) was constructed, supporting conclusions by Payton *et al.* (in preparation).

Profile D1C shows stronger evidence for a phase of blown sand deposition on a waterlogged groundwater gley soil marginal to the peaty depression that might correlate with the first stages of encroachment of the dune field onto the site. It is suggested that this phase also accounts for the sandy layer described beneath Cairn No.2 by Payton *et al.* (in preparation), the introduction of sand into the Oh2 horizon of Profile D1D and the thin sandy lenses in the Oh1 horizon of Profile D1E. The bAh and Eg horizons of Profile D1C are apparently developed in a layer of blown sand 16 cm thick which preceded the main burial of the soil toposequence by the dunes.

There was time during this interval for an Ah horizon to form and for iron oxides to be eluviated under waterlogged reduced conditions to form the sandy Eg horizon. The latter overlies a buried 2bAhg representing the former waterlogged topsoil of a groundwater gley soil. More detailed observations are needed to confirm these hypotheses.

Thin section analysis demonstrates a well developed root channel network in the 2bAhg horizon which disappears completely in the overlying Eg horizon and is therefore pre-burial.

Both pre- and post-burial Fe mobilization and mottling are shown in the field, the first by the spatial catenary relationships of mottle distribution in the buried paleo-soil horizons and the second by the gley pattern in the overlying sand deposit.

Evolution of the wetland depression marginal to the site

The thin stoneless silty clay found in Profile D1C thickens into the centre of the peaty depression and probably represents ponding of water in this low-lying site prior to peat formation, i.e. was deposited in standing water.

This is supported by preliminary soil thin section analyses of horizons 2bAh of Profile D1C, Eg of Profile D1D and Eg of Profile D1E which indicate traces of laminar banding of the fabric of the groundmass into clay-rich and silt/fine sand-rich layers. Further thin section work, accompanied by particle size analysis and diatom analysis of the stoneless silty clay layers could clarify this.

The soil investigations thus provide evidence for the character of the wetland environment immediately prior to peat formation. On the margins of the wetland depression (i.e. Profile D1C) the silty clay layer persisted at the land surface and was altered by soil formation into a waterlogged topsoil (2bAhg horizon). In more permanently waterlogged lower parts of the depression peat started to form above the silty clay layer which was subsequently transformed into an eluviated subsurface horizon (Eg horizon).

Further interpretation of the changing paleoenvironmental conditions, both preceding and contemporaneous with the cairn culture can be made by reference to the pollen analysis of the deeper peat beyond the end of Trench 1 already carried out during earlier investigations (Payton *et a*l., in preparation).

Evidence for incorporated flint fragments

Soil thin section analyses of horizons in Profile D1A showed sand- and grit-sized flint fragments with salt/pepper mosaic structure, up to 3 mm diameter, concentrated in areas of soil thin section 2079 and 2080 where the >2 mm fraction is dominant.

Natural flints are not present in the soil parent material, i.e till deposits of the Northumberland coastal plain. Their presence suggests that they may be fragments of Mesolithic and Neolithic artifacts found elsewhere on the site. Their occurrence in both the buried topsoil and subsoil horizons suggests either incorporation by soil forming processes such as bioturbation or swelling and shrinking, or could be related to subsoil disturbance by human activity. The pattern of orientation of the fine material (i.e. in the b-fabric) in the subsoil horizons of Profile D1A suggest that swelling and shrinking were important soil processes. Further investigation of b-fabrics could aid the interpretation of flint distribution.

Tentative stages of landscape evolution around the cairn site

The paleocatena of soils described by Payton *et al.* (in preparation), and investigated in the current assessment, provides a critical link through the paleo-groundsurface between the site of the cairns on the hillock and the surface layers of the buried peat in the adjacent former wetland depression.

Dating of peat deposits in a similar location to the north of the site by Innes and Franks (1988) indicated an early Flandrian III age with radiocarbon dates of 2810 ± 40 BP for the top of the peat and 4720 ± 40 BP for the base of the peat. Pollen analysis and radiocarbon dating of the peat in the depression immediately to the north of the cairn site was undertaken by Payton *et al.* (in preparation) and these results indicate a similar age range for the peat that is contiguous with the peaty topsoils described at the lower end of Trench D1.

The present assessment of Trench D1 provides further evidence for the hypotheses put forward in the previous work of Payton *et al.* (in preparation) which links the stage of construction of the first cairn with a period when the peat in the depression was already well developed.
The current assessment also gives further evidence for an early stage of encroachment of wind blown sand onto parts of the paleo-groundsurface which preceded the main phase of dune encroachment by a substantial interval (i.e. long enough for soil horizons to form and the peat to continue accumulating). It seems likely that this initial phase of sand deposition occurred before the construction of Cairn No. 2 of Bonsall (1984) for reasons stated earlier, and broad dates suggest the Late Bronze Age.

A tentative hypothetical model of the stages of paleo-landscape evolution is given in Figure 2, but these need confirmation by further detailed work, both on soils and other paleo-environmental markers. Further correlation will be possible if radiocarbon dating is undertaken of the peat of trench D1, and when radiocarbon dates for bone material from the cairns becomes available.

Significance of Trench D1

In order to obtain direct correlations with the cairn site and evidence for at what stage of the model of Figure 2 were the two cairns constructed, dating of the peat in trench D1 is recommended. Correlation with the previous work by Payton *et al.* (in preparation), however, shows the archaeological significance of Trench D1. As a transect along a set of paleo-soil units, Trench D1 is in a critical position and can broadly be assumed representative for that landscape which was formed between stages (2) and (3) of Figure 2.

Thus, any further paleo-geomorphological or paleo-ecological studies of the area are likely to mirror the extraordinary evidence of Trench D1 with regard to soils and sediments related to the Bronze Age cairns.

Potential of further soil/sediment analysis

Soil analysis for Trench D1, including thin section and particle size analysis, can give more evidence for the confirmation of the above interpretation and add more detail and environmental information.

Thin section and particle size analysis can help to confirm or provide additional information to the field evidence, give evidence for the extent/location of sand blowing into soils and of anomalous (physical or human-induced?) disturbance; for establishing the distribution of pre- and post-burial roots, pre- and post-burial waterlogging, the extent of profile development, the influence of vegetation; provide data for a testing and widening the interpretations of Figure 2. and thus improving the reconstruction of the paleolandscape.

To understand the sequence of events, however, it seems fundamental to obtain ^{14}C dating for the upper and lower part of the peat in Profiles D1D and D1E. Results will be more widely applicable if soil analysis is accompanied by plant, pollen, diatom and invertebrate analysis. The archaeological significance of the results will be improved by peat dating and by the employment of a multidisciplinary approach .

Recommendations

Following the above discussion, where recommendations are mentioned in each appropriate section, a summary of recommendations is outlined in Table 2. Total costs are described in Table 3.

Table 2. Recommendations and costs (continued in the next page).

Component	Notes	Staff	Time	Cost
1) Particle size analysis (22 samples)	Sample selection and packing	AML Res. Fell.	1.5 day	*
	4days/ 11 samples = 8 days; 1 day	AML Res. Fell.	9 days	*
2) ^{14}C dating (2 samples)	By EH			
3) Diatom analysis (2 samples)				
4) Organic C analysis (12 samples and 24 sub-samples)	Analysis Analysis and writing results	Technician AML Res. Fell.	2 days 0.5 day	*
5) Impregnation of 8 additional samples		External		
6) Preparation of 16 thin sections		External		
7) Measurement of sorting, size, shape and quantity of flints		AML Res. Fell.	2.5 days	*

8) Full micromorphological analyis for 22 thin sections		AML Res. Fell.	12 days	*
9) Preparation of report	Preparation of graphs, tables and figures	AML Res. Fell.	1.5 days	*
	Text	AML Res. Fell.	7 days	*
10) Telephone				
11) Computer consumables				
12) Paper, pens, extra postage, contingency etc.				

Table 2 (ct/d). Recommendations and costs. (*): Time included in AML contract work.

Total time	36 days
AML Research Fellow Time	34 days
Technician Time	2 days
Costs of analyses, travel, etc. (from Table 2)	

Table 3. Total times and costs

Retention/Disposal

Undisturbed and bulk samples, impregnated soil blocks and thin sections are retained at EAU (York University) and at the Agricultural and Environmental Science Department (Newcastle University).

Archive

All papers and electronic records are retained at EAU, York.

Acknowledgments

Thanks to Ann Jenner for impregnation of a large part of the soil samples, Muriel McLeod for thin section preparation, and Clive Bonsall for providing unpublished information.

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Appendix 1

Paleosol Profile Descriptions

In the following descriptions, precise elevations, information on the depth of dune sand, and part of the information on slope, requires archaeological input from the archaeological survey work.

Profile D1A

Date: 24/10/94

Low Hauxley, Druridge Bay, Northumberland. Paleocatena exposed in Trench D1 due north of the archaeological site excavated by Bonsall in 1983-84.

Paleosol Classification: Stagnogleyic (Argillic?) Brown earth (Avery 1980).

Elevation: Buried land surface at ...m O.D., dune surface ...m O.D.

Relief: Strongly undulating coastal dunes overlie convex moderate midslope of paleocatena on gently undulating buried land surface on thin till over rock-cored rises/low ridges running normal to the coast.

Slope of Buried Land Surface: 2-3^{o} convex. Aspect: North

Parent Material: Glacigenic deposits consisting of very stony, gritty brown coarse loamy ablation till over more compact fine loamy till with boulders over deformation till strongly influenced by local Carboniferous rocks below. Overlain by .... m of calcareous dune sand.

Land Use/Vegetation: Dune grassland.

Profile description:

0-9/11 cm bAh

Dark brown (10YR 3/3) very moist gritty medium sandy loam; common small to medium subrounded hard sandstone; massive to very weak medium subangular blocky structure; slightly sticky; slightly to moderately plastic; roots absent; clear wavy boundary.

9/11-42 cm Bw(g)

Yellowish brown (10YR 5/4) wet sandy clay loam with common strong yellowish brown (10YR 5/6-5/8) and few greyish (10YR 5/3-5/2) mottles; common small to large hard and common soft weathered sandstone giving sandy loam pockets; common soft medium tabular strong brown (7.5YR 5/8) weathered siltstone; massive structure; moderately sticky and moderately plastic; common clay coats; common coarse (1-4 cm diameter) black soft decayed wood (tree roots?) with high water content; living roots absent; gradual wavy boundary.

42-60 cm+ Btg

Light greyish olive brown (2.5Y 5/3) wet sandy clay loam with many yellowish brown (10YR 5/6) and common light greyish (5Y 6/2) mottles; abundant small to large hard subangular sandstone; massive structure; common grey (5Y 6/2) clay coatings in stone cavities; moderately sticky and moderately plastic; roots absent; lower boundary not observed.

Comments:

Similar to Profile SP2 of the original paleocatena (Payton *et al.* (in preparation) but bAh horizon is not developed in a distinct stoneless sandy layer of wind-blown sand as described below cairns on the original site, although this horizon does appear to be influenced by a blown sand component intermixed by earthworms (or human activity?). Very heterogenous Bt(g) with clayey pockets due the weathering of tabular siltstone and mudstone fragments. Morphological evidence of clay illuviation but needs confirmation in soil thin sections. Appears very open and gritty in parts. This raises question whether this is a disturbed layer into which clay has been illuviated but if so, where from? Only 10 cm of coarse loamy bAh currently above is an insufficient source of clay. Black humified woody fragments appear to be tree roots (thin sections will be useful to confirm). If so, indicates trees tolerant of imperfect drainage growing on edge of marshy depression. Slowly permeable gleyed Btg at 42cm indicated intergrade towards a stagnogley soil.

Profile D1B

Locality: Low Hauxley, Druridge Bay, Northumberland. Paleocatena exposed in Trench D1 due north of the archaeological site excavated by Bonsall in 1983-84.

Paleosol Classification: Typical Stagnogley Soil (Avery 1980).

Elevation: Buried land surface at ...m O.D., dune surface ...m O.D.

Relief: Strongly undulating coastal dunes overlie gentle footslope of paleocatena on gently undulating buried land surface on thin till over rock-cored rises/low ridges running normal to the coast.

Slope of Buried Land Surface:

Aspect: North. Parent Material: Glacigenic deposits consisting of stony, fine loamy till with boulders over deformation till strongly influenced by local Carboniferous rocks below. Overlain by .... m of calcareous dune sand.

Land Use/Vegetation: Dune grassland.

Profile description:

0-9cm bAh

Dark grey (10YR 4/1) to dark greyish brown (10YR 4/2) very moist sandy clay loam; few small soft angular weathered sandstone fragments; massive structure; moderately sticky and moderately plastic; few fine fibrous modern living roots; clear wavy boundary.

9-26cm Eg

Greyish brown (2.5Y 5/2) very moist sandy loam to clay loam with few small yellowish brown (10YR 5/6) mottles; common small to medium soft strong brown (7.5YR 5/8) strongly weathered sandstone and siltstone stones; massive structure; few fine fibrous modern living roots; clear wavy boundary.

26-42cm Btg

Brown (10YR 4/3) wet clay loam with many grey (10YR 5/1) mottles often around former root channels, stone cavities or on discontinuous fissure faces; many small to medium soft strongly weathered strong brown (7.5YR 5/6-5/8) and hard sandstone and siltstone fragments; many very large hard angular sandstone stones; weakly developed coarse blocky to prismatic structure; moderately sticky and moderately plastic; common greyish clay coats on fissures and in stone cavities; few fine fibrous modern living roots; gradual smooth boundary.

42-60cm+ BCtg

Olive (5Y 4/3) wet clay with many greenish grey (5BG 6/1) fine to medium mottles and common yellowish red (5YR 4/6) mottles; many medium to very large hard angular sandstone stones; massive structure; many greenish grey (5BG 6/1) clay coats in fine root channels; very sticky and moderately plastic; roots absent; lower boundary not observed.

Comments:

Developed from clayey boulder clay (till) strongly influenced by locally derived

Coal Measures sandstone. Btg shows gley morphology typical of a slowly permeable horizon of a stagnogley soil with discontinuous grey gleyed fissures but no clear development of prismatic structure. This suggests post-burial deterioration of soil structure. Thin section needed to check for illuvial clay coatings in Btg horizon.

Profile D1C

Date: 24/10/94

Locality: Low Hauxley, Druridge Bay, Northumberland. Paleocatena exposed in Trench D1 due north of the archaeological site excavated by Bonsall in 1983-84. Footslope marginal to paleo-depression.

Paleosol Classification: Humic Gley Soil (Avery 1980).

Elevation: Buried land surface at ...m O.D., dune surface ...m O.D.

Relief: Strongly undulating coastal dunes overlie gentle concave footslope marginal to peaty depression till-covered rock-cored rises/low ridges running normal to the coast.

Slope of Buried Land Surface: 1^{o} concave

Aspect: North

Parent Material: Thin (16cm) wind-blown sand over thin (9cm) stoneless lacustrine alluvium over glacigenic deposits consisting of slightly stony compact fine loamy till over deformation till strongly influenced by local Carboniferous rocks below. Overlain by .... m of calcareous dune sand.

Land Use/Vegetation: Dune grassland.

Profile description:

0-9cm bAh

Very dark grey (10YR 3/1) very moist humose stoneless medium loamy sand; massive structure; moderately weak soil strength; roots absent; upper boundary to dune sand is tongued with diffuse organic stained extensions into the overlying deposits; sharp irregular lower boundary.

9-16cm Eg

White (5Y8/1) to light grey (5Y 7/1) very moist stoneless medium sand stained strong brown (7.5YR 5/6 towards base of horizon; single grain structure; loose consistence; roots absent; sharp smooth boundary.

16-25cm 2bAhg

Dark greenish grey (5GY 4/1) wet stoneless silty clay; massive; moderately sticky; very plastic; roots absent; sharp smooth boundary.

25-50cm+ 3Bg

Dark grey (5Y 4/1) wet fine sandy clay loam with abundant greenish grey (5BG 5/1 to 6/1) mottles and few yellowish red (5YR 4/6) mottles mainly around former root channels; few small soft weathered and hard less weathered sandstone stones; massive structure; moderately sticky and moderately plastic; roots absent; lower boundary not observed.

Comments:

Diffuse tongued upper boundary of bAh horizon suggests post-burial alteration due to groundwater table fluctuations. Humose sand can be traced laterally northwards into thin peaty former topsoil which confirms that the bAh does indeed represent a buried landsurface. Eg horizon has been bleached by reduction, mobilisation and diffusion of iron oxides resulting in eluviation with receding groundwater. Lithologically distinct silty clay layer must represent lacustrine alluvial deposit on former soil surface in depressional site subject to ponding of water for part of the year. Morphology of the underlying Bg horizon (oxidation of iron around former root channels) indicates this is a groundwater gley soil subject to waterlogging by seasonal groundwater fluctuations.

Profile D1D

Date: 25/10/94

Locality: Low Hauxley, Druridge Bay, Northumberland. Paleocatena exposed in Trench D1 due north of the archaeological site excavated by Bonsall in 1983-84. Level concave paleo-depression.

Paleosol Classification: Humic Gley Soil (Avery 1980).

Elevation: Buried land surface at ...m O.D., dune surface ...m O.D.

Relief: Strongly undulating coastal dunes overlie level concave peaty depression between till-covered rock-cored rises/low ridges running normal to the coast.

Slope of Buried Land Surface: <1^{o} concave

Aspect: North

Parent Material: Thin (5cm) stoneless lacustrine alluvium over glacigenic deposits consisting of stony compact fine loamy till over deformation till strongly influenced by local Carboniferous rocks below. Overlain by .... m of calcareous dune sand.

Land Use/Vegetation: Dune grassland.

Profile description:

0-10cm bOh

Black (10YR 2/1) wet stoneless humified grass-sedge peat; few bleached sand grains; massive structure; few fine fibrous modern roots; abrupt smooth boundary.

10-17cm Oh2

Very dark grey (10YR 3/1) wet stoneless sandy peat; massive structure; abrupt smooth boundary.

17-23cm 2Eg

Dark greenish grey (5GY4/1) wet stoneless silty clay with few fine yellowish red (5YR 4/6) mottles around former fine root channels; massive structure; few fine fibrous living roots and few black decayed fine fibrous roots; abrupt smooth boundary.

17-64cm BG

Dark greenish grey (5Y 4/1) sandy clay loam with abundant greenish to bluish grey (5BG 5/1-6/1) mottles and few yellowish red (5YR 5/6) mottles that form halos (neoferrans) of iron oxide deposition up to 1cm diameter around fine vertical root channels; few small and medium hard and soft weathered sandstone, siltstone and mudstone stones; massive structure; moderately sticky and moderately plastic; few decayed black humified fine fibrous roots up to 1mm diameter; gradual wavy boundary.

64-100cm+ CG

Greenish to bluish grey (5BG 5/1) permanently waterlogged sandy clay loam with few yelloish red (5YR 4/6) fine mottles around root channels as above; common small and medium hard to soft weathered sandstone, siltstone and mudstone stones; roots absent; lower boundary not observed.

Comments:

Neoferrans (or iron oxide "pipe stems") in BG horizon confirm redox-related iron segregation due to groundwater fluctuation, i.e. groundwater gley soil. Sandy nature of peaty Oh2 horizon suggests phase when additions of windblown sand were common. Less sandy bOh above indicates subsequent period with less sand blowing in before final burial by blown sand. Soil morphology indicates waterlogged peaty groundwater-affected soil bordering deeper peat soil of central depression.

Profile D1E

Date: 25/10/94 ; Locality: Low Hauxley, Druridge Bay, Northumberland. Paleocatena exposed in Trench D1 due north of the archaeological site excavated by Bonsall in 1983-84. Depressional site at foot of paleocatena.

Paleosol Classification: Humic Gley Soil (Avery 1980).

Elevation: Buried land surface at ...m O.D., dune surface ...m O.D.

Relief: Strongly undulating coastal dunes overlie level concave peaty depression between till-covered rock-cored rises/low ridges running normal to the coast. Slope of Buried Land Surface: <1^{o} concave Aspect: North

Parent Material: Thin (17cm) stoneless lacustrine alluvium over glacigenic deposits consisting of stony compact fine loamy till over deformation till strongly influenced by local Carboniferous rocks below. Overlain by .... m of calcareous dune sand.

Land Use/Vegetation: Dune grassland.

Profile description:

0-20cm bOh

Black (10YR 2/1) very moist humified stoneless grass-sedge peat with thin (<2mm) discontinuous sandy lenses; massive structure; roots absent; gradual smooth boundary.

20-28cm Oh2

Very dark grey (10YR 3/1) very moist stoneless humified grass-sedge peat; massive structure; roots absent; sharp smooth boundary.

28-45cm Eg

Dark greenish grey (5GY 4/1) wet stoneless silty clay; massive structure; moderately sticky and very plastic; roots absent; sharp smooth boundary.

45-58cm 2Bg

Grey (5Y 5/1) wet sandy clay loam with few strong brown (7.5YR 5/6) fine mottles occurring as neoferrans 2-4mm diameter around fine vertical root channels containing black humified fine fibrous roots; common small and medium hard to soft weathered sandstone, siltstone and mudstone stones; moderately sticky and moderately plastic; gradual smooth boundary.

58-80cm+ 2CG

Greenish to bluish grey (5BG 5/1) permanently saturated wet sandy clay loam; massive structure; moderately sticky and very plastic; lower boundary not observed.

Comments:

Peat thickens in this profile which lies towards the centre of the former marshy depression. Eventually this peaty horizon thickens to >40cm thick just north of the end of Trench D1 to form a Eutroamorphous Peat Soil typical of a base-rich fen habitat. Thin lenses of sand indicate blowing in of beach sand at intervals during peat formation. This suggests that the waterlogged marshy fen lay not far behind the dune belt and was finally subject to burial as the dunes advanced inland. Permanent waterlogging of CG horizon is indicated by lack of mottles and uniform greenish to bluish grey reduced colour. The stoneless silty clay parent material of the Eg indicates sedimentation in a shallow pond prior to soil formation.

Appendix 2

Thin Section Analysis

Profile D1A, Thin section 2078 (Context 144, Horizon bAh)

The RDP of the fine and coarse material is mainly monic and subordinately enaulic in the upper part of the section and mainly enaulic in the lower part. The coarse fraction (approximately 80 % of the section) is mainly constituted by quartz, rare alkali- feldspars and rare rounded flint fragments (the sizes observed were between 200 Φm and 1 mm), with 10-50 % silt, 10-50 % very fine sand and 10-50 % fine sand. Only occasional coarse quartz grains are larger than 200 Φm and, whilst the overall coarse fraction is poorly sorted, the <200 Φm fraction is well to moderately sorted.

Subangular to very well rounded lithorelicts of different nature, often coarser than 2 mm, but including different sizes between 1 and 8 mm, constitute approximately 10 % of the area and include coal fragments, very rounded opaque-banded sandstone, very coarse sand, rounded quartzarenite grains up to 7 mm diameter, siltstone, weathered andesitic rock (plagioclase/clay/opaques), micaceous sandstone with platy muscovite.

Sand grains within sand litohorelicts are often coated by clay textural pedofeatures, frequently microlaminated, and/or by Fe/Mn textural pedofeatures, and/or by black/reddish haematite nodules, or other Fe/Mn/opaque nodules. Often, where Ferruginous nodules occur together with colloidal clay coatings, the spatial pattern at the scale of the feature suggest that Fe coatings are successive to clay coatings. In rare cases, however, and inverse order is also observed.

Groundmass

No clay or opaque coatings similar to those within the lithorelicts were observed in the dominant groundmass or around its sand grains. Haematite and other opaque nodules are also present in the matrix, where they are often sharp, rounded and of variable size, in cases > 5mm.

The b-fabric is mainly constituted by a brownish, often dotted, opaque or partly masked, undifferentiated fraction and, subordinately by brownish-red or dark brown to black undifferentiated fraction, including large amounts or organic matter.

Excrement pedofeatures of diameter between 1 to 2 mm were also observed.

Voids and peds

No peds or planes are visible and voids are mainly randomly oriented and distributed. Medium to large (40 to > 300 Φm) cavities and frequent small (< 40 Φm) channels and occasional (less than 5 observed) > 300 Φm channels.

Profile D1A, Thin section 2079 (Context 154) bBg

Gefuric and prophyric RDP between coarse and fine fraction.

Voids and peds

< 20 % area of the groundmass contains weakly developed, accommodated or not accommodated, < 500 Φm subangular blocky peds. Rare unclear or very weakly developed > 500 Φm subangular blocky peds. Frequent, randomly distributed and oriented and subordinately parallel, root channels of different sizes, observed from < 40 Φm to 1-2 mm, intrapedal or arranged along weakly defined ped walls.

Pedofeatures

Rare amorphous of cryptocrystalline pedofeatures, including coatings and hypocoatings around root channels, and rare yellowish-brownish-red limpid to masked typic clay coatings on small root channels or lining the walls or fractures of coarse grains, including flint grains. Occasional excrement pedofeatures between 0.5 and 1 mm diameter. Ferruginous quasicoatings, and ferruginous nodules of various shape (typic, concentric, nucleic, impregnative, other) of different sizes, up to 5 mm.

Abundant gley with diffuse distinct mottles impregnating large part of areas of the matrix. In addition to mottles, black amorphous material is present for approximately 50% of the area in the form of randomly distributed opaque nodules and impregnative pedofeatures and typic coatings, hypocoatings and quasicoatings in the proximity of voids and surfaces of weakness.

Coarse fraction

Approximately 10-50 % of the specimen is constituted by angular and subordinately rounded, often fractured, grains of quartz and subordinately alkali feldspar including silt and < 300 Φm sand of which the 200 Φm diameter fraction is apparently dominant.

Rounded or subrounded flint fragments of variable size (examples were observed around 50 Φm, 100-200 Φm, 500-1000 Φm) and shapes are approximately < 2% of the specimen. In some cases flints are fractured, with fractures filled by colloidal reddish or dark clay sized material.

The coarse fraction also includes < 2 % very coarse (> 1 mm) quartz and feldspar grains from angular to rounded,and rounded quartzarenite, subrounded siltstone, micaceous sandstone and coal fragments. As in the above sample from context 144, sandy litohorelicts often include clay colloidal textural pedofeatures (frequently microlaminated), and/or Fe/Mn textural pedofeatures, and/or black/reddish haematite nodules or other Fe/Mn/opaque nodules.

Groundmass

Reddish brown, dotted or masked, occasionally opaque fine material, undifferentiated or weakly differentiated but not speckled b-fabric.

Profile D1A, Thin section 2080 (Context 166)

The fine fraction is mainly in a porphyric RDP with the coarse material.

Fine fraction

Reddish-greyish brown, subordinately reddish, reddish brown or yellowish brown fine material (similar to that of context 154, but more abundant), with grey and yellow interference colours, generally masked by red.The b-fabric varies between undifferentiated, differentiated but not speckled and, rarely, grano-striated around coarse grains.

Voids and peds

Voids include cavities (< 40 Φm to 2-5 mm diameter) and channels (< 40 Φm to < 2mm thickness), mainly randomly oriented and distributed but in some cases distributed in bands. Surfaces of weakness (planes or bands of non-accommodated voids) define oblate areas, representing 3-5 mm subangular blocks or peds of other shapes.

Coarse fraction

The coarse fraction includes angular or rounded fragments, in random orientation and distribution. The nature of the material is very heterogeneous, including flint (sand size and, rarely, 2x3 mm fragments with clearer 'salt and pepper' microcrystalline mosaic structure), coal (from small up to 4 cm x 2.5 cm), different siltstones, basic volcanic rocks, sandstones of different types (including quartzarenite, orthoquartzite with or without clay translocation and nodules similar to those described for contexts 144 and 154 above), and different silty claystones (the finest textured including opaque black coatings and infillings in share planes or surfaces). Grain sizes includes silt, very fine to coarse sand and gravels, unevenly concentrated in different parts of the section -- where the fine material is dominant (> 90 %), the coarse fraction is generally < 500 Φm, but in approximately 1/2 of the section, the coarse fraction includes up to very coarse sand (2 mm) or gravels and occupies > 50 % of the area.

Pedofeatures

Different types of textural pedofeatures are present, including:

(1) small to medium (< 10Φm to 150 Φm) orange brown, or brown, or reddish yellow colour typic clay coatings, hypocoatings and quasi-coating with a variable ferruginous component and in cases with microlamination by darker, up to black, microlaminae;

(2) medium to large (10 to > 150 Φm) black opaque typic coatings, hypocoatings and quasicoatings;

(3) rare, medium silty textural pedofeatures.

Textural pedofeatures are generally integer and only in rare cases are fragmented. Pedofeatures (1) are distributed along void walls and grain surfaces, including flint surfaces of variable size below 1 mm. Pedofeatures (2) are often overimposed on the birefringent coatings (1). Pedofeatures (3) are, again, very rare and overimposed on (1) or (2). Thus the order of occurrence of textural pedofeatures is almost always:

- Soil groundmass
- clay coating
- black coating
- (silty coatings)
- void.

Presence of occasional excrement pedofeatures (observed between 1-2 mm).

Profile D1C, Thin section 2083 (Contexts 168/189; Horizons Eg/2bAhg)

Context 168

Very well sorted dominantly rounded and subordinately angular un-coated sand grains, mainly quartz. Though visible in the field, mottles do not fall in the area of this section, probably as a result of the scale of the changes in their distance in comparison with the thin section size. Absence of clearly pre-burial root channels or relevant voids, except some, probably present day, channels still containing root fragments. Flints were not observed.

Context 169

Horizon Moderately to poorly sorted coarse fraction, mainly including quartz sand grains. frequent root channels of variable size. Abundant inter grain organic matter. Local sandstone lithorelicts. Flints were not observed. The vertical spatial pattern of porosity and texture indicates that these root channels are pre-burial thus correlatable to the paleogroundsurface. No mottles observed.

Profile D1C, Thin section 2084, Context 174.

Frequent excrement pedofeatures (< 500Φ to > 3 mm), root channels, mottles and Fe-Mn nodules, paleo-root channels with parallel RDP in relation to nodules. Unsorted, mainly angular sand. Numerous lithorelicts. Large, probably present day or very recent, root channels. Frequent silt coatings. Few small charcoal flakes. Differentiated but not speckled b-fabric with porphyric RDP.

Appendix 3

Related Distribution of coarse and fine constituents (from Bullock *et al.*, 1985)

Monic: Only particles of one size group or amorphous material is present. Associated interstitial voids are always present though they may be ultra-microscopic.

Gefuric: The coarser particles are linked by braces of finer material. The coarser particles are not in contact with each other and thus have no skeletal function.

Chitonic: The coarser particles are wholly or partly coated by finer material. The finer material may be illuviation coatings or random clay deposits on grain surfaces.

Enaulic: There is a skeleton of coarser particles with aggregates of finer material in the interstitial spaces. The aggregates do not completely fill the interstitial space.

Porphyric: The coarser particles occur in a groundmass of finer material.