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SOIL REPORT ON THE HULLBRIDGE PROJECT, ESSEX: THE SITES OF PURFLEET, THE STUMBLE & OTHERS ON THE BLACKWATER RIVER.

R I Macphail BSc MSc PhD

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Summary

A soil micromorphological study was carried out on six sites. The investigation was an attempt to characterise early prehistoric soils in coastal river valleys now buried by estuarine peats and silts. The results are poor because estuarine inundation and associated saline salts caused leaching and dispersion of fine material in the soils, altering them to soils of the intertidal zone, that now may also contain sodium carbonate, pyrite and gypsum. Nevertheless, it can be suggested, that at Purfleet the molluscan woodland fauna may only have been established late on during the terrestrial period of the site, whereas the Blackwater sites, including the Stumble, had long established truly terrestrial soils. The report is supported by two figures, one table and seventeen colour plates.

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SOIL REPORT ON THE HULLBRIDGE PROJECT, ESSEX: THE SITES OF PURFLEET, THE STUMBLE AND OTHERS ON THE BLACKWATER RIVER

R I Macphail, BSc, MSc, PhD. 1989

Introduction In 1987/88 a number of Essex coastal archaeological sites, surveyed and excavated by Peter Murphy and Tony Wilkinson on behalf of Essex County Council since 1982 (The Hullbridge Basin Survey interim reports No's 1-7; Wilkinson and Murphy 1986a), were investigated by pollen (Dr Rob Scaife [AMLR 208/88] and Andy Evans [AMLR 7/90]) and soil/sediment studies. Already the study of the intertidal zone of the Crouch and Blackwater estuaries had more successfully supplied data on the environment and prehistory of the now submerged Essex coastal landscape than excavation of the adjacent dry land sites, because of diminished erosion and good preservation of organic materials through waterlogging. A number of prehistoric soil landscapes, buried by peat and estuarine silts, had been reported and these were to be investigated to assess both their preservation and usefullness in the overall environmental reconstruction of these lowlands. It was known at the time that prehistoric soils buried by freshwater alluvium in the Nene Valley (Macphail in prep.) and in the Fens (French 1988) had retained sufficient palaeo-pedological data to be interesting. Lastly, our knowledge of the pedological record for the lowland valleys of the south-east of England was very sparse and needed augmenting (Macphail 1987), because most soils of this zone had been either strongly transformed by agricultural practices or unavailable for study because they had been buried under alluvium, for example.

Sites and Methods The six sites investigated were at Purfleet, The Stumble and elsewhere on the Blackwater river (fig. 1).

At Purfleet (Thames site 2), Thames estuarine sediments containing in their upper 2 cm a woodland land snail assemblage (Wilkinson and

Murphy 1987:55-61), and buried by a probable 5,500-4,000 year old (Neolithic) wood peat (Murphy, pers. comm.), were sampled (Fig. 2).

At the Stumble, site 28 on the River Blackwater (Wilkinson and Murphy 1986b:19-54), three areas were investigated on London Clay Head; two areas of the Neolithic occupation - sites A and B - the latter sampled by Tony Wilkinson as a 50 cm long monolith (sub-sampled for four thin sections; fig. 2), and an off-site area (section 1) of the terrestrial landsurface (plate 1) beneath an estuarine detrital mud (ca. 1,700-2,000 bc). At both site B and section 1 the palaeo-surfaces were still well sealed by estuarine silts, whereas site A had become exposed to modern estuarine biological and soil ripening processes. On the present-day mudflat at site B, the estuarine sediment was considered to be ca. 1600/1500 bc in age, with Neolithic artefacts at 15-22 cm and slighty later charcoal scatters at 10-11 cm (Wilkinson, pers comm 1987).

Elsewhere on the Blackwater River two further areas of prehistoric soils developed on London Clay head were investigated at sites 3 (Maylandsea; Wilkinson and Murphy 1985:17-20, 1986b:44-54) and 18 (Wilkinson and Murphy 1986b:14-21, 54-60).

Fourteen undisturbed samples (thin sections A-M; fig. 2) were thus taken from the six sites for thin section preparation (Murphy 1986). Acetone replacement was carried out to remove saline salts that interfere with resin polymerisation. Unfortunately, the first series of sections were poorly impregnated and had to be surface re-impregnated. Extra leaching with acetone of the second batch (Stumble B) of samples permitted perfect slides to be made. Thin sections were described according to Bullock et al. (1985) and interpreted using the guidelines of Courty et al. (1989). Bulk samples, complementary to the thin section samples were analysed for calcium carbonate, organic carbon and grain size (Avery and Bascomb 1974).

Results Analytical data is presented in table 1, whereas soil micromorphological description and preliminary interpretation is presented in appendix 1. All the soil and sediments have unfortunately undergone a variety of transformations relating to the admixture of sodium salts at the time the soil was inundated and saturated by brackish estuarine inundation. These transformations include, hydromorphic (Bouma et al. 1990) iron depletion ("leaching" of upper soil horizons) and iron reprecipitation (ferruginous mottling associated with aquatic root channels; and pyrite precipitation in voids), and soil slaking. The last relates to the soil becoming saturated by water rich in sodium ions, and these totally displaced such cations as calcium which aid flocculation in soils, and as a consequence the soil became dispersed or defloculated (ie. the soil peds fell apart). This occurs because clay particles with attached sodium ions repel each other. At the Stumble and Blackwater sites most fine soil material was affected in this way, and dispersed fine silts and clay were translocated down into the "subsoil" . The removal of fine soil especially from the surface horizons and its relocation downprofile into a subsoil therefore means that there is little fine fabric data on the prehistoric soils, in the sense that many diagnostic features formed by the arrangement of clay and fine silt, that form a pedological record of a soil were completely lost or transformed. For example, the grey upper A2 horizons of the Blackwater land surfaces are typical of alkali soils (Duchaufour 1982), leached because of clay dispersion and are not a relic of prehistoric lessivage and are typical of soils developed in the intertidal zone (Kooistra 1978). Similarly soil material down as far as 40 cms was also alterred by hydromorphic and slaking phenomena. It is also likely that soil pollen dating to pre-estuarine soil conditions, became dispersed at the same time as the fine soil was slaked by brackish water inundation, and as a consequence the soil pollen may have to be regarded as unstratified. At the Stumble, however, where a soil column was studied for soil pollen, no pollen was found in the surface or "subsoil" horizons (Evans, AMLR 7/90).

Discussion

Thames site 2; Purfleet The clay loam (table 1; sample 39) estuarine soil/sediment (0-7.5 cm) that appears to be related to the Thames II transgression (Wilkinson and Murphy 1987:55) was calcareous and as suggested by Wilkinson and Murphy (1987:58) was partially decalcified during the Tilbury III regression (ca. 5410-3850 bp). The ripened soil/sediment, which experienced the presence of early-middle Neolithic people (leaf shaped arrowheads), was then sealed by a wood peat dated to 3910 bp at the base (Murphy, pers. comm.). The high amount of measured carbonate, however, relates to the strong impregnation of the soil/sediment by sodium carbonate (plates 2 and 3) which when in turn this was impregnated by iron after exposure, gave the dark red (2.5YR5/1) surface colour to the generally grey (5YR5/1) soil/sediment. The iron was probably drawn from the underlying hydromorphically depleted soil/sediment. The presence of iron sulphides (pyrite) are also evidence of minor soil/sediment ripening under brackish water conditions (Miedema et al. 1974), and like the weak ferruginisation of the surface, are probably recent post-peat phenomena relating to exposure. Movement of calcium carbonate may now only be occasional as indicated by the deposition of calcite in root channels.

Preservation of the nature of the "Neolithic" soil is very poor because of general leaching and total loss of fine structure caused by post-peat brackish water inundation. However, at least some of the coarse porosity (channels) and structures of the soil/sediment have been preserved by the continued existence of woody roots presumably from trees and shrubs that grew on the site, either during the period of subaerial weathering or later when the wood peat was forming. No tree stumps actually rooted in the soil/sediment, and thus dating to the period of soil ripening, were found by Murphy or Wilkinson (Murphy, pers. comm.). Therefore these preserved woody roots probably relate to trees such as alder, ash and yew, which were growing in the peat (i.e. their stumps have been found in the peat; Murphy, pers. comm.). Apart from waterlogging, later sodium carbonate and iron impregnation also helped preserve these roots and associated soil porosity. The upper soil/sediment was homogenised probably by biological activity when undergoing the period of subaerial weathering that occurred before peat growth. This biological activity was also active in burying the woodland snail fauna that predates the peat. As most of the mollusca occur only in the top few cms, then their occupation of the site may have been very short lived (Bal 1982) before peat formation, the depth of biological working and consequent deeper deposition of mollusc shells increasing with time. This terrestrial woodland fauna is believed to have needed several centuries of stable conditions to develop (Murphy, pers. comm.), and so it could mean that the soil/sediment was terrestrial for a lengthy period, but that the molluscan fauna was only established for a short time prior to a rise in water table and peat formation. Unfortunately not enough interpretive detail can be observed from the thin section to be more precise on this matter.

<u>The Stumble; site 28</u> Three areas at site 28 were studied (fig. 2). As noted previously estuarine inundation caused both anaerobic leaching of iron and dispersion of the fine soil, which is likely to have strongly alterred the grain size distribution of the soils from their pre-inudation character. The prehistoric parent material, nevertheless, can be considered as fine loamy (table 1; sample 41) as found presently on slopes on the London Clay (Jarvis <u>et al</u>. 1983). Possible ancient soil fragments preserved by ferruginisation indicate this although it is not

possible to state that the prehistoric soil cover was an argillic one developed under woodland (Scaife, pers comm), or as more commonly found now - a pelo-stagnogley soil (Windsor Association; Jarvis et al. 1983). The presence of charcoal at ca. 40cm depth may be the result of soil mixing after clearance, whereas the Neolithic pottery at an approximate soil depth of 13 cm (plate 4) at site B possibly occurred through earthworm working of the soil penecontemporaneously with continued Neolithic activity in the area (eg. site A). A little later a 2-3 cm thick charcoal-rich soil layer formed at the soil surface (plate 5). Elsewhere (i.e. site A), although not recorded in the microfabric, there is a surface soil association of charred seeds, wood charcoal, Neolithic artefacts and archaeological features (Wilkinson and Murphy 1986b:19-54; Murphy, pers. comm.). At site B, the surface charcoal layer seems to have been reworked in places by estuarine inundation, in so far as the overlying estuarine silts (plates 6 and 7) seem to contain some similar coarse charcoal. (No charcoal was found in the detrital peat at off-site section 2). The estuarine silty clay loam (table 1; cf. sample 40) in comparison with the underlying prehistoric soil, is better sorted and contains evidence of horizontally deposited organic detritus as an indication of weak bedding.

The charcoal concentrations at the Stumble although shown to be in situ (Murphy, pers. comm.) may nevertheless have become involved in some localised reworking associated with the dispersion of surface soils during brackish water inundation (as at site B). In soils and sediments associated with freshwater inundation alluvial clay balls of reworked soil may be in evidence (French 1988), but here all fine soil material seems to have been totally dispersed. So here again the lack of fine fabric data in the Neolithic surface horizons underlying the estuarine silts, makes it impossible to establish exactly the pedological relationship between the charcoal and mineral matrix at the soil's surface, and why the pottery here at site B occurs some 10 cms below this charcoal-rich soil layer.

The off-site area at section 2 (thin section I) shows that initial inundation leached and slaked the prehistoric soil, before the detrital organic and mineral sediment was deposited (plates 8 and 9), producing in places wetting fronts marked by fine soil accumulations. Across the whole prehistoric landscape surface horizons were dispersed and clay and fine silt were washed down profile, whereas it is possible that some soil (and charcoal; see above) may even have been washed away. Coarse artefacts remained in place. Further down profile finer soil was transported to produce the dark brown textural (argillic/Bt) horizons noted below 30 cm (plates 10 and 11). The movement of soil down profile is evidence of brackish water flooding, but at the same time shows that the permanent water table was low. This with the finding of charcoal at depth, and the presence of possible ancient soil fragments indicates that the area was truly terrestrial in the Neolithic, and not just seasonally wet mudflats as occupied by some Mesolithic communities (Balaam et al. 1987).

Some phenomena relating to exposure of the estuarine mud flats (Miedema et al. 1974) are rare gypsum (calcium sulphate), and the large amounts of pyrite (plates 12 and 13) and localised ferruginisation associated with reed penetration aerating the anaerobic sediment and soil (Bouma et al. 1990).

Blackwater site 3 (Maylandsea) and Blackwater site 18 Both sites like the Stumble, show near total transformation of the prehistoric soil formed on London Clay head by brackish water inundation; that is dispersion of fine material and its translocation down profile, and anaerobic leaching of iron. The phenomenon of clay movement, as recorded in the microfabrics, may also be reflected by grain size analysis, showing upper soil clay depletion and "subsoil" clay concentration (table 1; samples 45, 46). Soil ripening effects and marsh plant root penetration have also caused rare gypsum crystallisation (plates 14 and 15), localised ferruginisation (plates 16 and 17) and pyrite accumulation.

In their original state, the soils at sites 3 and 18 were more obviously different. At site 18 the high silt content and possible relic microfabric character give the appearance of an argillic brown earth formed on brickearth, but this cannot be proven from the present soil. In contrast, the underlying character of the soil at site 3 is of poorer sorting, probably related to the local high energy gravels. Presently in the area, typical argillic gley soils (Hurst Association; Jarvis et al. 1983) occur on river terrace gravels and so it may be assumed that similar soils were at site 3.

Again estuarine inundation affected terrestrial soils, for example, at site 18 washing clay down a probable earthworm channel. The translocation of mobilised fine soil down to some 37 cm, and its accumulation here as coatings and infills, again demonstrates that the soils were normally well drained to this depth, otherwise clay dispersed at the surface could not have been translocated so far down the profile.

Conclusions

1. Brackish water inundation and burial of soils by estuarine sediments has in the main totally transformed the prehistoric soils to salt marsh soil profiles (unripened gley soils) of the intertidal zone. The disposition of macrofossils and artefacts has been little affected, but it is likely that prehistoric soil pollen stratification has been totally lost and contaminated. At all sites the combination of estuarine inundation and recent exposure have caused a variety of hydromorphic effects including iron mottling, pyrite precipitation and gypsum

crystallisation.

2. At Purfleet it is possible that the area was dry for a sufficiently long time to permit general decalcification and biological homogenisation of the upper ripened soil/sediment, allowing a stable woodland vegetation to develop. It is probable that the woodland molluscan fauna only established itself a short time before another transgression induced a wood peat to form, the trees on-site rooting through into the underlying ripened soil/sediment.

3. The Blackwater sites of 3, 18 and 28 (the Stumble) can be shown to have been truly terrestrial soils, although details of their original soil type cannot be elucidated. At the Stumble, charcoal was found at depth (clearance ?), Neolithic artefacts seemed to have been earthworm worked in places, whereas surface charcoal scatters although essentially _in situ_ may have been locally involved with surface soil dispersion during primary inundation. The water tables of these Blackwater soils were relatively low, at least 40 cm, at the time of estuarine inundation. Therefore, the first flooding event is likey to have been a storm surge, such as has been this year (1990) experienced in North Wales, rather than just the result of creeping up of sea level.

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Appendix 1

Hullbridge Project: Soil Micromorphological

Description and Preliminary Interpretation

The samples examined come from the Purfleet section (on the R Thames), from the Stumble sites A and B, and profile 28 (on the R Crouch), and from the Blackwater, area 23 and profile 18. All soils and sediments had been affected by marine inundation and sodium salts (NaCl). These have had a deleterious affect on the palaeosol microfabric and has to be born in mind when reading the descriptions and interpretations. Secondly, although attempts were made to leach out the salts from the samples with acetone, prior to impregnation, this was only fully successful in the last batch of samples form the Stumble B site, after experience with the technique. Some materials such as sodium carbonate are preserved in the former samples, and even after re-impregnation was not always fully successful with the result that some thin sections are rather patchy.

Purfleet: (2 thin sections) (Thames 2, Section 2)

Thin section A.0-6.5 (7.5) cm. (rooted sediment/soil below "Neolithic" woodland peat).

Structure: massive (possible prismatic) with coarse channel microstructure. Porosity: 30%, dominant very coarse (1-1.5cm) moderately smooth wall channels extending full length (7.5cm) of thin section; with in main sediment frequent moderately smooth wall fine to medium channels. Mineral Coarse: Fine (limit 10mm), 70:30. Coarse well sorted; very dominant angular to subangular silt and very fine sand-size quartz; very few mica and glauconite: including medium size mica; calcite/aragonite, mollusc shell and phytoliths present. Fine pale to dark brown (according to degree of sodium carbonate impregnation), speckled (PPL); medium to moderately low birefringence; strong orange to pale orange (OIL; according degree of iron impregnation) red areas near surface. Organic Coarse very dominant woody (lignified) very coarse (>1cm) probable trees roots, generally non or very poorly birefringent; towards sediment surface roots are impregnated with iron. Fine occasional plant and organ fragments, and amorphous material. Groundmass close porphyric, speckled to weakly crystallitic (some micritic calcite/sodium carbonate impregnation). Pedofeatures Textural abundant silt in fills of root channels and empty root centres. Depletion general moderate decalcification of whole sediment. Also loss of iron at one stage Crystalline very abundant impregnation and void in filling by dirty grey brown (PPL), moderately high birefringent, yellowish orange (OIL) sodium carbonate. Many micritic patches, associated with sodium bicarbonate; sometimes with sparitic centres. Occasional (probably first phase) micro-sparite to sparite void infills and hypocoatings associated with roots and root holes. Amorphous toward surface and associated with some root material abundant ferruginous impregnation, less at depth. Ferruginisation has concentrated in (and post dates) sodium carbonate areas. (associated with some depletion of the carbonate) many iron sulphide (black under PPL; brassy under OIL) spherolites; pyrite. Fabric strong homogenisation of original sediment. No obvious excrements but faunal burrows and mixing is apparently evident.

Interpretation Probably the alluvial sediment was calcareous when it was first deposited. It was moderately depleted of calcium carbonate during woodland growth as shown by roots and root holes being affected by microsparite and sparite (calcite) growth. Also the sediment became homogenised, probably through some faunal activity although it is hard to prove this, and some possible prismatic and channel structures formed. The surface was probably dry ground and surface woodland molluscs (Murphy, pers. comm.) were worked into the soil. The sediment (and woodland) was then inundated and a wood peat developed. At the same time most of the soil became depleted and structureless. Hence lack of surface soil features. As the Thames water became estuarine/saline what calcium carbonate remained was influenced by sodium chloride and sodium carbonate began to impregnate and form nodules. Laterally, exposure had brought some further minor decarbonisation and its replacement by iron. Roots have been affected by this gleying effect.

The Stumble; Site B (on River Blackwater West Mersea Island).

Thin Section B. 8-14.5cm (a) 8-9(10)cm estuarine clay, b) 9-11(12)cm organic lens and c) 11-14.5cm buried soil).

Structure: massive, massive microstructure. Porosity 10%, very dominant very coarse plant channels (vertical orientation); few coarse chambers in c) a) very few horizontally oriented fine, elongate, smooth wall voids (plant detritus pseudomorphs, sometimes some plant material remaining in this estuarine layer. Mineral a) C:F 90:10. Coarse very dominant silt (with few very fine, fine and medium) - size quartz; well sorted, subangular to subrounded; very few mica and opaque minerals; rare phytoliths. Fine very pale brown, lightly speckled (PPL), very poorly birefringent, very pale brown (OIL). b) C:F, 85:15, Coarse very dominant silt, frequent fine and medium sand-size quartz. (as a). Fine pale brown to brown, heavily speckled in places (PPL), very low birefringence, pale brown to brown (OIL). c) C:F, 90:10, Coarse moderately well sorted; very dominant silt, with frequent fine to coarse sand size quartz, also very few angular coarse flint. (as a). Organic Coarse a, b, c frequent coarse to very coarse in situ vertically oriented roots, both browned and black (pyrite-replaced) material. a) very abundant woody? plant fragments and wood charcoal; many coarse horizontally oriented pale yellow (or absent because of oxidation) plant detritus. Fine very abundant thin amorphous organic matter, many fine fragments. b) Coarse very abundant very coarse to fine charcoal and charred wood (oak?), and cereal charcoal (Murphy, pers. comm.), straw? Fine very abundant fine charred material, thin amorphous organic matter, occasional phytoliths; some small patches of organic "clay", possible relic channel infills. c) Coarse rare coarse sclerotia (fungal), occasional charcoal, (roots already noted). Fine occasional fine charcoal, very abundant thin amorphous organic matter. Groundmass: porphyric, crystallitic (silty) b-fabric.

Pedofeatures Textural occasional evidence for inwash of organic "clay" related to rooting. Depletion whole fine fabric depleted of clay and iron. Amorphous abundant (focused in coarse porosity associated with roots) pyrite spheroids infilling voids. Fabric generally very homogeneous throughout; some mixing of fine fabric in buried soil, relating to rooting and movement of material down profile.

Interpretation Estuarine silt inundation had a very marked affect on the Neolithic soil. Firstly, however, the estuarine deposit is a weakly organic silt carrying detrital organic matter which it layed down horizontally inplaces. No mineral evidence such as laminae is visible. The silt contains rare fauna, and also charcoal suggesting source of underlying charcoal rich material is still open. The organic layer contains charred material of all sizes and therefore it is unlikely to be a sedimentary deposit. More likely it is occupation surface where much burning and trampling took place. Unfortunately estuarine inundation and the influence of sodium ions has completely slaked this soil and all fine material (iron and clay) has been leached out; therefore there are no pedological (structures, coatings etc) features to prove that this was the case. It can be inferred, however. The soil also differs from the estuarine silts by being less well sorted and by containing flint. All present rooting affects are post-depositional and estuarine in origin; the soil itself is apedal.

Thin section C: 16-23cm. (buried soil containing Neolithic pottery.)

Structure: massive. Porosity: 5%, very dominant medium to coarse vertically oriented channels. Mineral C:F, 90:10, Coarse: moderately well sorted, very dominant silt (frequent sand) - size quartz, very few flint (as B); single stone size pottery sherd, grey brown clay with flint tempering. Fine very pale brown, lightly speckled (PPL), very poorly birefringent, very pale brown (OIL), organic coarse many coarse roots (as B), occasional fine charcoal. Fine rare amorphous organic matter, rare charcoal. Groundmass porphyric, crystallitic (silty) b-fabric. Pedofeatures. Textural rare infills of organic "clay". Rare void in fills of yellowish brown, almost limpid, poorly oriented, moderately birefringent clay. Depletion Almost total depletion of iron and clay some secondary leaching around roots. Amorphous abundant pyrite infilling of voids, root channels. Fabric homogeneous.

Interpretation Slaking and leaching (of iron and clay) has developed an apedal and depleted soil the presence of pottery, sherd at c.21cm may indicate that earthworms may have been present to move this and charcoal around. Some evidence of the slaking affect is the rare presence of translocated clay, and dusty organic "clay". Later root penetration also permitted total depletion around some channel margins.

Thin section D. 22-29.5cm (dark brown layer).

Microstructure: moderately poorly structured, massive with impression of fine prisms. (crack microstructure although drying was by acetone replacement). Porosity 15%, very dominant medium, vertically oriented extensive (2cm) root channels; few fine zigzag cracks. Mineral C:F, 50:50, Coarse well sorted; very dominant silt - size quartz, few fine and medium sand; very few opaques and mica Fine very pale or speckled yellow brown (PPL), moderately low birefringence, pale orange (OIL). Organic many coarse in situ root traces some parenchymatous and lignified material; occasional charcoal. Fine occasional amorphous fine fragments. Groundmass close porphyric, crystallitic (silt) and weakly speckled b-fabric. Pedofeatures (within non-depleted areas) occasional clay separations (intercalations) fragmented, clay coatings and more rarely yellowish brown, laminated clay coatings. Elsewhere and dominating fabric are very abundant, pale yellowish brown, speckled; very pale yellowish brown, finely dusty; moderately to poorly oriented clay coatings and infills. (Probably most porosity pre-dating the new coarse root channels, has been infilled. Many large clay infills stained darkish black. Depletion very abundant depletion of iron and sometimes clay, around coarse root channels. Crystalline rare densely packed euhedral lenticular crystals, (colourless, highly birefringent) of probably gypsum. Amorphous occasional pyrite framboids concentrated around roots. Moderate ferruginisation of roots; abundant ferruginisation of clay coatings and infills; occasional black ferro-manganese impregnation of textural features. Fabric fabric homogenised (chemically and physically) then through hydromorphic deletion wood new roots become heterogeneous.

Interpretation Even this horizon is severely affected by estuarine inundation. Clay slaked in the upper soil by sodium ions had totally infilled porosity, and most in situ soil has been affected by minor depletion and slaking. There is, however, enough fabric evidence to suggest that the original soil was probably argillic in character. Later rooting by aquatics has caused severe iron depletion along channels. Further hydromorphic affects are iron sulphide (pyrite) formation, ferruginisation and rare occurrences of gypsum (calcium sulphate).

Thin section E: 33-40cm (brown layer).

Structure weakly structured, essentially massive. Porosity: 15%, very dominant coarse vertical root channels; frequent fine channels and chambers. Mineral C:F, as D, Coarse as D. Fine very pale brown and pale brown, speckled (PPL), moderately low birefringence, pale orange (OIL). Organic Coarse occasional coarse *in situ* root material; rare charcoal (3mm). Fine rare to occasional amorphous material. Groundmass close porphyric, crystallitic (silt) and speckled b-fabric. Pedofeatures Textural: very abundant, but less than in D: many pale dusty clay coatings in coarse channels; generally only moderately well oriented and birefringent; pale yellow brown and speckled; intercalations and total infillings usually; fewer microlaminated void infills (one shows at least 3 phases of few dusty particles, very many, to few again). Depletion very abundant pattern of depletion around possible relic subangular blocky structures within a a coarser prismatic structure, both iron and clay loss; also iron loss around more recent coarse root channeling. Amorphous occasional ferruginisation of textural features; occasional infilling of coarse root channels by pyrite. Fabric strong homogenisation of structural soil.

Interpretation as D, but less affected by down profile clay translocation.

Overall interpretation of this section B, C, D, E: the Stumble site B.

The Neolithic silt loam soils were probably argillic forest soils (see Scaife, this vol.) with biological action moving charcoal down to c.40cm probably after an initial clearance event. Pottery fragments themselves were moved down to c.20cm. The surface layer is dominated by coarse to very fine charcoal that may well relate to both secondary clearance, occupation and trampling (see Murphy, this vol). It seems that the main estuarine inundation occurred roughly at this time because these pure silts which feature horizontally layered plant detritus do contain charcoal which was probably locally mobilised.

The affect of estuarine inundation and its sodium salts was catastrophic on the Neolithic soil structure. It slaked it completely (like an irrigated solonetz) and most clay and iron was leached out of the top 20 cms, making this part apedal; and producing very abundant textural features down to c.40cm. depth. Even this lower part of the soil was affected and possibly only rare textural features and possible ghost solid structures are relic of the Neolithic forest soil. A further affect of the inundation was the development of sulphate (gypsum) and sulphide (pyrite) features, after associated with aquatic rooting through the estuarine silts.

The Stumble, Site A.

Thin Section F: 0-7.5cm.

Structure: (apedal) massive microstructure: Porosity 15%, common medium moderately smooth wall channels, and common coarse, elongate (3cm) vertical (root) channels. Mineral C:F, 90:10. Coarse well sorted, very dominant silt and fine sand size quartz, with few medium sand; very few mica, phytoliths. Fine very pale brown, lightly speckled (PPL), moderately low birefringence; pale brown (OIL). Organic Coarse occasional relic vertical root; occasional charcoal, Fine occasional amorphous material. Groundmass open porphyric, crystallitic (silty) b-fabric. Pedofeatures. Textural many dirty pale brown, finely dusty, moderately birefringent, moderately oriented clay coatings and infills of fine porosity. Depletion, very abundant moderately strong depletion of iron and clay. Amorphous many weak to moderate iron and manganese staining of textural features and relic roots; in coarse channels very abundant fine pyrite. Fabric very homogeneous.

Interpretation Strongly leached upper part of Neolithic soil. Later inundation caused the rooting by aquatics, inwash of dirty clay and hydromphic effects. General homogenisation. Possible buried soil/estuarine silt mixture (see table 1, sample 40).

Thin section 9 : 7.5-15cm (A2)

Structure massive with prismatic tendancy. Porosity 10%, fine channels and vughs. Mineral C:F, 75:25, Coarse as F with few coarse flints, Fine pale brown, speckled (PPL), moderate to moderately low birefringence, pale yellowish orange (OIL). Organic occasional organic fragments. Fine occasional amorphous organic matter. Groundmass open porphyric, patchy crystallitic or speckled b-fabric. Pedofeatures Textural many dirty brown dusty clay void infills. Depletion abundant, patchy and coarse iron and clay depletion. Amorphous many coarse ferruguious impregnated areas, mainly clear to diffuse. One 3mm piece rough edge, single ring impregnative nodule (seems to have protected from depletion a possible original piece of soil - C:F, 60:40, Coarse very dominant silt and few fine sand. Fine dark yellowish brown to dark brown, speckled (PPL), moderate to moderately low birefringence, brown to golden brown (OIL) - ferruginished - some disturbance in this soil produced strongly argillic part or infill.

Interpretation Generally strong leached, especially of clay, although also textural features present show whole zone not totally depleted. It is also moderately strongly mottled, one nodule possibly protecting the original somewhat argillic loamy soil.

Thin section H 22-29cm (A3)

(As D).

The Stumble; site 28; Section 1. At base of estuarine clay and estuarine detrital low peat at junction with mineral soil (c.1metre down).

Thin section I c1.00-1.06cm (0-0.4cm estuarine peat, 0.4-6.0cm bAg).

peat:

Structure: massive. Porosity 25%, few fine channels and vughs; also cut by coarse vertical channels. Mineral C:F, 60:40. Coarse very dominant very fine silt, mainly quartz with mica. molluscs present Fine very pale brown, finely speckled (PPL), low birefringence, dark brown (OIL). Organic Coarse very abundant finely layered (10mm), detrital organic matter; many organ fragments. Fine very abundant amorphous organic matter. Groundmass porphyric, crystallitic (silt) b-fabric. Pedofeatures Fabric microlaminated eg. every 250mm. Undulating but sharp boundary with b Ag. (also pyrite).

Interpretation: organic and very fine mineral low energy detrital peat deposition; depositing fine bands of amorphous detrital organic matter.

b. Ag

Structure massive, Porosity 20%, very dominantly medium to coarse, mainly vertical (aquatic) root channels. Mineral C.F. 80:20. Coarse very abundant silt, frequent fine and medium sand; very few mica. many photoliths Fine very pale brown, speckled; (PPL); very poorly birefringent, very pale brown (OIL). Organic Coarse (decalcifying mollusca present - in peat seem almost totally decalcified) many coarse root traces. Fine many (near top) to occasional (at base) amorphous organic matter. Groundmass close porphyric, speckled (silty) b-fabric. Pedofeatures Textural many, varying from a thin band of dusty clay ascribing a curve shape, beneath the peat in a fine infill/channel. - like wetting front (suggests soil was pretty wet and leached by inundation before actual peat deposition?), to numerous very dusty clay laminae, and intercalations also associated with root channels microlaminated clay coatings, some not oriented to way up? but in situ. Depletion. very abundant depletion of iron, clay and finest silt generally. Amorphous generally rare, but very abundant ferrugious impregnation around root channels, and pyrite infilling of many root channels. Fabric soil obviously churned up by aquatic rooting in places.

Interpretation Primary depletion of the soil by inundation of estuarine waters - washing down silt and clay and leaching (anaerobically) out the iron - probably took place prior to detrital peat deposition. Some further washing took place during this event and through root disturbance. The penetration of aerobic conditions by rooting caused localised ferruginisation.

Blackwater; site 18

Thin section J: 0-7cm (b Ag and lowest estuarine peat).

Structure massive. Porosity generally 10%, very dominantly medium to coarse vertical root channels. Mineral C:F, 80:20; Coarse very dominant silt, with frequent fine sand-size quartz. Fine a) dirty, pale brown, speckled (PPL), almost non birefringent, very pale brown (OIL). b) thick (1cm and as coarse tongue) surfaces areas (part of peat) and as patches (coarse channel/void infills) - dark brown heavily speckled (PPL), almost isotic, dark brown (OIL). Organic Coarse many root traces, brown lignified outer walls; rare charcoal, except for areas of fabric b. Fine many (in top few cm and in tongue) yellow amorphous organic matter infills of porosity, (sub-horizontal near surface). a) rare organic matter b) very abundant amorphous organic matter fragments, fine charcoal also, blackened and browned fragments. Groundmass porphyric, crystallitic b-fabric. Pedofeatures Textural rare thin dusty clay void coatings (dirty brown), many dirty fine silty clay pans and poorly birefringent intercalations. Depletion very abundant iron, clay and fine silt, and organic matter depletion. Amorphous rare weak ferruginous nodules. In coarse channels, abundant pyrite spheroids. Fabric. Abundant mixing of move organic fabric through coarse channel "infills" and surface disruption by plant growth(?).

Interpretation Surface soil shows strong effect of depletion by estuarine inundation and burial by peaty deposits. (see B, F).

Thin section K: 17-24cm.

Structure poorly developed coarse prisms in massive, Porosity 20%, fine to very coarse channels, many vertical Mineral C:F, 60:40, coarse (as J); Fine brown to darkish brown speckled. (PPL), low birefringence, pale brown to brown (OIL). Organic Coarse occasional root traces. Fine rare amorphous fragments. Groundmass porphyric, speckled b-fabric. Pedofeatures Textural very abundant dirty brown, dusty, sometimes microlaminated infills, affecting most intra-ped voids. Some infills (iron stained) up to 500um thick. Also possible relic worm channel affected by preferential down wash of clay. Depletion occasional (renewed) depletion of clay around channels. Crystalline rare interlocked gypsum crystals (200um long), euhedral in void. Amorphous very abundant weak ferrugiuous staining; occasional single ring nodules. Many pyrite in channels. Excrements probable relic earthworn channel.

Interpretation Soil at this depth lost its structure through overall slaking but one channel of earthworm worked material resisted and was affected by clay downwash from the surface horizon (J). Most soil affected by ferruginous textural features, from this inundation event. Later aquatic rooting permitted more localised depletion. Aerobic conditions through drying out of the section helped pyrite formation, possible also the rare development of gypsum.

Blackwater, Site 3

Thin section L: 30-37cm

Structure: massive. Porosity 15%, very dominant very coarse root channels; few fine closed vughs and channels. Mineral C:F, 60:40, Coarse moderately poorly sorted. Common fine and medium sand with frequent fine sand and silt, and coarse to very large sand; and few stones (5-12mm) of quartzite flint and mudstone. Quartz with flint sandsize material; sub-angular to sub-rounded. Fine pale brown, speckled (PPL), moderately low birefringence, pale brown. Organic Coarse rare charcoal, occasional root traces. Fine many amorphous fragments. Groundmass close porphyric, speckled b and min or grano-striate b-fabric. Pedofeatures Textural very abundant dirty brown very dusty and impure clay coatings infills up to 1mm wide. Amorphous. Abundant ferrugiuous nodular impregnation of fabric, including some of the textural features as though infilling fine cracks in the clay. Many pyrite in the coarse root channels. Fabric Heterogeneous; root re-working and infills causing this.

Interpretation As K, strong slaking and impure clay movement. Relic nodular soil fragments that are present, suggest again that soil was possibly an argillic silt loam. Soil is coarse and more poorly sorted than at Blackwater 18 (J and K).

Thin section M: 6.5-14cm.

As J - strongly leached and perforated by estuarine plants.

TABLE 1: ANALYTICAL DATA; HULLBRIDGE PROJECT

SAMPLE	SITE	%CACO3	%ORG.	Clay	FZ.	MZ.	CZ.	Silt.	VFS.	FS.	MS.	CS.	VCS.	Sand	Texture	Thin Section
39.	Purfleet	14.0*	2.9	21	12	18	25	55	14	3	4	2	1	24	clay loam	A
	The Stumble A															
40.	0-7.5cm	<0.1	0.5	20	6	24	40	70	2	3	4	<1	<1	10	silty clay loam	F
41.	22-29cm	0.1	0.2	15	7	17	51	75	4	4	1	<1	<1	10	silt loam	H
	Blackwater 3															
42.	0-8cm	<0.1	1.0	10	8	32	37	77	3	4	4	1	1	13	silt loam	M
43.	8-30cm	<0.1	0.3	29	7	19	27	53	4	6	6	1	1	18	silt clay loam	M
44.	30-37cm	0.1	0.2	34	4	6	17	27	8	11	16	3	1	39	clay loam	L
	Blackwater 18															
45.	0-17cm	<0.1	0.6	12	8	29	39	76	3	4	3	1	1	12	silt loam	J
46.	17-24cm	<0.1	0.2	21	7	23	39	69	2	4	3	<1	<1	10	silty clay loam	K

NB: * mainly sodium carbonate

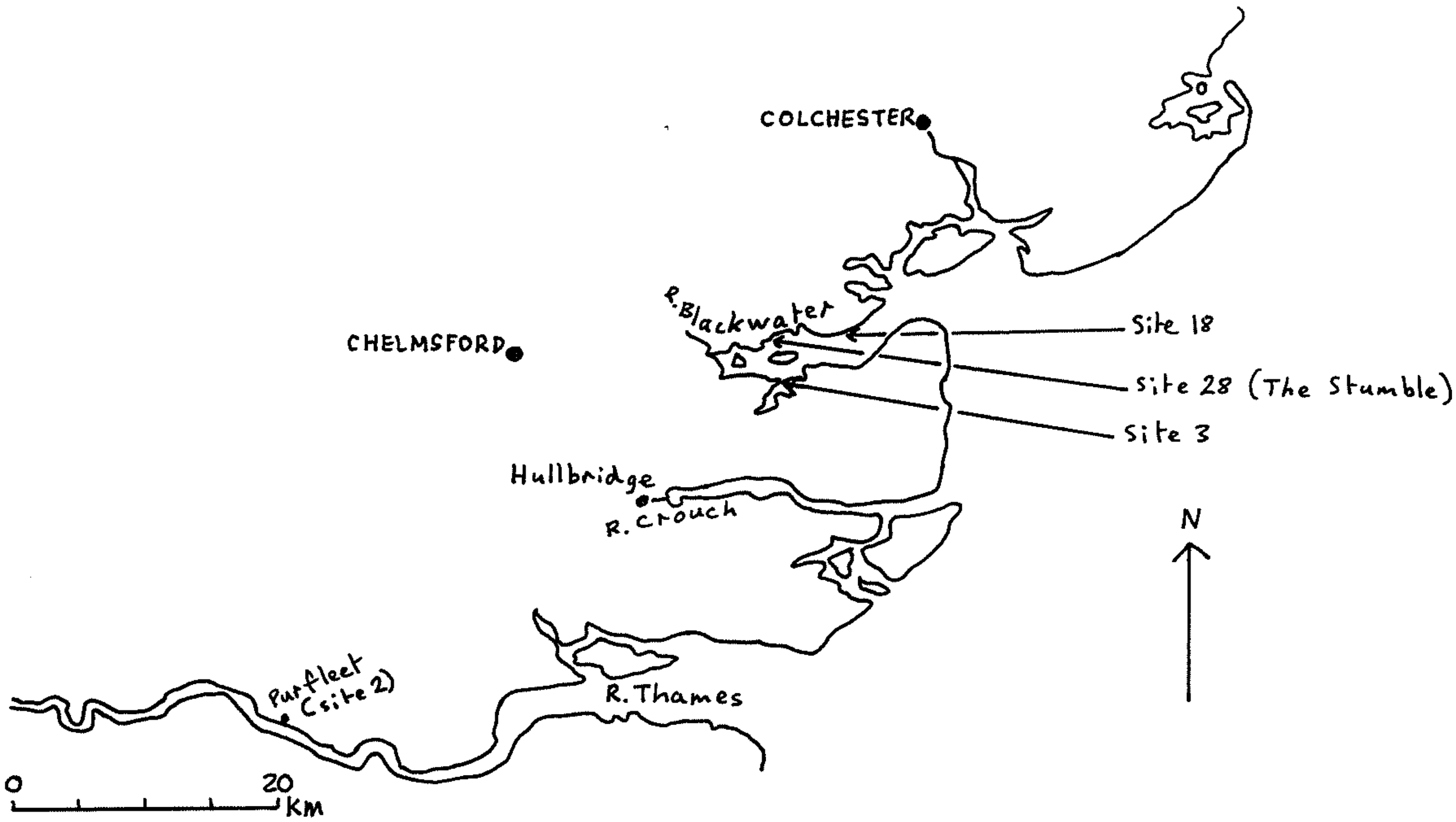
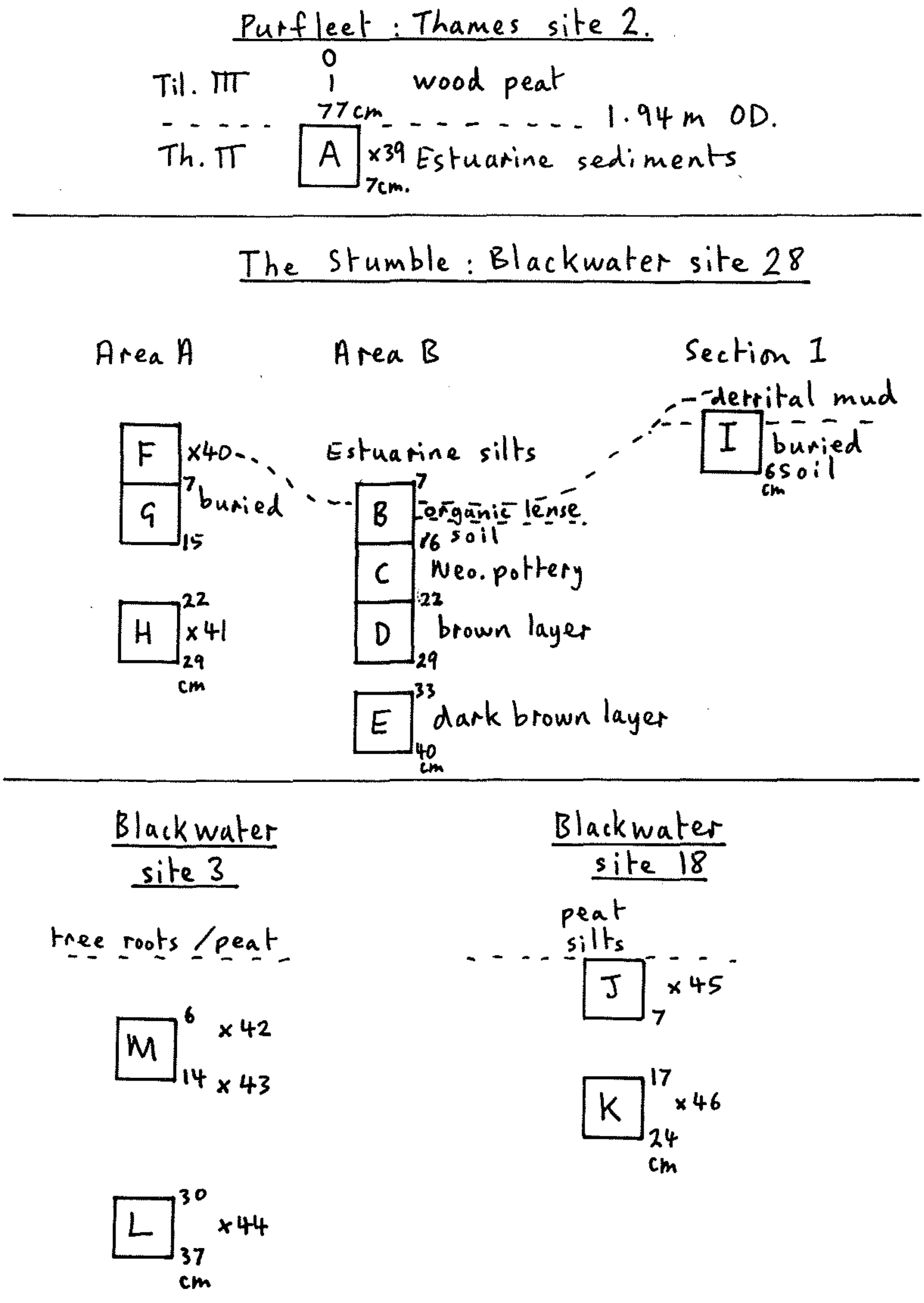


Fig. 1 – HULLBRIDGE PROJECT : SOIL/SEDIMENT SITES.

Fig. 2. HULLBRIDGE PROJECT: bulk sample (x) and thin section sample (□) location.



Macphail 87/89

Plate 1. Field photo of section 2 at the Stumble, Blackwater Site 28. A monolith sample through the buried soil and overlying detrital peat is illustrated.

Plate 2. Purfleet: the buried woodland soil; a photomicrograph of relic woody roots and dark greyish brown sodium carbonate that is partially impregnated with iron. Plane polarised light (PPL); frame length is 5.6 mm.

Plate 3. As plate 2, crossed polarised light (XPL), showing birefringent nature of iron stained sodium carbonate.

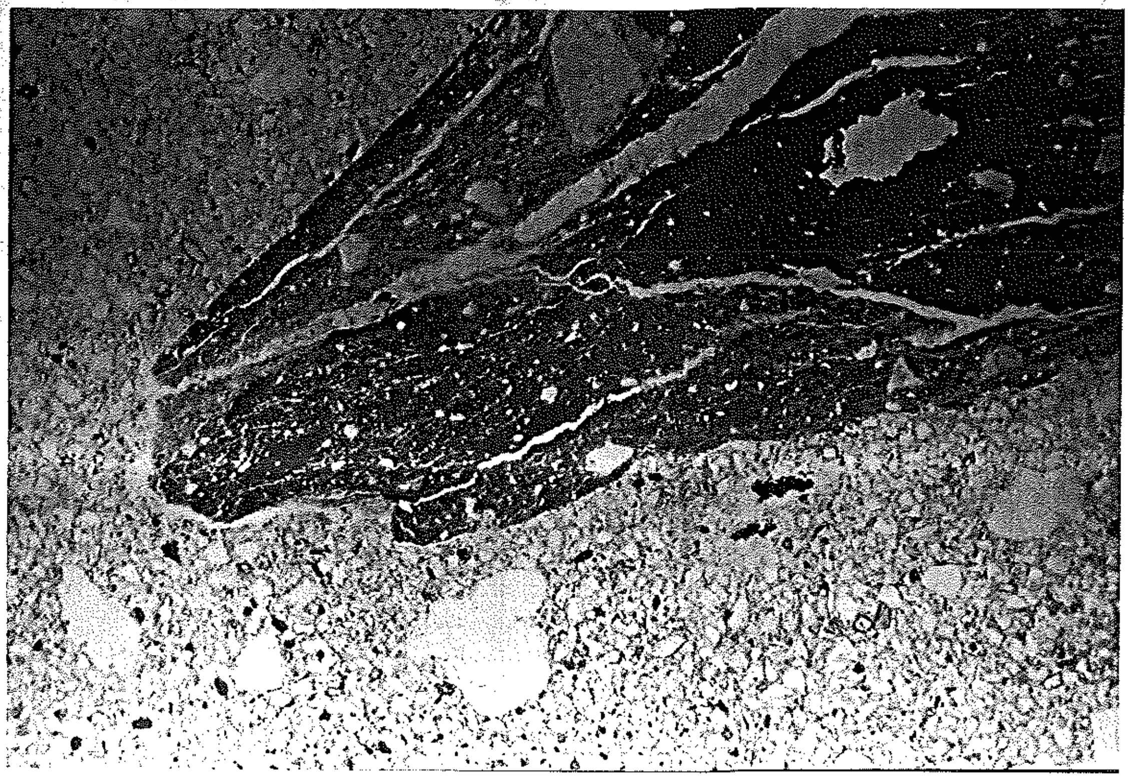


Plate 4. The Stumble: pottery sherd at ca.21 cm depth in leached "topsoil" of the Neolithic profile, which is very pale and mainly depleted in clay and iron. PPL; frame length is 5.6 mm.

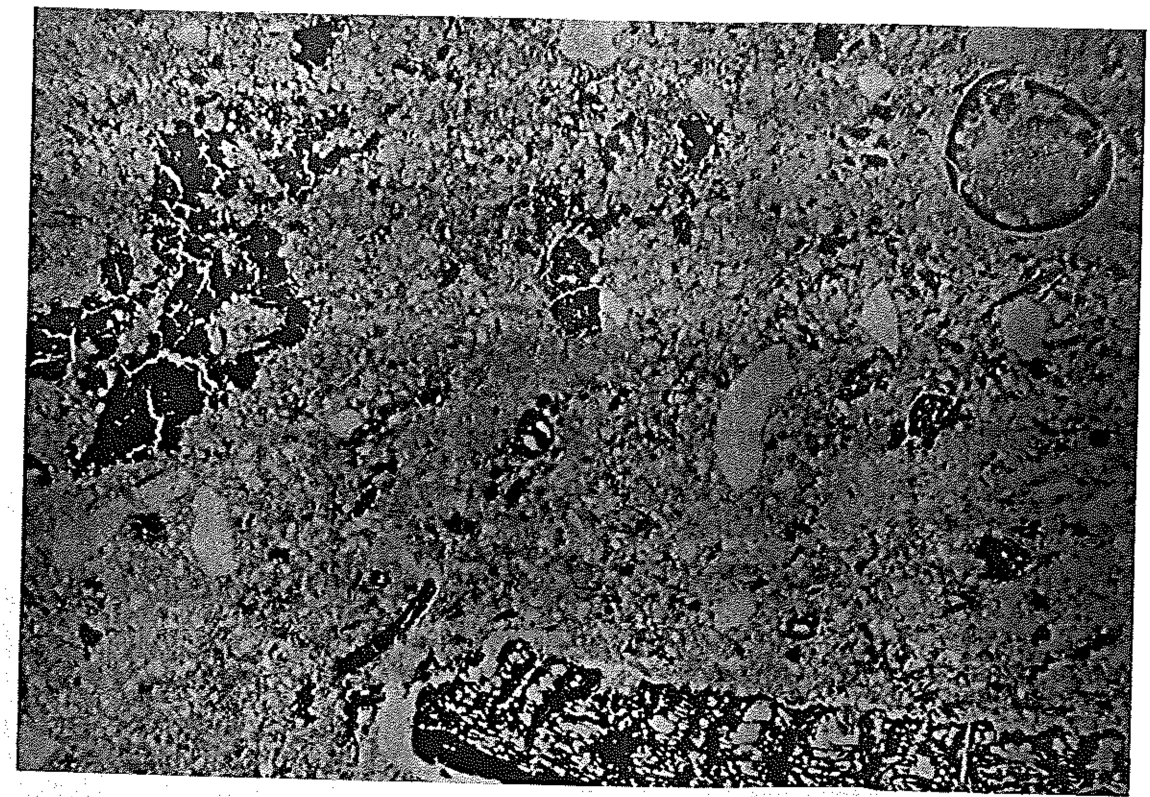


Plate 5. The Stumble: seed and wood charcoal lens accumulated at the surface of the Neolithic soil, which is depleted of iron and clay. PPL; frame length is 5.6 mm.

Plate 6. The Stumble: pale grey estuarine silts with thin horizontal voids as porosity pseudomorphic of decayed plant detritus. PPL; frame length is 5.6 mm.

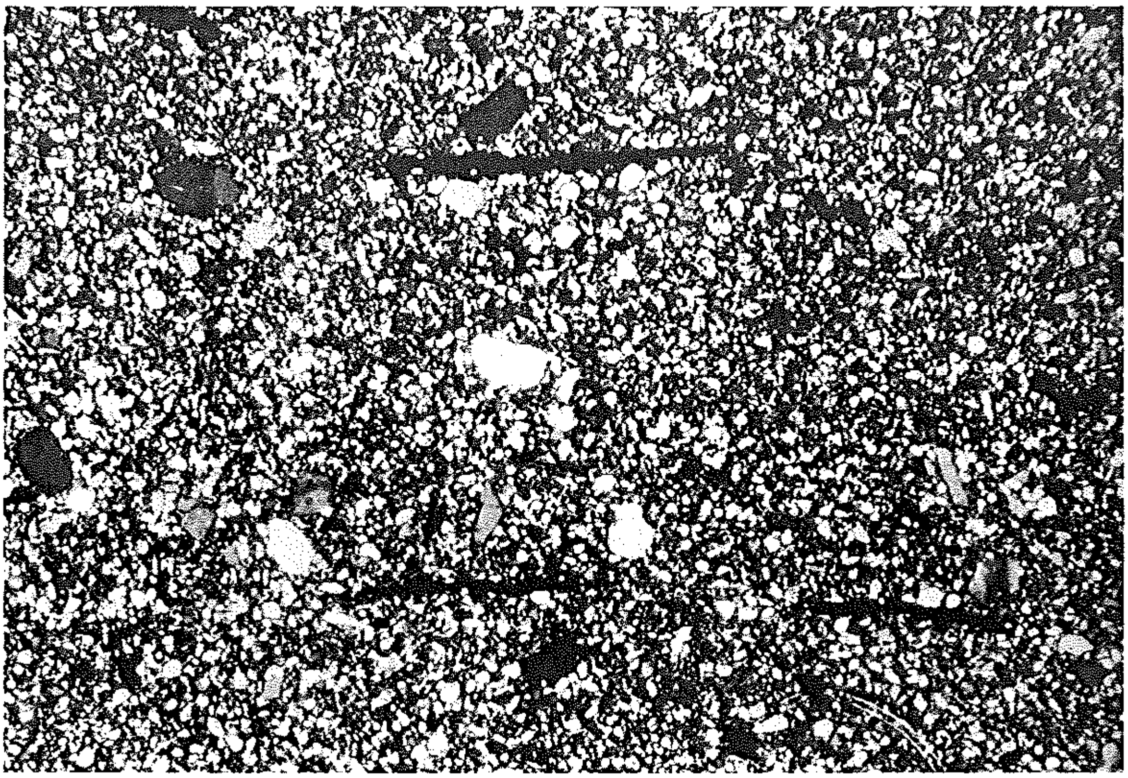


Plate 7. As plate 6, crossed polarised light, showing voids where organic debris was layed down horizontally. Note clay poor nature of the sediment.

Plate 8. The Stumble, section 2: the top of the Neolithic soil has become slaked through estuarine inundation which layed down detrital peat in thin brown lenses and at the same time mobilised fine material, which washed down profile. PPL; frame length is 5.6 mm.

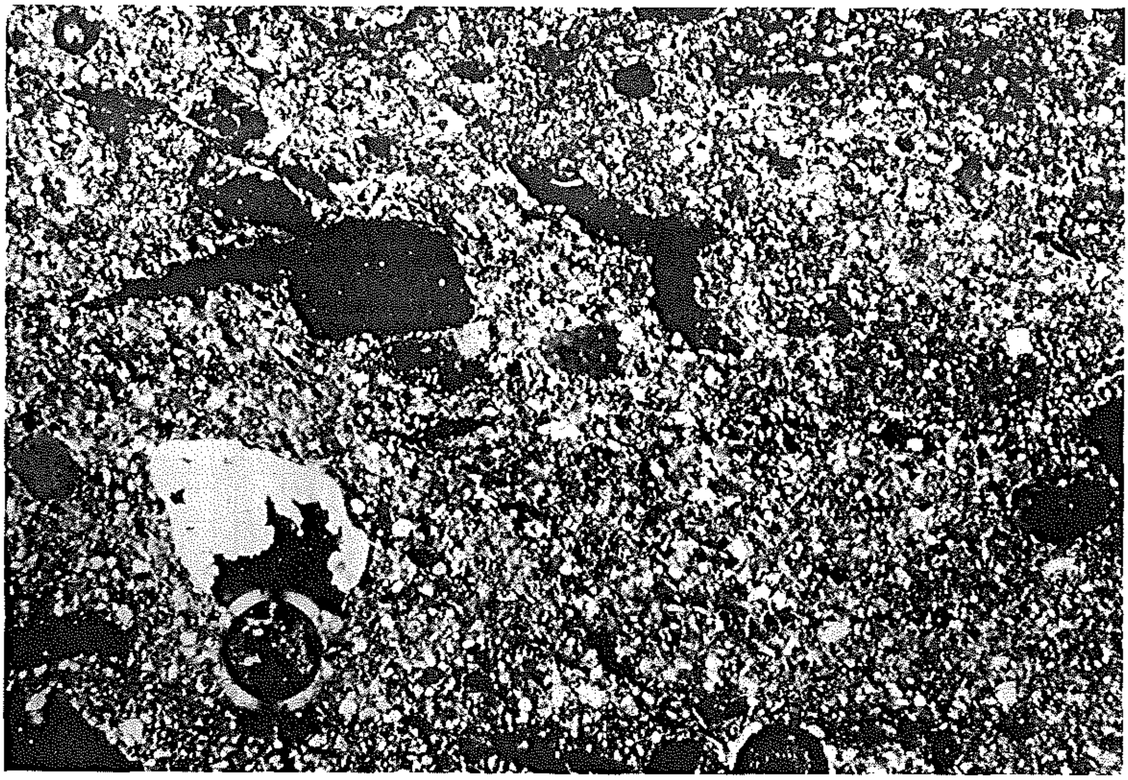


Plate 9. As plate 8, crossed polarised light showing bands of organic clay.

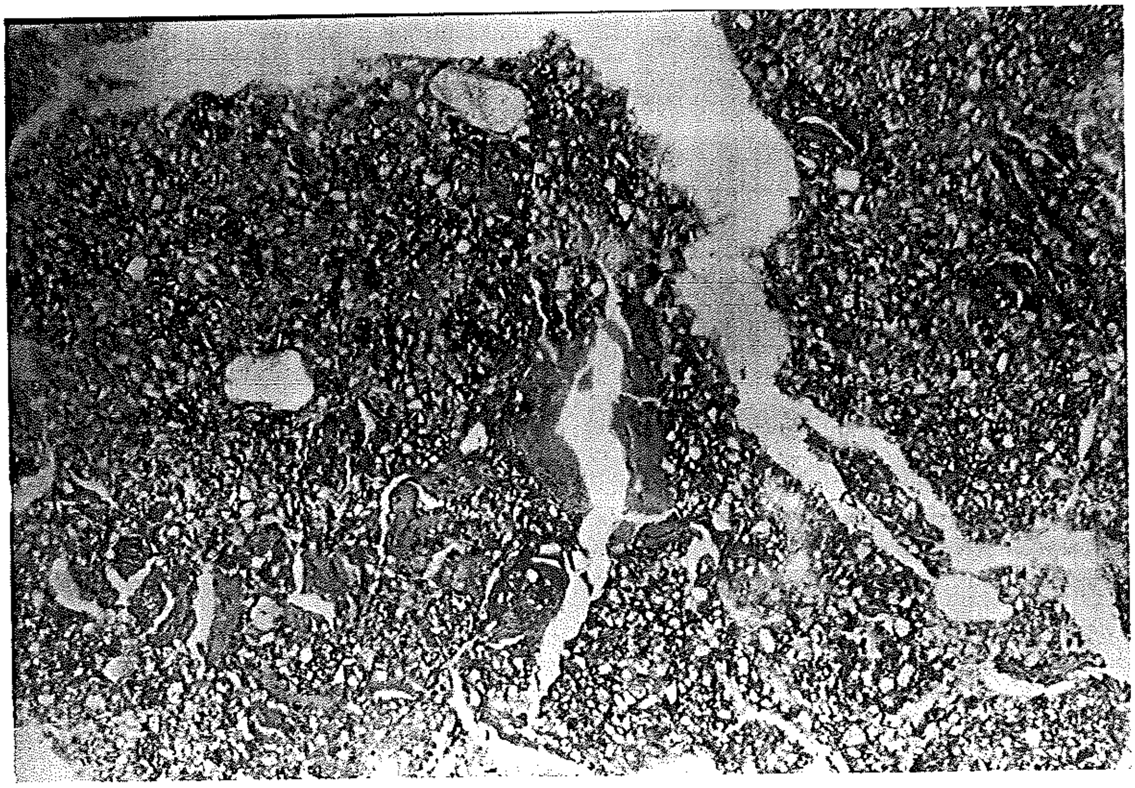


Plate 10. The Stumble: redistributed clay translocated from the Neolithic "topsoil" into a weakly iron and manganese stained "subsoil" at ca. 30 cm depth. Compare this with the depleted "topsoil" samples of plates 4, 5, 6, 7 12 and 13. PPL; frame length is 5.6 mm.

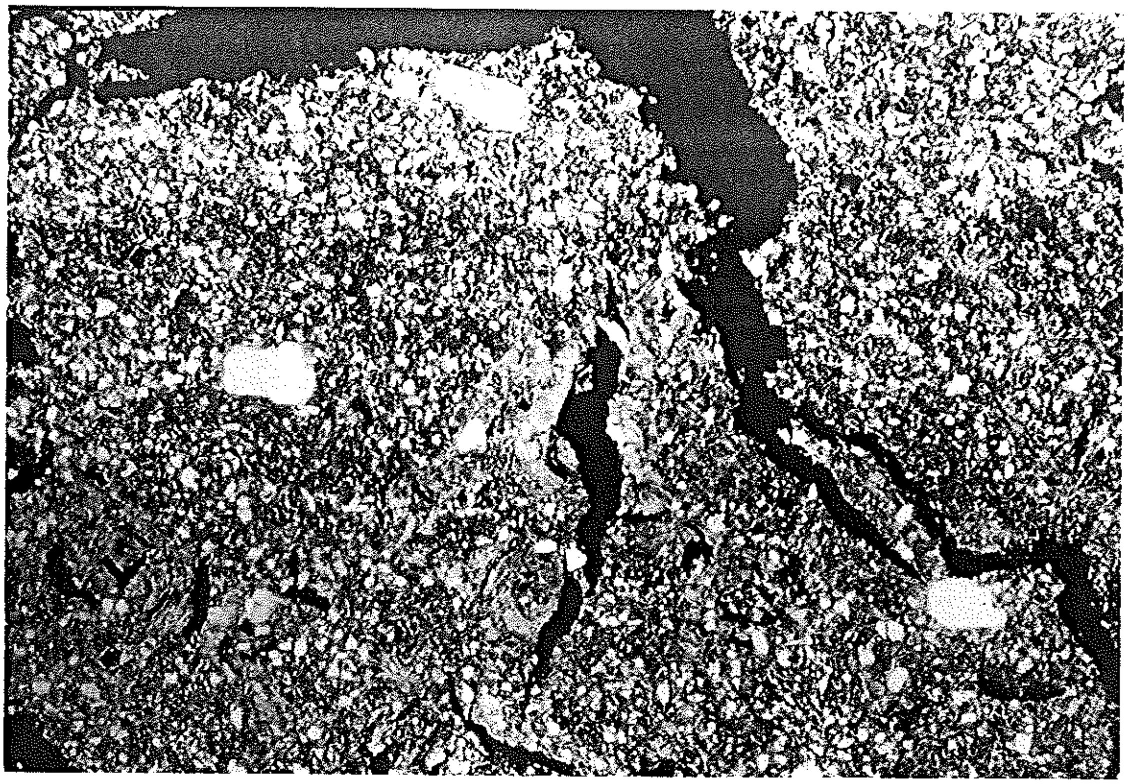


Plate 11. As plate 10, crossed polarised light showing abundant clay coatings and infills.

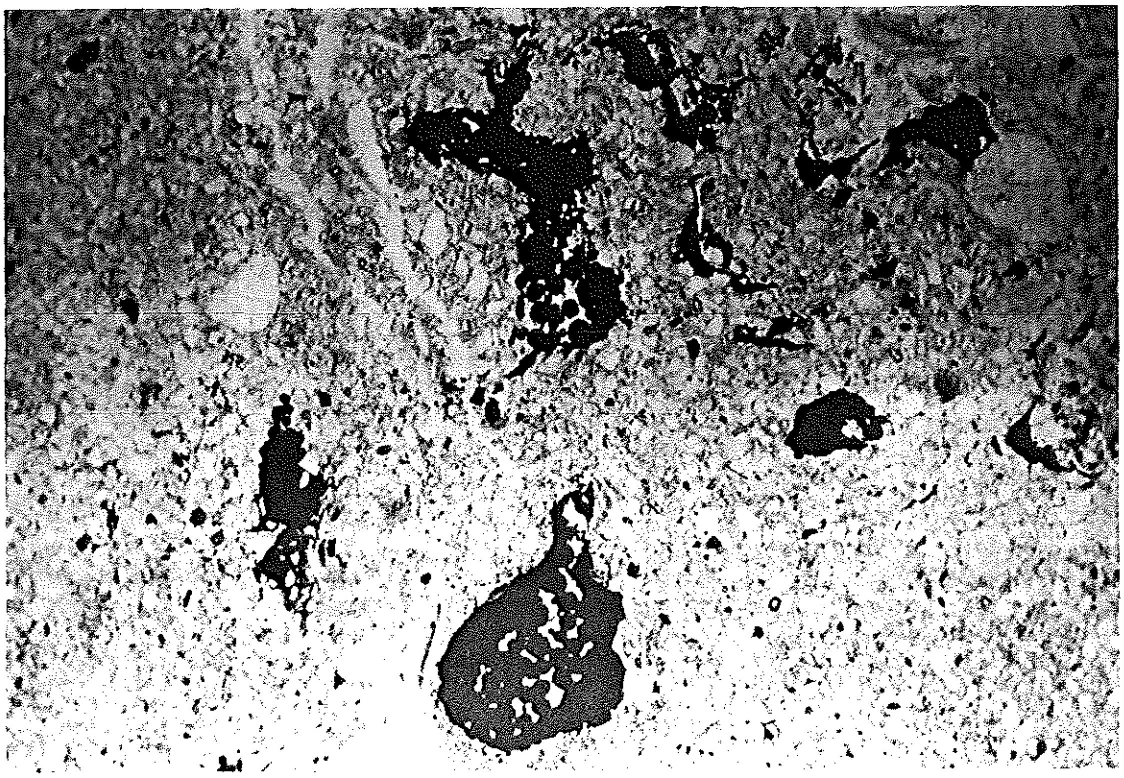


Plate 12. The Stumble: the depleted Neolithic "topsoil" in its new role as an intertidal soil contains many void infills of pyrite spheroids. PPL; frame length is 3.3 mm.

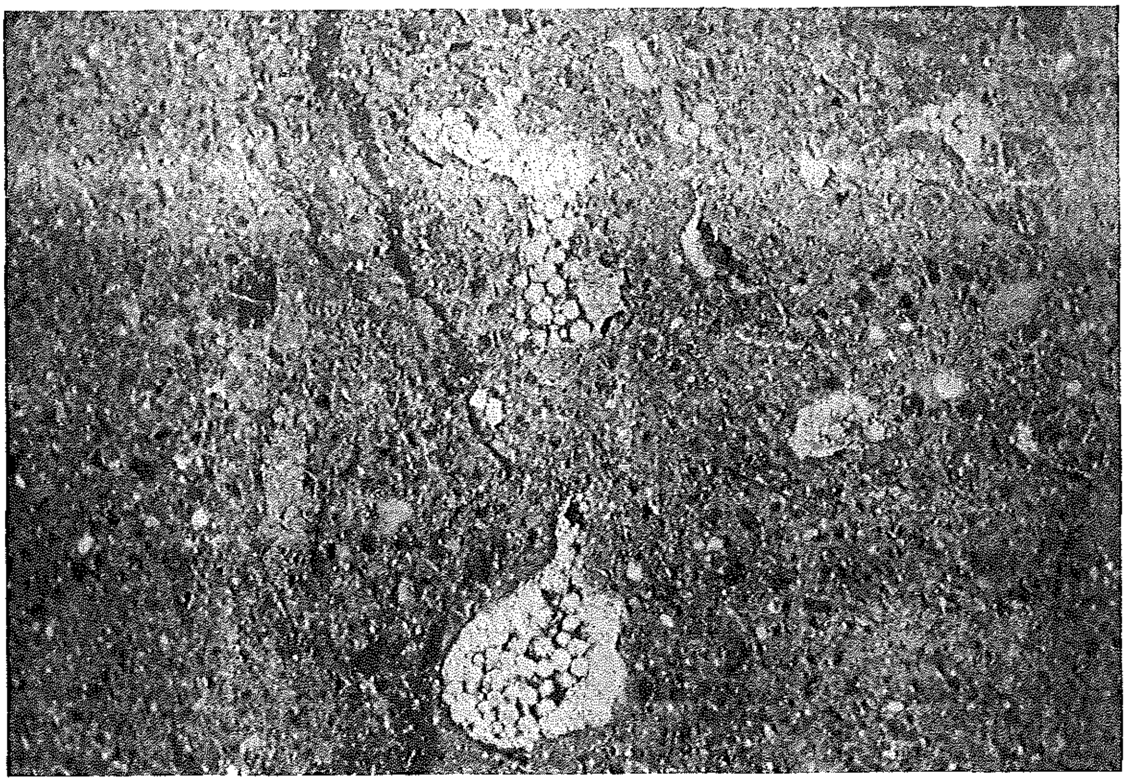


Plate 13. As plate 12, oblique incident light, showing pale depleted soil and typical brassy appearance of the pyrite.

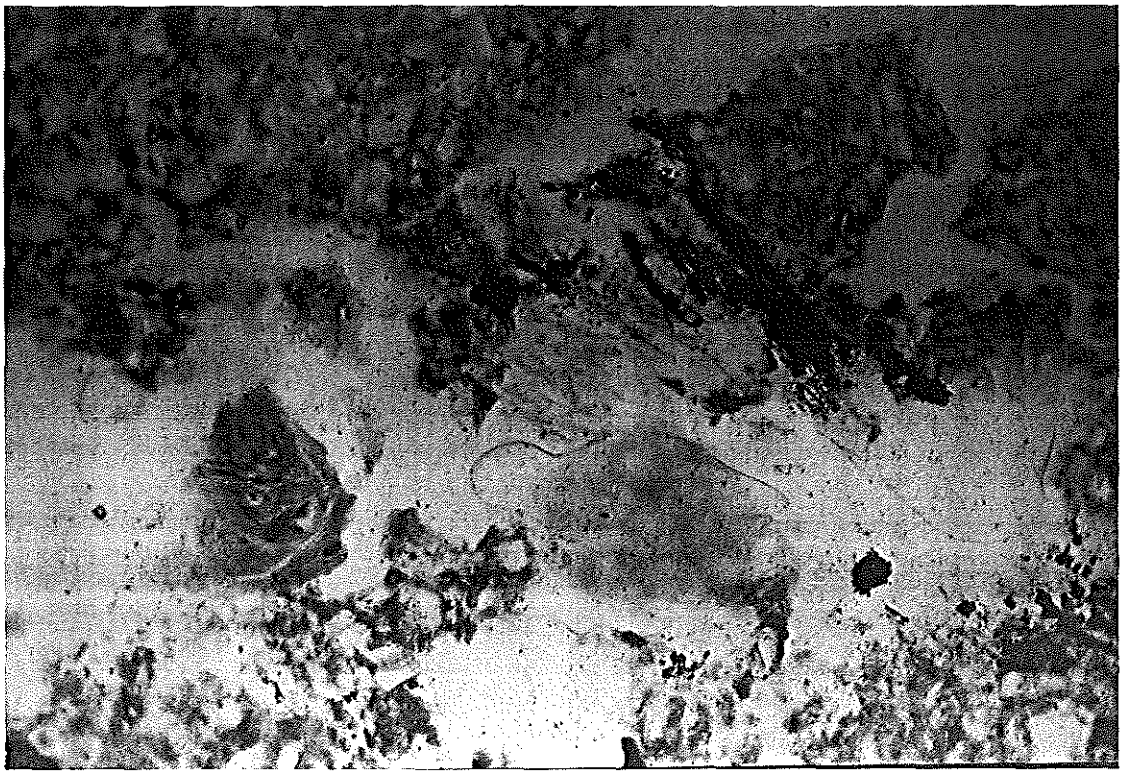


Plate 14. Blackwater site 18: Neolithic soil contains inwashed clay fragments, pyrite growth and gypsum crystallisation (centre), as indicators of the new intertidal regime. PPL; frame length is 1.6 mm.

Plate 15. As plate 14, crossed polarised light, showing typical euhedral crystals of calcium sulphate (gypsum).

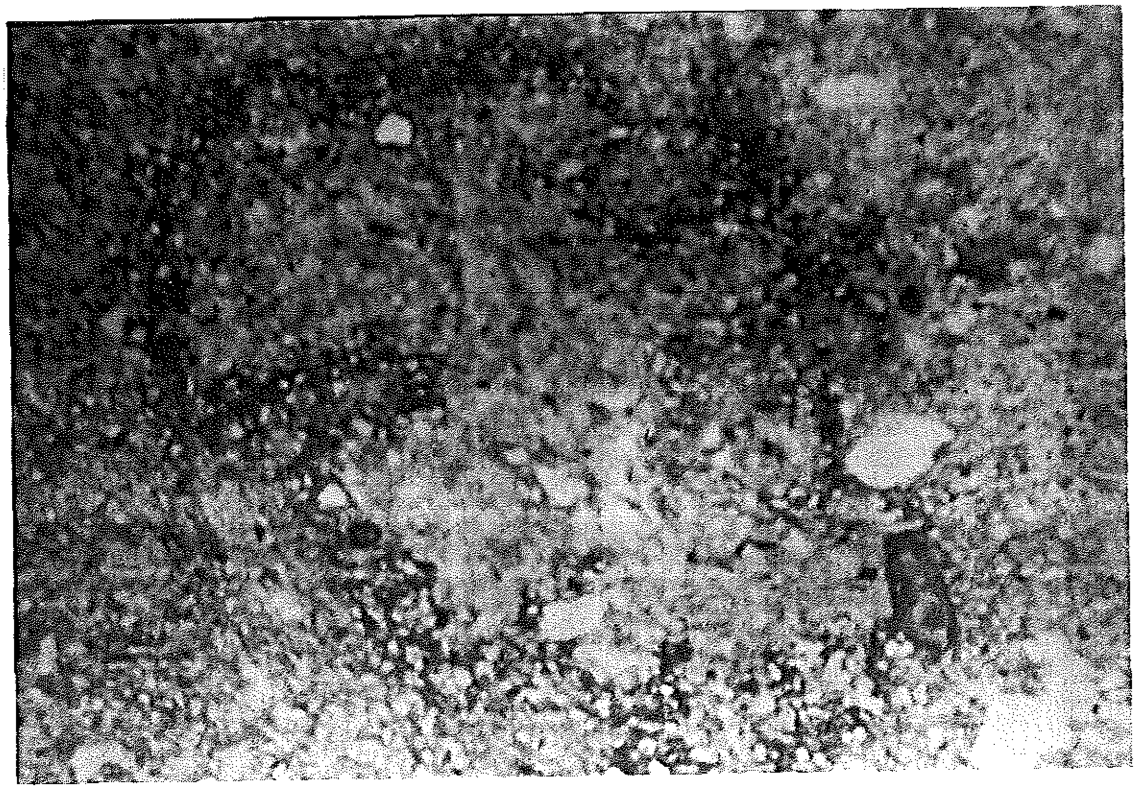


Plate 16. Blackwater site 18: Neolithic soil, now generally depleted, with clay poor zones protected by iron and manganese cementation (nodular formation) as a result of hydromorphism, set in a matrix subsequently enriched in translocated clay. PPL; frame lenth is 5.6 mm.

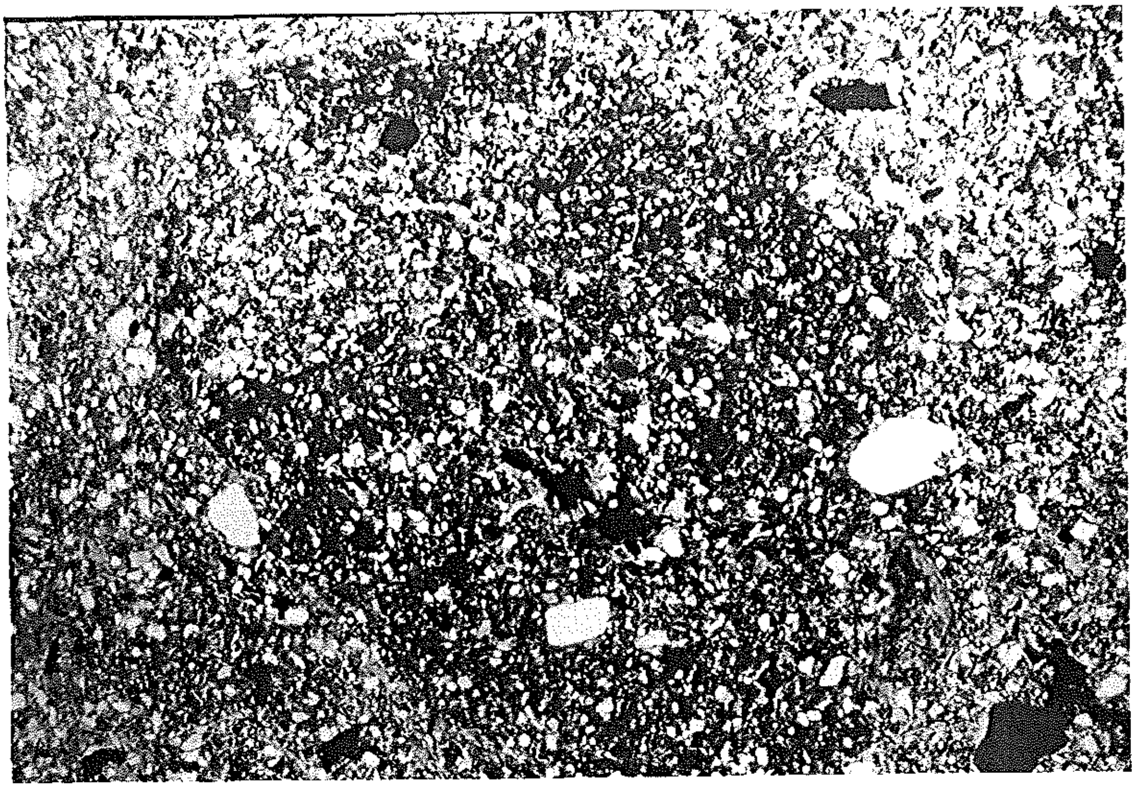


Plate 17. As plate 16, XPL, showing iron and manganese staining, and clay coatings and infills.