AML Report 4583

HBMC2 AM ARCH(2SP)1184

Review and discussion of magnetic susceptibility and micromorphology: examples of Hazleton Long Cairn, Gloucestershire and Seaford Head Hillfort, Sussex

1732 1827

M.J. Allen

R.I. Macphail

The 1980-1983 excavations of the Neolithic long cairn at Hazleton, Gloucestershire (Saville 1984) and the excavation of two trenches through the ramparts at the Seaford Head Iron Age Hillfort in 1983 (Bedwin, in prep.) permitted both magnetic susceptibility and soil micromorphology studies to be applied to the environmental study of these sites.

Magnetic susceptibility (X) measurements were made from samples of 100g air dried soil (<2mm) using a Bartington MS 1 magnetic susceptibility metre coupled to a MS 1 B sensor coil calibrated for 100g of soil. The results, presented in table 1, were recorded in Si units $\times 10^{-8}$ m^3 kg^{-1}.

Soils were described (Hodgson 1974) and analysed (Avery and Bascomb 1974) by standard methods, whereas mammoth thin sections (prepared at I.N.A. P-G, Grignon, France) were described utilising the new thin section handbook (Bullock et al in press.). Details are given elsewhere (Macphail 1983, 1984a, 1984b).

The buried Neolithic silty clay argillic brown earths developed on Oolitic limestone at Hazleton show anomalous (subsoil) enhancement in both samples 2 and 3 (Table 1), with the subsoil readings being higher than the A horizons. Modern local valley colluvium also reveals a higher readings than the buried A horizons.

Table 1

Hazleton and Seaford Head; Selected Analytical Data and Magnetic Susceptibility (MS) (Si units 10^{-8} m^3 Kg^{-1})

Site	Horizon	pH	% Org.C	% Clay	% Silt	% Sand	MS
Hazleton	(buried Neo soil and "modern" colluvium)						
2	bA	8.0	.94	37	41	22	50.40
"	bAg	8.1	.92	37	46	16	30.02
"	bBtg	8.1	.84	44	35	22	78.12
3	bAg	7.7	1.22	-	-	-	27.72
"	bBtg	7.8	1.15	-	-	-	75.60
Colluvium	Ap	7.7	3.48	43	34	23	-
"	B1	7.8	2.18	37	31	31	168.54
"	B2	8.0	0.89	47	28	24	110.88
Seaford Head	(buried Iron Age soil, rampart components and modern colluvium)						
buried soil	bA	7.7	.78	38	37	24	11
	bB	7.7	.94	43	36	21	18
Rampart	A	6.7	2.28	49	26	24	21
"	B	8.0	1.58	53	28	20	16
"	Dump B	-					12
"	Clay-w-Flints upper	-					17/21
"	Clay-w-Flints lower	-					14/19
Colluvium							10

At Seaford Head, a variety of clay soils all gave comparatively low readings. The buried Iron Age soils (bA and bB horizons) which are believed to have a major colluvial ploughwash component, again show anamolous enhancement. Soils developed in the rampart, and "unweathered soil" in the rampart also exhibit low enhancement, even though much of the bank comprises reddish paleo-argillic (Avery 1980) superficial materials (Clay-with-Flints).

MAGNETIC SUSCEPTIBILITY - BACKGROUND

Magnetic measurement is familiar to archaeologists as a method of prospecting using a variety of instruments to record variations in the magnetic field of surface and buried features. Magnetic susceptibility (X_o) has been used as a prospecting tool (Tite and Mullins 1970, 1971, Mullins 1974, Aitken 1974, Longworth and Tite 1977 and Clark 1983) however here we concentrate on this technique as a method for palaeoenvironmental interpretation. This study is partially derived from principles published by those mentioned above but also from the work (published and unpublished) of Oldfield et al (1978, u.d.).

Magnetic susceptibility (X_o) is a parameter which expresses the ratio between the magnetisation induced in a sample and the magnetising field (a more detailed defination is given in Thompson *et al* (1975) and Oldfield et. al. (1978). Magnetic susceptibility enhancement is due to the conversion of iron oxides in the soil from the weakly ferrimagnetic form, haematite ($\alpha\ Fe_2\ O_3$), to the strongly magnetic form maghaemite (γFe_2O_3) which has a strong positively aligned magnetic movement if placed in a field; moreover is capable of retaining magnetic remanance when removed from that field (Oldfield unpub.). This enhancement may be due to burning, or as we show here pedogenic processes.

DISCUSSION

At Hazelton, subsoils were heterogeneous, exhibiting a mixture of microfabrics, relating to tree-throw and other physical disturbances of the soil (Macphail 1984b). One component comprised reddish (and probably ferruginous) weathered clay from either the soil/limestone interface (Beta B horizon) or a paleo-argillic phase. These subsoils also contained mixed-in A, Eb and Bt horizon material, textural infills with included organic matter (dusty argillans), and were overall moderately affected by hydromorphism. All these factors may contribute towards magnetic susceptibility enhancement.

In the upper horizons of the buried soil, long burial had led to taphonomic (burial related) processes leading to a change in redox, through the anaerobic decomposition or organic matter (Duchaufour, 1982), with the result that soft iron and manganese pans formed at both the junction of the buried soil with the cairn, and at approximately 4-5cms depth (a phenomenom common to buried soils; Evans, 1972; Limbrey, 1975). The soil thus experienced zones of both depletion of, and impregnation by, iron minerals, presumably affecting local levels of magnetic susceptibility. Thus bulk sampling of these buried A horizons not only produce MS readings which "average out" this re-distribution of iron, but also which do not so much represent Neolithic MS, but post-burial affects. The texteral infills, for example, are primarily comprised of the clay fraction which may produce erroneously high MS levels as it has been demonstrated that ferromagnetic irons are concentrated in the clay fractions of the surface horizons (Oades and Townsend 1963.

The subsoil may have been affected by natural MS enhancement as iron-rich clay is translocated during early Holocene lessivage. In addition, the relic reddish clay fabric probably derives from the long weathering of ferruginous mineral material from the Jurassic limestone. In situ hydromorphism of these clay fabrics may also have enhanced MS.

Lastly, the subsoil is characterised by textural infills originating from surface soil disturbance by tillage (Macphail, 1984b). As ferromagnetic irons are concentrated in the clay fraction of surface horizons (Oades and Townsend, 1963; Dearing, et al, 1981) this process may "physically" produce subsoil MS enhancement.

However, the latter inference is complicated by the suggestion that the Neolithic soils at Hazleton may have been depleted of organic matter and as a result had low earthworm activity - thus possibly producing a rather low MS in any case. Indeed the two major components of pedologic magnetic susceptibility enhancement are high organic content and well aerated soils. Even though agricultural tillage will aid aeration of soils, the depletion in organic material which provides the ferrous iron (an obligatory precursor to the formation of the ferrimagnetic iron oxides (Oades and Townsend 1963)) will result in low MS levels. The resulting inference that colluvia resulting from early agriculture may be characterised by low enhancement as a general prediction also derives from the overall findings from Scotland (Romans and Robertson, 1983) where early cultivated soils were found to contain little organic matter and were characterised by low levels of biological activity as a result.

In contrast the high MS values of the modern colluvial soils at Hazleton in a local dry valley can be safely ascribed to enhancement due to present day agricultural practices, including burning and the artificial maintenance of high biological levels, although these colluvial soils also contain numerous rounded fragments of ferruginous subsoil material described from the Neolithic soil cover.

At Seaford Head, overall MS is low, and typical of levels present in soils developed in the chalk areas (Tite 1972, Fig 2, Aitken 1974 fig 6.8, Mullins 1974, fig 4/11 table 4/1). The 'Clay-with-Flints", deposits (Hodgson, Catt and Weir 1967, Avery et al. 1959) themselves are reddened by pre-Holocene weathering, as well as containing components from the Reading Beds (Eocene). This apparently produced low enhancement despite the apparent high levels of magnetite in the heavy mineral suite (Hodgson et al 1967) probably because haematite is dominant (Avery, et al 1959). (Compare interpretation of red clay fabrics at Hazleton). Little enhancement is exhibited by the modern A horizon developed in this material.

The buried Iron Age soils examined in thin section also show low MS, even though strong oxidisation of organic matter (including pollen - Scaife 1984) produced many ferruginous organic matter pseudomorphs. In addition, the buried A horizon may represent ploughwash colluvium - the buried A horizon being texturally different from the buried B horizon (Macphail, 1984). The latter also contains relatively more organic matter, suggesting it may have been an earlier soil deposit. Ploughing affects on the upper horizon (bA) produced textural coatings within the buried B horizon - possibly adding to subsoil enhancement. The MS data therefore supports the contention that the bA and bB horizons represent separate events - probably the bB horizon is a relict worm-worked (stone-free) A horizon affected by later cultivation (pottery and charcoal became included) which became buried by a phase of ploughwash colluvium.

The buried A horizon again shows only minor biological reworking, perhaps again reflecting low levels of organic matter.

Direct comparisons between Hazleton and Seaford Head cannot be drawn, as absolute

MS levels depend upon the geology from which the soils derive and determine the concentration of iron oxides in the soil which is available for conversion to strongly ferrimagnetic forms (Tite 1972). Moreover we are dealing with sites separated temporally, and thus theoretically enduring different agricultural regimes and thus contrasting soil conditions as a result. We suggest it is worth examining the possibility that low organic levels and biological activity (Romans and Robertson 1983) in the Neolithic may have produced low MS values in the resulting colluvium. The evidence from Seaford Head indicates a similar possiblity, although theoretically higher organic and biological activity (in ferred from Reynolds *pers comm*) may have produced potentially greater MS enhancement generally in the Iron Age, as reported from the Bourne Valley (Allen, 1983).

CONCLUSIONS Firstly, our findings are based on the assumption that MS readings do not relate to significant inclusions of pottery - as recorded during sample preparation and micromorphological examination. In addition no attempt has been made to evaluate the total iron content (Xn), and thus the potential magnetic susceptibility of the soils, nor to avaluate the percentage conversions (c); that is the ratio of the magnetic susceptibility (Xo) to the susceptibility (Xn) recorded after heating the soil in controlled laboratory conditions (Longworth and Tite 1977) to assertain total susceptibility values.

1. Soils on Limestone terrains produce higher MS values than those on the superficial deposits on the Chalk, although the latter have long histories of pre-Holocene weathering. Possibly the Oollitic Limestone is relatively more ferruginous, whereas the Clay-with-Flints is, for example, dominated by haematite. These results comply with Tite (1972), Aitken (1974) and Mullins (1974).

2. The effects of long burial, through redox and localised hydromorphism is to both deplete and concentrate iron in the upper soil horizons, probably producing a variable pattern of MS, and superimposing MS values differing from the original archaeological levels.

(Low MS values in A horizons affected by early cultivation may also possible reflect the low levels of organic matter produced by this land use).

3. Complicated pedogenic histories in B horizons, such as the inclusion of weathered red clay (lithorelicts), the incorporation of organic rich A horizon soil, hydromorphism and clay illuviation may contribute towards anomalously high subsoil MS readings.

4. Soils developed by ploughwash colluvium exhibit heightened MS, differentiating different phases - although colluviation under modern cultivation may produce much higher overall values.

Acknowledgements

The authors wish to thank Dr A Clark for his encouragement.

References

Aitken, M.J. 1974 Physics in Archaeology (2nd ed) (Oxford: Clarendon Press)

Allen, M.J. 1983. Sediment analysis and archaeological data as evidence of the palaeoenvironments of early Eastbourne: the Bourne Valley excavation. Unpub. B.SC. dissertation. Institute of Archaeology, London.

Avery, B.W. 1980. Soil classification for England and Wales. Soil Survey Monogy. 14. Harpenden.

Avery, B.W., Stephen, I., Brown, G. and Yaalon, D.H. 1959. The origin and development of brown earths on Clay-with-Flints and Coombe deposits. Journ. Soil Sci. 10, 177-195.

Avery, B.W. and Bascomb, C.L. (Eds) 1974. Soil survey laboratory methods. Soil Survey Tech. Monogr 6. Harpenden.

Bullock, P., Federoff, N., Jongerius, A., Stoops, G. and Tursina, T. In press. Handbook for soil thin section description. Waine Res. Publications, Wolverhampton.

Clark, A.J. 1983 'The testimony of the topsoil', in G.S. Maxwell (ed) The Impact of Aerial Reconnaissance on Archaeology. CBA Research Report 49; 128-135.

Dearing, J.A., Elner, J.K. and Happy-Wood, C.M. 1981. Recent sediment influx and erosional processes in a Welsh upland lake-catchment based on magnetic susceptibility measurement. Quat. Res. 16, 365-372.

Duchaufour, P. 1982. Pedology. George, Allen and Unwin. London

Evans, J.G. 1972. Land snails in archaeology. Seminar Press. London.

Hodgson, J.M. 1974. Soil Survey field handbook. Soil Survey Tech. Monogr 5. Harpenden.

Hodgson, J.M. Catt, J.A. and Weir, A.H. 1967. The origin and development of Clay-with-Flints and associated soil horizons on the South Downs. Journ. Soil. Sci. 18, 1, 85-102.

Limbrey, S. 1975. Soil science and archaeology. Academic Press. London.

Longworth, G. and Tite, M.S. 1977 'Mössbauer and Magnetic susceptibility studies of iron oxides in soils from Archaeological Sites. Archaeometry 19, 3-14.

Macphail, R.I. 1983. Soil report on Seaford Head, Sussex. An. Mon. Lab. Rep. 3981.

Macphail, R.I. 1984a. Second soil report on Seaford Head, Sussex. An. Mon. Lab. Rep. 4442.

Macphail R.I. 1984b. Soil report on Hazleton Long Cairn, Gloucestershire. An. Mon. Lab. Rep.

Mullins, C.E. 1974. The magnetic properties of the soil and their application to archaeological prospecting; Archaeo-Physicka 5.

Oades, J.M. and Townsend, W.N. 1963. The detection of ferromagnetic minerals in soils and clay. Journ. Soil Sci, 14, 2, 179-187.

Oldfield F, Dearing, J.A. Thompson, R. and Garret-Jones, S. 1978. Some magnetic properties of lake sediments and their possible links with erosion rates. Polskie Archiwum hydrobiolgii, 25, 321-331.

Oldfield, F, Drawiecki, A., Maher, B., Taylor, J.J. and Twigger, S. (undated) The role of magnetic measurements in Archaeology. unpub MS.

Romans, J.C.C. and Robertson, L. 1983. The general effect of early agriculure on the soil. In (G.S. Maxwell) Ed. The impact of aerial reconnaissance on archaeology. C.B.A. Res. Rep. 49, 136-141.

Saville, A. 1984 Preliminary Report on the excavation of a Cotswold-Severn Tomb at Hazleton, Gloucestershire. Antiquaries Journal, 64; 10-24.

Scaife, R.G. 1984 Seaford Head: Pollen analysis of buried ground surface A . Mon. Lab. Rep.

Thompson, R. Batterbee, R.W., O'Sullivan P.E. and Oldfield, F. 1975 'Magnetic Susceptibility of Lake Sediments', Limnology and Oceaonography, 26, 687-698.

Tite, MS. 1972 The influence of Geology on the magnetic susceptibility of soils on Archaeological Sites. Archaeometry 14, 229-236.

Tite, MS. and Mullins C.E. 1970 'Electromagnetic propecting on archaeological sites using a soil conductivity meter' Archaeometry 12, 97-104.

Tite, M.S. and Mullins, C. 1971. Enhancement of the magnetic susceptibility of soils on Archaeological Sites. _Archaeometry_ 13, 209-219.