An examination of the mobilisation of elements from the skin and bone of the bog body Lindow II and a comparison with Lindow III

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Abstract

The elemental content of samples of tissues derived from a 2,000- year old bog body, Lindow II, are described and the interchange of elements between the body and the surrounding or encompassing anaerobic peat medium is examined. A comparison is made of the chemical 'fingerprint' of Lindow II as compared with another bog body referred to as Lindow III. The application of body paint is noted. The bone has retained much of its structure and the Haversian Canal system is recognisable. The presence of a fungus mycelium on the skin samples is noted.

Introduction

In recent years, there has been a great deal of interest in the so-called 'bog bodies' which have been discovered in a state of excellent preservation in a variety of sites including those in Denmark and England. A comprehensive account of one of the bodies (Lindow II) has been published by Stead *et al.* (1986). This body, with its excellent state of preservation provides an exciting, unique, and important opportunity to ascertain aspects of weathering and element mobilisation under anaerobic bog conditions.

The find was made in 1984 during peat excavation on Lindow Moss in Cheshire, England. Since a female skull had also been unearthed at this site in 1983 this particular body is referred to as Lindow II and the subsequent 1987 find which consisted of leg and body fragments together with the stomach, as Lindow III.

Lindow II is the best-preserved 'bog body' from Britain. It is the upper part of a male torso, which was located *in situ* after the discovery of a dismembered right leg in the cut peat. The pelvis and left leg were never recovered, but the stomach and upper part of the small intestine were preserved within the torn abdominal wall. Externally the body is remarkably intact, the skin having been tanned like leather by the acidic bog environment. Bog acids were also responsible for softening and demineralisation of the bones and thus the body had become distorted and squashed during interment.

Using data from teeth and bones, Connolly (in Stead *et al.*, 1986) concluded that Lindow II was in his mid-twenties and estimated his height at around 168 cm (5'6"). He was muscular and powerfully built, perhaps weighing 60+ kg (~ 10 stones) at the time of death. He had a full head of dark hair that had been roughly trimmed, as had his beard and moustache. His fingernails were smooth and rounded, suggesting that he was not a manual worker. The body was naked apart from a fur armband just above the elbow of the left arm – "possibly a decoration, or perhaps a symbol of his status or clan" (Stead 1986). A sinew garotte remained firmly knotted around the neck, which had been broken.

The death is generally considered to have been a ritual murder. Head wounds suggest that he was initially struck from behind with an axe-like weapon (Bourke in Stead *et al.*, 1986), garotted by tightening the cord with a stick tourniquet-fashion (Budsworth *et al.* in Stead *et al.*, 1986) and finally the throat was cut through the jugular vein. The body was then submerged face down into a pool in the bog where it decomposed below water somewhat before finally becoming incorporated in the anaerobic bottom sediments.

The age of the body is something of an enigma, as carbon-14 dates showed considerable variation according to the tissue selected and the technique. The evidence is summarised by Stead (1986) who concluded "Palaeobotanists have presented a convincing argument suggesting that he met his death around 300 BC", during the Iron Age, rather than the Roman period.

Thus the body is likely to have spent 2,000+ years immersed in the bog and its preservation has involved changes in both the physical and chemical composition of some of the body tissues. The skin is remarkably preserved, but it is the dermis, rather than the epidermal cells, which survives. The basal layer of the human epidermis consists of thin-walled cells, the stratum Malpighii, from which the keratinised upper layer, the stratum corneum sloughs off during life. The thin-walled cells would rapidly decompose and their contents be dissolved by the acidic environment, thus separating the remaining epidermis from underlying layers, hence speeding its putrification. No trace of epidermis was found in the skin examined from Lindow III (Pyatt *et al.*, in press) and in Lindow II it is preserved only in the thickened friction ridges on the soles of the feet (Connolly in Stead *et al.*, 1986).

Dermal structure, on the other hand, is non-cellular and the collagenous connective tissue, (through which blood vessels, lymphatics, nerves and elastic fibres interlaced in life) remains intact, tanned by the tannic and humic acids of the bog. It is stained brown, but retains some flexibility. The skin of Lindow II was tested for the dye indigotin, the colorant in woad, (Taylor in Stead *et al.*, 1986), but with negative results.

Internally most of the soft tissues had been reduced by putrification and enzyme activity to an unrecognisable state apart from the stomach, jejunum and duodenum which may have been 'fixed' due to their acid nature. Whilst secretions from the small intestine are slightly alkaline, Lucas and Mathan (1989) gave the pH of such mucosal surfaces as 5.8 ± 0.09 in normal human patients. The acidity preserved their contents – probably the remnants of an unleavened cake made of ground wheat and barley (Stead 1986).

As noted earlier, the bones of Lindow II have altered both in physical and chemical structure. Normal bone owes its tensile strength to its organic matrix of collagen fibres and its hardness to the inorganic bone salts. The mineral component of mainly calcium and phosphate makes up two thirds of the weight of the bone or half its volume. In Lindow II demineralisation has caused the bones to become 'plastic' as it is mainly the flexible collagen fibres that remain. Thus distortion and compression have occurred to some extent throughout the skeleton. This is normal in an acidic environment and the skulls of Carboniferous vertebrates, where peat has been compressed to form coal, have often been reduced to two dimensions by plastic distortion without any cracking of the individual bones (Beaumont, 1977). In Lindow II the skull has twisted and the long bones of the limbs have become very thin and compressed.

Three samples obtained from Lindow II have been investigated to determine which elements had persisted in the skin and bone following a period of over 2,000 years burial in an anaerobic bog environment. Furthermore, the condition of tissue such as bone was examined and a comparison made with another bog body namely that referred to as Lindow III. Since Lindow Moss lies close to the former copper mining area of Alderley Edge in Cheshire, some evidence of trace elements associated with metal working might have been found in the body. Connolly *et al.* (in Stead *et al.*, 1986) thoroughly investigated the chemical nature of certain tissues including bone derived from Lindow II. Similarly, Pyatt *et al.* (in press) described the element composition of the skin and peat obtained from, and associated with, Lindow III. They noted 10 elements and suggested that some probably represented the residues of clay-based pigment emulsions applied probably in patterns to the body, perhaps for recognition purposes. Such may have been applied to the body before or after death.

Table 1 *Element composition (in %) from samples of tissues derived from Lindow II and III.*

Element	*Lindow III** *Skin sample* 20 (average repls)	*Lindow III** *Peat* 10	*Lindow II* *Skin sample* 5 (average repls)	*Lindow II* *Bone sample* 5	*Lindow II* *Peat and hair sample* 5
Mg	2.1398	5.3307	1.1178	1.5904	1.423
Al	7.7486	–	5.7916	5.649	3.5838
Si	7.7903	22.818	4.953	8.4446	10.7774
S	45.1666	54.2626	55.37	53.6672	28.741
Cl	13.6539	–	14.7394	19.1644	21.154
K	1.4836	–	0.6738	0.1366	1.3552
Ca	17.3024	17.5908	7.919	4.2056	22.5844
Ti	0.4001	–	–	–	–
Fe	3.5447	–	1.1032	0.6322	4.6098
Cu	0.7592	–	0.7754	0.95	1.3806
P	–	–	6.0398	3.2112	0.968
Zn	–	–	–	–	–
Mn	–	–	0.9492	0.3398	0.9914
Ni	–	–	0.5618	2.0044	2.4114

Peat and hair samples were obtained from below right shoulder and cheek. The skin samples from under right side of body (from arm) – excavation of back; and the bone samples from upper right orbit.

* From Pyatt *et al.* (in press)

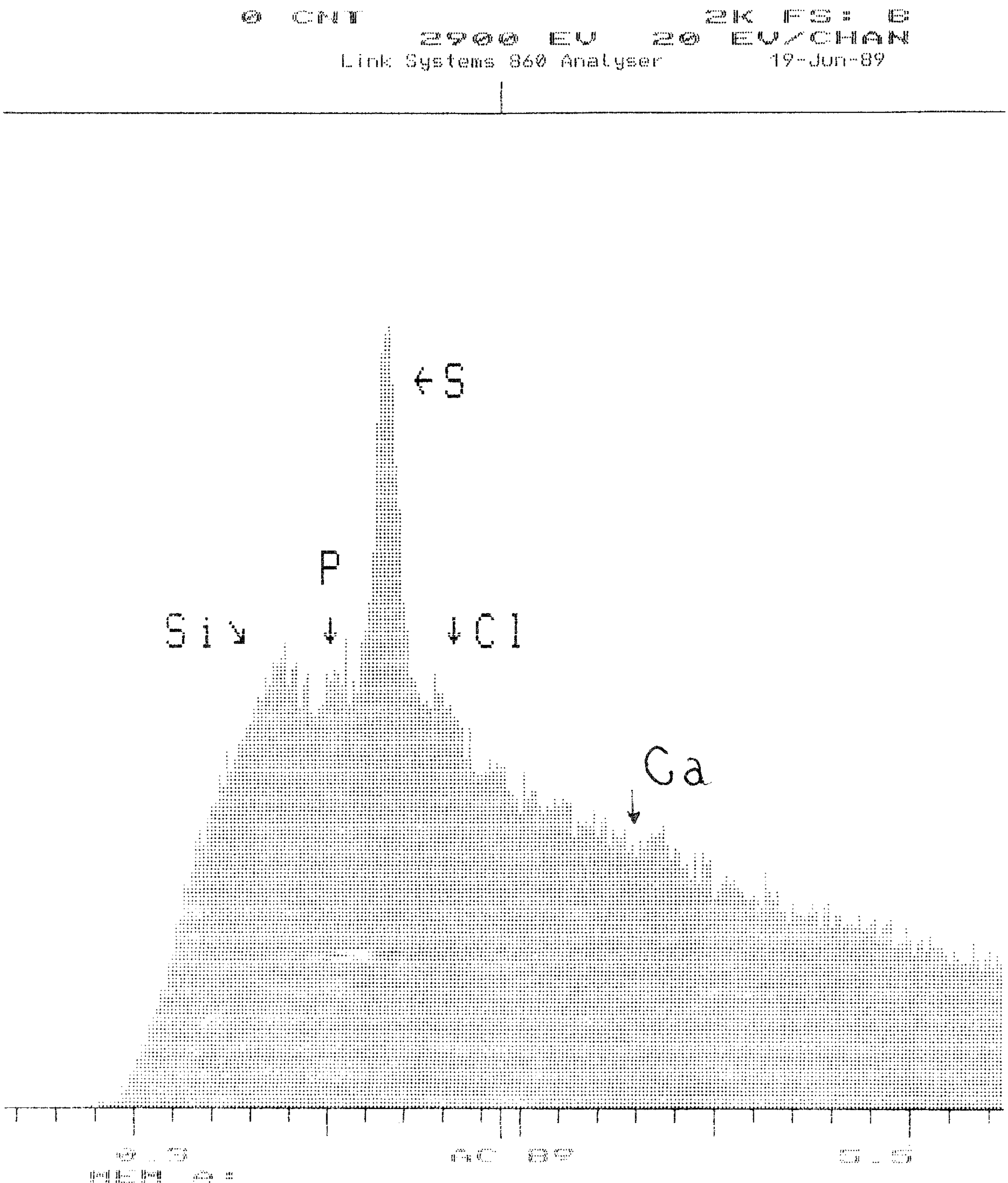


Figure 1 *Specimen results from bone sample of Lindow II.*

Experimental Procedure

The procedure employed involved electron probe X-ray microanalysis with a Link system 860 Series 2 Computer employing a ZAF-4 program; the technique is described in more detail by Pyatt and Lacy (1988) and Pyatt *et al.* (in press). The technique is accurate although it should be noted that only elements 'above' sodium will be recorded – hence elements such as hydrogen, carbon, nitrogen, and oxygen will not be measured and thus will not be represented in the results. However, the procedure, which is destructive only to small samples, produces data which serves to indicate all the important trends and is also invaluable for comparative studies of such materials as are currently being investigated in this research programme. Three samples obtained from the body of Lindow II were examined; these were:

(1) an intimate peat and hair mixture from below the right shoulder and cheek;

(2) a small sample of skin from under the right side of the body (from arm);

(3) a small sample of bone from the upper right orbit.

All samples examined were provided preserved in ethanol and were handled with extreme caution at all times to avoid any risk of contamination of the material from any source.

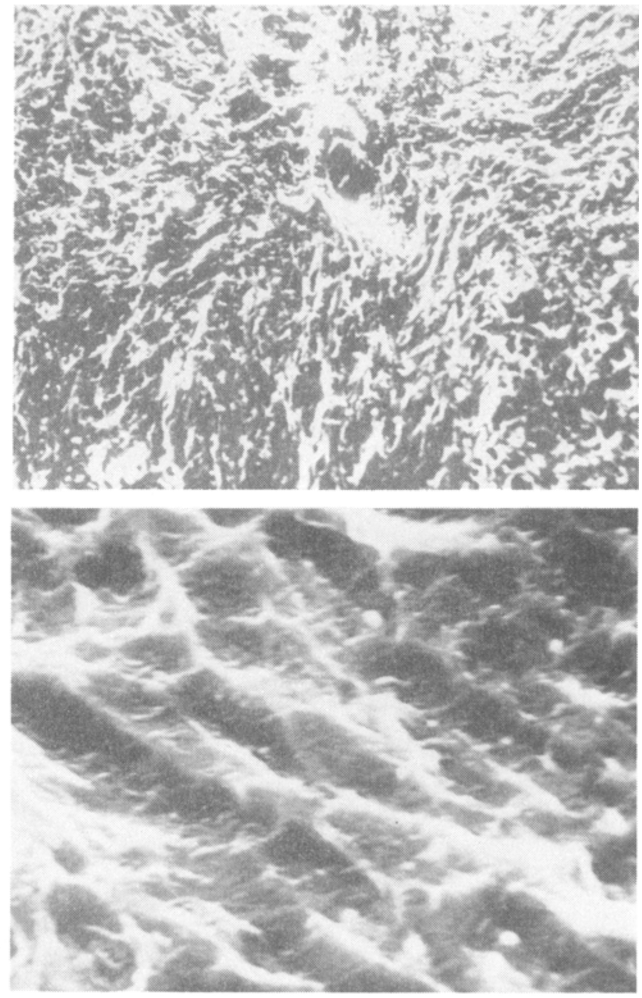
Results and Discussion

All elements which were detected within the three distinct sets of samples by this particular technique are listed in Table 1. Data from previous work (Pyatt, *et al.*, in press) on the body of Lindow III is also presented for comparative purposes.

Ground water movement within the bog may lead progressively towards equalisation between the ion content of the body and the enclosing peat; it is unlikely that elemental concentration into the body will occur. This is evidenced by the action of calcium where the calcium concentration of the body is markedly depleted and, in the case of Lindow III skin, approaches the value in the encompassing medium.

The bone samples obtained from the upper right orbit of Lindow II contained appreciable quantities of sulphur, phosphorus, calcium, aluminium, silicon, chlorine, and potassium (Table 1 and Figure 1) as has also been reported in previous work (Connolly *et al.*, 1986) and similarly there was an extremely well defined peak of sulphur content (53.667%) and clear evidence of demineralisation. However, in the samples of bone analysed in this investigation of Lindow II the presence of additional, clearly defined, cations was also noted; these were magnesium, iron, copper, manganese, and nickel. The percentage values of these 12 elements are presented in Table 1. The scanning electron micrographs (Figures 2a,b) show the structure of the bone of part of the upper right orbit. The spongy (cancellous) bone has retained its structure without undue distortion as part of the Haversian canal system is still recognisable. However, the structure is maintained due to the collagen component rather than the mineral elements which will have been mobilised, as internal decomposition proceeded, and thence migrated to the medium surrounding the body.

a



b

Figures 2a,b *Section through bone of upper right orbit of Lindow II: note Haversian Canal systems.*

The analysis of the skin samples obtained from under the right side of the body (from arm) revealed the presence of the same 12 elements (Table 1 and Figure 3) as found in the bone sample from the upper right orbit. It should be noted that Pyatt *et al.*, (in press) located only 10 elements in comparable samples obtained from the skin of another bog body namely Lindow III. Phosphorus, manganese, and nickel were peculiar to Lindow II; whilst the skin samples of Lindow III, unlike those obtained from Lindow II, contained titanium. The skin from the two individuals differs in both the concentrations of the various elements but also in the concentration ranking. From Table 1 it can be seen that the elements in Lindow III skin can be ranked (in terms of decreasing concentration).

S > Ca > Cl > Si > Al > Fe > Mg > K > Cu > Ti

whilst the elements in the skin obtained from Lindow II are ranked:

S > Cl > Ca > P > Al > Si > Mg > Fe > Mn > Cu > K > Ni

The problem of migration of metal and other ions in organic sediments remains incompletely understood. This is particularly evident in the problems surrounding the radiocarbon dating of Lindow II where the dates for the body are several hundred years younger than those of the surrounding peat and it is probable that the process of tanning of the body has led to carbon exchange over a period approaching 2,000 years. The process can lead to some migration of metal ions but the scale of elevation of metal ions within the body seems better explained in terms of clay mineralogy and pigment than in terms of diagenesis. This problem however merits further investigation.

Thus Lindow II and Lindow III have somewhat different chemical 'fingerprints' and this may have been because of dietary differences, perhaps a result of being native to different geochemical provinces (Pyatt, *et al.*, in press). However, further data would be necessary to develop constructively this speculation as, whilst differences may have existed in life they could also be affected by differential degrees of element leaching, a result of slightly differing depositional environments within the bog or a significant temporal difference in the date of their deaths. This, however, appears improbable. A further explanation, derived from the suggestions put forward by Pyatt *et al.* (in press) could be that Lindow II and Lindow III had a different chemical composition to the pigments applied to their respective bodies *i.e.*, they utilised different metal element based paints in the decoration of their bodies for battle and recognition purposes. As the pigments are likely to have not been applied generally but in discrete patterns and motifs (*op. cit.*), it is hardly surprising that differences exist and we would advise caution in the interpretation of such data from

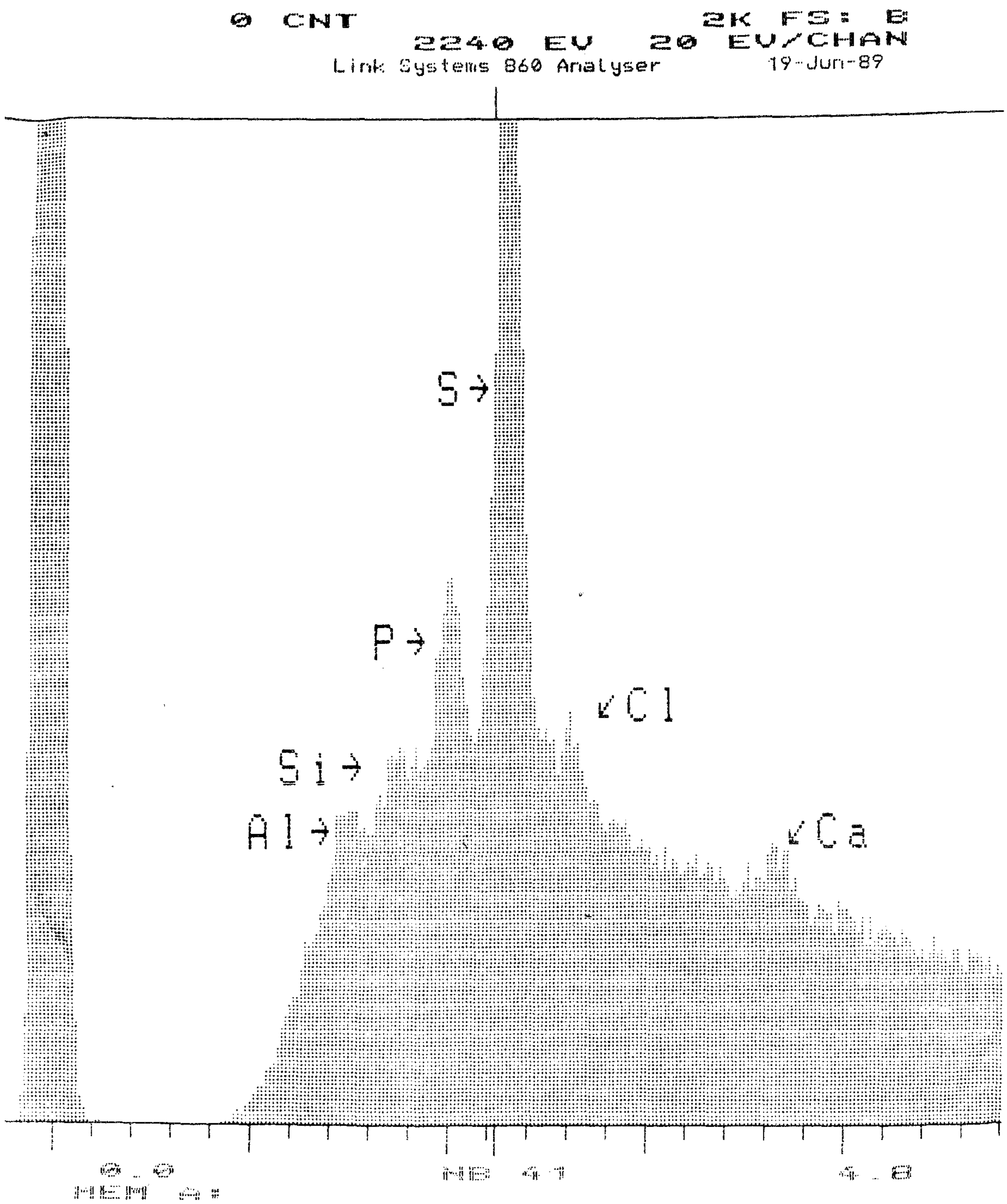


Figure 3 *Specimen results from skin sample of Lindow II.*

less well preserved inhumations.

It is worth stressing that the percentages of the various elements occurring in the skin samples of Lindow II and Lindow III are very different (Table 1). Thus, for example, the skin of Lindow II has less magnesium, aluminium, silicon, potassium, and far less calcium and iron; no titanium but more sulphur and chlorine than detected in the skin of Lindow III. The amounts of copper, likely to be the prime base of the pigment, are comparable in the skin from both bodies. Lindow II unlike Lindow III has skin containing/contaminated with (as also noted in the bone sample derived from the upper right orbit) phosphorus, manganese, and nickel. The total number of elements in the skin of Lindow III was found to be 10, whilst 12 were noted from Lindow II; they share nine in common. It is of course impossible to determine to what extent these differences may be explained by differential rates of weathering or leaching of elements or indeed other processes occurring after death.

It is easy to conjecture with this data but too much interpretation should not be attempted without firm proof as to the contemporaneity of the bodies – changes it must be stressed may be related to decomposition processes over a prolonged period of approximately 2,000 years and the

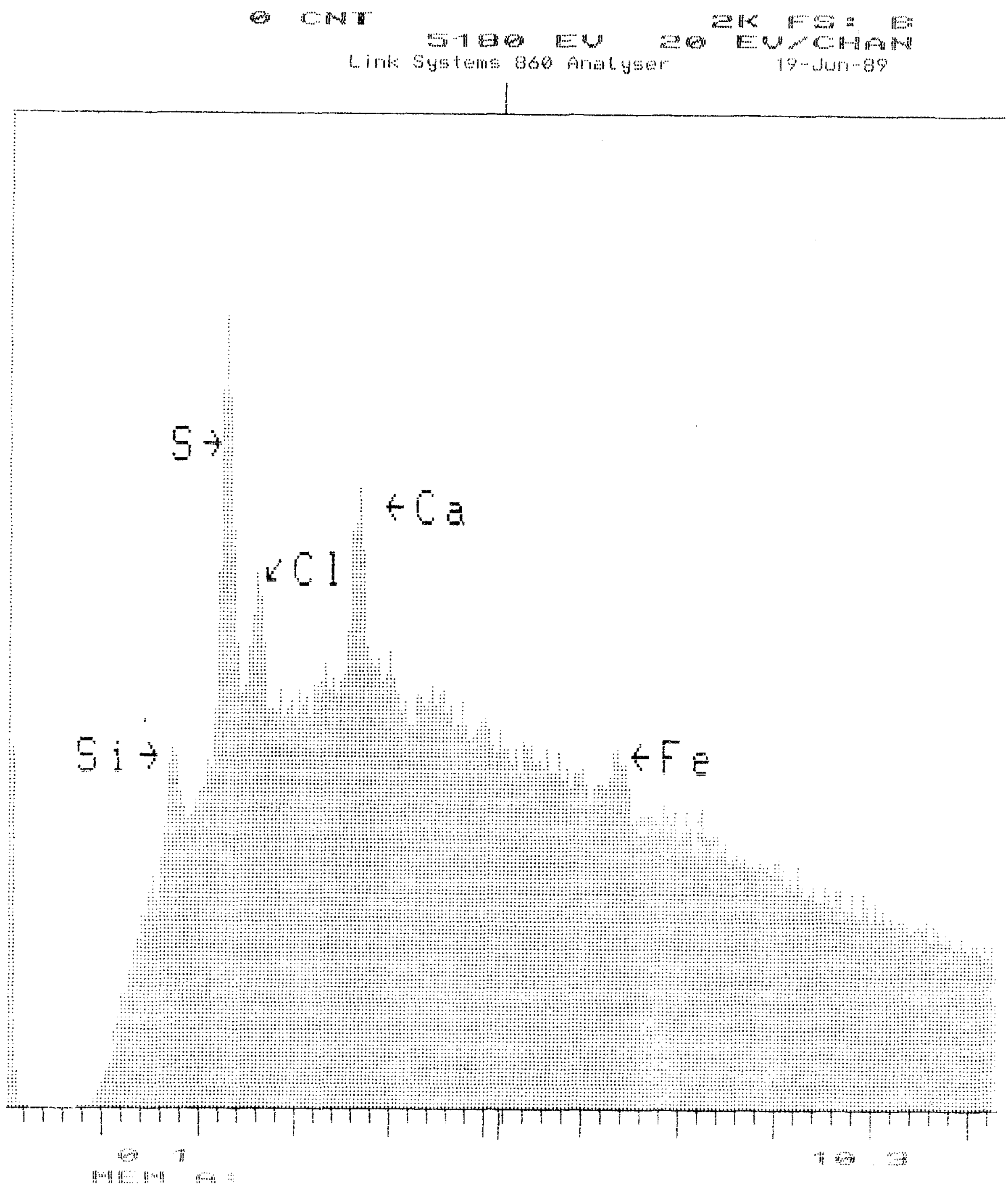


Figure 4 *Specimen results from peat and hair sample of Lindow II.*

subsequent mobilisation of elements from the body; a prolonged process in this particular environment. Similarly, the surrounding bog conditions at the burial sites may have generated dissimilar microenvironments and consequently permitted enhanced decomposition (*e.g.*, in the more aerobic site) and thence increased leaching in one of the two sites.

The samples of peat and hair (Table 1 and Figure 4) obtained from below the right shoulder and cheek of Lindow II contained the same 12 elements as noted in the skin and bone samples. The silicon content was enhanced which is probably due to sources such as from the decomposition of diatom frustules, phytoliths, *etc.* Calcium also was very well represented (22.58%) as compared with the bone sample from the upper right orbit (4.21%); this is probably indicative of the mobilisation of calcium from the body into the surrounding acidic medium. Values of chlorine, iron, and nickel were elevated (Table 1) whilst the percentage content of aluminium, sulphur, and phosphorus were less.

It is difficult to compare this sample with the Lindow III peat sample as the materials are not strictly comparable. However, it may be noted, Table 1, that the peat in close proximity with the body of Lindow III was found to contain only four elements whilst that peat and hair mixture associated with Lindow II contained 12. The elements were

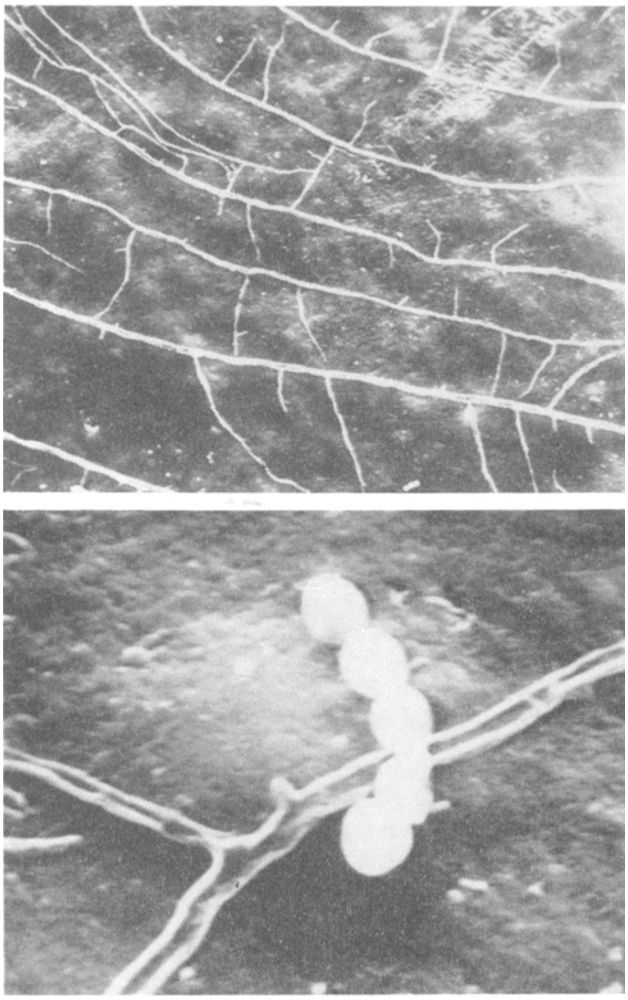


Figure 5 *Skin of Lindow II as observed under the scanning electron microscope: note the ramifying mycelium and the conidiospore like structures.*

also ranked differently. Thus, in order of decreasing concentration those from Lindow III were:

S > Si > Ca > Mg

whilst in the case of Lindow II the order was:

S > Ca > Cl > Si > Fe > Al > Ni > Mg > Cu > K > Mn > P

Although the order in neither case was identical to that found in the appropriate adjacent skin sample (Table 1) it is apparent that there is a clearly defined relationship between the geochemistry of the skin and the enclosing peat; one assumes an otherwise general chemical homogeneity of the peat as a whole.

As emphasised by R.C. Turner (personal communication) the body dates of Lindow are not the same as the stratigraphy and it is conceivable that the body has moved in the stratigraphy. Thus, whilst a comparison of the chemical ions within the peat immediately adjacent to the body with peat samples further from the body would be useful, this was not attempted as one could not be sure of the contemporaneity of the various peat samples. It would be very difficult to trace similar horizons across the bog to obtain peat samples which were certainly contemporary with the body from non adjacent locations.

Samples of skin (under right side of the body – from the arm) of Lindow II were also carefully examined under the scanning electron microscope (Figure 5). The skin sample was found to be covered by a network of ramifying tubes which probably represent the remnants of the mycelium of ancient decomposer/saprophytic fungi – the chains of spherical structures are possibly fungal spores such as chains of condiospores; they were not found to be viable – the material had been preserved in alcohol. It should be stressed that both the fungus and the spores may have existed in the peat and simply have become adpressed to the body of Lindow II. It is also conceivable that the fungus represents a far more recent invasion of the body tissue – perhaps directly after exhumation.

References

Beaumont, E.H. 1977. Cranial morphology of the Loxommatidae (Amphibia: Labyrinthodontia). *Phil. Trans. R. Soc. Lond. B.*, **280**, 29–101.

Lucas, M.L. and Mathan, V.I. 1989. Jejunal surface pH measurements in tropical sprue. *Trans. Roy. Soc. Trop. Med. Hyg.*, **83**, 138–142.

Pyatt, F.B. and Lacy, D. 1988. An appraisal of atmospheric pollution by aluminium fumes emanating from smelter works in Western Norway. *Environmental International*, **14**, 407–416.

Pyatt, F.B., Beaumont, E.H., Lacy, D., Magilton, J.R. and Buckland, P.C.. Non Isatis sed Vitrum or The colour of Lindow Man. *Oxford J. Archaeol.* (in press).

Stead, I.M., Bourke, J.B. and Brothwell, D. 1986. Lindow Man. *The Body in the Bog*. Published for the Trustees of the British Museum by British Museum Publications.

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