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EVALUATING THE USE OF MULTI-ELEMENT SOIL ANALYSIS IN ARCHAEOLOGY: A STUDY OF A POST-MEDIEVAL CROFT (OLLIGARTH) IN SHETLAND

Abstract - Multi-element soil analysis is an established technique in archaeology, but there has been little work to understand the processes and loadings involved. The abandoned farm (croft) of Olligarth, Shetland provided the opportunity of validating the technique by sampling from known contexts. The results showed multi-element soil analysis could accurately differentiate between areas of known function. Accuracy was increased using samples from the floor layers rather than topsoils. The elements that produced the best discriminant model of function were P, Ca, Cr, V, Fe, Nd, Ti, Pb, Al, and Yb. However because of cross-correlation between elements, Cu, Zn, Sr, Ba, K, Mg, Mn, Na, Ni, Co, Ni, and the rare earth elements, were also important potential discriminators. Of these P, Ca, Zn, Sr, Pb, Cu, Ba, Na, K, and Nd correlated positively with soil CEC and organic matter content and may, in part, originate from fuel materials, plasters, dung and bone. Ti, Cr, Al and many rare earth elements were influenced by local geological variation and are of less interest archaeologically.

Key words - Multi-element analysis, floor layer, topsoil, post-Medieval, Shetland, Great Britain.

Riassunto - *Valutazione dell'uso delle analisi multielemento dei suoli in archeologia: studio di una piccola fattoria postmedievale (Olligarth) nelle isole Shetland.* L'analisi multielemento dei suoli è una pratica consolidata in archeologia, tuttavia lo sforzo per comprendere i processi e la loro intensità è stato scarso. La fattoria abbandonata (croft) di Olligarth (Shetland) ha fornito la possibilità di verificare il metodo campionando da contesti noti. I risultati hanno dimostrato che questo metodo può differenziare accuratamente aree a funzione nota e che la precisione migliora campionando gli strati pavimentali anziché gli orizzonti superficiali del suolo. Gli elementi che si sono dimostrati migliori indicatori funzionali sono P, Ca, Cr, V, Fe, Nd, Ti, Pb, Al e Yb; tuttavia anche Cu, Zn, Sr, Ba, K, Mg, Mn, Na, Ni, Co, Ni e le terre rare si sono dimostrati potenziali discriminatori causa la cross-correlazione tra elementi. Tra questi, P, Ca, Zn, Sr, Pb, Cu, Ba, Na, K e Nd sono direttamente correlati con la CEC ed il contenuto in materia organica del suolo e potrebbero in parte derivare da combustibili, intonaco, letame ed osso. Ti, Cr, Al e molte terre rare sono influenzati da fattori geologici locali e sono di minor interesse archeologico.

Parole chiave - Analisi multielemento, strato pavimentale, topsoil, post-medievale, Shetland, Gran Bretagna.

INTRODUCTION

Many studies over the last two decades have shown that concentrations of some elements in archaeological soils have been enhanced by past human activity (e.g. Griffith, 1981; Entwistle *et al.*, 1998, 2000). These

studies have tended to use multi-element analysis techniques to establish elemental patterns for selected functional areas or across sampling grids covering entire archaeological sites. Spatial patterns have been identified for particular elements, but the outstanding problem is the interpretation of the results. The essential approach has been to establish patterns and then to propose reasons. We are proposing a project that will validate the approach much more robustly by sampling over a range of known archaeological contexts to gain unequivocal insight into the processes contributing to elevated elemental concentrations.

Different chemical elements can be incorporated into an archaeological deposit via fuel ash, manures and cess, midden deposits, food and crop processing residues, domestic residues, building materials, and industrial and manufacturing waste. Previous studies have suggested that phosphorus (P), lead (Pb), zinc (Zn), copper (Cu), cadmium (Cd), magnesium (Mg), manganese (Mn), calcium (Ca), titanium (Ti), rubidium (Rb), strontium (Sr), potassium (K) and barium (Ba) may all be potentially useful elements for archaeological interpretation (e.g. Lewis *et al.*, 1993; Linderholm & Lundberg, 1994; Middleton & Price, 1996; Entwistle *et al.*, 2000; Wells *et al.*, 2000; Parnell *et al.*, 2002).

Aston *et al.* (1998) interpreted signatures of P together with high concentrations of Zn, Cu and Pb as evidence of faecal material, and P with high levels of Mn and to a lesser extent Zn as wood and wood ash residues based on the results of analysis of modern materials. However, environmental and dietary differences are likely to have significant effects on the element composition of vegetable and faecal material. Although there have been few studies of this kind, studies of modern human and animal faeces, wood, and fuel ash (Aston *et al.*, 1998; Pierce *et al.*, 1998) have shown that no one element can be related to a particular activity or material. Instead it is the relative concentration of many different elements that produce a chemical «signature». The extent to which any element will become concentrated in soil depends upon the nature, duration and intensity of the polluting activity, and of the disposal process. Interpretation may be complicated, however, as materials are moved around the site and become mixed, before finally being deposited. Once in the soil, post-depositional pedogenic processes – including leaching, weathering, waterlogging, podzolisation, bioturbation, and surface vegetation – will affect the retention and

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distribution of the different elements in the soil. No studies to date have addressed this issue directly, although leaching of Ca and Mg has been identified by Ottaway & Matthews (1988). The effects of these soil processes on any one element will depend on local soil conditions, the element concerned, its concentration in the soil, and the other element species present (Alloway, 1995). Individual elements respond differently to conditions of pH, Eh, organic content, and soil texture, and hence individual elements may behave very differently in the same soil environment. This has the potential to produce a relative concentration or depletion of some elements relative to others. Large-scale, spatial patterns in soil geochemistry, therefore, may not directly reflect past human activity.

Effective validation of multi-element techniques requires that we firstly establish whether trace metal soil concentrations differ significantly according to the function of an area and whether these concentrations reflect the direct and indirect anthropogenic inputs to the soils. It is also necessary to understand better the effects of soil processes on the retention and distribution of trace elements within the soil. To answer these questions it is first necessary to understand fully the layout and functioning of the site being sampled. The

croft of Olligarth in Shetland offers this opportunity. It was abandoned in the 1950's and has remained relatively undisturbed since. The standing remains and recollections of the islanders provide a detailed history of building function and former land management practices.

METHODS

Study area

Located off the west coast of Mainland Shetland, Papa Stour (60.3322°N 1.6993°W) is a small island of 828 ha. The present population is less than 30 – in 1871 it was closer to 350 – and the principal land use is sheep farming; however, traditional farming practices survived here as recently as the 1960's (Fenton, 1997). The settlement of Olligarth (NGR HU 1758 6057) is first mentioned in documents dating to the early 17th Century (Smith, 2000). The layout of the modern croft (a small farm) dates to the mid 19th C when the three croft houses of the pre-existing township were rebuilt and allotted their own lands. The steading as it survives today was built in the mid 19th C (Fig. 1). The croft house was abandoned in 1940 though the house continued in

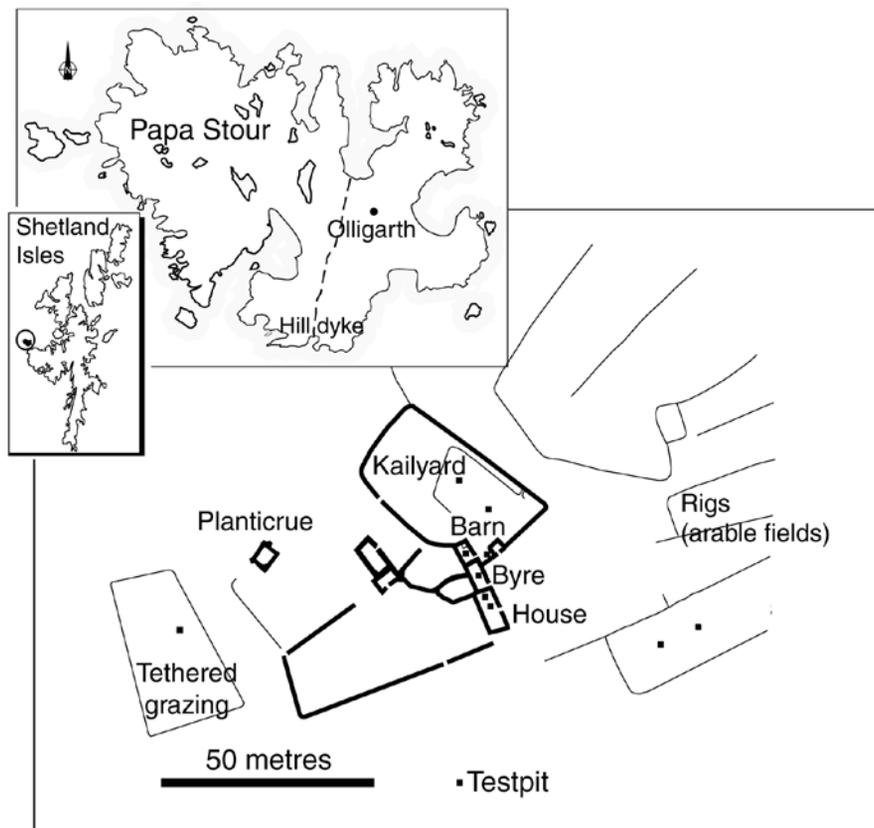


Fig. 1 - The site of Olligarth, Papa Stour.

use for a short time as storage; the roof was finally removed in the 1950's (Peterson G., pers. comm., 2002). The croft is stone built and clay mortared, finished with internal and external coarse shell plaster and harl (exterior coating of plaster with small stones embedded in it). There is a linear arrangement of house, byre (cow house) and barn (building for storage and threshing). Before the house and byre were abandoned the traditional roofing material (thatch) of turf had been replaced by a roof of mineral felt (mat of inorganic fibres) and bitumen, however, the barn still retained a turf thatch (Petersen G., pers. comm.). The house and barn have earth floors, whilst the byre has a flag stone floor with what may have been a central drain.

To the side of the croft is an enclosed kailyard (garden) with topsoils deepened to almost 1 m. The kailyard was used for growing, potatoes, kale (a type of cabbage), and other crops, and would have received substantial amounts of manure from the midden. In a corner of the kailyard and opposite the entrance to the barn was a mound of material which when test pitted was found to contain pot, glass, charcoal, leather, iron and mineral felt items. It appears this midden was formed at the time the buildings were abandoned and cleared.

Below the croft house are the remains of the earth and stone banks delineating the rigs or cultivated fields. Here to the soils have been deepened through traditional manuring practices previously described by Adderley *et al.* (2000) and Davidson & Carter (1998). On the rigs bere (barley), oats and hay were grown. To the rear of the croft is an area of shallow organic soil, which has been cut for turf in the past. Here milk and young animals were tethered to graze during the day. Beyond the hill dyke is the scattald, or common lands, where animals were grazed, and turf was collected for use as fuel, animal bedding, roofing material and manure.

Olligarth lies on an east-west boundary between the Walls (peat, peaty pozols, and rankers) and Fraserburgh (brown calcareous soils and calcareous gleys) Associations as mapped by the Soil Survey of Scotland (1981).

The former has developed in tills derived from rhyolite and Old Red Sandstone, the latter in wind blown quartz sands. This division is reflected in the distribution of wind blown sand, which is absent from the grazing and scattald (common land where animals were grazed and turf was collected for fuel) soils, but is a significant component in the rigs and kailyard.

The house and hearth, byre, barn, kailyard, rigs, grazing and scattald were identified as known functional areas. In each area the soils were test pitted (0.7 m x 0.7 m) and sampled with five replicates from each horizon or every 20 cm. Grid based auger surveys around the test pits were used to record spatial variability in the topsoils; within the buildings a 1 m sampling interval was used, and a 2 m interval in the fields. The samples were taken from the upper 20 cm or the depth of the topsoil, whichever was least, and depth of topsoil was recorded in all cases.

Analysis and data processing

The soils were air dried and sieved to < 2 mm, 5 g of soil was accurately weighed and added to 5 ml of concentrated Aristar Nitric Acid and allowed to digest for 3 hours, with at least 1 hour of boiling at 120°C. Samples were then filtered and diluted to 100 ml. A Perkin Elmer Optima 3300RL ICP-AES was used for the multi-element analysis. Soil moisture was determined in the field using a theta probe. Soil pH was determined in distilled water (1:2.5) and diluted CaCl₂. Oven dried soils were combusted at 405° overnight to determine loss on ignition (LOI) and the residue then used for particle size analysis using a LS230 Coulter Counter. Percentage base saturation, and cation exchange capacity (CEC) methods followed Bascomb (1974).

To approximate multi-variate normality, natural logarithms of the multi-element data were used and the data treated for extreme outliers. Hierarchical cluster analysis used Euclidean squared distances and the final cluster groupings were decided by reference to the coefficients of similarity. Stepwise discriminant analysis

Tab. 1 - Mean topsoil properties and element concentrations in the functional areas at Olligarth.

| | Hearth | House | Byre | Barn | Midden | Kail yard | Rig | Out-field | Scat | Till | Sand |
|------------------|--------|-------|------|------|--------|-----------|------|-----------|------|------|------|
| pH | 6.5 | 6.4 | 5.2 | 4.0 | 4.0 | 5.0 | 4.7 | 3.8 | 4.5 | | |
| CEC mmolc/kg | 332 | 337 | 140 | 97 | 74 | 70 | 55 | 123 | 59 | | |
| % loss on ignit. | 31 | 34 | 27 | 23 | 24 | 15 | 13 | 44 | 17 | | |
| % clay | 1.8 | 1.9 | 2.9 | 2.7 | 2.4 | 2.5 | 4.4 | 2.8 | 2.7 | | |
| Fe % mass | 1.10 | 1.23 | 0.92 | 0.55 | 2.18 | 0.50 | 0.44 | 0.29 | 0.12 | 1.20 | 0.20 |
| Ca % mass | 3.03 | 2.99 | 0.76 | 0.17 | 0.12 | 0.17 | 0.09 | 0.08 | 0.14 | 0.07 | 0.04 |
| P % mass | 0.32 | 0.32 | 0.29 | 0.09 | 0.17 | 0.13 | 0.08 | 0.03 | 0.03 | 0.02 | 0.01 |
| Ba ppm | 107 | 124 | 143 | 149 | 153 | 142 | 108 | 19 | 64 | 19 | 14 |
| Cu ppm | 88 | 130 | 85 | 11 | 69 | 23 | 10 | 4 | 8 | 3 | 1 |
| Sr ppm | 263 | 241 | 92 | 31 | 34 | 43 | 26 | 14 | 27 | 4 | 6 |
| Zn ppm | 534 | 1037 | 499 | 77 | 194 | 72 | 34 | 15 | 28 | 24 | 23 |
| Pb ppm | 98 | 152 | 128 | 81 | 214 | 71 | 58 | 25 | 61 | 4 | 4 |

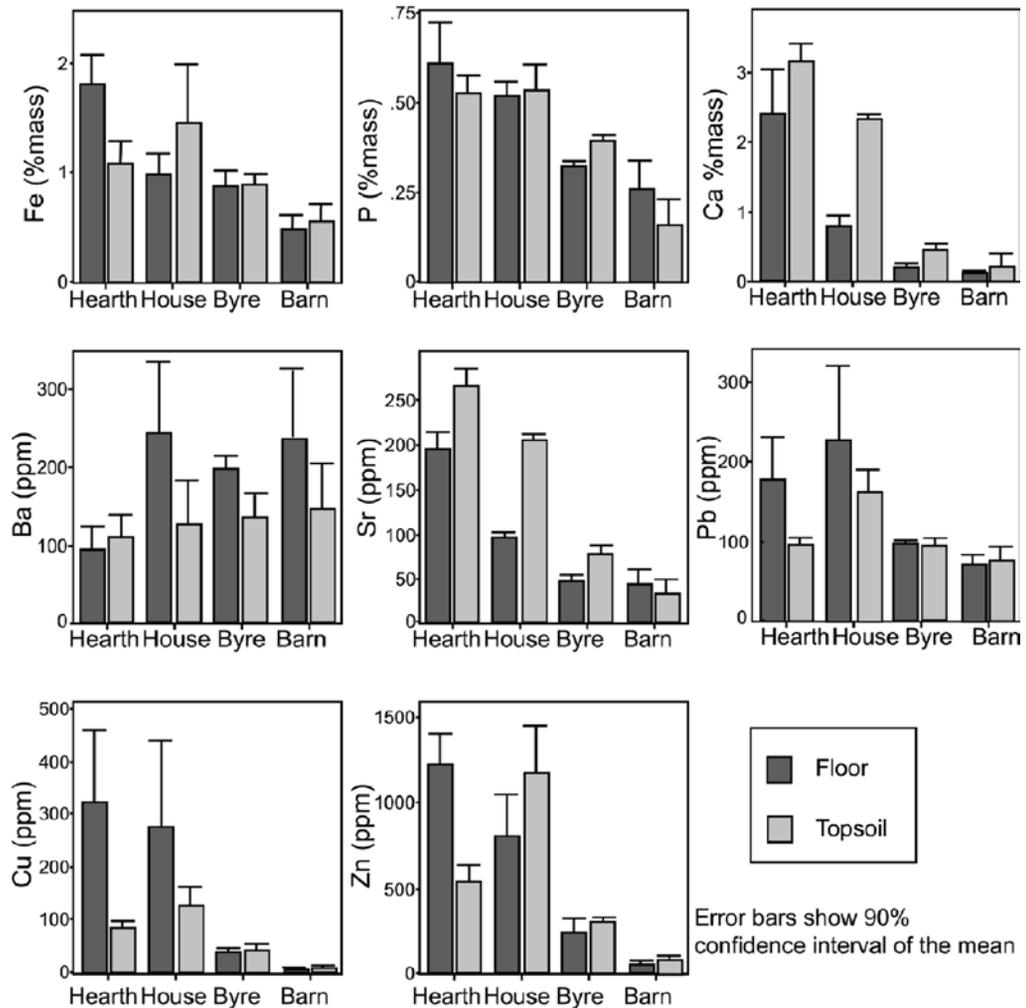


Fig. 2 - Mean element concentrations and confidence intervals of topsoils and floor layers.

using Wilks's Lambda was used to classify the data. This technique takes into account inter-correlations between the variables (element concentrations) and discards redundant variables; hence it is robust where there is multi-colinearity of variables (Klecka, 1980). For the same reason the structure matrix has been used to interpret function loadings.

RESULTS

The samples split into two categories: topsoil samples (0-20 cm) and building floor samples. Topsoils are most easily and frequently sampled during auger surveys, whilst floor materials can usually only be sampled during excavation. The chemical nature of these two deposits will be different because of different anthropogenic loadings, soil properties and soil processes. For this reason their results are considered separately. The aim of this study was to establish whether area function

can be identified on the basis of the multi-element data, to identify key elements for this process, and to identify and understand the groupings and correlations between elements as means of understanding the source of the loadings and the effects of soil chemistry.

Functional area differentiation

Table 1 outlines mean soil properties and element concentrations in the topsoils of the nine functional areas and sand and till parent materials. The highest element concentrations occur in the topsoil of house, hearth and byre areas; soil pH and cation exchange capacity are also greatest in these soils and they contain the lowest proportion of clay. Ca and Sr are significantly enriched in the house, hearth and byre (0.32-0.29%) and even in the barn, midden, kailyard and rigs are 3 to 6 times higher than in the scattald soil (0.03%). Mean Pb and Ba concentrations are highest in the midden soils (214

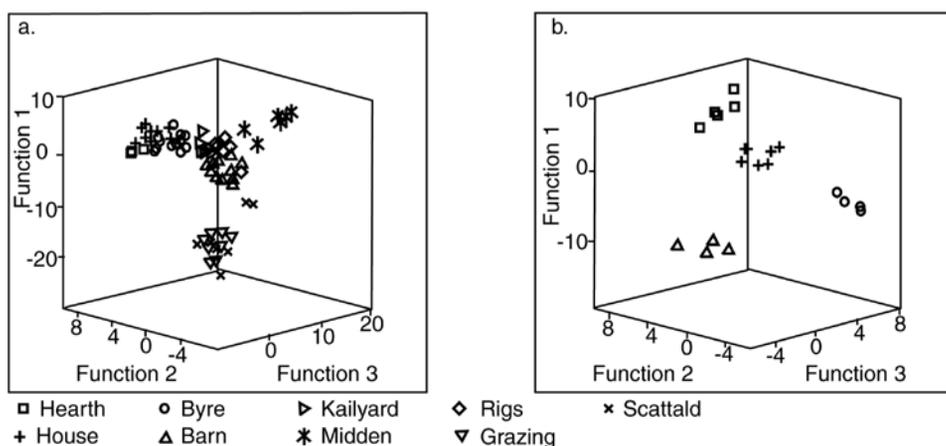


Fig. 3 - Discriminant plots of a, topsoils and b, floor layers at Olligarth.

and 153 ppm respectively), although the scattald soils also contain relatively high levels of these elements compared with the till and sand parent materials. Mean concentrations of Zn and Cu are highest in the house (1037 and 130 ppm respectively), are moderately high in the hearth, byre and midden, and are still above background in the barn, kailyard and rig soils.

Figure 2 shows the differences in mean concentration and the 90% confidence interval between the floor layers and topsoils immediately above. This shows how Sr and Ca concentrations are significantly enhanced in the topsoils compared to the floor layers below. Concentrations of Pb, Cu, and Zn are higher in the hearth area than in the topsoils that have developed over it, whilst Pb and Cu tend to be in the house floors, though because of high variability this is not significant. Likewise, Ba concentrations are higher in the floors of the house, byre and barn than in the topsoil.

Figure 3 shows the results of the discriminant analyses, and plots topsoil and floor layer samples along their first three discriminating functions. The variables chosen for inclusion in the stepwise model were P, Ca, Pb, Ti, chromium (Cr), vanadium (V), iron (Fe), neodymium (Nd), aluminium (Al), and ytterbium (Yb); together they account for 85.6% of data variation on the first three discriminating functions. Data for half the samples were used to build the model, the remainder were used to test its accuracy. This approach highlighted two main errors: house samples incorrectly classified as hearth, and rig soils incorrectly classified as kailyard. Despite this, the model was able to predict function based on the concentrations of these elements with 93.1% accuracy. Function 1 separates the on-site contexts from the grazing and scattald. Function 2 helps discriminate between the grazing and scattald, and between the house and other on-site contexts. Function 3 helps separate hearth from house, midden from barn, and midden from kailyard.

The elements retained in the model were chosen as they have the greatest, unique discriminatory powers. How-

ever, because of cross-correlation many of the excluded elements also correlate strongly with the discrimination functions (Tab. 2). In addition to Al, Nd and P, Cerium (Ce) and lanthanum (La) show strong correlations with function 1; however, they also correlate strongly with Nd and hence were redundant in the model. On function 2, Cu, Mg, Mn, Sr, Zn, cobalt (Co), dysprosium (Dy), europium (Eu), lithium (Li), sodium (Na), nickel (Ni), and yttrium (Y) are important in addition to Fe, Nd, P V, and Yb; and on function 3 there is a correlation with Na as well as V. Of the elements (variables) used in the model, Al, Cr, Ti, V, Yb, Pb, Fe, and zirconium (Zr) most strongly correlate with one of functions 4-8. Collectively, these 5 functions account for only 14.4% of the variation of the data.

Within the buildings, using floor samples helped to improve the model (Fig. 3b). This resulted in 100% correct classification of validating cases – resolving the problem of misclassification of house as hearth – using Ca, Mn, K, Sr, Ce, Ba, Ti, scandium (Sc), and samarium (Sm) over 3 discriminant functions. Function 1 discriminates between the barn and hearth, and the byre and house. Function 2 acts to separate the house and byre, and function 3 the hearth and barn.

Element groupings

Hierarchical cluster analysis identifies groups of elements behaving in similar ways (Tab. 3). Whether the samples are from the floor layers or the topsoils the groupings of elements are similar. Differences of group membership in samples from the floors and topsoils are only found for Ca, P, Cu, Ni, Y and Zr. The groupings can be summarised as Sc, Li, Co, Sm, Al, Fe, Dy, Eu, K, Yb, P, and Ca in one grouping, Mn, Ti, and Na in another, La, Nd, Ce, Cr, V and Ni in a third, and finally Zn, Sr, Pb, Cu and Ba. Groupings will reflect similarities in source – inputs to the soil, natural and anthropogenic – and the chemical properties of the elements and soils influencing their retention in the soil.

Tab. 2 - Structure matrix for topsoils showing correlations between discriminating variables and standardised canonical discriminant functions 1-3.

| | Function | | |
|----|--------------|--------------|--------------|
| | 1 | 2 | 3 |
| Al | .306 | .062 | -.067 |
| Ba | .214 | -.021 | .043 |
| Ca | .087 | .871* | -.101 |
| Ce | .374* | -.045 | -.055 |
| Co | .050 | .376* | .132 |
| Cr | .260 | .181 | -.084 |
| Cu | .012 | .501* | -.020 |
| Dy | .095 | .482* | -.043 |
| Eu | .284 | .437* | -.062 |
| Fe | .279 | .312 | .161 |
| K | .162 | .233 | -.270 |
| La | .329 | .096 | -.156 |
| Li | .036 | .319 | -.034 |
| Mg | .149 | .497* | -.120 |
| Mn | .224 | .484* | .148 |
| Na | .131 | .527* | -.328 |
| Nd | .335 | .408* | -.134 |
| Ni | .268 | .505* | .024 |
| P | .383 | .644* | -.088 |
| Pb | .153 | .288 | .189 |
| Sc | .175 | .137 | -.52 |
| Sm | .246 | .017 | .047 |
| Sr | .127 | .871* | -.101 |
| Ti | -.072 | .236 | -.009 |
| V | .173 | .384 | -.329 |
| Y | .274 | .374* | -.256 |
| Yb | .246 | .307 | -.176 |
| Zn | .020 | .627* | -.083 |
| Zr | .000 | .090 | .018 |

* Largest absolute correlation between variable and any discriminant function.

Figure 4 shows the elemental signatures of the local plaster, sheep dung, turf, coal, and bone. The fuels items (coal and turf) contain high levels of Cu, V and Pb. Bone is rich in Ca, P, Sr, and Nd, but low in Al, Ti, Co, Cu, Yb and Pb. A similar elemental composition is found for dung although in this case there are also high quantities of Ba and low levels of Cr. The plaster from the croft house contains high levels of Sr, Ca, Nd and Pb.

Table 4 shows significant correlations between element concentration and soil properties. There is a significant

correlation between cation exchange capacity and Ca, Na, P, Cu, Sr, Y, Zn, Nd and Pb. Soil pH is significantly correlated with the concentration of Al, Mg, Ca, Na, K, P, Mn, Cu, Li, Sc, Sr, Y, V, La, Ce, Nd, Sm, Eu, Dy, and Yb.

DISCUSSION

The results clearly show significant differences in soil geochemistry between the different functional areas of the croft. As found in previous studies, no one particular element appears to be exclusively related to any one particular context; instead it is the relative concentration of a whole suite of elements that marks out the different areas. The topsoils of the hearth area were enhanced in all the analysed elements relative to the reference soils and parent materials by factors of between 1.5 and 20 times. Particularly high levels of Ca, P, Ba, Cu, Sr, and Zn were recorded in the hearth. The house context contained similarly high concentrations of Ca, Mg, Cu, Ba, Li, Na, Nd, Ni, P, and Sr, and higher levels of zinc. The byre soils contained slightly lower concentrations of these elements, with the exception of V, Sc, Yb, Y, Sr and Al, which were found here in the highest concentrations. The barn followed broadly a similar pattern of enrichment as the other buildings, but with generally lower levels of enrichment (1.5-6x) and much lower levels of Ca and Sr. The midden was marked by the highest concentrations of Ba, Pb, and Fe. The rigs and kailyard contained significantly lower levels of all elements than the building contexts, but compared to the off-site soils are significantly enriched in Fe, P, Ba (1.5-5x enrichment). The kailyard also contained enriched levels of Cu, Sr and Zn (1.5-3x).

The results of the discriminant analysis (Fig. 2) suggested that the building contexts share similarities in soil chemistry and in particular the house and hearth, and the house and byre. The midden context shared similar characteristics with the barn and kailyard, and kailyard with the rigs. The similarities in chemistry between the house and hearth, and kailyard and rigs, in particular, did cause problems of misclassification in the discriminant analysis. This pattern seems to reflect similarities in usage of buildings and manuring practices in the fields.

The elements used in the discriminant analysis included P, Ca, Nd, V, Pb, and Sr, which discriminate clearly between the functional areas and also have potential anthropogenic sources in fuels, plasters, bone and dung (Fig. 4). However, although Al, Ti and Cr, for example, were included in the model, their concentrations do not clearly reflect the anthropogenic history of the site, nor are they significantly higher in the on-site contexts than in the reference soils. These elements are not strongly correlated to the first three discriminating variables and so are perhaps not strongly correlated with the main source of variation in this study (functional area). The site is located on a geological boundary between the sands, and the rhyolite and tills, and it may be this source of variation that is being picked out by these elements. This is supported by the fact that Cr and Ti concentra-

Tab. 3 - Element groups identified by hierarchical cluster analysis of ln transformed data.

| Topsoils | | Floor layers | |
|----------|----------------------------|--------------|--|
| Group | Elements | Group | Elements |
| 1aa | Sc, Li, Co, Sm, Al, Dy, Fe | 1aa | P, Ca, Sc, Li, Co, Sm, Al, Dy, Fe, Zr, Y |
| 1ab | Eu, K, Yb, Mg, P, Ca | 1ab | Eu, K, Yb, Mg |
| 1b | Mn, Ti, Na | 1b | Ti, Mn, Na |
| 2aa | La, Nd, Cr, V, Ce, Cu | 2a | La, Nd, Cr, V, Ce, Ni |
| 2ab | Y, Zr, Ni | 2b | Zn, Sr, Pb, Cu, Ba |
| 2b | Zn, Sr, Pb, Ba | | |

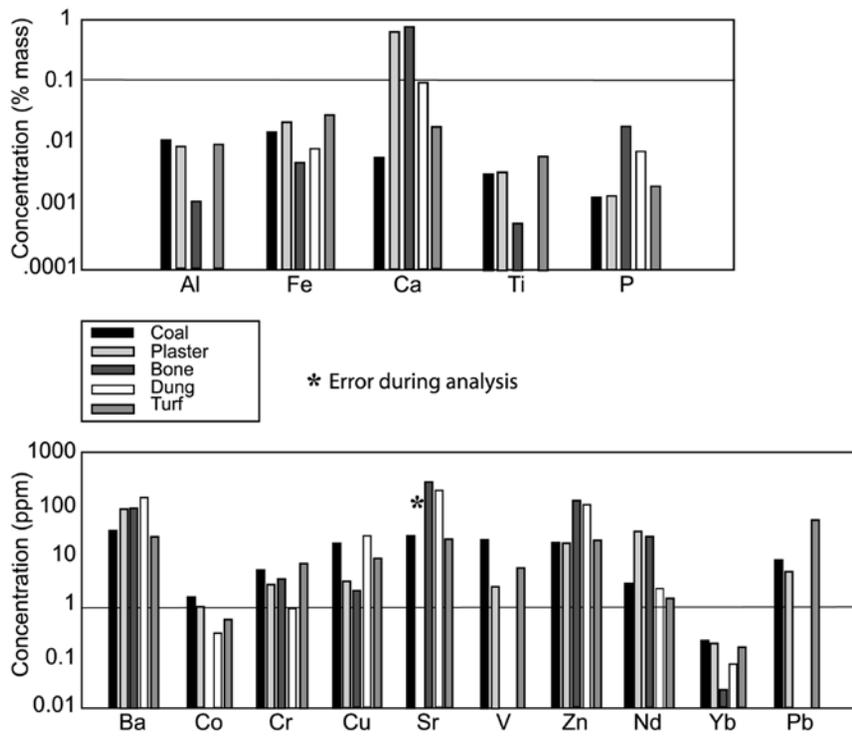


Fig. 4 - Element composition of fuel and other reference materials collected at Olligarth.

Tab. 4 - Significant Spearman Rank correlations between soil properties and element concentrations. Figures in bold denote < 0.01 significance.

| | Positive correlation | Negative correlation |
|--------------------------------|---|---|
| Clay content (Clay) | | CEC, Ca |
| Loss on ignition (LOI) | CEC, Na, Cu, Zn, Pb | Al |
| pH CaCl ₂ | Al, Mg, Ca, Na, K, P, Mn, Cu, Li, Sc, Sr, V, Y, La, Ce, Nd, Sm, Eu, Dy, Yb | Ex acid |
| Exchangeable acidity (Ex acid) | | pH, CEC, Al, Mg, Ca, Na, K, P, Mn, Cu, Li, Sc, Sr, Y, La, Ce, Nd, Sm, Dy, Yb |
| Cation Exchange Capacity (CEC) | LOI, Ca, Na, K, P, Cu, Sr, Y, Zn, Nd, Pb | Clay, Ex acidity |

tions do not reflect the soil pH or CEC, suggesting that they may be present in more crystalline forms linked to the mineralogy of the soils. Although useful at this site, these elements are less likely to be of interest archaeologically on other sites with unknown contexts.

The floor samples had a different chemical composition to the soils that overlie them. The floor layer of the house was richer in Pb, Cu and Ba and the concentrations of these elements were more variable across the space. The soils overlying the floor contained higher quantities of Fe, Ca, Sr, and Zn. Ba was also higher in the floors of the barn and byre than in the topsoil, whilst Fe, Zn, Cu, and Pb were higher in the area of the hearth than in the soils above it. Sr and Ca levels were generally higher in the topsoils of the buildings than in the floor layer.

High levels of Cu, Pb, Fe and Zn in the house floor could reflect the effect of scrapings and spills from the hearth, as these elements are also enhanced in the hearth context. This suite of elements also corresponds well with the data from turf and coal fuel materials, with high levels of Cu and Pb and significant amounts of Zn and Fe. The high levels of Ba recorded in the floor contexts are less simple to explain, but may be linked to the higher cation exchange capacity.

Despite the differences in element composition between the floor layers and the topsoils, the chemistry of the topsoils was sufficiently different to allow good differentiation of the samples according to functional area – the similarities between house and hearth samples was the main source of error. The bar graphs of floor and topsoil geochemistry (Fig. 3) do show that the chemistry of the floor layers is reflected in the chemistry of the soil that have formed in the debris overlying them. This indicates that pedoturbation processes, such as rooting and worm activity, have influenced the chemistry of the deposits making it possible to differentiate function on the basis of topsoil geochemistry.

The high levels of Ca and Sr in the topsoil of the buildings may have originated from bone and plaster deposits deposited as the building fabric decayed and animals took over the buildings for shelter. These decay products appear to mask the original geochemical signature of each area, and the discriminant analyses have shown that floor samples are a more sensitive indicator of function than topsoils.

Grouping of elements and correlations with each other and other soil properties provide hints on their source, behaviour and retention in the soil. The grouping of Zn, Sr, Pb, Cu and Ba appears to be particularly useful in distinguishing functional area and anthropogenic history. The concentrations of these elements tended to correlate with each other and with soil properties of LOI and CEC (Tab. 4). Not in the same cluster grouping (Tab. 3) but also correlating with CEC were P, Ca, K, Nd and Na, again elements found to be useful in differentiating former function. The remaining elements were not correlated with tested soil properties, suggesting a geological origin, or correlate positively only with soil pH. Soil pH affects the mobility of the elements, very many elements are less mobile where there is a high pH than in acid conditions (Alloway, 1995).

CONCLUSION

The study of this abandoned croft has shown that multi-element soil analysis can differentiate between samples from different contexts, in accordance with the known site history. Functional area differentiation is in accordance with known history of site. An auger survey of the topsoils was able to differentiate between functional areas with a high degree of accuracy, but samples taken from the original floor layers provided a more sensitive test, and would certainly be preferable for a more detailed study of space use within individual buildings.

A suite of elements were useful to interpretation of function (Ca, P, Sr, Ba, Zn, Cu, Fe, Pb, Nd, Na, V, K, Mn, and Mg) many of which were associated with the known anthropogenic history of the site – possibly originating in fuels, plasters, dung, and bone. Most interesting elements appear to strongly correlated not only with each other but also with soil CEC and organic matter content – suggesting they are bound/and possibly sourced with this soil fraction. Other elements such as Ti, Al, Cr and some of the rare earth elements appeared to be influenced by geological variation over the site and will be less informative in multi-element soil studies on other sites.

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