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The legacy of past manuring practices on soil contamination in remote rural areas

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Abstract

This paper demonstrates that there can be a legacy of contamination on former arable land in remote rural areas as a result of past manuring practices. In the first part of the study four farms abandoned in the late 19th to mid-20th century were investigated with samples collected from residual material in domestic hearths, the midden heaps, kailyards (walled garden for vegetables), infields (intensively managed arable land) and outfields (less intensively managed land for cropping or grazing). Consistent sequences in concentration values were found for such elements as Pb, Zn, Cu and P in the order hearth>midden>kailyard>infield>outfield. Such patterns can in part be explained in terms of atmospheric deposition on peat and turf which were subsequently burnt in hearths to result in enhanced elemental concentrations. The ash then was deposited in midden heaps and subsequently on kailyards or infields. In the second part, microanalytical results from St. Kilda are discussed. Enhanced loadings of Pb and Zn were found in the old arable land. The highest levels of Zn were found in small fragments of carbonised and humified material and bone fragments; in contrast Pb tended to be more uniformly distributed. Seabird waste was extensively applied to the arable land and some of the Zn may have accumulated in the soil by this pathway. The retention of Zn in bone is likely to have been very minor given the rarity of bone fragments as evident in thin sections (0.3%); this compares with 6.8% for black carbonised particles which are likely to provide the main storage sites for Zn.

Keywords: Soil contamination; Manuring of arable land; Black carbonised particles; Soil micromorphology

1. Introduction

Human activities can leave their imprints in the soil in the form of enhanced concentrations of a range of macro- and trace elements. This is particularly the case in urban areas where a variety of domestic and industrial processes can lead to elemental concentrations. Alexandrovskya et al. (2000), for instance, take Moscow as a case study and demonstrate that the maximum concentrations of some elements occurred in the 17–19th centuries—e.g. with enhanced Pb from its use in household utensils, paints, pipe and roofing materials and Cu in pest control and wood preservative solutions. In a geochemical survey of Oslo, Tijhuis et al. (2002) are able to distinguish loadings as a result of anthropogenic activities, especially from motor traffic, in contrast to differences due to mineralogy. Similarly, elevated levels of Mo, Ni, As, Ag, Cr, Sb, Fe, Mn, Mg and P have been shown to coincide with industrial and commercial areas of Berlin (Birke and Rauche, 2000). Metal concentrations in soils can decrease with distance from cities as demonstrated by Levado et al. (1998) for Buenos Aires and its local region. In archaeology multi-element soil analysis has been used as a survey tool to determine the extent of past human activity (cf. Entwistle et al., 2000; Middleton and Price, 1996). Old cultivated soils in remote rural areas which were managed in traditional ways can exhibit enhanced elemental loadings

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(Wilson et al., 2005); such a finding immediately poses questions as to how this can occur in areas far from cities and other industrial areas. This study aims to address this topic through discussing results from geochemical surveys in four remote localities in Scotland supplemented by microanalytical data from another (St. Kilda).

2. Sites and methods

2.1. The sampled farms for multi-element survey

Four farms (two townships and two small farms) from across Scotland were chosen for study (Fig. 1). Sites were chosen on the basis of the survival of identifiable standing remains and the lack of subsequent disturbance and improvement (Table 1). The four sites all represent traditional agricultural systems, widespread in Scotland at the end of the 19th Century. The sites were farmed in a mixed system of cultivation (principally oats, bere [a primitive form of barley], and potatoes) and livestock (dairy cows, sheep, pigs and poultry). Fuel for the hearth was provided by peat and turves cut from the common grazing land, supplemented by coal. Ash from the hearth together with other domestic waste and dung from the byre was stored in the midden before being spread on the kailyard (an intensively cultivated and sheltered garden immediately adjacent to the farm and typically used for the growth of cabbages) and the nearby rigs (ridged soil) or infield (manured fields). In addition to the midden material, seaweed, fishing waste, peat, turf, bracken, and proprietary fertilizers would all have been used to improve soil fertility where available. The repeated addition of such manures has led to deepening of the soil in the kailyards of all four farms (up to 1 m), and of the arable fields at Olligarth (up to 0.7 m).

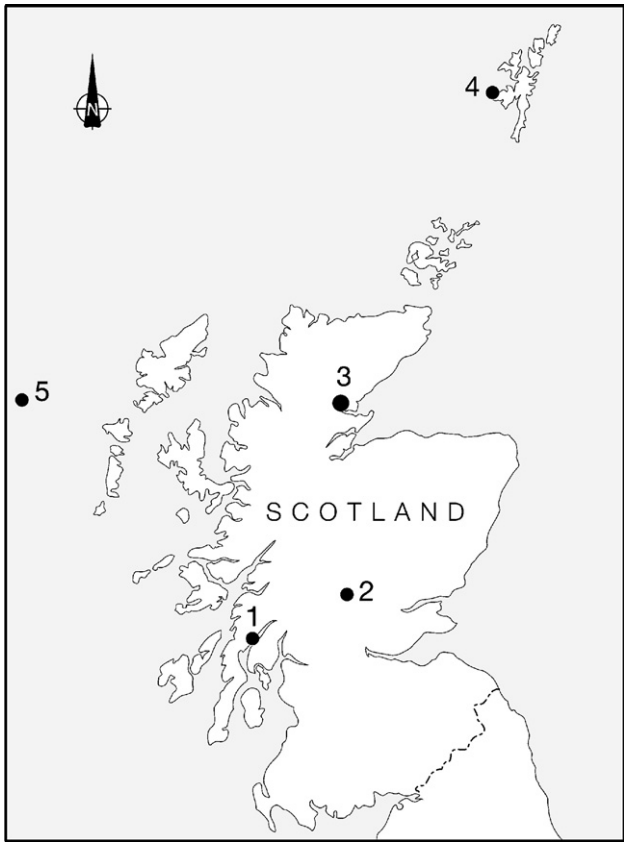

Fig. 1. Sampled sites in Scotland. (1) Auchindrain, (2) Easter Tombrek, (3) Grumby, (4) Olligarth, (5) St. Kilda.

The hearth, midden, kailyard, rigs and outfields at each farm were sampled according to their availability. The hearth was excavated and samples taken from the deposits within the hearth pit, or from the deposits immediately overlying the hearth stone depending on the design. The top soils (5–15 cm deep) of the middens and fields were sampled from 0.7 m × 0.7 m test pits (5 replicates from each pit). An auger survey of the fields and kailyard was also carried out over a 2 m sampling grid.

2.2. The sampled fields in St. Kilda for microanalysis

St. Kilda is a small archipelago some 160 km northwest of the Scottish mainland (Fig. 1); Hirta is the largest island and is the only one to have had extended occupation in the past. The total arable cultivated area of St. Kilda was 40–80 ha and this supported a population of up to around 200 people. The traditional economy gradually became unsustainable and resulted in the evacuation of the island in 1930. Central to the diet of St. Kildan's were seabirds, primarily puffins (*Fratercula arctica*), fulmars (*Fulmarus glacialis*) and gannets (*Morus bassanus*) including their eggs. Cropping of bere, oats and potatoes was limited mainly to improved land in the immediate vicinity of the settlement at Village Bay, where this land was intensively managed. Added manure consisted of ashes derived from burning of turf along with other waste materials—straw, urine and excrement, and bones, wings, and entrails of seabirds. The application of this material to the cultivated rigs gradually led to the considerable deepening of the soils, by as much as 1.5 m. The reasons for selecting this sampling area were its isolation and remoteness from industrial activity, with a high probability that any elemental enhancement could be attributed to land management practices.

Undisturbed samples for soil thin section micromorphology were collected from two depths (usually at ca. 10–18 cm and 30–38 cm), from soil pits dug within the old cultivated land for each of the sites. These sites were as follows:

Sites 1–7: in the cultivated areas of Village Bay,
Sites 8–9: a soil buried under a stone wall dating from AD 1830,
Sites 10–12: from An Lag (an uncultivated area in Village Bay),
Sites 13–15: from Gleann Mór where cultivation ceased before AD 1695.

2.3. Analytical methods—multi-elemental analysis

Five gram sub-samples of the oven-dried (105 °C), <2 mm soil fraction were each digested in 5 ml concentrated ARISTAR nitric acid at 120 °C for at least 1 h, the samples were then filtered and the filtrate diluted to 100 ml volume. The sample digests were analysed for a suite of elements by ICP-AES using a Perkin Elmer Optima 3300RL ICP-AES. Procedural blanks, replicate samples and external reference standards were also analysed to provide quality control.

2.4. Analytical methods—micromorphology and microprobe

Soil thin sections were produced according to Murphy (1986); details are given at http://www.thin.stir.ac.uk/. Once the thin sections were prepared they were described using the international system of soil thin section description (Bullock et al., 1985). Point counting was used to quantify the abundance of the various features present in the thin sections: between 1700 and 1900 observations were made per slide. At first 13 different types of features were recorded though these were later grouped