

An evaluation of using lead isotopes to identify anthropogenic sources of lead in soils.

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Summary

Soil multi-element analyses have repeatedly demonstrated enhanced concentrations of lead (Pb) associated with archaeological sites. However, interpretation of these Pb concentrations is difficult because of the multitude of possible Pb sources including the local geology, fuel materials, metal and alloys, and other imported goods.

This study of an abandoned croft in Shetland suggests Pb isotope ratios have the potential to:

- Identify sources of anthropogenic Pb and track the movement of materials around the site, in this case fuel materials and manures.
- Aid interpretation of space use and function.

The mixing of different materials in the soil, the availability of local and imported reference materials, and the relatively expensive nature of this technique are the biggest potential problems. However, where local Pb isotope ratios differ significantly from those of imported material this technique has significant potential for the elucidation of space use, soil inputs and management practices.

Introduction

Lead isotopes can provide a useful fingerprint for sourcing both anthropogenic and geogenic lead and have been used successfully in many archaeological studies to identify early mining activity (Monna et al. 2000), provenance metal objects (Gale 2001), and study human migration (Montgomery et al. 2000).

Multi-element studies on archaeological sites have found elevated concentrations of Pb associated with former human occupation (for example, Wells et al. 2000; Knudson et al. 2004). However, because of the diversity of possible Pb sources (soils and rocks, metal alloys, paints and pigments, leaded petrol etc.), it is difficult to identify particular inputs.

This pilot study investigated whether lead isotope ratios in the soil might be used to:

1. Identify anthropogenic inputs to the soil,
2. Aid interpretation of space use, and
3. Track the movement of anthropogenic materials in the soils around the croft.

Methods

Site

The site chosen was the abandoned croft of Olligarth on the island of Papa Stour, Shetland. This croft was abandoned in 1940 when traditional farming practices still persisted on the island. The traditional system consisted of turf from the grazings being used as fuel and manure. Turf is a poor fuel and hence coal was also being imported. Turf was also used as bedding in the byre, where mixed with dung and ashes from the fire, it was allowed to rot in the midden before being spread on the fields as manure. Seaweed was also commonly used as a manure.

The site was ideal for this study because:

1. Multi-element analysis had previously shown that there were clear enhancements of lead in the hearth, house and byre.
2. The post-Medieval period saw a number of imports to the island, whilst
3. The relatively isolated island setting provided a relatively simple system of imports.

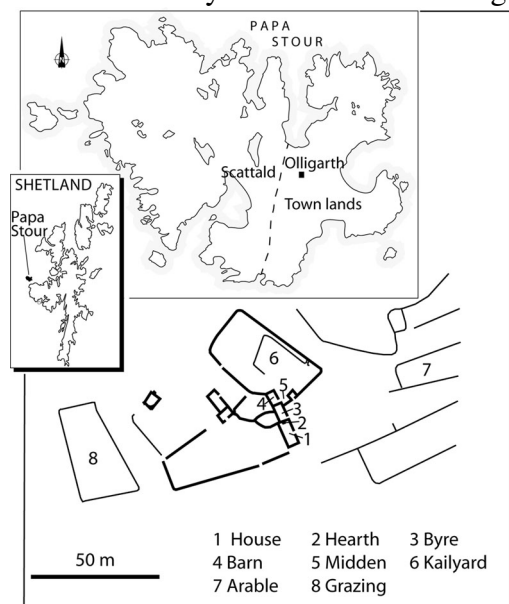


Figure 1: The abandoned croft site, Olligarth, Papa Stour, Shetland

Laboratory analysis

Soil samples were collected from the house, hearth, byre, kailyard, arable and grazed fields - both the floor layer and the overburden were sampled in the houses. Coal samples were taken from the old coal store in the byre, and plaster from the internal walls of the house. Turf was sampled from the scattald, and soil parent materials (glacial till and wind-blown sand) were sampled.

Samples (5 g) were digested (120°C, 1 h) in conc. HNO₃. Pb concentrations were analysed using ICP AES, Pb isotope ratios were determined by thermal ionisation mass spectrometry (TIMS).

Results and Discussion

Lead concentrations were highest in the house, hearth and midden (average 179-232 ppm Pb), but the byre, kailyard, and arable fields (100, 71, 67 ppm respectively) show moderate enhancement relative to the unmanured grazing land 25 ppm Pb. Hence, there is a significant enhancement of lead in and around the croft buildings and manured fields.

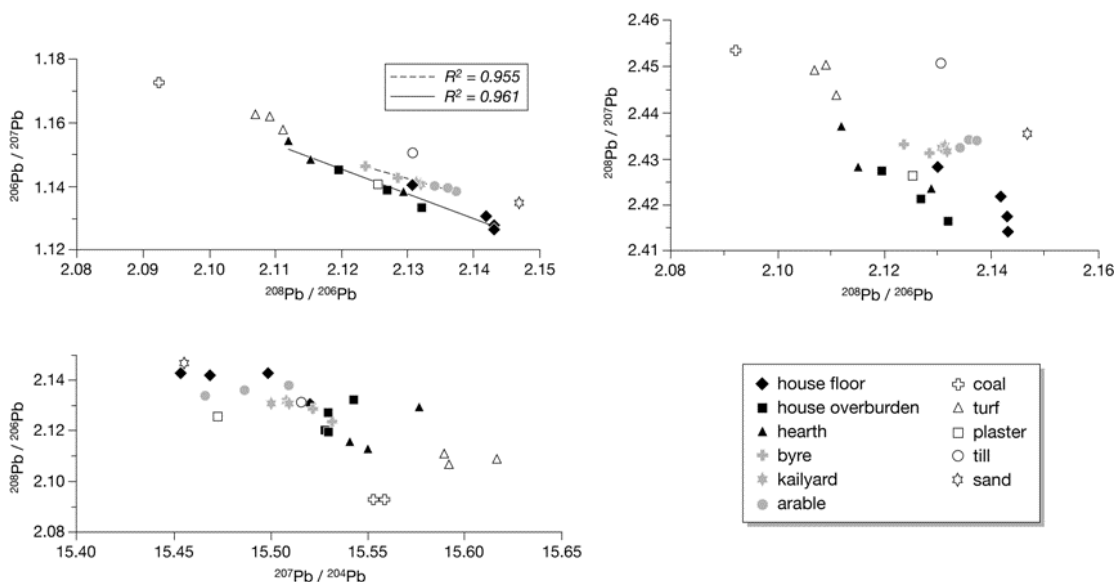


Figure 2: Bivariate scatter graphs of Pb isotope ratios for the soils and input materials

The graphs show the results of the lead isotope analysis. The plot of $^{206}\text{Pb}/^{207}\text{Pb}$ against $^{208}\text{Pb}/^{206}\text{Pb}$ indicates the presence of two different Pb systems. The first consists of house floor, house overburden and hearth, and may be caused by material from the hearth becoming incorporated within the beaten clay of the house floor, and both becoming mixed with the overburden soil. These contexts appear to be influenced by coal and turf, the two main fuel materials at this site, and an unknown end member with low $^{206}\text{Pb}/^{207}\text{Pb}$ (below 1.126) and high $^{208}\text{Pb}/^{206}\text{Pb}$ (above 2.143). Plaster was present as inclusions in the overburden soil, however, the isotope ratios for the plaster fall directly on line 1, so it is impossible to determine the influence of plaster on the Pb isotope ratios in the soil.

The identity of the other end member (input) is unknown, but appears to be an important source of Pb in the house floor. The $^{206}\text{Pb}/^{207}\text{Pb}$ ratio approaches the low ratios associated with imported Australian Pb ores used primarily for the manufacture of petrol additives. Similar low ratios have also been found in imported iron ores (J R Bacon, unpublished data). The analysed source materials cannot account for the high Pb concentrations in the house floor and overburden. Hence it is possible that the unidentified source is a manufactured material containing high concentrations of Pb derived from imported ores.

The second association of byre, kailyard and arable fields also corresponds to known movement of materials across the site. Dung from the byre was added in large quantities to the kailyard and in somewhat lesser amounts to the arable fields as manure. The mixing line appears relatively simple with probable end members (inputs) of wind-blown sand and hearth material. Hearth ash is known to have been spread in the byre to absorb urine, before being transferred with the dung to the midden and then to the fields. These groupings and the importance of fuel materials as sources of Pb in the hearth and house are confirmed by the other Pb isotope ratios.

Conclusions

Pb isotope ratios highlight two groupings of samples, each relating to known practices and movements of material across the abandoned croft. Also, they have confirmed the importance of fuel materials (coal and turf) as inputs for one association and wind-blown sand and hearth material as inputs to the second. The presence of at least one unidentified Pb rich input associated with the house floor was only apparent because of the isotope data.

The mixing of multiple signatures in the soil and the availability of local and imported reference materials, and the relatively expensive nature of this technique are the biggest potential problems.

Overall where local Pb isotope ratios differ significantly from those of imported material this technique has significant potential for the elucidation of space use, soil inputs and management practices.

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