Case study 31: Micromorphological and Microchemical Analysis of St. Kilda Soils

Christian Spring and Donald Davidson

Introduction

St. Kilda, to the west of the Outer Hebrides in Scotland, was studied to assess the nature of old cultivated soils with particular reference to anthropogenic features. This included evidence of any of material into the soil and any evidence of human activity. Also, the spatial distribution of key polluting elements within the St Kilda soils was investigated. This basically involves the mapping of elemental distribution in soil and focusing particularly on whether certain elements are associated with particular features within the soil.

To fulfil the aims of the project several techniques were used:

1. Micromorphological descriptions. This is the microscopic analysis of soil thin sections using a petrological microscope and various forms of illumination.
2. Quantification of features by point counting
3. Spatial elemental analysis using an electron microprobe.

Soil thin sections were taken from three sampling areas, and at two different depths, for a total of 15 pits. Figure 1 shows that the soil was homogenous in nature, which is typical of cultural soils. A kubiena tin is embedded into the wall of the pit ready for sampling.

Micromorphological descriptions and quantification of key soil features through point counting were performed on the thin sections from all the soil pits. Spatial elemental analysis was performed by mapping elemental distribution using an electron microprobe. Samples from pits 3, 5, 6 and 8 were analysed only. They were chosen because they had high concentrations of the elements under investigation.

Figure 1: Profile of pit 1 located in the village.

Methodology: Micromorphology

Micromorphological descriptions were performed on each thin section to assess the nature of the soil in terms of its structure, void space, organic & mineral components and the presence of pedofeatures. These descriptions were performed according to the handbook for soil thin section description, which outlines standard ways of describing, measuring and classifying features (Bullock *et al* 1985). The descriptive process was semi-quantitative since apart from identifying and describing key features within the soil according to their size, shape, distribution, their abundance was also assessed as a percentage of the whole thin section.

A number of features within the soil were identified as being of interest in the research. Figures 2 to 7 show some of the organic components.

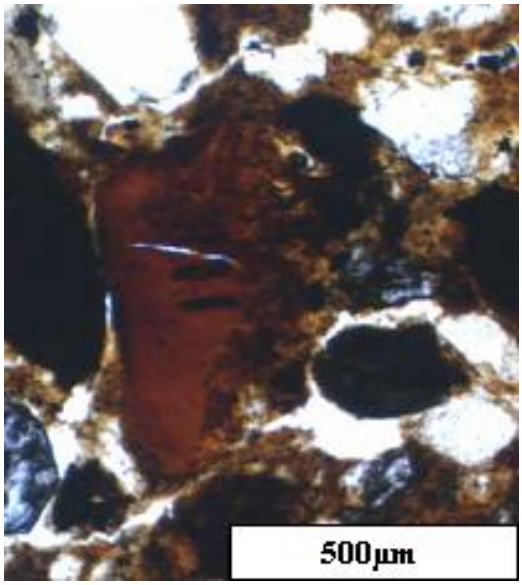

Figure 2: Amorphous OM- structureless organic material.

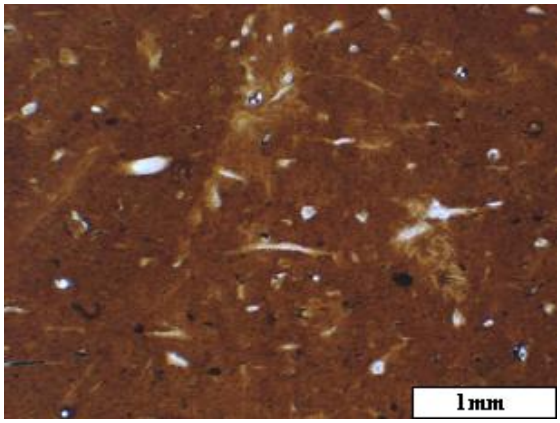

Figure 3: Compact peat with no plant structures identifiable.

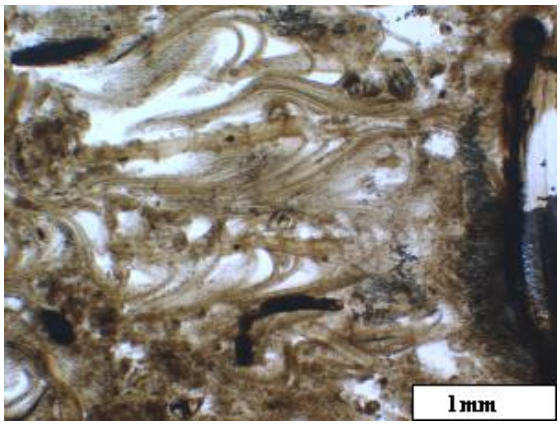

Figure 4: Fresh peat consisting wholly of plant fragments at varying stages of decomposition.

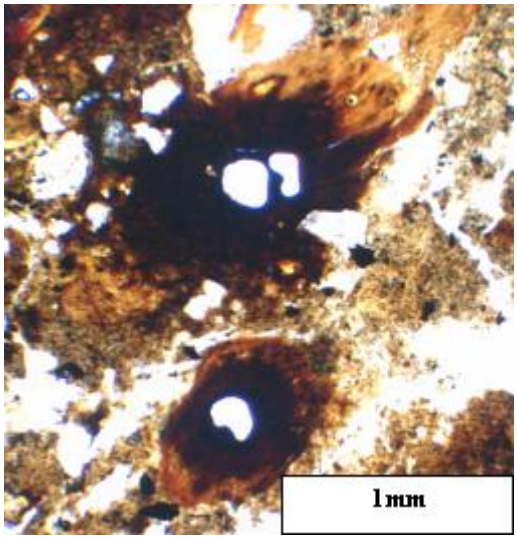

Figure 5: Humified plant fragments.

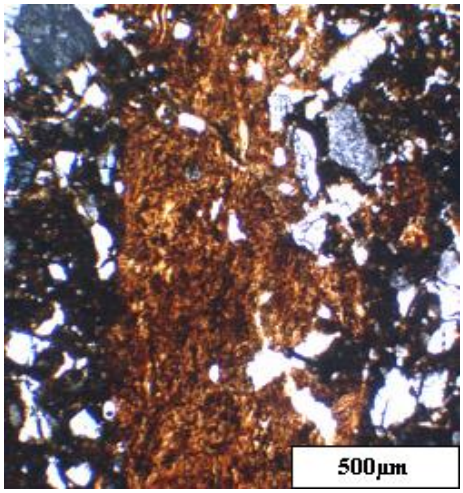

Figure 6: Hummified OM represents more decomposed OM that can usually still be identified as plant in origin.

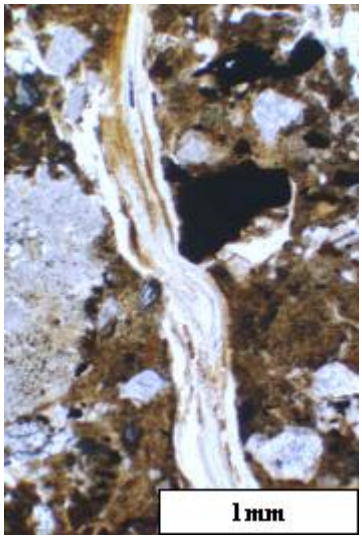

Figure 7: Plant fragments - relatively low abundance in the mineral soils.

Figures 8 and 9 both possibly represent anthropogenic inputs to the soil and therefore human activity. Both figures are carbonised but the charcoal still has evidence of plant/cellular structure.

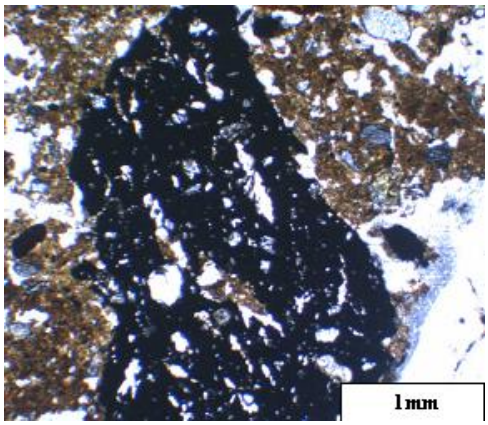

Figure 8: Charcoal fragment.

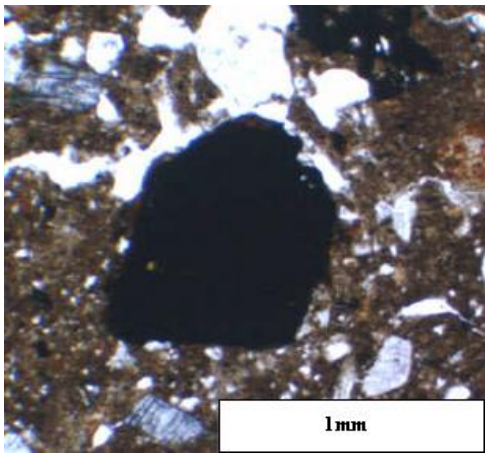

Figure 9: Carbonised material.

A number of bone fragments were found in thin section identified due to their structural features and crystalline nature. Figures 10 to 11 are of different examples of bone fragments found in the soil.

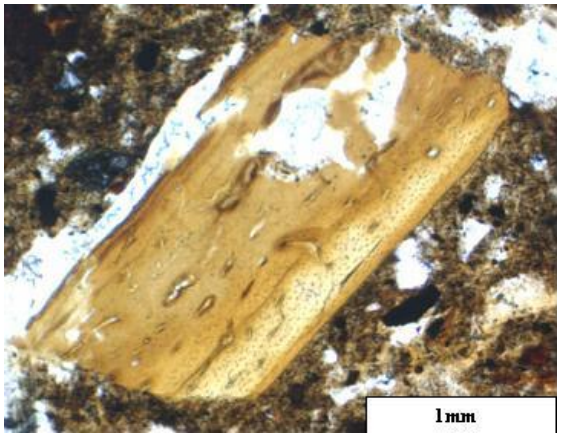

Figure 10: Image of what bone commonly looks like in thin section.

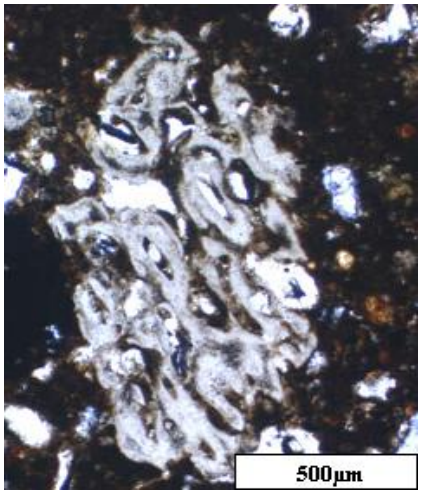

Figure 11: A bone fragment with a more open structure with a great deal of void spaces possibly indicating decomposition.

Large quantities of faunal excrement were found in the village soil indicating high biological activity in the soil (Figures 12 to 14).

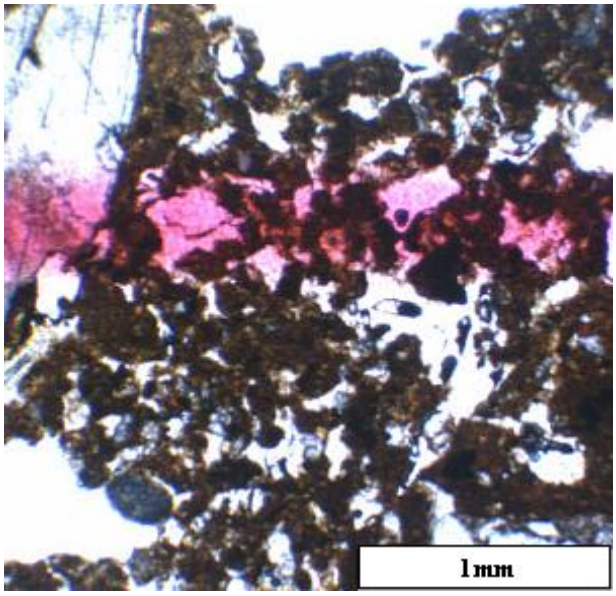

Figure 12: Enchytraeid excrements which are starting to fuse together.

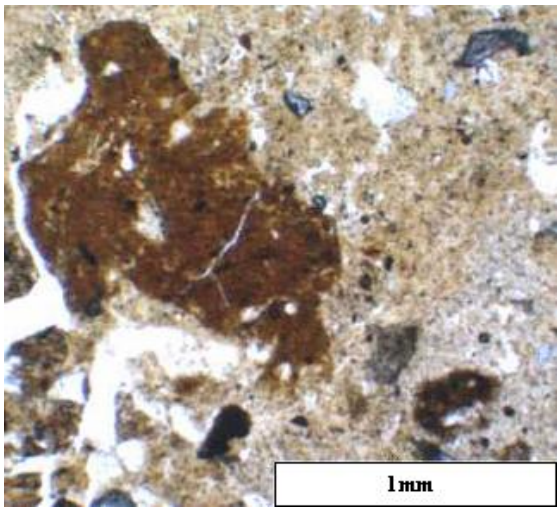

Figure 14: Infilling of an earthworm channel. Excrement is markedly different to the surrounding material.

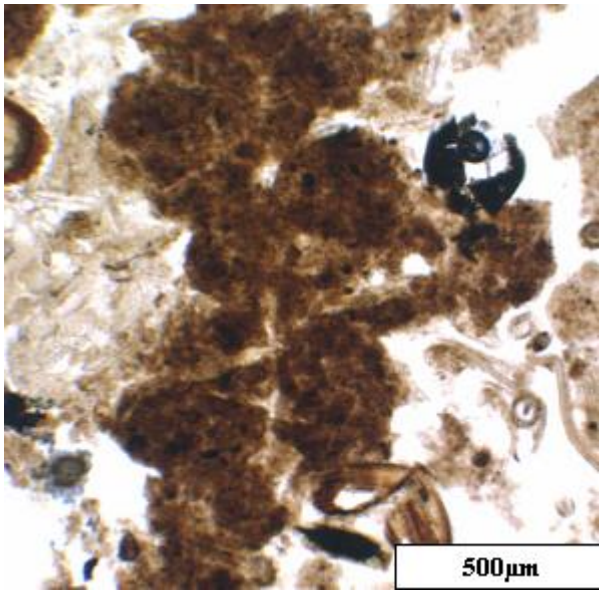

Figure 13: Fused excrements from a peaty soil. It probably originates from larger soil fauna such as soil arthropods.

The point counting technique was used to quantify the features found in thin section. Thin sections were mounted on a movable stage which was moved at 1mm intervals on the X axis and then by 2mm on Y at the end of the thin section. This led to roughly 1700-1900 points per slide (Figure 15).

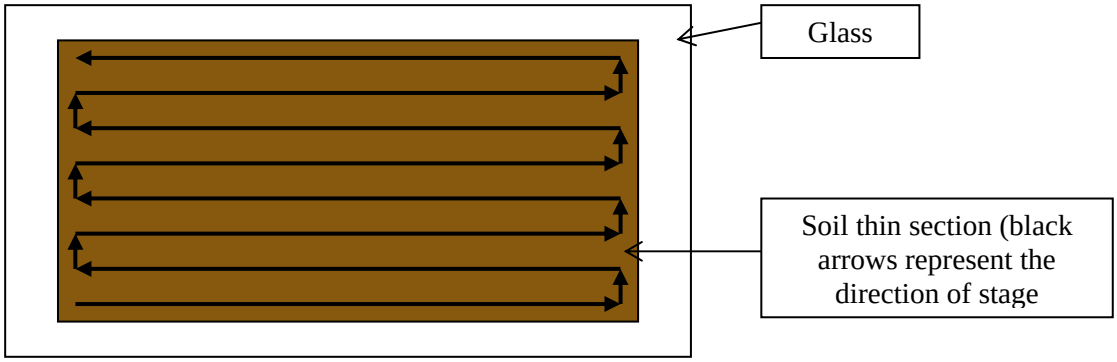

Figure 15: Mounted thin showing the direction of movement of the slide on the movable stage.

Crosshairs were located in the eye pieces of the microscope, so at 1mm intervals the feature that was present under the crosshairs was recorded. The features that were counted were voids, rock/mineral fragments, organic material, bone fragments and faunal excrement. The results were calculated by a percentage of abundance, which was equivalent to a percentage of the whole slide. For example, if voids had an abundance of 30%, this is equivalent to saying that 30% of the slide was composed of voids.

Methodology: Electron Microprobe Analysis

The microprobe work was carried out at the NERC microprobe facility at Manchester University. This technique is used to investigate where the elements of interest are within the soil. It is a high resolution elemental analysis technique which can analyse relatively low elemental concentrations within the sample. It makes use of specially prepared thin sections which can also be used for micromorphological description and point counting. This technique works by bombarding a sample with a focused electron beam and them measuring the emitted x-rays with a wavelength dispersive spectrometer (WDS). The WDS can identify the elemental composition of the sample because the wavelength of x-ray is unique to each element. The X-rays reflect off an angled crystal which is setup to reflect only a certain wavelength which corresponds to the element of interest (Figure 16).

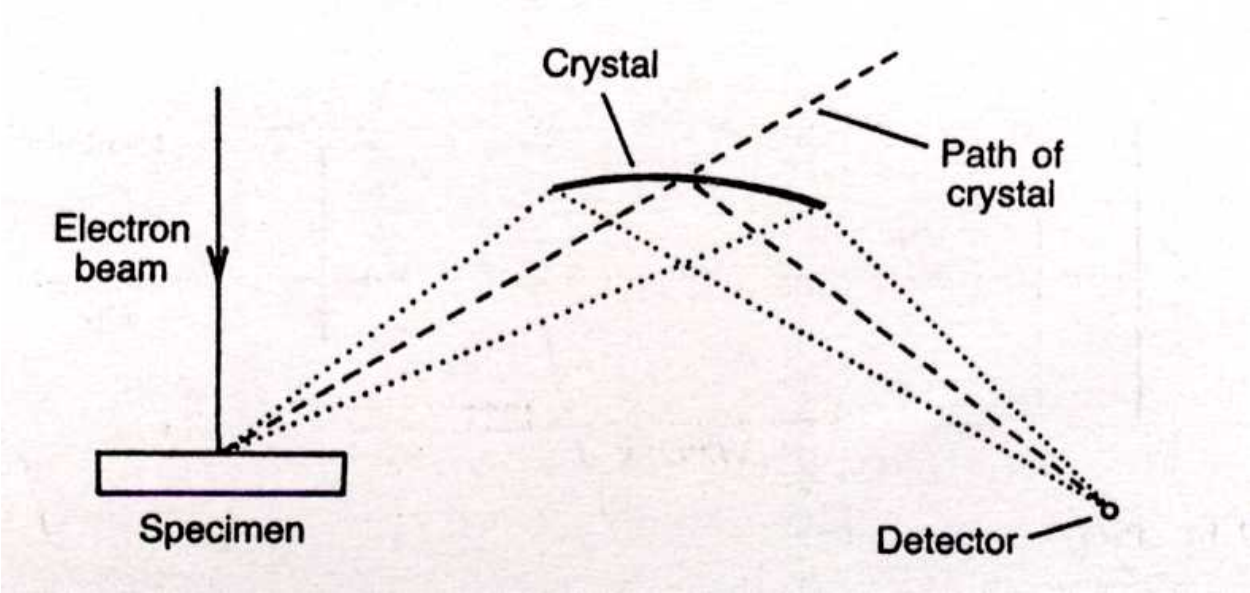

Figure 16: Uses Wavelength Dispersive Spectrometer to measure emitted X-rays.

The technique is both semi and fully quantitative. It is the semi-quantitative approach that is used in this research. It produces elemental maps where the abundance of the elements are relative only to the lowest values. Two different resolutions have been used to assess the spatial distribution of C, N, Ca, Pb (lead) and Zn (Zinc):

1. Low res: 1cm by 1cm
2. High res: 0.5cm by 0.5cm.

The resolution is dependant on both the voltage of the beam and spot size (area of the beam).

Key Features of Soil from the Village

1. Stony organo-mineral soil
2. Poorly structured except for some soil from the eastern side of the village
3. High abundance of charcoal & carbonised material
4. Presence of bone fragments.
5. High biological activity
6. Evidence of mixing
7. No differentiation of features with depth

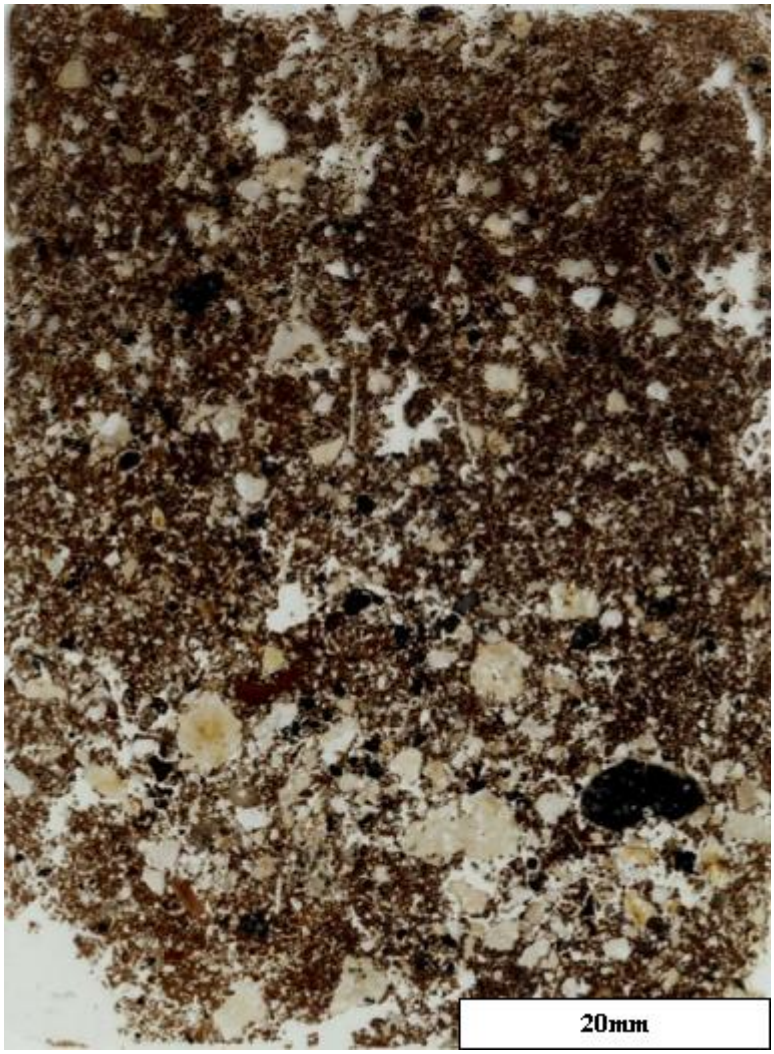

Figure 17: Scan of Typical Village Thin Section

Key Features of Soil from An Lag

1. Very stony organo-mineral soil
2. Low organic matter content
3. Generally similar to soil from the Village
4. No carbonised material, charcoal or bone fragments
5. No differentiation with depth

Figure 18: Scan of Typical An Lag Thin Section

Key Features of Soil from Gleann Mor

1. Very organic/peaty soil
2. Homogenous in nature
3. Some charcoal and carbonised material.
4. A few bone fragments in several thin sections
5. High degree of biological activity
6. Some evidence of mixing/digging

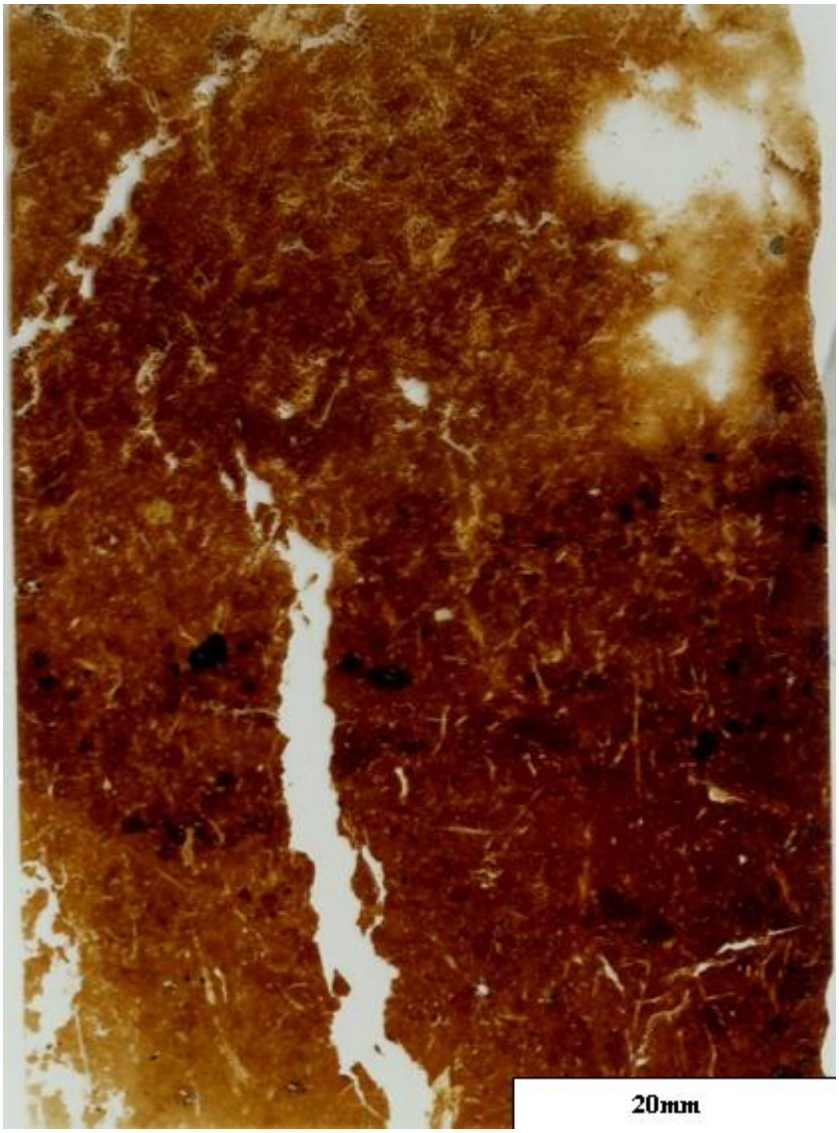

Figure 19: Scan of Typical Gleann Mor Thin Section

Results: Point Counting

Table 1 shows a high abundance of carbonised/charcoal material and when the two depths are compared there are not many differences for any of the features.

Features	Mean abundance of features (%)		
	All village thin sections	Uppermost thin sections	Deepest thin sections
Voids	13.0 (±1.8)	11.4 (±0.9)	15.1 (±4.2)
Rock/Mineral fragments	27.7 (±1.8)	29.0 (±2.7)	25.9 (±2.5)
Undifferentiated organo-mineral material	39.0 (±2.0)	39.5 (±2.5)	38.4 (±3.9)
Plant fragments	0.8 (±0.2)	1.0 (±0.3)	0.6 (±0.4)
Humified material	2.0 (±0.3)	1.6 (±0.3)	2.6 (±0.6)
Lignified material	0.0 (±0.0)	0.0 (±0.0)	0.1 (±0.1)
Amorphous OM	2.0 (±0.2)	1.6 (±1.6)	2.5 (±0.1)
Carbonised/Charcoal	6.8 (±0.5)	6.8 (±0.9)	6.7 (±0.7)
Bone/Ca-Fe-PO_4	0.3 (±0.1)	0.2 (±0.1)	0.3 (±0.1)
Faunal excrement	8.4 (±2.3)	8.9 (±3.7)	7.8 (±3.3)

Table 1: Mean abundance of features quantified by point counting from the village. Values in brackets represent standard errors.

Results: Microprobe

Figure 20: Bone Fragment.

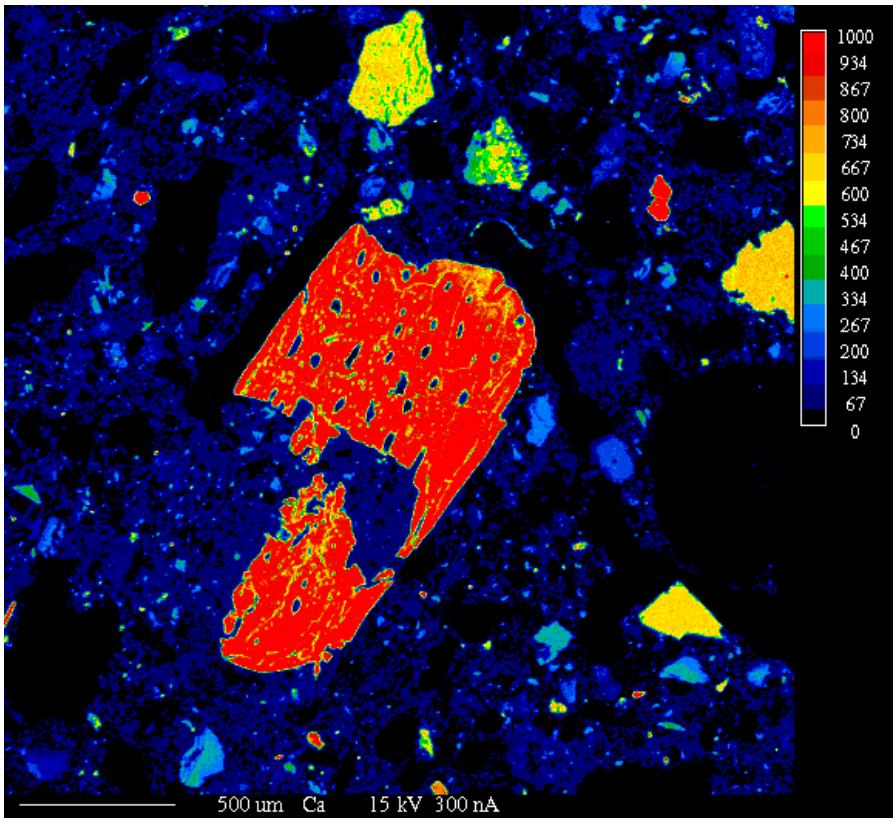

Figure 21: Element map: Ca.

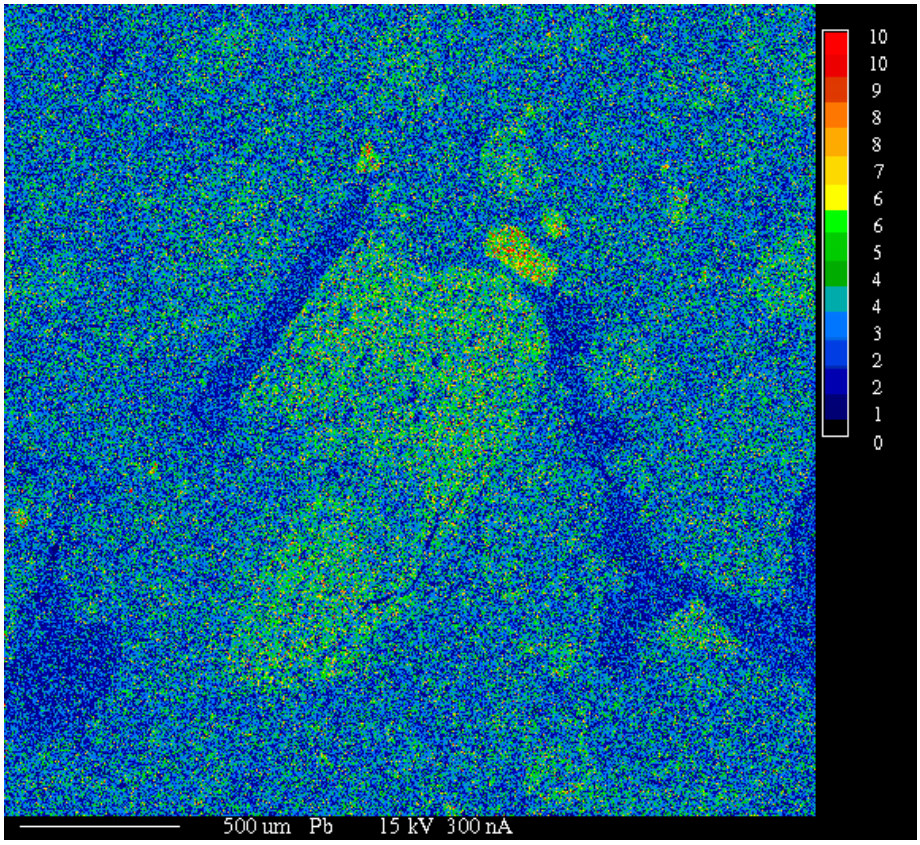

Figure 22: Element map of Pb showing it is mostly evenly distributed.

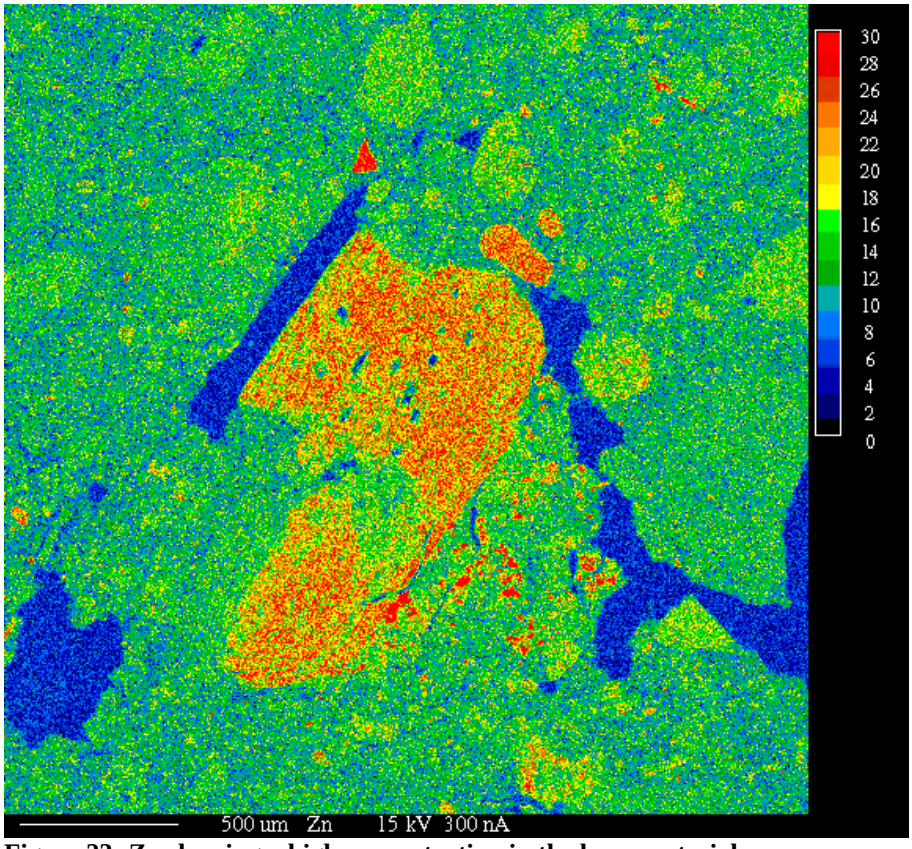

Figure 23: Zn showing a high concentration in the bone material.

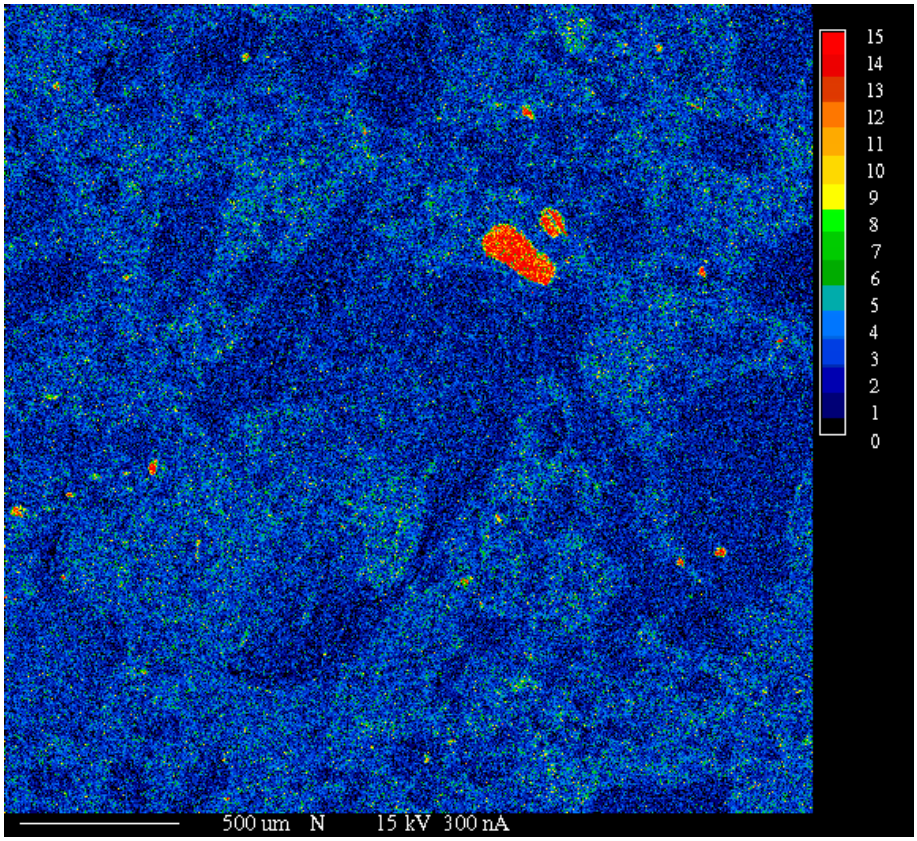

Figure 24: Element map of N.

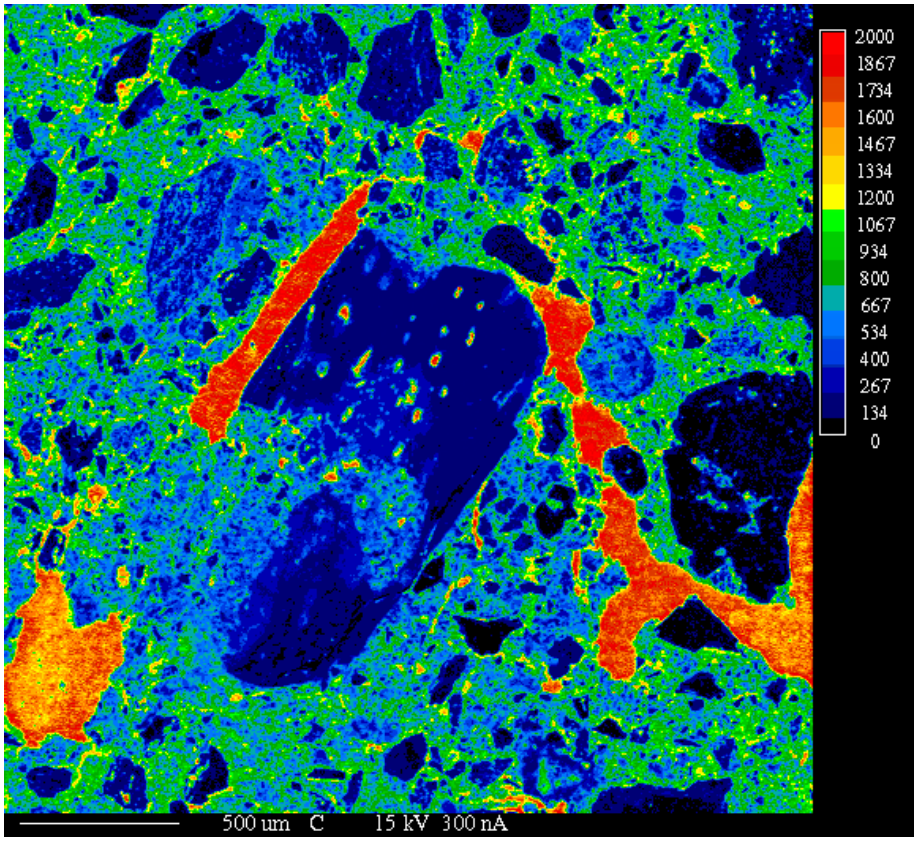

Figure 25: Element map of C.

Summary

- High anthropogenic activity in the village as seen in charcoal/carbonised material and bone fragments.
- Overall no differentiation of features down the profile.
- Zn concentrations tend to be elevated in bone material.
- Pb distributed more widely throughout the soil.
- Further microprobe analysis is required to investigate the spatial distribution of elements in the Village soil.

References

Bullock, P., N. Federoff, A. Jongerius, G. Stoops, T. Tursina, & U. Babel (1985) *Handbook for soil thin section description* Waine Research Publications, Wolverhampton, UK