Geochemical ore prospecting using samples of humus and peat in Finnish Lapland

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Summary

Ore prospecting using peat and humus samples was carried out in Lapland on a nickel critical area. The metals that were enriched in peat most readily were nickel, cobalt and molybdenum, while chromium was enriched in both peat and humus, and copper and lead in humus and rhizomorphous material. Zinc tended to favour the latter material. Geochemical anomalies in organic surficial deposits were also found in places where no mineralised bedrock is currently known, although that may be revealed upon closer examination. In critical areas the distance between transects should be less than 100 m, so that no ores are missed.

Introduction

Geochemical investigations concerning heavy metal concentrations in the organic surface layer and till deposits, were carried out by Outokumpu Oy Prospecting in Finnish Lapland. The study area was 2000 x 3000 metres between the hills of Vuossiselkä and Kermavaara in the municipality of Kittilä, Northern Finland. The nature of the bedrock there was well documented as a result of earlier drillings. The main rock types in the Lutsokuru area are granite, amphibolite and mica schist, with poorly mineralised serpentinites to be found between the latter two and some pyritic chert horizons also observable in the schist zone (Mikkola 1941). Pronounced geophysical anomalies have been identified in the area. The till has been transported over distances of 5 – 15 km, but there is also a great deal of local material (Kujansuu 1967). The surficial deposits are usually some 2 – 5 m thick.

Methods

A total of 551 humus and peat samples were taken on 40 transects, including 264 samples from points among the 951 in the area at which till samples had also been taken. In terms of their principal constituents, 229 of the samples were composed of peat (from a depth of about 0.3 – 0.5 m), 148 of humus and 174 of rhizomorphous material. The transects were located at 50 m intervals, in a manner designed to cover as well as possible the main areas of interest regarding variations in the lushness of the vegetation, the nature of the bedrock and the distribution of geophysical anomalies and of geochemical anomalies in the till.

Results

Heavy metal concentrations in the organic layer of the surficial deposits and effects of sample type and nutrient status of the site on the results

The metal concentrations in the humus and peat samples were expressed in terms of geometric means (Tables 1-2) or medians and logarithmic frequency distributions (Table 3). The classification of the samples is according to the nature of the ground material, till or peat, being marked as peat if this is present at the site to a depth of at least 30 cm. The geometric means are consistently lower than the arithmetic means in this material, as their method of calculation means that the large outlier values have less effect on the result. The background value (x) for heavy metals is taken to be the median, which reflects the average concentration better than do the means.

Table 1. Geometric means of heavy metal concentrations (ppm) in organic samples from surficial deposits, by type of sample.

Sample type / Ground soil	n	Ni ppm	Cr ppm	Co ppm	Cu ppm	Zn ppm	Pb ppm	Mo ppm
Rhizomorphous material / Till	37	4,9	0,6	1,5	5,8	46,7	14,6	0,14
Rhizom.+Humus / Till	137	4,1	0,5	1,3	5,2	41,6	14,0	0,17
Humus+Rhiz., Humus+Peat/Till	74	5,1	1,0	1,9	5,6	36,8	14,7	0,27
Humus / Till	50	6,3	1,8	2,2	6,2	32,9	15,4	0,34
Peat+Rhiz., Peat+Humus / Till	6	10,7	1,3	3,1	7,1	35,0	13,0	0,52
Peat / Till	34	7,4	0,7	3,0	5,3	20,6	10,2	0,28
Peat / Peat (> 30 cm)	175	6,6	1,4	3,0	4,0	9,7	6,5	0,58

Table 2. Geometric means of heavy metal concentrations in organic samples from surficial deposits, by nutrient status.

Nutrient status	n	Ni ppm	Cr ppm	Co ppm	Cu ppm	Zn ppm	Pb ppm	Mo ppm
Oligotrophic	33	4,7	0,6	2,2	4	24,8	11,3	0,2
Oligo-mesotrophic	191	4,8	1	1,7	5	28,1	12	0,2
Mesotrophic	93	6,3	1,9	2,9	4,9	21,6	10,9	0,4
Meso-eutrophic	50	9,6	2,4	3,1	5	11,4	7,6	0,9
Eutrophic	14	18,6	4,4	7,8	5,4	17,6	11,4	9,3
TOTAL	381	5,9	1,3	2,3	4,9	22,7	10,9	0,3

Table 3. Medians and anomaly thresholds for heavy metal and calcium concentrations in the humus/peat (n = 522) and till (n = 951) samples.

Humus and peat	Ni ppm	Cr ppm	Co ppm	Cu ppm	Zn ppm	Pb ppm	Mo ppm	Mn ppm	Ca ppm	Fe %
50 % Md	5	2	2	5	30	12	0,3	60	3358	0,13
84,10 %	15	4	5	8	60	19	1,5	248	8008	0,38
97,70 %	69	24	29	18	140	35	26,0	928	20696	0,87

Till	Ni ppm	Cr ppm	Co ppm	Cu ppm	Zn ppm	Pb ppm	Mo ppm	Mn ppm	Ca ppm	Fe %
50 % Md	48	317	20	51	32	12	2,0	..	..	..
84,10 %	174	594	42	109	88	21	5,0	..	..	..
97,70 %	1702	2558	163	307	311	54	20,0	..	..	..

The threshold for defining an anomaly is taken to be x + 2s, a concentration corresponding to 97.7% of the total frequency, i.e. 2.3% of the total number of samples were defined as anomalous (Table 3). In addition, weaker anomalies correspond to values exceeding 84.1% of the total frequency.

The arithmetic mean of nickel concentrations in the organic deposits is 13 ppm and the geometric mean 6 ppm. Nickel concentrations are seen to be slightly higher in the peat samples than in the humus or rhizomorphous samples. Ni concentrations appear to increase with nutrient status at the sampling site (Table 2). The chromium concentration is 3 ppm (arith. mean) and 1 ppm (geom. mean). No clear-cut variations between the types of sample can be observed. The lowest Cr concentrations are in oligotrophic environments, from where they increase towards the eutrophic end of the scale. The mean of the cobalt was 3 ppm (arith.) and 2 ppm (geom.). Cobalt appears to bind slightly more readily to peat than to either humus or rhizomorphous material, whereas the scatter in the results does not vary markedly between these major categories of sample. Cobalt does not react to nutrient status as clearly as do nickel and chromium. The mean of the copper concentration was 6 ppm (arith.) and 5 ppm (geom.). The pure peat samples from peat-dominated sites contained markedly less copper than the others, implying that, contrary to the heavy metals mentioned above, copper binds most readily to humus and rhizomorphous material. High outlier values are nevertheless to be found even among the peat samples, where the scatter is fairly large. The mean concentration of zinc was 35 ppm (arith.) or 23 ppm (geom.). Zinc appears to bind to peat still less readily than copper, the highest concentrations being recorded in the rhizomorphous group of samples. Zinc departs from the pattern for all the previously mentioned heavy metals in that its concentrations in the three more oligotrophic categories of sample are higher than those in the two more eutrophic ones. The arithmetic mean of the lead concentrations was 13 ppm and the geometric mean 11 ppm. Markedly little lead was present in the pure peat samples relative to the other categories. The frequency distributions for the peat and rhizomorphous samples are similar in form and the scatter small. The occurrence of lead in the organic material does not seem to be related at all to nutrient status. The arithmetic mean of the molybdenum concentrations was 1.8 ppm and the geometric mean 0.3 ppm. The relatively large discrepancy between the two means is attributable to certain very high outliers. Molybdenum appears to bind more readily to peat than to humus, and considerably more readily than to rhizomorphous material. The high outliers are mostly confined to the peat samples, while the results for the rhizomorphous samples are more evenly distributed. The occurrence of molybdenum is clearly dependent on trophic status, being especially pronounced in the most eutrophic category of all.

Relation of the location of heavy metal anomalies in organic material and till to the bedrock

The metal anomalies in the humus and peat samples were examined by transects, together with details of metal concentrations in the basal till, nature of the bedrock, mineralisations, types of loose deposits, thickness and nutrient status of the loose deposits, Ca content of the surface horizon and direction of water flow. For example, Ni-Mineralised serpentinite and skarn have been encountered on transect 31 (Fig. 1), the mineralisation being clearly visible in the till geochemistry but much less so in that of the humus and peat. At one end of the transect, where the surficial deposits are thicker and the bedrock less well known, there is a eutrophic mire that has a pronounced Cr, Ni, Cu and Zn anomaly in its peat and also a Cu and Zn anomaly in the basal till. This accumulation of peat may be due to a marked spring effect, causing cations to be transported to the surface in the groundwater.

Discussion and conclusions

The Ni anomalies in the humus/peat samples are in part located directly on top of serpentinite, especially in the Lutsokurunvaara area, but also in the amphibole-chlorite schist and chert areas further east. The pattern of anomalies in the till is fairly similar, except that here the Ni-rich serpentinites are more clearly visible. Cr anomalies in the humus and peat are to be found at more or less corresponding points to the nickel anomalies, except that the Vähänkuruntievat serpentinites are more clearly reflected in the chromium values. Cr content follows the pattern of the bedrock better in the till than in the organic material. Third metal which is typical of ultra-basic rocks, Co, provides a poor impression of the known bedrock serpentinites in its occurrence in the humus and peat samples, whereas its anomalies in the till come closer to the locations of the serpentinites. Cu concentrations in the humus and peat reach high levels in places in the area of the Lutsokurunvaara serpentinites, while other Cu anomalies are to be found in connection with the chert horizons. The Cu anomalies in the till are still more clearly coincident with chert zones in the schist area. The largest Zn anomalies in the humus and peat are located in the chert and amphibole chlorite schist zones east of Lutsokurunvaara and in the area of this hill itself, evidently being associated with the pyrite horizons occurring between the lumps of serpentinite. Virtually the corresponding pattern is also observed for the location of anomalies in the till samples. Pb anomalies in the organic material are fairly sporadic, although principally to be found in the zone where the chert horizons occur. They are still more clearly concentrated in this area in the till. The location of Mo anomalies resembles that for Cu in the case of both the humus and peat samples and the till samples. Concentrations of this metal are extremely high in some peat areas. The highest values are grouped to some extent alongside streams and in the vicinity of springs.

Of the factors likely to affect heavy metal concentrations in humus and peat, the present investigation was concerned mostly with the type of sample, nutrient status of the site, thickness of the surficial deposits and nature of the bedrock. The metals that became enriched in peat most readily were nickel, cobalt and molybdenum, while chromium was enriched in both peat and humus, and copper and lead correspondingly in humus and rhizomorphous material. Zinc tended to favour the latter material.

Nickel, chromium, cobalt and molybdenum showed positive correlations with the nutrient status of the sampling site, whereas copper and lead were indifferent in this respect and zinc was enriched most readily under oligotrophic conditions. If the loose deposits were more than 6 m thick, it was common for all the metals to show low concentrations in the organic surface horizon. On the other hand, only zinc and lead had a tendency for clear peaks in occurrence to coincide with places where the loose deposits were thinnest and the bedrock came close to the surface.

The Ni and Cr anomalies in both the organic samples and till were clearly indicative of known serpentinite occurrences, while cobalt was more reliable in till than in organic samples. Cu, Zn and Mo anomalies in humus and peat were observable in the skarn and serpentinite areas, but were above all typical of areas with pyrite-rich chert horizons. Zn, Mo and Pb anomalies in till were found mainly in chert areas.

Geochemical anomalies in organic surficial deposits were also found in places where no mineralised rocks are currently known to exist in the bedrock, although these may be revealed upon closer examination. On the other hand, it is important that in critical areas the distance between transects should not be more than 50 – 100 m, so that no mineralisations are missed.

References

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