COPPER IN PEAT FROM HUMMOCKS AND HOLLOWS AND FEATHER MOSS NEAR THE HORNE SMELTER, ROUYN-NORANDA, QUEBEC, CANADA

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ABSTRACT
In 1997, a sampling survey of 24 peatlands located 7 to 92 km from the Horne smelter was undertaken to investigate the value of peat as an historical record of smelter metal emissions. More than 340 peat and 15 feather moss samples (*Pleurozium schreberi*) were analyzed for Cu using ICP-AES after an aqua regia digestion. Within 12 km of the smelter, Cu levels are around 500 ppm in some peat samples, while at distances greater than 20 km, levels are less than 10 ppm. In hummocks within 12 km, Cu levels are relatively low in the uppermost 20 cm, increase about 5 fold between 20 and 50 cm depths, and decrease below 50 cm. In contrast, in peat hollows, Cu is consistently high in the uppermost 20 cm but below 20 cm it is near background. Feather moss had 78 ppm Cu at 8 km compared to 17 ppm at 23 km from the smelter. The differences in metal distribution patterns between hummocks and hollows affect their apparent potential value as historical records of smelter emissions.

INTRODUCTION
In 1997 Geological Survey of Canada initiated research on heavy metal concentrations in peatlands surrounding the Horne Cu-Zn smelter at Rouyn-Noranda, Quebec (Fig. 1). This work was carried out to determine and compare the physical and geochemical record of particulate smelter emissions in some of the main types of surficial media (till, soils, lake sediments, snow, lake waters, and peat). It is commonly known that metal smelters are point sources of heavy-metal loading in the landscape with concentrations decreasing with distance from the smelter (Davies, 1983). Near the Horne smelter which opened in 1927, previous work has been undertaken examining metal distribution in humus, surface mineral soils, and peat (Henderson et al., 1998; Glooschenko et al., 1986; Dumontet et al., 1990).

As part of study, reconnaissance sampling was carried out at 24 peatlands, located 7 to 92 km from the smelter. More than 340 peat profile samples and 15 feather moss (*Pleurozium schreberi*) were analyzed to provide baseline data on regional metal variation in these two types of materials. Feather moss was previously recognized as a useful bioindicator species for heavy metals in Precambrian shield areas (Rasmussen, 1994). In this paper, some results, based on the Cu data, are presented.

The study area is located in a low-relief boreal region of the Precambrian shield, and covers part of the Abitibi greenstone belt, comprising Archean metasedimentary and metavolcanic rocks and associated intrusions. Peatlands have developed on the extensive thick deposits of glaciolacustrine silts and clays and, to a lesser extent, in poorly drained bedrock depressions in the knobby shield terrane. In this region, the most dominant wind directions are to the north and to the southeast.

METHODOLOGY
Peatland sites dominated by *Sphagnum* species, with ericaceous shrubs such as *Chamaedaphne calyculata*, *Ledum groenlandicum*, *and Kalmia polifolia*, were selected. Where possible, two sets of samples were collected from each site - one from a peat hummock and the other from the flat part of

the peatland (hollow) adjacent to the hummock. From top to bottom in the hummock, samples were collected with stainless steel clippers at 2 to 4 cm intervals and, where possible, their volume was estimated. From the hollow, blocks of peat were hand cut from the surface and a core was collected through peat to the underlying mineral sediment. Two to 4 cm segments of feather moss (*Pleurozoium schreberi*) were clipped from the end of the moss branches growing on the hollow surface.

In the laboratory, peat samples were weighed, dried at 37^{o} C, reweighed, and their bulk densities calculated. All samples were digested with aqua regia and analyzed for selected trace, minor, and major elements using the ICP-AES method. Analysis of duplicate samples and laboratory standards were used to monitor analytical accuracy and precision.

RESULTS AND DISCUSSION

Hummocks in the Rouyn-Noranda region ranged in height from 20 to about 60 cm above the hollow and were commonly oval or sub-rounded in shape. The uppermost 10 cm of the hummock was composed predominantly of living or recently dead *Sphagnum*, whereas between 10 and 25 cm, the *Sphagnum* was light brown and poorly decomposed. In many hummocks, the bulk density increased from around 0.01 g/cm^3 at the surface to approximately 0.03 g/cm^3 at 25 cm depths. Below 25 cm, the *Sphagnum* graded from being brown and poorly decomposed with a bulk density of 0.03 g/cm^3 to being dark brown and moderately decomposed with a bulk density of about 0.06 at depths of around 40 cm. In the tallest hummocks, basal materials were very dark and decomposed with bulk densities of 0.10 g/cm^3. In contrast to the hummock, peat at the hollow surface was brown and moderately decomposed, whereas below 20 cm, it was generally very dark brown or black and moderately to well decomposed. In the hollow, the peat bulk density was generally 0.03 to 0.05 g/cm^3 in the uppermost 20 cm and 0.10 g/cm^3 at depths below 20 cm.

Preliminary data for four peat hummocks shows that the Cs-137 peak is located around a depth of 40 to 45 cm from the hummock surface (Kettles, unpublished data). The Cs-137 peak is considered to represent materials formed in the time interval between 1958 and 1962 when nuclear bomb testing was at its maximum.

Within 12 km of the smelter, there are very high concentrations of Cu (500 ppm) in some peat samples from the hummock and surface of the hollow (Fig. 2). Background concentrations (less than 10 ppm) occur about 20 km from the smelter. In hummock profiles near the smelter, the Cu levels are relatively low in the uppermost 20 cm, increase about 5 fold between 20 and 50 cm depths and, where accumulations are more than 50 cm, they may decrease again below 50 cm. In contrast, in peat hollows, Cu is consistently high in the uppermost 20 cm, below which it is generally near background. In places, however, Cu is enriched in basal peat from the hollows, though to a much lesser extent than in the surface peat of cores collected near the smelter. For feather moss, Cu levels within 12 km of the smelter are around 4 to 5 times higher (78 ppm) than they are at 23 km (17 ppm).

In the Rouyn-Noranda area hummocks, the vertical accumulation rate is sufficiently high that the metal profile record can be divided into smaller discernible time units than possible for peat accumulating in the hollows or for most other types of surficial materials (e.g. soil, humus and lake sediments). In hummocks near the smelter, the low levels in peat in the uppermost 20 cm may reflect the marked drop in Cu emissions from the smelter effected about 1980 by the installation of new smelting equipment (Noranda Mines, unpublished data). Also near the smelter, low Cu levels below 50 cm may reflect pre-smelter concentrations. Although there are no geochronological data available at present for the hollow peat sequence, it is likely that peat in the uppermost 20 cm from the hollow accumulated over a much longer time period compared to peat in the uppermost 20 cm of the hummock. In a northeastern Ontario peatland, 250 km northeast of Rouyn-Noranda, peat at 23 cm in a hummock, where peat bulk densities ranged from 0.05 and 0.08 g/cm^3 was dated at 110 years (Kettles et al., 2000; Turner and Kettles, 2000) while peat between 30 and 40 cm in the adjacent hollow formed about 3200 years ago.

To examine the relationship between Cu in peat and feather moss and the smelter emissions, Cu concentrations in the hummock surface peat (approximately 0-3 cm), hummock peat at 30 cm, hollow surface peat (approximately 0-5 cm), and feather moss were plotted against distance from the smelter and the best fit trendlines were determined (Fig. 2). Data for the hummock at 30 cm was chosen for this comparison because metal levels are highest in hummocks between 20 and 45 cm depths and most hummocks had accumulations of at least 30 cm.

For each of the four types of sample materials, an inverse relationship was noted such that the log concentration of the element decreases with the log concentration of the distance from the smelter. Near the smelter, Cu levels are highest in peat from the hummock at 30 cm and from the hollow surface. The trendline slopes are also similar, indicating that there is a similar pattern of decrease in Cu levels in these two types of materials. A trendline with a similar slope was also noted for humus in the Rouyn-Noranda region, although the Cu levels in the humus were approximately 40 times higher (Henderson et al., 1997). Near the smelter, Cu concentrations in feather moss and hummock surface peat are 3 to 5 times lower than they are at the hollow surface or in the hummock at 30 cm. The trend lines for feather moss and peat in the hummock surface are generally similar to each other.

These differences in metal distribution patterns between profiles from hummocks and hollows show the importance of understanding peatland setting in interpreting the anthropogenic metal record. The distributions of Cu is now being investigated in more detail, through sequential leach geochemical analysis and SEM analysis of peat metal phases, to determine to what extent high levels of Cu represent historical deposition from smelter emissions or the translocation of metals through post-depositional weathering processes.

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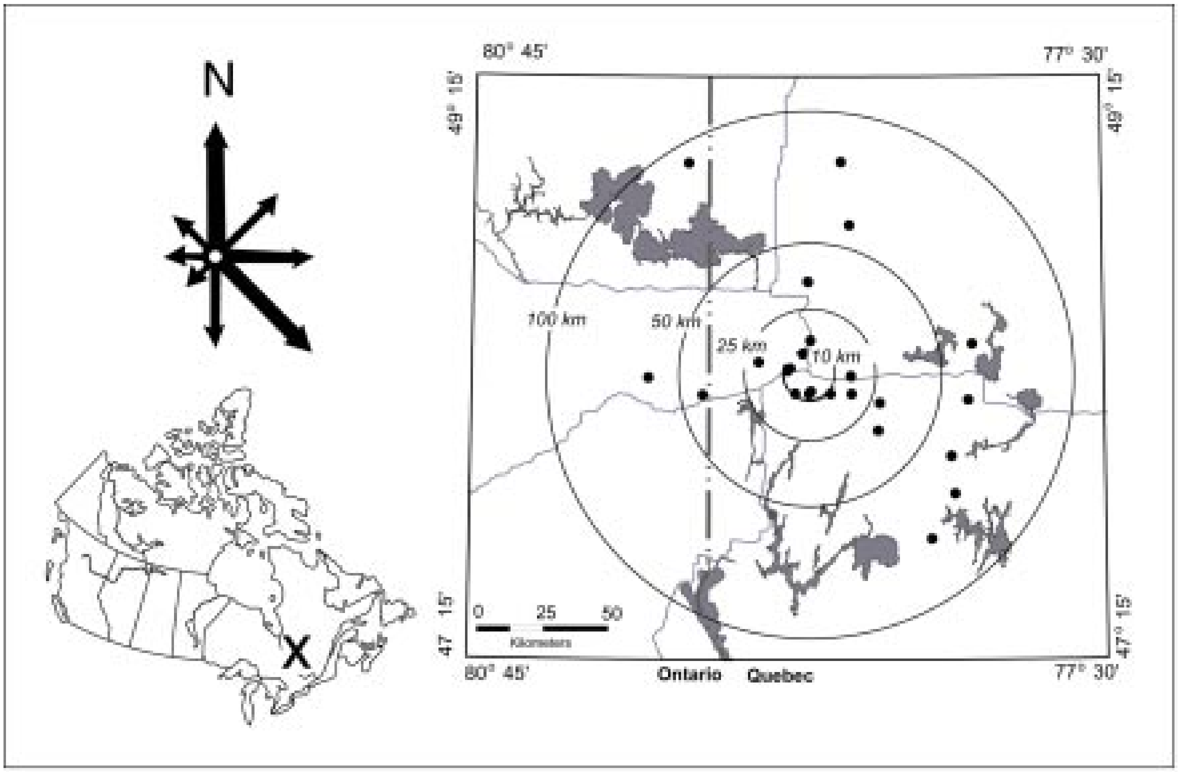

Figure 1. Maps depicting the locations of the 24 peatland study sites near the Horne Cu-Zn smelter at Rouyn-Noranda, Quebec, Canada. Also shown is a wind rose diagram centered on the smelter. The lengths and widths of the arrows are proportional to the wind frequency and strength, respectively.

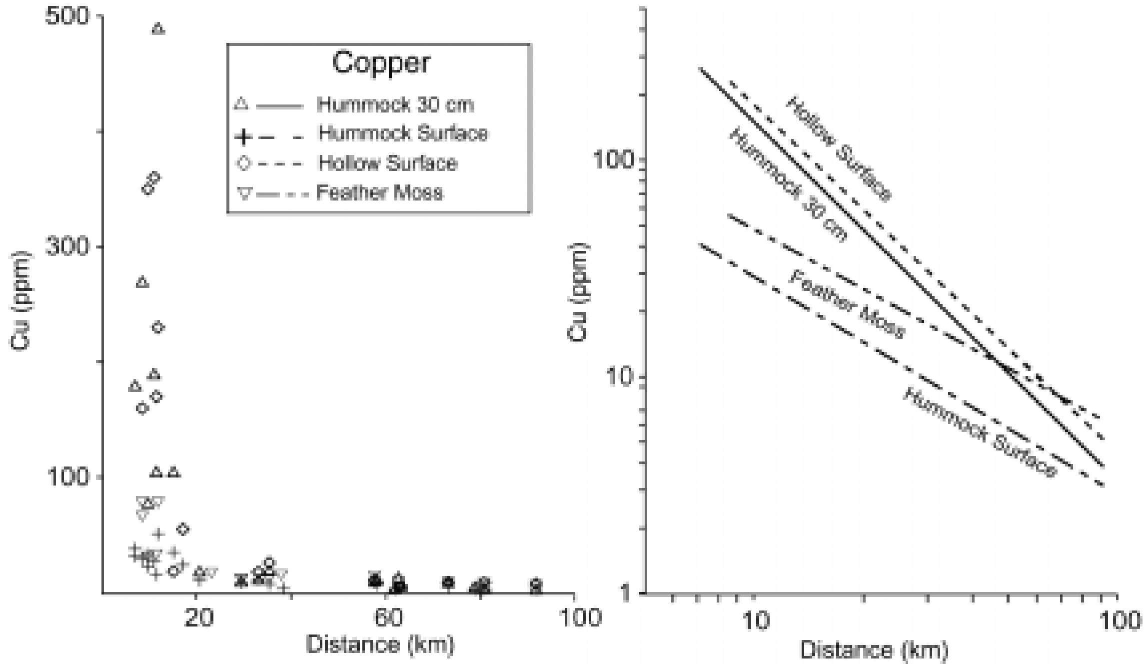

Figure 2. The dispersion of Cu in peat from the hummock surface (n=24), the hummock at 30 cm (n=20) and the hollow surface (n=14) and in feather moss (*Pleurozium schreberi*) (n=15). Also shown are the best fit trendlines for the four types of sample data (hummock surface: $\ln(y) = -1.00 * \ln(x) + 5.68$, $R^2=0.85$; hummock at 30 cm: $\ln(y) = -1.66 * \ln(x) + 8.83$, $R^2=0.87$; hollow surface: $\ln(y) = -1.61 * \ln(x) + 8.89$, $R^2=0.84$; feather moss: $\ln(y) = -0.91 * \ln(x) + 5.95$, $R^2=0.85$). The correlation coefficient (R^2) indicates the strength of the trend.