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ENVIRONMENTAL GEOCHEMISTRY AND MINERALOGY OF SNOW AND SOIL SAMPLES FROM THE KOLA NICKEL MINING AND PROCESSING AREA, NW RUSSIA

by

Dean Gregurek

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Montanuniversität Leoben

Institut für Geowissenschaften
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Chemical and mineralogical investigations were carried out on fifteen snowpack samples taken in the immediate vicinity (1.5–8 km) of copper-nickel mines and processing plants on the Kola Peninsula, NW Russia. Snow sampling was carried out in March 1996 in the surroundings of the ore roasting and dressing plant at Zapoljarnij, and the Cu-Ni smelters at Nikel and Monchegorsk. The collected snow cover represents the total atmospheric input of heavy metals during the 1995/96 winter season. In the laboratory snow samples were melted and filtered through 0.45 mm Millipore™ filters. Both fractions, filtered melt water (MW, < 0.45 mm) and snow filter residues (FR, > 0.45 mm) were analysed for up to 39 elements, using ICP-MS, ICP-AES, ion chromatography and graphite furnace atomic absorption (GFAAS) techniques.
Results indicate that all trace elements show unusually high concentrations in the immediate vicinity of the nickel ore roasting plant and smelters. Analytical data also reveal typical fingerprints of the two ore components (Noril`sk and Pechenga ore) used in the processes. Microscopical (reflected light) and electron microprobe investigations were carried out on polished sections of filter residues (> 0.45 mm) to identify the mineralogical composition of the particulate deposition. A wide spectrum of different geogenic (oxides, sulphides, silicates and rock fragments) and technogenic phases was observed. Geogenic ore particles from two different Ni-Cu deposits can be identified in the snow: i) local Pechenga ore and ii) imported ore from Noril`sk-Talnakh. Technogenic particles consist of a large spectrum of sulphides (Ni-Cu-Fe-Co), oxides (Fe-Ni-Cu), metallic phases and alloys (Ni-Cu-Fe-Co), as well as slag particles, coke and graphite. The technique allows us to directly distinguish between particles originating from geogenic sources (e.g. windblown rock dust) and additional anthropogenic input from industrial sources. Furthermore, it was possible to gain information on the metallurgical processes used in the different factories (one roasting plant and two smelters using different technology). The mineralogy of the particulate inpute can thus be directly used to unravel the source of observed heavy metal inputs at any one place even in complex situations with several industries located at close distance.

Particle size (median length and width) in snow samples from Nikel and Monchegorsk varies between 10 and 40 mm. Grain size parameters (median, arithmetic mean, sorting and skewness) show no significant differences in both localities. In Monchegorsk a positive correlation between Cu, Ni, Fe, S and the median of the grain size suggests that these elements are predominantly bound to very fine fractions. In contrast, in Nikel these elements show a negative correlation with grain size, suggesting that the majority of these elements are emitted as rather coarse grains.

Soil samples (O-horizon) were taken in July 1997 at the same localities as snow. In addition complete podzol profiles were sampled at three localities in the Monchegorsk area. Up to 32 elements were analysed in soil samples using ICP-AES and GFAAS techniques. Many of these elements are strongly enriched in the O-horizon due to the anthropogenic activities in the area. High concentrations of some elements that are not emitted in appreciable amounts show that other factors than just pollution (e.g., dust input, biogenic processes and pedogenic factors) have to be carefully considered when studying heavy metals in soils. Mineralogical studies of soil samples (O-horizon) at all sites reveal both similarities and significant differences. Similar in both sample groups is the wide spectrum of technogenic and geogenic phases present; different is their quantitative distribution. This applies particularly to the widespread oxidation of sulphides in soils, resulting in significantly lower sulphide and higher sulphate and oxide contents. Major mineral phases include silicates and geogenic and technogenic oxides. Six types of distinct alloys were observed in samples from Nikel and Monchegorsk; they frequently are surrounded by oxide rims. Several stages of weathering and replacement of sulphide particles by iron-bearing sulphate (probably melanterite) have been recognised. Oxide and silicates are more resistant to weathering processes.

Precious metals (Rh, Pt, Pd, Au) and Te were analysed by graphite furnace atomic absorption spectrometry (GFAAS). Values of up to 2770 ng/l Pd, 650 ng/l Pt and 186 ng/l Au in snow filter residues and up to 1090 mg/kg Pd, 450 mg/kg Pt and 89 mg/kg Au in soil (O-horizon) were found. Additionally, platinum-group elements (PGE) and Au contents in ore samples from Noril`sk, as well as in technogenic products ("Cu-Ni-feinstein" and copper concentrate) processed at the Monchegorsk smelter complex, were analysed using flameless atomic absorption spectroscopy (FAAS) for comparison with results obtained from snow and soil. Rh, Pt, Pd and Au distribution data reveal the presence of two ore components (Noril`sk and Pechenga). Concentrations of these metals decrease with distance from the industrial sources and with the prevailing wind direction (north-south). Microscopic investigations and electron microprobe analysis of polished sections of snow filter residues also reveal differences between particles from the two sources. PGE-bearing sulphides (pentlandite with 0.2–0.3 wt% Pd) have been observed in the particulate emissions from Zapoljarnij and discrete PGE-phases at Monchegorsk. In soil samples, Pd-Pt alloys within Fe-Ni-Cu oxide were encountered. The participation of PGE-rich Noril`sk ores is reflected in these observations; discrete PGE phases are only found near the main procession of these ores, i.e. Monchegorsk.