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Preliminary report on REE content in metamorphic black schists from the Precambrian Hecla Hoek Succession, West Spitsbergen*

We studied Proterozoic metamorphic rocks of the Hecla Hoek Succession that were collected from the area between Torellbreen and Hornsund, Spitsbergen. We analyzed schists of the Vimsodden Subgroup which occurs between Werenskioldbreen and Vimsodden. Analyzed rocks include quartz-mica black schists, carbonate-quartz-mica black schists and light quartz-sericite schists. Black schists are fineblastic assemblages of quartz, muscovite, paragonite, chlorite, chloritoide, with a metaanthracite-semigraphite pigment. As accessory minerals pyrite, zircon, and tourmaline were found. The schists probably represent bituminous clay shales metamorphosed in two stages: in albite-epidote-amphibolite facies, then in greenschist facies. The REE concentration is generally higher in the black schists than in other schists of the Vimsodden Subgroup. HREE abundances in black quartz-mica schists are similar to those in light quartz-sericite schists.

Since 1983, Instytut Geologii i Surowców Mineralnych Akademii Górniczo-Hutniczej (the Institute of Geology and Mineral Deposits — the University of Mining and Metallurgy, Kraków), together with Polska Akademia Nauk (the Polish Academy of Sciences) and Polskie Towarzystwo Przyjaciół Nauk o Ziemi (the Polish Society of Earth Sciences), has organized geological expeditions to Spitsbergen. So far, mineralogical and petrographical investigations of metamorphic and volcanic rocks were carried out on rocks found in the area between Torellbreen and the Polish Polar Station in Hornsund (Fig. 1). The geological map (1:25 000) of this area was preparation in 1993.

Local rocks comprise a Proterozoic metamorphic series: schists, gneisses, amphibolites, greenstones, marbles, and quartzites. These rocks are intersected by several, much younger, dolerite dykes of various thickness. Metamorphic rocks belong to the Hecla Hoek Succession which forms the Caledonian structural stage of Spitsbergen (K. Birkenmajer, 1981). In these rock series two stages of metamorphism (in albite-epidote-amphibolite facies and

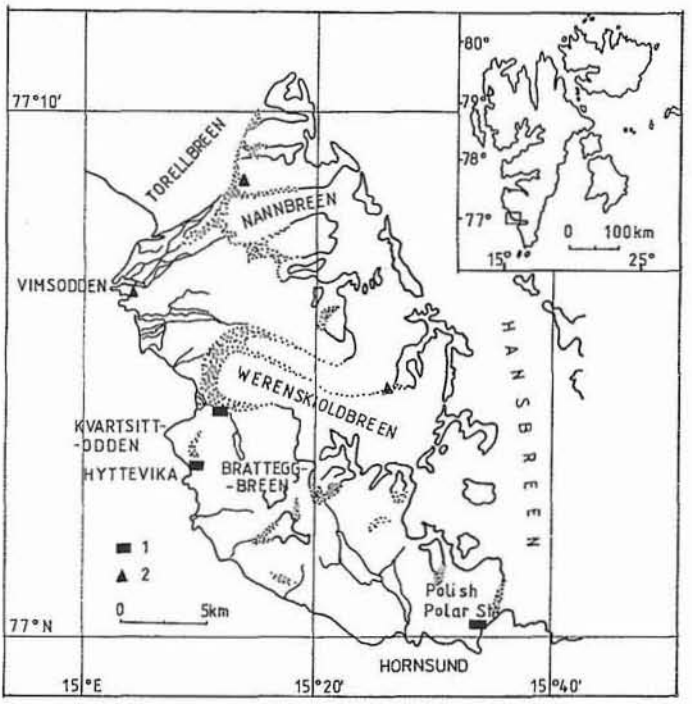

Fig. 1. Sketch map of investigated area
1 — bases; 2 — camps
Szkic obszaru badań
1 — bazy stałe; 2 — bazy namiotowe

greenstone facies) and at least three stages of tectonic deformations have been distinguished (J. Czerny *et al.*, 1992).

Black schists belong to the Vimsodden Subgroup which occurs between Werenskioldbreen and Vimsodden. The monoclinal complex dips steeply to the SW. Metamorphosed rocks are of volcanic origin (rhyolitic metaconglomerates, schists, greenstones) and of terrigenous origin (black schists, marbles, metaconglomerates, quartz-mica schists, quartzites). A pyrite-polymetallic mineralization zone was found in marbles, metaconglomerates and quartz-mica schists. Pyrite, sphalerite and others occur as both laminated ores and veins. The metamorphic rocks on the Vimsodden Peninsula are cut by several thin Lower Cretaceous dolerite dykes (K. Birkenmajer, T. Morawski, 1960).

Material for analysis was collected from three schist varieties occurring between Werenskioldbreen and Vimsodden: quartz-mica black schists, carbonate-quartz-mica black schists and light quartz-sericite schists. The black quartz-mica schists are about eighty metres thick, steeply dipping to the SW. To the South, through a thin marble layer, they are in contact with a sequence of metavolcanics, while to the North they border black and gray marbles. The northern contact with gray marbles is not sharp.

The black quartz-mica schists are fineblastic, with minute foliation often crenulated. The groundmass, which is composed of quartz, muscovite, and paragonite, is pigmented by

Table 1

Rare earth elements abundances (ppm) in black schists from Spitsbergen (1, 2, 3) and in average clay shale (PAAS) (4)

Element	1	2	3	4
La	141.00	44.00	33.80	41.10
Ce	240.00	97.00	34.00	81.30
Pr	–	–	–	10.40
Nd	100.00	–	–	40.10
Sm	18.40	10.5	6.30	7.30
Eu	2.09	0.76	0.47	1.52
Gd	–	–	–	6.03
Tb	3.00	3.00	0.75	1.05
Dy	–	–	–	–
Ho	–	–	–	1.20
Er	–	–	–	3.55
Tm	–	–	–	0.56
Yb	9.50	11.60	1.30	3.29
Lu	1.50	1.40	0.24	0.58
REE	515.49	168.26	76.86	204.00
$(La/Yb)_n$	10.00	2.50	17.60	8.40
Eu/Eu*	0.34	0.19	0.18	0.86

1 — quartz-mica black schist; 2 — quartz-sericite schist; 3 — carbonate-quartz-mica schist; 4 — average clay shale (after S. R. Taylor, S. M. McLennan, 1985); Eu* fixed from Sm-Tb line

a carbonaceous substance determined by DTA as metaanthracite-semigraphite. Chlorite and chloritoide are present as minor constituents. Chloritoide prisms, surrounded by asymmetric pressure shadows, are oriented transversally to foliation. Accessories include pyrite, zircon and tourmaline. The black schists probably represent metamorphosed bituminous clay shales (J. Czerny *et al.*, 1992).

REE's were determined by Instrumental Neutron Activation Analysis (INAA) by Dr. J. Janczyszyn. Samples were activated at the reactor of Instytut Energii Atomowej (the Institute of Atomic Energy) in Świerk, Poland. Sample weight was about 100 mg, the time of transport after activation — 3 days. Standards (SL-1, SOIL-7) from the International Atomic Energy agency were used. Two measurements were carried out: for short-lived and long-lived radioisotopes.

The results of analyses have been normalized to chondritic abundances (data after H. Evensen *et al.*, 1978 *fide* P. Henderson, 1984) and are presented in Table 1 and Figure 2. Average REE contents in an unmetamorphosed clay shale (PAAS, Post-Archean Australian average shale composite, S. R. Taylor, S. M. McLennan, 1985) are shown for comparison.

The REE concentration is higher in black quartz-mica schists than in other schist varieties. The abundance pattern for the black schists (1) shows distinct enrichment in REE's (REE = 515 ppm) and a well pronounced negative Eu anomaly (Eu/Eu* = 0.34). It is also characteristic of other schists analyzed, regardless of their LREE/HREE ratios and REE contents. This pattern is characteristic of sedimentary rocks, particularly of shales (S. R.

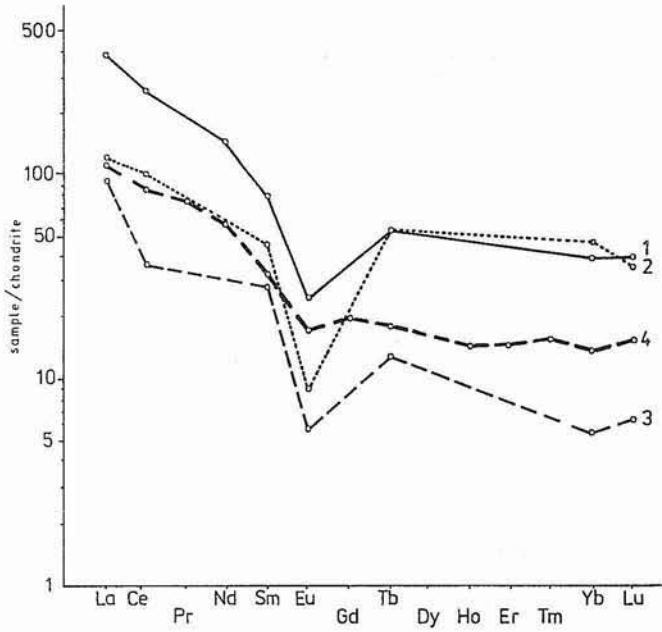

Fig. 2. Chondrite-normalized REE patterns for Proterozoic schists from Spitsbergen compared with an average unmetamorphosed clay shale (PAAS)

1 — quartz-mica black schist; 2 — quartz-sericite schist; 3 — carbonate-quartz-mica schist; 4 — average clay shale (PAAS, after S. R. Taylor, S. M. McLennan, 1985)

Wykresy zawartości REE (normalizowany względem chondrytu) w łupkach proterozoicznych ze Spitsbergenu, porównane ze średnim niezmetamorfizowanym łupkiem ilastym (PAAS)

1 — czarny łupek kwarcowo-mikowy; 2 — łupek kwarcowo-serycytowy; 3 — łupek węglanowo-kwarcowo-mikowy; 4 — średni łupek ilasty (PAAS według S. R. Taylora, S. M. McLennana, 1985)

Taylor, S. M. McLennan, 1985). Both black quartz-mica schists (1) and quartz-sericite schists (2) are relatively enriched in heavy rare earth elements. The contents of HREE's in these schists are similar to each other and are about 2–3 times higher than those in unmetamorphosed shale. When passing from the black schists to the overlaying gray marbles the REE content decreases and it is nearly 5 times lower in the carbonate variety of the black schists (3), suggesting concentration in terrigenous material. These trends, however, need further confirmations.

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WSTĘPNE BADANIA PIERWIASTKÓW ZIEM RZADKICH W CZARNYCH ŁUPKACH METAMORFICZNYCH PREKAMBRYJSKIEJ FORMACJI HECLA HOEK NA ZACHODNIM SPITSBERGENIE

Streszczenie

Badaniom poddano skały metamorficzne proterozoiku formacji Hecla Hoek, między Lodowcem Torella a fiordem Hornsund. Szczegółowo analizowano łupki występujące między Lodowcem Werenskiolda a półwyspem Vimsodden. Wyróżniono czarne łupki kwarcowo-mikowe, czarne łupki węglanowo-kwarcowo-mikowe i łupki kwarcowo-serycytowe. Czarne łupki zbudowane są z drobnoblastycznych kryształów kwarcu, muskowitu, paragonitu, chlorytu, chlorytoidu oraz metaantracytowo-semigrafitowego pigmentu. Akcesorycznie występują w nich piryt, cyrkon i turmalin. Łupki te powstały przypuszczalnie w wyniku dwufazowego zmetamorfizowania bitumicznych łupków ilastych (facja albitowo-epidotowo-amfibolitowa i zieleńcowa). Zawartości REE w czarnych łupkach są wyższe niż w innych łupkach podgrupy Vimsodden. Podwyższone zawartości HREE stwierdzono zarówno w czarnych łupkach kwarcowo-mikowych, jak i w łupkach kwarcowo-serycytowych.