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REE ACCESSORY MINERALS IN THE GNEISS PEBBLES FROM THE UPPER ISTEBNA BEDS – SUGGESTION FOR THE LOW TEMPERATURE METAMORPHIC EVENT

Abstract: Gneiss pebbles from the Gorlice, Krzesławice and Siekierczyna regions (the Upper Istebna Beds, Western Outer Carpathians) were studied. REE mobilization, enrichment of monazites in Th and formation of Th-phases and uraninite were determined. These might be related to metamorphic episode which occurred at relatively low temperatures.

Key words: extrabasinal clasts ("exotics"), gneiss pebbles, REE, Western Outer Carpathians

INTRODUCTION

Gravel size extrabasinal clasts (so-called "exotics"), which occur in the Outer Carpathians flysch, represent source areas of clastic material. The following main source areas that supplied Carpathian basins with sediments might be distinguished: northern source (external to the Western Outer Carpathians) related to the Brunovistulicum and/or Malopolska Massifs, the Silesian Ridge, and the Southern Magura Ridge. Internal source areas, so-called "cordilleras" (*e.g.* Wieser 1949, 1985; Książkiewicz 1965; Sikora 1976) are represented by two latter ones. Wide range of recent investigations of "exotics" is a continuation of works started in the middle of XIX century (vide Słomka *et al.* 2004 and refs. therein). This study provides preliminary constraints on alterations that resulted in REE mobilization in gneiss pebbles from the Silesian Ridge.

SAMPLE SELECTION AND METHODS OF INVESTIGATION

Various types of metamorphic rocks pebbles from the Upper Istebna Beds (Paleocene) were collected in three localities. Ten relatively non-altered samples of gneisses (G-1, G-2, G-3, G-4, G-5 and G-6 from the Gorlice region; K-2 and K-4 from the Krzesławice region; SE-1 and SE-3 from the Siekierczyna region) were chosen to analyses.

Transmitted light microscopy observations as well as analyses with use of cold field emission scanning electron microscope (FESEM) Hitachi S-4700 coupled with energy dispersive spectrometer (EDS) NORAN Vantage were performed at the Institute of Geological Sciences of the Jagiellonian University, Kraków. At the current stage ca. 300 EDS analyses were carried out of 10 thin sections.

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RESULTS

Typical assemblage of gneisses is plagioclase ($An_{<35}$), quartz, biotite, muscovite, K-feldspar, with accessory rutile, apatite, zircon, monazite, iron and titanium oxides, as well as iron and zinc sulphides. Medium to high degree of sericitization of plagioclase is common. Chloritization of biotite and/or carbonitization occur sporadically. REE concentrations above EDS detection limit were determined in the following minerals: apatite, monazite, uraninite, and zircon.

Apatite, up to ca. 150 µm in size, is subhedral to anhedral (Fig. 1). Quite often it contains REE – ca. 1 wt.% on average, up to 3.28 wt.% in single grains (e.g. sample K-4).

Monazite forms subhedral to anhedral grains or aggregates up to ca. 50 µm (Fig. 2). BSE observations revealed that monazite is not zoned. Single grains are present in quartz. Aggregates of monazite concentrate along cracks in plagioclase, as well as occur as dispersed grain in vicinity of apatite. Monazite intergrowths in muscovite are accompanied with Ti-Fe oxides.

Chemical composition of monazite slightly varies throughout different samples. Average Nd/Ce (wt.%) ratio is 0.292. Average ThO_2 and UO_2 content is 2.79 wt.% and 0.83 wt.% respectively. Sample K-2 from Krzesławice region contains monazite enriched in HREE, up to 27.88 wt.% ThO_2 and up to 3.43 wt.% UO_2 (Fig. 1). Some monazite grains exhibit significantly high amount of ThO_2 (up to 44.61 wt.%; sample K-2) accompanied by increase of CaO content (up to ca. 7 wt.%). Increase of ThO_2 content might be related to presence of inclusions of Th-phases. Moreover, uraninite (92.67 wt.% UO_2 and 3 wt.% PbO_2; Fig. 3 and 4) was determined in augen gneiss from the Gorlice region (sample G-6).

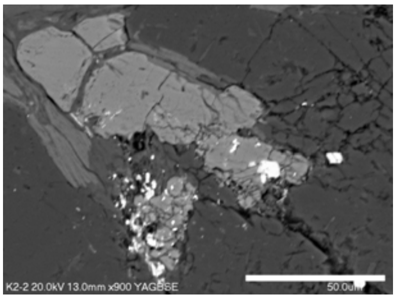

Fig. 1. Apatite and Th-enriched monazite in the gneiss (sample K-2). SEM-BSE image. Scale bar at the right bottom – 50 µm.

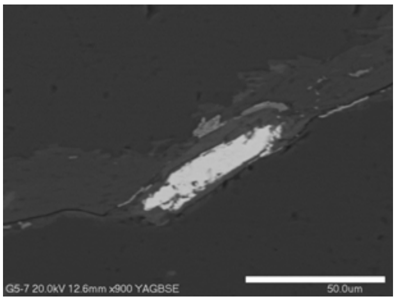

Fig. 2. Monazite in muscovite in the augen gneiss (sample G-5). SEM-BSE image. Scale bar at the right bottom – 50 µm.

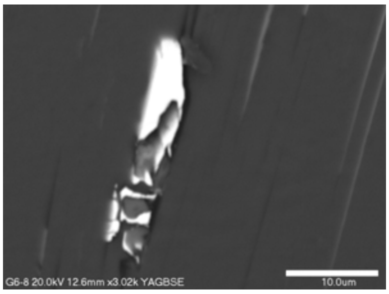

Fig. 3. Uraninite in muscovite in the augen gneiss (sample G-6). SEM-BSE image. Scale bar at the right bottom – 10 µm.

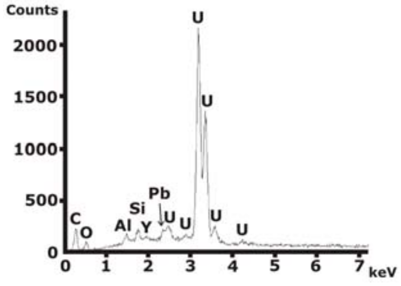

Fig. 4. EDS spectrum of uraninite presented at the Fig. 3.

Zircon commonly is ca. 10 μm in diameter and up to ca. 50 μm in elongation, usually exhibit euhedral shapes (Fig. 5). Some grains are affected by metamictization (Fig. 6). HfO_2 content is 1,98 wt.% on average (up to 6,39 wt.% in sample G-3).

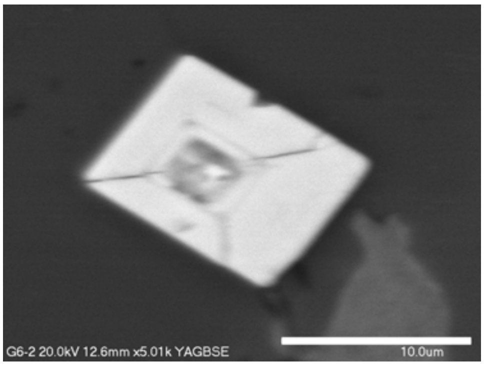

Fig. 5. Zoned euhedral zircon in the augen gneiss (sample G-6). SEM-BSE image. Scale bar at the right bottom – 10 μm.

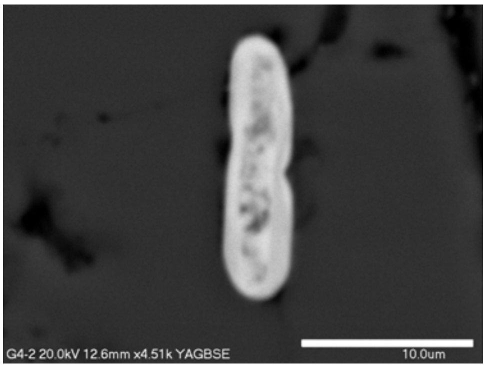

Fig. 6. Zoned zircon in the gneiss (sample G-4). SEM-BSE image. Scale bar at the right bottom – 10 μm.

DISCUSSION AND CONCLUSIONS

Monazite enrichment in Th (sample G-6), accompanied by decrease of LREE in the structure, might be result of the following cationic exchange: $2REE^{3+} \Leftrightarrow Th^{4+} + Ca^{2+}$ (Poitrasson *et al.* 1996). This suggestion is supported by relative Ca increase related to the sericitization of plagioclases. Higher increase in Th as well as Si in monazite structure (sample K-2), connected with P and LREE decrease might be result of exchange $REE^{3+} + P^{5+} \Leftrightarrow Th^{4+} + Si^{4+}$.

Temperature may have significant influence on HREE content in monazite, that can be used as a geothermometer for prograde metamorphism (Heinrich *et al.* 1997). According to Poitrasson *et al.* (2002), strong enrichment in HREE during alterations resulted from substitution, which involves both the P and REE crystallographic sites of monazite, might occur in temperature conditions of 260°C. Poitrasson *et al.* (*op. cit.*) pointed out that at 290°C the relative enrichment in HREE is more limited. Variations in Th and Si concentration are results of brabantite ($CaTh[PO_4]_2$) and huttonite ($ThSiO_4$) substitutions in monazite (vide Ayers *et al.* 1999 and refs. therein).

REE mobilization, enrichment of monazite in Th and formation of Th-phases and uraninite might be related to metamorphic episode which occurred at relatively low temperatures. It is possible to relate it to the late Carboniferous-early Permian episode dated in other “exotics” (*e.g.* Poprawa *et al.* 2004). Younger age (ca. 225 Ma) was roughly determined based on uraninite composition from the sample G-6.

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