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**SHORT NOTE**

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# PRIMARY AND SECONDARY MONAZITE IN A CALCITIZED GNEISS CLAST FROM BUKOWIEC (THE SILESIAN UNIT, WESTERN OUTER CARPATHIANS)

Abstract. Primary and secondary monazite-(Ce) in a calcitized gneiss clast from Bukowiec near Rożnowskie Lake (the Silesian Unit, Western Outer Carpathians) has been analysed using SEM-EDS methods. Secondary monazite-(Ce) formation probably took place prior to calcitization of the gneiss.

*Key-words*: primary and secondary monazite, gneiss clast, the Silesian Unit, Western Outer Carpathians

## INTRODUCTION

Monazite is a commonly studied mineral. These studies tend to focus on monazite stability, e.g. its formation and/or breakdown in magmatic, metamorphic and diagenetic environments (e.g. Bingen et al. 1996; Finger et al. 1998; Simpson et al. 2001; Catlos et al. 2002; Wing et al. 2003), the mobility of REE during various geological processes and the geochronological use of monazite in both radiometric and chemical dating (e.g. Parrish 1990; Suzuki, Adachi 1991; Montel et al. 1996; Williams, Jercinovic 2002; Jercinovic, Williams 2005). Monazite, a LREE phosphate containing U and Th, may also form during prograde metamorphism of metapelites.

REE-bearing minerals (including monazite, zircon, uraninite and thorianite) formed at various stages in the geological evolution of some gneiss and granulite clasts from the

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Silesian Unit, Western Outer Carpathians (e.g. Budzyń et al. 2005, 2006). A complete understanding of the origin of these REE minerals will provide the potential to date, using the CHIME method for instance, the sequence of metamorphic events, including secondary hydrothermal events that occurred in the source areas of clastic material in the Carpathian sedimentary basins. In this instance, alteration events in the source area may be dated as the monazite formed during secondary alterations evident in the gneiss.

## SAMPLE SELECTION AND METHODS OF INVESTIGATION

Eighteen gneiss samples and three granulite samples from five localities (Bukowiec, Gorlice, Krzesławice, Siekierczyna and Skrzydlna regions) in the Silesian Unit were analysed using transmitting light microscopy and SEM-EDS (Budzyń et al. 2005, 2006). Secondary monazite present in a gneiss clast strongly affected by calcitization from the outcrop of Ciężkowice Sandstones (Upper Paleocene — Lower Eocene) in Bukowiec (near Rożnowskie Lake) is the focus here. Clasts in those sandstones are considered to have come from the Silesian Ridge.

Chemical compositions of minerals was determined by cold field emission scanning electron microscopy (FESEM) using a HITACHI S-4700 microscope coupled with a NORAN Vantage energy dispersive spectrometer (EDS). Operating conditions were as follows: accelerating voltage 20 kV, beam current 10 μA, counting time 300 seconds and a beam diameter of < 1 μm focused on the polished thin section coated with carbon film. The analyses were performed in the Laboratory of Field Emission Scanning Electron Microscopy and Microanalysis at the Institute of Geological Sciences of the Jagiellonian University, Kraków.

## RESULTS

The gneiss sample contains essential plagioclase, quartz, biotite, muscovite, and microcline. Plagioclase composition ranges from oligoclase to andesine. The degree of plagioclase sericitization is generally low. Quartz occurs as polygonal blasts and commonly forms ribbons up to *ca* 500 μm thick. Biotite is dispersed and aligned or it forms elongate bands. Though typically not altered, the biotite may be locally completely chloritized. Calcite is dispersed through the rock as single crystals (up to *ca* 200 μm in size) replacing quartz and plagioclase and occurring also in the biotite bands. Calcite is also present as aggregates forming veins and lenses (up to *ca* 3 mm thick) and small veinlets (*ca* 100 μm thick). Zircon occurs as euhedral to anhedral grains up to *ca* 30 μm long. Apatite and Ti oxides are additional accessory minerals. Anhedral to subhedral grains of pyrite, up to 80 μm in size, are located along calcite veins.

Monazite-(Ce) usually forms lamellae (Fig. 1) and irregular aggregates (Fig. 2) within and/or around calcite grains. These are usually enclosed in biotite and, rarely, occur at the edges of biotite crystals. The monazite-(Ce) lamellae in calcite are typically parallel to the cleavage planes of neighbouring biotite (Fig. 1). Monazite-(Ce) breakdown involves replacement by apatite (Fig. 3)

Monazite-(Ce) contains *ca* 50 wt.% REE on average, up to 4.30 wt% $Y_2O_3$ and up to 6.16 wt% $ThO_2$. The average Nd/Ce ratio is *ca* 0.37. Uranium and HREE contents are too close to their EDS detection limits to merit discussion in detail. Average contents of $SiO_2$ and CaO are *ca* 3.6 and 5.5 wt%, respectively.

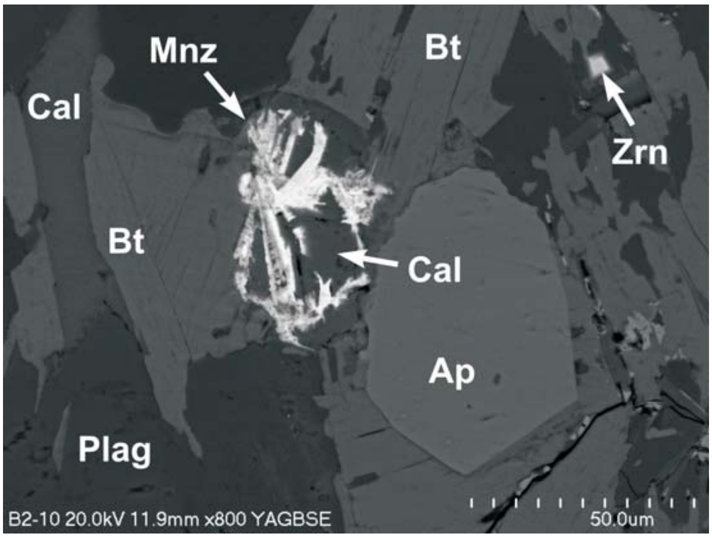


Fig. 1. Intergrowth of secondary monazite-(Ce) and calcite. SEM-BSE image.
Ap — apatite, Bt — biotite, Cal — calcite, Mnz — monazite-(Ce), Plag — plagioclase, Zrn — zircon

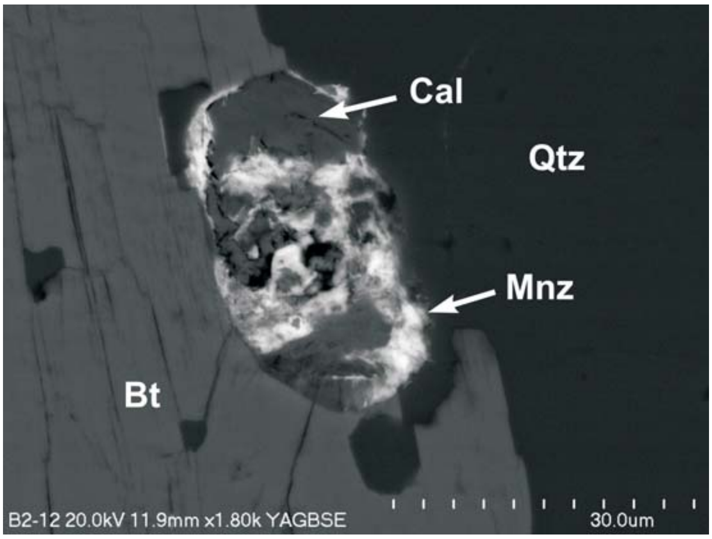


Fig. 2. Prismatic crystal of calcite associated with monazite-(Ce). SEM-BSE image.
Bt — biotite, Cal — calcite, Mnz — monazite-(Ce), Qtz — quartz

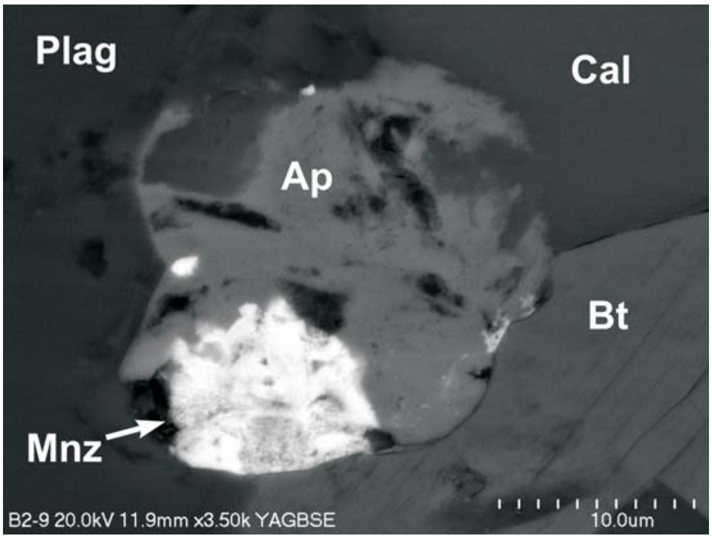


Fig. 3. Primary monazite-(Ce) partially replaced by apatite. SEM-BSE image.
Ap — apatite, Bt — biotite, Cal — calcite, Mnz — monazite-(Ce), Plag — plagioclase

## DISCUSSION AND CONCLUSIONS

Relict monazite associated with apatite can be considered as a primary component of the gneiss. Monazite breakdown and apatite formation are probably related to secondary hydrothermal processes. Formation of apatite at the expense of monazite requires a supply of $Ca^{2+}$ ions. Altered sericitized plagioclase was one probable source of Ca.

The monazite in the gneiss is interpreted as secondary and to reflect intense alteration that occurred in the parent gneiss during a low-temperature metamorphic episode (Budzyń et al. 2005, 2006). The relatively high Th content in monazite-(Ce) might suggest an origin under high-temperature conditions rather than a low-temperature metamorphic event or hydrothermal alteration (Schandl, Gorton 2004). The occurrence of monazite-(Ce) lamellae or veinlets within calcite that parallel the cleavage planes of neighboring biotite (Fig. 1) supports the conclusion that the secondary monazite-(Ce) probably developed during the alteration of biotite and before its replacement by calcite. Primary monazite-(Ce) breakdown (Fig. 3) and the growth of apatite suggest that primary monazite-(Ce) was a source of REE and Th. It may also be suggested that the alteration of biotite released an additional quota of REE as biotite may accept tens of ppm of LREE (see Dahl et al. 1993; Kohn, Malloy 2005 for details). Crystallization of apatite suggests high $Ca^{2+}$ fluids.

The prismatic shape of the calcite intergrown with monazite-(Ce) (Fig. 2) suggests that it is probably a pseudomorph after monazite or apatite. The former possibility would be in accord with primary monazite-(Ce) having been a major source of REE in solution.

Secondary monazite-(Ce) development and REE mobilization probably took place during a low temperature metamorphic event that affected rocks in the Silesian Ridge. These processes may have occurred at the same time as REE mobilization and formation of thorianite and uraninite in other gneiss clasts (Budzyń et al. 2005, 2006). Thus, the late Carboniferous-early Permian episode dated in other exotic clasts from the Silesian Unit (e.g. Michalik et al. 2004; Poprawa et al. 2004) provides the likely timing.

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## PIERWOTNY I WTÓRNY MONACYT W SKALCYTYZOWANYM KLAŚCIE GNEJSU Z BUKOWCA (JEDNOSTKA ŚLĄSKA, ZACHODNIE KARPATY ZEWNĘTRZNE)

### Streszczenie

W mocno zmienionym w wyniku kalcytyzacji klaście gnejsu z odsłonięcia piaskowców ciężkowickich (górny paleocen–dolny eocen; jednostka śląska) w Bukowcu (rejon Jeziora Rożnowskiego) stwierdzono obecność pierwotnego oraz wtórnego monacytu-(Ce). Forma występowania wtórnego monacytu-(Ce) wskazuje, że powstał on prawdopodobnie w trakcie przeobrażeń biotytu, przed kalcytyzacją gnejsu.