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REE ACCESSORY MINERALS IN CHLORITE-BIOTITE SCHISTS  
FROM THE WESTERN TATRA MOUNTAINS. PRELIMINARY RESULTS

**Abstract:** REE accessory minerals in chlorite-biotite schists from the Western Tatra Mts. were investigated by optical microscopy, SEM with EDS, EMPA, and XRD. The phosphates are associated by biotite-chlorite intergrowths, Ti-Fe oxides, carbonates, sulphides, sulphosalts. Studied monazites and xenotimes vary in composition and morphology. It is suggested that they may have different origin: pre-metamorphic, prograde metamorphism related, or retrogressive/hydrothermal.

**Keywords:** monazite, xenotime, REE, accessory minerals, chlorite-biotite schists, the Western Tatras

INTRODUCTION

Chlorite-biotite schists, described by Michalik & Dylska (1996), crop out in the metamorphic complex of the Western Tatra Mts. They usually form green schists or emerald-green massive rocks. Quartz, altered feldspar, biotite and chlorite were identified among main rock-forming minerals. Moreover, many Ti, Fe oxides and Fe, Ni, Cu, Cr, Co sulphides or sulphosalts occur. Assemblage of accessory minerals in this rock include: apatite, zircon, monazite and xenotime. All of them can contain REE, however, significant amounts are found only in REE phosphates: monazite and xenotime. Rocks were subjected to intense deformation and chloritization, sericitization and carbonatization. Temperature of chloritization was probably within a range from 250-300°C (Michalik, Dylska 1996).

ANALYTICAL MATERIAL AND METHODS

Representative specimens were collected in three localizations: on the slopes of Trzydniowiański Wierch, Jarząbczy Wierch and Siwiańskie Turnie. Chlorite-biotite schists appear there as a layer up to 50 cm thick (Michalik, Dylska 1996).

The samples were examined in thin sections under the petrographic microscope using reflected and transmitted light. Accessory phases were identified using back-scattered electron imaging and energy-dispersive spectroscopy (SEM-EDS).

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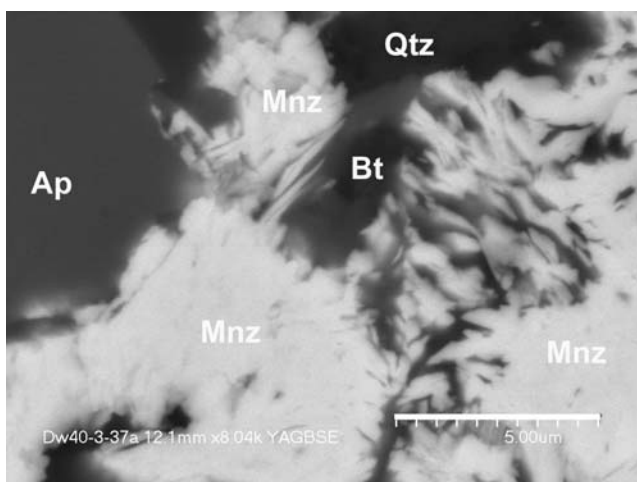


Fig. 1. BSE image showing irregular monazite aggregates with surrounding rounded apatite crystals, anhedral biotite and quartz. The bar in the bottom right corner represents 5.0  $\mu\text{m}$ .

Ap - apatite, Bt - biotite, Mnz - monazite, Qtz - quartz.  
(Sample from Trzydniowiański Wierch.)

Chemical composition of rock-forming and REE-bearing accessory minerals was determined by electron microprobe (EMPA) method.

## RESULTS

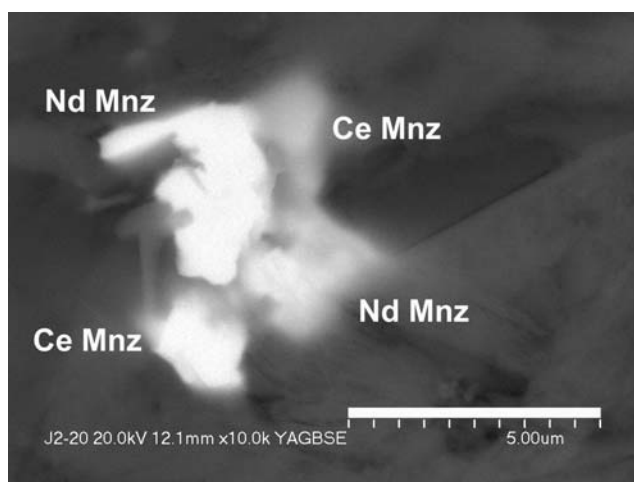
Common accessory minerals in the samples include apatite, zircon, xenotime, monazite, ilmenite, rutile, Fe-sulphides.

Apatite forms relatively large (around 100  $\mu\text{m}$ ), commonly rounded crystals. They may be the host phase for the other accessory phosphate minerals, i.e. xenotime and monazite. Apatite is often found surrounded by secondary carbonates, Fe-Ti oxides, quartz or Fe sulphides.

The most abundant REE-bearing mineral phase is monazite. It occurs usually in subhedral to anhedral grains or aggregates up to 10 (seldom up to 50)  $\mu\text{m}$ . Monazite is dispersed inside chlorite, biotite, Fe-Ti oxides, or quartz.

Fig. 2. Back-scattered electron (BSE) image showing bright coloured anhedral monazite crystals of two chemical compositions: dominated by Ce or Nd. The phosphates are enclosed in chlorite-biotite assemblage. The bar represents 5.0  $\mu\text{m}$ .

Ce Mnz – monazite; REE dominated by Ce,  
Nd Mnz – monazite; REE dominated by Nd.  
(Sample from Jarząbczy Wierch.)



In the biotite–chlorite intergrowths (often strongly deformed) several varieties of monazite have been noted: 1) euhedral crystals, 2) fractured crystals with corrosive boundaries, often containing biotite, or/and chlorite 3) feather-like concentrations grown between folded, strongly chloritized biotite crystals (Fig. 1). They may also form sieve intergrowths with Ti (or Ti-Fe) oxides and/ or quartz.

Chemical composition of monazite varies throughout different samples. Most common phase is rich in Ce. Nd/Ce [wt%] ratio is 0.512 on average. It has been noticed, however, that samples collected from the slopes of Jarząbczy Wierch (Fig. 2), may contain (less abundant) Nd variety of monazite, with Ce as the second major cation (Nd/Ce = 1.222 on average). Some analyses revealed almost equal amounts of Ce and Nd. What should be stressed, Th and U usually lay below detection limit of EDS. On the other hand, there may be up to 8,51 wt% Th in monazite associated with sulphides, where it is followed by presence of Pb (probably radiogenic). The ratio Pb/Th [wt%] is around 0.158. U, concentrated in the crystal core, is less abundant: around 0–1 wt%.

Xenotime occurs in the form of subhedral to anhedral grains, up to 5 µm in diameter. Additionally, overgrowths of xenotime on zircon were noted (Fig. 3). The mineral is usually disseminated as small inclusions in chlorite-biotite intergrowths. However, it can also occur in Ti-Fe oxides, most commonly in the outer rims of zonal oxide aggregates.

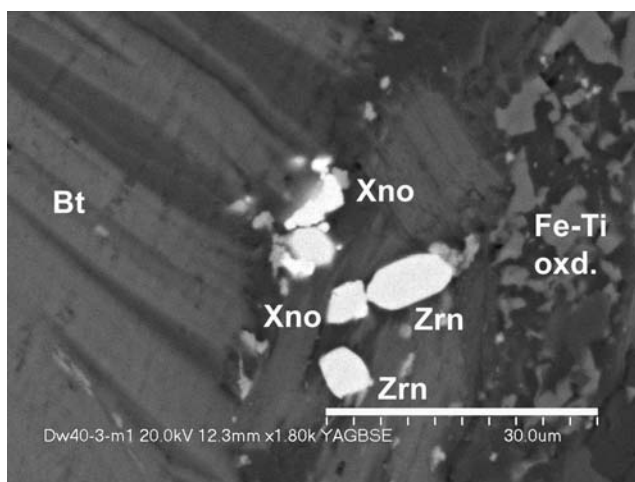


Fig. 3. BSE image showing xenotime and zircon relations in context of other minerals in chlorite-biotite schist, here comprised mainly by the dark mica. Irregular structure of oxides aggregates intergrown with quartz are visible. The bar represents 30.0 µm.

Bt = biotite, Xno = xenotime, Zrn = zircon, Qtz = quartz, oxd.= oxides.  
(Sample from Trzydniowiański Wierch.)

The chemical composition of xenotime is typical of the mineral with Y as the main cation (9.72 - 36.32 wt%  $Y_2O_3$ ). REE incorporated in the structure include HREE, predominantly Dy and Er, with some lighter elements, such as Nd and Eu in two samples. Calcium ions may also appear. Xenotime is subordinate in relation to monazite and/or zircon.

## DISCUSSION AND CONCLUSIONS

REE-bearing accessory phases in the chlorite-biotite schists in the Western Tatra Mountains are common. They are disseminated in the rock-forming chlorites and biotites, as well as in the later Fe-Ti oxides of hydrothermal origin.

Diversified morphology of monazite and xenotime suggests their multiple formation processes during metamorphism.

Some monazites may be pre-metamorphic (presumably, more euhedral with higher Th content), other are connected with prograde metamorphism – they could crystallized from other REE-bearing metamorphic accessory minerals, such as: allanite, titanite, or fluorapatite (Pan 1997). Local transport of substrates, suggested by the scenario, seems to be reasonable. It is also probable that some monazite crystals broke down during chloritization of biotite (Lanzirotti, Hanson 1996), giving rise to apatite formation and causing the elevated LREE contents in the new-formed chlorite. Then due to the shearing processes, anhedral monazite might have crystallized between chlorite flakes, incorporating mentioned LREE and using  $\text{PO}_4^{3-}$  from apatite decomposition. However, it is difficult to distinguish monazite of various origin.

Some xenotime may also be of pre-metamorphic origin, other could crystallized in metamorphic processes. Metamorphic xenotime, that appears in the vicinity of zircons, may crystallize *via* igneous zircon decomposition (Pan 1997). Magmatic zircon, containing Zr, Y, REE, probably broke down into zircon ( $\text{ZrSiO}_4$ ) and xenotime with REE in amphibolite facies conditions. Initial process of xenotime formation in expense of elements derived from zircon decomposition was observed in leucogranites in the Western Tatra (Michalik et al. 2000).

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