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Episodic Growth of Monazite during a metamorphic Cycle: a Case Study from a high-pressure Rock of the Bohemian Massif

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Based on textural and compositional criteria, three generations of monazite are identified in a peraluminous, garnet-rich, high-pressure metamorphic rock from the Bohemian Massif ("garnetite" from the Podolsko complex: Fisera 1977, Kotkova et al. 1997). The first monazite generation (M1) formed on the prograde branch of the clockwise PT loop, the second (M2) during a high-pressure stage (26 $\pm$ 3 kbar and 830 $\pm$ 30 ˚C according to Kotkova and Harley 1997), and the third (M3) during subsequent near-isothermal decompression of the rock

The high-pressure monazites (M2) are volumetrically dominant and form 100-300 μm grains. They are characterized by unusual Sr contents (SrO up to 2 wt.%) and grew in paragenesis with accessory Sr-apatites (SrO up to 33 wt.%). Both minerals are often enclosed in the garnet. The cause for the formation of Sr-apatite and Sr-bearing monazite was the breakdown of plagioclase during high-pressure metamorphism and the release of Sr that occurred during this process (Krenn and Finger 2004). Furthermore, M2 monazites are rich in ThO_2 (4-10 wt.%) and UO_2 (1-3 wt.%) and they sometimes exhibit a concentric growth zoning.

During decompression to 8 $\pm$ 2 kbar and 800-900 ˚C (Kotkova and Harley 1997) the original high-pressure assemblage (grt, Al-poor opx, qtz) was partially resorbed and replaced by fine-grained, commonly symplectitic intergrowths of sapphirine, Al-rich orthopyroxene, plagioclase, spinel and cordierite. M3 monazites formed preferentially within this secondary matrix and occur almost exclusively as small grains (10-100 μm) on the rims of relictic apatites. Textures indicate that they grew at the expense of the apatite grains. Apatites with M3 monazites at their margins always have low LREE contents (Ce_2O_3 $<$0.1 wt.%) and Ce/Y ratios ($<$0.3), implying that the LREEs were extracted and used for M3 monazite formation. Furthermore, all matrix apatites have lost their Sr through diffusion to newly formed plagioclase. In contrast, high-pressure Sr-apatites shielded by garnet show much higher LREE contents (Ce_2O_3 up to 1 wt.%). M3 monazites lack Sr and are characterized by very low Th contents (mostly < 1 wt.%), consistent with derivation from an apatite source.

The oldest monazites in the rock (M1) are represented by resorbed, irregular shaped cores, which are occasionally preserved within the Sr-bearing, Th-rich high-pressure monazites (M2). These cores are significantly lower in ThO_2 (2-4 wt.%) and generally free of Sr, so that they should have formed on the prograde branch of the PT loop, in the presence of plagioclase. One hypothesis is that LREEs released through the resorption process were taken up by the high-pressure apatites to some extent, and not completely by formation of M2 monazite. This would also explain the enrichment of Th seen in the M2 monazites. This would suggest that apatite can act as an interim host for LREEs at high pressures.

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