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Two-stage breakdown of monazite by post-magmatic and metamorphic fluids: An example from the Veporic orthogneiss, Western Carpathians, Slovakia

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ABSTRACT

The initial to advanced stage of monazite breakdown was identified in a granitic orthogneiss from the pre-Alpine basement in the Veľký Zelený Potok Valley (the Veporic Unit, Western Carpathians, central Slovakia). Monazite-(Ce) formed during Variscan metamorphism of the original Cambrian to Ordovician granitic rock. Two younger, Permian post-magmatic hydrothermal, and Cretaceous metamorphic-hydrothermal events caused a breakdown of the monazite to secondary egg-shaped coronal structures (100 to 500 μm in diameter) with concentric newly-formed mineral phases. Two principal breakdown stages and newly formed mineral assemblages are recognizable: (1) partial to complete replacement of primary monazite with an internal apatite + $ThSiO_4$ (huttonite or thorite) zone and an external allanite-(Ce) to clinozoisite zone; (2) hydroxylbastnäsite-(Ce) partly replacing apatite + $ThSiO_4$ and allanite to clinozoisite aggregates. The monazite breakdown was initiated by fluid sources differing in composition. Stage (1) originated due to post-magmatic hydrothermal fluids, whereas stage (2) indicates an input of younger, CO_2-bearing metamorphic-hydrothermal fluids.

1. Introduction

The rare-earth phosphate minerals, (e.g. monazite and xenotime), are some of the most widespread accessory phases in common granitic and metamorphic rocks. Their composition and alteration products have been commonly used as useful petrogenetic indicators (e.g., Bea, 1996; Berger et al., 2008; Broska et al., 2005; Budzyń et al., 2010, 2011; Finger et al., 1998; Förster, 1998a,b, 2006; Gratz and Heinrich, 1997; Harlov et al., 2011; Heinrich et al., 1997; Janots et al., 2008; Johan and Johan, 2005; Kohn and Malloy, 2004; Petrík et al., 1995, 2006; Poitrasson et al., 2002; Pyle et al., 2001; Spear and Pyle, 2002; Wark and Miller, 1993; Wing et al., 2003 and references therein). Monazite-(Ce) occurs especially in peraluminous, S-type granitic rocks and their pegmatitic derivates, as well as in orthogneisses and metapelitic to metapsammitic rocks. However, monazite can be unstable in domains affected by metamorphic/hydrothermal fluids, and variable breakdown products can be formed depending on fluid composition (e.g. Budzyń et al., 2011).

The most widespread breakdown products of monazite include apatite (often *REE*-rich), the $ThSiO_4$ phase (huttonite or thorite), and allanite-(Ce) to *REE*-rich epidote or clinozoisite which commonly form concentric corona-like textures around a partly dissolved monazite core (e.g., Broska and Siman, 1998; Broska et al., 2005; Budzyń et al., 2011; Finger et al., 1998; Petrík et al., 2006). Occasionally, bastnäsite- or synchysite-group minerals originated as replacement products of monazite, or allanite (Berger et al., 2008; Budzyń et al., 2010; Majka and Budzyń, 2006).

Monazite dissolution and breakdown depend strongly on local mineral compositions, on P–T conditions and on the character of pervasive hydrothermal/metamorphic fluids, so more complex and variegated breakdown products can originate in specific conditions. The aim of this study is to describe the breakdown of metamorphic monazite in a granitic orthogneiss from the Paleozoic West-Carpathian crystalline basement in central Slovakia. Different stages of monazite dissolution by metamorphic-hydrothermal fluids rich in H_2O, F and CO_2 can be recognized in the complex breakdown textures. The composition of secondary apatite, the $ThSiO_4$ phase, allanite to *REE*-bearing clinozoisite, and hydroxylbastnäsite-(Ce) as the final breakdown product are characterized and possible scenarios of their origin and fluid sources are discussed.

2. Geological background

The crystalline basement of the Central Western Carpathians (Fig. 1A) is incorporated into the Cretaceous Tatric, Veporic and Gemeric structural units (Plašienka et al., 1997), analogous to the Austroalpine

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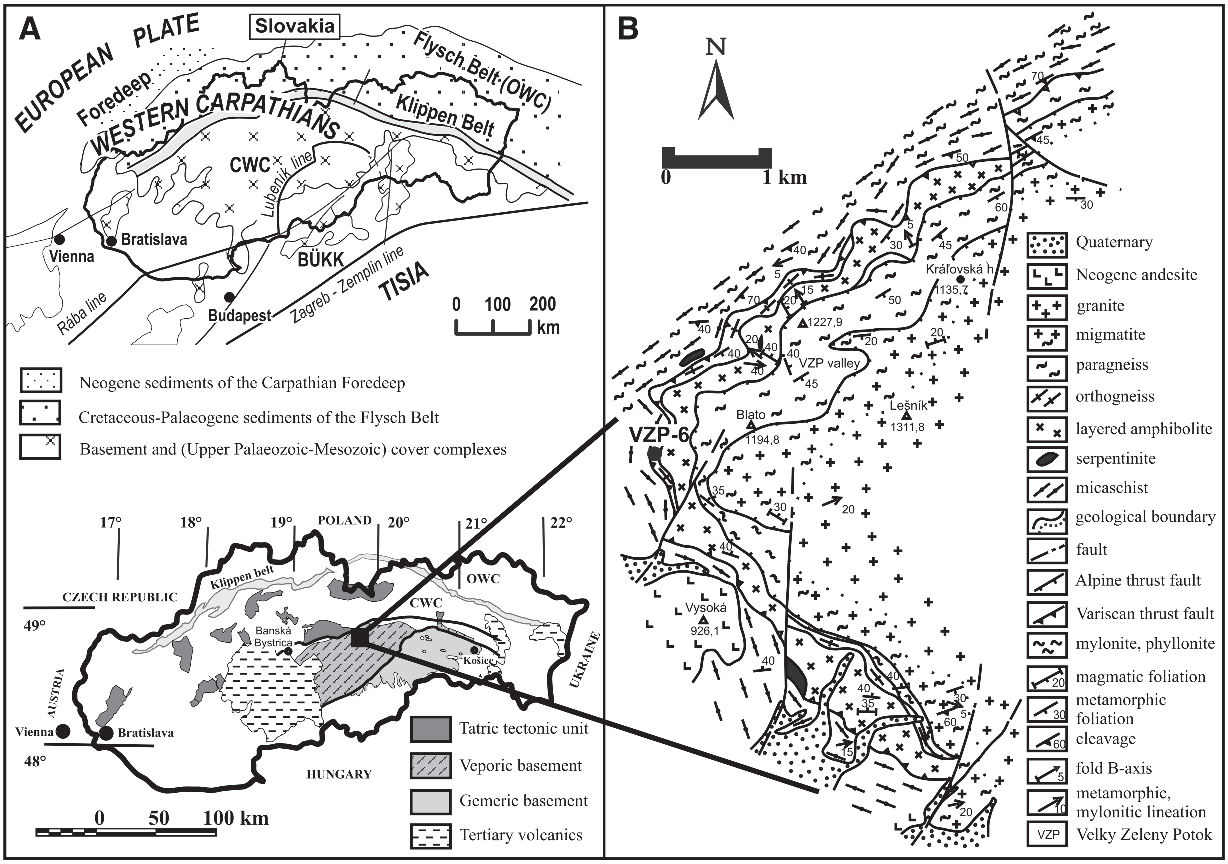

Fig. 1. A: geological-tectonic sketch map of the Western Carpathians. OWC = Outer Western Carpathians; CWC = Central Western Carpathians, divided into the Tatric, Veporic and Gemeric basement-cover complexes (Late Cretaceous tectonic units). B: geological map of the Veľký Zelený Potok Valley with VZP-6 samples location.

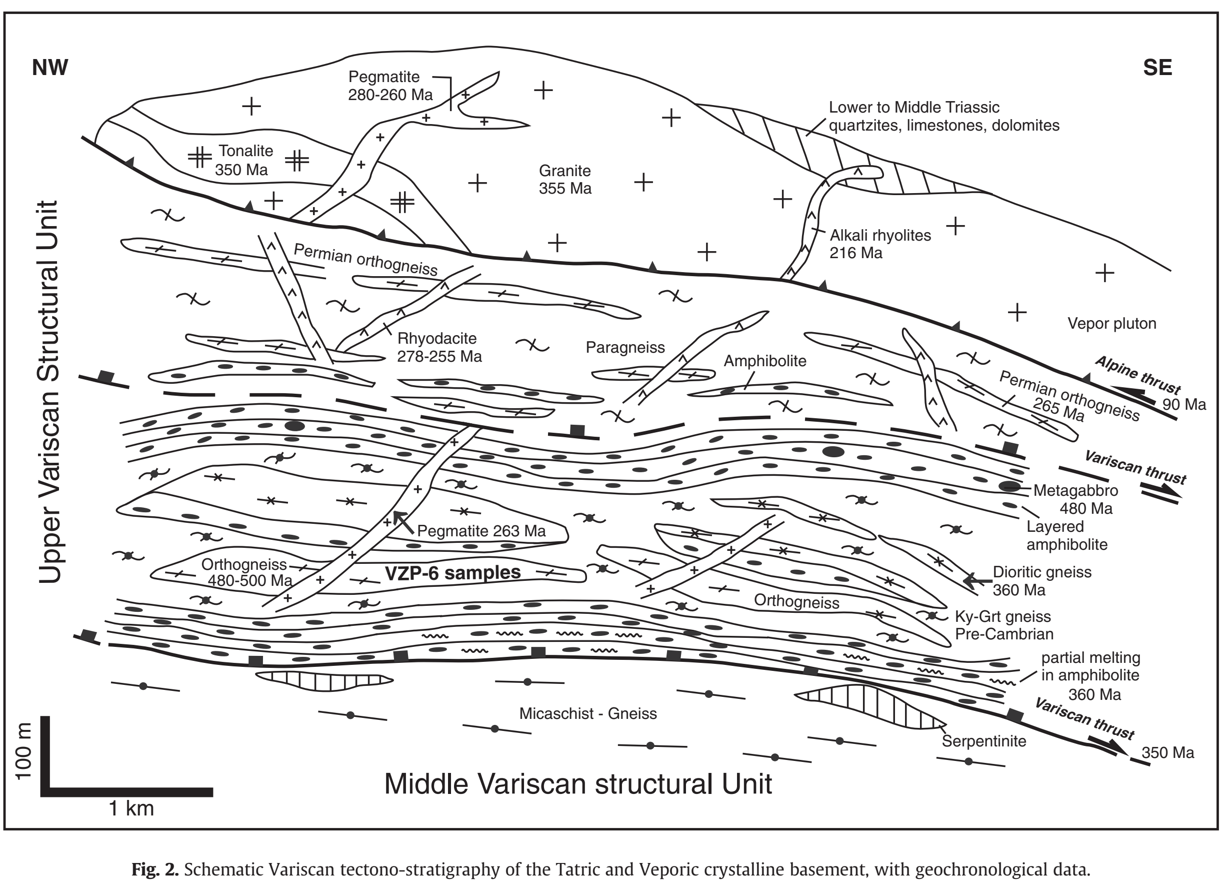

Fig. 2. Schematic Variscan tectono-stratigraphy of the Tatric and Veporic crystalline basement, with geochronological data.