Monazite stability as a tool used for identification of granite stacking (a case study from the Western Carpathians)

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The presence of monazite or allanite in granites is not only an important aspect of assessing their parental rocks to the I- or S-type, but their mutual relationship can also help to estimate PTX conditions in a given magmatic system. In the Western Carpathians, allanite and monazite became an effective tool for discrimination Variscan granites in terms of their I- or S-types affinity, in addition to the bulk-rock granite composition (Petrík & Broska 1994). For the S-type granites, typical is a reduction paragenesis of accessory ilmenite, monazite and apatite with higher content of Mn (Mn in reduced bivalent form easily replaces Ca). On the other hand, the I-type granites were identified by the presence of allanite, higher content of apatite with a low Mn and Fe, titanomagnetite, phlogopite (Mg-biotite), titanite, late pure magnetite, and locally also amphibole indicating a higher oxidation stage in this magmatic system compared to the S-type. It probably reflects initially a higher water content manifested also by late or post-magmatic oxidation of titanomagnetite, biotite and allanite.

Primary magmatic monazite and allanite: In arc orogenic granites, such as the Western Carpathian granites the presence of monazite is determined by PTX conditions, where parameter X represents the content of CaO and the REE`s. At a higher ratio of CaO/REE in granite the allanite is stable (Gieré & Sorensen 2004; Janots et al. 2008; Spear 2010). The S-type granites, where the whole-rock CaO content greater than 2.5 wt % stabilises allanite can also produce a monazite due to local decrease of CaO activity, e.g. after massive crystallization of plagioclase which was at the beginning suppressed by higher water contents (Johannes and Holtz 1996). A relict allanite in such case, as a precursor of monazite, was documented in accessory paragenesis of granites from the Tribeč and the Malé Karpaty Mts. Alternatively, some Western Carpathian S-type granites, rich in the REEs, may also have changed early allanite for monazite due to a pressure drop whereby their PT path crosses the Aln/Mnz boundary and the parent granites were emplaced into upper part of the crust. Monazite in this sense represents a mineral whose dating can records the cooling time of the parental granite system.

Monazite breakdown to allanite and REE epidote: In the granites of the Alpine Tatric Unit, monazite is typically stable or only weakly altered, on the other hand (Fig. 1A), the granites from the higher Alpine nappes as the Fatric and Veporic units, show monazite breakdown forming coronas of the apatite and allanite (Fig. 1B). The monazite breakdown into apatite-allanite coronas is facilitated by the higher content of CaO, Al_2O_3, and LREE, and alkali-rich fluids (Budzyń et al. 2011). The monazite breakdown in metamorphic granites is illustrated by stability diagrams of monazite – allanite (Spear, 2010). In the case of the Western Carpathians in the Tribeč crystalline basement, the monazite breakdown in high CaO granites is predicted for the estimated pressure of ca 4 kbar at the temperature of about 450 °C due to crossing the monazite/allanite stability boundary by cooling along a near-isobaric PT trajectory (Broska et al. in prep.). Since an Alpine monazite has not been detected in these granites, the breakdown of monazite has occurred due to prolonged residence in deeper parts of the Earth's crust achieving the isobaric trajectory. On the other hand, the non-altered monazite presented in the underlying Tatric granites in this Tribeč granite nappe system was preserved by the rapid ascent of granite into the upper crust, where the PT trajectory is close to isothermal. The rapid cooling here in the Tribeč field documents the shallow intrusion of the granites into phyllites.

Granite duplex: The undeformed S-type granites with unaltered monazite in the Tribeč Mts are found at deep part of the crystalline basement, i.e. these underlying granites are attributed to the Tatric Unit where unaltered monazite typically occursed. On the other hand, the granites from the higher, crest part of the mountain range, are metamorphosed and hydrothermally affected (altered) and contain monazite with breakdown coronas (Fig. 1B). Since both granite blocks, the upper metamorphic and the lower non-metamorphic, are similar in the age, the different monazite behaviour indicates existence of two different granite blocks. They had been originally at the time of generation during Variscan orogen at different crustal positions because otherwise they would not have shown different monazite responses. Moreover, the overlying granites with altered monazite are Alpine metamorphosed in PT conditions close to those known in the Veporic or Fatric unit but not high enough to produce a new Alpine monazite. Thus, in the present position of the Tribeč basement, there are two granite blocks one above the other, metamorphic block thrust on the non-metamorphic one. The stacking of the metamorphosed over non-metamorphosed block was flat and inclined to the northwest at an angle of about 20°, and in the present position represents an Alpine granite duplex. With altered granites Lower Triassic quartzites of the Lúžna formation were probably also moved, from which Uher et al. (2009) described a hydrothermal vein mineralization associated with fluids from the underlying granites forming in quartzites spectacular lazulite. The age of granite stacking is indicated by Ar/Ar age from muscovite of the overlying granites and it gives the age of 78 Ma. It postdates the stacking, since the dated muscovites have not been deformed. The identification of Tribeč granite alpine duplex can be considered as an example of the use of monazite stability for solving of geodynamic events.

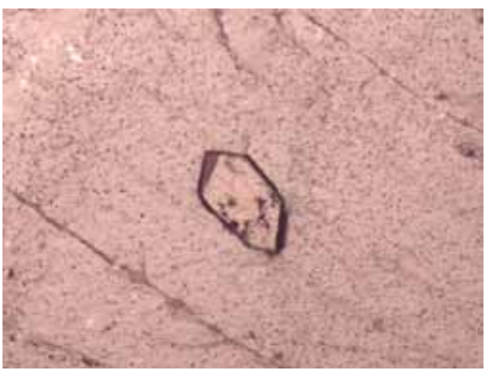

Fig 1A Stable monazite from low a CaO S-type granite; Nízke Tatry Mts, Tatric Unit. (Photo: I. Petrík, polarised light, lengths of monazite crystal is ca 300 μm).

Fig. 1B Monazite breakdown into coronas of apatite and allanite in the S-type granite (Tribeč Mts. Fatric Unit). BSE image.

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