



## Polymetamorphic evolution of Parvenets complex, Bulgaria – U-Th-Pb monazite geochronology and geochemistry

### Полиметаморфна еволюция на Първенецкия комплекс, България – U-Th-Pb геохронология и геохимия на монацити

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#### Introduction and geological setting

Parvenets complex comprises the northernmost parts of the Central Rhodope Mountains and was attributed by different authors both to the Srednogie Zone and the Rhodope Massif. According to Sarov (2012), the Parvenets complex is part of the Thracian Lithotectonic Unit, affected by the Maritsa Dextral Strike-Slip Shear Zone. New structural and geochronological studies suggest a polymetamorphic history for some parts of the Thracian Unit, with a high-grade metamorphism, followed by greenschist alpine metamorphic overprint (Naydenov et al., 2008). We present monazite geochronology data on kyanite-andalusite gneisses (in the vicinity of Hrabrino village) in order to reveal the polymetamorphic history of the Parvenets complex.

#### Analytical methods and samples description

Mineral chemistry and U-Th-Pb analyses of monazite were carried out by EMP and LA-ICP-MS (*in situ*, 9  $\mu\text{m}$  spot size) at the Laboratoire Magmas & Volcans in Clermont-Ferrand, France. The studied samples are fine grained with quartz- and plagioclase-dominated matrix with intense final static recrystallization. Petrographic studies and *Perple\_x* modeling recognized two metamorphic associations: relict (garnet-kyanite-biotite-white mica-plagioclase-quartz-rutile  $\pm$  staurolite, at 620–685  $^{\circ}\text{C}$  and 1.25 to 0.7 GPa) and syn- to post-kinematic (andalusite-biotite-plagioclase-chlorite-white mica, at 60–480  $^{\circ}\text{C}$  and below 0.4 GPa). Large monazite and zircon grains are present as inclusions in plagioclase porphyroclasts and within the matrix. Xenotime, rutile and abundant opaque minerals are also present.

#### Monazite geochronology and geochemistry

Monazite inclusions in plagioclase porphyroclasts are rounded to subhedral grains (30 to 85  $\mu\text{m}$ ), slightly elongated sub-parallel to the inner foliation. One grain is strongly resorbed and surrounded by smaller rounded satellite grains (4 to 20  $\mu\text{m}$ ). Monazite inclusions yielded a concordant age of 303.7 $\pm$ 3.3 Ma (2  $\sigma$  level) and intercepts at 303.6 $\pm$ 3.1 and 5526 $\pm$ 460 Ma (MSWD = 0.24) on the Tera-Wasserburg concordia diagram (Fig. 1). Matrix monazites (40 to 70  $\mu\text{m}$ ) vary in shape, from euhedral to rounded single grains, or form clusters of rounded to resorbed grains. They associate with biotite bands and garnet fragments, but

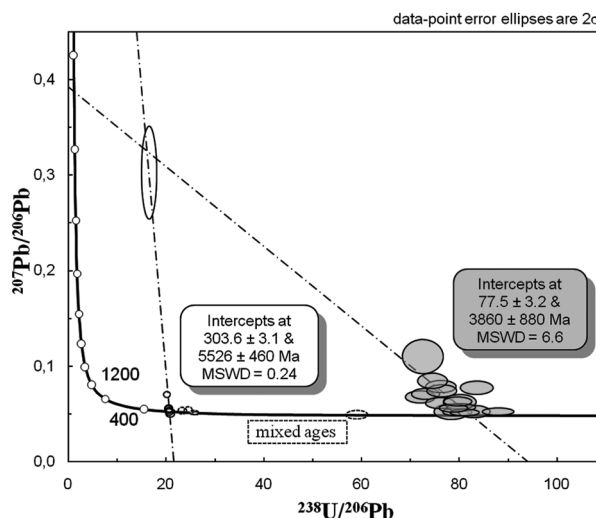


Fig. 1. Tera-Wasserburg concordia diagram for LA-ICP-MS data of all analyzed monazites

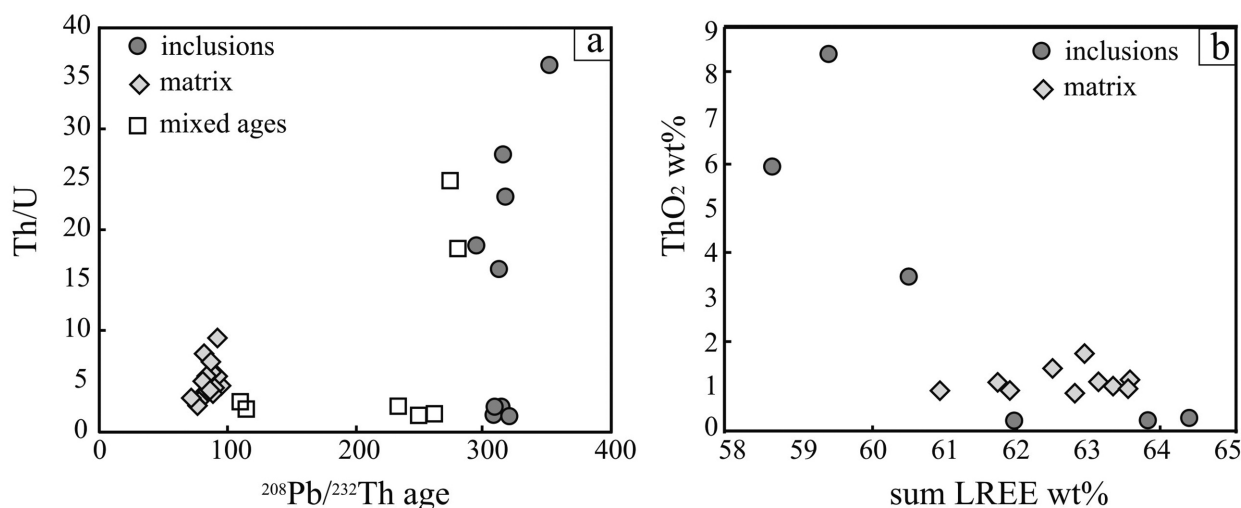


Fig. 2. a, Th/U vs.  $^{208}\text{Pb}/^{232}\text{Th}$  ages of studied monazites, LA-ICP-MS data; b, ThO<sub>2</sub> vs. sum LREE (La-Sm, Gd), EMP data

are also present in the quartz-plagioclase matrix. The  $^{208}\text{Pb}/^{232}\text{Th}$  ages range from  $72.2 \pm 2.3$  Ma to  $89 \pm 3.1$  Ma ( $2\sigma$  level) and do not yield concordant age. On the Tera-Wasserburg diagram, most analyses plot close to the lower intercept age of  $77.5 \pm 3.2$  (MSWD = 6.6) (Fig. 1). Mixed ages scatter between these two distinct groups.

Monazite inclusions show high variation in Th/U ratio (from 1.6 to 36, av. 14.4) compared to the matrix grains (from 2.6 to 9.3, av. 5) (Fig. 2a). Higher Th/U ratio and ThO<sub>2</sub> content are typical for the magmatic or high-grade metamorphic monazites (Engi, 2017). Single resorbed monazite in plagioclase yielded the highest ThO<sub>2</sub> content, lowest LREE (Nd, Sm, Gd) and lowest Y<sub>2</sub>O<sub>3</sub> content (Fig. 2b). The observed variations in the composition of monazite inclusions prevent the geochemical discrimination of the grains in terms of their textural position and age.

## Discussion and conclusions

Monazite geochronology is a powerful tool in studying the complex history of metamorphic rocks. In our samples monazites record two different tectonothermal events: Variscan and Late Cretaceous. The Variscan event ( $303.7 \pm 3.3$  Ma) could be related to high-grade metamorphism during the intrusion of Parvenets complex gneiss and amphibolite protoliths (330–340 Ma to 302–312 Ma; von Quadt et al., 2006). Monazite growth occurred again at lower pressure between 72 and 89 Ma and coincides with the Late Cretaceous magmatic activity along the Maritsa Strike-Slip Shear Zone (e.g., Kapitan Dimitriev pluton  $78.7 \pm 1.8$  Ma;

Kamenov et al., 2003). These new geochronological data together with petrography and thermodynamic modeling provide more evidence for complex poly-metamorphic history of Parvenets complex.

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