

In situ chemical dating of new accessory minerals from the Evate deposit in Mozambique

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This work is focused on in situ chemical dating of zirconolite, thorianite and monazite from the Evate apatite-magnetite-carbonate deposit in Mozambique.

The deposit is located in the eastern part of the Nampula province in the Monapo structure (Macey et al., 2013). The Evate deposit is one of the most important apatite deposits in Africa discovered during geophysical prospection in 1975, and investigated in 1983 by Bulgarian and finally by Czechoslovakian geologists (Intergeo, 1985). Drilling cores from the exploration work carried out by Geindustria state enterprise in 1985 represent and unique research material investigated in this study.

The deposit has an elongated shape and is approximately 3 km long and 850 m wide. A total of 155 413 000 t of apatite ores with an average composition of 9.32 wt. % P₂O₅ is present.

Original report of Intergeo (1985) mentions apatite, magnetite, forsterite, phlogopite and graphite, with a smaller amount of diopside, amphibole, wollastonite, antigorite, scapolite, spinel, garnet, feldspar, rutile, quartz, sulphides and anhydrite. In current research, we have identified additional accessory minerals such as monazite, baddeleyite, zirconolite, allanite, zircon, thorianite, sulphates (gypsum, celestine, barite).

The aim of this study is to determine the age of zirconolite, thorianite and monazite using an in situ chemical dating, and to interpret new data in the context of the evolution of the Evate deposit. The chemical dating was performed using a CAMECA SX100 electron microprobe at the State Geological Institute of Dionýz Štur in Bratislava. Calculated ages and individual statistical data were computed using a DAMON computer program (Konečný et al., 2004) with the equations given in the paper of Montel et al. (1996).

Zirconolite CaZrTi₂O₇ was present in two forms: younger zirconolite II created grains several µm size. Older zirconolite I created thin rims around magnetite, geikielite, zircon and baddeleyite. Zirconolite I has an increased content of REE+Y (0.323-0.613 *apfu*) and slightly increased content of Nb (0.009-0.180 *apfu*). Th (up to 0.185 *apfu*) and U (up to 0.074 *apfu*) contents are lower. Zirconolite II has low REE+Y (0.082-0.488 *apfu*) and Nb contents (0.012-0.152 *apfu*) and increased content of Th (0.012-0.218 *apfu*) and U (0.002-0.149 *apfu*). Grains of zirconolite I, 30-40 µm size, were used for dating. Their age calculated from 14 analyses corresponds to 443±3.4 Ma.

Thorianite ThO₂ was associated in the same sample with zirconolite, zircon, pyrrhotite, phlogopite and magnetite. Thorianite creates grains, 10-50 µm in size, with Th contents from 0.644 to 0.840 *apfu*. U and Pb contents ranged from 0.023 to 0.235 *apfu* and the calculated age from 11 analyses corresponded to 489±2.8 Ma.

Monazites from albitized gneiss underlying the magnetite-apatite deposit have increased LREE contents (0.810-1.000 *apfu*) dominated by Ce (0.37-0.50 *apfu*), being diagnostic of monazite-(Ce). HREE contents are low (0.006-0.08 *apfu*). Studied monazites

have low contents of the huttonite, xenotime and cheralite components. The age of monazite calculated from 6 analyses is 573 ± 13 Ma.

The monazite age is consistent with 584 ± 16.5 Ma old zircon rims correlated either with a cooling-related metasomatic event (Karlsson, 2006) or with a high-pressure metamorphism (Macey et al., 2013). The monazite age is also consistent with a 590 Ma U-Pb age of zircon and baddeleyite from magnetite-apatite-forsterite rocks (Siegfried, 1999; Hurai et al., 2017). Hence, the age of monazite from albitized gneiss is interpreted as that of alkaline metasomatization (finitization) caused by the penetration of carbonatite-silicate magma during the collapse of Gondwana supercontinent. Ages of zirconolite and thorianite from apatite-magnetite rocks are considerably younger and reflect the several alteration event caused by hydrothermal fluids, which penetrated the deposit during Cambrian and Ordovician tectonic fragmentation.

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References:

- Hurai V, Paquette JL, Huraiová M, Slobodník M, Hvožd'ara P, Siegfried P, Gajdošová M, Milovská S (2017) New insights into the origin of the Evate apatite-iron oxide-carbonate deposit, Northeastern Mozambique, constrained by mineralogy, textures, thermochronometry, and fluid inclusions. *Ore Geol Rev* 80, 1072–1091
- Intergeo (1985) Relatorio Final - Monapo, Prospeccao Regional Geoquimica, Mozambique. Inter. Rep., ING, Maputo, 105 p.
- Karlsson JP (2006) An investigation of the felsic Ramiane Pluton, in the Monapo structure, Northern Mocambique. Examensarbeten I Geologi vid Lunds universitet – Berggrundsgnologi 202
- Konečný P, Siman P, Holický I, Janák M, Kollárová V (2004) Metodika datovania monazitu pomocou elektrónového mikroanalyzátoru. *Miner Slov* 36, 225–235
- Macey PH, Miller JA, Rowe CD, Grantham GH, Siegfried P, Armstrong RA, Kemp J, Bacalau J (2013) Geology of the Monapo Klippe, NE Mozambique and its significance for assembly of central Gondwana. *Precamb Res* 233, 259–281
- Montel JM, Foret S, Veschambre M, Nicollet Ch, Provost A (1996) Electron microprobe dating of monazite. *Chem Geol* 131, 37–53
- Siegfried PR (1999) The Monapo structure and intrusive complex – an example of large scale alkaline metasomatism in northern Mozambique. In: *Mineral Deposits: Processes to Processing*. Rotterdam, 683-686