



Two-stage metamorphic evolution of the Bemarivo Belt (northern Madagascar): constraints from reaction textures and in-situ monazite dating

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To decipher geodynamic processes in polymetamorphic terranes, accurate in-situ dating of metamorphic minerals is particularly important in addition to petrological P-T path information. A major part of the metamorphic evolution of Madagascar is closely linked to the Neoproterozoic formation of the supercontinent Gondwana. Several geochronological studies revealed ages in the range from approximately 650 to 450 Ma, but due to high-grade metamorphic conditions, evidences from earlier events are mostly overprinted and therefore rare in the polyphase rocks of Madagascar. We sampled metapelites from the Bemarivo Belt of northern Madagascar that show textural evidence for a two-stage metamorphic history. The Bemarivo Belt strikes WNW—ESE and crosscuts all other adjacent tectonic units. It is subdivided into three distinct regions: the northernmost part consists of greenschist- to epidote-amphibolite-facies epicontinental series, whereas the southern part is made up largely of granulite-facies metapelitic rocks, which we have used for reconstructing the P-T evolution. The area in between is dominated by metagranitoids and granites. We deduced the pressure-temperature path from metamorphic reactions and did texturally controlled U-Th-total Pb dating of metamorphic monazites to get a more precise picture of the geodynamic setting of this tectonic unit. The first metamorphic stage is just preserved by small kyanite inclusions in garnet and prominent sillimanite pseudomorphs after kyanite, in agreement with results of the garnet–alumosilicate–quartz–plagioclase (GASP) equilibrium. The second stage is characterised by temperatures of 900-950 °C and pressures of 8-10 kbar, as deduced from GASP equilibria, feldspar thermometry and the alumina content of orthopyroxene (max. 8 wt.%) coexisting with garnet and

sillimanite. The peak metamorphism is followed by near-isothermal decompression to pressures of 5-7 kbar and subsequent cooling following a near-isobaric path. This coincides with the formation of cordierite rims around garnet and late-stage garnet-clinopyroxene-plagioclase-quartz equilibria. Monazites are common accessory minerals in the metapelites of this area. Their internal textures imply a two-stage growth history, but in rare cases magmatically zoned cores are also preserved. In-situ U-Th-total Pb dating with the electron microprobe was performed on monazites with different inclusion relationships. The magmatic cores give ages of 719 ± 38 Ma, correlating well with ages known from the northern Bemarivo Belt, the Seychelles, and western India. Two metamorphic stages are dated at 531 ± 25 Ma (monazite cores) and 495 ± 22 Ma (overgrown rims). Although both ages are overlapping within their 2σ errors, we consider it likely that they represent true metamorphic ages, due to textural control and differences in monazite chemistry. These results are supposed to reflect the Pan-African attachment of the Bemarivo Belt to the Gondwana supercontinent during its final amalgamation stage. In the course of this, equilibration in the kyanite stability field took place at ca. 531 Ma. Just approximately 35 Ma later the rocks underwent heating and subsequent uplift, interpreted as an orogenic collapse. Finally, they cooled at mid-crustal depths of 15-20 km. The older magmatic monazites found in metapelites of the southern Bemarivo Belt reflect an incorporation of detrital monazites, possibly derived from the northern part of the belt.