P-T EVOLUTION OF THE BEMARIVO BELT (NORTHERN MADAGASCAR): THE FINAL ASSEMBLY OF GONDWANA

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INTRODUCTION
Madagascar holds a central position in the East African Orogen (EAO), which has been formed during the amalgamation of the supercontinent Gondwana. The island largely consists of Archaean and Proterozoic rocks that have been affected by Pan-African (ca. 650-500 Ma) metamorphic overprinting. However, the timing of the collision and sequence of different metamorphic events is still under debate. This is mainly due to the fact that most rocks feature a polymetamorphic history, resulting in ambiguous geochronological data. The key for understanding the formation history of Gondwana lies in detailed observation of metamorphic reaction textures, in combination with in-situ techniques of geochronology.

The WNW–ESE striking Bemarivo Belt of northern Madagascar truncates all other tectonic units. Its northernmost part consists of low-grade metamorphic epicontinental series, whereas the southern part is dominated by granulite-facies metapelitic rocks. Large volumes of granitoids and charnockites occur between both distinct areas. We used metapelites of the southern part of the belt to determine the pressure-temperature (P-T) conditions of metamorphism. To get an idea of the timing and the duration of metamorphism, we performed texturally-controlled in-situ U-Th-total Pb dating of monazites.

P-T CONDITIONS
A clockwise P-T evolution is constrained by prograde inclusions of kyanite in garnet, peak-metamorphic Grt-Opx-Sil-bearing pelitic assemblages, and the late-stage formation of cordierite rims around garnet. The prograde stage is confirmed by geobarometry (GASP equilibria) and prominent sillimanite pseudomorphs formed after kyanite. Peak-metamorphic conditions of $T = 970 \, ^\circ\text{C}$ and $P = 8-10 \, \text{kbar}$ are inferred from the alumina content of orthopyroxene (8 wt.%) coexisting with garnet and sillimanite, feldspar thermometry, as well as GASP equilibria. Near-isothermal decompression to pressures of 5-7 kbar is deduced from late-stage Grt-Sil-Crd-Qtz assemblages. The subsequent cooling followed a near-isobaric path.

GEOCHRONOLOGY
Monazites generally consist of a homogeneous core (M\textsubscript{1}) and a narrow overgrown rim (M\textsubscript{2}). In rare cases, an additional magmatically-zoned core (M\textsubscript{0}) is preserved. From differences in monazite chemistry and from inclusion relationships, we conclude a two-stage growth history. The M\textsubscript{1} monazites are dated at ca. 531 Ma, correlated with the prograde garnet growth. The overgrown M\textsubscript{2} rims formed at ca. 504 Ma, likely during the peak of metamorphism and decompression. The M\textsubscript{0} monazites are ca. 717 Ma in age. They are interpreted as detrital grains giving the maximum age of sedimentation of the protolith. Although the M\textsubscript{1} and M\textsubscript{2} age are overlapping within error, due to textural control and differences in chemistry, it is likely that they represent true metamorphic ages, pointing to a duration of ca. 30 Ma from prograde garnet growth to heating and decompression.

CONCLUSION
The 717 Ma age of the detrital grains is interpreted as a maximum age of sedimentation. From the northern part of the Bemarivo Belt and from the Seychelles, which may be the source regions for the sediments, similar magmatic ages are known. At ca. 531 Ma the Bemarivo Belt collided with the already amalgamated parts of Gondwana, leading to burial of the sediments to depth of at least 30 km. Heating to temperatures of nearly 1000 $^\circ\text{C}$ is explained with heat supply by magmatic underplating just ca. 30 Ma later. The decompression points to fast extensional orogenic collapse that was followed by cooling at mid-crustal levels. The high-temperature metamorphism is one of the youngest known from the EAO and points to a very late accretion of the Bemarivo Belt to the Gondwana supercontinent.