U-Pb detrital zircon geochronological provenance patterns of supracrustal successions in central and northern Madagascar

[1]De Waele, B.; [2]Thomas, R.J.; [2]Horstwood, M.S.A.; [2]Pitfield, P.E.J.; [3]Tucker, R.D.; [3]Potter, C.J.; [2]Key, R.M.; [2]Smith, R.A.; [5]Bauer, W.; [6]Randriamananjara, T.; [6]Ralison, V.; [6]Rafahatelo, J-M.; [6]Rabarimana, M.

[1]SRK Consulting, 10 Richardson Street, West Perth, WA 6005, Australia
[2]British Geological Survey, United Kingdom; [3]United States Geological Survey, USA; [4]Aziana Exploration, Madagascar; [5]RWTH Aachen, 52056 Aachen, Germany; [6]Projet de Gouvernance des Ressources Minières, Madagascar

---

Key Words: Detrital provenance, Madagascar, Gondwana, zircon geochronology

INTRODUCTION

Madagascar comprises a mosaic of three Archaean blocks, the Antongil and Masora Cratons in the east and the Antananarivo Craton occupying most of the central part. Remnants of low-grade supracrustal sequences are preserved on the Antongil-Masora Craton(s), while metasedimentary units within the Antananarivo Craton underwent upper amphibolite- to granulite-grade metamorphism during the amalgamation of Gondwana at ca. 550 Ma. Juxtaposed against the Archaean cratons in the north, the Neoproterozoic Bemarivo Domain comprises granitoids, associated high-level intrusions and volcano-sedimentary units. This terrane is interpreted as an oceanic arc system that accreted to Archaean Madagascar during the late-Neoproterozoic to early Cambrian In terms of detrital zircon geochronology only successions in W Madagascar have been studied in detail. These include the low-grade Itremo and Molo Groups which yielded maximum depositional ages of ~1720 and ~620 Ma respectively (e.g. Cox et al., 1998), with minimum ages recorded by high U zircon overgrowths at ~560 Ma. In east Madagascar, Collins et al. (2003) reported limited data on two high-grade paragneiss samples adjacent to the Antongil-Masora Craton, indicating deposition after ca. 800 Ma. It was thus suggested that the Masora-Antongil Cratons were separated from the Antananarivo Craton by a Neoproterozoic oceanic basin that closed during amalgamation of Gondwana at ca. 550 Ma. The site of closure coincides with a broad zone of graphite-rich lithologies with small ultramafic pods that mark a proposed "Betsimisaraka" Suture Zone. In this study, we present new U-Pb SHRIMP and Laser-Ablation ICP-MS geochronology on detrital zircons from 12 of the main (meta)volcano-sedimentary successions in central and N Madagascar (see Figure), shedding new light on the geological history of the island. The data presented in this study form one of the main results stemming from a World Bank-funded geological mapping and sampling program undertaken by a BGS-USGS consortium between 2005 and 2008.

RESULTS

Betsiaka Group (N Bemarivo Domain): One sample of quartzite was analyzed and gave a detritral provenance age range between 3.38 and 2.47 Ga. The youngest concordant zircon dated at **2450 Ma**, giving a maximum age of deposition.

Mananara Group (Antongil Craton): Four samples were dated from this group: two psammitic kyanite-bearing schists, a quartzite (Ambodiriana Subunit) and a dacitic greenschist. Together, these indicate deposition between **2540** and **2510 Ma**, with minor

modes at 3.18, 2.76 and 2.65-2.55 Ga. Some low Th/U zircon rims ages between 540 and 520 Ma record a metamorphic overprint of that age affecting the Antongil Craton.

Andrarona Group (N Antongil Craton): Zircon grains in a conglomerate yielded a unimodal age component of **2355 Ma**, interpreted as the maximum age of deposition. No local source of this age has been recognized in the Antongil Craton.

Sahantaha Group (S Bemarivo Belt): Two quartzite samples yielded near-identical detrital age distributions with a dominant mode at ~1800 Ma and a maximum depositional age of **1750 Ma (c.f Itremo Group)**, with minor modes between 2700 and 2500 Ma. No metamorphic rims were seen, but Th-Pb monazite CHIME dates have shown an overprint, indicating minimum deposition age at 520 Ma (Jöns et al., 2006).

Maha Group (Masora Craton): Two samples gave detrital age patterns similar to the Sahantaha Group, with a dominant age mode between **1800** and **1750 Ma** and lesser contributions from age sources between 2700 and 2500 Ma. A maximum depositional age of 1750 Ma is given by the youngest concordant detrital zircon **(c.f. Itremo Group).**

Ampasary Group (W Masora Craton, E Antananarivo Craton): Three samples show a dominant contribution from Mesoarchaean sources (3.2-3.0 Ga) with minor modes at **780 Ma (**maximum age). This is in broad accord with data from Collins et al. (2003).

Manampotsy Group (E Antananarivo Craton): Two felsic volcanic units yielded ages of **800** and **790 Ma**. One paragneiss gave a near-unimodal detrital population at **840 Ma**. Metamorphic zircon rim at 560 Ma provide a minimum depositional age.

Ambatolampy Group (central-W Antananarivo Craton): Three quartzites gave detrital age patterns dominated by modes at **2.7** and **2.5 Ga,** suggesting source terranes within the Antananarivo Craton. One sample yielded an additional important mode at 1060 Ma, corresponding to the age of the regionally restricted Dabolava Suite (e.g. Müller, 2000). The youngest zircon dated had an age of **1056 Ma**, providing the maximum age of deposition of the group. Abundant metamorphic (high U) zircon rims indicate an overprint at 560-540 Ma, providing a minimum age estimate.

Andriamena Group (central Antananarivo Craton): Kabete et al. (2006) reported discordant detrital age data for a paragneiss with the age range 2870 to 1750 Ma. An Fe-quartzite from our study shows a much more restricted age range at ca**. 2500 Ma**.

Bealanana Group (Anaboriana Belt, N Antananarivo Craton): Four samples of quartzite or paragneiss yielded detrital age modes between **830 to 780 Ma**, with similar age patterns to the Manampotsy Group. Metamorphic zircon rims range up to 510 Ma, giving the minimum depositional age. Unimodal age spectra and lack of older detrital sources suggest volcanosedimentary rocks deposited proximally to an oceanic arc.

Milanoa Group (Southern Bemarivo Belt): Three samples indicate a narrow age distribution between **750** and **720 Ma,** corroborating suggestions that the group represents a juvenile Neoproterozoic volcanic arc succession. A metamorphic zircon rim age of 520 Ma correlates with Th-Pb CHIME monazite dates from the Sahantaha Group to the south (Jöns et al., 2006), indicative of major tectonothermal event at that time.

Daraina Group (N Bemarivo Belt): Two dates from rhyolite units gave dates of **740** and **720 Ma**, confirming the previous age constraints for the Daraina Group.

DISCUSSION

We recognise a metasedimentary-volcanoclastic sequence within the Antongil Block, known as the Mananara Group and the Ambodiriana Subunit, which was deposited sometime around 2.5 Ga. Another succession within the Antananarivo Craton, the

Adriamena Group, also has a syn-magmatic depositional age of 2.5 Ga, as has a strip of supracrustals in the northern Bemarivo Domain, the Betsiaka Group. Our new age data suggest that the Maha and Sahantaha Groups are coeval with the Itremo Group, being deposited during the Palaeoproterozoic, after 1750 Ma. Cox et al. (2005) suggested that deposition of the Itremo Group took place between 1700 and 1500 Ma, based on stromatolite morphologies. No source rocks of this age are known from Madagascar, suggesting an allochthonous setting for these units. Deformation and high-grade metamorphism of the Sahantaha Group in the S Bemarivo Domain, dated at 520 Ma, argue for tectonic juxtaposition of the Itremo-Sahantaha-Maha units with Madagascar before 520 Ma, but intrusion of the Itremo Group, and possibly the Sahantaha Group by 800 Ma granitoids similar to those intruding the Antananarivo Craton suggest juxtaposition before 800 Ma. We suggest that the three groups represent the remnants of a large thrust sheet that emplaced over the Antananarivo-Antongil-Masora cratonic assemblage, but the timing of thrusting remains controversial. The Ampasary, Manampotsy-Bealanana and Ambatolampy Groups are considered to be mid-Neoproterozoic successions deposited along the cratonic margins (Ampasary and Ambatolampy Groups) or within an oceanic realm (Manampotsy-Bealanana Groups) that separated the Antananarivo from the Antongil-Masora Cratons. The Ampasary Group shows the character of a marginal succession to the Masora Craton from which it derived prominent 3.2-3.0 Ga detrital modes. The Ambatolampy Group records a detrital age range for which source terrains within the Antananarivo Craton can be readily identified. The Manampotsy/Bealanana Groups show very restricted detrital age modes (830 and 780 Ma), indicative of a distal position with respect to the cratons, but proximal to active ocean arcs. Their association with 800-Ma peraluminous intrusive (Brickaville Gneiss) argue for a more proximal setting to older crustal source terrains. The Milanoa and Daraina Groups of the Bemarivo Domain also have a largely unimodal age distributions and are interpreted as being proximal volcanoclastic arc succession. Age data suggest that these oceanic arcs developed outboard between 750 and 720 Ma and were accreted to cratonic Madagascar around 520 Ma.

REFERENCES

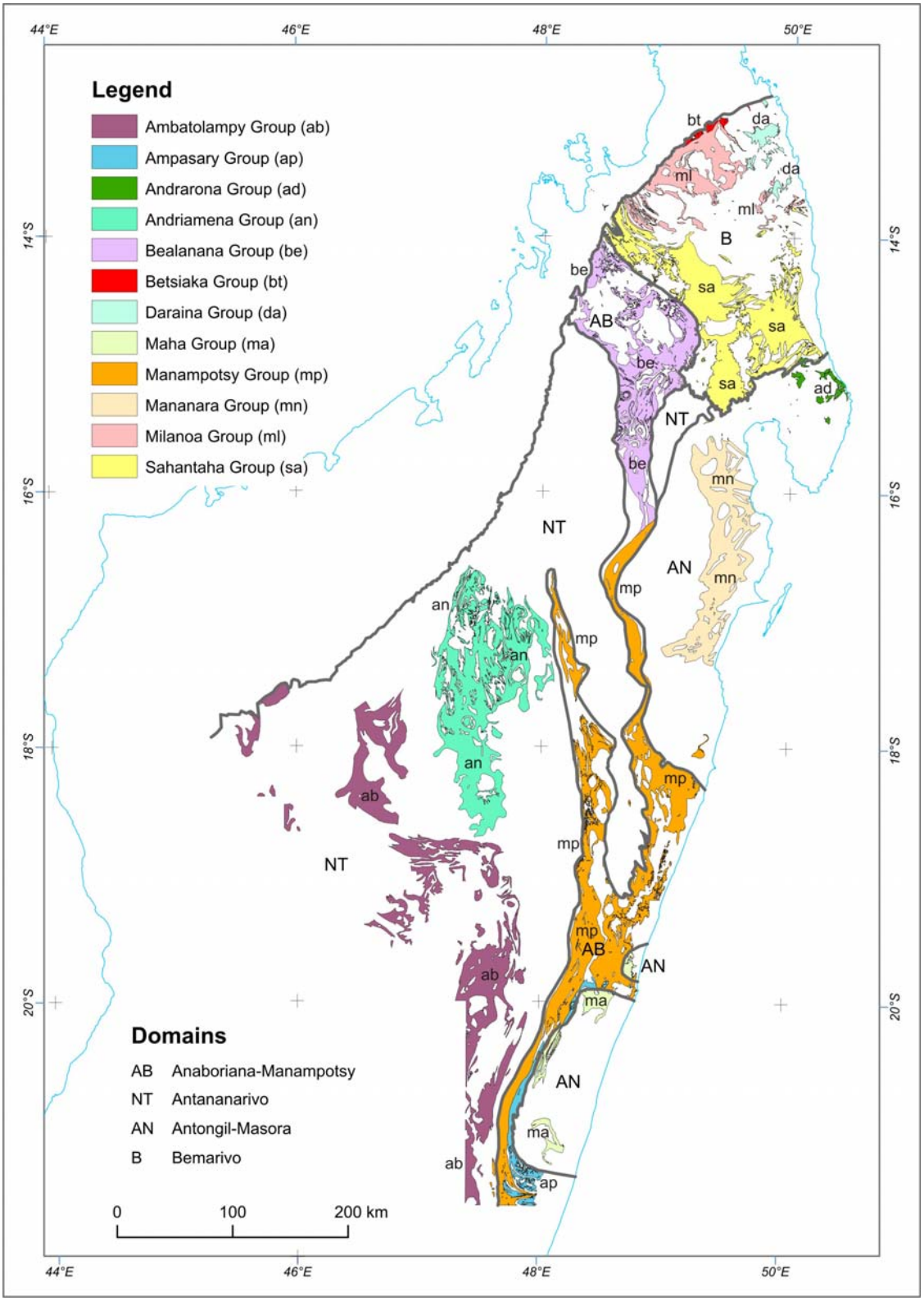
Collins, A S, Kröner, A, Fitzsimons, I C W and Razakamanana, T. 2003. Detrital Footprint of the Mozambique Ocean: U/Pb SHRIMP and Pb Evaporation Zircon Geochronology of Metasedimentary Gneisses in Eastern Madagascar. *Tectonophysics* 375, 77-99.

Cox, R, Armstrong, R A and Ashwal, L D 1998. Sedimentation , geochronology and provenance of the Proterozoic Itremo Group, central Madagascar, and implications for pre-Gondwana palaeogeography. *Journal of the Geological Society* 155, 1009-1024.

Jöns, N, Schenk, V, Appel, P and Razakamanana, T. 2006. Two-stage metamorphic evolution of the Bemarivo Belt of northern Madagascar: constraints from reaction textures and in situ monazite dating. *Journal of Metamorphic Geology* 2006, 10.

Kabete, J, Groves, D, McNaughton, N and Dunphy, J. 2006. The geology, SHRIMP U-Pb geochronology and metallogenic significance of the Ankisatra-Besakay District, Andriamena belt, northern Madagascar. *Journal of Africal Earth Sciences* 45, 87-122.

Müller, B. G. J. 2000. The evolution and significance of the Bongolava-Ranotsara shear zone, Madagascar. *Unpublished PhD*, Rand Afrikaans University, Johannesburg, South Africa, pp. 125.


Legend
Ambatolampy Group (ab)
Ampasary Group (ap)
Andrarona Group (ad)
Andriamena Group (an)
Bealanana Group (be)
Betsiaka Group (bt)
Daraina Group (da)
Maha Group (ma)
Manampotsy Group (mp)
Mananara Group (mn)
Milanoa Group (ml)
Sahantaha Group (sa)
Domains
AB Anaboriana-Manampotsy
NT Antananarivo
AN Antongil-Masora
B Bemarivo
0
100
200 km
44°E
46°E
48°E
50°E
14°S
16°S
18°S
20°S