The Ambatolampy Group, central Madagascar, a Neoproterozoic rift-basin sequence?

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Abstract

New U-Pb detrital zircon ages prove a Neoproterozoic sedimentation age of the Ambatolampy Group in central Madagascar. The youngest detrital zircons are most likely derived from the Imorona-Itsindro suite, a calc-alkaline, bimodal suite related to crustal extension between 855 and 720 Ma. Mafic gneisses and amphibolites show a geochemical signature similar to the mafic Itsindro-type intrusives. The Ambatolampy Group was most likely deposited in a continental extensional setting and the youngest parts of the group already contain unroofed, eroded parts of the Imorona-Itsindro suite.

Introduction

The crystalline basement of central Madagascar is composed of the Neoarchaean, high-grade metamorphic Antananarivo Domain, made up of granulite to upper-amphibolite orthogneisses and paragneisses, and intruded by Tonian igneous rocks of the Imorona-Itsindro suite (Archibald et al. 2016). Along its southern, western and northern margins several terranes were accreted between the Paleoproterozoic and the Neoproterozoic (Tucker et al. 2014) before Madagascar was affected by the collision of East- and West-Gondwana at the end of the Ediacaran.

Within the Antananarivo Domain, a more than 700 km long and up to 80 km wide belt of supracrustal amphibolite-facies rocks forms the Ambatolampy Group (Fig. 1).

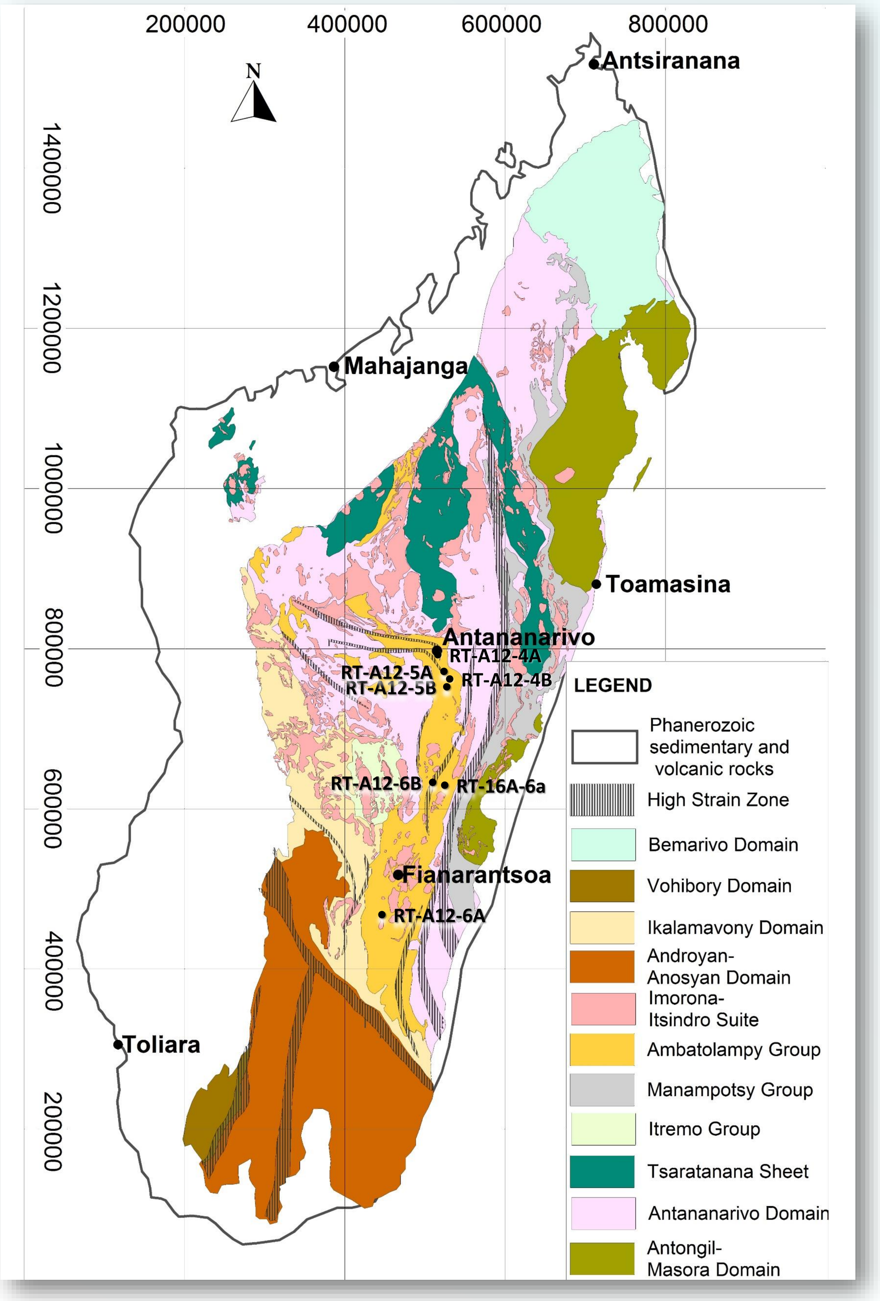

Fig. 1. Simplified geological map of Madagascar (after Roig et al. 2012) with localities of quartzite samples. RT-A12-5A is close to the type locality Ambatolampy.

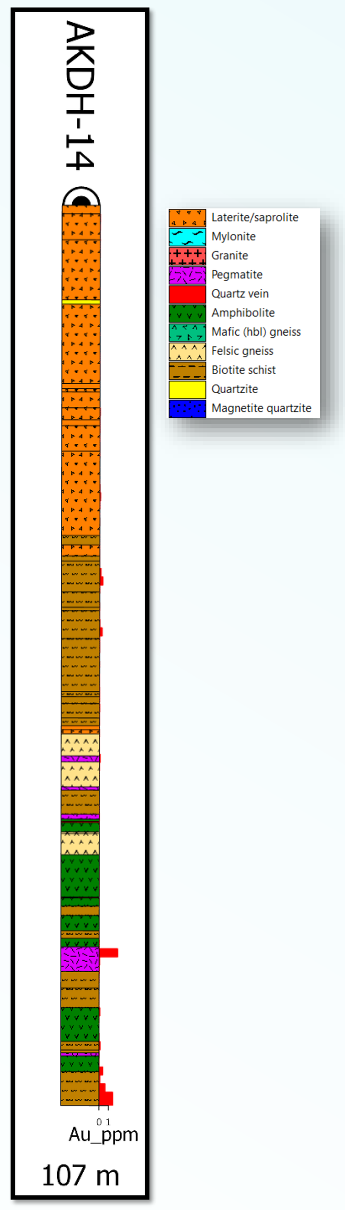

Fig. 2. Log of drill hole 14, with gold assays.

Lithology

The group is characterized by abundant mica schists with minor amounts of gneisses, amphibolites and migmatitic rocks (Fig. 2). The schists contain biotite, sillimanite, garnet and graphite. Related paragneisses are biotite-rich and commonly carry sillimanite or hornblende. Quartzites range from coarse-grained, thick-bedded ridge-forming units to dark, fine-grained, cm-scale interbeds with abundant magnetite. Small bodies of pyroxenite, pyroxene-amphibolite, amphibolite ±garnet, pyroxene gneiss are common.

Results

Geochronology

The age of the Ambatolampy Group is highly controversial. A group of researchers from BGS and USGS reported a youngest detrital zircon age of 1054 Ma, whereas Archibald et al. (2016) assumed a Mesoproterozoic age, based on their youngest zircons of roughly 1.8 Ga. We present new near-concordant U-Pb detrital zircons ages as young as 800 Ma, indicating a sedimentary input from igneous rocks of the Imorona-Itsindro suite. Sedimentation must have ceased before 630 Ma which is constrained by the U-Pb zircon age of an intruding leucogabbro.

To constrain the age of deposition (and metamorphism) laser-ablation split-stream (LASS) inductively coupled plasma-mass spectrometry (ICP-MS) U-Pb geochronology analyses were conducted on zircons from two samples. Seven quartzite samples from different parts of the Ambatolampy Group provided detrital zircons which were used to determine the maximum depositional age (Table 1).

Fig. 3 a and b shows detrital zircons from sample RT-A12-6A with age clusters around 3100, 2800, 2700-2600, 2500-2300, 1500, and 1350-1250 Ma (all ages <10% discordant). The youngest cores are ranging from 851 to 768 Ma (Fig. 3 c). Metamorphic rims have concordant ages of 539.1 ±2.0 Ma (Fig. 3 d). Most quartzite samples show similar age patterns regarding the older zircon provenances (Table 1).

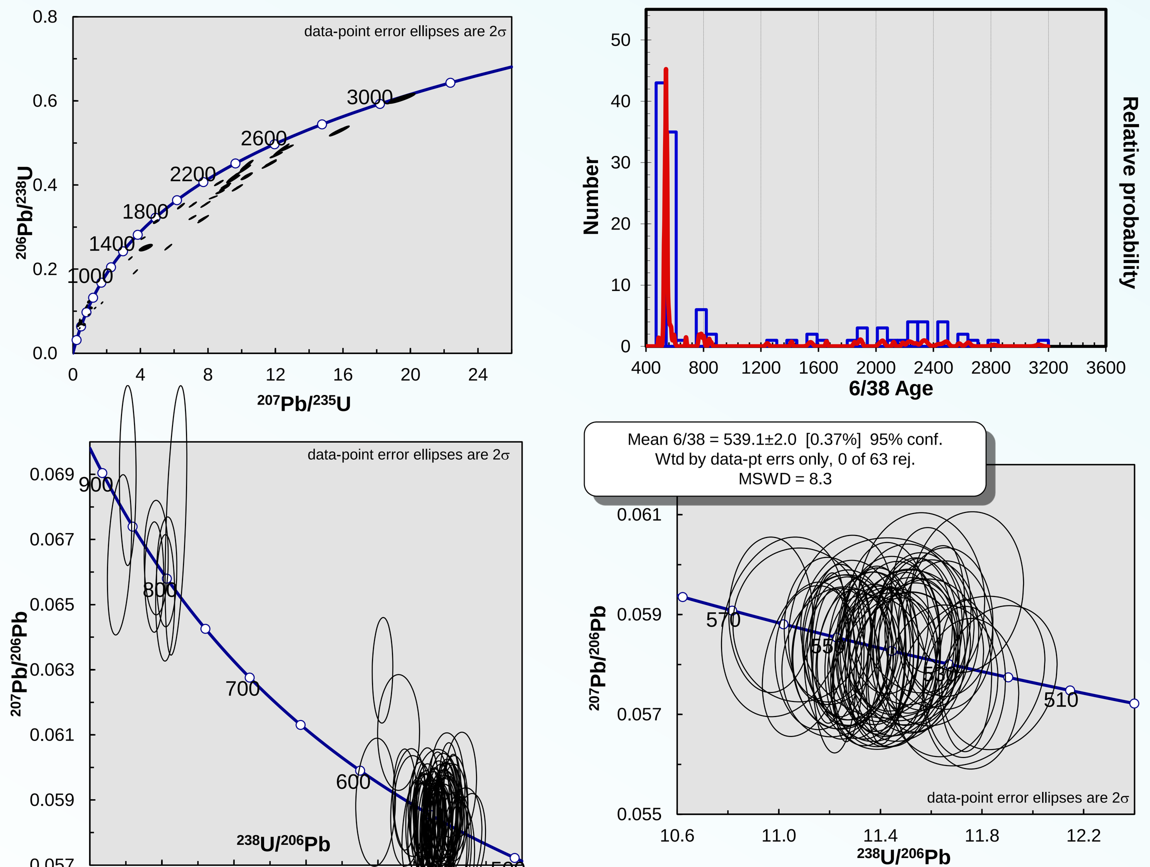

Fig. 3: U-Pb zircon geochronology of detrital zircons, sample RT-A12-6A : a) Wetherill plot; b) Relative probability plot, ages are 206 Pb/ 238 U in Ma. Analyses >10% discordant are not included; c) Concordia diagram; d) Tera-Wasserburg diagram for metamorphic zircon rims.

Table 1: Detrital zircon U-Pb ages from seven quartzites of the Ambatolampy Group.

Sample #	Northing	Easting	Provenance (Ga)	Youngest grain (Ma)	Metamorphic rims
RT-A12-4A	-18.904993	47.557430	>2.8 to 1.6		569.5 ± 2.8
RT-A12-4B	-19.422833	47.478367	2.8-2.4		525.8 ± 4.3
RT-A12-5A	-19.404867	47.488567	2.8, 2.6 - 2.5		532.6 ± 3.9
RT-A12-5B	-19.417527	47.524051	2.85, 2.6-2.45		543.3 ± 1.1
RT-A12-6A	-21.832136	46.961401	3.0, 2.8-2.5, 1.8	768	539.1 ± 2.0
RT-A12-6B	-20.299790	47.458683	2.75-2.5		533.6 ± 2.5
RT-16A-6a	-20.319671	47.440738	2.8-2.4, 2.1, 1.0		539.7 ± 5.3

Mineralization and Geochemistry

Madagascar produced approx. 70 t gold in colonial times. About half of Madagascar's known 1050 gold working sites are lying within the Ambatolampy Group, many of them are sites of artisanal activities in streams, others were sites of significant gold rushes during the last two decades (Fig. 4).

A diamond drilling program of 2911 m (26 holes) carried out in 2008/09 by the Australian Junior Explorer *Aziana Exploration Ltd* near the town of Ambatolampy revealed some insights into the type of mineralization. It is a gold-only mesothermal mineralization (Table 2) in thin quartz veinlets. Grades in fresh rock are sub-economic, averaging 0.14 g/t, maximum grades reach 1.9 g/t over 1 meter length only. Higher grades are only found in the oxidation zone with grades between 0.5 and 4 g/t over several meters. The gold in this surface near zone is enriched by supergene processes as lateritic gold.

Fig. 4: Artisanal gold workings in lateritic Ambatolampy Group near Firavahana, 90 km NW of Antananarivo.

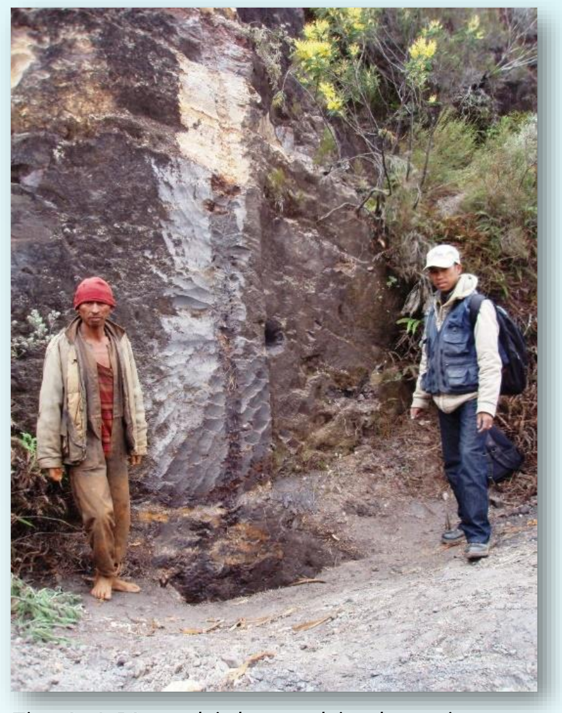

Fig. 6: A 12 m thick graphite layer in Ambatolampy Group micaschists, 15 km south of Ambatolampy.

Table 2: Correlation matrix for gold and 5 other elements, based on 1425 samples of a diamond drill program in Ambatolampy.

Cu	1					
Fe	0.34	1				
Mn	0.28	0.53	1			
Pb	0.06	0.18	0.34	1		
Zn	0.37	0.37	0.55	0.17	1	
Au	0.13	0.13	0.06	0.02	-0.03	1
	Cu	Fe	Mn	Pb	Zn	Au

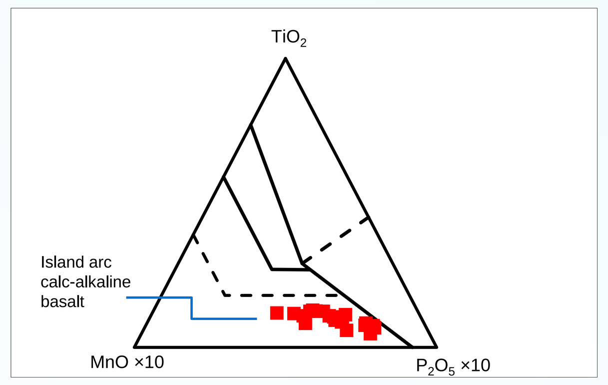

Fig. 5: 21 amphibolite/mafic gneiss samples from DH-13 in the Ambatolampy Group in the tectonic discrimination digram (Mullen 1983).

Whole rock geochemistry data are available for a limited number of amphibolites and banded hornblende gneisses (andesite/dacite tuffs?). Minor element compositions of mafic lithologies are similar to the mafic components of the Imorona-Itsindro suite (Archibald et al. 2017) and plot dominantly in the field of intra-plate and island arc basalts (Fig. 5). Another important commodity is graphite which occurs in up to 35 m thick seams. Graphitic carbon contents range from 10 to 27 % (Fig. 6).

Discussion

Detrital zircons with ages between 3 and 2.45 Ga are likely sourced from the Archaean basement of Antongil-Masora and Antananarivo domains. A detrital input of ~1 Ga was already recorded by BGS-USGS-GLW (2008), i.e. the sedimentation of the Ambatolampy Group postdates the collision with the juvenile Ikalamavony Domain. Local occurrence of detrital zircons as young as 768 Ma indicate a rapid unroofing of Imorona-Itsindro plutons and subsequent deposition of their detritus.

Available geochemical data from meta-igneous mafic rocks within the Ambatolampy Group indicate a calc-alkaline igneous activity similar to the Imorona-Itsindro suite which was recently interpreted as a result of re-melting Neoarchaean crust and mixing with sub-continental mantle melt in an extensional setting (Zhou et al. 2018).

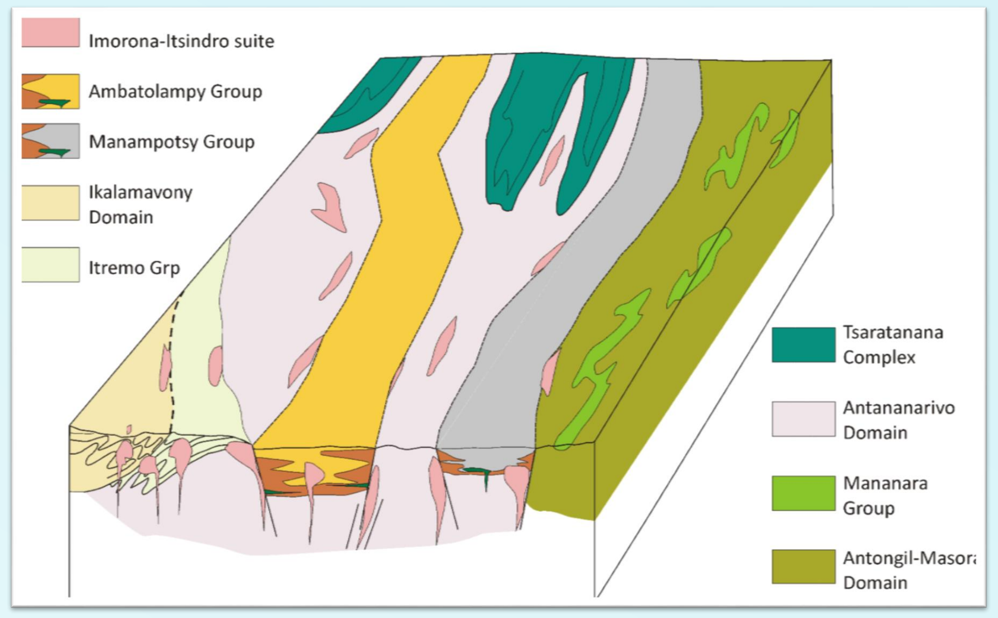

Fig. 7: Schematic block diagram, showing the Ambatolampy Group as rift-related sequence during the Tonian intrusion of the Imorona-Itsindro suite.

Conclusion

We interpret the Ambatolampy Group as a mainly siliciclastic fill of a continental rift basin during a phase of Tonian crustal extension occurring contemporaneously with the intrusion of the Imorona-Itsindro Suite (Fig. 7). The gold mineralization is most likely related to fluvial deposits from surrounding gold-bearing Archean basement, especially from the greenstone belts of the Tsaratanana sheet. The graphite layers are metamorphosed organic rich shales.

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