

# SYN-DEFORMATIONAL ~800 MA PLUTONS IN THE ITREMO SHEET, CENTRAL MADAGASCAR: INTRUSION DURING ARC FORMATION?

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## MADAGASCAR

Many reconstructions of the late Mesoproterozoic supercontinent, Rodinia, place Madagascar attached to India in its younger Gondwanaland fit on the eastern side of a wide Mozambique Ocean that separates India–Madagascar–East Antarctica from the Congo–Sao Francisco block of Africa. When Rodinia broke up during the mid-Neoproterozoic, the Mozambique Ocean is postulated to have contracted by subduction beneath either or both of the India–Madagascar and east African margins while the Palaeo-Pacific Ocean grew between Australia–Antarctica and Laurentia. Final closure of the Mozambique Ocean is thought to have occurred in the late Neoproterozoic during the end-Precambrian formation of Gondwanaland.

Based on observations on the sedimentary sequence of the Itremo Group and on basal amphibolites of the Itremo Sheet, we propose a new model in which Central Madagascar formed its own microcontinent at *ca.* 800 Ma, with the Mozambique Ocean subducting westward underneath, resulting in the formation of a retro-arc basin and associated plutons at this time.

## ITREMO SHEET

The Itremo Group of Central Madagascar forms a succession of metamorphosed quartzite, pelite and carbonate rocks more than 2 km thick, lying on top of a series of basal amphibolites. This ‘Itremo Sheet’ tectonically overlies a series of high-grade, reworked Archaean gneisses. The Itremo Group sediments have been previously interpreted as a passive margin or platform sequence ( $\leq 1855$  &  $\geq 800$  Ma). Their basin setting is still debated. We postulate here that the Itremo Group and the underlying thin sediment slivers and thick mafic sills (now amphibolites) are genetically related, and that they represent the onset of extension-related magmatism in Central Madagascar. Although the formation age of the Itremo Sheet units is poorly constrained, we favour a model of the development and infilling of a shallow, epicontinental, retro-arc basin during westward subduction underneath Central Madagascar when the Mozambique Ocean began to close at ~800 Ma. Such a supra-subduction setting can explain the facies associations and the patterns of deformation, metamorphism and intrusion found in both Itremo Sheet units around 800 Ma.

## DEFORMATION AND TECTONIC SETTING AT ~ 800 MA

The tectonic units of Central Madagascar (the Antananarivo Block and the Tsaratanana Thrust Sheet) and the Itremo Group are intruded by a 450 km-long meridional belt of coeval gabbroic and granitoid batholiths (804–770 Ma). This magmatic belt has been interpreted to be the roots of a former *ca.* 800 Ma continental magmatic arc.

The style of deformation documented in the Itremo Group recently by the Tectonics Centre Madagascar team could indeed reflect tectonic processes operating during arc formation. A penetrative deformation event with isoclinal recumbent folds and an early layer-parallel cleavage is overprinted by low-P–high-T minerals in the contact aureoles of the *ca.* 800 Ma plutons (at  $\leq 4$  kbar,  $\geq 650$  °C). This indicates that either there was a separate episode of deformation before the plutons were emplaced, or that progressive deformation had occurred during intrusion. In the second case, the isoclinal folds with penetrative fabrics formed early during the same tectonic event that emplaced the *ca.* 800 Ma plutons. There then are two possibilities. The first option is widespread crustal extension. Although metamorphic facies are strongly attenuated, as expected with this model, this is due to the rapid injection of voluminous plutons under vertical rather than horizontal stretching conditions, as outlined below.

Sheared pluton and aureole margins are often steep, but they are also sub-parallel and possibly reoriented by later deformation, making it difficult to distinguish between intrusion as largely layer parallel, sub-horizontal sheets, or as stocks that intrude the flat-lying fabric and the recumbent folds at a high angle, with ductile stretching of the wall rock leading to transposition into a vertical and thinned contact aureole.

However, while later upright folding is indeed present, it is possible to trace older, tight, syn-intrusion upright folds close to the pluton, with sub-horizontal fold axes, into the actual contact aureole, where the same fold axes rotate into vertical, parallel to a strong high temperature vertical stretching lineation that developed syn-intrusion in a stretched, vertical contact zone of both granite and wall rock (skarn).

The second option, and the preferred tectonic model, is therefore that the penetrative fabric and recumbent folds are related to upper-crustal imbrication of the postulated continental magmatic arc during contractional deformation, analogous to retro-arc thrusting in the Patagonian Andes. Both the extensional and contractional deformation model could account for the observation that heat locally outlasted deformation, in the latter case through voluminous pluton injections into the Itremo Group once incorporated in the arc. In the arc scenario, the *formation* of the (upper) Itremo Group and lower dolerite and gabbro sills could be explained by extension in a shallow retro-arc setting, while the observed early structures could reflect later *deformational* contractional components.