Terrane correlation between Antarctica, Mozambique and Sri Lanka: Comparisons of geochronology, lithology, structure and metamorphism

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Summary Analysis of lithological, structural, metamorphic and geochronological data from mapping in Mozambique permits recognition of two crustal blocks separated by the Lurio Belt. Comparison of the data, with data from Sri Lanka and Dronning Maud Land (DML) permits recognition of similar blocks in Sri Lanka and DML. Data interpretation suggests they once formed a mega-nappe, comprising part of northern Gondwana, emplaced ~600 km over southern Gondwana during final Gondwana amalgamation at ~590-550 Ma. The data suggest deeper levels of erosion in southern Africa compared to Antarctica. It is possible this event extends westwards to the Namibian Damara orogeny with the similar age Naukluft nappes fitting the mega-nappe pattern. Erosional products of the mountain belt are now represented by detrital zircons of 400-700Ma age, seen in sandstone formations of the Transantarctic Mountains, their correlatives in Australia, the Urfjell Group (western DML), the Natal Group and possibly the Cape Supergroup, South Africa.

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Introduction

Recent reconnaissance mapping from 2000 to 2005 in NE Mozambique (14°-17°S and 37°-41°E) has permitted the recognition that the basement of N. Mozambique is divided by the Lurio Belt into a northern accretionary complex (North Gondwana Block, NGB) with widely varying lithologies and ages and a southern relatively juvenile complex (South Gondwana Block, SGB) overlain by two small klippe, the Monapo and Mugeba klippe, emplaced by thrust faulting of the NGB over the SGB (Figure 1).

Geochronology

The geochronological characteristics of the two blocks show some similarities but show distinct as well as subtle differences. The broad similarities include numerous ~Pan African and ~Grenvillian crystallisation ages. Distinct differences between the two blocks are that (1) the NGB contains Paleoproterozoic ages whereas there are none in the SGB (except on the Zimbabwe Craton), (2) the NGB contains numerous ages between ~600 and 900 Ma whereas the SGB has virtually none and those seen are either from the Zimbabwe Craton (Rushinga Complex) or in tectonic klippen (Mugeba, Monapo) supporting the correlation of the klippen with the NGB, and (3) the SGB has many ~1000-1100Ma metamorphic ages (zircon rims, migmatitic veins) whereas no metamorphism at this time is recognized in the NGB (see reviews of Johnson et al., 2005, Grantham et al., 2003, Hanson et al., 2003 and significant data in Jamal, 2005, Kroner et al., 2001).

Both areas have numerous crystallisation ages of granitoid intrusions of ~490-540 Ma, with a greater volume of these intrusions being recorded in the SGB. Pan African metamorphic ages are broadly similar; however subtle differences are that those in the SGB are typically younger, ranging from ~600-475 Ma, whereas those in the NGB range from ~650 to ~500Ma.

Lithologies

Rocks of the NGB show a wide range of lithologies including meta-pelites, meta-carbonates, acid to ultrabasic alkaline orthogneisses and quartzofeldpathic gneisses, the alkaline gneisses being typical of extensional plate margin settings. Rocks of the SGB are dominantly quartzofeldspathic gneisses of intrusive and supracrustal origin, many of which are trondhjemite-tonalite gneisses, typical of accretionary collisional settings.

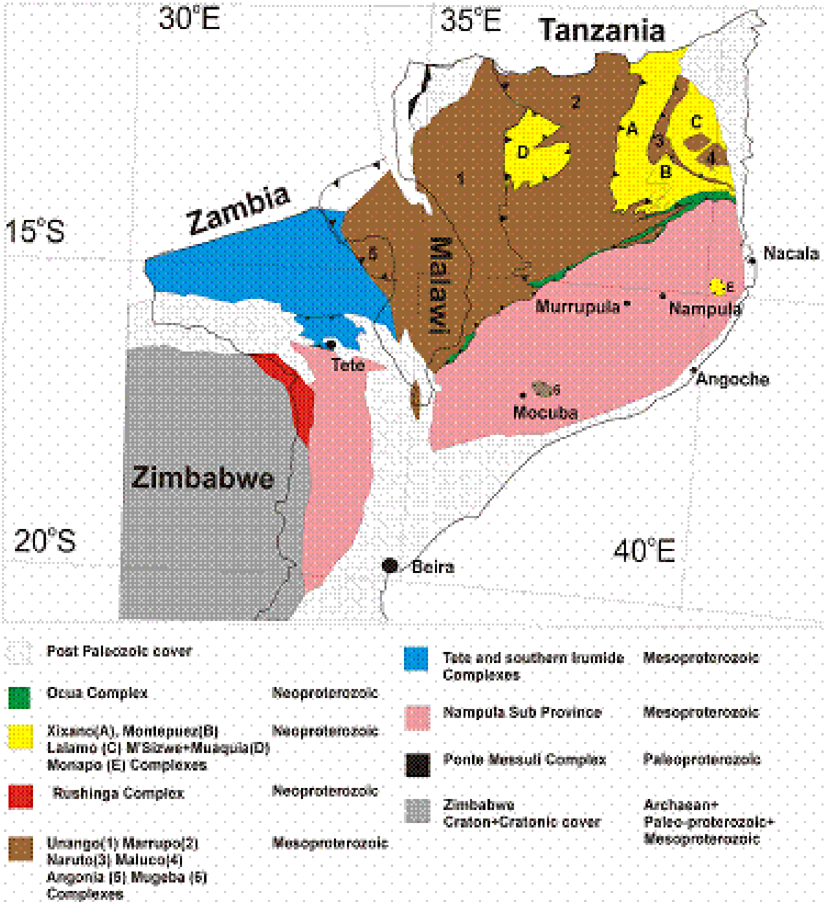

Figure 1. Tectonic blocks of southeastern Africa.

Lithology and Geochronology Correlations:

Extension of the NGB and SGB geochronological provinces (as defined above) to adjacent blocks in Gondwana including Sri Lanka and Dronning Maud Land (DML), Antarctica, show representatives of both the NGB and SGB (Figure 2). The central Highlands Complex of Sri Lanka appears to belong to the NGB province lithologically and geochronologically whereas the Vijayan Complex has ages and rocks comparable to the SGB. In central DML correlations between Sri Lanka and Lutzow-Holmbukta are widely acknowledged. Sor-Rondane is divided by a wide E-W shear zone (Shiraishi et al., 1991). NE Sor-Rondane has ages comparable to the NGB block (Asami et al., 1995). Few data are available from SE Sor-Rondane, south of the shear-zone, however, the lithologies from SE Sor-Rondane are comparable to the SGB block. Age data from Schirmacher Hills in Northern Muhlig-Hoffmanfjella (central DML) (Ravikant et al.,2004) are typical of the NGB as are the compositions of the granulitic lithologies from Schirmacher Hills and Mramornye nunataks (Piazola, 2004). The anorthosites underlying E Muhlig-Hoffmanfjella similarly are typical of the NGB whereas the gneisses of W Muhlig-Hoffmanfjella, including Gjelsvikfjella, are typical in age and lithology to rocks of the SGB. Further west, correlations between Sverdrupfjella and Kirwanveggan in DML and Mozambique are supported in the literature (Groenewald et al., 1991) and indicate that geochronologically and lithologically they form part of the SGB.

Metamorphism

Distinct differences are apparent in the metamorphic grade and metamorphic histories of the terranes belonging to the NGB and SGB. In Mozambique rocks from the NGB, including the Mugeba and Monapo klippen, typically contain high grade granulite assemblages. P-T-t studies on the Mugeba and Monapo klippen show two-stage evolutions at ~640Ma to ~580Ma beginning with isothermal decompression paths from ~10kb and ~900°C turning into post-tectonic isobaric cooling paths at ~6-7kb and ~650-700°C. Similar estimates are reported for rocks north of the Lurio Belt for the NGB. In contrast, the SGB is characterized by medium grade upper amphibolite facies quartzofeldspathic gneiss assemblages with rocks containing few assemblages useful for P-T estimates. The quartzofeldspathic gneisses are extensively migmatised with at least two phases being recognized locally. The migmatisation and extensive granitoid emplacement from ~530Ma to ~495Ma imply an increase in temperature. The increase in temperature is interpreted to result from the emplacement of a mega-scale nappe of NGB rocks over the SGB rocks resulting in thermal heating due to burial. The granitoids are largely undeformed. The relatively limited time span of undeformed granitoid genesis of ~40my, occurring approximately ~40my after the initiation of metamorphism and presumably deformation, is consistent with thermal modelling of crustal melting in continental collision zones (England and Thompson, 1981).

These metamorphic differences are mirrored in the NGB and SGB blocks in Sri Lanka and DML, Antarctica. Reported P-T-t paths from the Highlands Complex of Sri Lanka show near isobaric cooling at ~550Ma at ~6kb and 600-700°C after which rapid inversion followed. No P-T data are available for the Vijayan Complex of Sri Lanka.

P-T-t paths from NE Sor-Rondane and Schirmacher Hills (Baba et al., 2006, 2007) are virtually identical to those from Mugeba and Monapo showing initial isothermal decompression of granulites followed by isobaric cooling at mid crustal levels of ~6-7kb and 600-700°C at ~550-600Ma. In contrast, reported P-T-t paths from western Muhlig-

Hoffmanfjella, Gjelsvikfjella and Sverdrupfjella reportedly show Grenville-age isothermal decompression paths followed by a second phase of metamorphism and granite emplacement at ~490-550Ma (Grantham et al., 1995; Bisnath and Frimmel, 2005).

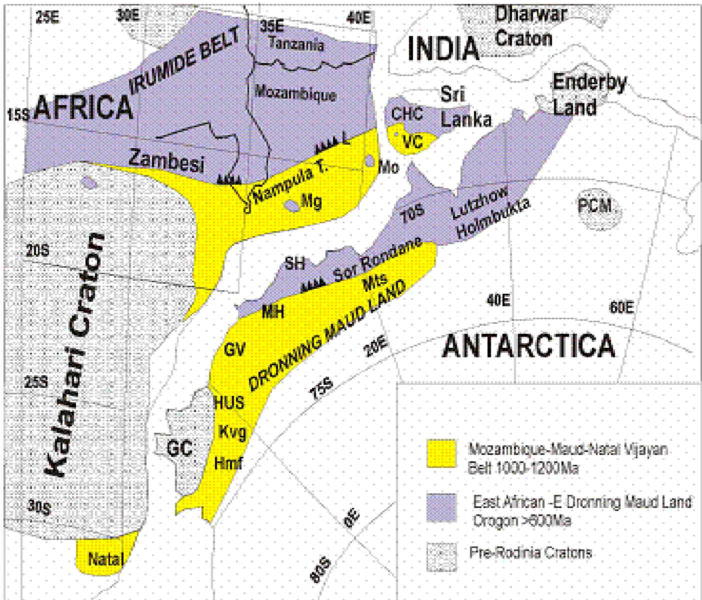

Figure 2. Schematic map showing the crustal blocks defined by geochronology, lithology, metamorphic and structural pattern comparisons. CHC=Central Highlands Complex, VC=Vijayan Complex, L= Lurio Belt, Nampula T=Nampula Terrane, Mg= Mugeba, Mo=Monapo, PCM=Prince Charles Mountains, SH= Schirmacher Hills, MH= Muhlig-Hoffmanfjella, GV= Gjelsvikfjella, HUS=H.U. Sverdrupfjella, Kvg= Kirwanveggan, Hmf=Heimefrontfjella, GC=Grunehogna Craton.

Structural

Structural and aeromagnetic data show the SGB rocks of northern Mozambique are complexly folded with many macro-scale interference structures evident. The dominant deformation involves tight isoclinal NE-SW striking NW dipping axial planes with NW dips and top to SE vergence, folded by open folds with NW-SE oriented fold axes. Lineations plunge dominantly between W and N. Progressing southwards from the Lurio Belt the structural attitude varies from an initial dominantly NW dipping direction to bimodal NW and SE dipping orientations. The Mugeba and Monapo structures have structural patterns distinct from their country rocks and are surrounded by thick circumferential mylonite zones supporting their interpretation as nappe klippen remnants.

In a broader Gondwana context, the top to the SE structures of Mozambique show structural orientations similar to late D_3 structures from NW Sverdrupfjella (Grantham et al., 1995). In NW Sverdrupfjella earlier recumbent NW verging Grenvillian-age fold structures are deformed by ~500Ma age upright SE verging folds yielding bimodal structural patterns on stereonets. Granitoids with ~490Ma ages in Sverdrupfjella (HUS) are interpreted to have been emplaced syntectonically and synchronously with upper amphibolite facies metamorphism (Grantham et al., 1991). Bimodal NW and SE dipping structures are also present in Gjelsvikfjella (Bisnath and Frimmel, 2005) and western Muhlig-Hoffmanfjella (Jacobs et al., 2003; Bauer et al., 2003). Progressing southward from the western DML Antarctic coast into southern Sverdrupfjella and southern Kirwanveggan, planar fabrics become unimodal dipping to the SE and do not show NW dipping D_3 structures (Grantham et al., 1995).

Discussion and Interpretation

The geochronological, metamorphic, structural and lithological data are interpreted to indicate that during the collision between north and south Gondwana along the Lurio Belt and its extensions in Sri Lanka at ~590-550Ma, the NGB, which can be correlated with the East African Orogen (Meert, 2003), was thrust over the SGB (Figure 3). The amount of shortening of the overthrust was probably ~600km using the areal extents of the different blocks in Figure 2. The northern and southern ends of the cross section are constrained by the virtually undeformed Geci Group (N) and Urfjell Group (S) sediments which have ages of ~580Ma (Melehzik et al., 2006)and ~530Ma (Moyes et al., 1997; Croaker, 1999) respectively. The distribution of the blocks requires an erosional level difference between Africa, Sri Lanka and Antarctica with only small erosional remnant klippen being preserved in Africa (Mugeba and Monapo) and Sri Lanka (Kataragama) in contrast to a potentially large contiguous block in northern DML, Antarctica, stretching from at least Lutzow-Holmbukta in the east to the Mramornye nunataks in the west. The mega-nappe proposed here may extend as far as the Damara Orogen in Namibia in the west with the Naukluft nappes being of similar tectonic style and age. Extensive top to the S thrust faulting of similar age is reported in the Zambesi Belt a remnant klippen of unknown age being recognized at Urungwe in Zimbabwe.

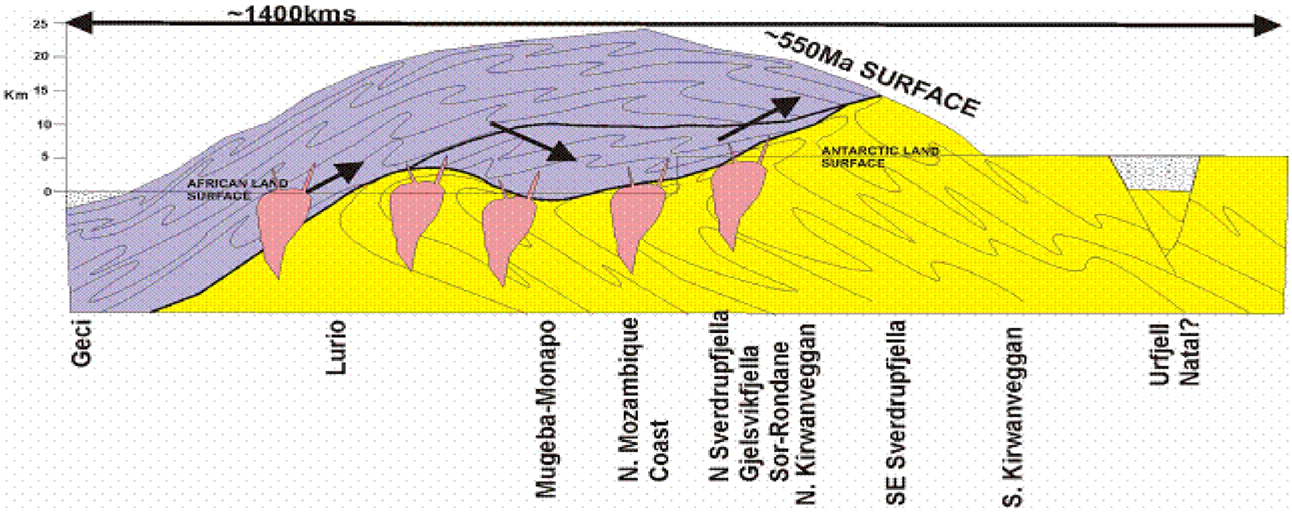

Figure 3. Schematic cross section from northern Mozambique to southern Kirwanveggan. Pale purple=NGB, Yellow=SGB, pink plutons =~495 to 550 Ma granites, and the stippled blocks are relatively undeformed Neoproterozoic sedimentary deposits at Geci in northern Mozambique and Urfjell in southern Kirwanveggan, WDML.

The cross section demonstrates the setting of the post-tectonic 490-550Ma granitic intrusions largely in the footwall rocks but also penetrating into the hanging wall. It demonstrates the D_{1-2} planar structures in the footwall immediately below the main suture being re-oriented by D_3 , resulting in the bimodal patterns recognized nearer the coast in Mozambique and in the northern DML rocks of the SGB. Thermobarometry implies that ~24km of rock, dominantly of NGB age-signature has been eroded from a belt hundreds of kms wide.

The similarity of detrital zircon ages (400-800Ma) in the Urfjell Group, southern Kirwanveggan in southwestern DML, as well as sandstones in the Transantarctic Mountains, Antarctica and in Australia (Veevers et al., 2006), to the zircon-age populations of the NGB suggest that the mountain belt reflected in Figure 3, comprising the Kungu Orogeny of Meert (2003), was eroded and deposited as sandstones in Natal, South Africa, Urfjell in western DML, in Australia and the Transantarctic Mountains. The mega-nappe would also have ensured that the provenence area was significantly closer to the depository, at least when erosion started. It is important to recognize that granite emplacement was progressing at ~6kb in Sverdrupfjella simultaneously with erosion and deposition of sandstone at Urfjell at ~500Ma ~300-kms to the SW. A recent titanite fission track study implies rapid inversion and erosion of the SGB block in Mozambique involving differential uplift of the Mozambique coastline of ~12km over a period of ~60Ma immediately prior to Gondwana breakup which is reflected by Karoo-age andesitic lavas along the coast with ages of ~183Ma.

Implications of this model are that amalgamation of Gondwana first involved E-W collision in the East African Orogen before ~600Ma involving the Congo-Tanzanian-Madagascan-Indian blocks to form northern Gondwana. After this, N-S collision (Kungu Orogeny) occurred between northern and southern Gondwana at ~590Ma (comprising the Kalahari Craton-East Antarctic Craton-Australia).

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