

# An Evaluation of Plate Tectonic Models for the Development of Sumatra

A.J. Barber<sup>1</sup> and M.J. Crow<sup>2</sup>

<sup>1</sup> Southeast Asian Research Group, Department of Geology, Royal Holloway, University of London, Egham, Surrey, TW20 0EX, UK

<sup>2</sup> Formerly British Geological Survey, Keyworth, Nottingham NG12 5GG, UK  
Present address: 28A Lenton Road, The Park, Nottingham NG7 1DT, UK

(Manuscript received March 3, 2002; accepted July 5, 2002)



## Abstract

Over the past two decades models have been developed which suggest that the Asian continent has been formed since the Late Palaeozoic by the accretion of continental blocks derived from the northern margin of Gondwana. Sumatra, forming the southwestern margin of the Southeast Asian promontory (Sundaland), is considered to be composed of fragments of continental plates and magmatic arcs which were derived from Gondwana during the Late Palaeozoic and Mesozoic. The Indochina Block forms the core of Sundaland, extending into the eastern part of the Malay Peninsula. The greater part of Sumatra is considered to form part of the Sibumasu Block which accreted to the Indochina Block along the Bentong-Raub Suture in the Triassic. A model has been proposed in which the southern part of the Sibumasu Block in the western part of the Malay Peninsula, and Sumatra, is divided into Malacca and Mergui Microplates by the Mutus Assemblage which represents another Triassic suture. A review of the Permo-Triassic stratigraphy of Malaya and Sumatra provides no support for this model.

Comparison of the Permo-Carboniferous stratigraphy and palaeontology of northern Sumatra with that of the Malay Peninsula and Peninsular Thailand, and in particular the occurrence of tilloids, links Sumatra firmly to the rest of the Sibumasu Block to the north. Comparison with the Permo-Carboniferous stratigraphy of Bonaparte Gulf region of northwest Australia shows a mirror image relationship, suggesting that the Sibumasu Block separated from this part of the Gondwanan margin in the mid-Permian. On the other hand Permo-Carboniferous rocks in Central Sumatra contain a Cathaysian fauna and flora, which relates this area to the Indochina Block rather than to Sibumasu. This anomaly was recognised early in the study of the geology of Sumatra and led to the proposal of the Djambi Nappe, thrust over Sumatra from the east. The Cathaysian fauna and flora is associated with an Early Permian Volcanic arc. It has been suggested that this was an independent island arc accreted to the western margin of Sibumasu, but from the relationships of the volcanic rocks to Permian sediments and the underlying basement, it is most probable that this arc was developed on the margin of the Cathaysian Block and was emplaced in its present position outboard of Sibumasu by strike-slip faulting. The most recently accreted pre-Tertiary tectonic unit on Sumatra is the Woyla Group, a Jurassic-Early Cretaceous oceanic volcanic arc which, together with its associated accretionary complex of oceanic crustal material, was thrust over the western margin of Sumatra in the mid-Cretaceous. Earlier plate models for the development of Sumatra are reviewed, and a revised model is proposed. However there are still many difficulties in interpreting the stratigraphy and the tectonic development of Sumatra which will require further detailed study, aimed at resolving the many outstanding problems.

**Key words:** Gondwana, Sibumasu, Permo-Carboniferous, Permo-Triassic, Cretaceous.

# Multiple Tectonothermal Events in the Granulite Blocks of Southern India Revealed from EPMA Dating: Implications on the History of Supercontinents

M. Santosh<sup>1</sup>, K. Yokoyama<sup>2</sup>, S. Biju-Sekhar<sup>3</sup> and J.J.W. Rogers<sup>4</sup>

<sup>1</sup> Department of Natural Environmental Science, Faculty of Science, Kochi University, Akebono-cho 2-5-1, Kochi 780-8520, Japan, E-mail: santosh@cc.kochi-u.ac.jp

<sup>2</sup> Department of Geology, National Science Museum, 3-23-1, Hyakunin-cho, Shinjuku-ku, Tokyo 169-0073, Japan

<sup>3</sup> Department of Geosciences, Faculty of Science, Osaka City University, Osaka 558-8585, Japan

<sup>4</sup> Department of Geological Sciences, University of North Carolina, Chapel Hill, North Carolina 27599-3315, USA

(Manuscript received July 12, 2002; accepted October 4, 2002)



## Abstract

We report age data on zircon, monazite, uraninite and huttonite from a suite of 29 samples covering four major granulite blocks in southern India using an electron microprobe technique. The rocks analysed in this study cover all of the major lithounits in these terrains and include garnet-bearing and garnet-free charnockites, garnet-biotite gneisses, khondalites, calc-silicate rocks, and a suite of orthogneisses (biotite gneiss, biotite-hornblende gneiss). Two pink metagranites representing the magmatic phase were also analysed. Zircons from the Madras Block yield well-defined isochrons at 2.5–2.6 Ga. Core to rim analyses of single zircon grains show age zoning with 2.6–2.9 Ga igneous cores mantled by 2.4–2.5 Ga rims. Detrital zircons show age up to ca. 3.2 Ga. Monazites in this block have cores and rims with 2.5–2.3 Ga. A suite of 19 samples from the Madurai Block brings out the multiple tectonothermal events in this terrain. Zircons from an orthogneiss yield well-defined isochrons at  $1.7 \pm 0.1$  Ga,  $0.82 \pm 0.05$  Ga and  $0.58 \pm 0.04$  Ga from core, inner rim and rim portions, respectively. Zircon grains in other rocks preserve either core or secondary growth ages at 0.8–1.0 Ga. Zircons in a pink metagranite from this block show sharply defined isochrons of  $0.68 \pm 0.03$  Ga for the core and  $0.57 \pm 0.01$  Ga for the secondary portion. A late Pan-African overprint is observed throughout this block with zircon rims, monazite, uraninite and huttonite yielding age values in the range of 0.45–0.60 Ga. Zircons from both the Trivandrum and Nagercoil blocks show a major tectonothermal event at 0.55 Ga with faint indications of previous tectonothermal events during 0.8–1.0 and 1.7–2.0 Ga. Monazite data from both the Trivandrum and Nagercoil blocks are essentially similar to those from the Madurai Block except for presence of relic monazite in the former.

Our study confirms the notion that the Palghat-Cauvery Shear Zone marks the major terrain boundary between an Archean craton in the north and Proterozoic terrains in the south. It also strengthens the view of Paleoproterozoic accretion and Pan-African reworking of blocks south of this shear zone. The ages of production, accretion, and reworking in the terrains of southern India yield important information for the histories of Columbia (~1.8–1.5 Ga), Rodinia (~1.1–1.0 Ga), and Gondwana (~0.6–0.5 Ga) supercontinents. The southern Indian terrains formed part of a worldwide network of orogenic belts that is centered around 1.8 Ga and outlines the configuration of Columbia. Accretion of terrains in the Madurai block to Archean rocks north of the Palghat-Cauvery Shear Zone at this time is consistent with the ages suggested to be the oldest metamorphic event in the Eastern Ghats orogen of eastern India and the Rayner belt of coastal East Antarctica. Our data confirm earlier evidence that all of southernmost India underwent resetting of isotopic systems during the final accretion of Gondwana at the time of the Pan-African orogeny (~0.5 Ga). The possibility that the Trivandrum and Nagercoil terrains accreted to the Madurai block after ~0.7 Ga suggests that this Pan-African zone may also have involved accretion and closure of ocean basins. If that happened, then this zone may be the long-sought suture between East and West Gondwana.

**Key words:** Electron microprobe dating, granulite blocks, tectonothermal events, southern India, supercontinent history.

# The Record of the Varanger Glaciation at the Río De La Plata Craton, Vendian-Cambrian of Uruguay

Pablo J. Pazos<sup>1\*</sup>, Leda Sánchez-Bettucci<sup>2</sup> and Ofelia R. Tofalo<sup>1</sup>

<sup>1</sup> Facultad de Ciencias Exactas y Naturales, Área Sedimentología, Universidad de Buenos Aires, Pabellón II, Ciudad Universitaria, CP 1428, Núñez, Buenos Aires, Argentina, E-mail: pazos@gl.fcen.uba.ar

<sup>2</sup> Facultad de Ciencias, Instituto de Geología y Paleontología, Área Geofísica-Geotectónica, Universidad de la República, Iguá 4225, Malvín Norte, Montevideo, Uruguay

\* Corresponding author

(Manuscript received December 3, 2001; accepted May 22, 2002)



## Abstract

A sedimentary succession included in the lower section of the Playa Hermosa Formation from the Playa Verde Basin, Uruguay, is described. Two facies associations, one mainly coarse- to medium-grained and other one fine-grained, have been defined (FA I–II). In the first one, breccias, conglomerates, sandstones and minor mudstones were deposited in a subaqueous depositional setting (proximal) suggesting slope instability and resedimentation processes. The second one contains diamictites, rhythmites, sandstones and mudstones and presents abundant evidence of soft-deformation, also interpreted to be deposited in a subaqueous environment (distal). Dropstones, clast layers, diamictites, rhythmites and varve-like deposits are interpreted as ice rafting processes generated during a glacial episode. This glacial-related succession constitutes the first record from the Varanger glaciation at the Río de la Plata Craton of the late Neoproterozoic age and also represents one of the oldest sedimentary records after the collision of the Río de la Plata and Kalahari Cratons. A combined interaction of extensional faulting and glaciation in a tectonically active basin with locally high subsidence rates, resulted in high rates of sedimentation and resedimentation processes. As a whole, the sedimentary succession sets a relevant datum to be used in future paleogeographic reconstructions of the Vendian glacial record in southern South America.

**Key words:** Vendian, Varanger, Neoproterozoic, glaciation, South America.

# Petrography and Geochemistry of the Carapé Granitic Complex (Southeastern Uruguay)

Leda Sánchez-Bettucci<sup>1</sup>, Pedro Oyhantçabal<sup>1</sup>, Stella Page<sup>2</sup> and Víctor A. Ramos<sup>2</sup>

<sup>1</sup> Facultad de Ciencias, Instituto de Geología y Paleontología, Depto. de Geología, Montevideo, Uruguay,  
E-mail: leda@fcien.edu.uy

<sup>2</sup> Facultad de Ciencias Exactas y Naturales, Laboratorio de Tectónica Andina, Universidad de Buenos Aires, Argentina

(Manuscript received October 22, 2001; accepted September 18, 2002)



## Abstract

The southern sector of Uruguay was intruded by numerous granitic plutons during the Brasiliano Cycle. The granites and granodiorites of the Carapé Complex comprise a large part of the Neoproterozoic terrain exposed in southern Uruguay. Typological and age relationships show that the characteristic of the granitic rocks changed during the Brasiliano Cycle. Four groups of granitoids can be distinguished according to their emplacement. The first group corresponds to the Campanero Unit, interpreted as a pre-Brasiliano basement, which includes mainly preorogenic granites. The second group, Pan de Azúcar and related granitoids, includes synorogenic granites and granodiorites. The third granitoid group, Dos Hermanos Granite and related plutons, is classified as late- to postorogenic granites. Finally, the fourth group, consisting of the Águila Granite and related plutons, is represented by alkaline amphibole-biotite granites and are considered as post-collisional alkaline granites, which we assign to an extensional event associated with post-collisional slab-break off marking the end of the late Proterozoic Brasiliano orogenic cycle. Most of the granitic plutons in this area (2,300 km<sup>2</sup>) are relatively well exposed and have well-defined intrusive relationships with the metamorphic country-rocks. These granitic rocks are the result of successive magma pulses from similar magma chambers through the late Proterozoic to early Paleozoic times.

**Key words:** Granitoids, geochemistry, Brasiliano Cycle, Uruguay, petrography

# Structural Framework of Deolapar Area, Central India and its Implications for Proterozoic Nappe Tectonics

Anupam Chattopadhyay<sup>1\*</sup>, A.K. Huin<sup>2</sup> and A.S. Khan

Geological Survey of India, Seminary Hills, Nagpur - 440 006, India

Present address:

<sup>1</sup> Geochronology and Isotope Geology Division, Geological Survey of India, 15A and B, Kyd Street, Kolkata - 700 016, India, E-mail: anuchatto@yahoo.com

<sup>2</sup> Op. West Bengal, Geological Survey of India, Salt Lake, Kolkata - 700 091, India

\*Corresponding author

(Manuscript received March 16, 2002; accepted September 18, 2002)



## Abstract

A controversial 'nappe-like' structure ('Deolapar Nappe') in the intensely deformed and polymetamorphosed Precambrian rocks of the Sausar Fold Belt around the Deolapar area of Central India has remained the subject of a long-standing, unresolved debate. While some workers interpreted it as the inverted limb of a large-scale recumbent fold which has been thrust onto the adjoining part of the supracrustal sequence (Sausar Group), others discounted the very existence of the nappe because of the lack of structural evidence in favour of the recumbent fold-thrust structure. Recent structural study by the present authors around the Deolapar area and also in the adjoining parts of the Sausar Fold Belt has looked back into the controversy surrounding the Deolapar Nappe. The study reveals that the Deolapar Nappe is constituted of an allochthonous block of metasedimentary rocks and crystalline gneiss-migmatites, placed over the metacalcareous rocks (Lohangi Formation) of the Sausar Group along a low angle thrust plane, marked by a sheared fibrolite-biotite schist. The whole thrust sheet has been folded by later ( $F_2$ ) upright folds. However, careful structural mapping confirmed that there is no evidence of any map-scale  $F_1$  recumbent fold in the whole area, although small-scale, thrust-related reclined ( $F_1$ ) folds are occasionally found. Also, there is not enough field evidence suggesting regional inversion of stratigraphic succession so as to indicate the lower limb of a recumbent fold. The Deolapar Nappe can therefore be best interpreted as a thrust-nappe. Details of the existing controversy, the new observations and a new tectonic model of the Deolapar Nappe is presented here.

**Key words:** Sausar Group, Deolapar Nappe, allochthon, thrust tectonics, Proterozoic.

# Geological Factors and Evolution of Southwestern Gondwana Triassic Plants

L.A. Spalletti<sup>1,3</sup>, A.E. Artabe<sup>2,3</sup> and E.M. Morel<sup>2,4</sup>

<sup>1</sup> Centro de Investigaciones Geológicas, Universidad Nacional de La Plata - CONICET. Calle 1 nro. 644, 1900 La Plata, República Argentina, E-mail: spalle@cig.museo.unlp.edu.ar

<sup>2</sup> Departamento de Palaeobotánica, Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, Paseo del Bosque s/n, 1900 La Plata, República Argentina, E-mail: aartabe@museo.fcnym.unlp.edu.ar, emorel@museo.fcnym.unlp.edu.ar

<sup>3</sup> CONICET, República Argentina

<sup>4</sup> Comisión de Investigaciones Científicas de la Provincia de Buenos Aires, República Argentina

(Manuscript received May 16, 2002; accepted October 15, 2002)



## Abstract

A synergistic model based on reciprocal influences between biotic and abiotic factors is developed for the Triassic of southwestern Gondwana. Changes in physical environment exerted a strong influence on the characteristics and evolution of plant assemblages. The Permian-Triassic extinction, and the change from palaeophytic to mesophytic floras, is one of the most striking examples of direct influence of physical environment upon plant communities. Pangea coalescence, the distribution of land masses and seas, the spreading of continental climates (megamonsoonal conditions) and the waning polar glaciation determined the expansion of xeromorphic morphotypes that became dominant during the whole Mesozoic. In southwestern Gondwana, the introduction or invasion of immigrant lineages suggests a strong asymmetrical interchange from the Euroamerican realm to the Gondwana realm. In addition, generalised extensional volcanism, development of intracratonic rifts and the palaeolatitudinal location of climatic zones during the early-Middle Triassic favoured extinction of the *Glossopteris* flora and explosive diversification of endemic groups.

From the chronological viewpoint, the Barrealian, Cortaderitian and Florian stages are recognised in the Triassic of southwestern Gondwana. These stages are respectively characterised by: (a) appearance of mesophytic elements, and coexistence of Palaeozoic and Mesozoic groups, (b) maximum diversification of the *Dicroidium* flora, and (c) *Dicroidium* flora decline and replacement by morphotypes with strong Jurassic affinity. These palaeofloristic changes seem to be strongly influenced by tectonic evolution of sedimentary basins, temporal and regional distribution of sedimentary environments, and intra-Triassic palaeoclimatic change.

**Key words:** Triassic, Gondwana, environments, palaeobotany, synergism.