Gondwana Research, V. 5, No. 3, pp. 581-589.

ISSN: 1342-937X

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Granitoid Series in Terms of Magnetic Susceptibility: A Case Study from the Barberton Region, South Africa

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(Manuscript received November 29, 2001; accepted April 2, 2002)

Abstract

Magnetic susceptibilities were measured on a representative collection of Archaean granitoids of the Barberton region using a portable KT5 magnetic susceptibility meter. The studied granitoids comprise, (1) syn-tectonic tonalite-trondhjemite-granodiorite (TTG) granitoids (132 samples), (2) late-tectonic calc-alkaline granitoids (402 samples) and (3) post-tectonic low-Ca and high-Ca granitoids (12 samples). Most of the early-stage syn-tectonic granitoids (~3450 Ma) have low magnetic susceptibilities, less than 3 x 10^{-3} SI units, and correspond to ilmenite-series granitoids. The late-stage Kaap Valley tonalite pluton (~3230 Ma) contains sporadically distributed higher magnetic susceptibility values (greater than 3 x 10^{-3} SI units), which are less than one-third in magnetic susceptibility of typical magnetite-series TTG of the Japanese Island Arc and thus strictly belong to an intermediate series. The Barberton TTG suite is essentially derived from reduced amphibolitic lower crust that reflects the anoxic nature of the Earth surface during the Archaean Eon. The more oxidized nature of the Kaap Valley tonalite may be generated in an oxidized lower crust by fluids squeezed out of the subducting plate.

Late-tectonic granodiorite – adamellite batholithic complexes (~3105 Ma) belong mostly to the magnetite series, and seem to suggest that relatively oxidized continental crust, reflecting oxic atmosphere and subduction mechanism operating, had evolved it by this time. Post-tectonic granitic plutons formed largely between circa 2900 Ma and 2700 Ma can be subdivided into low-Ca ilmenite series and high-Ca magnetite series.

Key words: Barberton, magnetic susceptibility, magnetite series, ilmenite series, tonalite-trondhjemite-granodiorite (TTG).

Gondwana Research, V. 5, No. 3, pp. 591-596.

ISSN: 1342-937X

GR Gondwana Research

Did South America and West Africa Marry and Divorce or Was it a Long-lasting Relationship?

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(Manuscript received April 3, 2002; accepted May 24, 2002)

Abstract

The 2.1–2.0 Ga Transamazonian orogen in South America can be well correlated with the 2.1–2.0 Ga Eburnean orogen along the western margin of West Africa. Both the orogens are characterized by early tangential tectonics, marked by large-scale thrusts and sinistral strike-slip faults, followed by later transcurrent tectonics, marked by dextral shear zones. Metamorphic evolution of the two orogens involved an initial phase of crustal thrusting and thickening, followed by exhumation and final cooling. These suggest that South America and West Africa may have been jointed along the Transamazonian-Eburnean orogen at 2.1–2.0 Ga. This is supported by the presence of ~2.0 Ga fluvio-deltaic formations in nearly every craton in South America and West Africa. The available Paleomagnetic data also indicate that between 2.1–1.5 Ga, coeval rocks in West Africa and South America recorded similar polar wander paths. If South America and West Africa remained coherent from their amalgamation at 2.1–2.0 Ga until their incorporation into Gondwana at 0.6–0.5 Ga, the positions of South America and West Africa in the present configurations models of Rodinia need to be re-evaluated, since these configurations did not bring the two blocks into close proximity.

Key words: South America, West Africa, collisional orogeny, Gondwana, Rodinia.

Gondwana Research, V. 5, No. 3, pp. 683-699.

ISSN: 1342-937X

GR Gondwana Research

Facies Associations and Discontinuous Surfaces in the Syringothyris Limestone Formation of Tethyan Margin of Gondwana, Kashmir

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(Manuscript received August 17, 2001; accepted April 10, 2002)

Abstract

The early Carboniferous sedimentation of the Tethyan Margin of Gondwana in the Kashmir Himalaya represents alternating siliciclastic - carbonate succession consisting of distinct stratigraphic sequences which are bounded by discontinuities. The discontinuities in the sedimentation are related to environmental changes in the form of subaerial exposure, subaqueous erosion, subaqueous omission or changes in texture and facies. These distinct surface zones or time significant boundaries can be correlated across the depositional platform. Low stand, high stand and transgressive sedimentation units in the lower and middle parts of early Carboniferous Syringothyris Limestone Formation in Banihal area have been recognised. This is explained by superposition of high frequency and low amplitude sea level fluctuations on a large-scale trend under greenhouse conditions during the early Carboniferous period. The facies associations present in the early Carboniferous succession of the Himalaya broadly represent intertidal (peritidal), shallow subtidal, deeper subtidal, off-shore-slope and deeper environments. Discontinuities that are interpreted as progradational, retrogradational and aggradational phases of sedimentation bound these facies associations. This formation represents continental margin depositional setting which is authenticated by deposition of siliciclastic sediments. This marginal depositional setting is greatly affected by numerous dynamic processes including tectonic and other active sea as well as continental processes. The records of all those processes in this formation reflect the eustatic changes in sea level. These periodic eustatic changes have generated the various discontinuities, stratigraphic sequences or systems tracts. Overall it appears that interplay of many processes such as sediment supply, thermal and tectonic activity, eustatic and climatic changes in the Kashmir Tethyan depositional basin generated these distinct depositional sequences during the early Carboniferous period.

Key words: Syringothyris Limestone, discontinuous surfaces, sequence stratigraphy, Carboniferous, Tethys Himalaya.

Gondwana Research, V. 5, No. 3, pp. 667-681.

ISSN: 1342-937X

GR Gondwana Research

A-Type Post-Collisional Granites in the Borborema Province – NE Brazil: The Queimadas Pluton

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(Manuscript received October 15, 2001; accepted April 8, 2002)

Abstract

The Queimadas Pluton constitutes an E-W elongated tabular intrusion, exposed over an area of 50 km^2. It is intruded in Paleoproterozoic gneiss–migmatite of the Alto Pajeú Terrane in the Central Tectonic Domain of the Borborema Province, and has a zircon U–Pb age of 570±20 Ma. It is cut by later shear zones with NNE direction, which provoked necking and disruption in the body. A suite of biotite±amphibole monzogranites, associated with quartz diorite and later leucogranite and diabase, dominates in these alkaline granites that are metaluminous to slightly peraluminous and show high FeOt/(FeOt + MgO) and K_2O/Na_2O ratios. Their REE patterns are moderately fractionated, with $(Ce/Yb)_N$ ratios of 10–16 and significant negative Eu anomalies (Eu* = 0.40–0.67). Geochemical and Nd isotopic data indicate that the Queimadas Pluton magma originated by partial melting of a crustal fertile granodioritic rocks. The studied granites crystallized under relatively low fO_2 and are A-type post-collisional granitoids.

Key words: Alkali granite, geochemistry, U–Pb geochronology, post-collisional, Neoproterozoic.

Gondwana Research, V. 5, No. 3, pp. 649-665.

ISSN: 1342-937X

GR Gondwana Research

Basalts of the Eastern Deccan Volcanic Province, India

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(Manuscript received September 4, 2001; accepted April 5, 2002)

Abstract

The Mandla lobe in the eastern part of the Deccan volcanic province represents an isolated lava pile having a thickness of ~900 m. The large thickness of this lava pile and its spatial detachment from the western Deccan outcrop points to a plausible second source. The stratigraphic configuration of the central and eastern Deccan lava sequences and their possible stratigraphic correlation are primarily based on geology and chemical signatures of the lava flows. Based on variations in the incompatible element ratios, the lava sequences of Chindwara, Jabalpur-Seoni and Jabalpur-Piparia sections were classified into four informal formations showing similarity with the southwestern formations. Major and trace element abundances in fifteen lava flows of Jabalpur area are similar to that of the southwestern Deccan lava flows. It has been found that the Ambenali Fm. and a few Khandala and Bushe Fm. flows are present in the northeastern Deccan. The regional mapping and detailed petrographic studies coupled with the lateral tracing have enabled the recognition of thirty-seven physically distinct lava flows and is justified by their major-elemental chemistry. The 'intraflow variations' studied in some of the flows is very low for most of the major oxides. These thirty-seven lava flows are grouped into eight chemical types. The order of superposition in this sequence reflects that the older flows occur in the west of the outlier at the Seoni-Jabalpur-Sahapura sector whereas, the younger flows are confined to the Dindori-Amarkantak sector in the east. The spatial disposition of the lava flows suggests that the structural complexity in the lava flow sequence in the Mandla lobe lies between Jabalpur and Dindori. The juxtaposition of distinct groups of lava flows are observed near Deori (flows 1 to 4 abeted aginst flows 5 to 14) and Dindori areas. At Dindori and towards its south the distinct lava packages (flows 15 to 27 and flows 28 to 37) are juxtaposed along the course of Narmada river. The possible explanation for this could be the presence of four post-Deccan faults at Nagapahar, Kundam, Deori and Dindori areas. The vertical shift of chemically distinct lava packages at different sectors in the outlier contravenes the idea of small regional dip and favours the presence of four NE-SW trending post-Deccan faults. Major geochemical breaks, when traced out from section to section, exhibit shifting in heights by approximately 150 m near Nagapahar and 300 m near Deori and Dindori areas. The field, petrographic and major-oxide data sets considered in conjuction with the magnetic chron reversal heights, support the inference that four faults trending NE-SW are present in the Mandla lobe.

A commonality in the mineralo-chemical attributes of the infra (Lametas)-/inter-trappean as well as weathered Deccan basalt further favours their derivation from Deccan basalt, implying the availability of Deccan basalt during the Maastrichtian Lameta sedimentation. This observation does not match with the models suggesting an extremely short duration of Deccan volcanism (<0.5 Ma) at the KTB, but is congruent with the models advocating a more prolonged Deccan volcanism.

Key words: Major-oxide, eastern Deccan volcanic province, lava-flow stratigraphy, N-R-N chron, Cretaceous-Tertiary Boundary.

Gondwana Research, V. 5, No. 3, pp. 641-647.

ISSN: 1342-937X

GR Gondwana Research

Analogue Sandbox Models of Thrust Wedges with Variable Basal Frictions

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(Manuscript received September 20, 2001; accepted April 4, 2002)

Abstract

Scaled analogue sandbox models have been used to simulate the growth of Coulomb thrust wedges in isotropic cohesionless and anisotropic cohesionless materials. Variations in the basal coefficient of friction by using different materials as basal detachments, combination of basal detachments and the anisotropy of the layered system have been investigated. Imbricate fans of dominantly foreland-vergent thrust systems are developed in the way similar to those developed in accretionary prisms and in foreland fold and thrust belts. Critical-taper wedges close to theoretically predicted geometries are developed for intermediate values of basal friction ($\mu b = 0.47$), whereas for the lower value of basal friction ($\mu b = 0.37$), low-taper wedges are formed with slopes less than the theoretically predicted. Supra-critical wedges are formed when the high basal friction ($\mu b = 0.55$), is either equal to or greater than the coefficient of friction of the deforming material in the wedges. Then the wedges have a high taper angle close to the angle of rest for the modelling material. Similar geometries developed when the experiments were carried out on combination of two materials with basal frictions as: intermediate-low, low-intermediate and low-high. The spacing of thrust faults increases with increased basal friction. Higher basal friction or anisotropy within the layered systems favours displacement along foreland-vergent thrusts and eventually checks backward breaking thrusting.

Key words: Analogue sandbox models, thrust wedges, basal frictions, back thrusts, fold-thrust belts.

Gondwana Research, V. 5, No. 3, pp. 619-640.

ISSN: 1342-937X

GR Gondwana Research

Palaeoenvironmental Framework of the Glacial-Postglacial Transition (Late Paleozoic) in the Paganzo-Calingasta Basin (Southern South America) and the Great Karoo-Kalahari Basin (Southern Africa): Ichnological Implications

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(Manuscript received November 19, 2001; accepted March 14, 2002)

Abstract

Sedimentological, palaeontological and geological data from the glacial to postglacial transition in the late Paleozoic successions of the Paganzo-Calingasta Basin (PC) in southern South America and the Great Karoo-Kalahari Basin (GKK) in southern Africa are analysed, revised and reinterpreted. A brackish depositional setting is inferred for main areas previously considered to be nonmarine based upon ichnological interpretations. Three stratigraphic intervals have been defined based on changes in sedimentary facies and trace fossils association: The glacial interval (GI), early postglacial interval (EPI) and late postglacial interval (LPI). The GI and EPI contain a dominance of arthropod trackways, fish trails with and subordinate grazing and feeding traces. The EPI in the PC Basin comprises both nonmarine and brackish-marine ichnocoenoses without significant differences in ichnological composition. Trace fossils are preserved in underflow and turbidite beds of deltaic deposits. Opportunistic grazing traces constitute a post-event ichnocoenosis, while a pre-event ichnocoenosis is preserved at the base of turbidite beds. In the GKK Basin ichnofossils were documented in turbidite fans. The LPI in the GKK Basin contains the first evidence of shallow water deltaic infauna and subordinate grazing traces. Conversely, in the PC Basin the infauna is lacking.

The GI and particularly the EPI ichnofauna resemble the nonmarine *Mermia* ichnofacies but they occur in large and long-lived stable marine basins which received enormous inputs of melt-water that markedly reduced the salinity. They are not ichnologically comparable with brackish marginal marine environments that are affected by frequent, sometimes diurnal, fluctuations in physical parameters such as salinity and temperature. The LPI in the GKK Basin constitutes a typical record of the classical marginal marine ichnofaunas, but in the PC Basin the ichnofacies assignment is problematic. Grazing traces of the *Mermia* ichnofacies appear in middle estuarine deposits where both palynomorphs and the presence of tidal features suggest brackishness. The Paganzo Basin ichnology, therefore shows some difficulties in differentiating nonmarine from subtle brackish environments without the full integration of sedimentological information. Ichnocoenoses dominated by trackways of arthropods are particularly inappropriate to distinguish between these types of depositional settings.

Key words: Gondwana, ichnofacies, brackish, nonmarine, glacial.

Gondwana Research, V. 5, No. 3, pp. 613-618.

ISSN: 1342-937X

GR Gondwana Research

Seismic Signature of Sub-Trappean Gondwana Basin in Central India

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(Manuscript received October 30, 2001; accepted February 14, 2002)

Abstract

The digitized and trace normalized record sections of original analog Deep Seismic Sounding (DSS) data collected along the Multai-Pulgaon profile, have been re-interpreted to find basement and intra-basement structure in the area between the Satpura basin and the Pranhita-Godavari Gondwana graben in Central India. It is found that the data are best satisfied by a model with a low velocity zone in between the Deccan Traps and the basement. The study delineates a basement fault that could be associated with the known Gavaligarh-Salbardi lineament. Low velocity sediments (V_p = 3.7 km/s) delineated from the present study could be Gondwana sediments, which have been reported in surrounding areas. This finding indicates the possible extension of Gondwana formations of the Pranhita-Godavari graben to the Satputra basin through the Wardha valley.

Key words: Travel time skips, sub-trappean sediments, low velocity layer, Satpura Gondwana, Narmada-Son lineament.

Gondwana Research, V. 5, No. 3, pp. 597-611.

ISSN: 1342-937X

GR Gondwana Research

Geochemistry and Geochronology of a Neoproterozoic Low-K Tholeiite-Boninite Association in Central Eritrea

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(Manuscript received June 15, 2001; accepted December 5, 2001)

Abstract

The N-S trending Neoproterozoic volcano-sedimentary-plutonic associations in Eritrea are part of the Arabian-Nubian Shield. In Central Eritrea, the dominant rocks are low-grade supracrustal volcanic rocks with subordinate sedimentary rocks. They are intruded by pre- to syn-kinematic diorites and tonalites, as well as late- to post-kinematic granites. The low-K tholeiitic metavolcanic rocks range in composition from basalt to rhyolite. The low-K tholeiites (K_2O = 0.03–0.40 wt.%) represent parental magma (Mg# from 0.46 to 0.71, average 0.63) and are characterized by relatively high abundances of MgO (5–11 wt.%), Cr (174–874 ppm) and Ni (28–249 ppm), as well as low abundances of HFSE (TiO_2 = 0.43–0.69 wt.%, Zr = 15–36 ppm, and Y = 8–20 ppm). A chondrite-normalised REE pattern for a tholeiite is depleted (Ce/Yb_N = 0.2). The low-K tholeiites have trace element characteristics and MORB-normalized geochemical patterns that are similar to those of modern arc lavas. Plotting of the intermediate to felsic metavolcanic rocks on various discriminant diagrams also indicates that the metavolcanic rocks are the result of plate-margin volcanism. The geochemical data, together with the low-K tholeiite-boninite association, indicate that the metavolcanic rocks were emplaced in an environment similar to a modern oceanic island-arc (fore-arc) setting.

In comparison to the boninites from this region, the low-K tholeiites have low abundances of LILE and HFSE, lower ratios of the more to the less incompatible elements, and higher initial ε_{Nd} values. The low-K tholeiites are also characterized by higher total FeO contents and relatively lower contents of refractory elements than is observed for the boninites. This may suggest that the low-K tholeiitic rocks were derived by a relatively lower degree of melting from a more depleted mantle source than the boninites.

SHRIMP U–Pb isotope analyses of zircons from a pre- or syn-kinematic tonalite yielded a concordant age of 813±9 Ma. This age is similar to the crystallization age of a pre-/syn-kinematic diorite from the same region and is interpreted to approximate the time of major magmatism in Central Eritrea. Magmatic zircons from a late to post-kinematic granite yielded a concordant U–Pb age of 585± 6 Ma. These results indicate that the crust of Central Eritrea was formed between ca. 600 and 850 Ma. These ages are comparable to those of northern Eritrea and adjacent juvenile terranes in the Nubian Shield.

Key words: Geochemistry, low-K tholeiite-rhyolite suite, Neoproterozoic, Eritrea, Arabian-Nubian shield.

Gondwana Research, V. 5, No. 3, pp. 701-719.

ISSN: 1342-937X

GR Gondwana Research

Multi-Stage Deformation in the Nallamalai Fold Belt, Cuddapah Basin, South India – Implications for Mesoproterozoic Tectonism Along Southeastern Margin of India

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(Manuscript received June 22, 2001; accepted April 18, 2002)

Abstract

The common occurrence of small-scale refolded folds, deformed lineations and overprinting of foliation in the northern Nallamalai Fold Belt (NFB) within the intracratonic Cuddapah Basin, South India, suggest three phases of deformation, D_1, D_2 and D_3 during the late Paleoproterozoic to Neoproterozoic. D_1 structures are represented by tight to isoclinal folds, a slaty cleavage and local development of mylonites. D_2 structures include NE trending tight to open folds (F_2) with variable plunge indicating control of large domal structures and a steep crenulation cleavage developed in phyllites and other schistose rocks. The above structures are overprinted by E-W trending D_3 folds and cleavage, which affect Mesoproterozoic rocks of the Srisailam Formation (uppermost Nallamalai Group) in the E-W trending Vami Konda range and metasediments of the Palnad area, thought to be equivalent of the Neoproterozoic Kurnool Group. Taking into account the ages of intrusive Vellaturu Granite (~1575 Ma) which is post-D_2 deformation in the NFB and the Chelima Lamproite (~1400 Ma) which intrudes the folded Nallamalai rocks, we suggest that the earlier episodes of multiple deformation in the NFB represent either late Paleoproterozoic or early Mesoproterozoic NW-SE compression in this part of the East Gondwana. The E-W fold-thrust structures affecting the Srisailam Quartzite and adjacent metasediments in the Palnad area represent late Mesoproterozoic and/or Neoproterozoic event. The granite gneisses and schists of the Nellore Schist Belt, bordering the NFB are affected by both early and later events and thrust over rocks of the Nallamalai Group.

We propose that early deformation in the NFB lying southwest of the Eastern Ghats and roughly parallel to the present southeastern coast of India, was unrelated to, and occurred prior to the main deformation in the Eastern Ghats, which is generally correlated with the ~1000 Ma old Grenville event. Alternatively, in view of the complex, protracted evolution of the Eastern Ghats and published geochronological data supporting pre-Grenvillian tectonism particularly in the Western Charnockite Zone of the Eastern Ghats, D_1 and D_2 deformation in the NFB may be linked to this older (1600–1400 Ma) tectonic disturbance in the Eastern Ghats.

Key words: Cuddapah basin, Eastern Ghats, Nallamalai Fold Belt, Proterozoic, multiple deformation.