The Indian Continental Crust and Upper Mantle: In honour of T. M. Mahadevan (International Association for Gondwana Research Memoir 10). C. Leelanandam *et al.* (eds). International Association for Gondwana Research, Department of Natural Environmental Sciences, Kochi University, Akebono-cho 2-5-1, Kochi 780-8520, Japan. 2007. 298 pp. Price not mentioned.

This Memoir is dedicated to T. M. Mahadevan on his 80th birthday and is a fitting tribute to a person who has devoted six decades in various fields of geological science and, in particular, for his deep and steadfast devotion to deep continental studies. He has played a key role in the formulation of major programmes towards achieving this under the patronage of Department of Science and Technology, Government of India. The Memoir, which presents some of the outstanding results of two decades of implementation of these programmes by many national institutions of the country, is indeed a good testimony to his endeavour towards fulfillment for an integration of geology, geochemistry and geophysics that can make 'every branch of earth science, especially modeling earth processes, far more realistic, exciting and absorbing'.

The twenty-one contributions in this Memoir bring out a clear exposition of various magmatic, sedimentary, metamorphic and tectonic events, from the Archaean to the Phanerozoic that had shaped the Indian continental lithosphere. Besides the conventional approaches through geology and geochemistry, a large segment deals with a variety of geophysical studies addressing geodynamics, lithospheric inhomogeneities, lithospheric architecture and mantle stratigraphy, collisional tectonics, tectonic and thermal histories of cratonic and mobile-belt areas leading to better insights into the geological evolution of the Indian continental crust and upper mantle. Excellent explanatory figures or maps, computer graphics and clearly reproduced photomicrographs, many of them in colour, make these contributions better understood. On the whole, the Memoir reflects the painstaking efforts the editors must have taken in bringing out such a well-planned and properly executed issue.

In the opening paper, Mahadevan consolidates multidisciplinary data available on various tectonic and magmatic episodes of early Archaean to late Phanerozoic geologic history of the Indian Shield and traces a plausible model of evolution of the deep-rooted sub-continental lithospheric mantle (SCLM). He has traced the evolution of the deep-rooted SCLM and envisages the overprinting of Proterozoic–Phanerozoic mantle regimes on an Archaean lithosphere. Notable inferences made include the lowering of lithospheric thickness with time, progressive enrichment of initially depleted SCLM through asthenospheric fluids even as early as the Late Archaean in some areas, lithospheric underplating with basaltic material leading to increase in density and heat flow, and a build-up of heterogeneity in the lithosphere through lithosphere–asthenosphere interactions during Proterozoic–Phanerozoic.

The next two papers highlight the evolution of the mosaic of cratonic bits that formed the northern Indian Shield around 3300 Ma. S. Sinha-Roy sums up the diverse geological evolution of the Greater Bundelkand blocks between 2.8 and 0.5 Ga, and development of the Bundelkhand and Mewar terrains, fold belts of Aravalli, Delhi and Marwar, and the products of crustal interactions between Mewar and Marwar. He recognizes through seismic reflection profiles across these terrains, several crustal-scale structures and exhumed tectonic wedges. R. S. Sharma dwells on the geodynamics of the evolution of fold belts in Central India – Mahakhosal (MFB), Satpura (SFB), Dongargarh (DFB) and Sakoli (SKFB), all developed within intracontinental settings and subjected to magmatic episodes and deformation during 1800–1000 Ma. He proposes a geodynamic model of evolution based on a pre-existing Rajasthan–Bundelkhand–Bastar craton that evolved sequentially through the DFB, MFB, SFB and SKFB orogenies.

In a detailed study of the ultrahigh-temperature metamorphic granulite facies rocks of the South Indian Madurai terrain bounded by the intracontinental Palghat–Cauvery and dissected by the Achankovil shear zones, T. Tsunogae and M. Santosh trace the *P–T* paths of exhumation of the mid-to-lower crustal rocks based on mineral equilibria and CO_2 fluid inclusions. Peak metamorphic temperature of 900–1000°C and pressures of 8–12 kbar are inferred. The thermal events of 550–600 Ma are arrived at by high-precision zircon and monazite dating and placed in the Neoproterozoic–Cambrian time-span, constraining the assembly of the Gondwana supercontinent. The geology along the Nubra and Shyok rivers in the Cretaceous Karakoram shear zone, the intra-oceanic arc-type volcanism arising from the closure of Tethyan Ocean along the Shyok suture zone and their mineralogy are described by A. K. Jain *et al.* They have correlated the tectonic events with SHRIMP–U–Pb dates and deduced the poly-chronous trends in the Indo-Asia convergence process and its associated magmatic and metamorphic episodes.

C. Leelanandam and K. Vijaya Kumar throw light on the chromitites and chromite-bearing ultramafic cumulates within the Kondapalli Layered Complex, Eastern Ghats belt, products of crystallization from a Mg-rich basaltic magma. They consider the layered complex to be derived from an Andean-type continental magmatic arc-related environment and that these cumulates and chromitites belong to plutonic arc-root complex. J. Ratnakar brings out lithospheric control on the Mesoproterozoic–Neoproterozoic alkaline magmatism in Orissa, Andhra Pradesh and Tamil Nadu. Eight major nepheline syenite complexes occurring within the coastal and southern granulite terrains investigated have a 'miaskitic' character and have evolved by low-degree partial melting of a thick metasomatically enriched SCLM.

Three papers that follow deal with the southern and Central Indian kimberlites. N. V. Chalapathi Rao highlights the significance of kimberlite studies in unravelling the nature and evolution of the SCLM beneath the Dharwar, Bastar and Bundelkhand cratons. He highlights the deep lithospheric sources for most of the ultrapotassic rocks emplaced in the Dharwar craton; existence of >2 Ga anomalously enriched metasomatized mantle beneath the Eastern Dharwar craton, the large span of time of their emplacement (1150–1400 Ma) that negates a plume concept, the distinctions between the cratonic kimberlitic rocks and the alkaline rocks of the Eastern Ghats mobile belt in terms of distinct geodynamic regimes; the uniqueness of the Central Indian Majhgawan and Hinota kimberlites and evidences within the Bastar craton for early Phanerozoic kimberlites, consistent with a Pan-African tectono-thermal event. S. Ravi *et al.* explain the petrogenesis of kimberlites of Wajrakarur, Narayanpet, Raichur and Tungabhadra areas from studies on mafic xenoliths (garnet pyroxenite and eclogite ± kyanite ± enstatite) and Cr-spinel macrocrysts. They propose a magmatic cumulate origin under high-pressure conditions through mineral chemistry, geothermobarometry and REE geochemistry. In a detailed study of the mafic xenoliths from the Kutch (spinel peridotite) and Murud-Janjhira areas (granulite, pyroxenite) in the western Indian volcanic province, N. R. Karmalkar *et al.* comment on their lithospheric source, the existence of contrasting geotherms at Kutch and Murud-Janjhira, the influence of dyke-swarms of the west coast on the thermal regimes, and the possible role of the Reunion plume in shaping these features, and through geophysical studies, the presence of a sharp Moho at shallow depths in Kutch.

Geophysical studies of the Indian lithosphere and its complex geodynamics are covered in the next ten papers. Deep continental reflective and refractive seismic investigations by B. Rajendra Prasad and V. Vijaya Rao, depict the features of the crust and the lithospheric mantle below the Indian shield. They stress the usefulness of high-resolution seismic images in understanding Moho and orogenic signatures, delineation of basement profiles of sedimentatry basins and deep-seated geological processes. A. S. N. Murty and P. R. Reddy review the crustal inhomogeneities, as reflected in the seismic velocity structure and seismicity occurring along important fault zones, rifts and contacts of different lithological units in the Peninsular shield. They discuss the relationship of shallow and deep focal earthquakes with respect to seismogenic layers and seismic inhomogenities. Microseismic aftershock investigations by J. R. Kayal throw light on the on-going processes at the seismic source areas, such as fault planes or fault ends of palaeo-rifts, basement thrusts and subduction zones of the strong earthquakes in the last sixteen years in the three major tectonic zones, viz. Central India (Killari, Jabalpur, Bhuj), Himalayan collisional zone (Uttarkashi, Chamoli) and Andaman-2004 tsunami earthquake.

D. S. Ramesh and Prakash Kumar, in a significant contribution related to seismic methodology, focus on the limitations of surface and *P*-wave inversions to unravel the much needed information of layering in the depth span of 100–300 km, critical to understanding several earth processes from a well-delineated mantle stratigraphy. They argue for complimenting of *P*-to-*S* receiver function data with other methods and notably *S*-to-*P* converted waves to overcome constraints imposed by the physics of the seismic waves. They illustrate the potential of such application by revisiting several tectonically diverse regions to find answers to several important questions related to earth processes. The questions addressed include the basic Precambrian crust–mantle configuration, 'hotspot' modification of such configuration, temporal character of the lithosphere–asthenosphere boundary, and upper-mantle stratification/discontinuities in space and time. K. Arora *et al.* make an assessment of gravity signatures along with geological data of the Western Dharwar craton and the Satpura Mobile belt to explain the Archaean and Proterozoic plate-tectonic analogues. They find characteristic density profiles for the granite–greenstone and mafic to ultramafic terrains, for regions of collisional tectonics and rifting prior to collision and also for sedimentary marine settings. Based on low-pass filtered magnetic data and joint modelling of gravity and magnetic data along a 600 km long E–W trending transect in the northern portion of the Dharwar craton, G. Ramadass *et al.* examine the various major, deep-seated faults of this craton and suggest an intervening additional or third-block stretching between Bababudan–Nallur shear and the western margin of the Closepet batholith.

The analytic signal map generated from earlier aeromagnetic surveys has been applied by S. P. Anand and Mita Rajaram to trace the structural, tectonic and thermal histories of the Dharwar, Bastar and Singbhum cratons They address the spatial distribution, nature and relative depths of the magnetic sources in these cratonic areas and adjoining mobile belts, the block structures and fractured nature of the regions, the Curie isotherm depth and heat flow. Dealing with the results of aeromagnetic telluric investigations, R. K. Sinharay *et al.* conclude that the source of high heat flow in the helium-rich Bakreshwar Hot Spring, in West Bengal, is not in the vicinity of the hot spring but lies deeper, and that the nearby N–S fault serves only as a feeder channel.

T. Harinarayana sums up the results of the magnetotelluric investigations by the National Geophysical Research Institute, Hyderabad on the electrical structure of the upper and lower crusts along important tectonic zones of the country. He distinguishes between older and younger crusts based on their resistivity values and shows how these crustal differences are correlatable with temperature, composition, presence of fluids, free carbon, and the cratonic nature or evolution of this crust. U. Raval and K. Veeraswamy integrate the available multidisciplinary geological data with electrical conductivity, gravity and heat-flow data of the Greater Bundelkhand and Greater Dharwar terrains and propose likely models for the accretionary growth of these early Indian protocontinents and the diverse Phanerozoic geodynamics arising from the Pan-African metamorphism, Gondwana tectonics, Asia–India collisional tectonics and plume-related tectonics of Reunion and Kerguelen plumes.

R. Dhana Raju sums up the findings of over five decades of India's exploration for atomic minerals, and draws inferences from uranium metallogeny on the evolution of Indian continental crust. After highlighting the various models of radioactive mineralization and the associated rare metals in the Indian crust, he points to the existence of a broad pattern of uranium metallogeny in the Palaeoarchaean and Proterozoic crusts

A. V. SANKARAN

No. 10, P&T Colony,
I Cross, II Block,
R. T. Nagar,
Bangalore 560 032, India
e-mail: av.sankaran@gmail.com