Chapter 1

Precambrian basins of India: stratigraphic and tectonic context

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The Indian shield represents a vast repository of the Precambrian geological record. The Precambrian sedimentary basins were developed on four major Archaean nuclei (Dharwar, Bastar, Singhbhum and Aravalli–Bundelkhand; Fig. 1.1) and are comparable to those of Australia, South Africa, Canada and Brazil in scale and importance for global studies of Precambrian crustal evolution. Some of the Indian basinal successions, as elsewhere, contain valuable economic resources. Notwithstanding their global relevance, many aspects of the Indian Precambrian basins and even entire basins are not well known to international readers. Although specialist papers, a book (Naqvi & Rogers 1987) and special publications (e.g. Mazumder & Sa ha 2012) have been written by several authors on specific aspects of the Precambrian geology of India, a comprehensive attempt over the time–space distribution of the Precambrian supracrustal successions is lacking; in particular, the interrelation between tectonics and sedimentation, and the similarities and dissimilarities of their evolutionary histories with other comparable successions in other parts of the world are yet to be addressed in any detail. The purpose of the present memoir is to fill in this knowledge gap. In addition, the memoir will assess the potential mineral resources of Indian Proterozoic basins and integrate piecemeal information to provide a comprehensive picture of Indian cratonic evolution during the Precambrian.

The content of the memoir has been divided into six sections; the first gives an overview of basin classification and of the evolution of Peninsular India during the Precambrian, to provide a framework for the following four sections. The latter are devoted to basins preserved in the four Archaean nuclei or cratons that make up the subcontinent. The sixth section addresses Precambrian mineralization of the cratons and is completed by a synthesis of basin evolution of Peninsular India as compared with the internationally accepted basin classification framework. The first section begins with an overview (Allen et al. 2015) on the classification of sedimentary basins with examples from Proterozoic basins of major cratonic blocks of the world. While presenting an authoritative discussion of the basin, strengths and weaknesses of the many classification schemes, these authors also emphasize that no one scheme provides a panacea framework for Precambrian (or younger) basins. Real basin examples are discussed by Allen et al. (2015) for several cratons around the world as a foil to Indian depositional complexes detailed in the balance of the volume. The most important finding of this chapter is that many Precambrian basins might require elements of several defined ideal basin types in their evaluation, many have complex polyhistories and some depositional sequences will merely defy classification altogether. In a complementary chapter, Meert & Pandit (2015) examine the evolution of the Precambrian sedimentary basins of India within a unifying chronological and tectonic framework, and evaluate possible correlation between different Indian Purana-type basins. Their seminal work provides an essential basis for understanding the more detailed individual basin studies making up the body of this book, within a unitary context.

The second section (Aravalli–Bundelkhand Craton) contains three chapters on the sedimentology and stratigraphy of northwestern Proterozoic basins of India. Roy & Purohit (2015) present lithostratigraphic, geochronological and depositional settings of the Precambrian succession of the Aravalli Mountains and adjoining areas, Rajasthan. Precambrian basins preserved on the Aravalli basement exhibit an unusual association of three major basin-fills, each succeeded by an orogeny over the period 2.2–0.85 Ga, in which rift-type depositional basins exhibit stable platform-style sedimentation in each case. Despite cratonization being completed by only 0.85 Ga, essentially stable basin-fills characterized the Aravalli Craton both long before this event and after it. Chakraborty et al. (2015a) discuss various controls on sedimentation in the poorly studied Gwai lori and Bijawar basins that overlie the Bundelkand granite-gneiss basement. These two basins contain the inferred thrust of rift–orogen. Deposition in this case both continental margin rift basins) characterized by largely chemical stable shelf deposits, one characterized by phosphorites and the other by iron formation. The different chemical evolution reflects responses to rising sea-levels dictated by subsidence regime, bathymetry, biological activity and the oxidation state of waters within each specific basin. This underlines the critical evaluation of both basin-specific characteristics and global-scale secular change in Precambrian palaeoenvironmental parameters in understanding Precambrian basin-fills. The configuration and evolution of the Vindhyan Basin are discussed by Bose et al. (2015). The importance of rifting in controlling deposition within this famous basin of the Aravalli–Bundelkhand Craton continues the prime tectonic control inferred for deposits on this craton. However, a much more complex model is pertinent to the Vindhyan, with two major east–west ridges defining long-lived sub-basins in the Vindhyan, while keeping separate this basin from a coeval depository underlying the Ganga tectonicic plain in the north. Horst-rift-style tectonic control in the Vindhyan thus persisted throughout basin-filling, in contrast to other basins, where rifting was followed by essentially stable platform deposition and relative tectonic quiescence.

The third section (Singhbhum Craton) encompasses Palaeoarchaean to Mesoproterozoic sedimentation and tectonics of eastern Indian basins; Hofmann & Mazumder (2015) summarize the Palaeoarchaean history of the Singhbhum Craton with insights from the Older Metamorphic Group (OMG) and the Older Metamorphic Tonalite Gneiss (OMTG). They interpret a classic cratonic evolutionary model of high-grade granitoid gneisses (OMTG) and interleaved greenstone belts; importantly they see these OMG greenstones as having low-grade equivalents in the Iron Ore Group of this craton rather than the latter sedimentary rocks being seen as a separate succession. Ghosh et al. (2015) present a detailed tectono-sedimentary inventory on the Palaeoarchaean–Mesoproterozoic successions of the northwestern margin of the Singhbhum Craton. They define two new formations, an older distal (deeper-water) equivalent of the IOG followed unconformably by a younger deposit reflecting fault-controlled basin opening (conglomeratic) and subsequent stable shelf sedimentation. Van Loon & De (2015) critically analyse the conglomerates of Jharkand and discuss their
Archaean sedimentation patterns on the Singhbhum Craton. Both IOG and subsequent immature conglomeratic facies thus appear to have been relatively widespread on the Singhbhum Craton, thus supporting possibly broadly correlatable greenstone successions, as for example also found in the Pilbara Craton of Western Australia, and in contrast to accretionary greenstones of the Superior or Kaapvaal cratons, which young across preserved cratonic nuclei. Issues related to the Archaean–Proterozoic transition in the Singhbhum Craton and the relation of Singhbhum Craton-specific geological events to possible global equivalents are discussed by Mazumder et al. (2015). Post-Singhbhum Granitoid cooling and later possibly plume-related crustal doming during the Chaibasa–Dhalbhum transition appear to have been prime controls on subsequent sedimentation.

The Palaeoproterozoic basinal successions of the Bastar Craton (Section 4) are discussed in four chapters. Mohanty (2015) presents a brief overview of the Palaeoproterozoic supracrustals of the Bastar (Dongargarh Supergroup and Sausar Group). The c. 2.5–2.1 Ga Dongargarh Basin-fill suggests post-orogenic collapse and concomitant rift basin formation followed by stable
shelf development, while a rift basin is also inferred for the c. 2.4–2.2 Ga Sausar Group; the latter includes glaciogenic deposits, correlatable with Earth’s first global glaciation during this time interval. Genetic modelling of this glacial interval thus compares favourably with the Huronian glacigenic strata discussed by Allen et al. (2015) in Chapter 2, where supercontinent formation, rifting and subsequent passive margin evolution accommodated these famous glacial deposits. Chaudhuri et al. (2015) discuss conflicting stratigraphic issues of the Purana succession of the Pranhita–Godavari valley basin. They interpret this depository as a polyhistory rift basin located along the Dharwar–Bastar Craton boundary where syndepositional geodynamics controlled sedimentation within two sub-basins. Chakraborty et al. (2016) provide a critical overview of the geology of the Mesoproterozoic Chhattishgarh Basin, another Purana succession, possibly reflecting a rift-sag basin evolution. These authors have highlighted controversial issues of Chattishgarh succession that deserve closer scrutiny. Das et al. (2015) have constrained the c. 1450 Ma felsic volcanism at the fringe of the East Indian Craton by geochronology and geochemistry of tuff beds from smaller Bastar basins.

In the fifth section (Dharwar Craton) begins with an overview of the late Archaean supracrustal successions of the Dharwar Craton (Sunder Raju & Eriksson 2015). Evolution of this craton is thought to reflect accretion of either arcs or an assembled arc-granitic whole batholith terrane (now preserved as the Eastern Dharwar Craton, EDC) on to the Western Dharwar Craton, which has a regionally correlatable greenstone succession, the c. 2.9–2.6 Ga Dharwar Supergrup. This craton thus displays both a widespread correlatable greenstone succession and accretionary greenstone belts which young eastwards (compare with Van Loon & De (2015) on the Singhbhum Craton greenstones), thus providing a possibly unique Archaean cratonic evolution on the global scale. Basin evolution related to tectonic shortening is also envisaged for the Proterozoic Cuddapah Basin, Cuddapah fold-thrust belt (CFTB) and the Kurnool Group succession (Matin 2015), thought to have been related to assembly of both Columbia (Cuddapah) and subsequent Rodinia (CFTB, Kurnool) supercontinents. Chakrabarti et al. (2015) espouse a plume model for earliest Cuddapah Basin evolution; this may have preceded the convergent setting postulated by Matin (2015). This once again emphasizes the inherent complexities in Precambrian basin interpretation and that most depositional models have polyhistories rather than simple, single-component evolutions; simple allocation of any basin-fill succession to a specific standard model in any of the globally accepted basin classification schemes thus has its hazards and is seldom recommended by serious researchers (as also stated clearly by Allen et al. (2015) in Chapter 2). The relationship of the Nellore schist belt, east of the Cuddapah Basin and the adjacent Nallamalai fold belt (together these make up the CFTB discussed in Matin’s chapter) to the Cuddapah depository are discussed by Saha et al. (2015). They relate this once again to Precambrian supercontinent cycles, specifically to Columbia break-up and Rodinia assembly. Dey (2015) examines the Purana successions making up the basin-fills of the Kaladgi–Badami and Bhima intracratonic depositories on the northern margin of the Dharwar Craton. The merits of a far-field tectonically controlled model for the former and a pull-apart basin model for the latter are discussed. Sengupta et al. (2015) provide new high-resolution geochronological data for suspected Purana deposits across the Palghat–Cauvery shear zone, Southern Granulite terrane, which confirm this supposition and furthermore suggest that the Purana basins formed across an amalgamated Indian shield–Madagascan basement.

In Section 6, Deb & Pal (2015) provide an overview of the mineral potential of the Proterozoic intra-cratonic basins in India, accompanied by Mishra’s (2015) brief account of Archaean mineralization of the four Indian cratons. The memoir ends with a synthesis (Miall et al. 2015) of the Indian Precambrian basins wherein the basin classification and inferred prime controls on the genesis of the basin-fills discussed by Allen et al. (2015) in Chapter 2 are applied to the Indian Precambrian sedimentary record. Classification of the Indian Precambrian basins reflects a dominance of divergent plate motion in their evolution, with convergent motion invoked for the Kurnool Basin and the Eastern Dharwar Craton supracrustal succession; transient current motion appears to have been uncommon, being apparent only for the Bhima and Kaladgi–Badami basins. A polyhistory with possible links to a Wilson cycle model may apply to the Cuddapah Basin. Mantle thermal influences and concomitant dynamic topography may have controlled sedimentation within Dhalbhum and Dalma–Chandil basins of the Singhbhum Craton. Time trends extracted from application of standard basin classification schemes to the Indian Precambrian supracrustal record indicate a more limited range of basin types prior to c. 2.0 Ga and a more varied record of depository types thereafter.

Key issues identified in this study of the Precambrian basins of Peninsular India are as follows:

1. Indian Precambrian basins, like almost all around the globe, are essentially intracratonic depositories with cratonic substrates to basin-fills; they thus tell us much about cratonic evolution and the plate motions, palaeo-atmospheric, palaeo-biological and physico-chemical controls on Earth’s continental terranes. However, little direct evidence is preserved of the Precambrian oceanic plates; the nature of their tectonism and models for Precambrian global-scale plate tectonics thus retain a significant element of postulation.

2. The Indian basins underline the critical importance of high-resolution geochronology in understanding better the evolution of ancient supracrustal stratified successions. While this issue has been significantly addressed in cratonic terranes in developed regions, such as North America and Australia, and increasingly rapidly also in China, the undeveloped segment of the world’s cratons has lagged behind. Studies of Indian cratons in this respect are in transition, and some of the fruits of such advances in the Indian Precambrian supracrustal successions are detailed in this volume.

3. The Indian basins studied here provide much food for thought on global issues of Precambrian crustal evolution, including formation of greenstone belts, Precambrian tectonic regimes per se and secular changes in global sedimentation regimes allied to evolving atmospheric compositions, amongst which major global glaciation events are possibly paramount, in addition to providing a major contribution to the field of Precambrian basin analysis of relevance to the international geological community.

We are sure that this state-of-the-art exposition of the Precambrian basins of India will help to address gaps in the existing global knowledge base and guide interested researchers, students and professionals to gain a better understanding of Precambrian Earth surface processes and crust–mantle interactions.

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