VOLUME 2, NO. 2 APRIL 1999 REPRINT

Supriya Sengupta with regards, Asru

INTERNATIONAL GEOSCIENCE JOURNAL

Gondwana Research

OFFICIAL JOURNAL OF THE
INTERNATIONAL ASSOCIATION FOR GONDWANA RESEARCH

Gondwana Research, V. 2, No. 2, pp. 213-225.

ISSN: 1342-937X

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Gondwana Research

The Neoproterozoic Cratonic Successions of Peninsular India

Asru K. Chaudhuri[1], Joydip Mukhopadhyay[2], Sarbani Patranabis Deb[1] and S. K. Chanda[3*]

[1]*Geological Studies Unit, Indian Statistical Institute, 203 B.T.Road, Calcutta 700035, India*
[2]*Department of Geology, Presidency College, 86/1 College Street, Calcutta 700073, India*
[3]*Department of Geological Sciences, Jadavpur University, Calcutta 700032, India*

(Manuscript received November 24, 1998; accepted December 8, 1998)

Abstract

The Peninsular India hosts extensive record of Mesoproterozoic and Neoproterozoic successions in several mobile belts and cratonic basins. The successions provide excellent opportunities for chronostratigraphic classification, in tune with the chronometric classification adopted by IUGS for inter-regional correlation on a global scale. Major tectono-thermal events at 1000-950 Ma in the mobile belts, correlatable with the Grenville orogeny may be considered as the datum for Meso-Neoproterozoic classification in India. Principles of chronostratigraphic classification, however, can not be applied yet to the cratonic successions of India because of inadequate radiometric data, paucity of biostratigraphic studies, and lack of regionally correlatable stratigraphic or palaeoclimatic datum. The kimberlite magmatism which affected the Peninsular India on a continental scale at about 1100 Ma , holds the key to the identification of Neoproterozoic successions of the cratonic basins. Thus, the stratigraphically confined diamond-bearing conglomerates and/or the tuffs associated with kimberlites, may be considered as the datum to define the base of the Neoproterozoic,fixed at about 1000 Ma. Accordingly, the Rewa and Bhander Groups in the Vindhyan basin, the Kurnool Group in the Cuddapah basin, the Jagdalpur Formation in the Indravati basin and the Sullavai Group in the Pranhita-Godavari basin are taken to represent the Neoproterozoic successions in the Peninsular India. The Chattisgarh Group in the central India, the lower part of the Marwar Supergroup in western Rajasthan, the Badami Group in the Kaladgi basin, and the Bhima Group are the other "possible Neoproterozoics" in the Peninsula.

The closing phase of the Mesoproterozoic in all these basins are characterised by stable shelf lithologic associations attesting to high crustal stability. The Neoproterozoic basins, by contrast, mark a new phase of rifting and extension, and the basin fills exhibit signatures of initial instability which evolved with time into a more stable platformal condition. A major episode of sea level rise has been recorded in most of the basins. The riftogenic origin and evolution of the basins are comparable with the history of Neoproterozoic basins of Australia though there is no unequivocal record of glaciation in the Indian formations.

Key words: Cratonic basins, Purana rocks, kimberlite pipes, diamondiferous conglomerate.

Introduction

The Peninsular India preserves an extensive record of Proterozoic successions which display extreme heterogeneity in stratigraphy, sedimentation pattern, metamorphism, deformation, and magmatism. In strong contrast to certain Proterozoic successions in mobile belts which show strongly deformed and metamorphosed character, there are a number of well developed cratonic successions which are virtually unmetamorphosed and are mildly deformed (Fig. 1). Radiometric age data from the mobile belt successions indicate that the history of evolution of deformed metasedimentary and metavolcanic successions with multiple episodes of deformation, metamorphism, and magmatism extends mainly between 2500 and 1500 Ma, though events reflecting crustal perturbations in the Indian Peninsula extended upto 1000 Ma and even upto the Proterozoic-Phanerozoic boundary. Not withstanding the above, there are evidences of development of cratonic basins during the period between 1700 Ma and 700 Ma on different early Proterozoic and Archaean basements. Existence of metamorphosed mobile

* Deceased

belt successions and unmetamorphosed cratonic successions with an overlapping period of evolution in the Indian Peninsula, present a unique opportunity to study the evolution of Proterozoic crust, and the nature of hydrosphere, atmosphere and biosphere interactions, as well as secular variations in each of these realms.

An impressive number of publications covering different aspects of the Indian Proterozoics have come out during the last two decades. However, an integrated analysis of the different aspects of the Proterozoic history of the Indian Peninsula is yet to emerge. The inadequacy appears to step up from the lack of well defined stratigraphic frame for correlating the events on a regional scale, and to characterise the secular changes in the trends of the geological processes during the Proterozoic era.

A three fold classification of the Proterozoic into Palaeoproterozoic, Mesoproterozoic, and Neoproterozoic has been formally accepted by the IUGS (Plumb, 1991) with boundaries at 2500 Ma, 1600 Ma and 1000 Ma respectively. The classification is essentially geochronometric though selection of time boundaries are strongly influenced by major epochs of orogeny and magmatism, generally accepted as key markers. It is quite clearly understood that the local record may not always neatly fit into the globally accepted time limits. It now seems that the chronostratigraphic classification of the Indian Proterozoics conforming to the chronometric classification of the Proterozoic by the IUGS (Plumb, 1991) is long overdue.

In India, Sarkar (1983) placed the Meso- Neoproterozoic boundary at 900 Ma on the basis of radiometric ages of metamorphism and emplacement of granitoid bodies in the different Proterozoic mobile belts. In recent years, a number of radiometric dates indicate major thermal/tectonic events around 1000 Ma and 950 Ma in the Satpura mobile belt (Sarkar, 1983), the Delhi-Aravalli fold belts (Volpe and Macdungal, 1990), as well as in the Eastern Ghats Mobile Belt (Grew and Manton, 1986, Shaw et al., 1997, Dasgupta and Sengupta, 1998). The 1000 Ma to 950 Ma events are broadly contemporaneous with the Grenville orogeny, and considering the diachroneity of orogenesis as well as their wide time span, they may have been considered to denote the Meso-Neoproterozoic boundary. Proterozoic cratonic sedimentary basins in India, by contrast, are still not analyzed in sufficient details to define a basis for classification. The problem is further compounded by paucity of geochronologic data. In this paper we intend to make an attempt to delineate the Neoproterozoic successions in the Indian Peninsula on the basis of

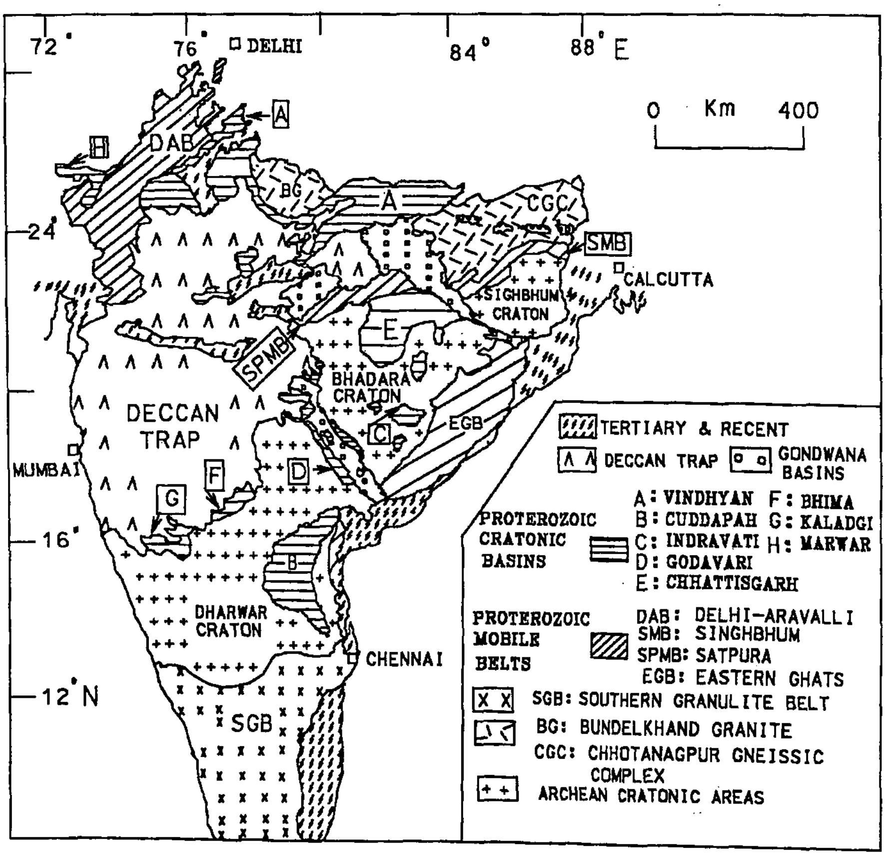

Fig. 1. Generalized geological map of Peninsular India showing distributions of Proterozoic cratonic basins, mobile belts, Archean cratonic areas.

information available till date. We also intend to evaluate the conditions at or near the Meso- Neoproterozoic transition and the broad pattern of sedimentation within the Neoproterozoic successions.

The Proterozoic Cratonic Successions of India

The unmetamorphosed and mildly deformed Proterozoic cratonic sedimentary successions believed to be younger than *ca.*1600 Ma are commonly designated as the Purana successions in the Indian stratigraphy (Holland, 1907; Radhakrishna, 1987). The Purana Formations occur in a number of detached belts, presumably representing fills of different basins that developed on different Archaean/early Proterozoic cratonic blocks, encircled or separated by mobile belts (Fig. 1). The basins have preserved records of multiple cycles of sedimentation, volcanism, episodes of major sea-level changes, and the development of several regional unconformities.

The lithostratigraphy in several basins have been studied in considerable details, and attempts are being made to identify major sedimentary cycles, regional unconformities, climatic changes, tectonic perturbations, and volcanism. However, temporal or causative relationships between the events, and chronostratigraphic classification of the Purana Formations as well as their interbasinal correlation are yet to be made.

Sedimentological and palaeobiological studies from the Purana basins do not reveal any possible palaeoclimatic or biostratigraphic marker, which can be used as datum for chronostratigraphic classification and interbasinal correlation. There is no firm evidence of Proterozoic glaciation in the Purana Formations, although there are reports of glacial or glaciogene rocks from the Semri Group and the upper part of the Kaimur Group of the Vindhyan successions in the Son Valley (Ahmad, 1955; Mathur, 1981). The origin of the above mentioned is questionable (Crawford and Compston, 1970). Williams and Schmidt (1996) also categorically stated about the absence of evidence of glaciation in the Vindhyan rocks. They interpret "Gangau tilloid", the most prospective candidate of glacial deposit from the base of Semri group, as a debris flow deposit derived mainly from a ferrugenous and locally silicified regolith. By contrast, several Purana Formations exhibit carbonate-evaporite complexes and evidences of aeolian arid zone sedimentation (Chaudhuri et al., 1987; Das et al., 1990; Chakraborty, 1991; Dasgupta, 1996). However, arid evaporite depositional regimes in different basins developed at different stratigraphic levels and do not bear any inter-regional temporal significance.

Most of the Purana Formations include thick succesions of carbonates, endowed with variety of algal stromatolites and microbial mats (Raha and Sastry, 1982; Chaudhuri, 1970; Raha,1987; Gururaja and Chandra, 1987). The formations could be very important testing grounds for biostratigraphic classification and interbasinal correlation. Stromatolites have been effectively used in the USSR as a key parameter in chronostratigraphic classification of the upper Proterozoic successions into the Riphean and the Vendian. The classification, however, was also supported by orogenic breaks as well as radiometric and lithostratigraphic data (Chumakov and Semikhatov, 1981). In the case of Indian cratonic basins,despite several significant attempts towards biostratigraphic classification (Gururaja and Chandra, 1987; Venkatachala et al., 1996), the correct use of stromatolite is yet to reach its full potential for evolving the interbasinal stratigraphic correlation.

The Proterozoic Formations at least in two major Purana basins include a diamond bearing conglomerate horizon as a unique lithosome. In each of these basins, the conglomerates are restricted to one particular stratigraphic interval, and their non-repetitive occurrence in the sequence make them potential markers for chronostratigraphic classification as well as for interbasinal correlation. The origin of the conglomerates has been traced to kimberlitic pipes and diatremes which have been recorded within the Vindhyan, the Indravati and the Cuddapah basins, as well as within the basement along the western margin of the Cuddapah basin (Fig. 2). Radiometric dates of the kimberlites suggest that despite certain uncertainties and divergent views, time of emplacement of most of the kimberlitic pipes is broadly contemporaneous, and the event affected the Indian shield region on a continental scale between 1050 and 1150 Ma (Crawford and Compston, 1970, 1973; Anil Kumar et al., 1993; Chalapathi Rao, 1996). It is noteworthy that the Proterozoic kimberlites of nearly the same age are also known from Western Australia and South

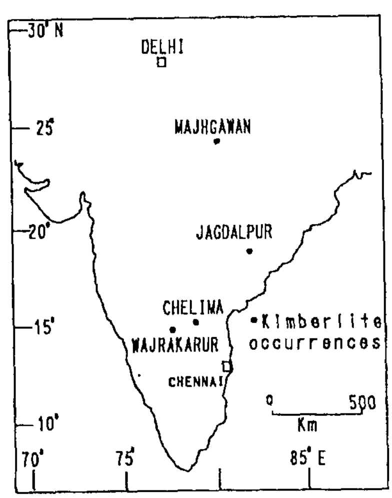

Fig. 2. Distribution of kimberlite diatremes (c. 1100 Ma) in Peninsular India.

Africa (Skinner et al., 1985), the regions which were geographically close to the Indian shield before the break up of the Gondwanaland. The kimberlites dated between 1050 and 1000 Ma provide the maximum age of the diamond-bearing conglomerates. The proposed age of the diamond bearing conglomerates which occur in force at the base of the Kurnool Group and at the base of the Rewa Group of the Upper Vindhyans is also supported by the ages of the sedimentary successions determined by isotopic dating of glauconitic minerals as well as other dike rocks which intrude the sedimentary formations (Crawford and Crompston, 1970; Tugarinov et al., 1965).

We propose here that the diamond-bearing conglomerates or the pyroclastic deposits related to kimberlite intrusions be fixed as the marker for determining Meso-Neoproterozoic boundary in India. The conglomerates or the pyroclastics denote closing or initiation of sedimentary cycles, and the time of their emplacement is very close to the 1000 Ma Meso-Neoproterozoic boundary of the IUGS chronometric scale (Plumb, 1991), or to 1050 ± 50 Ma boundary between the Middle Riphean (Yurmatinian) and the Upper Riphean (Karatavian) of the USSR (Chumakov and Semikatov, 1981). Further, the conglomerates or the pyroclastics can be directly studied in the rock record, and can be used as markers in classifying the successions.

The diamond bearing kimberlites are localised in very stable cratonic areas, and structural controls related to emplacement of kimberlitic magma are observed on a regional scale (Ferguson, 1980; Gupta, 1998), often associated with rifting, downwarping, and faulting of stable cratonic terrains. The Proterozoic kimberlites in Indian craton are the possible manifestations of an episode of rifting and magmatism which heralded the Meso-Neoproterozoic transition. The event is contemporaneous with the Grenvillian orogeny and the initiation of rifting in the Rodinia supercontinent (Rogers et al., 1995).

Geochronology and Correlation of the Neoproterozoic Successions in Peninsular India

There are only a few available isotopic dates of Purana rocks which mainly come from authigenic glauconitic minerals or from magmatic rocks that intrude the successions or are interbedded with them. A large number of age determinations have been made on the kimberlite and lamproites, and a wide spread of data between 1350 to 840 Ma have been reported (Paul et al., 1975; Basu and Tatsumoto, 1979; Crawford, 1969; Crawford and Compston, 1973; Anil Kumar, et al., 1993; Chalapathi Rao, et al., 1996). The dates were obtained by Rb-Sr and K-Ar methods and it has been noted that the spread in the measured ages is reduced significantly when Rb-Sr dates or K-Ar dates are considered separately. Anil Kumar et al. (1993) made Rb-Sr age determinations on acid leached phlogopite macrocrysts from samples collected from 4 pipes in the Cuddapah province, and obtained a close cluster of dates between 1091 ± 10 Ma and 1093 ± 20 Ma. The data indicate emplacement of the pipes in a very short time interval around 1090 Ma. The same authors obtained an age of 1067 ± 31 Ma for the Vindhyan kimberlites at Majhgawan near Panna (Fig. 3, Table 1) by analysing 4 subpopulations of phlogopite, and this is very close to the model ages of 1100 Ma obtained by Crawford (1969) from the Vindhyan. Rb-Sr determinations on the pipe rocks by Crawford and Compston (1970, 1973) suggest that kimberlites in both these provinces were emplaced almost at the same time, around 1140 Ma. Only one example from a diatreme at Chelima (Fig. 2) which intruded into the Nallamalai rocks of the Cuddapah Supergroup (Table 2) gives a slightly higher age of 1225 Ma (Crawford and Compston, 1973).

The age data indicate that the Kurnool Group (Fig. 4) with a diamond-bearing conglomerate at its base is younger than 1090 Ma, and deposition of the Nallamalai rocks ceased before 1225 Ma, the age of the Chelima dikes. The age of the conglomerates is constrained by the clasts derived from the pipe rocks from the Wajrakarur in the west (Nagaraja Rao et al., 1987), with ages between 1090 Ma or 1140 Ma. The ages of the basic dikes which do not affect the Kurnools but intrude only the underlying formations also indicate that the Kurnools are not older than 1090 Ma, and may even be younger than 870 Ma (Crawford and Compston, 1973).

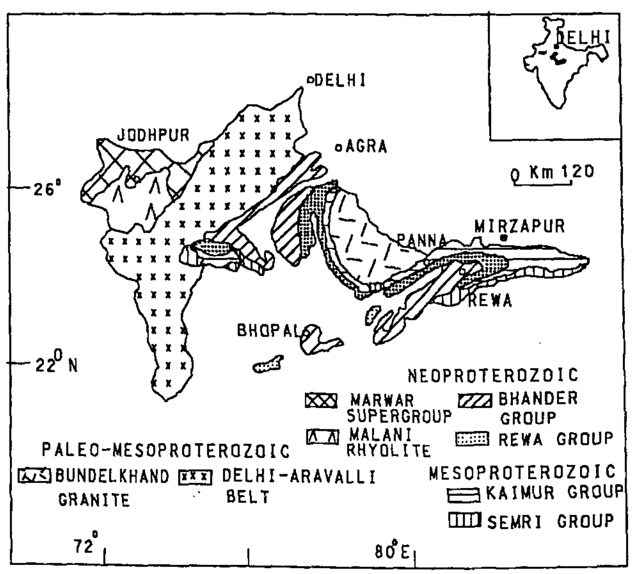

Fig. 3. Generalized geological map of the Vindhyan Supergroup and Marwar Supergroup.

Table 1. Lithostratigraphic succession of the Vindhyan Supergroup, Son Valley

Time	Group	Formation	Dominant lithology	Facies
Neoproterozoic	Bhander Group	Shikhoda Sandstone	quartzose sandstone, mudstone	Intertidal shoal bar /barrier island
		Sirbu Shale	mudstone, fine-grained sandstone	Lagoon-tidal flat
		Bundi Hill Sandstone	quartzose sandstone	Beach-shoal bar
		Lakheri Limestone	limemudstone, stromatolitic limestone	Open carbonate ramp
		Ganurgarh Shale	shale, mudstone.	Lagoonal-tidal flat
	Rewa Group	Govindgarh Sandstone	pebbly and coarse sandstone	Fluvial.
		Drammondganj Sandstone	quartzose sandstone.	Intertidal shoal bar
		Jhiri Shale	shale, siltstone, sandstone	Deep prodelta,
		Asan Sandstone	pebbly sandstone and sandstone	fan delta.
		Panna Shale	shale	
Mesoproterozoic	Kaimur Group	Dhandraul Sandstone	quartzose sandstone	Aeolian, fluvial, shallow marine
		Mangesar Formation	sandstone, shale	Shallow marine
		Bijaigarh Shale	carbonaceous shale	Lagoonal, intertidal
		Ghaghar Sandstone	sandstone, mudstone	Shallow marine
		Susnai Breccia	conglomerate, breccia	———
		Sasaram Formation	sandstone, mudstone	Shallow marine
		—Unconformity(?)—		
	Semri Group	Bhagwar Shale	shale, porcellanite, limemudstone, mass	Slope-basin
		Rhotasgarh Limestone	flow limeclast beds, tuff	
		Rampur Formation	glauconitic sandstone	Intertidal shoal bar
		Salkhan Limestone	stromatolitic limestone	Peritidal platform
		Koldaha Shale	shale, sandstone	Shelf to slope
		Deonar Formation	porcellanite	Outer shelf to slope
		Kajrahat Limestone	thin-bedded limemudstone,	Deep platform
		Arangi Formation	shale	Fan delta-prodelta
		Deoland Formation	conglomerate, quartzose sandstone	
		——Unconformity—		
		Bijwar, Aravalli, pre-Aravalli, Bundelkhand granite		

In the Vindhyans of the Son Valley (Fig. 3), the age of the Majhgawan pipe constrains the age of the diamond-bearing conglomerates at around 1000 Ma or less and the age advocates its contemporeneity with the conglomerates at the base of the Kurnools. The age of the Majhgawan pipes proves that the Semri and the Kaimur groups are Mesoproterozoic whereas the Rewa and the Bhander groups are Neoproterozoic. The proposition is also supported by K-Ar dates obtained by Vinogradov et al. (1964) and Tugarinov et al. (1965) from glauconitic minerals. Their dates suggest that the base of Semri Group is at least ~ 1200Ma and perhaps as much as 1400 Ma, and that the Kaimur Group is at least 910 Ma to 940 Ma and possibly >1150Ma (for discussion see Williams and Schmidt, 1996, and Seilacher et al., 1998). The K-Ar dates of glauconites are likely to indicate minimum ages (Hurley et al., 1960) so that the value of 910 Ma for the upper part of the Kaimur does not seriously conflict with the 1000 Ma age of the Rewa Group inferred on the basis of the age of the Majhgawan pipe rocks. It is tempting to note that the age of this transition closely matches the closing phase of the "Satpura Cycle" which ended at about 955 Ma (Holmes, 1955).

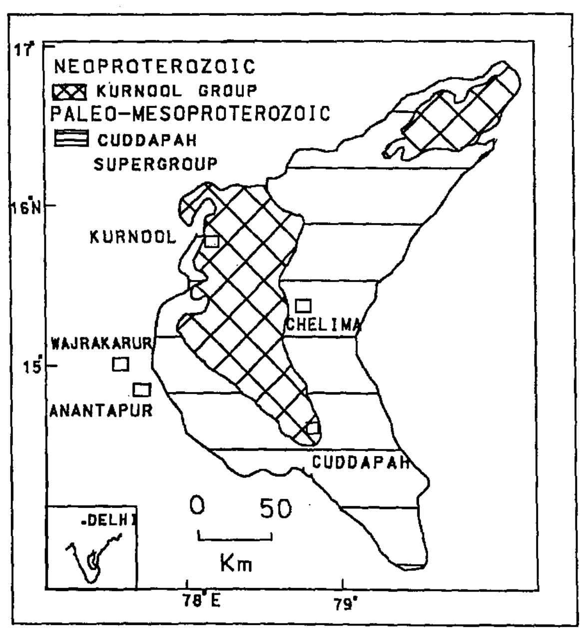

Fig. 4. Generalized geological map of the Cuddapah basin showing Cuddapah Supergroup and Kurnool Group.

Table 2. Lithostratigraphic succession of the Proterozoic rocks of the Cuddapah Basin, South India (modified after Nagaraja Rao et al., 1987)

Time	Group	Formation	Dominant lithology	Facies
Neoproterozoic		Nandyal Shale	calcareous shale	Subtidal
		Kolikuntala Limestone	limemudstone, conglomerate quartzite and shale	Deep-water carbonate paltform
	Kurnool Group	Paniam Quartzite		Shallow marine
		——Paraconformity——		
		Owk Shale	shale with thin sandy interbeds	Subtidal
		Narji Limestone	well bedded limemudstone	Deep-water carbonate paltform
		Banganapalli Formation	diamond-bearing conglomerate, sandstone, shale	Fandelta (?)
Mesoproterozoic		——Unconformity——		
		Srisailam Quartzite	quartzarenite and shale	Tidal flat, fluvial, aeolian
		———Unconformity——		
		Cumbum Formation	shale, phyllite, quartzose sandstone, Chelima kimberlite	intertidal, subtidal to slope
	Nallamalai Group	Bairenkonda/Nagari Quartzite	conglomerate, quartzose sandstone, shale, intrusives	Fandelta (?), shallow shelf
		—Unconformity (?)——		
		Gandikota Quartzite	quartzose sandstone	Tidal flat.
	Chitravati Group	Tadpatri Formation	shale, tuff, stromatolitic dolomite	Subtidal to intertidal
		Pullivendla Quartzite	conglomerate, quartzose sandstone	Beach-tidal flat
		——Paraconformity——		
	Papaghni Group	Vempalle Formation	stromatolitic dolomite, calcareous mudstone, basic lava flows: 1583 ± 143 Ma.	Shallow water platform
		Gulcheru Quartzite	quartzose sandstone, conglomerate	Alluvial fan, fan-delta
		——Unconformity——		
		Crystalline Basement		

The Jodhpur Sandstone (Blanford, 1877) in western Rajasthan, the trans-Aravalli Vindhyan of Heron (1932), subsequently redesignated as the Marwar Supergroup, (Awasthi and Parkash, 1981) unconformably overlies the Malani Group (Roy, 1998) that comprises felsic volcanics, minor basalt and sediments as well as granitoids. According to Rathore (this volume), the Malani Group was emplaced during 780 to 670 Ma. This age places the Marwar rocks in the Neoproterozoic. According to Awasthi (1979) the upper part of the Supergroup may extend into the lower Palaeozoic.

Recently, kimberlitic pipes have been reported from about 15 Km westsouthwest of Jagdalpur (Fig. 1) in the Indravati basin (Bhattacharya et al., 1996). The pipes intruded the lower part of the succession at around 1100 Ma and is overlain by a thick sequence of tuff (Table 3). Stratigraphic position of the pipe rocks suggests that the Indravati Group transgresses the Meso-Neoproterozoic boundary where Jagdalpur Formation represents the Neoproterozoic (Fig. 5, Table 3) and the underlying formations represent the Mesoproterozoic. The tuff at the boundary of the Kanger Limestone and the Jagdalpur Formation defines the Meso-Neoproterozoic transition.

In the Godavari Supergroup, glauconitic minerals from lower part of the Pakhal Group and the Sullavai Group (Table 4) were dated by K-Ar method and the results were reported by Chaudhuri and Howard (1985). The samples were collected from Ramgundam and Venampalli (Fig. 6)

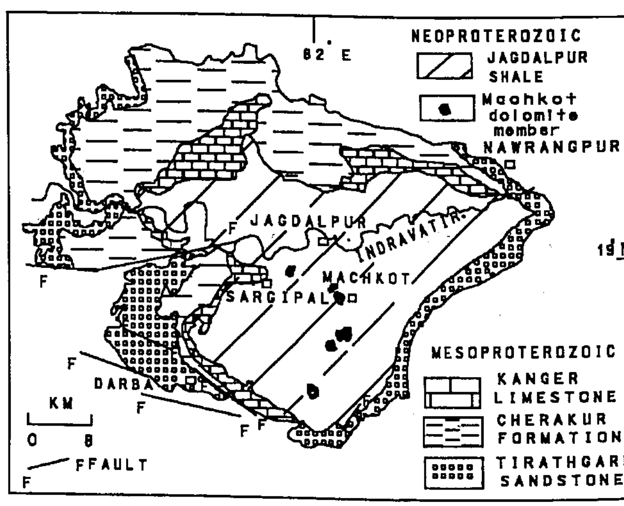

Fig. 5. Geological map of the Indravati Group.

Table 3. Lithostratigraphic succession of the Proterozoic rocks of the Indravati Basin, South India (modified after Ramakrishnan, 1987)

Time	Group	Formation	Dominant lithology	Facies
Neoproterozoic		Jagdalpur Formation	brown shale with stromatolitic mounds and reefs	Shallow siliclastic-carbonate shelf
Mesoproterozoic	Indravati Group	Kanger Limestone	gray to black bedded limemudstone brown shale, tuff and kimberlte **(1100 Ma ?)**	Deep-water carbonate platform.
		Cherakur Formation	glauconitic sandstone, siltstone-mudstone	Intertidal to subtidal
		Tirathgarh Formation	quartzarenite, basal conglomerate, pebbly sandstone	Beach, Fandelta (?)
		——Unconformity—— Granitic basement		

Table. 4. Lithostratigraphic succession of the Purana Rocks around Ramgundam, PG-Valley (*after* Chaudhuri and Howard, 1985)

Time	Group		Formation	Lithology	Facies
Neoproterozoic			Gondwana Supergroup (Permo-Jurassic)		
			——Unconformity——		
	Sullavai Group		Venkatpur Sandstone	fine-grained subarkosic sandstone	Erg deposit
			Mancheral Quartzite	ferruginous quartzose sanstone	
			Ramgiri Formation	pebbly arkose, arkosic sandstone. K-Ar date: **871 ±14 Ma**	Fan, braided fluvial
Mesoproterozoic			——Unconformity——		
	Pakhal Group	Mulug Subgroup	Rajaram Limestone	sandy limestone, intraclastic limestone, dolomite	Carbonate bank-lagoon
			Ramgundam Sandstone	subarkosic sandstone	Intertidal shoalbar
			Damla Gutta Conglomerate	pebbly and coarse sandstone, conglomerate	Coastal alluvial fan
			——Unconformity——		
		Mallampalli Subgroup	Pandikunta Limestone	flat-bedded and stromatolitic limestone, glauconitic sandstone. K-Ar date: **1350 ± 53 Ma**	Mixed carbonate-siliciclastic platform
			Jonalarasi Bodu Formation	Interbedded quartzose sandstone, limestone and dolomite,	Coastal, sabkha
			——Unconformity—— Granitic basement		

in the central part of the southwestern belt, referred to as the Pakhal-Penganga belt. The Pakhal sample gives the age 1330±53 Ma and the Sullavai sample collected from the uppermost part of the formation at Venampalli gives an age of 871±14 Ma. We infer that the Sullavai Group represents the Neoproterozoic in the Pranhita-Godavari basin, and the underlying Pakhal Group represents the Mesoproterozoic.

Authigenic glauconites from the sandstones of the Chaporadih Formation in the basal part of the Chattisgarh Supergroup was dated by K-Ar method, and yielded the age of 700-750 Ma (Kreuzer et al., 1977). However, palaeomagnetic studies indicate that the age of the Gunderdehi Shale which appears much above the Chaporadih Formation is likely to be close to 1250-1300 Ma (Murti, 1987). The anomalous age data prevents us from assigning the Chattisgarh basin either to Neoproterozoic or to Mesoproterozoic.

There is no isotopic date from two other well known basins, the Kaladgi-Badami basin and the Bhima basin. From the available information it is evident that the Kurnool Group of the Cuddapah province, the Rewa and the overlying Bhander groups of the Vindhyan Supergroup, the Jagdalpur Formation of the Indravati Group, and the Sullavai Group of the Godavari Supergroup, are the

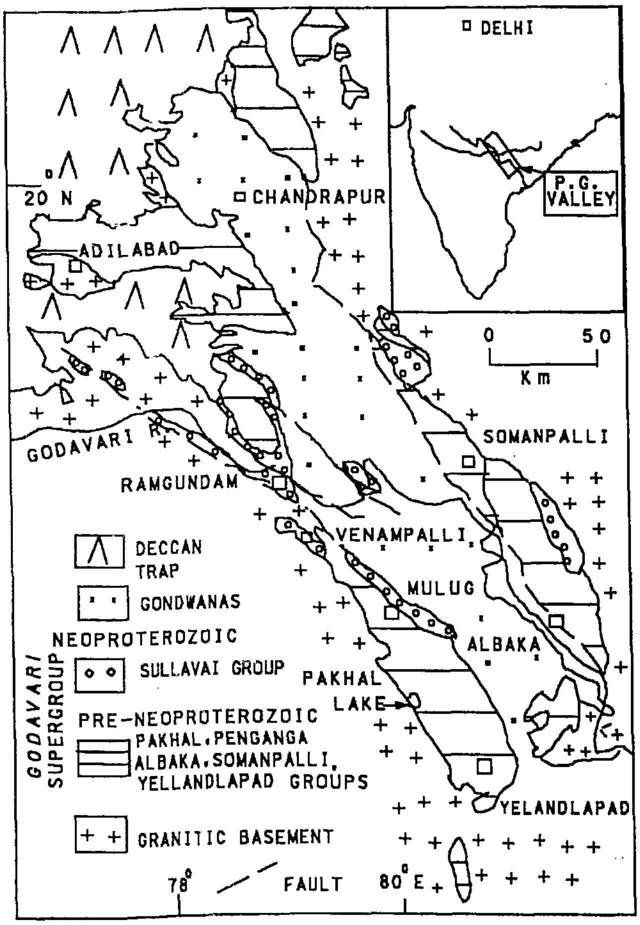

Fig. 6. Geological map of the Pranhita-Godavari Valley showing distribution of the Sullavai Group and the Neoproterozoic succession.

Neoproterozoic successions in the Indian Peninsula. The data on Chattisgarh, Bhima, Kaladgi-Badami and Marwar basins are either absent or inadequate for chrono-stratigraphic correlation. These successions are traditionally considered as "upper" or "late" Proterozoic in Indian stratigraphy, and have been considered here as "possible Neoproterozoics".

Depositional History of Neoproterozoic Successions

The Purana successions in different basins have been studied from different view points, but most of them still need systematic sedimentologic and stratigraphic analysis. The information on the evolution of basin-fill have been gathered mainly from the Vindhyan basin of the Son Valley, and other basins have been reviewed in broad terms.

The Vindhyan basin

The Vindhyan Supergroup is classified into four groups (Table 1). The Semri Group is traditionally known as "lower Vindhyans" and the upper groups as "upper Vindhyans" (Pascoe, 1975). The transition from the Semri to the Kaimur, with or without an intervening local unconformity, attests to increasing basin stability which ultimately resulted in the development of wide stable shelf, hallmark of high crustal stability at the closing phase of the Mesoproterozoic. The Meso-Neoproterozoic transition ushered in the deposition of the Rewa Group. The group is dominated by sandstone and shale and consists of subordinate amount of pyroclastics and diamond-bearing conglomerates at basal parts. Along the southern margin of the Son Valley, the Rewa rocks are arranged in a well-defined coarsening upward sequence. The aeolian-fluvial beds in the upper parts of the Dhandraul Sandstone of the Kaimur Group (Chakraborty, 1996) (Table 1) is overlain by a thick pile of deep-water Panna Shale and Jhiri Shale separated by Asan Sandstone beds (Shastri and Moitra, 1984), also referred to as Rewa Shale (Chakraborty et al., 1996). The Rewa Shale earlier considered as lagoonal (Banerjee, 1974) has been reinterpreted as a deepwater offshore deposit with features of wave reworking in its upper part (Akhtar, 1996; Chakraborty et al., 1996). This is successively overlain by a complex of linear shore parallel subtidal to intertidal bars (Drammondganj Sandstone), and coarse sandy to gritty braided fluvial Govindgarh Sandstone (Chakraborty and Chaudhuri, 1990; Chakraborty, et al., 1996). The contact between the fluvial-aeolian Dhandraul Sandstone and the overlying off-shore Rewa Shale marks an abrupt change in depositional regime, an event of major subsidence and sea level rise, and a possible indicator of tectonic rejuvenation, either within the basin or at the basin margin. The event was followed by gradual sea level fall and major progradation which resulted in the deposition of the coarse grained fluvial Govindgarh Sandstone (Chakraborty and Chaudhuri, 1990)

Along the northern belt, all the subdivisions of the Rewa Group (Table 1) are best developed at the Sohagi Ghat showing a coarsening upward sequence. Westward from the Sohagi Ghat, the Panna Shale and the Asan Sandstone pinch out, and whereas the Jhiri Shale overlies the Kaimur Sandstone, locally described as the Baghain Sandstone (Soni et al., 1987). Further west, the undifferentiated 'Upper Rewa Sandstone' (the Drammondganj Sandstone and the Govindgarh Sandstone) successively overlies the Dhandraul Sandstone and the Semri rocks (Pascoe, 1975; Shastry and Moitra, 1984). In the Bundelkhand region, around Panna and west of it,there are thin beds and lenticles of diamondiferous conglomerates intertounging with or are intercalated with the Jhiri Shale. The conglomerates also occur directly on the irregular erosional upper surface of the Baghain Sandstone within the Asan Sandstone, and also along the contact of the upper Rewa Sandstone (the Govindgarh Sandstone) and the overlying Ganurgarh Shale of the Bhander Group. Pyroclastics including welded tuffs have been recently reported by Chakraborty et al. (1996) from the Asan Sandstone and the Rewa Shale at several outcrops in the north.

Repeated occurrence of conglomerates in the succession in the Bundelkhand region and their interfingering relationship with different marine units strongly points to a fan-deltaic setting. The interpretation is consistent with the progradational sequence culminating into the Govindgarh Sandstone. A deltaic depositional mode is also proposed by Bose et al. (1997) at the northern margin of the Son valley (Table 1) and by Bharadwaj (1977) in Rajasthan. Stratigraphic relationship between the Rewa formations and the underlying units strongly suggests the occurrence of an unconformity at the base of the Rewa Group in the Bundelkhand region, which is either absent or remains hidden in the southern part of the Son Valley. Presence of multiple unconformities as well as fan deltaic depositional motifs in the northern belt are a typical manifestation of a basin margin which experienced multiple events of uplift and denudation and deposition of pyroclastics.

The unstable Rewa basin was followed by the Bhander basin marked by stable shelf sedimentation. All the Bhander formations (Table 1) were deposited in lagoon-tidal flat setting with signatures of minor sea level fluctuations (Banerjee, 1974, Singh, 1976; Chanda and Bhattacharyya, 1982, Soni et al., 1987; Bharadwaj, 1973; Sarkar et al., 1996). The depositional motif of Bhander formations clearly indicates deposition in shallow marine environments within a narrow bathymetric limit, and a prolonged equilibrium between subsidence and deposition, the manifestations of stable shelf conditions.

Stratigraphic-sedimentologic analysis thus reveals a major change from tectonically unstable condition during deposition of the Semri sediments to a highly stable basin condition, marked by the blanket-type deposits of the supermature Dhandraul Sandstone at the closing phase of the Mesoproterozoic. The basin stability was disturbed and a rift basin opened up at the Meso- Neoproterozoic transition. The emplacement of kimberlites as well as occurrence of intrabasinal felsic pyroclastics strongly support riftogenic setting during this phase. The initially unstable Rewa basin ultimately evolved into a stable one, resulting in the deposition of the Bhander formation.

The Cuddapah basin

The succession in the Cuddapah basin (Fig. 4) was classified into Cuddapah and Kurnool Systems, and further subdivided into several series and stages by King (1872). The stratigraphic classification was subsequently modified several times, and the commonly accepted classification (cf. Nagaraja Rao et al., 1987) and available isotopic dates from several formations are given in Table 2.

The Cuddapah Supergroup records sedimentation in three major tectonically unstable phases punctuated by more stable interludes (Dasgupta, 1996). The Kurnool Group that unconformably overlies the Cuddapah Supergroup comprises two major cycles of siliciclastic-carbonate sedimentation in a stable shelf condition. The Banganapalle Formation (Table 2) includes two diamondiferous polymictic conglomerate horizons, each about one metre thick, intercalated with sandstone and mudstone at its basal part (Narayanaswamy et al., 1971). The polymict conglomerates with chert, quartzite and trap rock in ferruginous matrix are interpreted as fluvial to neritic deposits (Meijerink et al., 1984). They are likely to represent coastal alluvial fan that were emplaced during rifting and opening of the Kurnool basin. The upper part of the Formation with quartzarenite and mudstone represents shallow shelf condition that experienced sea level rise culminating into deep water bedded lime-mudstone of the Narji Limestone. The overlying Owk Shale may indicate sea level fall and return of siliciclastic shelf setting. The Paniam Quartzite with a few thin conglomerate beds at the basal part represent the second cycle of sedimentation. Overlying Kolikuntala Limestone with bedded limemudstone represents deep-water carbonate ramp and second major transgression in the Kurnool. This is followed by probable sea level fall and siliciclastic sedimentation of the Nandyal Shale.

The Indravati basin

The Indravati succession (Fig. 5) has been classified into four formations (Ramakrishnan, 1987) (Table 3). As indicated in Table 3, the Kanger Limestones are gradationally overlain by a thick brown calcareous shale with intercalated small bodies of sandstone at different stratigraphic levels (Ramakrishnan, 1987). The presence of a kimberlite pipe has been recorded from this shale-sandstone interval (Bhattacharya et al., 1996). The kimberlite-shale-sandstone sequence is blanketed by a regionally extensive tuff deposits (observations by AKC, JM and SPD). We correlate the tuff bed as the uppermost part of the Kanger Limestone. The Jagdalpur Formation which overlies the tuff bed, consists of a thick sequence of shale with isolated mounds of stromatolitic limestone/dolomite at the lower part and stromatolite reefs with intercalated shale at the upper part.

The tuff at the uppermost part of the Kanger Limestone is likely to represent the Meso-Neoproterozoic transition. The Mesoproterozoic section includes the Tiratgarh Formation, the Cherakur Formation and the Kanger Limestone. The sequence represents a stable shelf association deposited in open marine circulation condition. The Neoproterozoic section, by contrast, is represented by the Jagdalpur Formation, deposited in relatively low energy mud depositing environments, protected by wave resistant stromatolitic mounds and reefs. Stromatolites, so well developed in the Neoproterozoic profile, are conspicuously absent in the Mesoproterozoic profile.

The Pranhita-Godavari basin

The Neoproterozoics in the Godavari Supergroup of the Pranhita-Godavari Valley (PG Valley) basins is represented by the Sullavai Group (Fig. 6, Table 4) which unconformably overlies other group of rocks, such as the Pakhal, the Penganga and the Albaka Groups. In contrast to the Mesoproterozoic formations which are confined either in the southeastern or the northeastern belts, the Sullavai Group occurs in both the belts (Chaudhuri and Chanda, 1991), and the sub-Sullavai unconformity is considered as regional and the most extensive one.

The stratigraphy and sedimentology of Meso-Neoproterozoic successions have been studied in detail in the central part of the southwestern belt (Table 4). In contrast to the Pakhal Group, the Sullavai Group consists entirely of coarse siliciclastics. Its lower part is characterised by conglomerates, pebbly sandstones and coarse-grained arkosic to quartzose sandstones deposited in alluvial fan braided-stream complex (Chaudhuri and Chanda, 1991; Chakraborty, 1991) in a rift basin, whereas the upper part consists of extensive erg deposits (Chakraborty, 1991). The Sullavai Group is unconformably overlain by the rocks of the Permo-Triassic Gondwana Supergroup.

Other possible Neoproterozoic successions

The Chattisgarh Supergroup is generally considered as a stable shelf association represented by minor conglomerates and quartzose sandstones which grade upward into a shale-carbonate assemblage (Murti, 1987). The carbonate rocks are profusely stromatolitic. The eastern part of the basin, however, exhibits a thick fan deltaic sequence (Patranabis Deb, unpublished data) overlain by the pyroclastics, shales, and deep-water limestones, all of which show seismic signatures, thus indicating unstable basin condition and a riftogenic setting.

The Marwar Supergroup consists of mature sandstones, shales, shallow marine limestones, anhydrite and gypsum, and occupies a vast area on the southwestern edge of the peninsular shield. The lithological assemblage points to deposition in a shallow intracratonic basin; and records a number of transgressions and regressions (Awasthi and Parkash, 1981). The middle part of the succession is characterized by extensive development of evaporites that is considered to form in a rift basin on the foreland slope of the Aravalli range (Dasgupta, 1996).

The Kaladgi Supergroup, exposed on the northern edge of the Dharwar craton, consists of the Bagalkot Group and the overlying Badami Group, and the two are separated by an angular unconformity (Jayaprakash et al., 1987). The succession consists of three broad transgressive cycles, each floored by clastic rocks which grade upward to shale-carbonate assemblages. The Bagalkot Group is pervasively deformed, next in intensity only to the Nallamalai fold belt of the Cuddapah Supergroup, whereas the Badami Group is only very mildly deformed (Kale and Phansalkar, 1991).

The Bhima basin occurring on the northwestern edge of the Dharwar craton, includes a lower siliciclastic assemblage, the Rabanapalli Formation and the upper Sahabad Limestone consisting of micritic and siliceous limestone (Kale et al., 1990). The clastics start with conglomerates and show development of a fining upward sequence into the overlying lime-mudstone. The sequence, according to Kale et al.(1990), represents one cycle of Proterozoic transgression onto an epicontinental depression whose geometry was controlled by faulted margins.

Epilogue

A comparison of the Neoproterozoic and the possible Neoproterozoic successions in different Proterozoic basins reflects certain similarities and also a number of dissimilarities. The closing phase of the Mesoproterozoic is characterised by very mature sheet sandstones such as the Kaimur Sandstone, the Srisailam Quartzite or the carbonate-orthoquartzite associations in the Pakhal and Indravati basins. The associations indicate that high crustal stability was achieved before the opening up of Neoproterozoic basins. Sedimentary assemblages in the Neoproterozoic basins bear signature of basin opening by rifting, extension and subsidence. Successions in most of the basins exhibit fining-upward trends with conglomerates and coarse sandstones at the base and fine clastics and carbonates at the top, indicating sea level rise and major transgression. The conglomerates and coarse sandstones primarily developed as fan deltas which were blanketed by transgressive shelf sandstones or carbonates. The scenario in the Sullavai basin may be slightly different where marine incursion has not been recorded, though absence of marine deposits may be a question of preservation. The upper part of the Sullavai succession was evidently eroded away during the hiatus of the sub-Gondwana unconformity. In most of the basins, such as, Rewa-Bhander, Kurnool, Chattisgarh or Kaladgi, a major phase of transgression is followed by regression pointing to either multiple tectonic rejuvenation or eustatic sea level changes. The riftogenic setting of the basins are recorded in fan deltas, rapid facies changes and signatures of seismic activity which are all confined mainly to the lower part of the successions. The upper parts of the successions, on the otherhand, bear signatures of greater basin stability and stronger equilibrium between deposition and basin subsidence.

The basin-fills, also exhibit significant variations in their evolutionary trends. The closing phases of the Kurnool and the Bhander basins are marked by shallow water deposits with stable basin signatures. The eastern Chattisgarh basin, by contrast, is characterized by pyroclastics, seismic deformations and thin-bedded turbidites in its upper shale which apparently was deposited in a deep unstable basin. The Indravati basin includes profuse development of stromatolitic reefs, whereas the Marwar basin evolved into an extensive evaporite depositing milieu towards the end of the Neoproterozoic.

The history of Indian Neoproterozoic basins show several similarities with the Neoproterozoic basins of Australia (Preiss and Forbes, 1981) in terms of riftogenic origin as well as in terms of their lithologic fills. However, Neoproterozoic successions in Australia record two major episodes of glaciation, the Sturtian glaciation probably little older than 750 Ma and the Marinoan glaciation at about 750 to 670 Ma (Preiss and Forbes, 1981). The glacial deposits may be correlated over 3000 km from Tasmania, through the Adelaide Geosyncline and the Central Australian basins to the Kimberley region in the northwest, and the characteristic glacial successions seem to allow continent-wide correlation (Plumb, 1981; 1985). Basin-wide glacial deposits are also known from the Neoproterozoics of South Africa (Buhn et al. ,1992). By contrast, there is no definite record of glaciation in the Indian Proterozoic successions, though the cratonic blocks of India, Australia, and South Africa are considered to have existed side by side during the Neoproterozoic (Rogers et al., 1995).

Acknowledgements

The present work is a part of the research programme of the Indian Statistical Institute, Calcutta, on the Proterozoics of the peninsular India. Our thanks to Prof. A. B. Roy's effort in inviting us to contribute the paper and also for offerring many useful suggestions. We are also grateful to Prof. Prasanta Kr. Bhattacharyya, Jadavpur University, for reviewing the manuscript and for suggestions which substantially improved our ideas.

References

Ahmad, F. (1955) Glaciation in the Vindhyan System. Curr. Sci., v. 24, pp. 231.

Akhtar, K. (1996) Facies, sedimentation processes and environments in the Proterozoic Vindhyan Basin India. In: Bhattacharyya, A. (Ed.) Recent advances in Vindhyan Geology. Geol. Soc. Ind. Mem., v. 36, pp. 127-136.

Anil Kumar, Padma Kumari, V. M., Dayal, A. M., Murthy, D. S. N. and Gopalan, K. (1993) Rb-Sr ages of Proterozoic kimberlites of India: evidence of contemporaneous emplacement. Precambrian. Res., v. 62, pp. 227-237.

Awasthi, A. K. (1979) Sedimentological studies of the Jodhpur Group in the districts of Jodhpur and Nagpur, Rajasthan, India. Unpub. Ph.D. Thesis, Univ. Roorkee, 314 p.

Awasthi, A. K. and Parkash, B. (1981) Depositional environments of microfossiliferous sediments of the Jodhpur Group, Western India. Sediment Geol., v. 30, pp. 15-42.

Banerjee, I. (1974) Barrier coastline sedimentation model and the Vindhyan example, in A. De (Ed.) Contributions to the Earth and Planetary Sciences, Golden Jubilee Volume, Quart. J. Geol. Mineral. Metal. Soc. Ind., v. 46, pp. 101-127.

Basu, A. R. and Tatsumoto, M. (1979) Samarium-neodymium systematics in kimberlites and in the minerals of garnet lherzolite inclusions. Science, v. 205, pp. 389-401.

Bharadwaj, B. D. (1973) Petrography and environmental significance of Bhander Limestone (Upper Vindhyan) in Kota-Rawatbhata area, Rajasthan. J.Geol. Soc. Ind., v. 14, pp. 89-95.

Bharadwaj, B. D. (1977) Stratigraphy and depositional environments of the Rewa Group (Upper Vindhyan) around Bhainsrograh, Rajasthan. J. Ind. Assoc. Sedimentol., v. 1, pp. 52-61.

Bhattacharya, A., Kamaraju, M. V. V., Dangwal, M., Shrivastav, N. S., Shrivastav, H. P., Mainkar, D., Tiwari, R. and Singh, H. P. (1996) IRS-IC discovers a new kimberlite pipe for diamond exploration. Interface Bull. NRSA Data Centre, v. 7, No. 4, pp. 7-8.

Blanford, W. T. (1877) Geological notes on the Great Indian Desert between Sind and Rajputana. Rec. Geol. Surv. Ind., v. 10, pp. 141-149.

Bose, P. K., Banerjee, S. and Sarkar, S. (1997) Slope-controlled seismic deformation and tectonic framework of deposition: Koldaha Shale, India. Tectonophysics, v. 269, pp. 151-169.

Buhn, B., Stanistreet, I. G. and Okrusch, M. (1992) Late Proterozoic outer shelf manganese and iron deposits at Otjosondu (Namibia) related to the Damara oceanic opening. Econ. Geol., v.87, pp. 1393-1411.

Chakraborty, C. (1996) Sedimentary records of erg development over a braid plain: Proterozoic Dhandraul Sandstone, Vindhyan Supergroup, Son Valley. In Bhattacharyya, A. (Ed.) Recent advances in Vindhyan Geology. Geol. Soc. Ind. Mem., No. 36, pp. 77-100.

Chakraborty, P., Banerjee, S., Das. N., Sarkar, S. and Bose, P. K. (1996) Volcaniclastics and their sedimentolozoic bearing in Proterozoic Kaimur and Rewa Groups in Central India. In : A. Bhattacharyya (Ed.) Recent advances in Vindhyan Geology. Mem. Geol. Soc. India, v.36, pp. 59-76.

Chakraborty, T. (1991) Stratigraphy and sedimentation of Proterozoic Sullavai Group in the Southcentral part of the Pranhita-Godavari Valley. Unpubl. Ph.D. thesis Jadavpur University, 188p.

Chakraborty, T. and Chaudhuri, A. (1990) Stratigraphy of the Late Proterozoic Rewa Group and paleogeography of the Vindhyan basin in Central India during Rewa sedimentation. J. Geol. Soc. India, v. 36, pp. 383-402.

Chakraborty, T., Sarkar, S., Chaudhuri, A. K. and Dasgupta S. (1996) Depositional environment of Vindhyan and other Purana Basins : A reappraisal in the light of recent findings. In:A. Bhattacharyya (Ed.) Recent advances in Vindhyan Geology. Mem. Geol. Soc. India, v.36, pp. 101-126.

Chalapathi Rao, N. V., Miller, J. A., Pyle, D. A. and Madhavan, V. (1996) New Proterozoic K-Ar ages for some kimberlites and lamprolites from the Cuddapah Basin and Dharwar Craton, South India : evidence for non-contemporaneous emplacement. Precambrian. Res., v. 79, pp. 363-369.

Chanda, S. K. and Bhattacharyya, A. (1982) Vindhyan sedimentation and paleogeography. In: K.S.Valdiya, S.B.Bhatra and V.K. Gaur (Eds.) Geology of Vindhyanchal, Hindustan Publ. Corpor. New Delhi, pp. 88-101.

Chaudhuri, A. K. (1970) Precambrian stromatolites in the Pranhita-Godavari Valley (South India). Paleogeogr. Palaeoclimatol. Palaeoecol., v. 7, pp. 309-340.

Chaudhuri, A. K. and Chanda, S. K. (1991) The Proterozoic of the Pranhita-Godavari Valley : an overview. In : S.K. Tandon, C. Pant and S.M. Casshyap (Eds.)Sedimentary Basins of India : Tectonic Context. Gyanodaya Prakashan, Nainital, pp. 13-29.

Chaudhuri, A. K. and Howard, J. D. (1985) Ramgundam Sandstone: A Middle Proterozoic shoal bar sequence. J. Sed. Petrol., v. 55, pp. 392-397.

Chaudhuri, A. K., Sarkar, S. and Chanda, S. K. (1987) Proterozoic coastal sabkha halite pans: An example from the Pranhita-Godavari Valley, South India. Precamb. Res., v. 37, pp. 305-321.

Chumakov, N.M. and Semikhatov, M. A. (1981) Riphean and Vendian of the USSR, Precambrian. Res., v. 15, pp. 229-253.

Crawford, A. R. (1969) Geochronology of the Precambrian rocks of Peninsular India and Ceylon. Unpub. Ph.D. thesis, Australian Nat. Univ., 270 p.

Crawford, A. R. and Compston, W. (1970) The age of the Vindhyan System of Peninsular India, Q. J. Geol. Soc. London, v. 125, pp. 351-371.

Crawford, A. R. and Compston, W. (1973) An age of the Cuddapah and Kurnool Systems, South India. J. Geol. Soc. Aust., v. 19, pp. 453-464.

Das, N., Das Ganguly, M. and Arora, Y. K. (1990) Micro-facies assemblage of gypsum from Chattisgarh Basin - A Sabkha model of evaporite formation. Geol. Surv. Spl. Pub., No. 28, pp. 639-647.

Dasgupta, P. K. (1996) Cyclicity in the Proterozoic Cuddapah Supergroup and its bearing on basin evolution, India (extended abstract). Session 3-6 (Sedimentation in intracratonic basins) 3-6-5, 01214, 0925, Abstract Volume 2 of 3, 30th IGC, Beijing, P. R. China, p. 198.

Dasgupta, S. and Sengupta, P. (1998) Re-working of an isobarically cooler deep continental crust : evidence of decompressive P-T trajectory from the Eastern Ghats Belt, India. Ind. J. Geol., v. 70, No. 1 & 2, pp. 133-144.

Ferguson, J. (1980) Tectonic setting and paleogeotherms of kimberlites with particular emphasis on southern Australia. In: J.E. Glover and D.I. Groves (Eds.) Kimberlites and Diamonds. Publ. No. 5, Geology Depart. and Extension Services, Univ. Western Australia, pp. 1-14.

Grew, E. S. and Manton, W. I. (1986) A new correlation of sapphirine granulites in the Indo-Antarctic metamorphic terrain : late Proterozoics dates from the Eastern Ghats. Precambrian Res., v. 33, pp. 123-139.

Gupta, A. (1998) Igneous Rocks. New Delhi, Allied Publishers, 690p.

Gururaja, M. N. and Chandra, A. (1987) Stromatolites from Vempalle and Tadpatu Formations of Cuddapah Supergroup (Proterozoic) Andhra Pradesh and their significance. In: B.P.Radhakrishna (Ed.) Purana Basins of Peninsular India.Mem. Geol. Soc. India, v. 6, pp. 399-428.

Heron, A. M. (1932) The Vindhyans of Western Rajasthan. Record, Geol. Surv. India, v. 65, pp. 457-489.

Holmes, A. (1955) Dating the Precambrian of Peninsular India and Ceylon. Proc. Geol. Assoc. Canada, v. 7, pp. 81-106.

Holland, T. (1907) Imperial Gazetteer of India, v. 1, pp. 50-103.

Hurley, P.M., Cormier, R. F., Hower, J., Fairbairn, H.W. and Pinson, W. H. (1960) Reliabilty of glauconite for age measurement by K-Ar and Rb-Sr methods. Bull. Am. Assoc. Petrol. Geol., v. 44, 1793p.

Jayaprakash, A. V., Sundaram, V., Hars, S. K. and Mishra, R. N. (1987) Geology of the Kaladgi - Badami Basin, Karnataka. In: B.P. Radhakrishna (Ed.) Purana basins of peninsular India. Mem. Geol. Soc. India, v. 6, pp. 201-225.

Kale, V. S., Mudholkar, V. G., Phansalkar, V. G. and Peshwa, V. V. (1990) Stratigraphy of the Bhima Group. J. Paleontol. Soc. India, v. 35, pp. 91-103.

Kale, V. S. and Phansalkar, V. G. (1991) Purana Basins of peninsular India: a review. Basin Res., v. 3, pp. 1 - 36.

King, W. (1872) The Kudapah and Karnaul Formations in the Madras Presidency. Mem. Geol. Surv. India, v. 8, pp. 1 - 346.

Kruezer, H., Karrc, W., Kursten, M., Schnitzer, W. A., Murti, K. S. and Srivastava, N. K. (1977) K/Ar Dates of two glauconites from the Chandrapur Series (Chattisgarh/ India) : On the stratigraphic status of the Late Precambrian Basins in Central India. Geol. Jb. B., v. 28, pp. 25-36.

Mathur, S. M. (1981) The Middle Proterozoic Gangau Tillite, Bijawar Group, Central India. In: M.J. Hambrey and W.B. Harland(Eds.) Earth's pre-Pleistocene Glacial Record. Cambridge University Press, Cambridge, pp. 428-430.

Meijerink, A. M. J., Rao, D. P. and Rupke, J. (1984) Stratigraphic and structural development of the Precambrian Cuddapah Basin, SE India. Precambrian. Res., v. 26, pp. 57-104.

Murti, K. S. (1987) Stratigraphy and sedimentation in Chattisgarh Basin. In : B.P. Radhakrishna (Ed.) Purana basins of peninsular India. Mem. Geol. Soc. India, v. 6, pp. 239-260.

Nagaraja Rao, S. T., Rajurkar, G., Ramalingaswamy and Ravindra Babu, B. (1987) Stratigraphy, structure and evolution of Cuddapah Basin of peninsular India. In: B.P. Radhakrishna (Ed.) Purana basins of peninsular India. Mem. Geol. Soc. India, v. 6, pp. 33-86.

Narayanswamy, S., Hunday, A., Rajaraman, S. and Deshpande, M. (1971) The current exploration of diamond in different host rocks of Andhra Pradesh. Misc. Pub. No. 19, Geol. Surv. India, pp. 43-48.

NACSN (1983) North American Stratigraphic Code, North American Stratigraphic Code of Stratigraphic Nomenclature. Amer. Assoc. Petrol. Geol. Bull., v. 67, pp. 841-875.

Pascoe, E. H. (1975) A manual of Geology of India and Burma, v. 2 (reprinted), Govt. of India Press, Calcutta, pp. 485-1343.

Paul, D. K., Rex, D. C. and Harris, P. G. (1975) Chemical characteristics and K-Ar ages of Indian Kimberlites. Geol. Soc. Am. Bull., v. 86, pp. 364-366.

Plumb, K. A. (1981) Late Proterozoic (Adelaidean) tillites of the Kimberley-Victoria River region, Western Australia and Northern Territory. In: M.J. Hambrey and W.B. Harland

(Eds.) Earth's pre-Pleistocene Glacial Record. Cambridge University Press, pp.504-527.

Plumb, K.A. (1985) Subdivision and correlation of Late Precambrian sequences in Australia. Precambrian Res., v. 29, pp. 303-329.

Plumb, K.A. (1991) New Precambrian Time Scale. Episodes, v. 14, No. 2, pp. 139-140.

Preiss, W.V. and Forbes, B. G. (1981) Stratigraphy, correlation and sedimentary history of Adelandean (Late Proterozoic) basins in Australia. Precambrian. Res., v. 15, pp. 255-304.

Radhakrishna, B. P. (1987) Purana basins of peninsular India. Mem. Geol. Soc. India, v. 6, 518 p.

Raha, P. K. (1987) Stromatolites and correlation of the Purana Basins. In : Radhakrishna, B. P. (Ed.) Purana basins of peninsular India. Mem. Geol. Soc. India, v. 6, pp. 395-397.

Raha, P. K. and Sastry, M.L.V. (1982) Stromatolites and Precambrian stratigraphy in India. Precambrian . Res., v. 18, pp. 293-318.

Ramakrishnan, M. (1987) Stratigraphy, sedimentary environment and evolution of the Late Proterozoic Indravati basin, Central India. In: Radhakrishna, B. P. (Ed.) Purana basins of peninsular India. Mem. Geol. Soc. India, v. 6, pp. 139-160.

Rogers, J. J. W., Unrug, R. and Sultan, M. (1995) Tectonic assembly of Gondwana. J. Geodynamics, v. 19, No. 1, pp.1-34.

Roy, A. B. (1998) The Malani Igneous Suit of rocks. Correspondence. J. Geol. Soc. India, v. 51, pp. 556-557.

Sarkar, S. N. (1983) Present status of Precambrian stratigraphy and geochronology of peninsular Ind,— A synopsis. Ind. J. Earth Sc., v. 10, pp.104-106.

Sarkar, S., Chakraborty, P. P. and Bose, P. K. (1996) Proterozoic Lakheri Limestone, Central India: Facies, Paleogeography and Physiography. In: A. Bhattacharyya, (Ed.) Recent advances in Vindhyan Geology. Mem. Geol. Soc. India, v. 36, pp. 5-26.

Seilacher, A., Bose P. K. and Pfluger, F. (1998) Triploblastic animals more than 1 billion years ago: trace fossil evidence from India. Science, v. 282, pp. 80-83.

Shastry, M. V. A. and Moitra, A. K. (1984) Vindhyan Supergroup—A Review. Mem. Geol. Surv. India, v. 116, pt. II, pp. 109-148.

Shaw, R. K., Arima, M., Kagami, H., Fanning, C. M., Shiraishi, K. and Motoyoshi, Y. (1997) Proterozoic events in the Eastern Ghats Granulite Belt, India : Evidence from Rb-Sr, Sm-Nd systematics, and SHRIMP dating. J. Geol., v. 105, pp. 645-656.

Singh, I.B. (1976) Depositional environment of the upper Vindhyan sediments in the Satna-Maihar area, Madhya Pradesh, and its bearing on the evolution of Vindhyan sedimentation basin. J. Palaeontological Soc. India, v. 19, pp. 48-70.

Skinner, E. M. W., Smith, C. B., Bristow, J. B., Scott Smith, B. H. and Dowson, J. B. (1985) Proterozoic kimberlites and Lamproites and a preliminary age for the Argyle lamproite pipe, Western Australia. Trans. Geol. Soc. Africa, v. 88, pp. 335-340.

Soni, M. K., Chakraborty, S. and Jain, V. K. (1987) Vindhyan Supergroup—A review. In : B.P. Radhakrishna (Ed.) Purana basins of peninsular India.Mem.Geol. Soc. India, v. 6, pp. 87-138.

Tugarinov, A. I., Shanin, L. L., Kazakov, G. A. and Arakelyants, M.M. (1965) On the glauconite ages of the Vindhyan system (India). Geokhimiya, no. 6, pp. 652-660.

Venkatachala, B. S., Sharma, M. and Shukla, M. (1996) In: Bhattacharyya, A. (Ed.) Recent Advances in Vindhyan Geology, Mem. Geol. Soc. India, v. 36, pp. 137-165.

Vinogradov, A., Tugarinov, A., Zhykov, C., Stapnikova, N., Bibikova, E. and Khorre, K. (1964) Geochronology of Indian Pre-Cambrian.Rep.22nd Int.Geol.Cong.,New Delhi, v. 10, pp. 553-567.

Volpe and Macdaugall, J.D. (1990) Geochemistry and isotopic characterisitic of mafic (Phulad Ophiolite) and related rocks in the Delhi Supergroup, Rajasthan, India: implications for rifting in the Proterozoic. Precambrian Res., v. 48, pp. 167-191.

Williams, G. E. and Schmidt, P. W. (1996) Origin and palaeomagnetism of the Mesoproterozoic Gangau tilloid (basal Vindhyan Supergroup), Central India. Precambrian Res., v. 79, pp.307-325.