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PALEOGEOGRAPHY OF VINDHYAN BASIN AND ITS RELATIONSHIP WITH OTHER LATE PROTEROZOIC BASINS OF INDIA

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ABSTRACT

Evaluation of facies association and palaeo-environmental data of the Vindhyan basin suggests the existence of a large embayment running E-W, roughly following the present-day distribution of Vindhyan outcrops; the deposition took place in littoral areas under the influence of both current and wave activity. Study of palaeocurrent pattern of the Kaimur Sandstone in Son Valley clearly demonstrates that N-NW directed waves were active, suggesting the existence of a prominent N-NW directed palaeo-wind system. The current-formed structures show westerly trend and are considered to reflect an ebb-current system. This data suggests that an open-sea might have existed in the west, beyond Rajasthan. The Vindhyan sea might have been connected near Agra to the embayment of the Gangetic Alluvium—Lesser Himalaya. On the other hand, it is proposed that during Late Proterozoic, extensive shallow seas on a peneplained landscape dominated the scene, forming embayments, where deposition took place essentially in littoral areas and the different Late Proterozoic basins, i.e. Chhatisgarh basin, Cuddapah basin, Pakhal, Badami etc. were probably all interconnected. The available evidence fails to support the existance of deep oceans during Late Proterozoic times on the Indian subcontinent.

INTRODUCTION

Vindhyan basin of central India exhibits well-developed and well-preserved sedimentary successions of Late Proterozoic age (ca. 1400-700 Ma. B. P.) and represents deposits of shallow marine environment (see Auden, 1933; Banerjee and Sen Gupta, 1963; Misra, 1969; Singh 1973, 1976a, 1980a, b; Banerjee, 1964, 1974). Recently, Singh (1980a) discussed, that Vindhyan basin can be considered as littoral basin as its sediments represent deposition exclusively within the littoral zone. An obvious question then arises : what was the position of Vindhyan basin within the Late Proterozoic sea of India, and where was the open sea ? Further, the other Late Proterozoic basins of Indian shield, i.e. Chhatisgarh basin (Schnitzer, 1971), Cuddapah basin, Pakhal and Sullavai Groups in Godavari valley (Basumallick, 1967; Chaudhuri, 1970; Chaudhuri and Howard, 1984) etc. all represent deposits of littoral area. Obviously these isolated basins were part of an extensive sea of Late Proterozoic times. In the present paper a plaeogeographic reconstruction of the Vindhyan basin and its possible relationship with other Late Proterozoic basins is attempted.

VINDHYAN BASIN

The Vindhyan basin has an exposed area of about 104,000 square kilometres, but a large part is probably covered under Deccan Traps, and extends from Sasaram in Bihar to trans-Aravalli area in Rajasthan. It consists of mainly carbonates, mature sandstones, and siltstones and shales. Banerjee (1974) proposed a barrier coastline model for the sedimentation of the Vindhyan sediments and assigned tidal flat, lagoon and barrier beach dune environments to different lithounits. Singh (1973, 1976a, 1980a) argued that the palaeoenvironment of Vindhyan sediments fluctuates amongst tidal flat, lagoon and shoal complex and the succession has been formed mainly due to syn-sedimentary sinking of the basin and the lateral shifting of the shallow marine environments, and that there were no progradational offshore-coastal sequences in the conventional sense; he stressed that the major sandstone bodies, namely Kaimur, Rewa and Bhander represent deposits of shoal complex of a shallow tidal sea without development of characteristic beach sequences. The thickness of sediments varies in different areas with time, implying shifting of depositional centers (areas where synsedimentary sinking of the basin was maximum to accommodate a thick pile of sediment during a particular time) (see Banerjee, 1964). During sedimentation of the Semri and Kaimur sediments, Son Valley was important depositional center and contains the thickest successions. During deposition of Rewa sediments the depositional center shifted to the Dhar forest area, while for Bhander sediments the

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'depositional center' shifted to the Satna-Maihar area (Figure 1).

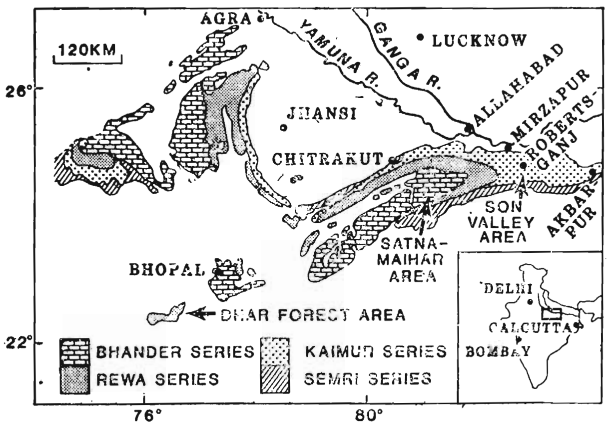

Fig. 1. Location map showing outcrop distribution of Vindhyan sediments.

Vredenburg (1906) and Auden (1933) suggested that the coastline of the Vindhyan sea was located just north of the present-day outcrops of the Vindhyan sediments in Panna and Chitrakut area respectively, but Ahmad (1962) made an attempt to reconstruct the palaeogeography of Vindhyan basin. On the basis of isopach form lines, Ahmad (1962) suggested, that the Vindhyan sea followed roughly the outline of present-day Vindhyan outcrops and the open sea existed in the west toward present-day Arabian Sea, in the north, east and south of the Vindhyan Sea, a craton was inferred; he suggested that the Vindhyan did not extend below the Gangetic Alluvium except in a narrow strip around Mirzapur, Allahabad and Agra.

On the contrary, Krishnan and Swaminath (1959) proposed that the shape of Vindhyan basin indicates its extension deep into the Lesser Himalaya, and proposed that the upper Vindhyan are equivalent to the sequences in Lesser Himalaya, e.g. Shali and Krol belts, and pushed up the age of these rocks as Palaeozoic, a suggestion made earlier by Boileau (1954). Jafar et al. (1966), Misra (1969) supported the idea of extension of Vindhyan sediment below the Gangetic Alluvium, on the basis of palaeo-current data, assuming that palaeocurrent direction always corresponds to the palaeoslope. Valdiya (1969) correlated the stromatolites of the Vindhyan sediments with parts of the Lesser Himalayan succession, especially the Calc Zone of Pithoragarh, and suggested that they are both of the same age. S. Kumar (1978a) proposed a direct correlation of succession of the Semri and Kaimur sediments with the Zone of Badolisera in the Lesser Himalaya, mainly on the basis of similarity in lithology and stromatolite assemblages, and expressed the possibility that both of them are products of deposition in a single basin, which implies the extension of the Vindhyan basin below the Gangetic Alluvium. S. Kumar (1978a) also noted the alternative, that the two areas, i.e. the Vindhyan and Zone of Badolisera may represent deposition in two separate homotaxial basins.

Valdiya (1980, fig. 4.12) published a palaeogeographic map showing Vindhyan basin enclosed to the East, West and South by cratons, and opening up to the North and connected with the Lesser Himalaya across Gangetic Alluvium ; he does not discuss this map in the text, but seems to suggest that NW directed palaeocurrents in the eastern part of Vindhyan basin follow the palaeoslope; further, in the Simla region the Simla slates represent deep sea turbidite deposits with northerly flowing turbidity currents. Valdiya (1980, figs. 4.10, 4.12) also considers that in the Lesser Himalayan zone (dominantly shallow tidal sea deposits) the NE palaeocurrent denotes a palaeoslope in that direction.

Before making any evaluation of these suggestions regarding the extension of Vindhyan basin *sensu-stricto* in the Lesser Himalaya, certain problems inherent in the palaeocurrent interpretation of shallow marine deposits are discussed.

PALAEOCURRENT ANALYSIS IN SHALLOW MARINE SEDIMENTS

Palaeocurrent studies are helpful in determining provenance, palaeoslope, shore line orientation and basin geometry. Because rivers flow from the higher to lower altitude, in fluvial environments the direction of palaeocurrent (especially the vector mean) corresponds with the paleoslope.

However, in the shallow marine environments, current patterns are rather complex as various types of current systems, e.g. longshore current, rip current, tidal currents (ebb and flood systems) co-exist. Further wave induced currents and waves are also present which are largely controlled by wind directions. Because of the complex interplay of various current and wave systems, the palaeocurrent patterns in the shallow marine successions are mostly polymodal (often bimodal rare cases, unimodal). Determination of sediment transport in the modern tidal seas shows, that their palaeocurrent patterns are extremely complicated (see fig. 403, Reineck and Singh, 1973). In some cases unimodal distribution of palaeocurrent pattern is present when one of the current systems overshadows the other systems (Reineck and Singh in Dörjes et al., 1969). The vector mean of the palaeocurrents in shallow tidal sea deposits cannot be considered as an indicator of palaeoslloe (Singh, 1976a). In shallow tidal sea sequences, however, the pattern of palaeocurrents can sometimes be helpful in determining the palaeoenvironment (see Klein, 1967).

For the Vindhyan sediments Banerjee (1974) utilized palaeo-current patterns to interpret the palaeo-environment along with data on lithology and sedimentary structures. Singh (1976a) pointed out that in Vindhyan sediments, palaeocurrent direction cannot be used to determine the palaeoslope.

In the light of above discussion, the statement by Banerjee and Sengupta (1963) that palaeocurrent data suggests a gentle NW regional slope, Jafar et al.'s (1966) interpretation that NW palaeocurrent in Mirzapur area corresponds to palaeoslope and that deeper part of the basin must exist northwards below the Gangetic Alluvium and Misra's (1969) postulation that the Vindhyan basin extends futher north below the Gangetic Alluvium cannot be accepted.

Even the palaeogeographic reconstruction of Valdiya (1980, fig. 4.12) also cannot be accepted, as his basic assumption, that paleocurrent in shallow marine successions correspond to the palaeoslope, is questionable. Further, the inferred direction of turbidity currents in Simla Slates also loses its significance as the Simla Slates represent shallow tidal sea deposits, mainly in tidal flats, lagoon, and embayments (Singh and Merajuddin, 1976, 1980; Singh, 1980).

Consequently, all these palaeogeographic studies based upon palaeocurrent data to interpret the palaeoslope of Vindhyan basin, but neglecting the facies analysis are to be viewed with scepticism or discarded.

FACIES AND PALAEOCURRENT OF THE KAIMUR SANDSTONE IN THE SON VALLEY AREA

The Kaimur Sandstone in the Son Valley area is differentiated into a lower unit—Scarp Sandstone, and an upper unit-Dhandhraul Quartzite. Both the units show similar facies characteristics and differ from each other in that the Dhadhraul Quartzite is more mature than Scarp Sandstone. The Kaimur Sandstone represents deposits of a transgressive phase above the lagoonal Bijaigarh Shale (Singh, 1980a, b) and make an extensive plateau in the Son Valley area. Environment of deposition of this sandstone succession is a shoal complex (Singh, 1973, 1976a, 1980a) and lacks many of the characteristics of beach sequences.

The Kaimur Sandstone is characterized by large-scale cross-bedding, which can be distinguished into genetically two different types. i.e. bar cross-bedding (fig. 2) and megaripple bedding (fig. 3). Bar cross-bedding is made up of lenticular-shaped units extending laterally up to ca. 5-10m, and 1-2m in height. Internally foreset laminae dip mostly ca. 12-15°, where bundles of foresets with slightly differing attitude and angles are distinguished. These units coalesce to produce bigger compound bar and shoal morphology (Singh and Howard, in prep.). These large-scale bar cross-bedded units are product of deposition by wave action, and show a rather consistent N-NW palaeocurrent direction, which denotes existance of a rather strong N-NW directed wind system during deposition of Kaimur Sandstone in Son Valley.

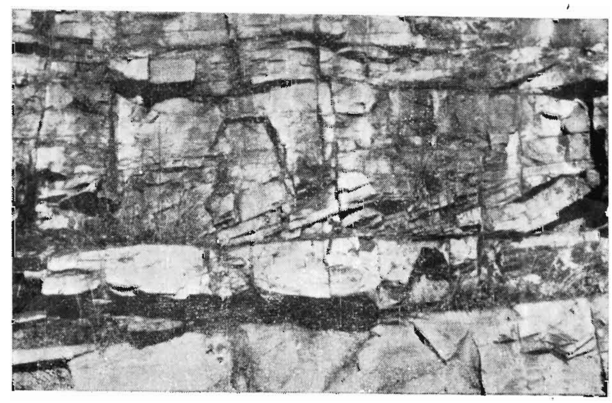

Fig. 2. Succession showing mostly dc n thick planar crossbedded units produced due to migration of of wave-built bars in a shoal complex. The undulatory surfaces represent ercsional basal plnes of wave-built bars. In the middle of the photograph bar cross-bedding with distinct low-angle planar foresets is visible. Scarp Sandstone, Churck-Gurma road. Length of the hammer=15 cm.

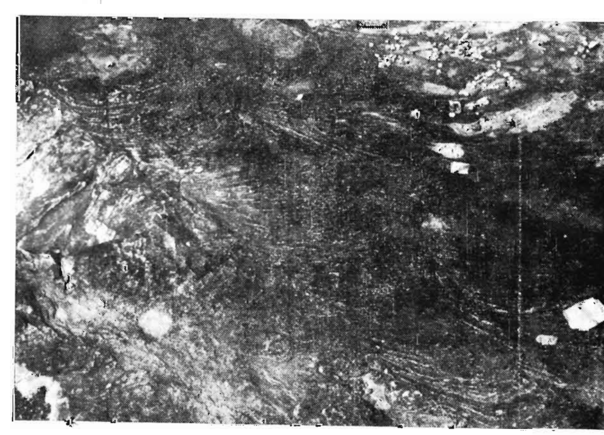

Fig. 3. Surface (top) view of megaripple bedded unit. Prominent festoon-shaped cross-bedded units are seen in the form of curved laminae. Scarp Sandstone, Churk-Gurma Road. Length of the hammer =35 cm.

Interbedded within the bar cross-bedded units are 10-20cm thick units of festoon-shaped megaripple bedding, which show a consistent westerly direction. These megaripple units are product of deposition by current action. In tidal embayments ebb-current are commonly stronger than flood currents, and the westerly current direction is considered to correspond to the ebb-current direction (Singh and Howard, in prep.).

Consequently, the open-sea of the Vindhyan embayment must have existed towards west, and the present eastern limit of the basin corresponds more or less to the eastern limit of the Vindhyan embayment. This model is supported by data on sediment thicknesses in the Vindhyan basin (Ahmad, 1962).

Banerjee and Sengupta (1963) and Jafar et al. (1966) also suggested dominantly NW palaeocurrent direction for the Kaimur Sandstone in the Son Valley but related this to the current and paleosolope; while the present study demonstrates that NW direction is in fact prominent wave propagation direction controlled by wind direction, thus unrelated to palaeoslope. Banerjee (1974) also commented, that the Vindhyan sediments have a bimodal distribution of palaeocurrent where NW direction is prominent and may possibly reflect wind direction.

PALAEOGEOGRAPHIC RECONSTRUCTION OF VINDHYAN BASIN

In view of the preceeding discussion, it seems reasonable to assume that the Vindhyan sediments are product of deposition in a shallow littoral embayment, following roughly the present-day distribution of Vindhyan outcrops. The eastern limit of the embayment was not far from Son Valley, while an open sea may have existed in the west; but in the Son Valley, the embayment did not extend much farther in the north than its present-day distribution. In the eastern and central part of the Vindhyan basin (embayment) NW directed waves and westerly-directed current (corresponding to ebb-current) were present during deposition of Kaimur sediments (fig. 4).

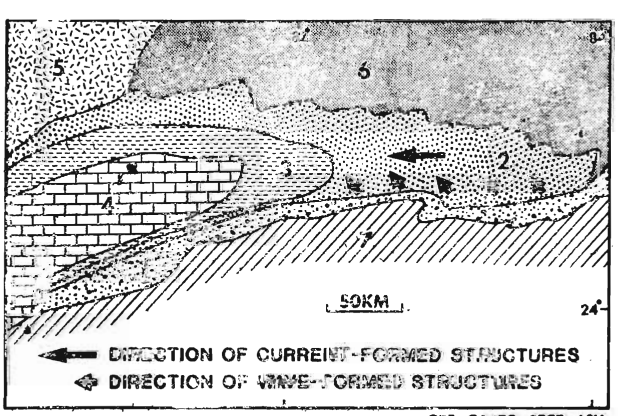

Fig. 4. Sketch geological map of the eastern part of Vindhyan basin. Kaimur Sandstone (2) show a prominent NW-palaeocurrent direction of the wave-formed structures; and a dominant W-palaeocurrent direction of current-formed cross-bedding, probably the ebb-direction. 1-Semri Series, 2-Kaimur Series, 3-Rewa Series, 4-Bhander Series, 5-Bundelkhand granite, 6-Gangetic Alluvium, 7-Pre-Vindhyan rocks (mainly Bijawar).

Interestingly, the Rewa Sandstone and Maihar Sandstone show similar facies characteristics to those of the Kaimur Sandstone and represnt deposits of shoals (Singh, 1976a, 1980a) and also exhibit a dominant NW palaeocurrent direction (see also Banerjee, 1974). This suggests that the palaeogeographic setting, including palaeowind directions and palaeocurrent directions were surprisingly constant throughout the sedimentation history of Vindhyan basin (1400-700 Ma. B. P.).

Palaeocurrent measurements by S. K. Misra (1967) have a NE trend near Dhar forest and Bhopal, while Jafar et al. (1966) found a NE trend near Agra. It seems that palaeocurrent patterns near the margins of the central part of the Vindhyan basin show different directions, though we do not have any information on whether these palaeocurrent patterns are related to wave or current activity.

The trans-Aravalli Vindhyan represents another embayment probably not directly connected to the main Vindhyan basin embayment where conditions of barried basin existed leading to extensive development of gypsum and halite deposits, and may be slightly younger in age than the uppermost Vindhyan sediments.

The deposition of salt may correspond to the latest Precambrian-Lower Cambrian salt deposition event of Salt Range and other parts of Arabia and Iran (see Gorin et al., 1982; Singh, in preparation).

PALAEOGEOGRAPHY OF LATE PROTEROZOIC SEA IN INDIA

In the Indian Peninsular Shield unmetamorphosed Late Proterozoic successions (ca. 1700-600 Ma.) are common, and are preserved in separated basins. All of them represent deposits of a shallow tidal sea, mainly in littoral zone and are characterized by orthoquartzite, shale and carbonate (Singh, 1980a). Joining up of these isolated and widely separated basins gives a landscape of embayments. All these embayments must have been part of an open sea system which might have existed in the west, in the area presently occupied by the Arabian Sea, and in the NW towards present day Afganis tan and probably also in the East to which Late Proterozoic deposit of Godavari Valley might have been connected (fig. 5).

An interesting point about the Late Proterozoic deposits is that none of the Late Proterozoic basins in Peninsular India show sedimentary units which have been deposited in water depths exceeding 15-20 m. This fact demands that during Late Proterozoic times in India, vast peneplaned areas existed separated by moderate to low highlands. Within the peneplaned areas extensive embayments of shallow tidal sea existed

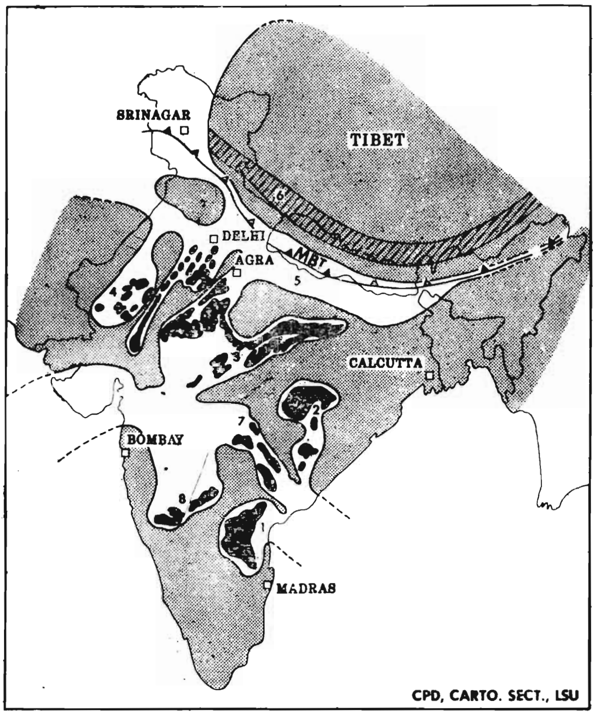

Fig. 5. Schematic palaeogeographic reconstruction of India during Late Proterozoic (ca. 1700 - 600 Ma. B. P.). The unmetamorphosed Late Proterozoic sediments were laid down in an extensive shallow sea which existed in the form of embayments on the Indian subcontinent. The Vindhyan basin (3) was open towards west; in the north it may be connected to embayment of Gangetic Alluvium near Agra. It is also likely that in some parts of the sea, sedimentation started earlier than in the other parts and transgression-regression history in different basins show marked differences. 1-Cuddapah basin, 2-Chhatisgarh basin, 3-Vindhyan basin, 4-Trans-Aravalli Vindhyan, 5-Gangetic-Alluvium-Lesser Himalaya embayment, 6-Tethys zone, where sedimentation started in Latest Proterozoic (ca. 700 Ma.), 7-Godavari Valley, 8-Badami Group. Black-outcrops of late proterozoic sediments on peninsular India, white-sea, dotted-land. MBT-Main Boundary Thrust denoting southern limit of the Himalaya.

where deposition took place mainly in the littoral zone. Nowhere in India during the Late Proterozoic is there any evidence of continental margin or deep sea sedimentaiton. It is quite possible that during Late Proterozoic times no extensive deep oceans existed, and this may be one of the reasons that marine waters covered very large continental areas in the form of embayments where mostly littoral zone sedimentation took place.

In the Himalayan area too (Lesser and Central Himalaya), which represents an integral part of the Indian shield, during Proterozoic only shallow tidal sea deposits such as orthoquartzite, shale and carbonate are present (Singh, 1976b, 1979). Below the Gangetic Alluvium too probable Late Proterozoic successions are recorded in a number of deep boreholes (see fig. 2 in Acharyya and Ray, 1982) which are mostly classed as Vindhyan sediments. These Late Proterozoic successions (so called Vindhyan below the Gangetic Alluvium) must also have been laid down in one or more embayments of Late Proterozoic sea in the Himalaya and Gangetic Alluvium areas (fig. 5). However, the Vindhyan basin *sensu-stricto* could not have continued below the Gangetic Alluvium into the Himalaya as visualized by several workers. It is proposed here that a large EW-trending embayment existed during Late Proterozoic times, below the present-day Gangetic Alluvium and also covered the areas of the Lesser Himalaya.

This large marine embayment was probably closed towards the East, but was open towards the Northwest, connected to the main open ocean which is supposed to have existed during Late Proterozoic in the Norh of present-day India (fig. 6). During Latest Precambrian this littoral sea of Gangetic Alluvium and Lesser Himalaya started receding towards West till final withdrawal took place during the Lower Cambrian (see Singh and Rai, 1983).

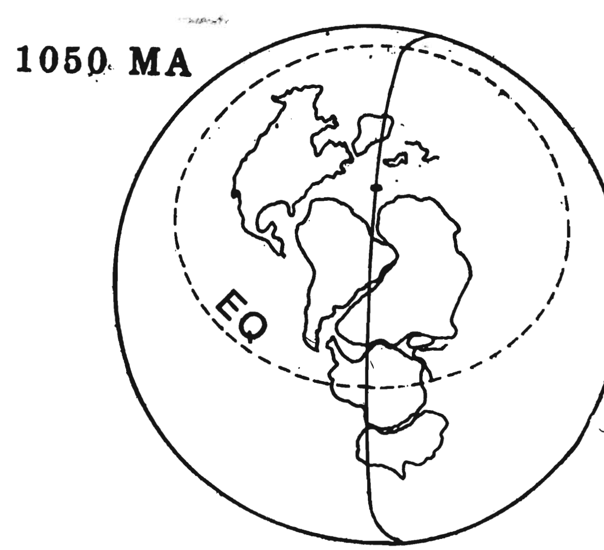

Fig. 6. Reconstruction of continents in 1050 Ma. A ocean is present north of India. EQ=equator (Redrawn after Morel and Irving, 1978).

During Latest Precambrian-Early Cambrian, deposition of evaporite took place in the NW part of India-in Rajasthan (trans-Aravalli Vindhyan), in the Mandi area of the Lesser Himalaya, and in Salt Range of Pakistan. This evaporite deposition marks the eastern extension of carbonate-salt platform of Arabia-Iran as proposed by Gorin et al., 1982.

It is possible that the Vindhyan basin was connected to the Gangetic Alluvium-Lesser Himalaya embayment near Agra.

During the Latest Proterozoic (approx. 700 Ma.) a new sea-way opened up north of Central Himalaya where shallow marine sedimentation was initiated (Tethys zone/Tibetan Zone) which continued throughout the Palaeozoic and Mesozoic.

PALAEOECOLOGY OF VINDHYAN SEDIMENTS

Vindhyan sediments have yielded a number of organic remains, some of which have been doubted (for discussion of earlier reports see Misra, 1969). Tandon and Kumar (1977) record some body fossils which they consider to be annelid and arthropod. Singh and Chandra (1980) record remains of jellyfish-like organisms. Maithy and Shukla (1974) report microorganisms from the Suket Shale. Kumar (1978b) records well-preserved microorganisms from the cherts of Lower Vindhyan sediments.

More recently a few records of burrows made by some unknown metazoans are reported. Verma and Prasad (1968) reported trails, i. e. *Bostricophyton*, *Rouaultia*, and *Tasmanadia* from Bhander Limestone. Kumar (1978c) describes a horizontal trail, *Muniaichnites* from Glauconditic Sandstone. Sarkar (1974) records spindle-shaped bodies from Bhander Limestone in Maihar area, and refer to them as burrows. Most of these burrows are like sand-filled shrinkage cracks; but a few may be related ot metazoans.

The present author has also observed a number of features, which resemble bioturbation structures and burrows, in the Lower Quartzite and basal part of Bijaigarh Shale of Son Valley as well as in glauconitic sandstone at Lodhwara hill, Chitrakut area.

The exact nature of these bioturbation structures is not yet clear, and we still do not have an idea as to what type of organisms produced them. But it is significant that all these burrows are from intertidal facies of low to medium energy. Associated subtidal facies have not yielded bioturbation structures. For example, they are not found in Rohtas Limestone (mostly representing subtidal deposit), which provides rather suitable lithology for burrowing organisms.

This suggests that the meagre benthonic metazoan population of Late Proterozoic times preferred, the low to medium energy intertidal flat areas of littoral seas, as their habitat. Singh (1980a) discusses that the extensive growth of algae in supratidal areas with ponds during Late Proterozoic led to local increase in oxygen and helped in the evolution of metazoan. It was only during later evolution that the benthonic communities migrated to the subtidal areas on one hand and to the adjacent alluvial plain areas on the other. However, this hypothesis need be further tested by the data in other Late Proterozoic basins in India and in the other parts of the world.

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