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Contents

Volume, 53 (2), December 2008

INDEX

(VOLUME, 53)

NO. 1, JUNE, 2008

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AN UPDATED INTRODUCTION TO THE SPITI GEOLOGY

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ABSTRACT

The paper discusses controversies pertaining to the nomenclatures of the Ordovician Thango (Shian), Ordovician-Silurian Takche (Pin) and Triassic-Jurassic Lilang sequences. The latest classification of the Lilang, raised to supergroup level and various time boundaries with in the Triassic are also described. Also listed are the latest palaeontological contributions to the Early-Middle Cambrian (Kunzam La Formation), Ashgill-Wenlock (Takche Formation), Givetian-Tournaisian (Lipak Formation) and Induan-Early Carnian (Mikin, Kaga and Chomule formations). A short review of the entire sequence together with that of the structure updates the geology of the Spiti Valley.

Keywords: Spiti Valley, Peri-Gondwana Tethyan Himalaya, lithostratigraphy, sedimentation, structure

INTRODUCTION

The Himalayan Mountain Chain extending over a distance of more than 2000km is traditionally subdivided into the following zones:

1.1. The Siwalik Foothills of the Sub-Himalaya constituted of the Neogene-Quaternary molassic deposits of the Siwalik Group.

1.2. The Lesser Himalaya exposing from the outer to the inner parts (i) the Palaeogene sediments juxtaposed against the Siwalik Group in south along the Main Boundary Fault *s.s.*, and against the Proterozoic rocks in north along the Main Boundary Thrust, (ii) isolated Early Cambrian, Early Permian and Late Cretaceous outliers over the Proterozoic rocks, (iii) crystalline thrust sheets and (iv) windows of Proterozoic/ Paleogene rocks within the crystalline/Proterozoic rocks along the antiformal valleys.

1.3. The Higher Himalaya consisting of the crystalline thrust sheets with the Vaikrita Thrust Sheet (=Main Central Thrust, Bhargava and Bassi, 1994) occupying the highest tectonic level. The Vaikrita Thrust Sheet known by different names (e.g. Salkhala in Kashmir, Thimphu in Bhutan) extends through out the Himalaya.

1.4. The Tethyan Himalaya made up of the Neoproterozoic-Eocene succession resting as detached synclinoria over the Vaikrita Crystalline or its strike equivalents. The main synclinoria often referred to as basins, from west to east are (i) Kashmir, (ii) Chamba-Bhadarwah-Tandi, (iii) Zanskar-Spiti, (iv) Kinnaur-Kumaon, (v) Nepal, (vi) Sikkim-Bhutan and (vii) Arunachal.

1.5. The Indus-Tsangpo Suture Zone representing rocks associated with the Suture between the Indian and Asian plates.

The Spiti Valley, located north of the Pir Panjal Range, exposes an excellent section of Neoproterozoic-Cretaceous rocks in the Tethyan Himalaya of Himachal Pradesh (Fig. 1). The Spiti Tethyan rocks towards NW through the Lahaul Valley extend into the Zanskar area.

Hutton (1841), Stoliczka (1865), Griesbach (1889), Hayden (1904), Srikantia (1981), Fuchs (1982), Ranga Rao *et al*, (1984), Bagati (1990) and Bhargava and Bassi (1998) have dealt with the geology of the Spiti Valley. Main palaeontological contributions have come from Blanford (1863, 1864), Stoliczka (1864), Davidson (1864), Diener (1895, 1897, 1903, 1907, 1908, 1912, 1915), Mojsisovics (1899), Reed (1910,1912), Holdhaus (1913), Bhatt *et al.* (1977), Goel (1977), Goel and Srivastava (1978), Bhatt and Joshi (1978), Bhatt and Arora (1984), Goel *et al.* (1984. 1987), Ravi Shanker *et al.* (1993), Draganits *et al.* (2000; 2001), Bhatt *et al.* (1981; 2004), Krystyn *et al.* (2004) and Suttner (2003). The manuscript of the Memoirs, Geological Survey of India 124 was submitted to the Publication Division of the Geological Survey of India in 1990, though it was published only in 1998 (Bhargava and Bassi, 1998), thus included references only up to 1990. Since 1990, several important contributions to the geology of the Spiti Valley have been made. The present paper gives an updated summarized version of the geology of the Spiti Valley.

LITHOSTRATIGRAPHY AND PALEOENVIRON-MENT

Proceeding from the Rohtang Pass in west and from Karcham in east, the metamorphic grade of the rocks of the Vaikrita Group gradually decreases and these are succeeded by the Neoproterozoic-Cretaceous sequence, referred to as the Peri-Gondwana Tethyan succession (Matsuda, 1985). The contact between the Tethyan succession and the crystalline rocks is variously regarded as tectonic (Thakur, 1992), conformable and gradational (Srikantia, 1981; Ranga Rao *et al.*, 1984) and unconformable (Bhargava and Bassi, 1998). Such conflicting views are peculiar not only to the Western Himalaya but are also prevalent in the Eastern Himalaya. For example in Bhutan, Gansser (1981) considered the contact between the crystalline rocks and the Tethyan rocks as gradational, Tangri and Pande (1995) due to discovery of a 150m thick volcanic pile (Singhi Volcanics) below the Tethyan sequence regarded the contact as non-conformable, while Grujic *et al.* (2002) visualize a tectonic contact.

The lithostratigraphy of the Tethyan sequence in the Spiti Valley is furnished in Table 1.

Haimanta Group

This group is divisible in two formations viz. the Batal and Kunzam La formations.

Batal Formation: From a distance, the Batal Formation is recognizable as a dark grey to light grey sequence forming rather steep slopes. It comprises grey, locally carbonaceous slaty shale and local lenses of grit and conglomerate in its

Journal of the Palaeontological Society of India
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MICROFACIES AND DEPOSITIONAL ENVIRONMENT OF THE GAJ FORMATION (MIOCENE) EXPOSED NEAR BHATIA, DISTRICT JAMNAGAR, SAURASHTRA

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ABSTRACT

Complex tectonic features surround the Saurashtra Peninsula of the Gujarat state on the western extremity of India, a consequence of the breaking up of Gondwanaland in the Triassic. The arching up of the Saurashtra peninsula was a result of pre-Eocene thermal expansion of the crust while moving northeastward over the Reunion hot spot. This, together with lower eustatic sea level during the Eocene in comparison to higher global sea level in the Miocene, has resulted in the absence of Eocene sediments from the Saurasthra upland. The oldest sediments deposited at the northwestern coast of Saurasthra, which forms the Palaeogene-Neogene pericratonic sedimentary basin, belong to the Miocene. These Miocene sediments of Saurashtra have been, lithostratigraphically, grouped into the lower Ashapura Clay Member and the upper Ranjitpur Limestone Member of the Gaj Formation. Fossil records suggest a marine environment of deposition, however, rapid temporal change of facies can be attributed to fluctuating depositional environments. In the present paper, a 1.5 m thick section of the Ranjitpur Limestone Member exposed along a ridge near Bhatia, district Jamnagar, Saurashtra, has been investigated and interpreted to represent nearshore to subtidal environments.

Keywords: Gaj Formation, Saurashtra, depositional environment, microfacies, molluscs

INTRODUCTION

The tectonic framework of the Saurashtra Peninsula on the western extremity of India (Fig. 1) is related to the evolution of the whole of the state of Gujarat, which was initiated sometime in the Triassic with the breaking up of Gondwanaland. The subsequent geological history including Deccan Volcanism is related to the northward drift of the Indian subcontinent. The Saurashtra Peninsula with its coastal margins, although situated away from the plate boundary and sometime considered a passive area (Mathur, 1999; Mathur and Pandey, 2002), witnessed periodic earthquakes as a result of a complex tectonic features within and around the state of Gujarat (Biswas, 1987). The development of the Cambay and the Kachchh grabens can be traced, along with the western Ghat uplands, back to the splitting up of Gondwanaland. These features have developed as a result of rifting between Madagascar and India. While moving northeastward, the Indian Plate passed over the Reunion hot spot (Fig. 2). As a result of thermal expansion of the crust, the arching of Western Ghat uplands, Saurashtra and Kachchh took place (Courtillot *et al*., 1986). The radial drainage observed in Saurashtra is the result of such arching. The uplift of the Saurashtra Peninsula can be dated as pre-Eocene, because Eocene and Oligocene marine sediments are missing on the Saurashtra upland (not Lower Miocene as postulated by Radhakrishna, 1993). The global sea level during Eocene has been suggested to be lower than that in the Miocene (Lincoln and Schlanger, 1991). The outcrop distributions of marine Eocene and Miocene sediments are not similar. This is because of difference in sea level and also perhaps due to change in the degree of arching up of the Saurashtra Peninsula during Eocene-Miocene epochs. The marine Eocene sediments have been recorded from the western coast of Gujarat Mainland, and the Kachchh, Jaisalmer, Bikaner-Nagaur basins on the northwestern part of Indian craton, whereas the Miocene sediments have been recorded from the western Saurashtra and Kachchh basins only (Fig. 1).

STRATIGRAPHY

The deposition of oldest marine sediments in the pericratonic-shelf basin at the fringe of the Trappean highlands of Saurashtra (Fig. 1), started at the beginning of the Neogene (early Miocene). These sediments have been grouped into the Gaj Formation (Shrivastava, 1963). Lithostratigraphically, the Gaj Formation has been divided into the lower Ashapura Clay Member and the upper Ranjitpur Limestone Member (Bhatt, 2000; Kachhara *et al*., 2000) (Table 1). The Ranjitpur Limestone Member is rich in both micro- and macro-invertebrate fossils. Both sediments and faunal elements provide a good opportunity for palaeoenvironmental studies. Earlier records suggest a marine depositional environment as indicated by the abundance of foraminifers such as *Lepidocyclina* and *Miogypsina*, echinoids, molluscs, etc. (Mathur *et al*., 1988; Kachhara *et al*., 2000; Jain, 2002). However, rapid temporal facies changes suggest fluctuating conditions characteristic of the shallow shelf. Only a few good outcrops of the formation exist. One of them investigated here is an exposure of the lower part of the Ranjitpur Limestone Member (Lower Miocene) exposed along a ridge crossing the road to Dwarka about 10 km east of Kuranga village near Bhatia, district Jamnagar, Saurashtra (Fig. 1). The present paper deals with the microfacies and depositional environment of the lower part of the Ranjitpur Limestone Member at that locality.

The Gaj Formation

The highly fossiliferous Gaj Formation (early to middle Miocene) occupies a wide area of about 300 km^2 in the district of Jamnagar, Saurashtra. However, the best exposures are in

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MIOCENE DEEP -SEA BENTHIC FORAMINIFERAL BIOSTRATIGRAPHY OF SOUTHEASTERN INDIAN OCEAN

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ABSTRACT

The Miocene sections at ODP sites 754A (Broken Ridge) and 760A and 761B (Wombat Plateau) in the southeastern Indian Ocean were examined to understand the biostratigraphic significance of benthic foraminifera. Detailed benthic foraminiferal biochronology at each site is used to record the total stratigraphic ranges of taxa. Most of the benthic foraminiferal species recorded in the present study are long ranging and distributed throughout the studied section. However, some of them show their first and last appearances within the studied sections. On the basis of total stratigraphic ranges of significant taxa, seven distinct benthic foraminiferal zones have been proposed. The proposed biozones, in stratigraphic ascending order, are *Uvigerina proboscidea* Interval Zone, *Ehrenbergina praebicornis* Interval Zone, *Gavelinopsis lobatulus* Interval Zone, *Bulimina glomarchallengeri – Globocassidulina tumida* Concurrent Range Zone, *Buliminella grata spinosa* Interval Zone, *Uvigerina flintii* Interval Zone and *Bulimina macilenta* Interval Zone. The first appearances of *Uvigerina proboscidea* Schwager, *Ehrenbergina praebicornis* Rai and Srinivasan, *Gavelinopsis lobatulus* (Parr), *Globocassidulina tumida* (Heron-Allen and Earland) and the last appearances of *Bulimina glomarchallengeri* Tjalsma and Lohmann, *Buliminella grata spinosa* Parker and Bermudez, *Uvigerina flintii* Cushman and *Bulimina macilenta* Cushman and Parker are taken as zonal markers to define the zonal boundaries.

Keywords: Miocene, Benthic Foraminifera, Biostratigraphy, southeastern Indian Ocean

INTRODUCTION

Benthic foraminifera have not been much used as biostratigraphic tool due to increased emphasis on planktic foraminifera for biostratigraphic subdivision and correlation of marine sequences. The long ranging nature and relatively greater endemic behavior of majority of benthic foraminiferal taxa are the serious problems in utilizing them for the purposes of biostratigraphic subdivision. In addition, considerable time and energy are required to sort out the sufficient number of benthic foraminiferal tests for biostratigraphic studies. Also, the changing depth preferences with time in different basins made the benthic foraminifera less significant for biostratigraphic purposes (Douglas and Woodruff, 1981; Tjalsma and Lohmann, 1983; Kurihara and Kennett, 1992).

The study of deep-sea benthic foraminifera from Deep Sea Drilling Project (DSDP) and Ocean Drilling Program (ODP) cores has provided improved taxonomic base to better understand their biostratigraphic distribution. The deep-sea benthic foraminifera from various uninterrupted sequences through the Cenozoic reveals that large numbers of them have distinct morphology and wide geographic distribution and some of them also have short stratigraphic ranges to be used for biostratigraphic purposes. Boltovskoy (1978) attempted to demarcate major late Cenozoic boundaries in the northern Indian Ocean on the basis of relative occurrences of important deep-sea benthic foraminiferal assemblages. He (1978) broadly grouped these assemblages characterizing different time intervals without proposing any biozonal scheme. Based on benthic foraminifera of DSDP site 397, Lutze (1979) subdivided the Neogene and Quaternary sequences of northwest African continental margin in five faunal units (NB 5a to NB 6c). Berggren and Miller (1989) proposed a comprehensive Cenozoic benthic foraminiferal zonal scheme by using deep water benthic foraminiferal data of van Morkhoven *et al.* (1986). Srinivasan *et al*. (1993) suggested ten distinct Neogene deep-sea benthic foraminiferal zones of the northern Indian Ocean deep sea sequences using the total observed stratigraphic ranges. A late Neogene deep sea benthic foraminiferal zonation for the southeastern Indian Ocean was proposed by Rai and Singh (2004) using data from ODP sites 762B and 763A. In the present work, an attempt has been made to propose Miocene deep sea benthic foraminiferal zones on the basis of faunal data at ODP sites 754A, 760A and 761B in the southeastern Indian Ocean.

SITE LOCATION AND OCEANOGRAPHIC SETTING

ODP site 754A (Latitude 30^{0}56.43'S; Longitude 93^{0}33.99'E; water depth: 1074m) is located on the Broken Ridge in the subtropical area and influenced by the West Wind Drift (WWD), South Equatorial Current (SEC) and Subtropical Convergence Zone (STCZ). ODP sites 760A (Latitude 16°55.32'S; Longitude 115°32.48'E, water depth 1969.7 m) and 761B (Latitude 16°44.23'S; Longitude 115°32.10'E water depth: 2167.9m) are located on the Wombat Plateau in the tropical–subtropical transition (TRANS). The Wombat Plateau region has more complex current pattern than the Broken Ridge region because (i) The Wombat Plateau is contemporarily influenced by the monsoonal climate, which causes periodical reversal of wind direction and surface current. (ii) The Wombat plateau lies in the direct confluence of Indonesian Through Flow (ITF), which connects Pacific and Indian Ocean (Rockford, 1961; van Aken *et al.,* 1988). Wombat Plateau is bathed by current system off the coast of Western Australia consisting of South Equatorial Current (SEC), the Leeuwin Current (LC) and the South Indian Current (SIC) a synonym of West Australian Current (WAC). The SEC and SIC flowing west

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PERMIAN-TRIASSIC PALYNOFLORAL TRANSITION IN THE SATTUPALLI AREA, CHINTALAPUDI SUB-BASIN, GODAVARI GRABEN, ANDHRA PRADESH, INDIA

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ABSTRACT

Palynological investigation of sub-surface sediments of the borecore SSP-133 from the Sattupalli area, Chintalapudi Sub-basin has revealed presence of three palynoassemblages, one belonging to Late Permian (Raniganj) palynoflora and two belonging to Early Triassic (Panchet) palynoflora. Assemblage-I characterised by dominance of striate disaccate pollen chiefly, *Striatopodocarpites* and *Faunipollenites* alongwith presence of rare but stratigraphically significant taxa viz., *Strotersporites, Verticipollenites, Corisaccites, Guttulapollenites, Hamiapollenites, Falcisporites, Chordasporites, Crescentipollenites, Striatites, Striomonosaccites, Lunatisporites* represents Late Permian.

Assemblage II is characterised by high percentage, of taeniate disaccates chiefly, *Lunatisporites*, while Assemblage III is characterised by abundance of cingulate-cavate trilete spores, chiefly, *Lundbladispora* and *Densoisporites.* Striate disaccates show a sharp decline in these two assemblages. Early Triassic palynoflora has been recorded for the first time in the Sattupalli area indicating existence of the Panchet sediments in the Chintalapudi Sub-basin.

The study further supports the view studies of Jha and Srivastava (1996) that the Kamthi Formation represents Early Triassic (=Panchet Formation) overlying the Raniganj-equivalent sediments with a gradational contact.

Keywords: Palynology, Gondwana, Permian, Triassic, Godavari Graben

INTRODUCTION

The Chintalapudi Sub-basin represents south-easterly continuation of the Kothagudem Sub-basin of the Godavari Graben. To its further south-east lies the coastal Gondwana tract of the Krishna-Godavari Sub-basin. The stratigraphy of this sub-basin is not well understood. The Gondwana rocks of Chintalapudi Sub-basin were earlier referred to as the Kamthi Sandstone (Blanford, 1872), Kamthi Formation (Raja Rao, 1982), Chintalapudi Formation (Raiverman, 1985) and it was said that the sub-basin mainly consists of the Kamthi and there is general absence of the Barakar Formation and Barren Formation Measures over a large part of the sub-basin. Lakshminarayana and Murthy (1990) revised the stratigraphy of the Chintalapudi sub-basin in which the Barakars are overlain by the Kamthi Formation. Thus, a considerable gap in stratigraphic sequence is evident between the Lower Barakar Formation and the Upper Kamthi Formation. In order to date and correlate the coal-bearing and associated sediments and to better understand the stratigraphic frame-work of this sub-basin, palynological studies have earlier been carried out in various borecores from different areas of the Chintalapudi sub-basin viz., Ayyanapalli-Gompana, Chintalapudi (Srivastava and Jha, 1993), Bottapagudem (Jha, 2004), Gattugudem, (Jha, 2002), Amavaram (Srivastava and Jha, 1992) and Sattupalli (Srivastava and Jha, 1994, 1997). The occurrence of Talchir, Karharbari, Barakar and Raniganj palynoassemblages have been recorded in the Chintalapudi sub-basin, but there is no previous record of Early Triassic palynoflora in this sub-basin.

In a quest for getting more data regarding the palynology of the Kamthi Formation and Permian-Triassic transition in the Chintalapudi Sub-basin, palynological investigations of the samples in the borecore SSP-133 from the Sattupalli area were undertaken. These studies allow to record the Late Permian and Early Triassic palynoflora from the study area. This work adds to our existing knowledge about the palynoflora of the area (Srivastava and Jha, 1994, 1995) and is a part of our ongoing study on the palynology of the Sattupalli area.

MATERIAL AND METHODS

The palynomorphs were recovered by usual palynological maceration technique. The samples were treated with conc. hydrofluoric acid, conc. nitric acid and 5% potassium hydroxide. The slides were prepared in canada balsam and studied qualitatively by identifying the palynotaxa on the basis of morphographical characters and quantitatively by counting the percentage frequency of different taxa. Palynological slides have been deposited in the repository of Birbal Sahni Institute of Palaeobotany, Lucknow.

The borehole SSP-133 was drilled in Sattupalli Block III by Singareni Collieries Company Limited (SCCL), Kothagudem. The location of borehole SSP-133 has been shown in Fig. 1.

GEOLOGY

Sattupalli Block III falls in Sattupalli–Chintalapudi coal belt, which forms the southern part of the Godavari valley coalfields. Sattupalli Block III is located in the central part of the coal belt. Archaean gneisses, granite and schists form the basement for the Gondwana sequence in the area. The stratigraphic succession in the block based on surface and sub-surface data is shown in Fig. 2.

The sedimentary sequence beneath 3m soil cover from the top (3-69m) in upper part of the borecore SSP-133 consists of brown soft sandstone and fine-to medium-grained, white and violet sandstone. The underlying sequence (69-98m) consists of fine-grained, greenish grey sandstone, micaceous at places.

The middle part of the sequence (98-185m) consists of fine to coarse-grained, grey sandstone and siltstone, grey clay, shaly clay and clayey sandstone. The sandsstone is sometimes

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FORAMINIFERAL EVIDENCE FOR THE EOCENE FAULTING IN THE SUB SURFACE SECTION NEAR SAM, JAISALMER BASIN, RAJASTHAN

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ABSTRACT

The cores from the subsurface section located in the Kanoi fault zone near Sam village ($27^0 30':70^0 30'$), Jaisalmer district, record a sequence of carbonaceous shale and lignite at the base overlain by the pale carbonate and bentonitic clay units. These core samples contain well - preserved planktic and benthic foraminifers in the carbonaceous shale and bentonitic clay units. The carbonaceous shale consists of an assemblage of planktic foraminifera indicative of Zones P7–P8 (early Eocene), while the overlying bentonitic clay unit contains the assemblage characteristic of Zone P2 (Early Palaeocene). These age assessments are further supported by the occurrence of *Assilina granulosa* (d'Archiac, 1857) and *A. subdaviesi* Gill, 1953 in the carbonaceous shale and *Laffitteina bibensis* Marie, 1946 (index species of SBZ1) in the overlying bentonitic claystone. The ages indicated by the planktic and the larger foraminiferal species confirm the stratigraphic inversion due to fault in the subcrops.

Keywords: Foraminifera, Subsurface Section, Sam-6 (Jaisalmer), Kanoi Fault zone

INTRODUCTION

The samples for the study of foraminiferal content came from the cores drilled by the Rajasthan state Department of Mining and Geology at the Site Sam-6 (Fig.1). In the present work, the early Eocene foraminifers are recorded from the strata underlying the rocks having foraminiferal assemblage of Palaeocene age. The studied assemblages are recorded from the basal 12 m of the 45 m thick subsurface Sam-6 section (Fig,2).The present assemblages provide evidence for faulting in the subcrops (Kalia *et al.*, 2005).

LITHOSTRTIGRAPHY

The Palaeogene shelf sedimentary succession in the Jaisalmer Basin, northwest India merges with the Sulaiman-Kirthar foredeep belts (Fig.3) in Pakistan. Largely concealed by the sand-cover in the Thar Desert, the Palaeocene-Eocene exposures in the Jaisalmer Basin are limited to the Sanu-Ramgarh-Khuiala region (Fig.1). The major tectonic elements of the basin (Fig.3) consist the Mari-Jaisalmer Arch flanked by the Ramgarh and Kanoi regional strike-slip fault zones, aligned parallel to it (Das Gupta and Chandra, 1978). The drilling near Sam village of the Jaisalmer Basin showed a 45 m. thick sedimentary succession. The lower 12 m portion of this succession is characterized by carbonaceous shale, lignite and carbonate rocks at the base which are overlain by bentonitic clay-carbonate intercalations topped by a thick foraminiferal (larger) limestone unit (Fig.2). The sediments are richly fossiliferous, and the samples from the carbonaceous shale (sample nos. 50 & 53) and bentonitic claystone (sample no. 46) have yielded well-preserved planktic and benthic foraminiferal assemblages that include biostratigraphic indices.

FORAMINIFERAL RECORD AND BIOZONES

The samples from the studied sequence show that the lower Palaeocene part contains more diversified assemblage of planktic foraminifers than the early Eocene part. Planktic foraminifers are moderately preserved in the argillaceous rocks studied, but their wall texture clearly shows the effect of diagenesis as illustrated by the SEM pictures (Pls. I and II). Amongst benthic index taxa, *Assilina* spp. are well preserved in the carbonaceous shale unit, while *Laffitteina bibensis* Marie, 1946 in the lower Palaeocene bentonitic claystone is not that well preserved.

As shown in the Fig.4, the carbonaceous shale unit is characterized by the occurrence of the two widely recorded lower Eocene species of the genus *Assilina* d'Orbignym 1826, namely, *A. granulosa* (d'Archaic) and *A. subdaviesi* Gill,1953 (Pl. III, figs. 3 and 2 respectively). Planktic foraminiferal assemblage from the carbonaceous shale unit is represented by the common occurrence of the Eocene species of *Acarinina* represented by *A. interposita*, *A. pentacamerata* and *A. pseudotopilensis* along with *Parasubbotina inaequispira* (Pl. II). Association of these species suggests equivalence with a standard planktic foraminiferal zones P7-P8 (in accordance with biostratigraphic scheme by Berggren *et al.*,1995), corresponding to the Zones E5-E6 (Berggren and Pearson, 2005). The overlying bentonitic claystone contains a well-preserved, diversified assemblage of planktic foraminifers consisting of *Praemurica inconstans, P. uncinata, Eoglobigerina spiralis, Parasubbotina pseudobulloides* and *Morozovella praeangulata* (Pl. 1) which correlate with Zone P2, i.e. Danian. A few specimens of *Laffitteina* Marie, 1946 identified as *L. bibensis* occur in the bentonitic claystone (sample no. 46, Pl. II, figs. 14-15; Pl. III, fig.4) in association with early Palaeocene planktic foraminiferal assemblage. The planktic foraminiferal species not documented earlier from Rajasthan are systematically described and illustrated, whereas the larger foraminiferal species compared with forms reported from the Indus Basin (Gill, 1953a; 1953 b) are only illustrated (Pl. III).

SYSTEMATIC DESCRIPTION

From the basal 12m a total of nine planktic foraminiferal species of lower Palaeogene were identified from the studied section. The type reference of each species is given with its systematic description. The detailed synonyms of each species have been omitted as they are described in Olsson *et.al.* (1999) and Pearson *et al.* (2006). For the taxonomy "Atlas of

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FRESHWATER OSTRACODA FROM THE (?) PALAEOCENE-AGE DECCAN INTERTRAPPEAN BEDS OF LALITPUR (UTTAR PRADESH), INDIA

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ABSTRACT

A fairly diverse freshwater ostracod assemblage comprising 14 species has been recovered for the first time from the Deccan intertrappean beds at Papro, near Lalitpur (U.P.), on the eastern fringe of the Deccan Traps volcanic province of peninsular India. The probable Palaeocene age (based on palynomorphs) of the Lalitpur locality makes this intertrappean section potentially important in addressing the issue of faunal survivorship in fresh water aquatic systems across the Cretaceous-Tertiary boundary in the Deccan. The Lalitpur assemblage includes *Gomphocythere akalypton*, *G. paucisulcatus*, *Mongolianella cylindrica*, *M. subarcuata*, *Cypridopsis hyperectyphos*, *Cypridopsis* sp., *E. ucypris intervolcanus*, *E. catantion*, *E.* sp., *Zonocypris spirula*, *Frambocythere tumiensis*, *Cypria cyrtonidion*, cf. *Paracypretta elizabethae* and *Cyprois rostellum*. While this diversity may further increase with additional investigations, the recorded assemblage from Lalitpur significantly shows a striking similarity to ostracod faunas previously documented from a number of Maastrichtian intertrappean localities in the Deccan volcanic province. If the Palaeocene age of the Lalitpur section is correct, then it is apparent that freshwater ostracods were not significantly affected, at least qualitatively, by the initiation of Deccan volcanic activity, a situation that is reminiscent of some other groups of freshwater organisms, particularly molluscs.

Keywords: non-marine Ostracoda, Palaeocene, Deccan Traps, Intertrappean, India

INTRODUCTION

The Deccan intertrappean section near Papro, District Lalitpur (UP), lying on the eastern fringe of the main Deccan Trap volcanic province of peninsular India, occupies a special place in the province as it is the only known continental intertrappean locality in India that is possibly Palaeocene in age. This section came to light in 1978 with the description of a small charophyte assemblage (Singh and Mathur, 1978; Singh, 1980). Subsequently, Kumar *et al.* (1980) gave a general geological account of the area and suggested an Eocene age based on charophytes. Recently, Singh and Kar (2002) described palynofossils from the black cherts of this intertrappean section, and the assemblage recovered by them includes *Phragmothyrites eocaenica*, *Inapertusporites kedvesii*, *Cyathidites minor*, *Todisporites major*, *Dandotiaspora dilata*, *Dandotiaspora pseudoauriculata*, *Spinizonocolpites echinatus* and *Lakiapollis ovatus*. Significantly, a Palaeocene age was suggested by Singh and Kar (2002) based on correlation of this palynoassemblage with that from the Matanomadh Formation of Kutch, western India. It is important to note that the continental intertrappean deposits occurring in the main volcanic province are mostly considered to be latest Cretaceous (Maastrichtian) in age (e.g. Sahni and Bajpai, 1988). Prior to a Palaeocene age determination by Singh and Kar (2002), there was no firm basis to assign such an age to any intertrappean deposit except for the well-known marine intertrappean outcrops occurring near Rajahmundry on the southeast coast of India, hundreds of kilometers away from the main Deccan province (Keller *et al.*, 2008), and the recently studied intertrappean section at Jhilmili, Chhindwara District, M. P. (Keller *et al.*, accepted; Keller *et al.*, under revision).

Intertrappean deposits near Lalitpur are exposed in a stream-cutting about 3 km north east of the Papro village (24^{0}48'20'':24^{0}14') (Fig.1). The Deccan Traps in this locality (fig. 1) rest over the Kaimur Sandstone of the Vindhyan Supergroup (Late Precambrian), and the two are separated by a major unconformity represented by conglomerates (Kumar *et al.*, 1980). Geological data on this section (Fig. 1) have been provided by Kumar *et al.* (1980) and Singh and Kar (2002). Intertrappeans in this section include about a meter and half of grey and black chert that yielded charophytes described previously by Singh (1980). Kumar *et al.* (1980) noted the presence of ostracods in these cherts. In addition, freshwater molluscs, particularly *Physa* and *Lymnaea*, have also been recorded (but not described or illustrated) by Singh and Mathur (1980) and Singh (1980). Ongoing investigations by Joseph Hartman (University of North Dakota, USA, personal communication) have led to the recognition of a few more molluscan taxa in these cherts. The presently described ostracod fauna was recovered from chert samples collected by one of us (MPS).

The ostracods described in this paper are housed in the Paleontology Laboratory, Department of Earth Sciences, Indian Institute of Technology, Roorkee, under the acronym IITR/SB/LI.

SYSTEMATIC PALAEONTOLOGY

Phylum **Crustacea** Pennant, 1777
Class **Ostracoda** Latreille, 1806
Order **Podocopida** Muller, 1894
Suborder **Podocopina** Muller, 1894
Superfamily **Cytheracea** Baird, 1850
Family **Limnocytheridae** Klie, 1938
Subfamily **Timiriaseviinae** Mandelstam, 1960
Genus ***Gomphocythere*** Sars, 1924
Gomphocythere akalypton Whatley *et al.*, 2002
(Pl. I, figs. A-D)

Material: 11 carapaces.

Description: Medium- sized species of *Gomphocythere*; subrectangular in lateral view; s-shaped median sulcus strongly

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RELICT FAUNAL TESTIMONY FOR SEA-LEVEL FLUCTUATIONS OFF MYANMAR (BURMA)

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ABSTRACT

The distribution and ecological significance of the relict benthic foraminiferal assemblage found in the study area off Myanmar is discussed here. Of the 126 surface sediments studied for foraminiferal content, relict foraminiferal assemblage comprising the genera *Operculina-Amphistegina-Calcarina-Alveolinella-Heterostegina* were encountered at 22 different locations nearly parallel to the west coast of Myanmar. Soft coral sclerites, coral rubble and calcareous algae were found associated with this assemblage. These signatures confirm the existence of fossil patch reefs in the region, which were never reported before. A conceptual framework is proposed to explain the proliferation of coral patches at different depths during different times in the geological past. Radiocarbon AMS dating of 7 select samples representing different depths revealed different ages at different depths. To derive a sea-level curve, the sea level was assigned to 17.5 m above the depth of finding the relict fauna as deciphered from soft coral assemblage. On the basis of the faunal ecology and chronology, for the first time a sea level curve for the past 16,000 radiocarbon years is proposed for the west coast of Myanmar. This study suggests an episodic sea-level rise in the region. A comparison of this sea level curve with the ones proposed for the East and West coasts of India indicates that in addition to the global Holocene sea level rise, tectonic vertical displacement is the cause of the destruction of the soft coral patches off west coast of Myanmar.

Keywords: Relict Foraminifera, soft coral sclerites, AMS dates, sea level, subsidence, Myanmar

INTRODUCTION

The Bay of Bengal has always been the least understood water mass in the Indian Ocean, particularly towards its east, with very few studies carried out along the west coast of Myanmar and the Andaman Sea. Thus, the 'India-Myanmar Joint Oceanographic Studies' were initiated by the Ministry of External Affairs, Government of India, with active support from the Department of Ocean Development (DOD) and Council of Scientific and Industrial Research (CSIR), to understand this region better. Global climate change has become synonymous with global warming, of which sea level rise is the most dreaded consequence. At the direct risk of assured inundation are the coastal low-lying regions all over the globe which are most populated. Thus, the estimation of past, present and thereby future sea-level fluctuations remains a major challenge to palaeoclimatologists. The results brought out by the IGCP Project 61 demonstrated that determination of a single sea-level curve of global applicability was an illusory task. Thus, the need was felt for individual regions to be studied for local sea-level histories considering all local influencing factors (Pirazzoli, 1991; Stanley, 1995). Several attempts have been made to reconstruct past sea levels in regions adjoining the study area, namely West Coast of India (Bruckner, 1989; Merh, 1992; Hashimi *et al.*, 1995; Rao *et al*., 1996; Vora *et al*., 1996; Mazumder, 2005), East Coast of India (Vaz, 1996 and 2000; Vaz and Bannerjee, 1997; Banerjee, 2000; Rana *et al*., 2007), Thailand – (Sinaskul, 1992) and South China Sea (Yim *et al*., 2006). However, the coast of Myanmar had remained unexplored in terms of signatures of high resolution sea-level history before the present study. Being a promising basin in terms of petroleum and natural gas reserves as well as a tectonically active margin, the study area faces far reaching consequences of sea-level fluctuations. Thus, the present results not only form baseline data for future workers but are also very promising for the academia and industry alike.

The marine protists, Foraminifera, have been chosen as a proxy to meet our objectives because of their dual utility. First, their sensitivity to slight changes in their environment and extensive preservation potential make them useful in palaeoclimatic analysis. Secondly, their distribution is indicative of the various physical, chemical, biological and geological processes pertaining to the study area. The objective of this paper is to present foraminiferal evidence supported by other relict coral fauna and AMS ^{14}C dates for sea level fluctuations along the west coast of Myanmar.

REGIONAL SETTING

The Coast of Myanmar can be divided into two significant physiographic divisions; the western Rakhine Coast opening into the Bay of Bengal and the southern Ayeyarwady delta (former Irrawaddy), Gulf of Martaban and the Mergui platform into the Andaman Sea. The Andaman-Nicobar Ridge, which is a part of the northern segment of the Sunda subduction zone, separates the Andaman Sea, from the Bay of Bengal. The western margin along the Sunda Trench is an oblique convergence continental and arc margin. The sedimentary cover over the subducting plate is very thick because of the Bengal Fan (Curray *et al*., 2003), and the sediments and ocean crust have been accreted and uplifted into the Indoburman Ranges, the Andaman-Nicobar Ridge and the outer arc ridge off Sumatra and Java (Curray, 2005). The outer shelf in the Gulf of Martaban has a rough topography and is characterized by features such as pinnacles, highs, and valleys, buried channels and scarps. The sediments in the outer-shelf of the Ayeyarwady is constituted by >80% relict sands (Rao *et al*., 2005). A complex system of N-S trending dextral strike slip faults runs through the Ayeyarwady shelf and the Gulf of Martaban, the most promi-

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FUNGAL REMAINS FROM LATE HOLOCENE LAKE DEPOSIT OF DEMAGIRI, MIZORAM, INDIA AND THEIR PALAEOCLIMATIC IMPLICATIONS

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ABSTRACT

The present communication is an attempt to portray the fungal remains retrieved from a 2m deep sediment profile analysed from Demagiri, southern Mizoram. Several types of fungal forms/spores encountered in the lake sediments comprise *Alternaria*, *Helminthosporium*, *Tetraploa*, *Curvularia Cookeina*, *Nigrospora*, *Multicellaesporites*, *Ornasporonites*, *Dyadosporonites*, *Actinopelte*, *Kutchiathyrites*, *Clasterosporium*, *Helicoma*, *Entophlyctis*, etc. encompassing a time bracket of last 850 yr BP. In fact, the organic-rich sediments drifted from the nearby tropical humid forest cover provided an ideal habitat/substratum for the growth of fungi. The preponderance of fungal remains in the investigated lake bed sediments could be attributed to in situ proliferation of the fungi as well as their transportation from the adjoining forest belt, from higher riches by wind and water and by upthermic winds from the lower elevations to the depositional site. In all, the recovery of fungal remains in great diversity and numbers suggests that the region enjoyed a humid climatic condition during the course of sediment accumulation the lake basin.

Keywords: Late Holocene, Fungal remains, Palaeoclimate, Demagiri, Mizoram

INTRODUCTION

The role of fungal remains in stratigraphy was dealt by Graham (1962) and Elsik (1974). However, their relevance in palynostratigraphical studies of the sedimentary deposits is rather uncertain, as they have a wider range of distribution in term of geological time scale, i.e. Precambrian to Recent times and do not demonstrate any marked variability in their gross morphological characters and forms over such a long span of time. The record of Microthyriales from the Cretaceous Period to the Recent is a well-known example of such case (Elsik, 1978). Despite all this, their presence in the sedimentary deposits provides a very reliable information in order to unravel the depositional environment of the sediments, nature of substrata and the host plants upon which the fungi flourished prior to getting buried in the sedimentary deposits as well as their habits and local habitats during the past. So far, considerable work has been carried out on the Tertiary fossil fungal remains from the various regions of the country such as Himachal Pradesh (Saxena**,** Sarkar and Singh, 1984; Sarkar and Singh, 1988), Gujarat (Kar and Saxena, 1976, 1981; Kar, 1979,1985; Rawat, Mukherjee and Venkatachala 1977), Rajasthan (Sah and Kar, 1974), Kerala (Rao and Ramanujum, 1975, 1976; Patil and Ramanujum, 1988), Tamil Nadu (Venkatachala and Rawat, 1972) and northeastern India (Kar, Singh and Sah, 1972; Salujha, Kindra and Rehman**,** 1972; Hait and Banerjee, 1994; Kar, Mandaokar and Ratan**,** 2005, 2006).

However, there are only a few sketchy publications on the fungal remains from the Quaternary deposits of the country such as West Bengal (Gupta, 1970), Tripura (Prasad and Ramesh, 1983; Prasad, 1986), Tamil Nadu (Rao and Menon, 1970), Gujarat (Sharma, 1976) and Arabian Sea (Ratan and Chandra, 1982). Hence, in this pursuit, it was intended to extend such studies on Quaternary fungal remains in Mizoram, where there are a good number of potential organic-rich lacustrine deposits available, owing to presence of diversified forest floristic of this part of northeast India. During the course of pollen analytical investigation of 2 m deep sediment profile from Demagiri, southern Mizoram (Chauhan and Mandaokar, 2006), encompassing a time span of last one millennium, we have come across a large number of fungal spores in the sediments. The database gathered on this aspect has enabled us to get acquainted with the fungal diversity and palaeoenvironmental conditions prevailing in the region during the period of sediment accumulation in the lake basin as well as to strengthen and to substantiate the pollen-based palaeoclimatic inferences drawn from southeastern Mizoram (Chauhan and Mandaokar, 2006).

The site of the present investigation, i.e. Demagiri lies between 22°52’ E latitude and 92°28’N longitudes approximately 120 km west of Lunglei hills in southern Mizoram (Fig.1). Topographically, the area is mountainous comprising medium-sized hills with gentle slopes and attaining an average altitude of 900m. The lake basin is encircled with mountain range all around. The lake is perennial and measures 30m in diameter. It is bordered with a 1-2m wide swampy margin.

GEOLOGY

Geologically, the Mizoram-Tripura miogeosynclinal basin is a part of larger Assam-Arakan region. The early geological investigation in Mizo hills was carried out by La Touche (1891), Hayman (1937) and Franklin (1948). Das Gupta (1948) reviewed the geology and petroleum prospects of the Lushai hills and concluded that in general the area was unattractive. The beds generally trend N–S, dipping at 20° to 50° either eastward or westward and comprise sandstones, siltstones, shale, mudstones with a few pockets of shales, limestones, calcareous sandstones and intraformational conglomerates (Karunakaran, 1974; Ganju, 1975; Ganguli, 1983).

CLIMATE

The region is characterized by the prevalence of a humid climate which is influenced by southwest monsoon. The mean minimum and maximum winter temperatures are 11ºC and 21ºC, whereas the mean minimum and maximum summer temperatures are 20ºC and 30ºC respectively. The months of April and May are marked by stormy winds. The monsoon rainfall takes place

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ICHNOFOSSILS FROM THE NEOGENE-QUATERNARY SEDIMENTS OF THE PORBANDAR AREA, SAURASHTRA, GUJARAT, INDIA

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ABSTRACT

The Neogene-Quaternary sediments are exposed in and around Porbandar area, Saurashtra, Gujarat. These sediments are classified into: Gaj Formation (early Miocene), Dwarka Formation (early to middle Miocene), Miliolite Formation (early middle to late Pleistocene) and Chaya Formation (late Pleistocene to late Holocene). Eight ichnofossils are recorded from the Dwarka Formation and the Adatiana Member of the Miliolite Formation. They are: *Granularia* ichnosp, *Ophiomorpha borneensis, O. irregulaire, O. nodosa, Palaeophycus heberti*, *P. tubularis, Planolites berverleyensis* and *P. montanus.* Out of the 8 species, 3 ichnospecies, namely, *Ophiomorpha irregulaire, O. nodosa* and *Planolites berverleyensis* occur in both the formations whereas 3 ichnospecies, namely, *Granularia* ichnosp., *Palaeophycus heberti* and *P. tubularis* occur exclusively in the Dwarka Formation and 2 ichnospecies *Ophiomorpha borneensis* and *Planolites montanus* occur exclusively in the Adatiana Member of the Miliolite Formation. The ichnospecies from the Dwarka Formation belong to *Skolithos* and *Cruziana* ichnofacies indicating that the Dwarka Formation was deposited in shallow marine water conditions. Dominance of *Ophiomorpha* burrows and their geometric relationship with the country rock clearly indicate that the Adatiana Member of the Miliolite Formation was deposited under near-shore environment.

Keywords: Ichnofossils, Dwarka, Miliolite and Chaya Formation, Porbandar, Gujarat

INTRODUCTION

The Neogene-Quaternary sediments exposed in and around the Porbandar area, Saurashtra, Gujarat are classified into the Gaj Formation, Dwarka Formation, Miliolite Formation and Chaya Formation (Fig. 1). Kundal and Dharashivkar (2006) have recorded seventeen ichnospecies from Neogene-Quaternary deposits of the Dwarka-Okha area, Jamnagar district, Gujarat. Eight ichnofossils are recorded from the Dwarka Formation and the Adatiana Member of the Miliolite Formation in the present paper. Ichnofossils are very useful for depositional or palaeoenvironmental interpretation. The depositional environment of the Dwarka Formation and the Adatiana Member of the Miliolite Formation has been interpreted based on ichnofossils. In the present paper, authors have scanned different localities in and around Porbandar for the search of ichnofossils. Only two localities, namely, Visavara village and Adatiana quarry were chosen for the study of ichnofossils as in both the localities ichnofossils are well preserved. The Dwarka Formation is exposed at Visavara village (Figs. 1, 2a), located 18 km NW of Porbandar. Here, six species, namely *Granularia* ichnosp, *Ophiomorpha irregulaire, O. nodosa, Palaeophycus heberti*, *P. tubularis* and *Planolites berverleyensis* are present. Adatiana village (Figs.1, 2b) is located 18 km towards north of Porbandar and the Adatiana quarry exposes limestone of the Adatiana Member of the Miliolite Formation. Here, five species, namely, *Ophiomorpha borneensis, O. irregulaire, O. nodosa, Planolites berverleyensis* and *P. montanus* are identified.

GEOLOGICAL SETTING

Deccan Trap basaltic flows occupy the major part of the Saurashtra peninsula, except the coastal area. As inliers, thick Mesozoic sediments are exposed in the northeastern part of peninsula. Mio-Pliocene and Quaternary carbonate sediments overlying the Deccan trap basaltic flows are exposed in western, southwestern and southeastern coastal regions of Saurashtra.

The Saurashtra Basin is a pericratonic-shelf basin along the northwestern coast of India. The Neogene-Quaternary sediments are very well exposed along the coastal tract in and around Porbandar. Mathur *et al*. (1988) have classified sediments of Porbandar area into four formations: Gaj, Dwarka, Miliolite and Chaya (Table 1). The Miliolite Formation is subdivided into two, namely, Dhobaliya Talav Member and Adatiana Member. Pandey *et al.* (2007) studied the Neogene-Quaternary sediments of Saurashtra, concentrating mainly on the Chaya Formation in different localities for stratigraphic distribution and depositional environment. They introduced a new member in the Chaya Formation and thus the Chaya Formation consists of three members; Okha Shell Limestone Member, Aramda Reef Member and Porbandar Calarenite Member.

SYSTEMATIC DESCRIPTION

This study of palichnology follows the Treatise on Invertebrate Paleontology (Haentschel, 1975). The morphological classification of Simpson (1975), ethological classification of Seilacher (1964) and facies classification of Seilacher (1964, 1967) and Chiplonkar (1980) are adopted in the present paper.

Ichnogenus ***Granularia*** Pomel
Granularia **ichnosp**
(Pl. II, fig. 9)

Material: Specimen No. PGTDG / IF / 51.

Dimensions: Diameter of burrow: 5-7 mm.

Remarks: Elongated burrow runs parallel to the bedding plane. It is a branched burrow and preserved as positive epirelief. Burrow is filled with coarser material forming pellets, which are

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FIRST RECORD OF ANACARDIACEOUS FOSSIL FRUIT FROM NEYVELI LIGNITE DEPOSITS, TAMIL NADU, INDIA

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ABSTRACT

A carbonised fossil fruit (drupe) belonging to the family Anacardiaceae has been recorded from the Lignite deposits of Neyveli (Mine- I). The fruit is small, bilaterally convex with prominent dehiscence suture. It is 17 mm long and 07 mm broad. On splitting, the fruit shows pericarp divisible into two parts: an outer thin epicarp and inner thick mesocarp. The mesocarp is further divisible into outer and inner layers. The outer layer is composed of compact parenchymatous cells with scanty air spaces, whereas inner part is spongy in nature. Endocarp represented as a compact thin layer of indistinguishable cellular detail. The seed is disintegrated, represented by a cavity in the fruit. The single loculed drupe with thin epicarp, spongy mesocarp and thin compact endocarp constitutes first report of the family Anacardiaceae from the Miocene deposits in the penninsular India.

Keywords: Fossil Fruit, Anacardiaceae, Neyveli Lignite, Miocene, Tamil Nadu, India

INTRODUCTION

Apart from the palynological investigations, a large number of plant megafossils referable to bark, axis, woods, leaves and cuticles are described by various workers from Neyveli Lignite deposits, Tamil Nadu, India. viz.- (Chatterjee & Bhattacharya, 1965; Navale, 1962, 1974; Thiergart & Frantz, 1963; Ramanujam, 1963, 1966a, b, 1967, 1968, 1982; Ramanujam & Ramachara, 1963, 1980; Deb, 1972; Deb *et al*., 1973); Venkatachala, 1973; Navale and Misra, 1979; Bande and Ambwani, 1982; Reddy *et al.*, 1984; Ambwani, 1982, 1999; Ramanujam and Reddy, 1984; Sarma *et al.*, 1984; Saxena, 1992; Ramanujam *et al.*, 1984, 1985; Siddhanta, 1986; Sarma & Ramanujam, 1988; Singh and Misra, 1991a, b, c; Awasthi, 1974, 1984; Awasthi and Agarwal, 1986; Rao, 1995; Agarwal, 1988, 1990a, b, 1991a, b, c, 1992, 1994, 1996, 1998, 2002, 2003, 2005; Agarwal and Ambwani, 2000, 2002; Ambwani, 1999). The present fruit recovered from Neyveli Lignite (Mine I), 1982, (Fig. 1), shows the affinities to some extent with the fossil fruit of (*Odina*) of the family Anacardiaceae (Reid & Chandler, 1933), represented in the tropical and sub-tropical regions of the globe.

GEOLOGY

The Neyveli Formation is generally sub-surface stratigraphic unit with thick lignite deposits overlain by Cuddalore Formation. The lignite deposits of Tamil Nadu mined around Neyveli are known as Neyveli Lignites and constitute the largest lignite reserves in India. Earlier the geologists considered this lignite as a part of Cuddalore Formation. (Siddhanta, 1986) divided Cuddalore Formation into two parts, the lower part including lignite was termed Neyveli Formation while the upper part was retained as Cuddalore Formation. The Neyveli Formation lies between latitude 11º 15' to 11º 40' North and longitude 79º 25' to 79º40' East. The sub-surface lithostratigraphic unit consists of semi-consolidated sandstone and clay beds with occasional limestone intercalations followed by 1m thick carbonaceous clay and brown lignite (upto 20m thick). The whole system is overlain by 60-120m thick Cuddalore Formation is made up of ferruginous arcosic semi-consolidated sandstone. According to (Siddhanta, 1986); (Fig.- 1A), the contact between two formations is marked by an erosional unconformity (Figs. 1 & 1A). The lignite and the underlying clay bands are very rich in plant fossils and provides a huge research scope related to both mega and microfossils to understand the palaeoecology in precised manner using their corresponding taxonomical identification.

MATERIAL AND METHODS

The fossil fruit was collected from Neyveli Lignite (Mine-1), Tamil Nadu, India by one of the authors (A.A.). The detailed study has been carried out under LM & SEM. The specimen was opened to see the location and nature of the seed, however, no seed was seen preserved, only the pericarp could show its cellular details. For SEM study, the specimen was cleaned and dried under the controlled temperature between 30-50ºC to remove moisture contents and mounted on the metallic stub, subsequently conducted by silver dag and finally coated with gold/ palladium alloy. The accelerating voltage for image analysis varied from 15-20Kv. The detailed anatomical observations were made as follows:

Holotype - B.S.I.P. Museum No. 39474.
Horizon - Neyveli Formation.
Age - Miocene.

DESCRIPTION

The carbonized fruit is a small drupe, generally oblong, bilaterally convex; measuring 17mm in length and 07mm in breadth. It has a prominent dehiscence suture along entire length. Surface of the fruit is rough (scabrate) showing some undulations (possibly a part of preservation factors) (Pl. I, figs. A-B). The fruit could easily be splitted into two halves along its suture (Pl. I, Fig. C), showed the pericarp distinctly divisible into outermost thin *epicarp* (about 100mm) and thick *mesocarp* (about 07mm) which is further divisible into outer compact and inner spongy layers (Pl. I, figs. D, F-G). *Endocarp* represented by thick compact layer without cellular details, the seed is not preserved (Pl. I, figs. C). The cavity of the fruit

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ECHINOIDS FROM THE BHUBAN FORMATION (SURMA GROUP), MIZORAM

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ABSTRACT

The two echinoid genera namely, *Coelopleurus* (*Keraiophorus*) Michelin, 1862 (an arbacioid echinoid) and *Schizaster* L. Agassiz, 1836 (a spatangoid echinoid) are being recorded and described systematically, for the first time, from the rocks of the Upper Bhuban Unit, Bhuban Formation, Surma Group (lower to middle Miocene) exposed at South Hlimen Quarry, Aizawl, Mizoram.

Keywords: Arbacioid and spatangoid echinoids, Bhuban Formation (early middle Miocene), Mizoram, India

INTRODUCTION

The note systematically records, for the first time, the arbacioid and spatangoid echinoids (Echinodermata) from the rocks of the Upper Bhuban Unit of Bhuban Formation, Surma Group (lower to middle Miocene) exposed in and around Aizawl, Mizoram (Fig. 1). La Touche (1891) was the first to report a *Schizaster* sp. from the Surma rocks of Lunglei, Mizoram. Sinha *et al.* (1982), Das Gupta (1982) and Patil (1990), while reporting the occurrence of bivalves, gastropods, echinoids, crabs, shark teeth, foraminifers and ostracodes from the Surma rocks of Mizoram, made passing references about the echinoid fauna from these rocks. Detailed palaeontological investigations carried by subsequent workers in these rocks (Tiwari, 1992, 2001 & 2006; Tiwari and Bannikov, 2001; Tiwari and Kachhara, 2000 & 2003; Tiwari and Satsangi, 1988 and Tiwari *et al.*, 1997 & 1998) have also missed out detailed study of echinoid fauna. Recently, Jauhri *et al.* (2003) reported a hemiasterid echinoid from the rocks of Upper Bhuban unit of Bhuban Formation exposed in a section near Zemabawk, east of Aizawl, Mizoram. As such, a detailed documentation of the echinoid fauna from the Surma rocks of Mizoram is yet to come.

The echinoids described and illustrated here come from (a) 6.0m thick brown-coloured, fine grained poorly sorted silty-sandstone bed at South Hlimen Quarry (about 5.0 km South of Aizawl) (Fig. 2). These have also been recovered from (b) 3.0m thick sandstone bed at Bika Quarry (about 8.5 km N65^{0}W of Aizawl) and (c) 4.8m silty-sandstone bed near Luangmual Complex (about 7.8 km N50^{0}W of Aizawl). These echinoids are found in association with host of bivalves and a few gastropods, fish teeth, crabs and plates of barnacles.

GEOLOGICAL SETTING

Geologically, Mizoram is a part of the Tripura-Mizoram Accretionary belt of Cenozoic age (Evans, 1964). The state is occupied by the argillaceous and arenaceous rock sequences that occur in alternation. These rock successions are thrown into N-S trending and longitudinally plunging anticlines and synclines (Ganju, 1975; Ganguly, 1983). The general trend of the rock formations is N-S with dip varying from 20º to 50º either towards east or west (Karunakaran, 1974). Main rock types exposed in the area are sandstone, siltstone, shale, mudstone and their admixture in various proportions and a few pockets of shell limestone, calcareous sandstone and intra-formational conglomerate. Sequentially, these rock successions are organised into the Barail, the Surma and the Tipam groups in ascending order. The stratigraphic succession in the state (Karunakaran, 1974; Ganju, 1975) is given in Table 1.

SYSTEMATIC PALAEONTOLOGY

(Fell and Pawson, 1966; Smith, 2008)

Class **Echinoidea** Leske, 1778
Superorder **Echinacea** Claus, 1876
Order **Arbacioida** Gregory, 1900
Family **Arbaciidae** Gray, 1855
Genus ***Coelopleurus*** L. Agassiz, 1840

Subgenus ***Keraiophorus*** Michelin, 1862

Coelopleurus (*Keraiophorus*) sp.
(Pl. I, figs. a-c)

Material: Eight specimens (Type Nos. MZ/E/1, 2, 3, 4, 5, 6, 7 and 8), few are broken and incomplete; preservation poor due to weathering and erosion.

Description: Test medium, ambitus rounded to subpentagonal and low hemispherical shape with almost flat oral surface. Apical system small and dicyclic. Ambulacra straight, expanding to ambitus; slightly inflated; pore-pairs small, uniserial, subconjugate, widely separated and obliquely placed. Interambulacra a little wider than ambulacra. Primary tubercles with imperforate mamelon and non crenulate. Peristome subcircular or subpentagonal, large.

Dimensions (in mm):

Specimen No.	Maximum diameter	Minimum diameter
MZ/E/1	31.12	27.43
MZ/E/2	29.91	22.42
MZ/E/3	29.22	?
MZ/E/7	30.52	24.21

Remarks: Depending on the preserved morphological characters, the studied specimens are placed, with much reservation, under the genus *Coelopleurus* L. Agassiz, 1840 and the specific identification of these specimens is not possible. However, in the Indian subcontinent, the genus is known from the Eocene sediments of Sind (d'Archiac and Haime, 1853), Kachchh (Wynne, 1872); Oligocene sediments

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PALAEOGENE LARGER FORAMINIFERAL CORRELATION OF ASSAM-SHILLONG SHELF-AN EXAMPLE OF HIGH RESOLUTION BIOSTRATIGRAPHY

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ABSTRACT

The Assam–Arakan Basin covering north-eastern India and the adjoining areas is one of the hydrocarbon producing sedimentary basins with great thickness of the Cenozoic sediments. The lower Palaeogene shelf carbonate and intermittent clastic facies over the Assam-Arakan shelf signifies marine sedimentation of the Tethyan realm. Recent oil finds in the pre-Barail sediments in Assam has pointed to the enhanced stratigraphic exploration of the pre-Barail sediments in future by bringing in new concepts and high impact biostratigraphic tools, being developed world over. One such scheme followed have is that of shallow benthic zones [SBZ] proposed by Serra-kiel *et al*. (1998). This biostratigraphic zonation comprises twenty zones covering the Palaeocene-Eocene time span (32 M.A) and represents faunal assemblages of both concurrent and mutually exclusive species from the key-levels and key-localities. The SB zones are largely “Oppel zones” with key foraminifera along with the association of other taxa spread over vast areas in the Tethyan region.

Twenty three wells spread over the Assam-Arakan shelf were analyzed to propose a framework of biostratigraphic correlation on the lines of IGCP-286 scheme. Several other wells were also studied for supportive micropalaeontological data. Indian equivalent species for each SBZ have been worked out. They include both the Tethyan key foraminifera and concurrent shallow larger benthic species acting as the local reference. Recognition of Indian equivalent species to the European and far-Tethyan taxa is primarily aimed to make the SBZ scheme directly useful to the biostratigraphic correlations in our sedimentary basins. These of local bio-events in chronostratigraphic mapping is expected to provide robust framework to the sequence stratigraphic models in the area. Integration of SBZ data with other geological information would also be immensely useful in the stratigraphic exploration.

Keywords: Larger foraminifera, shallow benthic zones [SBZ], Paleogene, Assam-Arakan shelf. The views expressed in the paper are of authors only and may not necessarily be of the organization to which they belong.

INTRODUCTION

The Assam–Arakan Basin covering northeastern India and the adjoining areas is one of the hydrocarbon producing sedimentary basins with great thickness of the Cenozoic sediments. It is also one of the oldest basins where the hydrocarbon exploration started as early as 1889 (Digboi). In the upper Assam shelf, a great sedimentary thickness has been postulated north of Brahmaputra, around Lakhimpur, so also in the Nazira, Dimapur and Safrai lows. The present study is confined to the first two areas as most of the hydrocarbon exploration activities are concentrated there. The Assam-Shillong shelf has also been significant in exhibiting marine lower Palaeogene and non-marine younger sequences, in several wells and surface sections. The lower Palaeogene carbonates and finer clastics have preserved considerable amount of correlatable biota. As the hydrocarbon occurrences were mostly concentrated in the Barail and post-Barail sequences of paralic or non-marine origin, more emphasis was given to the study of post Oligocene sediments. Now, with the advent of encouraging leads in the pre-Barail sections in many parts of Dhansiri valley and Upper Assam, the marine sediments belonging to Tura [or equivalent], Sylhet and Kopili formations have come into exploration focus. It is a matter of common observation that similar facies in the Dhansiri valley area, have provided abundant larger foraminifera with good diversity. The problem, however, exists in the vertical demarcation of smaller zones, by the study of ditch cuttings, which are often mixed with the caved in foraminifera too. Identification of various useful datums, based on the age boundaries / zonal boundaries or the first down hole occurrence of index foraminifera and tracing the lateral extent of the zones has helped demarcate finer biostratigraphic zones and assign these zones to the shallow benthic zones [SBZ] proposed by Serra Kiel *et al*. (1998). Their biostratigraphic zonation comprises twenty zones covering the Palaeocene-Eocene time-span (32 M.A) and represent faunal assemblages of both concurrent and mutually exclusive species from key-levels and key-localities. The Indian subcontinent’s input to Serra-Kiel *et al*.’s scheme is from the South Shillong outcrop areas, mostly representing the Palaeocene zonation (SBZ 2-4) and Salt Range, Pakistan including to SBZ 4 -8. The SBZ zones are largely the “Oppel zones” with key foraminifera along with the association of other taxa spread over vast areas in the Tethyan region (Hottinger,1998; Pignatti,1998). Summarization of the Indian equivalents to the non-representative species in different SBZ was essential and has also been done, to make the application of SBZ scheme easy and focused in our sedimentary areas.

The main objective of the study is to develop a viable biostratigraphic tool for stratigraphic trap exploration. In the process, the use of local bio-events and their mapping across the shelf to create stratigraphic framework became an essential aspect of the study. In order to study and propose Palaeogene larger foraminiferal zonation for the selected wells from Assam-Shillong shelf and correlate with the International Geological Correlation Programme (IGCP-286 and 393) scheme, twenty three wells spread over the entire shelf area were analyzed (Fig.1) to present a framework for biostratigraphic correlation. The present study is the first attempt at the precise biozonation of the sediments and provides a framework for