ABSTRACTS

XXI INDIAN COLLOQUIUM ON MICROPALAEONTOLOGY AND STRATIGRAPHY

November 16–17, 2007

Organized by

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53 University Road, Lucknow, INDIA

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XXI Indian Colloquium on Micropalaeontology and Stratigraphy

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PAST INDIAN COLLOQUIA ON MICROPALAEONTOLOGY AND STRATIGRAPHY AT A GLANCE

Colloquium	Year	Venue	Convener
I	1971	Dept. of Geology, Bangalore University, **Bangalore**	Dr. S. Sambe Gowda
II	1972	Dept. of Geology, Lucknow University, **Lucknow**	Dr. S. N. Singh
III	1973	Centre of Adv. Studies in Geology, Panjab University, **Chandigarh**	Dr. B. S. Tewari
IV	1974	KDMIPE, ONGC, Dehradun	Dr. V.V. Sastri
V	1975	Dept. of Geology, Aligarh Muslim University, **Aligarh**	Dr. S. N. Bhalla
VI	1976	Dept. of Geology, Banaras Hindu University, **Varanasi**	Dr. M. S. Srinivasan
VII	1978	Dept. of Geology, Madras University, **Chennai**	Dr. D. A. Rasheed
VIII	1980	Dept. of Geology, M. S. University, **Vadodara**	Dr. D.M. Sringarpure
IX	1981	Dept. of Geology, M.L. Sukhadia University, **Udaipur**	Dr. S. C. Khosla
X	1982	Agarkar Research Institute, **Pune**	Dr. R. M. Badve
XI	1984	Dept. of Geology, Calcutta University, **Kolkata**	Dr. B. K. Samanta
XII	1986	Dept. of Geology, Delhi University, **Delhi**	Dr. Prabha Kalia
XIII	1989	Dept. of Geology, LucknowUniversity, **Lucknow**	Dr. M. P. Singh
XIV	1994	Dept. of Geology, Madras University, **Chennai**	Dr. V. Ragothaman
XV	1996	KDMIPE & WIHG, **Dehradun**	Dr. Jagadish Pandey
XVI	1998	NIO, **Goa**	Dr. Rajiv Nigam
XVII	2000	School of Studies in Geology, **Ujjain**	Dr. Pramendra Dev
XVIII	2002	Postgraduate Dept. of Geology, Nagpur University, **Nagpur**	Dr. Pradeep Kundal
XIX	2003	Dept. of Geology, Banaras Hindu University, **Varanasi**	Dr. Devesh Sinha
XX	2005	Dept. of Geology, Vishakhapatnam University, **Vishakhapatnam**	Dr. T. Y. Naidu

FROM CONVENER'S DESK

It is just the time for me to go down the memory lane. I came to know about the colloquium sometimes in the summer of 1971 soon after I had enrolled as a research scholar under Prof. S. N. Singh at the Micropalaeontology Lab of the Department of Geology, Lucknow University. He was then preparing to go to Bangalore to attend the *first* "**Indian Colloquium on Micropalaeontology & Stratigraphy" (ICMS)** which was being hosted by Prof. S. Sambe Gowda as part of the 75th Birthday Celebrations of Prof. L. Rama Rao. After returning from Bangalore, a beaming Prof. Singh proudly announced that the *second* Colloquium would be held at Lucknow. The colloquium was held in 1972 and the proceedings were eventually published in 1973. The idea mooted by a small group of "*soft rock*" geologists (read "*micropalaeontologists & stratigraphers"*) from all over the country soon acquired continuity as the fraternity grew very rapidly and the subsequent colloquia just started happening.

The **ICMS** has, since then**,** provided a common platform for meeting of scientists and students from both Academia and Industry in India studying varied groups of microfossils with diverse approaches. It has proved to be a strong Forum to discuss current themes and emerging areas of research, share experiences and excitements, and to project future directions for the development of micropalaeontological research in the country. The spectrum of microfossils is vast, spread over all the kingdoms of life. The virtue of their small size and numerical abundance combined with the wide range of body composition and ecological niche occupancy, enhance utility of microfossils in multifold geo-scientific interpretations. Technological advancements further helped microfossils remain in the forefront in serving the cause of human needs be it for better resource development (e.g. fossil fuels) or expansion of knowledge (e.g. search for early life, understanding earth history & climate change etc.). Quantum shifts in research efforts and approaches due to multidisciplinary fusion with allied disciplines has made micropalaeontology indispensable with multifaceted applications in Earth System Sciences.

ICMS gives an excellent opportunity to micropalaeontologists and stratigraphers for fruitful interactions and in building acquaintances to facilitate multidisciplinary integrative group research in the present scenario of boundless disciplines. Birbal Sahni Institute of Palaeobotany at Lucknow is privileged to host the **XXI ICMS** to be held in continuation of its **Founder's Day Celebrations**. The Colloquium aims to focus on both basic and applied aspects of micropalaeontological research and highlight its role and significance to enhance its visibility for end-users and stakeholders.

Focal themes of the Colloquium are:

- Precambrian Palaeobiology and search for Early Life
- Phanerozoic biostratigraphy and palaeoenvironmental analysis
- Past global climate changes and Extreme Climates in Earth History
- Global bioevents, time boundaries and mass extinction
- Microfossil proxies and Quaternary Palaeoclimate
- Microfossils and Sequence Biostratigraphy
- Microvertebrates: Evolutionary and stratigraphic significance
- Role of microfossils in Palaeooceanography and integration with isotopic & trace elemental studies
- Applied Micropalaeontology and Fossil Fuel Exploration
- Palynology and Palynofacies: Application in biostratigraphy and Source Rock Evaluation
- Recent foraminifera: Culture studies and their application
- Recent and Ancient benthic communities – their ecological significance
- Evolutionary trends in microfossils
- Molecular Micropalaeontology
- Modern techniques, tools and computer applications in Micropalaeontological research

I am overwhelmed by the response to the colloquium and the abstracts received. This volume includes abstracts of both oral & poster presentations and the Key Note Lectures. I am grateful to all those who have contributed their valuable abstracts and also to all the delegated who have come to participate in the colloquium. Sincere appreciation goes to my colleague Dr. R. K. Saxena and all members of the Abstract Committee for taking pains in compilation of this volume.

Lastly I sincerely desire that the platform given by ICMS would not only be scientifically rewarding but also help in strengthening professional and personal contacts with colleagues working at different parts of the country. I wish you all a pleasant and comfortable stay at Lucknow.

Rahul Garg
Convener,
XXI Indian Colloquium on Micropalaeontology & Stratigraphy

ACKNOWLEDGEMENTS

I wish to express our deep gratitude to Dr. T. Ramasami, Secretary, Department of Science & Technology, Govt. of India and Chairman, Governing Body, BSIP for kindly accepting our request to be the Patron of the Advisory Committee. I am indebted to all the distinguished scientists and academicians who have very kindly agreed to be in the Advisory Committee.

I am beholden to Prof. Ashok Sahni for kindly consenting to be the General President of the XXI ICMS. Grateful thanks are due to all the colleagues who have agreed to deliver Key Note lectures, even at a very short notice and to chair various sessions.

I am especially grateful to Dr. Naresh C. Mehrotra, Director, BSIP for his permission, unflinching support and enthusiastic involvement in each and every activity associated with the organization of this event at the Institute. Without his help and keen interest, organization of this colloquium would not have been possible.

I am thankful to the Department of Science and Technology, Govt. of India for permission and financial support to hold the colloquium at BSIP. Sincere thanks are expressed to Oil & Natural Gas Corporation for sponsoring the event.

I wish to express my sincere thanks to Prof. M. S. Srinivasan, Prof. T. Y. Naidu, Dr. Anil Bhandari and Dr. Rajiv Nigam for reposing faith in me while entrusting the responsibility of hosting the Colloquium at the Vizag meeting.

I feel extremely happy to express my most sincere gratitude to all my colleagues in the Institute for extending overall support and their untiring efforts in organizing an event of this magnitude.

Rahul Garg

Convener,
XXI Indian Colloquium on Micropalaeontology & Stratigraphy

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HOLOCENE ENVIRONMENTAL CHANGES BETWEEN CUDDALORE AND ODIYUR, EAST COAST OF TAMIL NADU: GEOCHEMISTRY, SEDIMENTOLOGY, FORAMINIFERA AND RADIOCARBON DATING

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Estuary and tidal zone records represent various climatic, tectonic and geomorphic settings that hold signatures for understanding palaeoenvironmental and climate changes. The present work was undertaken with a view to inventory the benthic foraminiferal fauna between Cuddalore and Odiyur to evaluate the trace metal content of the core sediments and to understand the sea level change during the Holocene. The area selected is a narrow coastal strip along the East Coast of Tamil Nadu extending from Lat. 11º45'N: Long. 79º45'E to Lat. 12º15'N: Long. 80º00'E. Five sediment cores were collected from Cuddalore (Core I, Lat. 11º46'N: Long. 79º47'E; Core II, Lat. 11º46'N: Long. 79º47'E; Core III, Lat. 11º45'N: Long. 79º47'E), Marakkanam (Core IV, Lat. 12º13'N: Long. 79º58'E;) and Odiyur (Core V, Lat. 12º13'N: Long. 70º58'E), ranging in depth from 100 to 125cm, from the estuary and tidal zones. Care was taken to retrieve cores from sites that are not presently affected by the modern day tidal processes. All the cores, when sliced, revealed multicoloured layers and were compact with dispersed sandstone rock fragment. Four radiocarbon dates, 3 of organic carbon and one of oyster shell, indicate Early Holocene and Middle Holocene ages. Altogether, 61 foraminiferal taxa belonging to 23 genera, 17 subfamilies, 14 families, 12 superfamilies and 4 suborders were identified. The four suborders are Textularina (6 arenaceous, agglutinated taxa), Miliolina (24 calcareous, imperforate, porcelaneous forms and the rest calcareous, perforate, hyaline species), Rotalina (calcareous and perforate, hyaline species and Lagenina (with calcareous tests). Among these, Rotalina and Miliolina were predominant.

Four benthic foraminifer species, viz. *Ammonia beccarii, Ammonia tepida, Elphidium advenum* and *Elphidium crispum,* are abundant and occurred in all the five cores. The benthonic foraminifera that were abundant in Core I are *Ammonia beccarii, Amphistegina radiata, Elphidium craticulatum, Elphidium* sp. 1, *Quinqueloculina seminulum, Quinqueloculina tenuicollis* and *Spiroloculina orbis.* In Core II, *Ammonia beccarii, Elphidium advenum, Elphidium crispum, Elphidium* sp.1, and *Quinqueloculina seminulum* were predominant, whereas in Core III,

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Ammonia beccarii, Ammonia tepida, Elphidium advenum, Elphidium sp. 2, *Nonionoides elongatum* and *Quinqueloculina seminulum* revealed higher occurrences. In core IV *Ammonia beccarii, Ammonia tepida, Elphidium crispum, Elphidium hispidulum, Elphidium* sp. 2 were abundant and in the core V, *Ammonia beccarii, Elphidium hispidulum, Elphidium excavatum* occurred relatively high. There were 17 species of foraminifera that were found common along both east and west coasts of India.

All the five cores varied in sediment texture predominantly with sand in the Cuddalore site. Marakkanam (Core IV) was dominantly sandy silt and silty clay. This may be due to different source material from the hinterland and coastal configuration processes. Low concentration of organic matter in Cuddalore sediments may be due to sediment texture variation and partial decomposition of organic material. High organic matter content in the sediment cores from Marakkanam and Odiyur are due to algal bloom spread over the water body and carbonaceous wood fragments. Litho-units in the tidal zones between Cuddalore and Odiyur point to a local fluctuation of sea level. Sedimentation in the tidal and estuary zone has taken place in phases. The organic-rich clay units represent a phase of the advance/ transgression thereby increasing the marine influence. This suggests that the position of the tidal and estuary zones did not alter drastically since the Early Holocene, but the amplitude of the shoreline moved horizontally as revealed by the occurrence of the sand and fine silt. Short periods of decreased storminess, intense warm periods are recorded by the occurrence of immature soil formation in the bordering beach dunes.

Probably, the terminal Pleistocene–Early Holocene period was characterized by a relatively low sea level with high–saline conditions. This probably resulted in an increased availability of sand in the shore zone. Large pulses of sand were supplied to the beach by southward-running coastal currents with returning monsoons. The low sea level partly eroded the terminal Pleistocene–Early Holocene coastal tract. Reworking of the inner shelf sediments as a result of the dropping sea level provided the ultimate sediment source for the progradation of the present coastline. Sediment data and radiocarbon dates indicate that since the early Holocene period the coastal area between Cuddalore and Odiyur has been modified over a submerged zone, subsequently modified by neotectonic activity. This research work gains importance as the results show that the Early Holocene (~9 Ka BP), Middle (~5.5 Ka BP) and Late Holocene (1.1 Ka BP) sea level rise was due to intense warm condition with weak NE monsoons. This was in response to the alternate weakening and intense NE monsoon. Warm events during the Holocene are associated with the weakening of the NE monsoon.

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AFFINITIES OF *TRILATIPORITES* RAMANUJAM (=*SCLEROSPERMA*): SEM STUDY FROM THE NEYVELI LIGNITE DEPOSITS, TAMIL NADU

NOTES

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Studies on triporate pollen, *Trilatiporites* Ramanujam (=*Sclerosperma*) have been carried out under scanning electron microscope. Based on the morphological characters, a comparison between *Trilatiporites* and *Sclerosperma* has been done. Efforts are also made to understand the affinities and evolution of this genus in relation to *Sclerosperma manii* and *Areca klinkangensis* of Arecaceae. Triporate, radiosymmetric pollen with perforate tectum without any supratectal structures, which occur in *Areca klinkangensis,* indicate that *Sclerosperma* had close affinities also with *Areca*. Fossil records of tropical West African genus *Sclerosperma* in India do not extend beyond Miocene probably due to mountain building process of Himalaya. It is likely that dispersal of *Sclerosperma* could not be possible from one geoprovince to another due to lack of suitable land connections.

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THE VINDHYAN AGE ENIGMA REVISITED

NOTES

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The occurrence of Lower Vindhyan fossils resembling forms known from Ediacaran–Cambrian rocks has recently been confirmed [Bengtson et al. 2007, GSA Abstracts with Programs 39(6): 331]). The main question now arises about the meaning of the recent radiometric dates indicating a Palaeoproterozoic age to the Lower Vindhyan, containing these fossils. Did the Lower Vindhyan small shelly fossils evolve in the Palaeoproterozoic Era? It does not seem so at least in the Vindhyan stratigraphy. The regional stratigraphy of the Vindhyan Basin does not support a Palaeoproterozoic age (~1800-1600 Ma) for the Lower Vindhyan, because the unconformably underlying low-grade Bijawar Supergroup metamorphics and its stratigraphically equivalent highly deformed Delhi Supergroup metamorphics fall in this radiometric age bracket. The Delhi Orogeny is constrained to be ~1450 Ma, and the Vindhyan Supergroup (VSG) sediments, which are undeformed and unmetamorphosed, have always been placed stratigraphically younger than the Delhi Supergroup on ground realities. These stratigraphic observations strongly go against the radiometrically assigned Palaeoproterozoic age to the Lower Vindhyan as also those of the recorded Ediacaran-Cambrian fossils. In western Rajasthan, the Trans-Aravalli Vindhyan (now the Marwar Supergroup) of latest Neoproterozoic to early Palaeozoic age thus becomes equivalent to the VSG of the author's age concept (Vendian-Early Cambrian) of the main Vindhyan Basin - an original proposition by A. M. Heron that has stood well with the test of time. The most striking feature that emerges out of these stratigraphic observations is that a sedimentary hiatus of more than 1 Billion-Year duration exists in the Proterozoic Eon of the Indian Peninsula, similar to that recently brought out in the Lesser Himalayan stratigraphy [Azmi and Paul 2004, Current Science 86(12): 1653-1660]. From the above it is evident that micropalaeontology is playing a unique role in reshaping the chronostratigraphy of the Purana Basins of India.

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EDIACARAN MICRO-PHYTOFOSSILS FROM THE BILARA GROUP, MARWAR SUPERGROUP, RAJASTHAN

NOTES

Rupendra Babu, Veeru Kant Singh and Manoj Shukla†

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A thick sedimentary sequence of Marwar Supergroup is exposed in the north-west of Narmada-Son Lineament. This sequence is characterized by least disturbed and unmetamorphosed rocks with evaporates sediments in Nagaur Basin. The sediments of this supergroup are developed in the Marwar region and to the west of Aravalli ranges and Delhi mountain belt, and unconformably overlie the igneous rocks of Malani Group. The Marwar Supergroup is divided into three groups, including Bilara.

The present paper deals with abundant and well preserved, unusually crumpled, light brownish palynofossil assemblage of planktic and benthic biocommunities from the intraclastic chert specks of Gotan Limestone Formation, Bilara Group. The outcrops are exposed in and around Haras and Bilara townships in Jodhpur District, Rajasthan. The rock samples were collected by Late Dr. Manoj Shukla from these two localities in the year 2005 under IGCP Project 493, "The rise and fall of Vendian Biota". The Bilara Group (100-300m thick) is characterized by carbonate sediments and is a marker horizon between the underlying Jodhpur Group and the overlying Nagaur Group. This group is divided into three formations, viz. Dhanapa dolomite, Gotan limestone and Pondolo dolomite in Jodhpur district, Rajasthan.

The assemblage comprises 12 taxa of acritarchs and 4 taxa of algae. The acritarchs are mostly simple, along with few ornamented sphaeromorphs and rarely acanthomorphs, belonging to Sphaeromorphida, Sphaerohystrichomorphida and Edromorphida subgroups. These acritarch taxa are *Stictosphaeridium, Leiosphaeridia, Trachysphaeridium, Synsphaeridium, Polyedryxium, Octoedryxium, Cymatiosphaera, Cymatiogalea, Cristallinium, Buedingiisphaeridium, Pterospermella* and *Aremoricanium*. The algal remains show both coccoides (solitary cells and aggregating sphaeroidal cells) and trichomes (septate and aseptate) with/ without mucilaginous sheath comparable to modern Chroococcaceae, Nostocaceae, Oscillatoriaceae and Chlorococcaceae. These taxa are *Obruchevella, Polythrichoides, Myxococcoides, Siphonophycus* and *Gloeocapsamorpha.*

†Deceased

The Marwar Supergroup has been assigned age ranging from Late Neoproterozoic to Cambrian by earlier workers based on geology, few isotopes and palaeontological aspects. The present assemblage is significant in inferring the age and environment of deposition. These forms are widely distributed and are known from the equivalent sediments from other parts of the world. Morphological features and frequency of the recorded organic-walled microfossils indicate an Ediacaran age and moderate deep marine water with high salinity for these sedimentary deposits.

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DISPERSED PLANT CUTICLES: UNDER-ESTIMATED TOOL FOR PALAEOBOTANICAL RESEARCH

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The plant fossil record is the result of interaction between component vegetation and depositional environment. Its significance depends on the taxonomic level up to which the plant fossils can be identified. Taxonomic identification of fossil plants helps in reconstruction of communities and ecosystems. It is based on two distinct set of characters. Intrinsic characters comprise those features of morphology, anatomy, physiology, and chemistry which are preserved within organisms. Extrinsic characters comprise the stratigraphic, geographic, and facies distribution of fossil remains in rock record. Intrinsic information on systematics, physiology and reproductive biology of parent plants combined with extrinsic information is used to reconstruct communities, ecosystems and palaeoclimates, and patterns of their change through time. However, it is not always that plants are preserved as megafossils, and hence other parameters have to be used to decipher not only their presence but also their taxonomic status. Intensive investigations on cuticles of extinct and extant plants have proved that the cuticular micro-topography is a very good taxonomic feature and provides reliable means of deciphering the presence of those plant taxa which are not represented as megafossil. Certain features of cuticular physiognomy, such as, cuticular thickness, stomatal features, hairiness, etc. can be correlated with ecological and climatic conditions. Dispersed plant cuticles often sufficiently preserve these features and a very small piece may suffice for identification up to species level. Due to their low transport potential dispersed cuticles are relatively more suitable for reconstructing palaeocommunities and palaeoclimates, and even in working out phytostratigraphy.

The plant cuticle is a thin continuous extra-cellular membrane, which is mainly composed of cutin, relatively un-biodegradable polymers. The remarkable resistance of cutin has enabled the plant cuticles to persist through the aeons, right from late Devonian (375 million years approximately) to Recent.

Dispersed plant cuticles can be segregated from coals, lignites and shales of almost any age from Devonian to Recent. Very often these are abundant and excellently preserved. Fossil cuticles were first investigated in the nineteenth century by palaeobotanists in Europe. Studies on dispersed cuticles followed the studies of cuticles recovered from the phytolemma on the plant megafossils. First dispersed cuticles were studies in the mid-1800s, but the first significant attempt to study them was made in 1956 by

Harris, who recovered these through bulk maceration of the rock samples. Earlier studies were primarily directed towards identification of plant remains. Now these studies may even constrain the time of origin of plant groups, rates of extinction of plant communities, quantitative estimates of atmospheric CO_2 during the past, and the origin and palaeoecology of coals. Sometimes the dispersed cuticles can not be identified with morphotaxa of megafossils. For such remains, Meyen introduced a system of classification on the lines of one proposed by Potonié for dispersed spores and pollen.

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DEPOSITIONAL ENVIRONMENT, BIOSTRATIGRAPHY AND CHEMOSTRATIGRAPHY OF MIO–PLIOCENE SEQUENCE IN TICHNA, GOJALIA AND SUNDULBARI STRUCTURES, WESTERN TRIPURA

NOTES

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The synergistic approach through palynological, palaeontological, sedimentological and chemostratigraphic studies enabled characterization of the different geochemical units deposited during Miocene and also understanding the depositional set up of sediments in the area around Sundulbari, Tichna and Gojalia structures in Tripura. The boundary between Early-Middle Miocene and Middle-Late Miocene is demarcated. The Early Miocene sediments were deposited under inner shelf condition whereas the Middle Miocene sediments were deposited under inner shelf, lower deltaic and upper deltaic conditions in the area around Sundulbari and Tichna structures and under inner shelf and lower deltaic environments around Gojalia structure. During Late Miocene, the sediments of Sundulbari area were deposited under deltaic condition whereas those of Tichna and Gojalia were deposited under marginal marine and inner shelf environment.

Chemostratigraphic studies helped in characterizing the units based on the variations in trace element concentration. These units are described with the lithological characters, electro-log, organic matter facies, microfossil assemblage and the depositional environments. In Sundulbari-A, five units in Early Miocene and six units and ten subunits in Middle Miocene are identified. In Gojalia-B, one unit in Early Miocene and seven units in Middle Miocene are identified. These units are correlated from Sundulbari to Gojalia structures. Such integrated studies are useful for correlating sequences with high stratigraphic resolution.

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POLLEN RAIN FROM THE VEGETATION OF TROPICAL MOIST DECIDUOUS FOREST, EAST GARO HILLS, MEGHALAYA

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Moss and subsurface soil were analysed for pollen contents, in contrast to existing flora, from Rongrenggiri, Darugiri and Songsak Reserve Forest, East Garo Hills, Meghalaya to define pollen/ vegetation relationship. The study depicts predominance of nonarboreals over arboreals, suggesting the existence of an open lowland forest. Comparison between pollen spectra and vegetation shows site to site variation in pollen assemblages in relation to heterogeneity of forest. It appears that face taxa show good correlation between plant cover and pollen assemblage.

The occurrence of exotic plants is suggestive of long distance transportation of pollen from high altitude. Degraded pollen and spores, festooned with fungal remains, signify the biological degradation during sedimentation. Abundance of fungal spores along with both monolete and trilete pteridophytic spores indicates moist and humid climatic condition. This presentation will be helpful to interpret the pollen diagrams in terms of past vegetation and climate in and around the studied areas.

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POLLEN INTERPLAY IN AND AROUND IMPORTANT WETLANDS OF ASSAM VALLEY, NORTH EAST INDIA: EVIDENCE OF ANTHROPOGENIC INFLUENCE

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The natural wetlands constitute an integral part of landscape in North East India and harbour a large diversity of macro and microbiota, representing almost all taxonomic groups. Several wetlands are becoming an easy target for anthropogenic exploitation in present time, causing massive degradation of important biota due to nonconducive environment to live in. Large open water bodies, like wetlands, lakes and estuaries, provide a dynamic and sensitive system where sedimentary deposits can preserve a record of past or ongoing environmental processes. The chemical, physical and biological characters of aquatic sediments, incorporating tiny pollen-spores, diatoms and desmids, can also provide a finely resolvable record of environmental change, in which natural events may be clearly distinguishable from human inputs. The present paper communicates the result of pollen/ spore concentration in both atmosphere and subsurface sediments of four most endangered wetlands namely Deepor, Kumri, Hasila and Urpad beels of Lower Assam, North East India. The analysis of air suspension has reflected that the air was charged with varied bioparticles like pollen, fern spores, fungal spores and other air borne vegetal which are mostly drifted from nearby forest land and high altitudes along with upcoming wind heaped mass of dirt. The palynological study on subsurface sediments procured from the study area has revealed the occurrence of high value of exotics (*Pinus, Picea, Betula, Alnus, Ulmus, Quercus*, etc.) in contrast to the existing macro and micro-vegetation in and around the wetland areas. The forest arboreal taxa, represented by *Terminali*a, *Syzygium, Salmalia, Acacia*, Moraceae and Meliaceae, are less represented. The aquatic and marshy plant taxa are either absent or are present in low frequency. Occurrence of ferns and nonarboreals in moderate value is suggestive of local origin. Diatom and other algal remains are also less represented despite the presence of wide open water area at places. Fungal spores along with degraded pollen spores are indicative of biological degradation during sedimentation. The state of pollen preservation in different wetlands is assessed through the quantum of palynoassemblage and other factors recovered from sediments in which Deepor and Kumri beels found most threatened. The study has opened new areas to explore

various issues regarding the status of preservation of microbiota in endangered wetland ecosystem and its conservation to restore the lost wealth. It has been observed that introduced exotic species, especially water hyacinth (*Eicchornia crassipes*) and *Salvinia molesta,* have threatened the wetlands and clogged the waterways competing with the native vegetation. The major cause for paucity of important microphytes like diatoms, desmids and other alga might be due to heavy sewage disposal, industrial pollution and agricultural runoff in the near vicinity. From an ecological point of view natural wetlands are much more important as resting sites for many migratory birds where aquatic vegetation is a valuable source of fruits especially for waterfowl in order to search the sediment for nutritious seeds, roots, tubers and other microbiota. Therefore, a congenial atmosphere is needed in forming the meaningful sediments in the pristine wetland ecosystem to maintain natural biodiversity and environmental research of high quality for which a beginning is probably made.

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MICROSCOPIC CYPRINID FISH REMAINS FROM DHARMSALA GROUP (LATE EARLY MIOCENE) OF KANGRA VALLEY, HIMACHAL HIMALAYA AND THEIR PALAEOBIOGEOGRAPHICAL SIGNIFICANCE

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Many-fold enlarged microfish collection from Dharmsala Group is an outcome of ongoing systematic palaeontological work and forms subject matter of the present endeavor. Dharmsala cyprinid fishes comprise *Barbus*, *Labeo, Squalius* and *Chondrostoma,* besides some other non-cyprinid forms such as *Hepsetus*, molariform, and villiform. These are associated with typical fresh water taxa of charophytes, ostracods, etc. the fishes are represented by numerous (>1000) isolated teeth.

Tertiary stratigraphic sequence on the southern flank of the Himalaya begins with marine Subathu which is succeeded by non-marine Dharmsala or homotaxials and Siwalik. Change in regimes from marine to freshwater is well marked by a faunal gap in the sequence that depicts a rather continuous sedimentation. Record of freshwater otophysan fishes of "primary division" (e.g. Cyprinidae) from earliest non-marine horizons in the sequence turns out to be a big deal when we find them to be immigrant Asian natives dispersing via freshwater hydrographical link, that is, through inland water streams though may be in discreet steps. Early Eocene cyprinids from Kuldana Formation, Pakistan remain unsubstantiated and hence not taken into consideration. Cyprinid fishes, as a whole, typical fresh water forms, are specialists and generalists feeding on all trophic levels in the aquatic ecosystem. Their presence along with *Chara,* in the stratigraphically younger levels above marine Subathu Group, marks beginning of absolute freshwater depositional regime without ambiguity on the southern flank of the Himalaya. Moreover, biochronological age (late Burdigalian, ~17 Ma) [1] inferred from the associated exotic deinothere taxon (with a palaeogeographic context) imparts temporal control to the freshwater cyprinids of Kangra Valley and to those known from rather coeval Trans-Himalayan molasse horizons. These late Early Miocene records are potential proxy to the key changes in landscape that have occurred due to the Himalayan tectonics. Earlier studies explaining their distribution in time and space provide an appropriate background for visualizing cyprinid occurrences from coeval beds presently across the central Himalayan water-divide by taking into account the regional mid-Tertiary tectonics. Plausibly,

the cyprinids reached outer Himalayan region from the Ladakh molasse basin as a consequence of tectonically driven integration of former with latter's southern part due to longitudinal water-divide inducing tectonics of early Miocene in the intervening region. Relatively older Trans-Himalayan molasse basins were in the realm of cyprinids, native of adjoining Asian region through freshwater streams. These streams are held responsible for initiating shifting of eroded detritus from Asian plate on to the Indian side, not too long after recent estimate of India-Asia collision at ca. 34 Ma.

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CLIMATE SINCE 11 KA BP AROUND DOKRIANI AREA, GARHWAL HIMALAYA, INDIA

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The spore-pollen analysis from a 10m thick glacio-lacustrine deposit, exposed near the snout of Dokriani glacier (Lat. 30°48' to 30°54'N: Long. 78°40' to 78°51'E), Uttarakhand, Garhwal Himalaya, unravels the climatic scenario from Pleistocene-Holocene transition to Middle Holocene. The study reveals that prior to 9227 yr BP (10633 cal. yr BP), climate was cool-dry in the area as sediments either have less amount of spore-pollen or are devoid of them. The maximum area would have been under snow cover during this time period thus giving less ground exposure for the growth of local herbaceous elements. The tree line would have been further down stream from its present position. This cool-dry phase could be correlated with the Younger Dryas event. Subsequently, around 9227 yr BP (10633 cal. yr BP), there is an amelioration of climatic evident by the increase in diversified pollen taxa at the site indicating the Holocene warmth. Further, there were some intermittent dry episodes recorded around 8.6 to 8.1 Ka BP (9670 to 9000 cal. yr BP) and 6.2 Ka BP (7100 cal. yr BP).

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LATE HOLOCENE CLIMATIC CHANGE FROM PARADISE LAKE, ARUNACHAL PRADESH, EASTERN HIMALAYA

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The present study is based on pollen analysis, supplemented by carbon isotopic data, of shallow sediment profile from Paradise Lake (4176 m a.m.s.l.) near Sela pass, Arunachal Pradesh. It is an exploratory attempt on analysis of climatic and glacial fluctuations covering past 1800 years (245 AD) from the Alpine region of the eastern Himalaya. This analysis shows that in the beginning conifer-broad leaved forest used to grow near site revealing comparatively warmer and moister climate similar to present day conditions. There is further amelioration of climate around 1100 years BP (985 AD) corresponding to Medieval warm period. Around 550 years BP (around 1400 AD) decrease in both conifers and broad leaved taxa suggests a trend towards cooler and comparatively less moist climate corresponding to the little Ice Age. This is followed by an amelioration of climate comparable to present day climatic condition. Carbon isotopic analysis in sediments at different intervals reveals ratio of $\delta^{13}C/ \delta^{12}C$ ranging from -23.9 ‰ to -25 ‰ which indicate dominance of C-3 type over C-4 type of plants around the site. This also suggests that the region has been in general under cool moist climate during last 1800 years BP and does not show much change towards drier climate.

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USE OF BENTHIC FORAMINIFERA AS PROXY FOR GAS HYDRATE ACCUMULATION AND ITS DESTABILIZATION: OBSERVATIONS FROM BLAKE RIDGE

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Gas hydrate, an ice like solid natural crystal composed of water and short chain hydrocarbon (mainly methane) molecule, is metastable in nature and isn formed in low temperature (d"12ºC) and high pressure (e"2.6 MPa) with adequate amount of sedimentary organic carbon (2–3.5 %). It is usually formed at depths greater than 500m in the ocean and in permafrost regions showing wide geographical distribution on the earth surface. So far, seismic reflection profiles called bottom simulating reflectors (BSRs) and geochemical studies (e.g. Chlorine anomaly, Sulfate concentration, ä^{18}O, etc.) are widely used to locate gas hydrate deposits and for their characterization.

Benthic foraminifera are an important component of marine communities and have great potential to reconstruct past climate and oceanic changes owing to their wide distribution, strong sensitivity to different ecological factors, high morphological diversity, and well documented fossil record. Numerous studies on benthic foraminifera show their distribution pattern closely tied to the organic carbon flux, amount of organic carbon in the sediments and oxygen levels of bottom water as well as pore water oxygenation. Thus benthic foraminifera can be used as potential proxy to interpret the methane rich (highly redox) and bacteria rich environment. It is already known that in the methane rich setting benthic foraminiferal $\delta^{13}C$ are typically of depleted nature. Numerous recent studies suggest that some species of benthic foraminifera prefer to feed on rich bacteria mats in methane rich environments.

We have generated a 7-Ma record of benthic foraminifera, carbon and oxygen values, and total organic carbon (TOC) from ODP Hole 994C, Leg 164, Blake Ridge (Lat. 31°47.139'N: Long. 75°32.753'W, water depth 2799m). We identified two groups of benthic foraminifera as high-organic carbon rich taxa (*Uvigerina hispida*, *U. hispido-costata*, *U. peregrina*, *U. proboscidea* and *Melonis barleeanum*) and seep-related taxa (*Bolivina paula*, *Cassidulina carinata*, *Chilostomella oolina*, *Fursenkoina fusiformis*, *Globobulimina pacifica*, *Nonionella auris* and *Trifarina bradyi*) following some recent studies from methane settings. In the methane and hydrate rich interval (7 to ~2.5 Ma) high organic carbon taxa dominate over the

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seep-related taxa indicating presence of elevated organic carbon which might be responsible for the formation of methane by bacterial degradation (methanogenesis). This observation is also supported by the high TOC (<1%) during this interval. On the other hand, seep-related taxa dominate over the high-organic carbon taxa since 3.6 Ma coinciding with the initiation of Northern Hemisphere glaciation. Particularly during the sea-level low stand, increasing population of seep-related taxa indicates dissociation of gas hydrate owing to the reduction of hydrostatic pressure. This observation is also supported by the depletion of pore water sulfate related to the anaerobic oxidation of methane since ~3 Ma. It is remarkable to note that benthic $\delta^{13}C$ values of *C. wuellerstorfi* are not as negative as have been observed in some of the previous studies. This probably suggests that the infaunal species record seep signals better than epifaunal species in such settings.

Moderate porosity, high opal and TOC content, lower carbonate concentration, high pressure (~292 Atm) and low temperature (~9.4°C) provide the suitable environment between 5 and 3 Ma for the formation of gas hydrate. Enrichment in benthic $\delta^{13}C$ in this interval indicates in-situ formation of gas hydrate entrapping biogenic methane rich in ^{12}C (generated by bacterial methanogenesis). Study on $\delta^{13}C$ of methane versus methane-ethane ratio also supports this observation.

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REWORKED PALYNOFOSSILS FROM THE INDIAN TERTIARY SEDIMENTS

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Occurrence of older fossils or other geologic matter in younger sediments is called reworking. A careful study of reworked palynofossils is considerably important in interpreting palaeoecology and environment of deposition and in determining the source area of sediments whereas nonrecognition of the same may lead to erroneous conclusions. It has been observed that Permian, Triassic and Jurassic-Cretaceous palynofossils are commonly found as reworked in Tertiary deposits. In the present paper, such occurrences from various Indian sedimentary sequences have been recorded and their significance has been discussed.

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CARBON ISOTOPIC BEHAVIOUR OF PEAT LAYERS FROM BENGAL BASIN: A MARINE ANALOG OF HOLOCENE PRECIPITATION VARIATION

NOTES

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The carbon isotopic analysis of a sediment profile consisting of peat and peaty clay from south Bengal Basin has been carried out to study the past precipitation pattern. The record spans since early mid-Holocene (ca. 7 Ka). Two distinct layers of peat were identified ca. 7500±200 and 3700±150 cal yr ago. The carbon isotopic composition of the organic matter preserved in the peat layers shows episodic negative excursions during these periods, indicating the arrival of humid phases. However, these diminutions are superimposed by a long term increasing trend in ä^{13}C that indicates a progressive reduction in monsoon precipitation. Such kind of decrement in monsoon rainfall during the Holocene in northern India, comprising the Ganga-Brahmaputra catchment, has also been documented in marine sediments. The long term trend in the carbon isotopes of the sediment organic matter in these sample and that in the oxygen isotopes of foraminifera in a marine sediment core from the north Bay of Bengal show similar behaviour. This probably indicates that the carbon isotopes in terrestrial sediments and the oxygen isotopes in marine sediments in this region responded to the same external forcing, that is monsoon precipitation during the Holocene.

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CLUSTER ANALYSIS AS A TOOL TO STUDY DISTRIBUTION AND ECOLOGY OF RECENT FORAMINIFERA OFF KUTCH, WEST COAST OF INDIA

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Understanding the processes responsible for changes in coastal zone and monitoring the same is the need of hour in order to adopt a holistic approach for solving the problems relevant to coastal hazards in future. To monitor changes in coastal zone, study of foraminifera is very useful. In a study on the distribution and ecology of foraminifera from the shelf of Kutch, 47 surface sediment samples were collected between the water depth of 1.5 and 20m. A total of 128 foraminiferal species belonging to 58 genera and 36 families were identified from the study area. In order to draw meaningful inferences, the large sets of foraminiferal data were subjected to Q- and R-mode cluster analysis. Q-mode cluster analysis reveals that all the sample stations can be classified into three major clusters namely A, B and C at 64-linkage distance value. Cluster C is further classified into 3 distinct sub-clusters, viz. Cluster C1, C2 and C3 at 56-linkage distance value. The results of R-mode clustering reveals at 160 level of linkage distance that most of the genera are clustered in cluster C. This leaves only two more genera, i.e. *Rotalidium* as cluster B and *Ammobaculites* as cluster A. When compared with results of Q-mode clustering with R-mode cluster, it can be concluded that results of Q-mode and R-mode cluster are matching with each other, as Q-mode cluster 'A' is mainly composed of *Ammobaculites* (cluster A of R-mode clustering), Q-mode cluster 'B' is composed of *Rotalidium* and *Asterorotalia* (i.e. cluster B of R-mode) and Q-mode cluster 'C' is composed of varied fauna (i.e. cluster C of R-mode). Further, the distributions of various clusters of Q-mode cluster show the strong similarity to the distribution pattern of dominant genera of particular cluster.

The distribution pattern of foraminifera of the study area further shows the similarities with the results of Q- and R-mode cluster analysis. The foraminiferal study reveals that the distribution pattern of benthic forms like *Ammonia, Rotalidium, Miliolidae, Elphidium* exhibit their particular place of habitation on sandy substratum where as *Ammobaculites* an abundant agglutinated foraminifera in the study area is mostly dominant in mud. The percentage distribution of *Pararotalia* (mainly of *Pararotalia takayanagi* and *P. minuta*) shows a patchy distribution. The study have

further revealed that the foraminifera specimens on sand substratum are thick, strong, larger in size, smooth and mostly with rounded test morphology whereas the muddy substratum holds number of foraminiferal specimens with thin and small test. The calcareous foraminiferal tests of muddy substratum in deeper region are generally smaller than the normal test size. The general test sizes in muddy substratum are less than 150-micron meter. These stunted/ juvenile tests indicate particular physiochemical conditions that affect the growth of the test in the study area.

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FAUNAL ASSEMBLAGE FROM THE BEACH ROCKS OF RAMESWARAM ISLAND, EAST COAST OF INDIA-ENVIRONMENTAL IMPLICATIONS

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In southern Tamil Nadu, wide range of rocks occurs between Rameswaram coast and Kanyakumari. Between Rameswaram and Narikuli, calcareous beach rocks are noticed. Coral cliffs are common in this island. From Mandapam to Kilakarai, beach rocks are of calcareous to siliciclastic nature, observed in the wave cut platforms. A terrace, located at Valinokkam, is made up of friable sandstone to an altitude of 3.5 m. In Manapad, four terrace levels are recognized within the massive dune system extending to an altitude of 25.5 m. Along the Ovari and in the mouth of Nambiyar River, friable calcareous sandstones are exposed in the intertidal region. At Idinthakarai, beach rocks comprise of terrigenous grains of gravels, sand and shell fragments. Apart from these exposures in Tamil Nadu coast, ferricretes are noticed around the coast of Chennai. They are formed by evaporation in red soils. In spite of the sporadic presence of various beach rocks reported in Tamil Nadu, a systematic study on faunal assemblages has not been attempted so far. Most of the beach rocks have been found to be calcareous in nature and being described with C^{14} dating. In Tamil Nadu there are beach rocks without any biogenic content. The present study is aimed to describe the beach rocks formation and its nature. Besides, an attempt is made to find out the faunal assemblages reported from the beach rocks. The microfauna from the beach-rock of the Rameswaram Island, east coast of India have been investigated for this work. The beach-rock fauna reflects the reefal environment of deposition. The occurrence of raised beaches and terraces has been attributed to the neotectonic activity in recent times. C^{14} dates indicate that the Rameswaram beach-rock (4410-4500 years BP), indicating different oscillations, show at least two phases of neotectonic activity. In general, the foraminiferal preservation is moderate to fair in thin sections recovered from Rameswaram Islands. From the preserved section of foraminifers, it is clearly indicated that their depositional environmental ranging form shallow and intermediate environmental conditions and it is mainly due to the fluctuation of sea level variations.

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GLACIAL-INTERGLACIAL VARIABILITY OF THE INDIAN MONSOON DURING THE PAST 440 KA

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The Indian monsoon is marked by seasonal reversals in the wind patterns. In summer, the strong, wet southwesterly winds blow towards the land whereas in winter, the weak, northeasterly winds blow towards the Indian Ocean. The monsoon is an important part of the climate system for hydrological and thermal budget, affecting the most densely-populated parts of the Asian and African regions. The summer monsoon is critical to the people of Asia as region's water needs for agriculture and domestic use are largely dependent on the monsoon rainfall, particularly the summer monsoon rainfall. A good monsoon means a booming India whereas an unusual monsoon will bring misery to the large component of the country's population by causing droughts and floods. Thus monsoon is a crucial resource for the region's largely agrarian economies. Significant efforts have been made toward reconstruction of high resolution proxy records of monsoon from marine cores and continental deposits that have helped in the understanding of its evolution, its variability over various time scales, and forcing factors that drive the monsoon on orbital and sub-orbital time scales. Numerous recent studies have shown that monsoon has varied at orbital (eccentricity, obliquity and precession) and sub-orbital (centennial to millennial) time scales. The centennial to millennial scale changes in the monsoon have been linked to both the internal (linked to North Atlantic Oscillation, ENSO, etc.) and external (solar) forcings, but mechanistic links of monsoon variability to these forcing factors require further studies. We have recently analyzed 444 Ka record of monsoon from IODP Hole 716A, Leg 115 to understand millennial scale variability in the Indian monsoon. Hole 716A is located on the broad central plateau of the Maldives Ridge at a water depth of 533.3 m (Lat. 04^{o}56.0'N: 73^{o}17.0'E), equatorial Indian Ocean (southeastern Arabian Sea). We analyzed 892 samples at an interval of 135 years per sample up to 151 Ka and 328-1304 years per sample from 151 Ka to 444 Ka BP. The foraminiferal faunal and pteropod data suggest millennial scale changes during the studied interval. The data show that monsoonal winds were stronger during interglacial periods (high surface productivity) and weak during glacials.

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EVENT STRATIGRAPHY ACROSS BATHONIAN-CALLOVIAN BOUNDARY OF KULDHAR MEMBER, JAISALMER, RAJASTHAN

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The Kuldhar Member of Jaisalmer Formation is well exposed near Kuldhar village, Jaisalmer district, Rajasthan. The sediments of this section span across Bathonian-Callovian boundary and four ichnological events have been proposed. Ichnologically, beds 1 to 4 exhibit multiple hardgrounds with boring sequences whereas beds 5 to 13 exhibit cyclic development of recurring ichnoassemblages. Prominent among these is *Zoophycos* ichnohorizon along with rare trochospiral ichnospecies of *Rhizocorallium uliarense*. Based on the ichnological data, the Kuldhar Member exhibits palaeoenvironmental cyclicity, with development of multiple hardgrounds during the Bathonian and shelf environment with dysoxic oxygen condition during the Callovian. It also marks the effect of Early Callovian transgression in Jaisalmer Basin.

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BELEMNITE BIOSTRATIGRAPHY OF CALLOVIAN SEDIMENTS OF JARA DOME, SOUTHWESTERN KUTCH, GUJARAT

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The Jara Dome, situated on the western extremity of Kutch Mainland, is exposed in a prominent cliff section (GPS location Lat. 23°43'38''N: Long. 68°59'42"E). The section shows fine grained, fossiliferous (bearing ammonites and belemnites) calcareous shales (basal ca. 1m), followed by gypsiferous and nongypsiferous shales, and is capped by three prominent bands of hard indurated marker limestones of Dhosa oolite. The entire succession represents upper part of Chari Formation. Only the nongypsiferous shales yielded datable calcareous nannofossil assemblage. The age of the shale unit is constrained by FAD of *Stephanolithion bigotii bigotii* of the European late Early Callovian *Calloviense* Zone and the LAD of *Ansulasphaera helvetica* in the late Late Callovian *lamberti* Zone. The interval corresponds to the NJ 13 *S. bigotii bigotii* calcareous nannofossil Zone. The Dhosa oolite (Oxfordian) contains marker ammonites.

Belemnites from Callovian sediments of Jara Dome, containing datable ammonites and calcareous nannofossils, were taxonomically assessed. The recorded nine belemnite species are assigned to four genera, viz. *Belemnopsis*, *Dicoelites*, *Hibolithes* and *Conodicoelites* and three belemnite concurrent range zones are proposed. It is expected to provide a better palaeoenvironmental interpretation along with stratigraphic resolution and biostratigraphic correlation with standard ammonite-nanno biozones.

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ARCELLACEAN MORPHOMETRY: A POTENTIAL INDICATOR OF WETLAND ECOLOGY

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To understand the effects of climate and salinity change on wetland ecosystems, the ecological preferences of the composing organisms are required. A very sensitive group of organisms is formed by the testate amoebae (Protozoa, Sarcodina and Rhizopoda). In the last ten years, their usefulness as palaeoenvironmental indicators has become better understood because researchers have recognized that certain morphotypes (strains) prefer distinct microenvironments. Testate amoebae are present in a variety of habitats and their short generation time makes them useful indicators of limnic condition influenced by environmental changes. Test size vary from 50 to 300 µm, which is determined at the time of fission by the volume of cytoplasm available in the parent test. Cytoplasmic volume is probably controlled by the availability of food and favourable conditions in the period preceding reproduction. Study on Nilarevu river (a tributary of Godavari) delta, Andhra Pradesh reveals that morphometry of arcellacean species is particularly sensitive to environmental variations like increase or decrease in salinity, due to marine incursion or fresh water influx, during the past in coastal wetlands. *Arcella* and *Centropyxis* species are common in the coastal wetlands of India. Quantitative reduction and a significant decrease in size and variation in inconsistent morphological features have been recorded with the increase in salinity. The quantitative and qualitative succession of arcellaceans in a sedimentary soil section also indicates an abrupt change in sea level that serves as potential markers of Tsunami-like events.

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BENTHIC FORAMINIFERA AND SEDIMENT CHARACTERISTICS ALONG THE COAST OFF MANDAPAM AND TUTICORIN AND THEIR INFLUENCE ON DEPOSITIONAL ENVIRONMENT, EAST COAST OF INDIA

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The study area extends from Mandapam to Tuticorin on the southern coast of Tamil Nadu (India) over a distance of 120 km. A total of 36 sediment samples were collected from beach (6) and offshore (30). Grain size studies show that the frequency curves vary from unimodal to bimodal in places of river discharge from the Vembar, Kallar, Vaippar and Tamiraparani, as a result of which an additional sub-population is deposited. Otherwise, the nature of the frequency curve is controlled primarily by wave dynamics and littoral currents. The mean size of the sediments is finer in the Mandapam sector, where low-energy conditions prevail and accretionary processes are taking place; this is corroborated by the positive skewness of the sediments. The skewness values characteristically discriminate the energy conditions obtaining in the study region: low energy in the Mandapam sector, higher energy in the Valinokkam sector and a mixture of high and low energy in the Tuticorin sector is observed. The CM pattern indicates the deposition of sediments in graded suspension. The binary plots help to discriminate the different environmental conditions prevailing in the study region.

Altogether, 77 benthic foraminiferal species (post-tsunami) and varieties belonging to 39 genera, 13 families, 10 superfamilies and 4 suborders have been reported and illustrated. The following species are widely distributed in the pre and post-tsunami samples namely S*piroloculina communis, Quinqueloculina elongatum, Q. lamarckiana, Q. seminulum, Triloculina trigonula, Cibicides lobatululs, Ammonia beccarii, A. dentata, A. tepida, Elphidium crispum* and *Assilina ammonoides*. The following species are found in lesser amount in all the stations: *Elphidium discoidale, Rectobolivina raphanaus, Cribrononion simplex, Cymbaloporetta bradi, Eponoides rapandus, Spiroloculina aqua* and *S. inca*. At Mandapam and Tuticorin, the total species are increase in the deeper depths whereas in Kallar there will be reverse trend. Similarly the living species also play the same trend at Vallinokkam. The scatter plot of salinity vs living species shows positive correlations. The scatter plot of organic matter vs living species shows strong negative correlation and positive correlation with

dead species shows a negative relation with the biomass. Further, the trend of organic matter vs carbonate reveals that due to littoral drift activities the drifting of sediment brought from the inner shelf regions have played a great role in the contribution of dead species as well as carbonate shells. As the present study indicates that the sediment were brought from inner-shelf region, it is essential to track the source of sediment in the deeper part by carrying out a detailed investigation on the microfossil studies.

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RECENT BENTHIC OSTRACODA FROM TAMIRAPARANI ESTUARY AND ADJOINING SHELF AREAS, OFF PUNNAIKAYAL, TUTICORIN, SOUTHEAST COAST OF INDIA

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Studies on Recent ostracod fauna from the seas and other marginal marine water bodies of India, especially along the east coast, are still not known fully. In order to know the occurrence of ostracoda in three different habitats such as Tamiraparani river, estuary and adjoining shelf sediments, the present study has been taken up. However, no microfauna has been encountered in the riverine sediments and hence, the study has been restricted to the estuary and adjoining shelf. The present work on morphological and systematic studies of Recent Ostracoda from the estuary and adjoining inner shelf sediments off the coast of Punnaikkayal, south of Tuticorin (Lat. 8°36.883' to 8°40.007'N and Long. 78°07.284' to 78°13.379'E) has been undertaken to enhance the existing knowledge on ostracods of east coast of India. Sediment samples were collected twice in a year representing pre-monsoon (July 2003) and post-monsoon (January 2004) periods from estuary and adjoining shelf areas. In each season, 22 estuarine samples and 16 offshore samples were collected. Thus, 76 sediment samples have been collected. The depth of sample collection in offshore area ranges from 5.4 m to 25.3 m.

All the sediment samples were subjected to standard micropalaeontological techniques and ostracod fauna were retrieved. Seventy-five ostracod taxa belonging to 53 genera, 24 families, 4 superfamilies, and 2 suborders of the order Podocopida have been identified. Among these, 2 species belong to suborder Platycopa and the remaining to suborder Podocopa. For the sake of brevity, an updated synonomy and remarks for the already established species are given. *Xestoleberis malaysiana* is recorded for the first time from Indian waters. The following three species are reported for the first time from the east coast of India: *Cyprideis* sp. cf. *C. mandviensis, Henryhowella (Neohenryhowella) hartmanni, Keijella whatleyi.* SEM photomicrographs of all the 75 species, depicting different views, have been given.

An analysis of the ratio between the carapaces and valves (10:1) indicates that a faster rate of sedimentation prevails in Tamiraparani estuary and adjoining shelf region. The Tamiraparani estuary and adjoining shelf area fauna has been compared with the fauna reported from various other localities in the east and west coasts of India and other localities in the

Indo-Pacific region, to analyse their distribution and also to know their faunal affinity and zoogeographic implications. A majority of taxa are found to be common or having close affinity with the fauna reported from the east and west coasts of India and other coastal margins of the Indo-Pacific region, showing a strong Indo-Pacific faunal affinity and exhibiting a shallow and tropical water habitat.

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DISTRIBUTION AND ECOLOGY OF BENTHIC FORAMINIFERA FROM THE INNER SHELF SEDIMENTS OFF TUTICORIN, SOUTHEAST COAST OF INDIA

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The occurrence of benthic species is controlled, to a great extent, by physical factors such as depth, temperature, amount of light available, turbidity and turbulence of the water, character of the bottom sediments, chemical factors like salinity of water and availability of elements and biological factors such as food supply, presence of symbiotic organisms, parasites and predators.

For the present work on the distribution and ecology of foraminifera from the inner shelf of Gulf of Mannar, off Tuticorin, the bottom water and sediment samples were collected from 21 stations ranging in depths from less than 1 m to 10 m. The samples were collected for every three months of the year, starting from July 2004 and thus, the collection amounts to a total of 84 samples.

Specific composition of the foraminiferal fauna reveals that 117 foraminiferal species, belonging to 54 genera, have been encountered in the present area of study. A correlation of the living foraminifera population with observed environmental factors reveals that, in general, a higher temperature, dissolved oxygen and salinity of bottom waters combined with higher CaCO3 and moderate organic matter content of the substrate of the summer season are congenial for maximum reproduction of foraminifera and thus resulting in abundance of living population.

Trace elements have been found to be concentrated in the sediments collected near the thermal plant and near the harbour of the study area and have resulted into few abnormal tests. Spatial distribution of the foraminiferal population shows that the substrate with higher sediments provides a favourable niche for population abundance.

The following six species namely, *Ammonia beccari, Ammonia tepida, Nonian boueanum, Quinqueloculina seminulum, Spiroculina communis* and *Astrorotalia inflata* are considered to be wide spread and abundant. Comparison of the foraminiferal assemblages of the present area with those from off Rameswaram, Porto Novo and Chennai, reveal that 34 species are common to all these area and 10 species have not found in other areas of study but restricted only to the present area of study.

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DANIAN CALCAREOUS NANNOFOSSILS FROM KHASI HILLS, MEGHALAYA

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The Um Sohryngkew section in Cherrapunjee, Khasi Hills, Meghalaya exposes a continuous shallow marine Late Cretaceous- Palaeocene succession, including the Cretaceous-Tertiary Boundary (KTB), with an almost complete biostratigraphic record provided by nannofossils, dinoflagellate cysts and planktonic foraminifera. The K/T boundary has earlier been drawn at the massive extinction of Cretaceous nannofossils and last appearance of *Micula prinsii* below a thin, iridium-spike bearing, rust coloured boundary clay layer.

The exposure, located on the western bank of the river, includes several metres thick succession belonging to the Mahadek and Langpar formations. The Langpar Formation (uppermost Maastrichtian to Danian) mainly comprises calcareous shales, carbonaceous shales and argillaceous limestones. Rich and well diversified assemblages of calcareous nannofossils recovered from the Langpar Formation have revealed a succession of nannofossil events (FADs & LADs) closely comparable with globally well established, low-latitude nannofossil zonations. In the present study, Danian zonal markers of NTp1, NTp2, NTp3, NTp5 and NTp7 zones (corresponding to NP1-NP4 and CP1-CP3 zones) of Tethyan Intermediate Province, Europe and Tunisia have been recorded. The studied interval shows successive first appearance (FAD) of Danian markers *Biantholithus sparsus, Neobiscutum romeinii, N. parvulum, Cruciplacolithus primus, Futyania petalosa, Coccolithus pelagicus, Neochiatozygus modestus, N. saepes* and *N. perfectus*. Four zones viz. *Neobiscutum romeinii* Zone, *Neobiscutum parvulum* Zone, *Cruciplacolithus primus* Zone and *Coccolithus pelagicus* Zone are proposed in the ascending order. A comparison of the important nannofossil events in the Um Sohryngkew section, lying just south of the palaeo-equator, with known global zonations and other low latitude nannoevents is presented to highlight their biostratigraphic potential in this region.

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AN EXCLUSIVE AGGLUTINATED FORAMINIFERAL ASSEMBLAGE FROM RUPSI SHALE, JAISALMER AND ITS PALAEOECOLOGIC SIGNIFICANCE

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Rich and diversified microfauna, comprising 55 species belonging to 34 genera, and consisting almost exclusively of agglutinated foraminifera with simple interiors are recovered from the Rupsi Shale exposed at a scarp section near Rupsi village, Jaisalmer. The stratigraphic succession consists mainly of sandy shale and sandstone with several hard, ferruginous and fossiliferous bands (containing ammonoids, few belemnites and bivalves) and evidences of worm tracks and burrows in the upper part and gypsiferous shale and micaceous-carbonaceous shale intercalations in the lower part. An *Ophiomorpha*-rich highly bioturbated sandy band occurs near the top, capped by a hard ferrugenous sandstone. Three microfaunal assemblages are recognized based on the differential composition of the agglutinated microfauna:

***Bathysiphon-Rhabdammina-Rhizammina* Assemblage**: Confined mainly to the grey to dark grey micaceous-carbonaceous silty shale in the lower part of the succession, this low diversity assemblage is dominated by simple primitive tubular agglutinated genera, e.g. *Rhizammina, Rhabdammina* and *Bathysiphon* which commonly have large robust, coarsely agglutinated and often poorly cemented tests. The other constituents of this assemblage are represented by rare occurrence of species of *Saccammina, Psammosphaera, Lagenammina, Reophax, Trochammina, Haplophragmoides* and *Riyadhella*. The tubular tests are frequently distorted, deformed or compressed and often show organic cement, especially from carbonaceous matter rich levels.

***Trochammina-Reophax-Ammobaculites* Assemblage:** This more profuse and diversified simple agglutinated foraminiferal microfauna shows dominance of lituolid foraminifera having simple interiors. It is recovered from the succeeding soft gypsiferous, grey shale containing ammonoids and few belemnites. Predominant genera in this assemblage are *Trochammina, Ammobaculites, Reophax* and *Haplophragmoides,* represented by several species. Associated forms include *Lagenammina, Ammosphaeroidina?, Plectotrochammina?, Eggerella, Verneuilina, Verneuilinoides,* etc., with sporadic occurrence of simple tubular forms and poorly preserved calcareous foraminifera and ostracod moulds. The foraminiferal tests are often large and robust and do not show signs of

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deformation. In contrast to the coarse agglutination of tests in the underlying assemblage, foraminifera from this bed are mostly finely agglutinated.

***Ammobaculites-Haplophragmoides* Assemblage**: The overlying thick succession of interbedded sandy shale and sandstone with several hard ferruginous nodular bands yielded impoverished and poorly preserved microfauna, represented by only few species of *Ammobaculites, Haplophragmoides* with *Ammodiscus, Reophax, Lagenammina, Lenticulina* and *Eoguttulina*. Rare internal moulds of calcareous forms and ostracods are also found.

Predominance of agglutinated species and rarity of calcareous species in foraminiferal assemblages are attributed to several ecological factors. Agglutinated foraminifers dominate in areas of low availability of calcium carbonate, characterized by low salinity and/or low temperature, lack of oxygen and considerable pH fluctuations, as in lagoons, bays, estuaries or brackish water or hypersaline marshes and also in the deepest part of the oceans. Agglutinated tests with organic-type cement suggest anoxic mudddy substrate with O_2 depletion and higher CO_2 content of bottom water. However, the selective post-depositional dissolution of calcareous tests cannot be ruled out as an important factor for decalcified agglutinated-dominated fossil assemblages.

Simple agglutinated foraminifera thrive freely in marsh or near shore brackish water environment which is subjected to strained ecologic conditions due to salinity and pH fluctuations where calcareous species are usually rare. The general low specific diversity and large populations of simple agglutinated foraminifers is also characteristic of marsh environments. The primitive agglutinated forms such as *Bathysiphon* and *Rhizammina,* are usually more robust, thicker walled with coarse agglutinates in the paralic zone under adverse environmental conditions.

The appearance of an exclusive assemblage of agglutinated foraminifera, predominated by simple tubular forms with low specific diversity and large population in the lower part of Rupsi Shale, suggests near shore hyposaline marshy conditions. The coarse agglutination and poorly cemented tests, often with organic cements, with evidences of distortion and deflation/compression of tests and low diversity indicate anoxic muddy substrate with low pH. Distortion or compression of the tests is considered to be due to post-depositional compaction. Occurrence of fossil wood fragments and organic matter rich layers in the lower part attests to paralic setting with enhanced terrestrial run-off.

The change from *Bathysiphon-Rhabdammina-Rhizammina* Assemblage to a diverse microfauna of *Trochammina-Reophax-Ammobaculites* Assemblage with appearance of several coiled and multiserial forms, suggests slightly increased salinity and depth, leading to brackish estuarine environment with open-sea connections facilitating influx

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of nekto-benthic ammonoids and belemnites. Absence of other benthonic marine biotope is attributed to lower than normal salinity.

The overlying assemblage is much improverished. Occurrence of moulds of ostracods and polymorphinid and lenticulinid foraminifers may suggest a decalcified, assemblage. Occurrence of ammonites and belemnites suggests that the site of deposition had open-sea connections with periodic marine incursions in overall salinity stressed conditions almost throughout the upper part of the Rupsi Shale.

Trochammina quinqueloba, a common element of the *Trochammina-Reophax-Ammobaculites* Assemblage, has some stratigraphic significance. This species is known to date only from Kimmeridgian-Tithonian sequences. However, the association of ammonoids provides a firm basis for precise dating of the Rupsi Shale. The *Bathysiphon-Rhabdammina-Rhizammina* Association overlies a moderate ammonite assemblage of small perisphinctins referable to *Torquatisphinctes*, closely resembling *Perisphinctes* sp. recorded from northwestern Pakistan, suggesting Kimmeridgian age. The *Trochammina-Reophax-Ammobaculites* Association co-occurs with *Aulacosphictoides-Pachysphinctes* assemblage of Kimmeridgian age. This is overlain by *Aulacosphinctoides-Hildoglochiceras* assemblage of early Lower Tithonian age. Thus, the age of the foraminiferal assemblage is considered to be restricted to the Kimmeridgian- early Tithonian.

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NEW EARLY WETZELIELLOID DINOFLAGELLATES FROM KHASI HILLS, SOUTH SHILLONG PLATEAU, NORTHEASTERN INDIA: EVOLUTIONARY AND PALAEOENVIRONMENTAL SIGNIFICANCE

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The wetzelielloid dinoflagellates are exclusively known as the fossil dinosporin cysts from marine strata of Palaeogene age and serve as excellent biostratigraphic markers. These peridiniacean dinoflagellate cysts are distinguished by a simple, middorsal quadra intercalary archaeopyle, which is unique in the entire fossil dinoflagellate cyst record. The earliest representative of the group is the genus *Apectodinium*, which was long believed to have originated and rapidly diversified during Late Thanetian times. Evidences from Tunisia and India now suggest that *Apectodinium* first appeared much earlier, close to the Danian-Selandian boundary in the low latitudes. Onset of *Apectodinium* dominated assemblages, calibrated with CIE, is known to be a global phenomenon associated with the Palaeocene Eocene Thermal Maximum (PETM).

Apectodinium dominated assemblages are widely reported from India and have been precisely calibrated with NP9/P5 zones in the Cauvery Basin and with Shallow Benthic Zones SBZ5-SBZ6 (close to mid P5zone) in the South Shillong Plateau. The assemblages under study from the South Shillong Plateau are recorded from the coal bearing Lakadong Sandstone exposed in the Cherrapunji -Mawsynram area, Khasi Hills, Meghalaya. These assemblages contain several new morphotypes characterized by morphological features intermediate between *Apectodinium* and *Rhombodinium/ Wilsonidium.* These taxa represent the early wetzelielloid evolutionary stock that subsequently gave rise to the genera *Rhombodinium* and *Wilsonidium*, globally known from younger Eocene strata only. Morphologically similar forms have been reported only from the Late Thanetian of the Turgay Strait, Kazakhstan. Based on detailed morphological study of the new morphotypes, one new genus with 3 new species is described.

According to the latest concept, the Palaeocene-Eocene boundary is now favoured to be placed at the CIE. The erstwhile uppermost part of the Thanetian Stage (lying above CIE) is replaced by Sparnacian which is reinstated as the oldest stage of Eocene. The new taxa recorded from the uppermost levels of Lakadong Sandstone, above the CIE, therefore, have immense biostratigraphic potential for identification of Sparnacian and/or Palaeocene/Eocene boundary in the region.

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Further, due to the unique morphological characters overlapping between *Apectodinium* and *Rhombodinium*, the new taxa have a significant bearing on the evolutionary lineage of this biostratigraphically important dinoflagellate cyst group. The existing model of possible phylogenetic relationship between genera of the subfamily Wetzelielloidae (Family Peridiniaceae) is emended. New lineages are proposed indicating the new genus originating from *Apectodinium* and being ancestral to the genera *Wilsonidium* and *Rhombodinium*. A key to the identification of various wetzelielloid genera, based on significant morphologic characters, is proposed.

Apectodinium is supposedly a warm water heterotrophic taxon preferring low salinity marine waters. By coincidence, the newly found wetzelielloid taxa also might have favoured similar palaeoecological conditions. Runoff related high input of organic detritus and nutrient availability possibly led to a significant increase in the surface water productivity in the marginal marine setup conducive to the environmental preferences of these organisms. The marginal seas in the (palaeo) equatorial latitudes during Late Thanetian- Sparnacian, thus, provided suitable niches for rapid proliferation of *Apectodinium* and the new early wetzelielloids with great morphological diversity. It has been suggested that PETM related profound global warming and associated climatic perturbations induced a rapid evolutionary turnover in the earliest wetzelielloid stock within a brief time span.

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PHYTOLITHS IN EXPLORING VEGETATION AND ENVIRONMENT DYNAMICS DURING LATE QUATERNARY: A CASE STUDY FROM ZIRO VALLEY, ARUNACHAL PRADESH

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The reconstruction of the vegetational history and microclimatic oscillations since last 40000 years BP in Ziro valley, Arunachal Pradesh is carried out using phytolith proxy. The results are compared with the palynological data from the same sediments as well as published records from the same area. Fossil phytolith assemblages are interpreted using different phytolith indices, i.e. D/ P (Tree cover density index), Humidity–aridity index [Iph (%)], Climatic index (Ic) and Fs (Water stress index) to estimate the density of the tree cover, the trends of aridity, the proportion of C3 versus C4 grasses and tendencies of transpiration rate performed by the regional taxa at the time of deposition.

The analysis reveals dominance of pooid grasses (C3 grass) over panicoids (C3-C4 grasses) and chloridoids (C4 short grasses) in and around the region since >40 Ka BP indicating a general cool moist climatic condition corroborating the earlier palynological data. A gradual decline of woody dicot morphotypes during 3540 ± 150 yrs BP to 1370 ± 71 yrs BP suggests a slight thinning of the vegetation cover in the area. A slight increase of chloridoid morphotypes in phytolith assemblage suggests a trend towards decreasing moisture condition during 3540 ± 150 yrs BP to 1370 ± 71 yrs BP. In addition, an increasing trend of fan-shaped bulliform cells indicates a probable gradual increase in rate of transpiration by the plants since 40000 years BP. Fresh water diatoms, viz. *Navicula* sp., *Eunotia* sp. and *Amphora* sp., recovered in highest frequencies during 1370±71 yrs BP is suggestive of occurrence of a fresh water source near the site.

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SEDIMENTOLOGICAL CHARACTERIZATION AND PALYNOFACIES VARIATIONS OF LAKADONG LIMESTONE OF SOUTH SHILLONG PLATEAU, MEGHALAYA

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The Lakadong Limestone of South Shillong Plateau is the lower most unit of Sylhet Limestone Formation of Jaintia Group. The age assigned for the lithounit is Early Thanetian as it can be correlated with Shallow Benthic Zone SBZ 3 of larger benthic foraminifera and Early P4 Zone of planktonic foraminifera. The Lakadong Limestone is made up of microcrystalline, allochemical rocks of biomicrite type that normally develop in shallow protected shelves or lagoon. It contains 23.73% of micrite along with sparry calcite, pellets and terrigenous constituents. Texturally, the limestone is a mixture of wackstone, packstone and grainstone. Staining of thin section confirms the presence of low Mg calcite, high Mg calcite, aragonite and dolomite. However, diagenetic processes observed in Lakadong Limestone include solution, cementation, compaction, neomorphism, pressure solution and dolomitisation.

For palynofacies analysis of the Lakadong Limestone quantitative variations of organic matter were analysed. Based on abundance and/ or paucity, presence and/ or absence of palynological organic matter, the Lakadong Limestone is divided into three distinct palynofacies units, viz. Unit-I, Unit-II and Unit-III. Each palynofacies unit is characterized by its significant characters and thus helps in interpretation of palaeoenvironment. An attempt has been made to establish the possible distal-proximal trend of deposition of identified palynofacies units in Lakadong Limestone in relation to palaeoshore line. The study reveals that palynofacies Unit-III was deposited nearer to the palaeoshoreline and palynofacies Unit-I was deposited on the seaward side of the palynofacies Unit-III and it is followed by palynofacies Unit-II.

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SEA SURFACE TEMPERATURE CHANGES IN THE EASTERN ARABIAN SEA

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Cooling or heating of the Arabian Sea plays an important role in the initiation of summer monsoon in the Asian Continent, therefore, sea surface temperature (SST) changes and associated evaporation and precipitation are strongly coupled in the Arabian Sea. Thus, a strong link exists between ocean dynamics and the atmospheric heat and moisture transfer that are critical to the strength of the monsoon. In this context, SST change of eastern Arabian Sea was reconstructed by using Magnesium/ Calcium ratios in a planktonic foraminifera species *Globigerinoides ruber.* About 4.5^0C temperature change is noticed over last 67,000 years in the eastern Arabian Sea, the minimum SST of 24.5^0C during last glacial and a maximum of 29^0C during the Holocene is documented. Strikingly during Marine Isotope Stage (MIS) 4 higher SSTs are noticed as compared to MIS 3. Similarly, the δ^{18}Osw also shows higher values during MIS 4 than the MIS3, therefore, higher SST during MIS 4 would be caused by the higher evaporation in the eastern Arabian Sea in association with less precipitation which results in higher δ^{18}Osw along the eastern Arabian Sea. The δ^{18}O record as well as SST data shows that deglacial warming was initiated around 18 cal Ka BP in the eastern Arabian Sea.

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BENTHONIC FORAMINIFERAL PROXIES TO INTERPRET DYSOXIC DEEP WATER PALAEOENVIRONMENT: EXAMPLE FROM MIOCENE SEDIMENTS OF OFFSHORE KRISHNA-GODAVARI BASIN AND ITS SIGNIFICANCE IN DEEPWATER EXPLORATORY TARGETS.

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The palaeoenvironmental reconstruction of outer shelf and slope assumes greater significance as the emphasis is now shifted to deeper water exploratory targets. Benthonic foraminifera are known to inhabit oxygen-depleted environment and provide valuable information to infer productivity, marine palaeo-oxygen conditions and water depth. Hence, these serve effectively as palaeoenvironmental proxies in dysoxic deeper water sites and help to identify petroleum source. The deposition of Mio-Pliocene Ravva Formation in the deeper offshore waters in Krishna-Godavari Basin, Bay of Bengal has taken place mostly under oxygen minimum dysoxic bottom waters. The report of deepwater alveolar agglutinated species such as *Alveovalvulinella pozonensis, Alveovalvulina suteri* and *Guppyella miocenica* besides representatives of *Cyclammina, Alveophragmium, Reticulophragmium, Karreriella, Pavonitina* and *Karrerulina* and in addition several low oxygen indicator microfossils of *Bolivina/ Uvigerina* assemblage is a pointer towards this. A change from well ventilated bottom waters to oxygen depleted bottom waters is evident during the deposition of over bank fines and meandering channel levee sediments of Ravva Formation.

Several Miocene deepwater benthonics chiefly agglutinated species indicating dysoxic marine bottom water conditions from offshore Krishna-Godavari Basin have been recorded. Most of these forms are also reported from offshore Louisiana (Gulf of Mexico), offshore Caribbean Islands, Gabon, Cabinda, Angloa, offshore Western African basins and offshore Venezuela. Deepwater agglutinate - predominant benthonics are the only autochthonous microfossils sufficiently present at many of these sites for palaeoenvironmental studies in the producing section. Slope fa ilures are common in these basins and mixing of contrasting depth habitat faunal elements is often recorded. A detailed comparative foraminiferal analysis of these deepwater basins is presented. All these basins are proven rich hydrocarbon reserves in the Neogene. A successful deepwater exploratory target warrants a cohesive integrated study on the deepwater benthonic

foraminiferal species along with sedimentological and geophysical aspects. In the absence of conventional cores and only ambiguous seismic signatures and wire line log motifs, the study of microfossils assumes a greater significance for inferring the depositional setting of the target.

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CRETACEOUS FORAMINIFERAL BIOSTRATIGRAPHY OF THE CAUVERY BASIN, SOUTH INDIA – A SYNTHESIS

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The Cauvery Basin on the east coast of India is known widely for its Cretaceous outcrops, seen as disconnected patches, bordering the basement along the western margin of the basin. Mega and microfaunal remains from the exposed Cretaceous sequences are well known. Intense exploratory drilling for hydrocarbon in the basin both in the onland and in the offshore waters of Bay of Bengal has provided significant information on the foraminferal distribution in the subsurface sedimentary pile across the basin.

An integrated Cretaceous foraminferal framework is presented based on detailed study of both well-cuttings and conventional core samples from several deep exploratory wells drilled in the basin in addition to samples from the exposed sections. Foraminferal assemblages consisting of 120 planktonic and 215 benthonic species belonging to 107 genera ranging in age from Albian to Maastrichtian are documented. The presence of moderately abundant and diversified foraminiferal assemblage has been recognized in the down dip subsurface sequence of the basin due to favourable facies and environmental changes in the Coniacian to Late Maastrichtian interval. This is in contrast to that of impoverished and less diversified foraminiferal record in the exposed Coniacian - Santonian sequences. A moderate increase in the foraminiferal and diversity is observed in the exposed sediments from post Santonian age. Some commonly occurring species of this basin with observed stratigraphic ranges are presented. Some of the less known species from this basin including two species and 1 genus are described as new. Seventeen biostratigraphic zones are recognized for interbasinal and regional correlation. Application of this improved foraminiferal framework has helped to recognize certain bio events as chronostratigraphic horizons within the basin.

The composition, distribution and preservation of Cretaceous foraminiferal assemblages suggest considerable fluctuations in the palaeobathymetry during sedimentation in the different parts of the basin. This is evidenced in the foraminiferal assemblages in which agglutinated and resistant calcareous smaller benthonics predominates during highstands and by of calcareous benthonic/ plantonic assemblages dominating during low stands. A detailed analysis integrating chronologic, lithostratigraphic

and biostratigraphic data and local tectonics suggest that vertical movements due to reactivation of basement faults in different sub-basins came to a standstill at the close of Santonian and the basin nearly attained stability during Campanian- Maastrichtian. palaeoceanographic and palaeoclimatic changes in the Cretaceous are briefly dealt by analysing the faunal diversity and morphotypes of foraminferal assemblages.

Conditions that are thought to favour the development of agglutinate – dominated assemblages in the faunal succession at certain stratigraphic levels in the Cretaceous include sedimentation at greater depths in outer neritic/ upper bathyal environments and reduced oxygen concentration at the sea floor. The development of Corg rich dark grey/ black shales in the deeper parts of the basin in Albian had been correlated to Global anoxic OAE 1b, 1d events. These sections seem to be the primary source for generating hydrocarbon in the basin.

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PALYNOSTRATIGRAPHY AND DEPOSITIONAL ENVIRONMENT OF CAMBAY AND OLPAD FORMATIONS IN NAWAGAM - ASMALI AREA, CAMBAY BASIN, INDIA

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The area of the present study falls in the Ahmedabad Block of Cambay Basin. Recent discoveries of hydrocarbon in this block hold promise for exploration of pay sands of Olpad and Cambay formations. The wells have been drilled to explore the hydrocarbon prospects of Deccan Trap, Olpad and Cambay formations. The longitudinal and transverse fault blocks at these levels and the pinch out termination of Eocene sands are the probable locales of hydrocarbon entrapment.

Palynological studies have been carried out on the subsurface samples of Olpad and Cambay formations from Nawagam, Naika, Mahelaj, Dholka and Asmali fields to bring out the palynostratigraphy and palaeodepositional environment for future exploration leads. The detailed studies enabled mapping of the variations in palynofloral contents and demarcating the age boundary between Palaeocene/ Early Eocene. The palynofloral assemblage is dominated by angiospermous pollen, pteridophytic spores and marine phytoplanktons. The palynofloral yield in general is moderate. The stratigraphic ranges, appearance and disappearance levels of various marker taxa have been used for dating and correlation of the sediments in different wells.

Two palynozones have been recognized in all the studied wells. Palynozone-I corresponds to Palaeocene age while Palynozone-II to Early Eocene in age. The palynofloral assemblage recorded belongs to eight floral ecological complexes. These complexes are inland, freshwater, fern, fungal, palm, low salinity water plant complex, mangrove and marine phytoplankton. The subsurface sedimentary sequence from the base of Kalol Formation up to the top of the Trap has been studied to decipher the palaeoenvironment at micro-level. The palynofloral association suggests that the Olpad Formation was deposited mainly under subtidal environment, while Cambay Formation was deposited under subtidal to inner shelf conditions.

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A RARE OCCURRENCE OF DINOFLAGELLATE AND MARINE FILAMENTOUS ALGAE IN A PALM PEDUNCLE RECOVERED FROM THE OFFSHORE SEDIMENTS OF GOGHA, NEAR BHAVNAGAR, GUJARAT

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While collecting plant fossils from the coastal region of Bhavnagar, the author collected two buried woods/woody samples at a depth of about 6m from the surface, off Gogha coast (Lat. 21Ë%37'N: Long. 72Ë%22'E), Gujarat. The samples were collected when the sea bed was exposed during low tide slightly north of Gogha Light House. They were found buried in the mud and due to burial the samples acquired dark colour. The sediments seem to be Sub-Recent to Recent in age.

On examining the material, it was found that the woody material represents a palm peduncle. Palms are the most common arboreal elements of coastal vegetation in the tropics. The most significant features observed in sections of the woody material are that the palm material has been invaded by marine filamentous algae and dinoflagellates. This may be the first record of invasion of terrestrial plant tissues by dinoflagellates.

The invasion of palm material by marine micro-organisms indicates that either the sea has extended towards the coast or the material has been transported towards the sea. A detailed survey of the area can throw light on the changes in shoreline during Sub-Recent to Recent times.

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PALYNOSTRATIGRAPHY AND DEPOSITIONAL ENVIRONMENT OF KADI FORMATION IN NORTH KADI STRUCTURE, MEHSANA BLOCK, CAMBAY BASIN

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North Kadi structure is the southward extension of Mehsana Horst in the northern part of Ahmedabad-Mehsana Block. The North Kadi field is a multipay producer from the Kadi and Kalol formations. The North Kadi field is bounded by the Mehsana Horst towards north, Linch field towards east and Jotana Field towards north-east. In the area between Jotana and North Kadi fields lies the Jakasana low, which was the site of additional sediment deposition. The rising flanks and highs, adjoining this low, form excellent targets for exploration of hydrocarbon.

The present paper attempts to bring out the palynostratigraphy of different members of the Kalol/ Kadi Formation, on the basis of their palynofloral contents, their distribution both vertically and laterally and also infer the depositional environments for constructing depositional model for hydrocarbon exploration. The palynological assemblages recorded from the subsurface samples of the various wells of the study area consist of variety of spores, pollen and dinoflagellate cysts. The palynotaxa are represented dominantly by angiosperms, pteridophytes and phytoplankton. The palynofloral assemblage recorded from the Kadi Formation is suggestive of an Early Eocene age. The upper part of Kadi Formation is Middle Eocene in age in the southern part of North Kadi field. Towards the northern and north western part of North Kadi field, lower part of Kalol Formation is Early Eocene in age. But wherever the Kalol/ Kadi formations are undifferentiated, the Early Eocene top has been marked by the first downhole appearance of *Pellicieroipollis langenheimii* and *Striacolporites striatus* palynotaxa.

Palynofloras recorded from different wells have been grouped under nine floral ecological complexes. These include montane, inland, fresh water, fungal, palm, low salinity plants, mangrove and marine phytoplankton complexes. The variations in the percentage of the floral ecological complexes have been considered to infer the depositional environment. The palynofloral evidences suggest that the Mandhali Member was deposited under littoral environment. The depositional environment of Mehsana Member varies from subtidal to intertidal in the southern part of the North Kadi field while supratidal environment prevailed in the northern part. The undifferentiated Kalol/ Kadi formation appears to have been deposited under supratidal to subtidal conditions.

ICMS - 35 **Key Note**

EVOLUTION OF THE INDIAN MONSOON SYSTEM DURING THE NEOGENE: PRESENT STATUS AND UNRESOLVED ISSUES

NOTES

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The Indian monsoon, also known as the South Asian monsoon, is a large scale feature of the climate system affecting the most densely-populated parts of the Asian and African continents. Monsoon plays an important role in global hydrological and carbon cycles. Across the region, the effects of the monsoon are preserved in different proxies that include tree rings, soils, ice, lake deposits, peat deposits, cave deposits and marine sediments.

The Indian summer monsoon affects climate and societies over a large part of Asia between 35^{o}N and 10^{o}S. The monsoon is the lifeline to the people of Asia as region's food production and water supply are largely dependent on the summer monsoon rains. Thus the Indian monsoon constitutes a critical resource for the region's largely agrarian economies. A good monsoon means a booming Asia whereas a failed or an over intensified monsoon will cause misery to the large component of the region's population. Considerable efforts have been made toward high resolution (high density sampling of the marine cores) reconstruction of proxy records of monsoon that have helped in the understanding of monsoon evolution, its variability over various time scales, and forcing factors that drive the monsoon on orbital and sub-orbital time scales. However, there are still unresolved questions as to the timing of the advent of the modern monsoon and driving mechanisms of monsoon variability. The elevated heat source of the Himalayas and the Tibetan Plateau is of vital importance for the establishment and maintenance of the Indian summer monsoon circulation through mechanical and thermal factors. But there are different propositions about the attainment of the critical elevation by the Himalayas and the Tibetan Plateau to drive the Indian monsoon, ranging from 35 to 7.5 Ma (Table 1). While the marine records indicate a major shift in the monsoon system between 9 and 8 Ma, the continental records suggest a range from 22 to 7.5 Ma during which time the monsoon may have evolved. The model studies, on the other hand, put the origin farther back in time at ~ 35 Ma. Numerous recent studies have shown that monsoon has varied at orbital (eccentricity, obliquity and precession) and sub-orbital (centennial to millennial) time scales. The centennial to millennial scale changes in the monsoon have been linked to both the internal (linked to North Atlantic

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Oscillation, ENSO, etc.) and external (solar) forcings, but mechanistic links of monsoon variability to these forcing factors require further studies. Thus to resolve these issues, a coordinated effort is required to analyze high resolution records from marine cores from high sedimentation areas of the Arabian Sea and the Bay of Bengal as well as continental records of continuity.

Table 1. Evidence and timing of the Himalayan uplift and monsoon intensification

Source	Type of evidence	Event	Timing (Ma)
Rowley and Currie 2006	Oxygen isotope	Tibetan Plateau	35
Ramstein et al. 1997	Modeling	Monsoons and Paratethys retreat	~30
Guo et al. 2002	China loess deposits	Monsoon climate	22
Wang 1990	Sediments in China	Monsoons	20
Clift and Gaedicke 2002	Indus Fan sediments	Erosion and weathering	~16
Clift et al. 2002	South China Sea smectite mineral	Precipitation and monsoons	~15.5
Spicer et al. 2003	Fossil flora	Himalayan elevation and monsoons	>15
Coleman and Hodges 1995	Tectonics	Himalayan elevation	>14
Blisniuk et al. 2001	Tectonics	Himalayan uplift and monsoons	>14
Chen et al. 2003	Oceanic microfossils	Monsoons and upwelling	12–11
Dettman et al. 2001	Isotopes and land	Monsoons	~10.7
An et al. 2001	Land and marine sediments	Uplift and onset of monsoons	9–8
Kroon et al. 1991	Oceanic microfossils	Monsoons and upwelling	8.6
Filipelli 1997	Weathering and sediments	Monsoons	~8
Quade et al. 1989	Isotopes and flora	Monsoons	8–7.6

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MODERN POLLEN DEPOSITION IN SUBTROPICAL-TEMPERATE ZONES OF KUMAUN HIMALAYA BASED ON POLLEN ANALYTICAL RECONNAISSANCE OF LIVERWORTS

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The knowledge of modern pollen deposition is a pre-requisite to assess past vegetation and climate, particularly of Quaternary. Liverworts (leafy and thalloid) collected from different places (situated at different elevations, ranging from subtropical to temperate zones) in Kumaun Himalaya have been pollen analyzed. The recovered palynoassemblages contains pollen of a large number of arboreals and nonarboreals.

Among arboreals *Pinus* and *Quercus* are chief elements. *Pinus* dominantly occurs throughout whereas *Quercus* shows high values in temperate zone. The *Quercus* represents the nearby flora while *Pinus* also shows drifted presence from neighboring areas due to long distance transportation of pollen. Other arboreals such as *Alnus, Carpinus, Ulmus, Betula, Juglans, Celtis, Corylus* and Myrtaceae, etc., encountered in varied low values, reflect the mixed nature of forest. Nonarboreals exhibit predominance of Poaceae followed by Cyperaceae. Cheno/ Ams, Caryophyllaceae, Ranunculaceae, Brassicaceae, Urticaceae, Polygonaceae, Tubuliflorae, Liguliflorae, Malvaceae, Apiaceae, etc. are represented sporadically. Presence of culture taxa indicates human activities in the region. Pteridophytic and bryophytic spores are well represented reflecting their local source. Beside spores, the sporelings and elaters are also encountered and their percentage frequency is reduced in the samples collected from outskirts indicating their restricted distribution. Aquatic vegetation is poorly represented by *Typha* and *Potamogeton*, etc. Fungal remains are well represented in subtropical zone than in temperate zone. Certain taxa (*Rhododendron, Salix, Aesculus, Myrica*, etc.) fail to express their actual representation in the spectra, possibly due to their entomophilous nature. Paucity of pollen of different taxa may also be the result of biodeterioration (often caused by fungi), poor production of pollen/ differential preservation, etc. Besides, there is interplay of pollen from one regime to another. In spite of considerable disturbances that certain taxa exhibit pseudo-presence, certain others fail to express their actual representation in vegetation, and certain show interplay of pollen. The samples from different localities contain characteristic elements, thus broadly reflect existing vegetation, i.e. chir pine forest, oak forest, and admixture of two with diversified AP/ NAP ratio.

Thus, liverworts are useful for the pollen analytical investigations like those of conventional sources. Data generated from leafy as well as thalloid forms provide basic criterion for the pollen analytical investigations of sedimentary profiles to reconstruct the palaeovegetation and decipher past climate.

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SEDIMENT CHARACTERISTICS AND DISTRIBUTION OF OSTRACODA IN THE ENNORE CREEK, CHENNAI, TAMIL NADU

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Ostracods have been successful inhabitants of every aquatic environment from deep oceans to brackish water lagoons, estuaries and even in freshwater streams, lakes, etc. Chennai is a metropolitan city with a high density of population and industrialization. Major and small-scale industries located in the northern part of Chennai are expected to contribute stress on the study area and also contribute to the level of heavy metal pollution. Along Ennore-Tiruvottiyur industrial belt, thermal power station, petrochemical and metallurgical industries use coal as fuel in huge quantities. Coal slurry is being dumped directly into the coast and estuary through pipelines and also through canals and natural waterways, causing total degradation of the fragile estuarine/ creek and marine environment. For the first time a study on the systematics and distribution of Recent Ostracoda from the Ennore creek, north of Chennai, Tamil Nadu has been carried out, particularly in view of the insufficient information on these tiny organisms from the marginal marine environs along the east coast and also to understand environmental pollution.

In the creek, twenty sediment samples were collected during February 2006 (Lat. 13°12’52"-13°14’53"N and Long. 80°18’32"-80°19’50E). Ostracod fauna were retrieved from all the sediment samples. A total of 29 species belonging to 23 genera, 15 families, 2 superfamilies and 2 suborders of the order Podocopida, have been identified and described with SEM photomicrographs. Out of 29 species reported, *Basslerites liebaui, Jankeijcythere mckenziei, Kalingella mckenziei, Neomonoceratina jaini* are endemic to Indian waters only. Some ostracod species, characteristic of brackish water, such as *Cyprideis* cf. *mandviensis, Jankeijcythere mckenziei, Kalingella mckenziei* and *Neosinocythere dekrooni* occur in the creek. Freshwater species like *Cyprinotus salinus* occur in the outer creek region, i.e. towards riverine side. The colour of the ostracod carapaces and valves is pale yellow to white and preservation is good. This shows the creek is not fully polluted. Overall, the recorded ostracod assemblage is strongly of tropical, shallow and brackish water habitat in nature.

Various sedimentological parameters such as organic matter, $CaCO_3$ and sand-silt-clay have been measured and correlated with the observed ostracod population. It is attributed to higher values of organic matter in the creek. Calcium carbonate content is generally found to be low in the

creek. The sand-silt-clay ratios were estimated and the following four sediment types are recognized: Silty sand, sand, sandysilt and silt. Fine grained substrate, such as silt, sandy silt and silty sand are found to be the most accommodative sediment types for the fauna in the creek. An account on the carapace-valve ratio indicates a faster rate of sedimentation in the Ennore creek. An attempt on the sediment texture and surface sculpture of the carapace infers that the smooth, less ornamented and feebly calcified carapaces reflect the fine grained nature of the sediment.

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PALYNOSTRATIGRAPHY OF THE ATHGARH FORMATION IN MAHANADI BASIN, ORISSA

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A rich and diversified palynoflora has been recovered from the Athgarh Formation exposed in fire clay mines of M/s Tata Refratories Limited in Talbast area of Orissa. The assemblage is dominated by *Murospora.* The presence of *Impardecispora apiverrucata, I. purverulentus, Cibotidites* sp., *Aequitriradites spinulosus,? Cooksonites* sp., in association with *Cyathidites australis, C. concavus, Concavissimisporites variverrucatus, Klukisporites variegatus, Ischyosporites crateris, Callialasporites segmentatus, C. dampieri, C. trilobatus, C. turbatus, Cerebropollenites* sp., indicates a definite Early Cretaceous (pre-Aptian) age for the palynological assemblage from Talbast. A lot of morphological variations have been noticed in the genus *Murospora*. Morphological variations have also been noticed in *Impardecispora, Klukisporites, Ischyosporites,* etc. Several tetrads have been encountered which have been placed in *Deltoidospora, Biretisporites* and *Klukisporites.*

In addition to Talbast palynoflora, the other known palynological assemblages from Athgarh Formation have also been dealt here. The study reveals the occurrence of *Araucariacites*-rich palynological assemblage in Jagannnath Prasad Quarry (JPQ) and Sidheshwar Hill and *Murospora*-rich assemblage from Talbast area. Of these three, the richest palynoassemblage is from Sidheshwar Hill containing Early Cretaceous (pre-Aptian) indicating associaton of taxa, viz. *Impardecispora apiverrucata, Cicatricosisporites ludbrookii, Klukisporites scaberis* and *Ischyosporites crateris.* The *Murospora florida*-rich palynoassemblage from Talbast is found in association with Early Cretaceous age indicating association of taxa, viz. *Impardecispora apiverrucata, Klukisporites scaberis, Ischyosporites crateris, Aequitriradites spinulosus* and *?Cooksonites*. The palynoassemblage from JPQ is devoid of any such forms. So the oldest assemblage is from JPQ and probably the youngest one is from Talbast. Comparison has also been made with global Late Jurassic and Early Cretaceous palynofloras.

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CORALLINE ALGAL ASSEMBLAGES IN THE OLIGOCENE OF KUTCH, GUJARAT, WESTERN INDIA

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The present paper examines the coralline algal assemblages of the Oligocene successions of Kutch, western India to explore possibilities of their use in palaeoenvironmental interpretation. The coralline algae are facies dependent and in Kutch their distribution appears to be controlled by lithofacies characteristics. The Oligocene sequences of Kutch can be conveniently divided into a lower carbonate-dominated Ramanian stage (lower Oligocene) characterized by dominance of mastophoroids which occur in association with nummulites and corals, and an upper mixed carbonate-siliciclastic Waiorian stage (upper Oligocene) showing presence in large numbers of melobesioids, infaunal echinoids, *Heterostegina*, *Spiroclypeus, Miogypsinoides,* etc. Mastophoroids along with the associated biota of the Ramanian stage are indicative of patch reefal environment (shallow ramp build-up), while melobesioids in association with *Spiroclypeus* of the Waiorian stage mark deposition in a relatively deeper ramp environment. The observed distribution of the corallines in the study area is consistent with general distribution and diversity patterns of melobesioids and mastophoroids in the Palaeogene. The mastophoroid-dominated corallines and the associated coral assemblage correspond to a general trend of increased diversity of mastophoroids and corals in the warmer early Oligocene, whereas the melobesioid-dominated assemblage along with the co-occurring *Spiroclypeus* represents the acme of melobesioids in the late Oligocene when relatively lower temperatures prevailed.

This differentiation of algal and faunal distribution is attributed to a change in depositional regime due to fluctuating climate, sea-level and terrigenous clastic input. The composition of the corallines in the Oligocene succession of Kutch tends to reflect this change.

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PERMIAN TRIASSIC PALYNOFLORAL TRANSITION IN CHINTALAPUDI AREA, GODAVARI GRABEN, ANDHRA PRADESH

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Palynological investigation of bore core MCP-7 from Chintalapudi area, Chintalapudi sub-basin was carried out. Five palynoassemblages demarcated in this bore core MCP-7 from Chintalapudi area essentially fall under two groups. Group1 (Assemblages I, II and III), has dominance of striate disaccates along with presence of some stratigraphically significant taxa and belongs to Late Permian (Raniganj). Group 2 (Assemblages IV and V) shows sharp decline of characteristic taxa of first group, i.e. striate disaccates, and corresponding increase in taeniate and cingulate cavate spores and belongs to Early Triassic (Panchet).

Assemblage I is characterized by dominance of striate disaccates chiefly, *Striatopodocarpites* and *Faunipollenites*, significant presence of *Densipollenites* along with presence of rare but stratigraphically significant taxa, viz. *Strotersporites, Verticipollenites, Guttulapollenites, Hamiapollenites, Falcisporites, Chordasporites, Crescentipollenites, Striomonosaccites, Lunatisporites, Vitreisporites*. Assemblage II is characterized by dominance of striate disaccates chiefly, *Striatopodocarpites* and *Faunipollenites,* significant presence of *Crescentipollenites,* along with presence of rare but stratigraphically significant taxa, viz. *Strotersporites, Verticipollenites, Guttulapollenites, Hamiapollenites, Falcisporites, Vitreisporites, Chordasporites, Striomonosaccites, Lunatisporites, Klausipollenites, Weylandites, Gondisporites*. Assemblage III is characterized by dominance of striate disaccates chiefly, *Striatopodocarpites* and *Faunipollenites,* significant presence of *Guttulapollenites* along with presence of rare but stratigraphically significant taxa, viz. *Klausipollenites, Falcisporites, Lunatisporites, Crescentipollenites, Corisaccites, Weylandites, Strotersporites.* Assemblage IV is characterized by high percentage of taeniate disaccates chiefly *Lunatisporites* while Assemblage V is characterized by cingulate-cavate trilite spores chiefly, *Lundbladispora* and *Densoisporites.* Striate disaccates show a sharp decline in Assemblages VI and V.

Early Triassic palynoflora has been recorded for the first time in Chintalapudi area indicating existence of Panchet sediments in Chintalapudi sub-basin as in Sattupalli area. Presence of Raniganj Formation has already been established based on palynological studies in different areas of

Chintalapudi sub-basin. The study further supports the earlier view that Kamthi Formation represents Early Triassic (=Panchet Formation) and overlie Raniganj equivalents with a gradational contact.

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PALYNOLOGICAL DATING OF COAL BEARING AND ASSOCIATED SEDIMENTS IN SATRAJPALLI AREA, GODAVARI GRABEN, ANDHRA PRADESH

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Palynological investigation of bore core GSP-1 and GSP-9 from Satrajpalli area, Mulug coal belt, Godavari sub-basin has revealed presence of two palynoassemblages, one belonging to Early Permian (Barakar) and the other belonging to Late Permian (Raniganj). Assemblage-I is characterized by dominance of non-striate disaccate *Scheuringipollenites* and subdominance of striate disaccates, viz. *Striatopodocarpites* and *Faunipollenites.* The other taxa recorded include *Platysaccus, Ibisporites, Primuspollenites, Divarisaccus, Parasaccites, Indotriradites, Brevitriletes* and *Horriditriletes.* Assemblage-II is characterized by dominance of striate disaccates chiefly, *Striatopodocarpites* and *Faunipollenites* along with presence of rare but stratigraphically significant taxa, viz. *Strotersporites, Verticipollenites, Corisaccites, Hamiapollenites, Falcisporites, Crescentipollenites, Lunatisporites, Weylandites* and *Lundbladispora* The presence of the Lower Raniganj palynoflora has been demarcated in lithologically designated Barren Measures Formation.

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PRECAMBRIAN-CAMBRIAN BOUNDARY MICROFOSSILS FROM THE SHALI GROUP, INNER CARBONATE BELT, LESSER HIMALAYA, INDIA: ITS CHRONOSTRATIGRAPHIC REVISION AND CORRELATION

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The carbonate sequences all along the Himalayan strike are among the major constituents of the Lesser Himalayan stratigraphy. The chronostratigraphic understanding of these carbonate sequences has been a major problem for over a century, which hindered the right perspective of the Lesser Himalayan tectonostratigraphy.

The Lesser Himalayan carbonate sequences are divided into two belts: the Outer Carbonate Belt (OCB) - the Krol Belt, and the Inner Carbonate Belt (ICB) - Jammu-Shali-Tejam-Nawakot-Buxa Belt. The age revision of the Krol Belt succession (OCB) in 1980s that brought the age of the succession from Mesozoic to Vendian-Early Cambrian also brought this succession chronostratigraphically relatively much closer to the ICB. The latter succession (ICB) has been held for several decades as of Meso-Neoproterozoic (Riphean) age mainly based on the stromatolite biostratigraphy. However, the recent discovery of Precambrian-Cambrian boundary protoconodonts from the Gangolihat Dolomite (Tejam Group) of ICB (Azmi and Paul 2004 Current Science 86(12): 1653-1660) has pointed out that the Tejam and Krol belts carbonates are unequivocally of the same age (Vendian-Early Cambrian). To test this view, we extended the search for the Precambrian-Cambrian boundary microfossils in the Shali Belt (ICB) of the Himachal Inner Lesser Himalaya. A large assemblage of Precambrian-Cambrian microfossils from the Shali Group that comprises small shelly fossils, sponge spicules, acanthomorphic acritarchs and calcareous skeletal algae is reported here. A synthesis of the latest biostratigraphic results from the ICB along with a refined correlation scheme of the Lesser Himalaya is presented, which would be useful in understanding the tectonostratigraphic evolution and palinspastic reconstruction of the Lesser Himalayan fold-thrust belt.

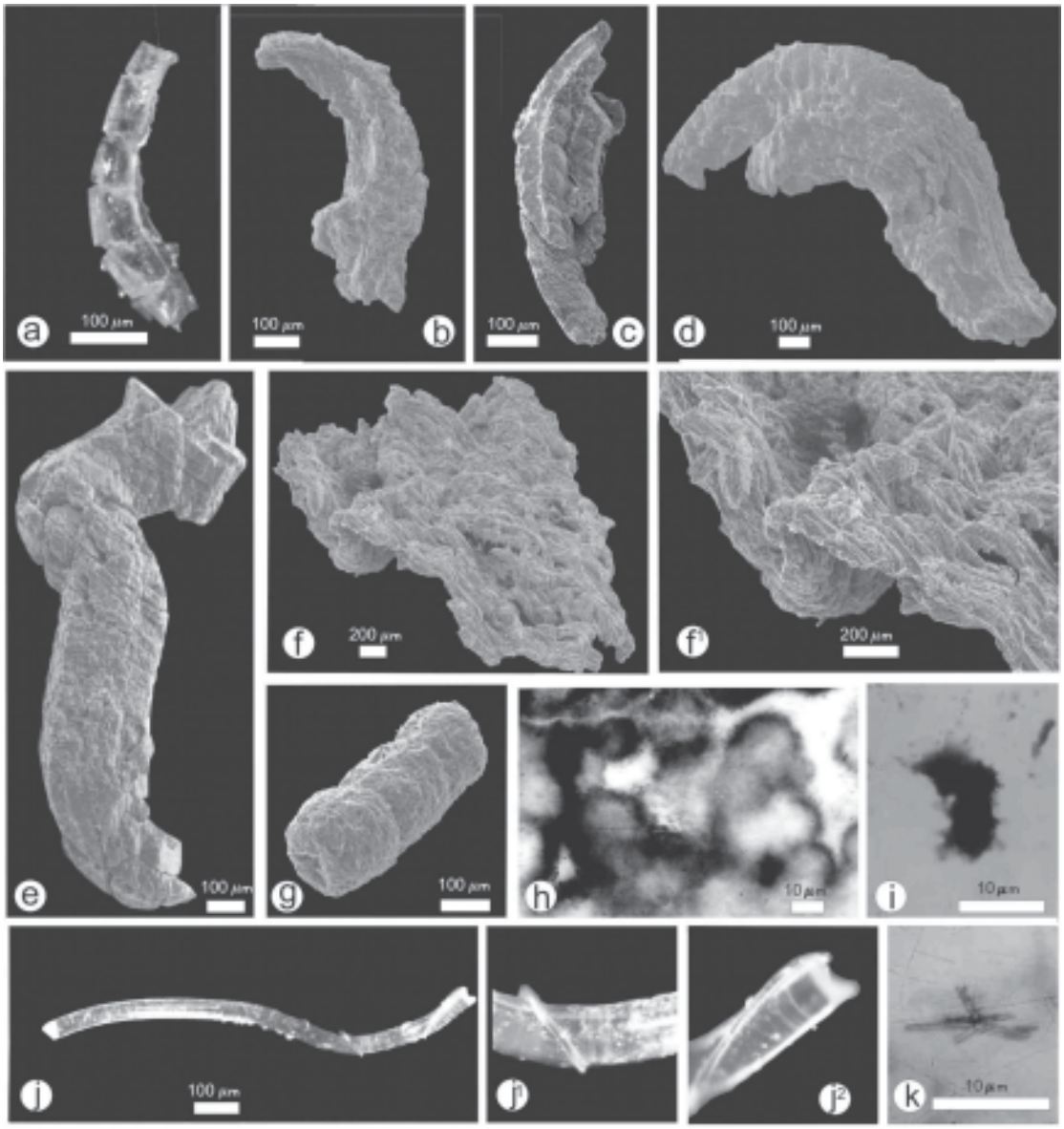

Plate-1 (Joshi and Azmi)

Plate 1. Precambrian-Cambrian boundary interval microfossils from the Shali Group, Himachal Lesser Himalaya. a-e and g, small shelly fossils; f, h and j, calcareous algae; i, small acanthomorphic acritarch; k, sponge spicule.

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TAPHONOMY OF LATE QUATERNARY DEPOSITS IN NARMADA VALLEY, CENTRAL INDIA

NOTES

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In view of the importance of discovery of *Homo erectus* from Narmada valley, Central India, the taphonomical investigations and palaeoecological reconstruction of the Late Pleistocene landscape of the area between Jabalpur and Narsinghpur was undertaken. It seems that the area provided a favourable climate to the animals which had migrated from the northwest because of the harsh climatic conditions during the glacial period of the early Pleistocene.. Micromammalian remains were used for taphonomical investigations. The remains indicate that the fossil assemblage was initially accumulated by a predator and a significant amount of hydraulic sorting was also involved. The fauna on the whole suggests warm climate during the Middle-Late Pleistocene.

For taphonomical investigations, only the rodent bones were studied. The taphonomical history was examined using methods of data collection and analysis designed to elucidate three taphonomical processes, e.g. death and initial accumulation, transport and burial and post-burial alteration. The fossil material was sorted by using degree of completeness of the skeletal elements, position of breaks (proximal or distal), presence or absence of rounded, corroded or abraded surfaces and tooth puncture marks. The resulting data was included in the analysis of initial accumulation and transport and burial processes.

The initial accumulation of the fossil assemblage in the study area was brought about by a predator. The tooth puncture marks, visible on some of the bones strengthen this observation. The breakage pattern of skeletal elements such as the broken articulating ends, intact smaller bones like tarsals and metatarsals, high proportional representation of the limb bones hint at the possibility that the predator was probably a barn owl. Broken epiphyses of some bones in the present collection exhibit corroded surface, betraying the impact of the digestive juices. The proposition that barn owl was the predator responsible for the initial accumulation of the assemblage is strengthened by the fact that bones of such a predator have been reported from Narmada valley from the Pleistocene deposits.

In addition to the contribution of predators to the fossil assemblage, there are indications (e.g. weathered bone surface, weak planes along the length of the bones, irregular fracture planes and fractured incisors) that the bones were sub-aerially exposed for some time before burial. The dissolution cavities are formed when the bones are exposed sub-aerially

for considerable time in hot and humid climatic conditions. Therefore, it is assumed that the dissolution cavities in the Narmada bones were also formed due to sub-aerial exposure. The deposition of iron in the bones suggests that the fossil material remained sub-aerially exposed for a considerable time in the humid climatic conditions.

Another aspect of the taphonomic history is that of transport and burial. The pattern of breakage and abrasion suggests that the fossil assemblage was subjected to a significant amount of hydraulic transport. Almost 33% bones show well rounded ends and 25% show effects of mechanical abrasion in the form of longitudinal striations. Mechanical abrasion is evident in the jaws and the bones. The sediment enclosing the assemblage is also well sorted, further strengthening the proposition that the micromammalian assemblage has been subjected to hydraulic sorting. The presence of post mortem cracks in the incisors indicates the post-burial deformation. The post fossilization breakage of the bone due to digenetic alteration or mechanical stress is quite common. The high incidence of post-burial fracture in the bones suggests that they may have been weakened by digestive processes before burial.

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LATE MIDDLE MIOCENE CRICETIDAE AND ALLIED RODENTS FROM THE SIWALIK SEQUENCE NEAR KOTLA, KANGRA DISTRICT, HIMACHAL PRADESH

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Cricetid rodents characterize the smaller mammals of the Siwalik Group horizons older than ~9 Ma. Record of cricetid and allied rodents, through screen washing, is from Lower-Middle Siwalik transitional beds exposed near Bharil village near Kotla. The area is known to local amateur fossil collectors for sporadic larger fossils. Through our sustained efforts, we now have a diversified vertebrate assemblage from the area comprising lower vertebrates (fish, amphibians and reptiles), smaller and larger mammals besides charophytes, fossil seeds, ostracods, and gastropods. Micro-mammalian remains of the assemblage largely belong to Rodentia. The >11 Ma old rodent assemblage, though dominated by the Cricetidae, has murids, ctenodactylids and sciurid (sans rhizomyids) as allied taxa.

Size-wise microscopic isolated molars and incisors represent entire Rodentia including Cricetidae in the local fauna. The cricetid rodents are diversified, being represented by all four lineages, and well represented. The minute cricetid molars led to identification of genera/ species that are described and evaluated for their biochronologic potential in refining late middle Miocene age range of the local fauna; cricetid taxa thus identified comprise *Megacricetodon mythikos. Myocricetodon sivalensis, Dakkamyoides perplexus, D. lavocati, Dakkamys barryi, Punjabemys downsi, Paradakkamys chinjiensis Democricetodon kohatensis* and *Democricetodon* cf. *kohatensis*

Cricetid record from Siwalik Group of Indian subcontinent complements their northern Asia and Europe record to provide a narrative of Cenozoic evolution of this stem group of muroid clade. Noticeable fact in this regard is that earliest unanimously accepted cricetid record is from Eocene of China[2] where this family was retreated recording their post 9 Ma evolution after giving rise to Muridae in the Siwalik basin. Mmurids presumably out competed and drove them out of the habitat.

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OCCURRENCE OF DEVONIAN MICROFOSSILS FROM EASTERN KARAKORAM AND THEIR IMPACT ON PALAEOBIOGEOGRAPHY

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Eastern Karakoram in northwest India occupies an intermediate position, among various small blocks, between the Indian and Eurasian plates. Biostratigraphic studies in this area are still in their infancy as this is visited by very few palaeontologists due to its difficult approach. Hence sketchy biostratigraphic studies have so far been made in this area. During the course of recent biostratigraphic work in the eastern Karakoram the author recorded certain fossil assemblages which were hitherto unknown to this region. These fossils are crucial in understanding biotic events which took place in the region during Devonian Period. Stratigraphic units exposed in the region comprise Saser Brangsa, Aq Tash, Chhongtash, Morgo, Burtsa (marine) and Qazil Langher (fresh water) formations, in ascending order. The biostratigraphic investigations carried out in the area have shown that the lowermost lithounits, i.e. Saser Brangsa and Aq Tash formations, are rich in fossils of Devonian age. The fossil assemblages recovered from these lithounits are represented by *Cribrosphaeroides* sp., *Pachythurammina* sp., *Irregularina lobata?, Neoarchaesphaera* sp., *Elenella* sp. and *?Biorbis* sp. from the upper part of Saser Brangsa Formation indicating Early-?Late Devonian age for this part. The overlying Aq Tash Formation has yielded *Neoarchaesphaera magna, Arakaevella arakaica, Arakaevella* s p. *Uralinella bicamirata, Marginara cordata, Marginara* sp., *Diplosphaerina inaequalis, Parastegnammina fustisaeformis, P. operturata, Elenella corpullata, Sogdianina angulata, Sogdianina* sp. and *Uslonia* sp. (forams) and *Drepnodus* sp., *Oneotodus* sp. and other unidentifiable conodonts. This faunal assemblage indicates Middle-Late Devonian age to the Aq Tash Formation. These taxa are comparable with similar forms recorded from Europe and some parts of USSR. These lithounits were considered to be of Carboniferous (Saser Brangsa) and Early/Late Permian (Aq Tash) age by the earlier workers. The fossil assemblage recorded here is important from the viewpoint of palaeobiogeographic history of the region during Devonian Period.

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OSTRACOD DISTRIBUTION IN THE SEDIMENTS OF MULLIPALLAM CREEK (MUTHUPET AREA), VEDARANYAM WETLAND, TAMIL NADU

NOTES

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Ostracods are abundant and diverse group of tiny crustaceans with a long fossil record from Ordovician to Recent. Ostracods possess a dorsally hinged, bivalved carapace (comprising a left and right valve), which is laterally symmetrical and preserves as fossil. Ostracods live in environment in which the controlling factors are temperature, bottom topography, depth, salinity, dissolved oxygen, substrate, food supply and sediment organic matter. However, the major controlling factors governing ostracod distribution in estuarine environments and continental shelf zones are salinity, water temperature and substrate. Coastal zones are very sensitive to environmental changes. Though, India has a long coastline of about 7500 km with various marginal marine water bodies such as creeks, lagoons, estuaries, marshy land and mangroves, the study of Recent ostracoda has received scant attention. Hence, this work on the systematics and distribution of Recent ostracoda from the Mullipallam creek (near Muthupet area), has been carried out. The study area is a mangrove wetland located in the southern-most end of the Cauvery delta in the districts of Thiruvarur and Tanjavur along the coastal zone of Bay of Bengal and Palk Straits.

In the creek, twenty-four sediment samples were collected (Lat. 10°18’13" to 10°20’71"N and Long. 79°30’90" to 79°34’87"E) during July 2006 representing pre-monsoon period. A total of 25 species of ostracod fauna belonging to 19 genera, 11 families, 2 superfamilies and 2 suborders of the order Podocopida, have been identified by referring to standard publications and supplemented with SEM photomicrographs. Few species endemic to Indian waters are recorded. *Neomonoceratina iniqua* is the only species dominant (90% and above) in the entire population. Some taxa recorded in the creek are due to the tidal influence. All the species are well preserved. In general, the recorded ostracod assemblage is strongly of tropical, shallow and brackish water habitat in nature. Sedimentological analysis infers that fine grained substrate such as silt and sandy silt are found to be congenial sediment types for the fauna in the creek. A faster rate of sedimentation is observed in the Mullipallam creek, near Muthupet, based on the study of carapace and valve ratio.

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APPLICATION OF MULTI-MICROFOSSIL FACIES ANALYSIS FOR CHARACTERIZATION OF DEEP WATER SEDIMENTS

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Discovery of commercial hydrocarbons by Reliance Industries Limited in 2004, in the deep waters of the Krishna-Godavari Basin, is the landmark for intensifying exploration of the deep water basins of India, which is presently still in an infant stage. Deep water sedimentation, on the continental slope and neighboring basin floor, is a result of a complex interplay of changes in rates of sediment supply, rate of change of accommodation space and sea level fluctuations. Sediment dispersal on the continental slope and basin floor is through submarine canyon systems, the slope-basin floor channel complexes and the basin floor fans. In addition to these, slides and slumps by slope failure are common mechanisms of sediment transport. Microfossils (foraminifera, nannofossil and palynomorphs) are a ubiquitous component of deep water sediments. Their study provides vital clues for understanding of the processes and events that controlled the sedimentation in the geologic past and also deciphering the environments in which the sediments are finally deposited.

Detailed studies on cuttings and cores for the foraminiferal, nannofossil, palynomorphs and organic plant debris assemblages were undertaken by Reliance in wells drilled in the deep waters of the Krishna-Godavari basin, for providing primary understanding of the chronologic framework and depositional environments of sediments. The sediments analyzed ranged in age from Late Palaeocene to the Pliocene. The present study deals with the characterization of sediments to understand the sub-environments in which they are deposited in a deep water channel system (wells KG-A1, A2, A3, B1 and B2) in one part and analysis of deep water sediments to understand the sequence framework (wells KG-C and D) in the other.

Nannofossils provided the basis for the biostratigraphic framework and identification of key surfaces of condensation and flooding. Foraminifers provided biostratigraphic, palaeobathymetric and palaeoenvironmental information. Palynomorphs and other plant debris provided clues about the palaeoclimatic and provenance controls on the sedimentation. Variations in relative percentages of various classes of foraminifers viz. planktonic, bulluminids, deep water benthics, deep water arenaceous, calcareous benthics, larger and milliolids, in the stratigraphic

section were primarily utilized for division into intervals with uniform microfossil facies having distinct patterns and assemblages.

The boundaries of these intervals were integrated with the geophysical data (wire-line log and seismic), which together helped in identifying key process responsible for deposition of the intervals. Correlation between seismic reflection geometries and attribute maps with the intervals provided inputs for understanding of facies distribution. The main depositional facies identified include slumps/slides, debris flows, turbidity intervals, pelagic deposits, with varying degrees of bottom current activity and condensed sections/ flooding surfaces.

Integration of the microfossil facies with the seismic data lead to the identification of three major sequences in the Pliocene-Pleistocene sediments from the KG-A and B series of wells, while in the wells KG-C and D, eight sequences could be identified ranging in age from Late Palaeocene to Pleistocene.

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RAPID CLIMATIC CHANGES IN THE PALAEOCENE-EARLY EOCENE GREENHOUSE WORLD: CONSEQUENCES IN THE CONTINENTAL SHELF REGIME

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A major climatic perturbation expressed by rapid and extreme warming is globally marked in the deep sea to the continental shelves and terrestrial environments at the Palaeocene-Eocene boundary. As the episode of Palaeocene-Eocene Thermal maximum (PETM) has many parallels with the modern climate crisis, it has attracted a wide range of interest amongst the palaeontologists, geochemists, sedimentologists and earth system modelers. During PETM, sea surface temperature (SST) rose by 5°C in the tropics and as much as 8-10°C at high latitudes, whereas bottom water temperatures increased by 4° to 5°C. The coeval global carbon isotope excursion (CIE) of about –3.0 per mil in the deep sea cores presents the compelling evidence for the greenhouse forcing for the PETM that should have warmed all the latitudes. Records exist for the increase in high latitude temperatures at the sea surface and the bottom waters but the character of tropical SST response to PETM remains poorly defined till date.

It is generally accepted that the climate warming during the PETM was caused by the elevated concentrations of atmospheric greenhouse gases (CO_2 and CH_4). The prolonged global warmth (~ 50-200 Ka) of the PETM was driven primarily by elevated concentrations of atmospheric CO_2. The trigger and the source for massive increase in the greenhouse gases in the earth atmospheric system remain highly debated. Attempts to account for the PETM event include exogenous mechanisms, e.g. impact of a comet, from within the earth, e.g. exhalation of thermogenic methane, or on Earth‘s surface, e.g. dissociation of marine clathrates, oxidation of terrestrial organic carbon and oxidation of organic matter due to uplift of epicontinental seas. It is now increasingly demonstrated that the PETM is not unique, but simply the largest event in a series of hypothermal events in the early Eocene (ca. 55-50 Ma) leading to the Early Eocene climatic Optimum (EECO), ca. 53 to 50 Ma. To explain the PETM and the following multiple hypothermal events, a number of hypotheses ranging from repeated injections of $\delta^{13}C$ depleted carbon from a dynamic source, e.g. dissociation of submarine methane hydrate into ocean atmospheric system in response to orbital pacing to volcanic intrusions have been forwarded.

Biotic response to PETM: The PETM first described from the Southern ocean was later extended to Atlantic, Pacific and the Tethys oceans and the

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palaeosol carbonates. One and a half decades of research on PETM has focused on the causes and the consequences of the global warming. The biotic response to the rapid global warming in the deep sea was first noticed by the record of Benthic Foraminiferal Extinction Event (BFEE) at the onset of CIE associated with a decrease in $CaCO_3$ content in the shallow to deep sea sedimentary record. Oceanic dissolution of CO_2 derived by the oxidation of methane lowered the pH and carbonate ion content of the seawater resulting in the transient shoaling of the lysocline and calcite compensation depth (CCD) by more than 2 km within a few thousand years and caused widespread dissolution of seafloor carbonates. At each of the deep sea sites, the P/E boundary was *characterized* by an abrupt transition from carbonate-rich ooze to a dark clay which graded back into ooze. The BFEE is thought to have been caused by the difficulties in calcification faced by the organisms. Most planktonic species survived and a diversification of planktonic foraminifers is marked by the appearance and occurrence of weakly calcified morphotypes, *Morozovella allisonensis, Acarinina Africana* and *Acarinina sibaiyaensis* generally referred as the Planktonic Foraminiferal Excursion Taxa (PFET) within Zone E1. The duration of Zone E1 coincides with that of CIE at the base of Eocene and the presence of PFET represents lesser carbonate dissolution in surface and shallow waters. Similarly, the Calcareous Nannoplankton Excursion Taxa (CNET), viz. *Discoaster araneus, Rhomboaster cuspis* and *Tribrachatus bramletti* and associated common occurrence of *Coccolithus subpertusus* and *Discoaster* spp. characterize the CIE interval. Increase in discoasters is mainly caused by *D. araneus* which is regarded as malformed and represents transient adaptations to changes in chemical (nutrients, CO_2, pH) and temperature of surface waters during the PETM. The genus Fasciculithus very common in the tropical Pal*a*eocene, suffered a dramatic decline and subsequent extinction probably due to an acidification of the oceans following the course of PETM. The Ostracod response to oceanographic changes during the PETM is largely unknown. A high resolution record from ODP Hole 689, Southern Ocean indicates a brief ecological response and the other from the middle neritic setting in Egypt (Gebel Duwi section) records a faunal turover during PETM accompanied by sea level rise. A globally significant dinoflagellate event marked by the bloom of probably thermophilic and heterophilic genus *Apectodinium* in surface waters during PETM signifies elevated primary productivity associated with increased delivery of terrestrial material to the continental margin. Coastal marine PETM sections in Khasi Hills, Meghalaya located in the tropics record a similar *Apectodinium* acme during CIE and the warm humid climate during PETM.

Focus on Continental Shelf regime: Carbonate deposited in relatively shallow water areas with high sedimentation rates in the continental shelves with significant terrigenous input and little or no dissolution are more likely

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to preserve the complete CIE interval in the expanded P/E sections. One of the key challenges in identifying the source and trigger for PETM is to constrain the rate and magnitude of the CIE which is complicated by the fact that all pelagic P-E boundary sections are truncated or condensed as a consequence of ocean acidification and carbonate dissolution. These sections are characterized by distinct clay layers or low carbonate dissolution horizons. Owing to the high sedimentation rates and high clay content, foraminifer preservation is god in the expanded P/E Tanot well Section in Jaisalmer, Rajasthan northwest India in which PFET marking the PETM are recorded in 8 m thick Zone P5b. In the landward P-E sections in Jaisalmer Basin, morozovellids are rare to absent and *Acarinina africana* and *Acarinina sibaiyaensis* mark the Zone E1 (=P5b) which is related to PETM.

PETM data are currently available from a few continental shelf locations in Arctic Basin, New Jarsey, Tanzania and eastern New Zealand. The continental shelf deposits are continuous across Palaeocene-Eocene transition in India, e.g. Jaisalmer Basin, Rajasthan and Khasi Hills) positioned in the equatorial belt. These regions deserve special attention to investigate the reasons and significance of warmer temperatures during P-E hypothermal events in the continental shelves than projected in climate models and to test the shallow tropical to pole thermal gradient indicated by recent estimates of sea temperatures from PETM to EECO.

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PALYNOSTRATIGRAPHY OF GONDWANA SEDIMENTS FROM TATAPANI-RAMKOLA COALFIELD: IMPLICATIONS IN COAL EXPLORATION

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The Tatapani-Ramkola Coalfield is the western extension of the Damodar-Koel Valley basin and is situated in the Surguja District of Chhattisgarh. It is a composite basin, of which Tatapani Coalfield lies in the northern part and Ramkola Coalfield occupies the southern part. The coalfield is flanked on all sides by Precambrian basement rocks and the Gondwana sequence is represented by the sediments of Talchir, Karharbari, Barakar, Barren Measures, Raniganj, Panchet and Mahadeva formations. The coalfield has been taken up as a thrust area by the Coal Wing, Geological Survey of India for the exploration of coal reserves and has received importance due to the occurrence of good quality coal at relatively shallow depths. The commercially viable coal seams mostly occur within the Barakar Formation and the estimation of reserves is underway through extensive mapping and drilling operations. In this context, the proper identification, depth and extent of the coal bearing horizons is of paramount significance for optimising the drilling operations in the area. As lithological demarcation of the different formations is often deceptive, palynology has been found to be an effective tool for the resolution of the economically important strata.

Detailed palynostratigraphical studies from a number of surface exposures and boreholes have been carried out covering the entire Gondwana sequence. Thirteen palynological zones have been established ranging from Lower Talchir to Lower Panchet formations. Demarcation of inter-formational and time boundaries, with special reference to the Permo-Triassic boundary, has been carried out. The palynological data generated has proved to be of immense help in delimiting the chronological position, lateral extension and correlation of the surface and sub-surface coal bearing horizons.

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BIOTIC ASSEMBLAGES OF CHILKA LAKE AND THEIR ROLE IN PALAEOENVIRONMENTAL INTERPRETATION

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Chilka Lake, the largest open lagoon along the eastern coast of India, is one of the ecologically and socio-economically important wetlands of India covering an area of 1165 km^2 during monsoon and 906 km^2 during summer. As an estuarine lagoon, it supports a unique assemblage of marine, brackish and fresh water flora and fauna. This lake has been chosen as nodal area for palaeoenvironmental researches based on microfossil proxies. Many sediment cores from different salinity regimes of Chilka Lake, dated from 13 Ka BP to recent, have been studied through biotic assemblages in order to reconstruct vegetation development, depositional environment and to infer sea-level changes during late Quaternary. Based on the integration of geological information, radiocarbon data, pollen, dinoflagellate cysts and modern mangrove distribution, the palaeoenvironmental scenario of Chilka Lake has been reconstructed.

Multiple sites within the lake have shown variable patterns of biotic assemblages that are probably caused by differences in microclimate, groundwater setting, hydrologic changes or other aspects of lake. It has been envisaged that climatic interpretation from multiple proxies in an individual lake is also not coherent. These inconsistencies can be resolved with continued development of spatial network of sites to refine the understanding of how organisms and lake respond to and integrate climate variation at a suite of spatial and temporal scales. The monitoring of hydrobiological parameters is needed with an overall objective of enhancing the flow regime and optimising salinity levels for the maintenance of lake's rich biodiversity.

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LATITUDINAL CHANGES IN THE PLANKTIC FORAMINIFERAL SPECIES DISTRIBUTION ALONG A NORTH-SOUTH TRANSECT IN THE SOUTHWESTERN INDIAN OCEAN

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Application of temporal changes in the planktic foraminiferal assemblage (PFA) for palaeoclimatic/ palaeoceanographic reconstruction is based on the observed spatial changes in the planktic foraminiferal assemblage due to changing physico-chemical conditions. Therefore, reliable reconstruction of palaeoclimatic/ palaeoceanographic conditions from PFA requires understanding of changes in PFA in surface sediments of oceans from different parts of the world and correlation of such changes with prevailing physico-chemical conditions. Here we present the changes in the PFA in a set of 26 surface sediment samples collected along a north-south transect from the southwestern Indian Ocean. A total of 33 planktic foraminiferal species were reported. Of these, 14 species (*Hastigerina pelagica, H. digitata, Globigerinoides conglobatus, Sphaeroidinella dehiscens, Orbulina universa, Globorotalia tumida, G. scitula, G. crassaformis, G. hirsuta, G. theyeri, Globigerinella calida, Bolliella adamsi, Globoquadrina conglomerata, Candeina nitida*) are rare (relative abundance <5%). The remaining 19 species (*Globigerinoides ruber, G. sacculifer, G. tenellus, Neogloboquadrina dutertrei, N. pachyderma, N. hexagona, Globigerina bulloides, G. humilis, G. falconensis, G. quinqueloba, G. rubescens, G. glutinata, G. bradyi, Globorotalia menardii, G. truncatulinoides, G. inflata, Globigerinella aequilateralis, Beella digitata, Pulleniatina obliquiloculata*) are abundant (relative abundance >5% at one station). The relative abundance of most of the species shows a significant change at ~40° S latitude, which is apparently the boundary between Subtropical Front (STF) and Sub Antarctic Zone (SAZ). The results of the present study will be useful for reconstructing temporal changes in the latitudinal position of STF and SAZ, if any, from the changes in the PFA.

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OCCURRENCE OF *NEOCYPRIDEIS RAOI*, A BRACKISH WATER OSTRACOD SPECIES IN THE INTERTRAPPEAN BEDS OF JHILMILI, CHHINDWARA DISTRICT, MADHYA PRADESH

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The paper records occurrence of *Neocyprideis raoi*, in fair abundance, from the Intertrappean beds of Jhilmili, Chhindwara district, Madhya Pradesh where it is associated with other non-marine ostracods. This species has been earlier described from the Intertrappean beds of Duddukuru, West Godavari district, Andhra Pradesh, east coast of India. The genus *Neocyprideis* is closely related to the living genus *Cyprideis*, which probably evolved from it. The latter genus inhabits freshwater to hypersaline conditions, but is most abundant in mesohaline salinities and therefore is regarded as the most typical brackish-water ostracod. *Neocyprideis* also occurs predominantly in brackish-water environments. Keen, in 1977, recorded the genus from three brackish-water assemblages, maximum predominance being in assemblage IV of the Upper Eocene beds of Hampshire Basin, U. K. Assemblage IV is taken to represent salinities of 9.0 to 16.5%o. The occurrence of *Neocyprideis* in the Intertrappean beds of Jhilmili indicates a possible marine influence during their deposition.

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EOCENE DINOFLAGELLATE CYSTS FROM GARO HILLS, MEGHALAYA

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Rich and well diversified dinoflagellate cyst assemblage, in association with terrestrial organic matter, of Lower-Middle Eocene (Ypresian-Bartonian) age is recovered from the upper part of Tura Formation and the Siju Limestone Formation exposed at Dilni River Section along Tura Dalu Road near Adugiri, Garo Hills, Meghalaya. The Siju Limestone in the studied section is characteristically much reduced in thickness (~5m) as compared to the Siju Cave Section or the Simsang River Section. Lithologically, the Siju Limestone Formation is represented here by foram rich marls interspersed with ferruginous nodular sandy marl horizons. Significant dinoflagellate cyst taxa recovered are: *Areosphaeridium diktyoplokum, Cordosphaeridium exilimurum, C. fibrospinosum, Damassadinium impages, Diphyes colligerum, D. Spinula, Enneadocysta arcuata, Hemicystodinium* spp., *H. unispinum, Hystrichosphaeridium tubiferum, Lingulodinium machaerophorum, Melitasphaeridium* cf. *M. pseudorecurvatum, Operculodinium major, Polysphaeridium subtile, Turbiosphaera galatea,* and *T. symmetrica.* The assemblage shows a significant variation in dinoflagellate cyst/ organic matter distribution in the vertical column. Low diversity dinoflagellate assemblage (represented mainly by *Cordosphaeridium* and *Glaphyrocysta*), along with high terrestrial organic matter debris, occurring in the upper part of Tura Formation (Ypresian) is replaced by a rich and well diversified dinoflagellate cyst assemblage in the larger foram bearing Siju Limestone Formation (Lutetian-Bartonian), containing several dinoflagellate cyst marker taxa viz. *Areosphaeridium diktyoplokum, Damassadinium impages, Enneadocysta arcuata, Melitasphaeridium* sp. cf. *M. pseudorecurvatum,* and *Turbiosphaera symmetrica*. Palynofloral distribution in the upper part of Tura Formation shows dominance of more diversified deciduous coastal forest elements represented by *Lanagiopollis, Tricolporopilites, Margocolporites,* and *Paleocesalpiniaceaepites*. The variation in dinoflagellate cyst/ palynofacies distribution pattern is indicative of a sudden change from marginal/ coastal marine conditions to more stabilized, shallow inner shelf normal marine depositional environment.

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A NEW SPECIES OF FOSSIL *MUS* (RODENTIA, MURIDAE) FROM THE INDIAN HIMALAYA: EVOLUTIONARY AND PHYLOGENETIC IMPLICATIONS

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A new species of *Mus* (Rodentia, Mammalia), *Mus dulamensis*, is reported from the Late Pleistocene (ca. 30 Ka BP) fluvio-lacustrine deposits of the Kumaun Himalaya. The fossiliferous horizon, medium-coarse grained sand lenses embedded in the massive carbonaceous mud, is exposed at locality Dulam. *Mus dulamensis* is included in the *booduga* group and is characterized by strongly distorted and moderately elongated M^1 (about 170% of M^2 length) with prominent conules in front of t_2, higher magnitude of stephanodonty (between t_1 and t_4 and between t_3 and t_6), moderately reduced M^3 (about 56% of M^2 length) and stronger connection between the cusps.

There are five major trends in progressive evolution in Murinae molars, (a) interlocking of one molar with the next, (b) lengthening of M^1 and shortening of M^3, (c) lower cusps strongly joined through a broader crest to other cones, (d) bending backwards of the cusps in upper molars and bending forwards of the cusps in lower molars, and (e) degree of stephanodonty. Considering these characters important in progressive evolution, it is clear from Fig. 1 that *M. dulamensis* is highly evolved. Narrowing of upper first molars is also a derived character which can be observed in the position of the t_1 in the first chevron. Fig. 1 demonstrates that the distance between the posterior ends of t_1 and t_3 in the upper molars is reduced from older to younger forms. If the t_1 is more compressed, the distance between the posterior ends of t_1 and t_3 is increased and this is reflected in narrowing of the molars. Similarly, the bending forward of the cusps in the lower molars is yet another derived character. In the lower molars, the distance between posterior ends of protoconid and metaconid is reduced from the older to younger species (see Fig. 1). This may be taken, in particular, as bending forward of the protoconid.

By comparing measurements, morphological features and all known evolutionary characters, a tentative phylogeny of *Mus*, at least in the Indian subcontinent, can be suggested as *Progonomys debruijni-M. auctor-M. jacobsi-Mus* sp.*-M. dulamensis -M. booduga* (Fig. 1). Thus, *M. dulamensis* n. sp. is comparatively more derived than *M. auctor, M. jacobsi* and *Mus* sp. and it probably gave rise to the species very close to more specialized

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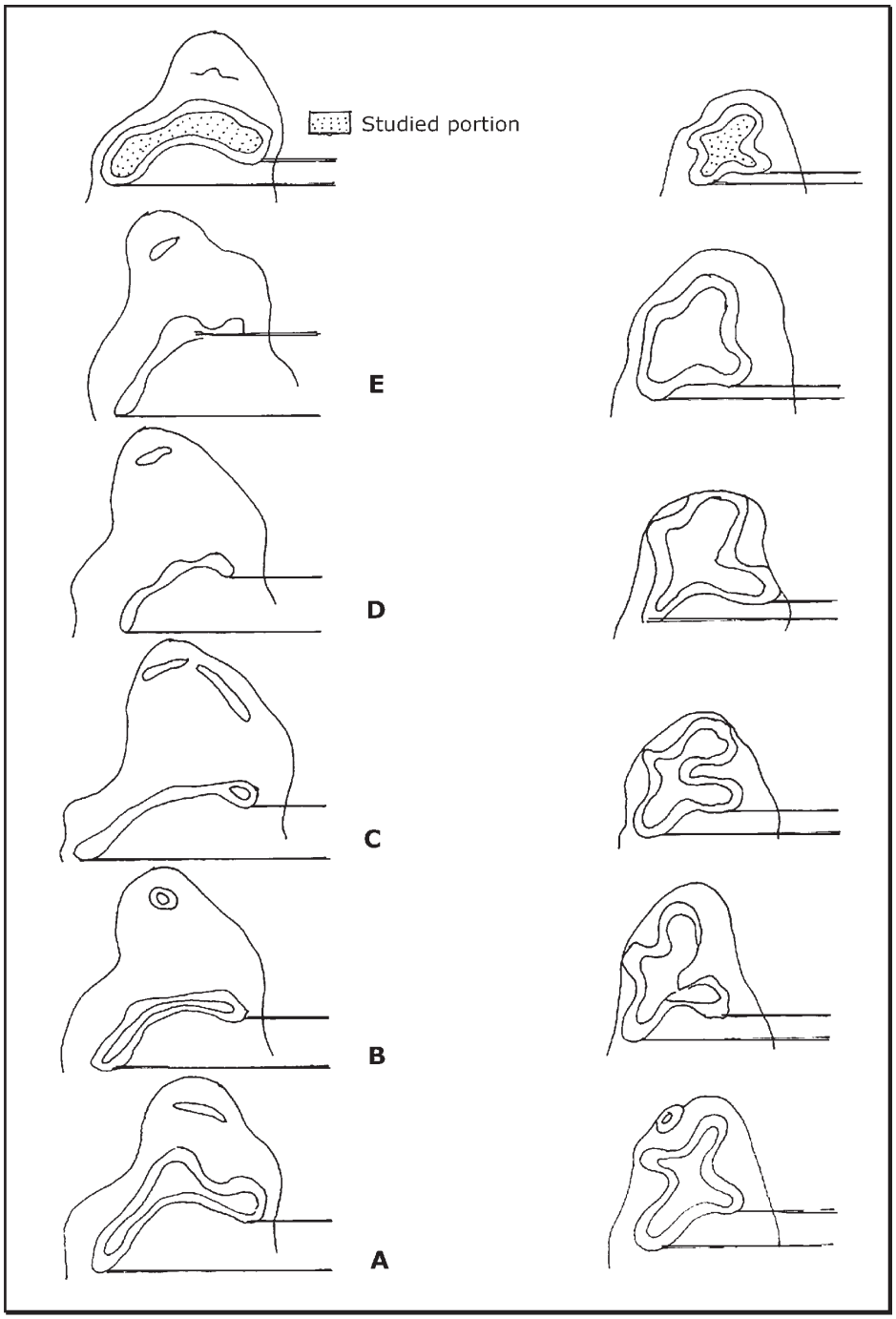

Fig. 1. Narrowing of upper molars and bending forward of lower molars in *Mus* from older to younger species (note the increase in the distance between posterior ends of t1 and t3 in upper molars and decrease between the posterior ends of protoconid and metaconid in lower molars). A. *M. auctor*; B. *M. flynni*; C. M. jacobsi; D. *M. dulamensis* n. sp.; E. *M. Booduga*.

and extant *M. booduga/ M. dunni*. The great diversity of *Mus* in terms of localities and taxa and their ages indicate that the probable place of its origin was the Indian subcontinent and it may have migrated to the African continent during Late Miocene.

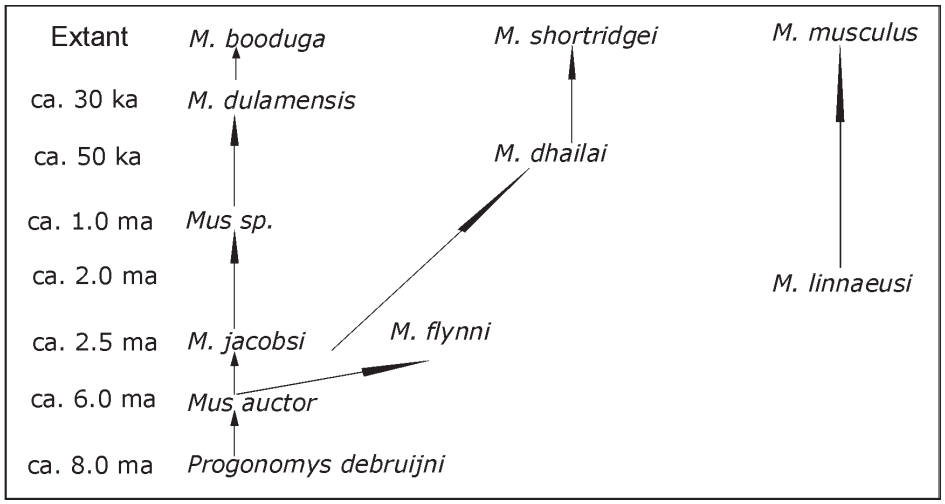

Fig. 2. Tentative phylogeny of *Mus* in the Indian subcontinent

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PALYNOLOGICAL INVESTIGATION OF SOME HOLOCENE FLUVIO-LACUSTRINE DEPOSITS AROUND BURFU (MILAM), KUMAUN TETHYS HIMALAYA

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An episode of neotectonic activity on an east-west trending fault in the zone of active intracrustal Trans-Himadari fault in the eastern Kumaun Himalaya (Fig.1) resulted in the formation of a lake around 22 Ka BP. A 25.6m thick sequence, largely made up of laminated sediments, represents the lake that disappeared probably due to the revival of neotectonic activity at ca. 11 Ka BP. Palynological investigations testify to the occurrence of two temperate humid and at least two well defined arid climatic phases.

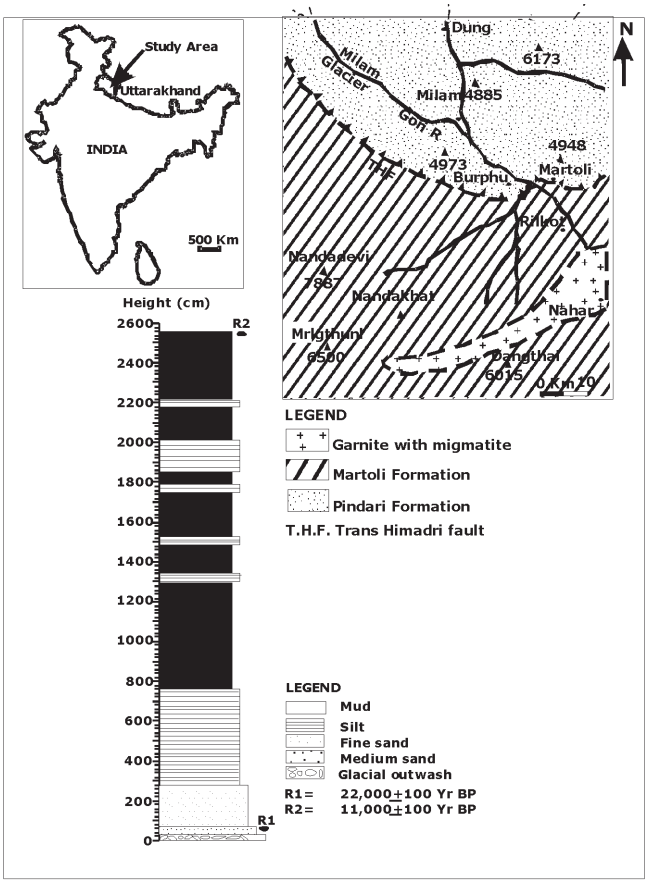

Fig. 1. Geological map of the study area and profile of laminated sediments

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The conventional method of pollen analysis using 10% aqueous KOH solution, 40% HF and acetolysis mixture was employed to extract the pollen/ spores from the sediments. Fifty three samples, collected mainly from varve sequence, yielded pollen and spores. Four pollen zones, with abbreviations "BPZ" (Burfu pollen zone) are described in the ascending order.

The pollen diagram is presented in Fig. 2. The vegetation around ca. 22 Ka BP (pollen zone BPZ-I, 0-410cm) is dominated by *Pinus* and *Artemisia* indicating cool and arid climatic conditions. This was followed by a phase of warm humid climate (pollen zone BPZ-II, 410-1110cm) during which Cyperaceae swamps grew and the vegetation was dominated mainly by Poaceae, *Picea* and trilete fern spores. The conifer forests grew under warm-moist climate. A comparatively shorter phase of arid climate (pollen zone BPZ-III, 1110-1580cm) was restored in the area which is indicated by a significant rise in Cheno/ Ams, reduction in marshy taxa, declining trend in shrubby elements and aquatics, abrupt decline in fern spores and negligible presence of *Picea*. It seems that the weaker (summer) monsoon may have resulted in less precipitation in the Kumaun Tethys Himalaya during this time. These changes are indicative of the steppe vegetation under cool and arid conditions. A comparatively longer phase (pollen zone BPZ-IV 1580-1840cm) is represented by higher percentage of ferns, increase in *Quercus, Carpinus, Ulmus* and *Juglans*. Relative decrease in Cheno/ Ams suggests a change to warmer humid conditions.

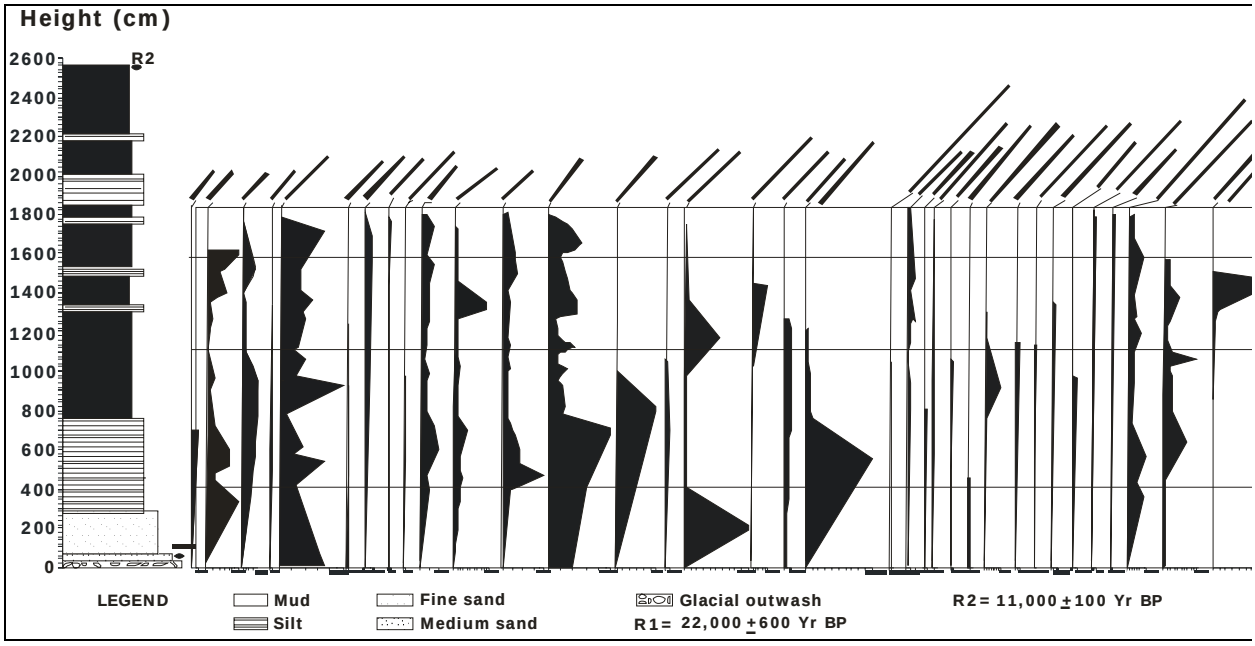

Fig. 2. Pollen spectra of the Burfu palaeolake sequence

ICMS - 56 **Key Note**

APPLICATION OF PALAEONTOLOGY IN SEQUENCE STRATIGRAPHIC FORMULATION: EXAMPLES FROM THE INDIAN MESOZOIC

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Over the last two decades, it is being increasingly realized across the globe, in particular, in Euro-America, as to how crucial and essential is the newly developed area of sequence stratigraphy in geological studies, be those fundamental or applied. Sequence stratigraphy is here understood as high resolution integrated geological modelling, and mega and micro-palaeontological data, in-turn, are considered the single most important element in the formulation of outcrop/subsurface/off-shore sequence framework.

Much unlike the widely accepted universality, application of well resolved palaeontological information here demonstrates the tectonically governed regionality of the 1st and 2nd order sequences of more than two Ma duration on the Mesozoic of Gondwanian Tethyan Margin (GTM) from Arabia to Australia, while the sea-level driven globality is restricted to 3rd order and finer sequences of less than two Ma duration inclusive of fine Milankowich climatic cycles.

The so developed tectonically controlled and palaeontologically précised GTM mega-sequence ranges from the intra-Permian origin of Neotethys to its intra-Palaeogene closure. It in turn includes (Figure-1) three 1st order sequences; a) Late Permian to Pliensbachian, b) Toarcian to Albian, and c) Cenomanian to Early Palaeogene, along with their respective intra-Anisian (determined in Spiti), intra-Oxfordian (determined in Kutch) and intra-Turonian (determined at both western and eastern Indian sectors) 1st order Maximum Flood Surfaces (MFSs). The 2nd, 3rd and finer Milankowich sequences are detailed and demonstrated in Kutch where the Jurassic part of the Toarcian-Albian sequence is further organized into eleven 2nd order and forty-one 3rd order sequences.

The palaeontological parameters applied are ranges of index taxa and lineages; density, diversity, frequency, benthic to nectic/planctic ratio, faunal/ floral similarity, spatio-temporal distribution and migration patterns of fauna/ flora and biofacies, faunal morphological composition, etc. Salient examples of the application of high resolution palaeontological data are here highlighted.

The oldest Mesozoic 1st order Sequence Boundary (SB) is palaeontologically précised in early Early Toarcian through index ammonoid

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Bouleiceras bearing marls/limestones unconformably over non-marine Triassic sands involving a large subaerial stratigraphic gap of few tens Ma of varying parts of Triassic to Middle Jurassic. The determination is also supported and strengthened by published palynological data in exposed non-marine and subsurface/ offshore successions.

The earliest Mesozoic 1st order MFS is for the first time here determined in Spiti Triassic, that has been splendidly documented in recent years and also biostratigraphically zoned, in a hard-grounded condensed interval (beds 34 to 40), yet further précised at the top of bed 40 of mid-Anisian ammonoid Trinodosus Zone and broadly corresponding range of the conodont species *Neogondolella bulgarica* on the basis of maximum density, diversity and frequency of ammonoids of the entire Triassic in the Indian subcontinent. The conodont diversity, however, is maximized at lesser depth distinctly below the MFS in the 1st order Transgressive System Tract (TST).

The intra-Jurassic 1st order MFS is précised in Kutch above the late Middle Oxfordian Transversarium Zone Schilli Subzone in a condense hard-grounded bed with maximum ammonoid density and diversity, while maximum diversity of benthic forams of 15 to 25 species is realized in the 1st order TST at lesser depth below the MFS. Interestingly, maximum dinocyst species diversity in off-shore K-G basin is also realized around the same time in Oxfordian in the dinocyst *L. jurassica-C. continuum* Interval Zone. Tectonically induced sudden deepening is also interpreted on the entire Tethyan Himalayan margin on the basis of ammonoid dense slow sedimented fine textured ammonoid, dinocyst and coccolith rich Late Jurassic Spiti Shale that is sandwiched between several fold thicker moderately deposited Late Triassic-Early Jurassic Kioto Limestone below and medium to coarse textured rapidly deposited Guimal Sandstone above. The 1st order intra-Cretaceous MFS is here suggested in Late Turonian intrabasinally persistent hard ground within the Nodular Limestone in Narmada basin, above the Parh Limestone in subsurface of Jaisalmer basin, above the Raghavapuram shale in K-G off-shore, above the Sattapadi shale in subcrops and Karai Shale of outcrops in Cauvery basin. The level is included within or above the *Marginotruncana helvetica* Zone in Cauvery Basin and Jaisalmer). In Narmada, it is constrained with Late Turonian ammonoid *Placenticeras kaffrarium* from a level below the hard grounded MFS.

The regionality of the above determined 1st order SB and MFSs and associated respective large subaerial and submarine gaps are palaeontologically interpreted in at least over a dozen basins between Arabia to NW Australia. The said gaps are even palynologically proved even in non-marine exposed and subsurface Gondwana successions.

Submarine gaps are also palaeontologically differentiated from subaerial gaps, and their duration measured. For example the substantive gap above the Dhosa Oolite in Kutch Mainland, that even after one hundred

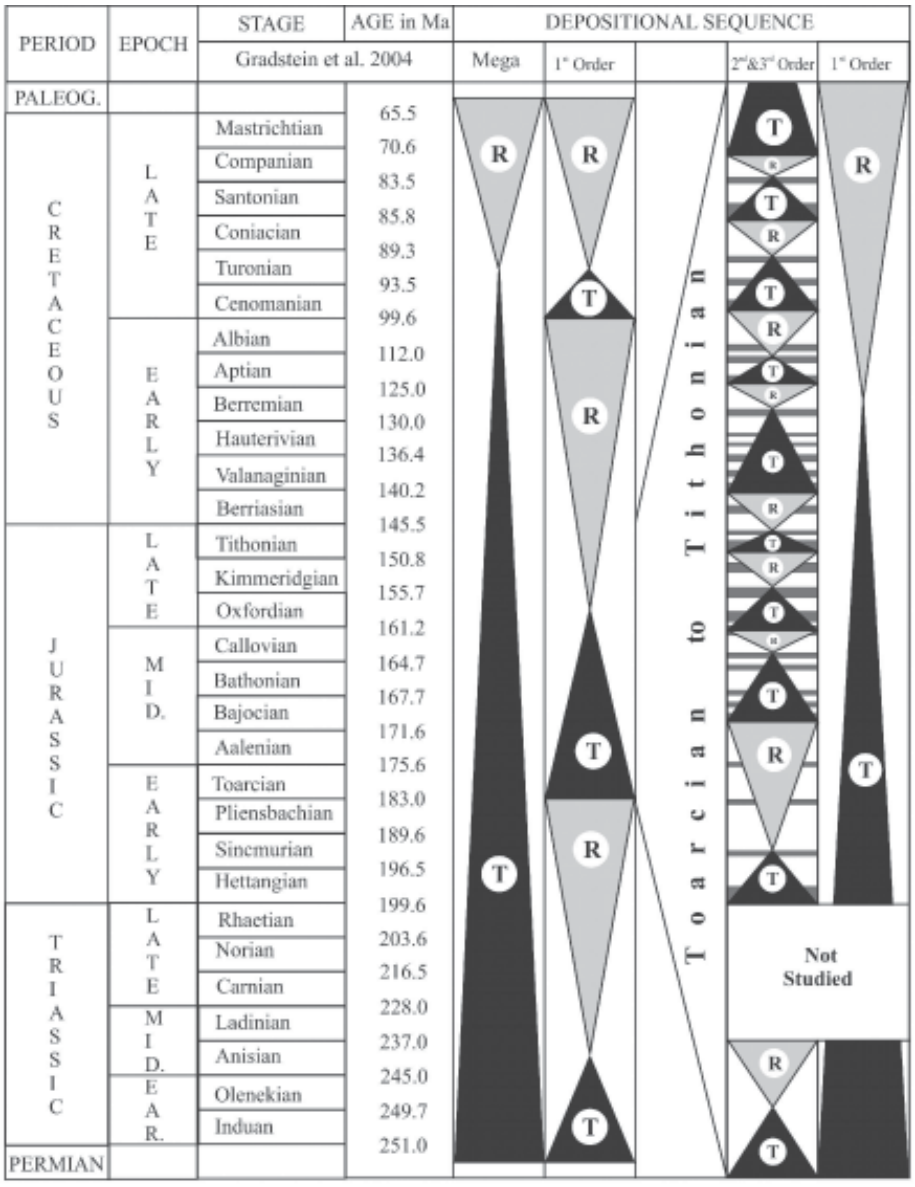

Figure 1: **1st to 3rd order Mesozoic Sequence Stratigraphic Framework in India**

and fifty years of intensive and extensive investigations continues to be considered subaerial and localized, has been recently measured as of over 5 Ma at Lakhapur and held submarine on palaeontological considerations. Much in contrast to subaerial gaps, the post-Dhosa Oolite gap is found to decrease in duration from basin to margin with complete disappearance in the margin at Kantkote, so interpreted through uninterrupted succession of ammonoid zones. The ammonoid rich Dhosa Oolite, earlier considered shallow marine, is here on palaeontological considerations, considered to have deposited well below wave base at subtidal depths of several tens of meters as the deepest form of the Kutch Jurassic. Dhosa Oolite body fossil

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rich condensed to starved biofacies is also found to retrograde towards the margin upward up to the 1st order MFS.

Orbitaly induced fine climatic sequences of even ca. 40 Ka and ca. 20 Ka have also been differentiated within the 4th and 5th order rapidly deposited Highstand System Tracts (HSTs) of the Kutch Jurassic, e.g. in the late Late Kimmeridgian Katrolensis Zone.

It is concluded that integrated well resolved mega and micro-palaeontological data serves vital role in all aspects of sequence stratigraphic studies of all orders, be that demonstration of tectonically controlled regionality of sequences greater than 2 Ma or eustatically driven globality of sequences less than 2 Ma, precision dating of SBs and MFSs, differentiation of submarine and subaerial gaps, estimation of bathymetry, sediment accumulation rates, sudden drastic changes across the MFS/SB and SB/MFS boundaries, dating of plate-tectonic events, prediction of hydrocarbon source rocks and intervals, and many other areas. It also allows matching and correlation of facies tracts within the basins, among the basins of a region, as also interregionally, involving numerous dimensions and scales of intra-basinal to global geological processes and dynamics. To top that all, through joint future efforts it should be possible to tranaslate, facilitate and strengthen subsurface sequence stratigraphic investigations through integration with the palaeontologically précised outcrop based framework through extension of the SBs and MFSs, particularly of 3rd and finer order into well logs and seismic profiles.

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PLANKTONIC FORAMINIFERA AND TRACE METALS CONCENTRATION IN THE SEDIMENT CORE FROM NINETY EAST RIDGE, INDIAN OCEAN

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In this paper we present planktonic foraminiferal assemblage from the ODP Leg 121 site 758, lying at the northern end of Ninety East Ridge of the Indian Ocean. The core details are: ODP Leg 121 sites 0758 – sector B core 001H 05W (1-150 cm). The main objectives were to evaluate the abundance of planktonic foraminifera and trace metals concentration. Samples at every 2 cm interval were analysed for planktonic abundance, organic matter, total organic carbon and $CaCO_3$, content. Geochemical data reveals that the trace elements concentration is in the order represented by Pb>Ni>Co>Cu>Cr, and shows no distinct variation through the depth while the concentration of Zn and Mn is more towards the surface and decrease gradually with depth. The time frame of the studied sequence is based on planktonic foraminiferal faunal datum. The data collected reveals 12 most abundant species *Orbulina universa, Globorotalia tumida, G. scitula, Pulleniatina obliquiloculata, Globigerina* spp., *Sphaeroidinella dehiscens, Neogloboquadrina dutertrei, Candeina nitida, Globoquadrina hexagona, Globigerinoides conglobatus, G. rubber, G. sacculifer.* Of these, the four most abundant species are *Globigerinoides rubber, G. sacculifer, G. conglobatus* and *Orbulina universa. Orbulina universa* and *Globigerinoides rubber* show an increase towards the top of the core.

The data on planktonic foraminifers were treated statistically using both factor and cluster analyses to decipher the relationship between the species assemblages and environmental parameters. The factor nalysis determined by R-mode analysis account for 76% of the total variance. The graph of planktonic foraminiferal assemblage versus age (ka) indicates an incursion around the Marine Isotope State II and III (MIS 2 and 3) and correlation with organic matter content during these stages.

An abundance of *Globigerinoides sacculifer* (a surface dwelling, warm water, mixed layer tropical planktonic foraminifer) and *Orbulina universa* (an intermediate depth, warm water subtropical foraminifer) with *Globigerinoides rubber* indicates a warm, thick mixed layer in the eastern Indian Ocean during 100 Ka to 82 Ka. Relative abundance of *Orbulina universa* with *Globigerinoides rubber* in the core top samples at the northern end of Ninety East Ridge, Indian Ocean correlates well with winter

upwelling and productivity. A comparison of foraminifer faunal variation with carbonate also points towards faunal productivity. A decrease in the population of *Orbulina universa* and abundance of *Globigerinoides sacculifer* and *G. rubber,* together with variation in the organic matter, total organic carbon and calcium carbonate content along the depth of the cores, indicate a fluctuation in productivity.

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ISOTOPE EVENT STRATIGRAPHY OF SELECTED PROTEROZOIC AND MESOZOIC BASINS OF INDIA

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The Proterozoic and Mesozoic basins of the world have hydrocarbon resource potential. The commercial finds of hydrocarbons in the Proterozoic basins are reported from Russia, USA, Oman, China and Australia while the Mesozoic basins are characterized by the oil reserves of ~50% and gas reserves of ~40%. Indian hydrocarbon resources are mostly confined to Cenozoics. However, a large number of unexplored frontier Proterozoic and Mesozoic basins exist in the country which may have hydrocarbon prospects and these need to be studied for their isotope event stratigraphy. Carbon and oxygen isotope event stratigraphy of marine carbonates can demarcate the intervals of increased organic carbon burial/productivity and infer about their depositional, diagenetic and palaeoenvironmental conditions. The Proterozoic and Phanerozoic time intervals are marked by several carbon and strontium isotopic excursion events. The positive $\delta^{13}C$ excursions have been related to Oceanic Anoxic Events which are time intervals of widespread to global deposition of organic carbon rich sediments in marine environments and the sea level rise associated with transgression. The negative $\delta^{13}C$ excursions characterize the catastrophic reduction of organic productivity and sea level regression. Carbon isotopic excursions have also been associated with major boundary events in the stratigraphic record, viz. Permian/ Triassic, Cretaceous/Tertiary and Precambrain/ Cambrian boundary intervals. Strontium isotope records provide information on tectonic evolution of the earth system and reflect the increase and declining of Sr input from continental flux vs. the input from mantle flux. The present study reports the $\delta^{13}C$, $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ records of stratigraphically controlled carbonate sequences of selected Proterozoic (Vindhyan, Bhima and Krol-Tal) and Mesozoic (Jaisalmer, Kutch and Ariyalur-Pondicherry) basins.

C and Sr isotope data of carbonate rocks of the Vindhyan Supergroup correlate with the global isotope evolution curves of the later Proterozoic and suggest that the Lower Vindhyan sediments were deposited during the Mesoproterozoic times and those from the Upper Vindhyan represent a Neoproterozoic interval of deposition. The $\delta^{13}C$ enrichment of up to 5.7‰, observed in carbonates of Nagod Formation belonging to the Bhander Group, represents intervals of high organic productivity/burial. The carbon isotopic data on carbonate rocks of the Bhima Basin are characterized by

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$\delta^{13}C$ enriched values of up to 4‰ and the data integrated with the palaeontological records indicate a Terminal Proterozoic age for Bhima sediments. The $\delta^{13}C$ and $\delta^{18}O$ data of the Late Precambrian-Cambrian carbonates of Krol-Tal successions of Lesser Himalaya show two distinct cycles of ^{13}C maxima-minima and one distinct ^{18}O maxima which suggest that the isotopic variations across Precambrian-Cambrian stages relate to marked changes in the carbon and oxygen fluxes.

Carbon and oxygen isotopic composition of Mesozoic carbonates from Jaisalmer Basin, Ariyalur-Pondicherry Sub-basin and Kutch Basin shows: (i) isotopically altered signatures for carbonates of Lathi, Baisakhi, Badasar and Habur formations and for most of the samples of Jaisalmer Formation (Jaisalmer Basin) and also for carbonates of Jhuran Formation (Kutch Basin); (ii) primary isotopic signatures for the fossils and few of the carbonates of Jaisalmer Formation (Jaisalmer Basin) and carbonates of Uttatur Group including few samples of Kallankurichchi Formation (Ariyalur-Pondicherry sub-basin); and (iii) anomalously depleted $\delta^{13}C$ signatures for Tiruchirapalli Group carbonates of Ariyalur-Pondicherry sub-basin.

The paper shall present and discuss the isotopic results in relation to the $\delta^{13}C$, $\delta^{18}O$ and $^{87}Sr/^{86}Sr$ trends of carbonates during Proterozoic and Mesozoic times; construct the isotope event stratigraphy of the basins; find the environmental conditions of their deposition; and demarcate the intervals of high organic carbon productivity/burial which have bearing on the hydrocarbon generation potential of the basin.

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STRATIGRAPHIC ANALYSIS OF MICROSCOPIC CHARCOAL AND OTHER PALYNOFACIES IN SEDIMENTS OF JABALPUR FORMATION (EARLY CRETACEOUS) IN SOUTH REWA BASIN, CENTRAL INDIA

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The distribution pattern of microscopic charcoal along with other palynofacies types are analyzed in eight sections exposed around mine pits, road and river cuttings in Umaria district, Madhya Pradesh of South Rewa Basin. These charcoalified plant fragments show bordered pits, vessels and other tissues, while other palynofacies assemblages comprise leaf fragments (leaf epidermis and stomata), biodegraded terrestrial, amorphous organic matter, resin pieces and spore-pollen, etc. The morphology of charcoalified plant tissues is observed under light and scanning electron microscopes showing linear, quadrangular to multi-angular and sometimes curved shapes. Morphologically, they are least to well altered, showing uncompressed noncellular to cellular details along with change in colour from pale yellow-brown-dark brown and black. The change in colour exhibits effect of enhanced temperature that might have been caused by forest fire before their dispersal and burial in sediments. The quantitative analysis of these microscopic charcoals (peak and low in abundance) and other elements, including spores and pollen grains in each sedimentary stratum provides clues for exploring the effect of ecological changes, fire episodes and fluctuations in the severity of wild fire over the vegetation. The dominance of microscopic charcoal in the organic matter assemblages in some sections and vice-versa in others indicate that the vegetation of the basin was severely to moderately affected by seasonal wild fire causing modification of a large amount of plant biomass to charcoalified tissues. Applying the analysis of threshold and peak distribution pattern of the thermally altered, unaltered and microbially affected plant fragments occurred in bottom to top of the strata signifying their preservational biases in the studied sedimentary sequences. The distribution pattern along with sorting of their size from large (3-1 mm), medium (<1mm-200 μm) and small (<200 μm to 5 μm), explains the depositional set up and influx of organic matter from source to distant places in the study area. The dispersal model, in two-dimensional pattern, exhibits that the sediments deposited at north-eastern region of the district show comparatively higher frequency of microscopic charcoal than those occurring at north-western region. The spore-pollen assemblage

recorded in these sequences exhibits dominance of conifers, pteridophytes and cycads. The palynoassemblage suggests existence of moderately elevated to low lying rainforest vegetation with alternating wet and seasonal aridity under the subtropical regime. Such data also provide evidences about fluctuation in growth of the plant community and recurrence of wild fires on the vegetation of Upper Gondwana Period (Early Cretaceous) in the Basin.

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PALYNOLOGICAL STUDIES AND PALAEOENVIRONMENTAL INTERPRETATIONS FROM CAMBAY SHALE (EARLY EOCENE) EXPOSED AT VASTAN LIGNITE MINE, SURAT DISTRICT, GUJARAT

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The communication presents analysis of data generated from palynological and dispersed organic matter studies from Cambay Shale exposed at Vastan Lignite Mine, Surat District, Gujarat. The studied sequence is located in an open-cast lignite mine and is situated at about 60 km NE of Surat. Sample collection was made from a thirty metre thick sequence which exposes six lignite seams (1-5m thick). These seams alternate with greenish-grey shale and clay-marls. Rock samples from all these lithologies were collected and chemically processed for the recovery of palynofossils and dispersed organic matter.

Lower part of the section shows high frequency of structured terrestrial matter followed by biodegraded, amorphous and black debris. Based on the occurrence of such assemblage it is inferred that this part of the sequence was deposited under moderately anoxic condition where large amount of terrestrial vegetal matter was incorporated. The middle part of the section is rich in biodegraded and amorphous organic matter followed by the structured terrestrial OM. In upper part of the section reduced frequency of structured terrestrial matter was observed whereas the biodegraded matter increased quantitatively. Based on such representation of organic matter it is inferred that the middle part of the sequence was also deposited under moderately anoxic condition whereas the upper part got deposited under the influence of completely anoxic conditions. General trend perceived through the organic matter studies in the sequence from lower to top strata is increase in biodegraded and amorphous contents, more or less uniform representation of resinous contents and fluctuating frequency of spore/ pollen.

Quantitative analysis of organic matter contents recovered from various lithologies indicates that the structured terrestrial elements increase in frequency in claystone beds. Biodegraded organic matter contents are also represented in high frequency in claystone beds and in one of the lignite samples from top of the sequence. Amorphous contents are present in high frequency in samples from lignite seams.

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Palynological assemblages have been recorded from many fossiliferous layers of the section. The assemblage is represented by spores, pollen grains, dinoflagellate cysts and fungal remains. The assemblage is marked with overall dominance of angiospermous pollen whereas, pteridophytic spores are characteristically lower in frequency. Presence of dinoflagellate cysts was noticed in the middle part of the sequence. Based on the palynofloral composition it is inferred that deposition of the studied sequence took place in fluctuating conditions ranging from lacustrine, swampy and marshy to deltaic environment.

Based on palynological studies the Vastan sequence can be divided into three zones. The Lower Zone, represented by about 5.5 m thick sediments, is rich in coastal and tropical rainforest elements. Most of the forms recorded from this part are related with the families Arecaceae (Palmae), Bombacaceae and Alangiaceae. The Middle Zone, represented by 10m thick sediments, shows characteristically impoverished palynological assemblage and has distinctly low concentration of organic matter indicating prevalence of drier conditions in vicinity of the depocentre. The central part of this zone is marked by presence of dinocysts indicating marine incursions. Continuance of shallow marine deposits is noticed almost up to the top of the studied sequence. The Upper Zone, represented by about 10.5m thick sequence, shows a mixture of marine and terrestrial palynofossils. Within this zone a horizon of two-metre thick claystone shows very high frequency of algal filaments, non-structured organic matter and monotypic assemblage of *Operculodinium* spp. The top part of this zone contains good amount of bombacaceous pollen but is devoid of dinocysts.

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MIDDLE JURASSIC OSTRACOD FAUNA FROM THE BADABAG MEMBER OF JAISALMER FORMATION, JAISALMER

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This paper records a rich ostracod assemblage from the Badabag Member of Jaisalmer Formation, Jaisalmer. Altogether, seventy eight species have been recorded, of which 47 are assigned to the previously known taxa. Thirty one species, viz. *Anchistrocheles* sp., *Bythocypris* sp., *Cytherella* spp. A and B, *Cytheropteron* spp. A, B, C and D, *Ektyphocythere*? sp., *Eocytheridea* sp., *Fabanella* spp. A, B and C, *Fastigatocythere* (*Habocythere*) sp., *Galliaecytheridea* sp., *Glabellacythere* spp. A and B, *Lophocythere* sp, *Mandelstamia* spp. A and B, *Oligocythereis* sp., *Paranotacythere* spp. A and B, *Theriosynoecum* sp., *Trichordis* sp. and Genus A, B, C, D and E are left under open nomenclature.

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MIDDLE-LATE EOCENE CORALLINE ALGAE FROM BASSEIN FORMATION, BOMBAY OFFSHORE BASIN: PALAEOENVIRONMENTAL SIGNIFICANCE

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The Bassein Formation (Middle to Late Eocene) of Bombay Offshore Basin is composed of different types of limestone. The present paper incorporates taxonomy of 9 nongeniculate coralline algal species, viz. *Lithoporella melobesioides, L. minus, Lithothamnion* spp. 1, 2 and 3, *Sporolithon fosteri, S. myriosporum, S. oulianovi* and *S. praeerythraeum*, and 3 geniculate coralline algal species, viz. *Arthrocardia* sp., *Corallina* sp. and *Jania* sp. recovered from the core samples of limestone of the Bassein Formation. The algal assemblage indicates that the core samples, representing the Bassein Formation, were deposited in low to moderate energy, clear and calm tropical water conditions at a depth of 40- 50m.

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CALCAREOUS ALGAE FROM THE REWORKED PLEISTOCENE CARBONATES AROUND DIU

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The reworked Pleistocene carbonates of Diu and adjacent Saurashtra area, dominantly composed of calcareous algae associated with foraminifers, bryozoa, echinoids and large number of crustaceans' faecal pellets, belong to Miliolite and Chaya formations. The Miliolite Formation (Middle Pleistocene) has been divided into Dhobalia Talav Member (DTM) and Adatiana Member (AM) whereas the Okha Shell Limestone Member (OSM) belongs to the Chaya Formation (Late Pleistocene). On the basis of present study, the Dhobalia Talav Member has been lithologically separated into four parts, viz. Lower pelletoid limestone/ calcarenites [DTM(CA)], Nodular Calcrete [DTM(NC)], Massive hardpan calcrete [DTM(MHC)] and upper Pelletoid limestone/ calcarenites [DTM(CA)]. The Adatiana Member is lithologically divided into two i.e. lower highly recrystallized limestone (HRAM) and upper lithologically friable Adatiana Member (FRAM).

The members of Miliolite and Chaya formations contain 4 nongeniculate coralline algal genera such as *Lithothamnion, Lithophyllum, Lithoporella* and *Sporolithon* along with dominance of geniculate coralline alga *Amphiroa* with minor occurrences of *Jania* and *Corallina.* There are sporadic occurrences of the green algae *Neomeris* (Dasycladales) and *Halimeda* (Bryopsidales).

The coralline algae occur usually from low tide level down to depth of 25 to 30 m and sometimes extend up to 270 m. Hence, coralline algae do not indicate the precise depth of deposition. Dasycladalean algae generally occur at a depth of low tide level down to 5 to 6 m. In the HRAM the corallines are associated with the dasycladalean alga, *Neomeris* and Halimedacean alga, *Halimeda* pointing its depth of deposition in low tide level. The genus *Lithoporella* exclusively occurs in tropical water while *Sporolithon* is limited in tropical to sub-tropical water. The genus *Lithoporella* occurs in FRAM of the Miliolite Formation having aeolian origin deduced on the basis of sedimentary structures and petrography. Hence, it becomes difficult to attribute the same environmental condition on the basis of presence of *Lithoporella*. But, it can be surmised that originally the *Lithoporella* would have been deposited in tropical to sub-tropical waters before its aeolian transportation and further deposition forming a part of Miliolite Limestone and Chaya formations.

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The overall petrographic, floral and faunal characteristics of calcarenites suggest that they were initially deposited in a clear, shallow and warm water marine environment. The micrite facies interbedded with calcarenites in the Dhobalia Talav member indicating the change in the depositional environment from an unsheltered, turbulent, warm, shallow marine water (pelletoid calcarenites) to calm water conditions. The progressive rolling of grains, presence of polished quartz along with other biota including calcareous algae signify long distances of aeolian transportation. Alternating coarse and fine grained laminations suggest fluctuating wind velocity. The limestone particles have originated in a shallow marine beach-coastal dune set up during high sea level and progressive regression of the sea are exposed to the reworking by winds and re-deposited as miliolite rocks which have subsequently undergone meteoric diagenesis. Such miliolites are well exposed at Diu Fort belonging to the Adatiana Member of the Miliolite Formation.

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MICROVERTEBRATES FROM THE NAGROTA FORMATION, UPPER SIWALIK SUBGROUP OF JAMMU, JAMMU AND KASHMIR

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The Himalayan mountain system is the product of collision between the Indian and Asian plates. Upliftment and erosion of these mountain ranges over, past 55 Ma, have led to the accumulation of about 7 km thick sedimentary pile in the Himalayan foreland basin representing continental molassic sequence**.** The foreland basin is composed of Muree Group of Late Oligocene and Early Miocene age and overlying Siwalik Group of Middle Miocene to Late Pleistocene age. Tectonically, the foreland basin is separated from the Lesser Himalaya to the north by the Main Boundary Thrust (MBT) and the Indo-Gangetic plain to the south by the Himalayan Frontal Fault (HFF).

In the Jammu region, a complete succession of the Siwalik Group ranging in age from Middle Miocene to Middle Pleistocene is exposed in the Southern limb of Suruin-Mastgarh anticline. The Siwalik succession of Jammu Hills, the eastern extension of Potwar Plateau and lying in a linear belt between the Line of Actual Control and Ravi River, is relatively least studied area from vertebrate palaeontological point of view. No microvertebrates have been reported from the Siwalik deposits of Jammu until now except Gupta and Prasad (2001) and Prasad *et al*., (2005). In comparison to this, lot of work have been done on micromammals in the Moginand area, east of Chandigarh and Himachal Pradesh and Potwar area of Pakistan in the west. The micromammal based biostratigraphic framework provided for this part of the Siwalik succession is the most precise.

In the present study, a good assemblage of microvertebrates including Pisces- Cyprinidae Gen. et. sp. indet., Reptilia- Lacertilia indet., Incertae sedis and Rodents- cf. *Rattus,* ?*Golunda kelleri*, *Golunda kelleri*, *Mus* sp., cf. *Mus jacobsi*, *Mus flynni*, *Diatomys* sp., *Millardia* sp., ?*Tatera Pinjoricus*, ?*Cremnomys blanfordi* and indeterminate bones in association with microfossils such as ostracodes, gastropods, pelcypods and flora charophytes have been recovered, for the first time, from the mudstone immediately underlying the geochronologically dated bentonite tuff band (BTB) (2.48±0.56 Ma, which concides with Gauss-Matuyama boundary) exposed at Dora, Karju nalla, Karju Tiba, Stonywaste, Kherdi, Anandpur, Uttarbehani, Mandal, Khanpur, and Kamni, of the Nagrota Formation

(=Pinjore Formation), Upper Siwalik Subgroup of Jammu. Based on the rodent fauna recovered from the investigated sections in conjection with Pisces, Reptilia, gastropods, pelecypods and charophytes a Late Pliocene-Early Pleistocene age is favored for the investigated levels of the Upper Siwalik sequence of Jammu.

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EFFECT OF DIFFERENT COMBINATIONS OF SALINITY AND TEMPERATURE ON BENTHIC FORAMINIFERA *PARAROTALIA NIPPONICA*: OBSERVATIONS FROM LABORATORY CULTURE EXPERIMENT

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In view of the growing importance of culture experiments on foraminifera to understand ecology of different species, benthic foraminiferal species *Pararotalia nipponica* was studied in laboratory culture experiment. The response of juvenile specimens of *Pararotalia nipponica* to different combinations of temperature (25° C, 27° C and 30° C) and salinity (25‰, 30‰ and 35‰) was observed. At each temperature, specimens were subjected to three different salinities, therefore a total of nine sets were used for the experiment. Besides salinity and temperature, other parameters were kept constant throughout the experiment. The experiment was conducted in replicate. With 10 specimens per set, a total of 180 specimens were subjected to different temperature and salinity. Maximum growth was reported in the specimens kept at 35‰ salinity and 27° C temperature, which is also the salinity and temperature at which specimens reproduced in the laboratory. Growth was also noticed in the specimens kept at other temperatures (25° C and 30° C) with 35‰ salinity, but the growth was lesser than that in specimens kept at the same salinity (35‰) and 27° C temperature. In case of specimens subjected to 25‰ salinity, growth was observed initially, regardless of temperature (25° C, 27° C and 30° C). But later on, the specimens started dissolving and eventually died. Similarly at 30‰ salinity, specimens kept at all three different temperatures grew initially, but growth stopped later. However in this case, instead of dissolution, the specimens turned opaque. Based on the study, we conclude that under the present set of conditions, the optimum growth and reproduction in *P. nipponica* occur at 27° C temperature and 35‰ salinity. We further conclude that the salinity is more influential for the growth and reproduction of *P. nipponica*. The study also shows that hyposaline water is more detrimental for *P. nipponica* specimens.

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APPLICATION OF BENTHIC FORAMINIFERA IN MONITORING MARINE POLLUTION: EFFECTIVENESS OF LABORATORY EXPERIMENTS

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Pollution studies have gained wide attention of the scientific world since long. Marine environment is the ultimate destination of all terrestrial runoff, and hence affected badly by various kinds of pollutants ranging from domestic and industrial garbage to radioactive wastes. Looking into the severity of the coastal marine pollution, effective measures are the demand of the hour. Different techniques, including chemical and biological studies, are available for detecting spatial variation in marine pollution, while there is hardly any to detect the temporal variation of the same. The present study aims at validating some of the field based results and also developing an effective proxy for marine pollution monitoring (spatial as well as temporal) by using benthic foraminifera as tools.

Foraminifera are considered to be one of the best indicators for marine pollution studies along the marginal marine environments. They are highly sensitive to the changes in the physico-chemical parameters in their ambient environment (natural as well as anthropogenic). The response to such changes may vary from variations in abundance, diversity, growth, morphology and chemistry of the hard parts. Foraminifers incorporate signatures of these changes and preserve them in their hard part called test. The foraminiferal test has a very good fossilization potential which makes the studies possible even long after their death. This made them better than other micro organisms which are commonly used in the pollution studies, for effective monitoring of spatial as well as temporal variations in marine pollution. But the credibility of such studies was hampered when the field reports failed to document specific features/ responses of foraminifera from areas affected by specific pollutants; and few studies reported similar foraminiferal characteristics from naturally stressed environments also. Laboratory culture studies emerged as a supporting tool, providing experimental support to the field based findings, there by refining and revaluating them. In the laboratory, field conditions are regenerated and only desired parameters (like type and amount of pollutants) are varied in such a way that the foraminiferal responses to specific pollutants/ changes can be documented separately; which helps in solving the above controversies and extend credibility to the numerous field based claims/

findings. In view of the foregoing, a foraminiferal culture laboratory is established at the National Institute of Oceanography, Goa.

This poster exhibits the basic principles and methodology engaged in the laboratory experiments of benthic foraminifera in the above discussed context. Some of the results are also presented, which will help establishing laboratory culturing as an advanced tool for effective monitoring of spatial and temporal marine pollution. Special emphasis is given to the effect of heavy metal (Hg and Cd) on foraminiferal species collected from the coastal areas off Goa.

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EOCENE PTEROPODS (HOLOPLANKTONIC GASTROPODS, MOLLUSCA) FROM THE UPPER DISANG FORMATION, NAGALAND

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A small assemblage of thecosomatous (shelled) pteropoda or holoplanktonic gastropoda (Mollusca) is reported from the Upper Disang Formation (Middle-Late Eocene) of south central Nagaland (Assam-Arakan Basin), north-eastern India. It is based exclusively on juvenile or incompletely preserved adult shells, yet its documentation is important for palaeoecological considerations because the distribution of pteropods is influenced by environmental parameters such as water temperature, salinity, depth, and oxygen-contents, etc. Prior to this, the only systematic report of Cenozoic pteropods from the Indian subcontinent was from the Ghazij Shales (Eocene) of the Zinda Pir section in Pakistan, though their presence was also noticed in the Anklesvar Formation (India). Other microfossils from the Upper Disang Formation, that were found associated with the pteropods, include planktonic, benthic as well as larger foraminifers, benthic gastropods, bivalves and some ill- preserved ostracodes.

The new fossils comprising shells of limacinoids (juvenile) and cavolinioids (protoconchs and some incomplete adult shells) were recovered from the nodular/ concretionary silty shale of the Upper Disang Formation exposed at several localities near the town of Pfutsero in the Phek District, Nagaland. Three families are distinguished, viz. Limacinidae, with sinistrally coiled shells and Creseidae and Cliidae?, with straight, uncoiled shells. Limacinids are represented in the assemblage by three morphologically distinct shell types that cannot be related to known genera. Type 'A' shells are depressed and trochospiral, whereas type 'B' shells are planispiral, with the apical whorls invisible in frontal view. Type 'C' shells are also planispiral, but coiled in a tighter spiral.

Creseids are also represented by at least three distinct shell types. Type 'A' shells are long-conical and more or less needle-shaped. Type 'B' shells are cylindrical, but have a slight inflation in the middle and taper posteriorly. Type 'C' shells are characterized by their rounded, slightly swollen protoconch-1 and a distinctly inflated protoconch-2. Cliidae are represented by several deformed and incomplete shells having a wider apical angle and an elliptical transverse section. They are adaperturally more compressed than the other conical shells.

The age of the pteropod assemblage is constrained by the occurrence, in the same beds, of certain index planktonic foraminifers belonging to the zones P15-P17 (=tropical planktonic foraminiferal zones E14 to E16), which indicates a range of Bartonian to Priabonian (late Middle Eocene-Late Eocene). Reports on well preserved uvigerinid foraminifers, from the same stratigraphic levels and sites that yielded the pteropods reported here, suggest a deep marine anoxic environment (lower part of upper bathyal zone) for the fossiliferous horizons of the Upper Disang Formation. The occurrence of pteropods in the Upper Disang Formation indicates deposition in an open marine basin above the aragonite compensation depth (ACD). Based on the combined evidence of pteropods and previously reported uvigerinid foraminifers a palaeobathymetry of ~500 m, i.e. upper bathyal zone, and a tropical-subtropical climate is inferred for the Upper Disang Formation. The presence of larger foraminifers including simple radiate *Nummulites*, benthic microgastropods and bivalves in the same beds that yield pteropods is attributed to transportation into the bathyal zone from shallower areas.

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MULTIVARIATE STATISTICAL APPROACH TO EVALUATE BENTHIC FORAMINIFERAL BIOTOPE AND BIOFACIES ALONG DIGHA-CHANDIPUR SECTOR OF BAY OF BENGAL, NORTH EAST COAST OF INDIA

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A comprehensive study of benthic foraminifera from the near shore inner shelf environment along the Digha-Chandipur Sector of Bay of Bengal was carried out, based on 90 surface sediments collected from three transects, viz. TIV, TV and TIV, during summer, monsoon and winter seasons of 1991 and 1992. 66 species of benthic foraminifera belonging to 33 genera under 23 families and 4 suborders were identified and reported for the first time from the study site. Faunal assemblages revealed a distinct dominance of suborder Rotaliina (34 species) over suborder Miliolina (14 species), suborder Textulariina (13 species) and suborder Lagenina (5 species). The trilinear plot in all the three seasons for both the years also exhibited an overwhelming dominance of suborder Rotaliina. Multivariate Statistical Analyses (R-mode Factor analysis and Q- mode Cluster analysis) were performed on a reduced data set based on relative abundance of all the taxa in order to establish correlations between foraminiferal assemblages and prevailing oceanographic conditions. R-mode Factor analyses revealed six biofacies during summer and monsoon, while 7 major biofacies were recognized during winter season. Based on Q-mode Cluster analyses, 3 and 2 major biotopes were delineated during summer 1991 and 1992, and monsoon and winter of 1991 and 1992 respectively. Distinct seasonal trends were observed in hydrological parameters. However, less defined seasonal variations were noticed as far as sedimentology was concerned. *Ammonia beccarii, A. tepida, Asterorotalia trispinosa, A. dentata, A. multispinosa, Elphidium discoidale* var. *multiloculum, E. somaense* and *Quinqueloculina seminulum* were most abundant from the study sector. Most of the foraminifera belonged to Indo-Pacific zoogeographical provinces.

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SEQUENCE STRATIGRAPHY OF INFRA AND INTERTRAPPEAN BEDS IN GOWRIPATNAM QUARRY SECTION, NEAR RAJAHMUNDRY, WEST GODAVARI DISTRICT, ANDHRA PRADESH

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The Infra and Intertrappean beds are exposed in Gowripatnam quarry section near Rajahmundry in the West Godavari District, Andhra Pradesh. The sequence stratigraphic frame work has been established for these beds and has been assigned under *Duddukuru sequence*. The Infra and Intertrappean beds comprise essentially of limestone, sandy limestone, shale, marl and shelly limestone. There is a well marked unconformity that separates the Infratrappean, Trap rock and Intertrappeans. The vertical section of 67m has been studied at Gowripatnam quarry section for biostratigraphy and construction of sequence stratigraphic framework. The *Duddukuru sequence* is represented by TST, MFS and HST deposits of Infratrappean beds. The Intertrappean beds have been assigned to transgressive systems tract (TST) deposits with in the sequence stratigraphic framework.

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PALAEOECOLOGICAL SIGNIFICANCE OF A TURRITELLINE GASTROPOD-DOMINATED ASSEMBLAGE IN THE INTERTRAPPEAN BEDS OF RAJAHMUNDRY AREA, ANDHRA PRADESH

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Blocks of sandy limestone dredged from the bottom of a quarry section in Devarapalli (canal section) of Rajahmundry intertrappean contain a turritelline gastropod-dominated macrofossil assemblage, in which turritellines are most abundant. Turritelline dominated assemblages are common in other sediments of different ages. This is the first report of turritelline-dominated assemblage from the Intertrappean beds (Palaeocene) of Rajahmundry area, Andhra Pradesh. The matrix of the turritelline layer is sandy limestone, the carbonate is present as cementing material and the fossil assemblage did not form in a typical carbonate-dominated environment. The ecology of turritelline assemblage is somewhat heterogeneous and the recent turritellines are most abundant in cooler waters, commonly associated with upwelling areas, and are rare in warm-water carbonate environments. This pattern is consistent with the hypothesis that turritellines, as a group, have become less thermophilic since the Cretaceous.

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MIOCENE FLORAS FROM KUTCH BASIN AND THEIR RELATIONSHIP WITH CONTEMPORANEOUS WEST COAST VEGETATION OF INDIA

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The Miocene sediments of the west coast of India are essentially marine and were deposited in N-S aligned basins. Plant fossils, both micro and mega, are recorded mainly from the early Miocene sediments along coast from Kutch to Kerala. In Kutch, palynofloras from the Khari Nadi (Aquitanian) and Chhasra (Burdigalian) formations corresponding to N5-N7 zones are poor but demonstrate relationship in their constitution. The assemblages contain Parkeriaceae and Malvaceae as major elements, pteridophyte and palm meagrely and no fungal remains. Poor assemblages (both micro and mega) may be related to basin uplift and influx of clastic sediments (ca. 8.5 cm/ millennium).

The contemporaneous floral assemblages from Sindhudurg, Mangalore and Quilon-Warkalli areas, in contrast to Kutch, are rich and diverse. Both the micro- and mega floral data of these areas suggest swampy, fresh water, beach and mangrove plant communities which indicate deposition in estuary/ lagoon. Lignitic sediments suggest for swampy condition.

Vegetation of west coast demonstrates presence of evergreen-semievergreen forest dominated by angiosperms and moist, tropical climate. A comparison reveals that members of Pinaceae are represented more in Kutch, become rare southwards and absent in Kerala. Similarly, few members of Arecaceae and Ctenolophonaceae are common in Kerala and occur meagrely in Kutch.

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FUNGAL REMAINS FROM THE LATE HOLOCENE LAKE DEPOSIT OF DEMAGIRI, SOUTHERN MIZORAM

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The present communication is an attempt to portray fungal remains from a 2 metre deep sedimentary deposit analysed from Demagiri, southern Mizoram. A diversified assemblage of fungal spores, comprising *Alternaria*, *Helminthosporium*, *Tetraploa*, *Curvularia*, *Cookeina* sp., *Meliola*, *Nigrospora*, *Pericornia*, *Leptosphaeria* type, *Herpotrichiella*, *Multicellaesporites*, *Ornasporonites*, *Dyadosporites*, *Ceratophorum*, *Actinopelte*, *Clasterosporium*, *Helicoma*, *Entophlyctis*, etc., has been recovered from the sediments. In fact, the organic rich sediments, transported from the adjoining tropical humid forest cover, provided suitable substrates for the growth, multiplication and dissemination of fungi. The preponderance of fungal remains in the investigated lake bed sediments could be attributed to their in situ proliferation of the fungi as well as their transportation from the forest belt from higher riches by wind and water and by upthermic winds from the lower elevations to the depositional site. The recovery of fungal remains in great diversity and numbers suggests that the region enjoyed a humid climate during the course of accumulation of the sediments in the lake basin. However, abundant occurrence of the common pathogens of grasses, viz. *Alternaria*, *Helminthosporium*, *Tetraploa*, *Curvularia* and *Nigrospora*, indicates the open nature of forests in the vicinity of the lake during the Late Holocene. The inferences drawn from the present investigation can be usefully employed for the precise assessment of the Quaternary palaeoenvironmental conditions and also to substantiate the implications based on coeval palynological and other evidences.

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RESPONSE OF DEEP SEA BENTHIC FORAMINIFERA TO THE MIOCENE PALAEOCEANOGRAPHIC CHANGES AT ODP SITE 754A, SOUTHEASTERN INDIAN OCEAN

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Miocene deep-sea benthic foraminifera at ODP site 754A on the Broken Ridge (southeastern Indian Ocean, water depth: 1074.6m) are quantitatively examined which shows distinct changes in the benthic foraminiferal assemblages. The faunal data have also been integrated with the available stable isotope records to understand the relationship between biotic and abiotic variations in response to palaeoceanographic changes. A Q-mode factor analysis was carried out on reduced data set of 55 highest ranked species using commercially available statistical package (SPSS) in order to understand the benthic foraminiferal assemblages and past environmental conditions. This method involves Principal Component Analysis (PCA) with varimax rotation. In Q-mode factor analysis, the first five factors were retained which represent 77.03% of the total faunal variance and used to distinguish five benthic foraminiferal assemblages, viz. *Cibicides kullenbergi* assemblage, *Stilostomella lepidula-Globocassidulina subglobosa* assemblage, *Cibicides wuellerstorfi* assemblage, *Globocassidulina subglobosa* assemblage and *Ehrenbergina trigona-Eggerella bradyi* assemblage.

The interval of Late Oligocene to Early Miocene (~25-19 Ma) is characterized by the *Cibicides kullenbergi* assemblage with lower values of ä^{18}O and ä^{13}C broadly reflecting warm, less oxygenated bottom waters with moderate food supply to the sea floor. The interval of ~19-13.5 Ma was marked by the *Stilostomella lepidula-Globocassidulina subglobosa* assemblage and low values of ä^{18}O reflecting relatively warm and stable bottom water. This interval closely corresponds to the Miocene climatic optimum. The interval of Middle Miocene to Late Miocene (~13.5-6 Ma) is characterized by the step-wise increase in ä^{18}O and gradual decrease in ä^{13}C values and *Cibicides wuellerstorfi* assemblage reflecting cold, oxygenated and active bottom currents with relatively higher food supply to the sea floor. This may be due to major expansion of East Antarctic Ice Sheet (EAIS) between 15 and 13 Ma and establishment of thermal gradients between the high and low latitudes. The further decrease in

ä^{13}C values during Latest Miocene to Early Pliocene (~6-3.6 Ma) coincides with the development of a high food exploiting *Ehrenbergina trigona-Eggerella bradyi* assemblage indicating further increase in the surface productivity in the eastern Indian Ocean.

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PHYSICO-CHEMICAL CONTROL ON NUMBER OF CHAMBER AND AVERAGE TEST SIZE OF *NEOGLOBOQUADRINA PACHYDERMA* (EHRENBERG) IN SOUTHERN INDIAN OCEAN

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A total of 26 surface samples, collected from 9.69°N to 55.01°S latitudes and 40°E and 80°E longitudes, were analyzed with special emphasis on the number of chamber and average test size in indicator planktonic foraminiferal species, *Neogloboquadrina pachyderma* (Ehrenberg). The number of chamber and average test size were counted for at least 40 specimens picked for each sample. The results show high correlation between number of chamber and temperature-salinity. Average test size also highly correlated with the temperature and salinity. Both the number of chamber and average test size were found to be decreasing from equatorial to polar region. Besides the temperature and salinity variation, carbonate saturation and nutrient availability could possibly be other causes for the variation in number of chamber as well as the average test size. This study may help to understand the shift in the polar front in geologic past, if studied in the subsurface sediments of Southern Ocean near Antarctic region.

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PALYNOLOGICAL DATING OF CHATURDHARA NALA SECTION NEAR BAKI-BIHAR AREA, IB-HIMGIR BASIN, ORISSA

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The samples for the present study were collected from the western side of Chaturdhara Nala section near Baki Bihar, situated at about 3 km south-west of Gopalpur village, Sundargarh District, Orissa. Two palyno-assemblages are recovered. Palynoassemblage-l, which resembles the Upper Barakar palynoflora (Early Permian), has the dominance of *Faunipollenites* and *Striatopodocarpites* (striated disaccate taxa) followed by non-striate disaccate pollen such as *Scheuringipollenites.* The other significant taxa are *Cyclogranisporites, Verticipollenites, Rhizomaspora, Crescentipollenites Distriatites, Striamonosaccites, Distriamonosaccites, Densipollenites* and *Ibisporites.* Palynoassemblage II (Late Permian) has dominance of *Striatopodocarpites* and *Faunipollenites* along with the presence of *Verticipollenites, Rhizomaspora, Crescentipollenites, Distriatites, Striamonosaccites, Distriamonosaccites, Densipollenites, Scheuringipollenites, lbisporites, Striapollenites* and *Ephedripites.* FAD of *Arcuatipollenites, Densoisporites* and *Lundbladispora,* etc. suggests Late Permian age. Hence, the present palynoassemblage are the first report from this area which are equated with the palynoflora of Late Permian in age.

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RECORD OF BARAKAR-RANIGANJ TYPE OF PALYNOASSEMBLAGES FROM THE SUBSURFACE SEDIMENTS NEAR BRIJRAJNAGAR AREA OF IB RIVER COALFIELD, JHARSUGUDA DISTRICT, ORISSA

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The palynological study of Borehole OIOC-74 reveals the presence of two palynoassemblages, recovered from 256m to 287m depth and 55.5m to 238m depth respectively. The Palynoassemblage-I can be distinguished from the Palynoassemblage-II by the dominance of *Faunipollenites* and subdominance of *Striatopodocarpites.* The non-striate disaccate genera *Scheuingipollenites* and *Ibisporites,* etc. are other important genera. The Palynoasseamblages-II is characterized by the dominance of *Striatopodocarpites* followed by *Faunipollenites.* The other forms, viz. *Crescentipollenites, Scheuringipollenites, Ibisporites, Striapollenites, Verticipollenites, Densipollenites magnicorpus, Rhizomaspora, Parasaccites, Microbaculispora* and *Inaperturopollenites,* etc. have also been observed along with the younger elements such as *Arcuatipollenites, Densoisporites* and *Lundbladispora.*

The dominance of *Faunipollenites* and *Striatopodocarpites* (striated disaccate pollen) followed by non-striated disaccate pollen in Palynoassemblage I and absence of younger elements like *Arcuatipollenites, Densoisporites* and *Lundbladispora* show its Upper Barakar affinity and thus Early Permian age has been assigned to it. The overall composition of Palynoassemblage II shows its Raniganj affinity and so a Late Permian age has been assigned to it.

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POTENTIAL OF TREE-RINGS FOR RIVER FLOW CHANGES: LOOKING BACK AND MOVING FORWARD

NOTES

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The atmospheric concentration of CO_2 and other trace gases has increased substantially over the past century and is expected to be doubled by the later part of 21st century if no control measures are adopted. This steady increase in greenhouse gases has resulted in global warming. Proxy records and climate models show increasing trend in precipitation in past century. However, the precipitation patterns will vary geographically depending on the importance of regional forcing. Changing precipitation pattern will affect the river flow with hydropower generation. River flow records in India are very limited and do not provide sufficient data to understand the recurrence behaviour of extreme events (high and low) which have significant impact on human society.

Tree rings are one of the high-resolution proxy records of climate. Tree ring chronologies from moisture stressed sites near river catchments area could be used to develop long-term river flow records. Tree ring samples of Himalayan cedar (*Cedrus deodara*) were collected from seven moisture-stressed steep slope sites in Satluj river basin Kinnaur, Himachal Pradesh. Standard dendrochronological techniques were used for the preparation of chronologies. Strong intercorrelations in different site chronologies have been found indicating common forcing factor affecting tree growth that could be climate. The longest chronology spans 1353-2005 AD. All the chronologies showed strong positive correlation (r = 0.62) with the total monthly river flow from February to July and precipitation from February to May. Reconstructed river flow showed high year-to-year and inter decadal variability. Spectral analysis of the reconstruction showed significant cycles of 2.1, 2.4 and 29-33 years. Strong 29-33 years cycle is dominant over the 20th century. The analysis of such periodicities are very important for climate prediction models.

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DECCAN VOLCANISM RESPONSIBLE FOR TERMINATION OF INDIAN DINOSAURS BEFORE CRETACEOUS-TERTIARY BOUNDARY AND TRIGGERING OF ASSOCIATED FLORAL CHANGE

NOTES

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Studies were conducted on the Deccan Volcanic associated sediments (DVS) of different Late Cretaceous inland basins and volcanic terrains/ sub-terrains for establishing their spatio-temporal correlation. Sediments deposited at different stratigraphic levels within the volcanic sequences having a well-established stratigraphy were selected for such studies. The focus remained on analyzing the influence of the volcanism on the contemporary sediments and biota, especially the dinosaurs and the contemporaneous flora. The effect of Deccan volcanism and response of the biota is more discernible for dinosaurs and flora than the other associated biota. The studies were supplemented with magnetic susceptibility based Milankovitch analysis for time-series analysis, magneto-stratigraphy and organic carbon isotope stratigraphy.

The in situ dinosaur bearing DVS have been reported from Anjar and Kheda, Bagh valley, Jabalpur and Ranipur, Nand-Dongargaon (N-D basin) and Kallamedu (Trichinopoly) in the south. Of these, Anjar and Ranipur represent the non-marine intertrappean localities, whereas all other localities represent the non-marine infratrappean (Lameta) localities. The Kallamedu Sandstone is considered as the continental deposit. Observations suggest that Late Cretaceous dinosaurs, dominated by titanosaurid-abelisaurid, first appeared during the magnetochron 30N on the Indian subcontinent (ca. 500 Ka before the Cretaceous-Tertiary Boundary (KTB)) and vanished during 29R (ca. 350 before reaching the KTB). This means Indian Late Cretaceous dinosaurs could never reach the KTB level and their extinction has nothing to do with the extra-terrestrial impact at KTB that is considered as a responsible factor for the mass extinction of biota at KTB. Association of the dinosaur bearing sediments with DVS, diversity and abundance of the dinosaurs before the initiation of the Deccan volcanic activity in the terrain and their scarcity in the immediately overlying inter-trappean sediments to their complete absence in the sediments at higher stratigraphic levels suggest that volcanism is responsible for the termination of these reptiles before the KTB. Implicitly, the dinosaur struggled to survive the onslaught caused by the initiation of Deccan volcanism possibly adapting

the survival strategy of migrating to safer areas but got totally extinct with the increasing volcanism that is presently considered as spanning 69-61 Ma.

Palynofloral analysis of DVS at different stratigraphic levels from a large number of selected sections, including a number of new localities, strongly suggests that though falling in majority within the 29R of the Maastrichtian, there exists a strong spatio-temporal difference between the sedimentary beds associated with Deccan volcanic sequences. With the advent of Deccan volcanic activity a strong floral change initiated much before the KTB, thereby suggesting that the Deccan volcanism is responsible for the floral change. Bioevent of appearance of diatoms and dinoflagellates within the Late Cretaceous (Maastrichtian) freshwater ecosystem with the advent of Deccan Volcanism have been recoded. The appearance of Late Cretaceous titanosauriform dinosaurs and angiosperm flora, on the Indian subcontinent, before the arrival of the Deccan volcanic flows are indicated to be coeval.

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CHARACTERIZATION OF 2500 YEARS OLD HEMP (*CANNABIS SATIVA* L.) DNA FROM NORTH-WEST CHINA

NOTES

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Cannabis sativa L. (Hemp) is an important crop, which is being cultivated and utilized since ancient times. Although there are some controversies on the origin and subsequent spread of this species, it is believed that its centre of origin is Central Asia. Ancient plant DNA is now proved to be a powerful tool to solve phylogenetic problems and has been successfully utilized for solving several problems regarding phylogeny. In this study, ancient DNA was extracted from an archaeological specimen of *Cannabis sativa* associated with archaeological human remains from Yanghai Tombs, Xinjiang, China. Ribosomal and *Cannabis* specific chloroplast DNA regions were PCR amplified. Sequencing of a species-specific region and subsequent comparison with published sequences were also performed. Successful amplification, sequencing and sequence comparison with published sequences suggested the presence of authentic DNA in the archeological specimen. When compared with the published DNA sequence of *C. sativa indica*, the Chinese samples clustered separately from it, showing that the Chinese gene pool of the species is different from the Indian gene pool. *Humulus japonicus* (a member of the family Cannabaceae) is clustered with the Chinese samples. One previous report also showed that the 26s rDNA region of *H. japonicus* is almost identical with *C. sativa*. These data indicate that there is a probable role of *H. japonicus* in the evolution of *C. sativa.*

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NEOPROTEROZOIC MICROFOSSILS FROM HALKAL FORMATION, BHIMA GROUP, SOUTH INDIA

NOTES

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The Bhima Basin is located in north eastern part of Karnataka and north western part of Andhra Pradesh between Latitudes 16º15' and 17º35'N and Longitudes 76º15' and 77º30'E. The sedimentaries of Bhima Group, confined to mainly conglomerates, arenites, argillites and carbonate, are divided into Sedam and Andola subgroups.

Well preserved and abundant, brownish plant microfossils assemblage, represented mainly by acritarchs and cf. algae, has been recovered from the shale of Halkal Formation (Bhima Group) exposed at seven localities, viz. Jewargi, Ganwar, Kolkur, Manadwadi, Kamhipparga, Halkal and Saidapur. The recovered assemblage, both in thin section and macerated residue, includes 8 taxa of acritarchs and 5 taxa of algae and single form of incertae sedis. The acritarch taxa are *Leiosphaeridia, Granomarginata, Schismatosphaeridium, Nucellosphaeridium, Leiovalia, Vavosphaeridium, Baltisphaeridium, Micrhystridium* and *Ovulum*. The algal remains include groups of sphaeroidal cells and septate and aseptate trichomes belonging to chroococcales, osillatoriales and chlorococcales. These taxa are *Palaeonacystis, Heliconema, Gloeocapsamorpha, Paratetraphycus* and *Tasmanites*. The algal taxa dominate over the diversified acritarchs in present assemblage. Similar assemblage is also known from the equivalent sediments of other parts of world. A comprehensive analysis of the present assemblage and published information from other formations of Bhima Group on geology, palaeobiology, etc. suggest that the Halkal Formation is not older than Tonian and was deposited in marine/ tidal environment.

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FACIES STRATIGRAPHY OF GARUDAMANGALAM FORMATION OF TIRUCHIRAPALLI GROUP, CAUVERY BASIN

NOTES

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The Cauvery Basin has fascinated many geoscientists around the world to initiate an integrated research approach for documenting major geological events such as Cenomanian transgression, Turonian basinal upliftment and KTB transition. This basin has been intensively explored for hydrocarbon occurrence by national and private oil companies for over 40 years. The present work attempts to understand the lithological relationship of on land sediments of Tiruchirapalli Group exposed in Kulakkalnattam and Anaipadi areas. The Garudamangalam Formation, belonging to Tiruchirapalli Group, consists of Kulakkalnattam Sandstone and Anaipadi Calcarenite which are facies variants of the same sandstone. This sandstone is overlain by Garudamangalam limestone followed by Saturbhagam sandstone. The petrological attributes, facies signatures and diagenetic parameters also support this lithological relationship. After the deposition of deep marine Karai clays there was a forced regression which was marked by abrupt shallowing of the basin resulted in the deposition of Kulakkalanattam sandstone. These sands are massive, fine to coarse grained, often pebbly, glauconitic and ferruginous concretionary bodies, arkoses materials of granitic provenance with an early calcite cementation. Abundant vertical burrows like *Skolithos, Ophiomorpha* and *Thalassinoides* in this sandstone facies are suggestive of shoreface facies environment. Calcarenite inferred to be deposited as sandy tidal to beach to shelf-lagoonal regime and the diversified fossil assemblages indicate distinct lateral variation in rock record. An attempt to interpret various lithofacies in a sequence stratigraphic framework has brought out that the Kulakkalnattam sandstone and Anaipadi Calcarenite facies represent TST deposits, the shell rich Garudamangalam limestone formed under MFS conditions, followed by arenite facies of Saturbhagam characterizes HST within the Garudamangalam sequence.

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NOTES

RECONSTRUCTION OF LATE QUATERNARY SEDIMENTARY DEPOSITIONAL ENVIRONMENTS OF LOWER GODAVARI DELTA BASED ON MICRO-PALAEONTOLOGICAL, SEDIMENTOLOGICAL AND PALYNOLOGICAL CRITERIA

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Hydrocarbon explorations are being actively carried out for more than two decades in both offshore and onshore Krishna-Godavari basin. Micropalaeontological, sedimentalogical and palynological studies were carried on a 200m long sedimentary core (SH-2 well), drilled in the lower Godavari delta, to decipher the Late Quaternary sedimentary depositional environments. 100 sub-samples were analyzed for foraminifera and ostracoda, sediment type/ texture (sand % and silt+clay %) and palynomorphs (pollen and spores, dinocysts, algae, etc). It was observed that the lower and upper sections of the well are fossiliferous, whereas middle section is poorly fossiliferous to unfossiliferous. Foraminifers are abundant to common and ostracoda is common to rare. Sediment type is mostly mud and muddysand. Mangrove and dinocysts are present at two levels of the well. Based on these results, palaeosedimentary depositional environments were identified from bottom to top of the well, e.g. shallow marine (open sea, inner shelf) fluvial and marginal marine/ brackish water environments. These sequences reflect the sea level variations and progradation of this part of the delta during the Late Quaternary Period which will be helpful to build-up the Quaternary architecture of the Godavari delta. This model can be projected to understand the Neogene/ Palaeogene sedimentary package of delta that can be useful in hydrocarbon exploration.

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PLANKTONIC FORAMINIFERAL DIVERSITY AND CHANGE IN LATE QUATERNARY ENVIRONMENTS OF A SEDIMENTARY CORE FROM THE LOWER BENGAL FAN

NOTES

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Bengal fan, the largest deep sea fan in the world, extends from Latitudes 20°N to 7°S with a total length of 3000 km and width of 2000 km. A 160cm long sedimentary core sample was collected from the lower Bengal fan and was divided into 40 sub-samples. These were analysed for planktonic foraminiferal studies. Three diversity indices such as Simple Species diversity (S), Shannon Weiner diversity H(S) and Equitability (E) were measured for planktonic foraminifera and used in the present investigation to determine the environmental variability, if any. S, H(S) and E range from 2-14, 0.61-2.25 and 0.48-1.0 respectively. Three major peaks and depressions were observed among all the diversity indices from bottom to top of the core. It can be suggested that these variations in planktonic foraminiferal diversity were caused due to environmental change during the Late Quaternary Period in the lower Bengal fan region and at this core location in particular.

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LATE QUATERNARY PALAEOCLIMATE: INFERENCES FROM SEDIMENTARY AND POLLEN RECORDS OF SOUTH WEST COAST OF INDIA

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Sediments and peat records of the coastal environments present an ideal archive to study the past fluctuations in climate and environmental systems. The temporal variations in sedimentation rates and pollen records serve as good proxies to understand the Late Quaternary palaeoclimate. Sediment and peat samples from a borehole near Cochin, southwest coast of India were recovered and analyzed for sediment characteristics, C^{14} ages and pollen analysis to understand the environmental changes during the Late Quaternary. Southwest coast of India is characterized by various landforms such as lagoons, barrier islands, beach ridges, palaeostrandlines, alluvial plains, marshy lands and flood plains. Peat deposits of Middle to Late-Holocene age occur along the coastal tracts at varied subsurface levels. The sediment characteristics suggest that the climate varied during the Late Quaternary, and consequently the rainfall and sediment input to the coastal and marine environments. Occurrence of peat deposits at subsurface levels reveals that mangrove vegetation was predominantly present along the coastal tracts in the Late Quaternary period, subsequently inundated by the higher sea levels, and led to the formation of peat deposits.

The pollen analysis of peat samples reveals abundant occurrence of Rhizophoraceae pollen (core mangrove). Occurrence of other plant taxa assignable to Combretaceae, Anacardiaceae, etc., in low to moderate values, indicates existence of peripheral mangroves. The major midland taxa are Oleaceae, Fabaceae (legumes) and Meliaceae whereas Poaceae, Lamiaceae, Urticaceae, Asteraceae, Apiaceae and Chenopods, being ubiquitous, are present in low to moderate numbers. Plant derived organic matter, with fungal and pteridophytic remains, was also recorded in the collected sediments. The samples represent important sub-environment of the delta during seasonal hydro-periods that indicate variable influence of brackish water – fresh water revealed by the deposition of various palynomorphs. Humid climate accounts for the development of mangrove vegetation, as the abundant rainfall increases the continental drainage.

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NOTES

PALAEOECOLOGICAL SIGNIFICANCE OF BENTHIC FORAMINIFERAL SPECIES *ASTEROROTALIA TRISPINOSA*: A CASE STUDY

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As a part of the 'Indo-Myanmar Joint Oceanographic Studies' 13 gravity cores and 126 surface sediment samples were collected using a modified Peterson grab ranging from a water depth of 10 to 1030 m, on board ORV Sagar Kanya in April 2002, on the West Coast of Myanmar and the northern Andaman Sea, specifically on the Ayeyarwaddy continental shelf.

During the study of Recent benthic foraminiferal distribution in the region we observed that the occurrence of the species *Asterorotalia trispinosa* was ubiquitous in surface samples. Speciation in foraminifera being a function of their ecology and habitat, the ecological behavior of single foraminiferal species has been used extensively to draw palaeoclimatic interpretations. Though many previous workers have reported the occurrence of *A. trispinosa* as a major constituent in foraminiferal assemblages, its ecological significance has never been studied before. In order to understand the same, the abundances of *A. trispinosa* were determined and correlation analysis was performed using STATISTICA 5.0 to understand the relationship between its distribution and the physical parameters at the respective locations.

Of more than 300 species recorded from all the surface sediments, the occurrence of *A. trispinosa* was observed in 39 samples with abundances ranging from ~1 to 43%. Correlation with station wise physical parameters like sand-silt-clay, salinity, temperature and TOC revealed that *A. trispinosa* prefers low salinity and muddy substrates.

The ecology of *A. trispinosa* should thus be useful as a proxy for wet and dry periods of the past. To use this result, the downcore variation in the abundances of *A. trispinosa*, its Mean Proloculus Size, maximum diameter and stable isotopic values were analyzed, in sediments of the core GC-5 (178cm) collected at 35 m water depth on the delta front. The studies revealed that the Mean Proloculus Size of *A. trispinosa* is inversely proportional to salinity. 4 major wet periods are observed at 330, 476, 571 and 675 C-14 years BP. Prior to 675 C-14 years BP, the study area experienced a prolonged drier period with occasional and minor wet phases.

Reported from all the Eastern deltas of the world (along the East Coast of India, Myanmar, Taiwan) *Asterorotalia trispinosa* is absent in the Arabian Sea and all other deltas of the world. Thus, its distribution suggests that the study area belongs to the Indo-pacific foramo-geographic province.

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MICRO AND MINISTROMATOLITES FROM THE NEOPROTEROZOIC BHANDER LIMESTONE (UPPER VINDHYANS), CENTRAL INDIA

NOTES

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The paper records well preserved micro and ministromatolites from the bedded cherts of the Bhander Limestone, Maihar-Satna area, Satna district, Madhya Pradesh. These have been described from the petrographic thin sections of chert. The size of the stromatolite ranges from 0.12 to 4.8 mm in height and from 0.1 to 2.75 mm in width. On the basis of size, type of branching and their relationship with the bedding, five different stromatolite morphologies are identified. Two forms belong to ministromatolites and three to microstromatolites. The stratigraphic significance of the stromatolites is discussed

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CAMBRIAN ICHNOFOSSILS FROM THE PARAHIO VALLEY OF SPITI BASIN, N-W HIMALAYA: THEIR PALAEOECOLOGY AND PALAEOENVIRONMENTAL IMPLICATIONS

NOTES

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The Cambrian succession of Spiti- and Zanskar basins of the NW Himalaya represents not only the best preserved sections but also exposes the largest synclinorium of Tethys Himalayan succession. This part of the Tethyan Himalaya documents extensive sedimentary record from Precambrian onwards. The present work, however, is restricted to the Cambrian succession of the Parahio Valley. The Cambrian Parahio (=Kunzum La) Formation of the Spiti Valley represents the oldest sedimentary rocks with well preserved fossils and sedimentary structures The diverse assemblage of ichnofossils recorded from the Parahio Valley ranges in age from Early to Middle Cambrian. The Ichnofossil assemblage indicates change in abundance and diversity throughout the succession. The ichnofossils belong mostly to the *Cruziana* ichnofacies and can be assigned to the behavioral categories from cubichina, domichina, pascichina and fodinichnial behaviors. The abundance and diversity of ichnofossils is prominent in the Lower Cambrian, and are indicative of low current velocity and low to moderately oxygenated waters. The ichnocenosis dominates the high behavioral diversity from suspension to deposit feeders. The palaeoecological community inhabiting oxygen deficient condition was well adopted for the turbulent setting, stability of substrates and nutrient influx. The diversity of ichnofossils is high in the sediments deposited in shelf environment which indicates the possibility of ecological disturbance.

Field observations and lithological details reveal three lithofacies for the Cambrian succession exposed in Parahio Valley. The relationship of ichnofacies and lithofacies indicates anaerobic to dysaerobic trends. The temporal stratigraphic trend indicates an overall upward coarsening of the sediments. The ichnofossil assemblage permits the interpretation of the palaeoecological conditions for elucidating the temporal palaeoenvironment and palaeoecological conditions during the Lower Cambrian. It supports shallow to deep water marginal basin with low energy depositional environment varying in degree of bioturbation.

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FOSSIL FROG FROM THE LOWER SIWALIK DEPOSITS OF JAMMU

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Micropalaeontological investigations of the Lower Siwalik Subgroup of Jammu province have resulted in the delineation of three microvertebrate-bearing horizons near Ramnagar, Raun and Jhajjar Kotli. Of these, one exposed about 8 km southwest of Ramnagar, near village Dehari, yielded a rich microvertebrate assemblage represented by many taxa of fishes, crocodilies, snakes and mammals, particularly rodents. Based on the stratigraphic range of *Kanisamys potwarensis,* the fossiliferous level has been assigned an age of 14.3 to 13.3 Ma. Four, almost complete, ilia of Anura were also recovered from this horizon. The ilia recovered from the Lower Siwalik deposits of Jammu are assigned to the subfamily Discoglossinae on account of overall morphological similarities, viz. relatively small subacetabular region, nearly circular acetabular fossa, small dorsal prominence and relatively high dorsal crest. These ilia differ from Alytinae, Bombinatorinae and Gobiatinae in having a prominent iliac crest. They show a set of characters that does not correspond to any known genus of Discoglossinae. It is therefore not possible to assign any generic status to the ilia, but they most likely represent new taxa. Until now, only a couple of reports on Siwalik frogs were published which pertain to ranid frogs. The present find represents the first report of discoglossid frogs from the Siwalik strata of the Indian subcontinent.

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PALYNOASSEMBLAGES FROM THE LOWER SIWALIK SEDIMENTS OF ARUNACHAL PRADESH AND DARJEELING FOOTHILLS

NOTES

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The present study highlights palynoloassemblages recovered from the Lower Siwalik (Middle-Late Miocene) of Arunachal Pradesh (Dafla Formation) and Darjeeling foothills (Gish Clay Formation). Diverse types of palynofossils, consisting of algal and fungal remains, pteridophytic spores and gymnosperm and angiosperm pollen were recovered from these sediments. The palynofloral data have been applied in palynostratigraphy and in deducing palaeoclimate and depositional environment of the studied sequence.

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BRACKISH WATER TRACE FOSSILS FROM EOCENE CORES OF NORTH CAMBAY BASIN, GUJARAT

NOTES

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The Eocene subsurface rocks of North Cambay Basin, Western India (Linch and Nandasan area) comprise essentially of Cambay Shale, Kadi and Kalol formations. These formations are clastic in nature, showing coarsening upwards sequences, and consist of medium to fine grained sandstones, siltstones, silty and carbonaceous shales with thin lignite bands having woody matters, resins, leaf impressions and sideritic nodules. These are characterized by well developed and abundant but ethologically, low diversified trace fossils. Twelve ichnogenera are developed in the cores of these formations, viz. *Chondrites, Cochlichnus, Diplocraterion, Gyrolithes, Monocraterion, Palaeophycus, Planolites, Skolithos, Taenidium, Teichichnus, Thalassinoides* and *Zoophycos*. These ichnogenera are arranged into seven recurring trace fossil associations, with non-descript passive filled burrows and fugichnia (escape structure). These associations are characterized by distinct groups of trace fossils that collectively reflect specific environmental conditions which were recurrent in space and time during the deposition of the Eocene rocks. Low taxonomic diversity to monodominance and size dwarfism of these trace fossil associations indicate that the deposition of the Eocene sediments took place in low energy, brackish water and reducing conditions.

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CLIMATIC CHANGES IN EAST ANTARCTICA DURING THE HOLOCENE-A PRELIMINARY STUDY

NOTES

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During the austral summers of 25th and 26th Indian Antarctic Expeditions (2005-06 and 2006-07), palaeolakes and the drying lakes of the Schirmacher Oasis region of East Antarctica were marked and glaciolacustrine sediments were collected for high resolution palaeoclimatic studies using various parameters, viz. mineral magnetism, sedimentology, clay mineralogy, geochemistry and palynology. This region is known for more than 100 pro-glacial, land locked and epi-shelf lakes. Evidences from the presence of >1 m thick sedimentary fill in the SO show that the oasis must have been a host of big lake systems in the recent past. Our observations record the presence of 6 major lakes during the Quaternary Period. Several of these lakes have been reduced to mere lakelets and ponds. Lithological study of several sections in east-west transact along SO was made. These lacustrine sediment-fills seem to be a potential source of information to trace the Quaternary geological history and palaeoclimatic records. The rock magnetic measurements, carried out at Palaeomagnetic Laboratory of the Wadia Institute of Himalayan Geology, Dehradun, included low-field mass specific susceptibility (χ), anhysteric remanent magnetization (ARM) and isothermal remnant magnetization (IRM) at increasing steps till 1500mT and backward fields till -300mT. Various interparametric ratios, [IRM (-0.3T), ARM/ χ, SIRM/ χ and ARM/ SIRM] were calculated for final interpretations. Variations inχ, IRM's, SIRM reflected gross change in relative concentration of magnetic minerals while the interprametric ratios ARM/ χ, SIRM/ χ reflect the magnetic grain size. On the basis of these results, coupled with published palynological data, it can be said that, during the early Holocene, Antarctica experienced a trend towards warming climatic conditions intervened by a cold dry phase at ~8.3 Ka BP. Climatic optimum and deglaciation is recorded from ~8 to 3 Ka BP with a brief cooling phase at ~4.5 Ka BP. From ~3 Ka BP onwards, the climate is deteriorating and shows a cold climatic phase. Our ongoing studies on other proxies, viz. palynology, isotopes, geochemical analysis, etc., would supplement this data-set.

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CHANGING AGRICULTURAL PATTERNS DURING HARAPPAN PHASES IN RELATION TO SOCIAL AND ENVIRONMENTAL CHANGES AT KANMER, KUTCH DISTRICT, GUJARAT

NOTES

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The north-western part of Indian subcontinent is the centre of Harappan or the Indus Valley Civilization where urban settlement is thought to have begun during 3rd millennium BC. The present paper embodies the recently generated palaeoethnobotanical data from a site Kanmer (Lat. 23°23'N: Long. 70°52'E) in Kutch District, Gujarat, covering the cultural time span of Early (2800 BC) to Late (1500 BC) Harappan phase. The crop economy during Early Harappan phase comprises mainly of winter crops and their associates like common vetch, Cheno/Ams and indigo. The crop assemblage reveals decrease in the winter crops (barley, bread-wheat, field-pea) and dominance of summer crops (rice, cotton, millets, black-gram) during Late Harappan phase, suggesting changes in agriculture patterns in relation to shifts in the socio-economical structure while progressing from Early towards Late Harappan time. The above find indicates weak winter or north-east monsoonal activity, resulting into dry and semi-arid climate during Late Harappan time in this region near Little Rann of Kutch.

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PALAEOBIOLOGY OF SEDIMENTARY DEPOSITS EXPOSED AROUND TAKEN AREA OF SOUTH REWA BASIN, MADHYA PRADESH

NOTES

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The South Rewa Basin is a discontinuous graben along the northern part of Son-Mhanadi geofracture and transects the Indian shield in the middle of the peninsula. The lithological lay-out in the basin documents various formations, from Pali to Bansa, and is overlain by the Lameta Formation or alluvium. The plant fossils, belonging to pteridophytes, cycadophytes and conifers, have been collected from carbonaceous shale. Floral assemblage on the whole is dominated by pteridophytes and conifers and is closely comparable to Dhrangadra, Gardeshwar and Himmatnagar floral assemblages of western India. The floral documentation suggests subtropical to tropical palaeoclimate and an Early Cretaceous age is assigned for these sedimentary deposits.

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NOTES

BIOSTRATIGRAPHIC AND EVOLUTIONARY SIGNIFICANCE OF PROTEROZOIC ORGANIC-WALLED MICROFOSSILS FROM VINDHYAN BASIN

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Latest biostratigraphic studies on Vindhyan sediments in Son Valley have shown the occurrence of characteristic Upper Palaeoproterozoic to Terminal Proterozoic organic-walled microfossils (acritarchs, nematomorphs and synaplomorphs). Biostratigraphic significance of some globally known and age-marker Proterozoic organic-walled microfossils from the Vindhyan sediments, is discussed in the light of latest radiometric (SHRIMP) dates.

In basal Semri succession, Kajrahat Limestone recorded filamentous microfossils and sphaeromorphs which correlate with Upper Palaeoproterozoic assemblages, and the inferred age broadly corroborates the absolute dates of Kajrahat Limestone (1729±110 Ma). Appearance of *Tappania* and *Satka* in Deonar Formation and their abundance in overlying Koldaha Shale with appearance of *Navifusa, Pterospermopsimorpha* and *Simia* and disappearance of *Tappania* are the remarkable features of the assemblage. In the succeeding Rampur Formation, important biostratigraphic events have been noticed. Latest SHRIMP dates for Deonar and Rampur formations, 1631±5Ma and 1599±8Ma respectively, suggest that above forms appeared during latest Palaeoproterozoic and are important elements of Lower Mesoproterozoic assemblages. Occurrence of budding leiosphaerids, and vase-shaped microfossils in Rampur Formation (ca. 1599 Ma), known for their appearance close to Meso-Neoproterozoic boundary (ca. 1000 Ma), reveals that these forms appeared during Palaeo-Mesoproterozoic transition. Similarly, 1599±48Ma absolute date for Rohtas Subgroup indicates that *Trachysphaeridium, Stictosphaeridium* and *Lophosphaeridium* also made their appearance during Lower Mesoproterozoic (ca. 1550 Ma).

Sediments of Kaimur Group recorded abundant coccoids and leiosphaerids. The absence of distinctive aforementioned Semri microfossils indicates a Lower Neoproterozoic age. However, K/ Ar dates of ca. 1140-940 Ma for this unit suggest Upper Mesoproterozoic-Lower Neoproterozoic age. Rewa Group is marked by the Upper Neoproterozoic marker acritarchs, suggesting Upper Cryogenian (ca. 700-630 Ma) age. Bhander Group shows the presence of exclusive Terminal Proterozoic microfossils, viz.

Obruchevella spp. and large acanthomorphs, that characterize the Ediacaran (ca. 630-542 Ma) organic-walled microfossil assemblages world-wide. Radiometric dates of 710-675Ma and 625±24Ma for Rewa and Bhander groups respectively corroborate microfossil age evidences.

The latest absolute datings of ca. 1750-1700 Ma (Upper Palaeoproterozoic) for Mirzapur Group, ca. 1635-1450 Ma (Upper Palaeoproterozoic-Lower Mesoproterozoic) for Semri Group, ca. 1140-940 Ma (Upper Mesoproterozoic-Lower Neoproterozoic) for Kaimur Group and ca. 710-542 Ma (Upper Neoproterozoic-Terminal Proterozoic) for the Rewa-Bhander groups, covering a time span of about 1200 Ma (ca. 1750-542 Ma), reveal that Vindhyan units are bounded by large unconformities. Though, its age ranges from 1750 Ma to 542 Ma (duration ca. 1200 Ma), the actual sedimentation period is only 350-400 Ma, and the major Proterozoic time-span is attributed to non-depositional/ erosional hiatuses. The span of hiatuses between Mirzapur and Semri groups (ca. 70 Ma), Semri and Kaimur groups (ca. 300 Ma) and between Kaimur and Rewa-Bhander groups (ca. 250 Ma) is discussed. Available microfossils and radiometric age evidences suggest that the Vindhyan succession had four sedimentary packages (basins) at different Proterozoic times.

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PALYNOLOGY OF LOWER SIWALIK SEDIMENTS (MIDDLE MIOCENE) OF KOILABAS AREA, WESTERN NEPAL AND THEIR PALAEOECOLOGICAL SIGNIFICANCE

NOTES

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The fossil locality Koilabas lies at Indo-Nepal border in Dang Section of the Churia Hill in western Nepal. In this area, the Lower Churia Formation is observed from Koilabas to Darwaja containing fine grained sandstone beds with variegated clay with some pebbles.

The present study highlights the palynoassemblage consisting of algal (2 genera and 2 species) and fungal (5 genera and 5 species) remains, petridophytic spores (5 genera and 8 species), gymnosperm (6 genera and 10 species) and angiosperm (6 genera and 6 species) pollen. Plant megafossils, belonging to several dicotyledonous families, have also been recorded from Koilabas. Based on qualitative and quantitative analyses, it is inferred that gymnosperm pollen dominate the pteridophytic spores followed by fungal remains and angiosperm pollen. Important genera present in the assemblage are: *Zygnema*, *Botryococcus*, *Lygodiumsporites*, *Lycopodiumsporites*, *Striatriletes*, *Inaperturopollenites*, *Tsugaepollenites*, *Pinuspollenites*, *Abiespollenites*, *Piceaepollenites*, *Retistephanocolpites* and *Graminidites*. Based on their affinities with modern equivalents, a humid, tropical to sub tropical climate has been inferred during the deposition of sediments. A fresh water environment has been interpreted for the Lower Siwalik sediments. Algal remains, viz. *Zygnema* and *Botryococcus* colonies, provide cogent evidence for this observation. The presence of algal and fungal remains, fern spores (*Lycopodium*, *Ceratopteris*) and grass pollen indicates that the prevailing flora was mainly wet, open and of mixed nature. Plant fossil evidences depict an evergreen to moist deciduous vegetation in the area during the time of deposition. The gymnosperm pollen (*Abies*, *Picea*, *Pinus* and *Tsuga)* were possibly derived from the high mountains in the north.

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CLIMATE AND RELATIVE SEA LEVEL CHANGES AS REFLECTED IN THE PALYNOFLORAL AND PALYNOFACIES DISTRIBUTION DURING PETM EVENT IN MEGHALAYA

NOTES

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Palaeocene Eocene Thermal Maxima (PETM) event represents one of the most profound global warm periods in the entire Cenozoic Era. The record of this warm interval is spread all over the globe and is being studied extensively. The temperature related climatic as well as vegetational changes are more pronounced in the mid to high latitudinal regions. In order to assess these changes in low latitude, two shallow marine successions encompassing Palaeocene-Eocene transition, from Jathang and Cherrapunji areas of Khasi Hills, Meghalaya have been investigated. The studied successions comprise coal bearing clastic sandstone (Lakadong Sandstone) sandwitched between underlying Lakadong Limestone (SBZ3-SBZ5) and the overlying Umlatodoh Limestone (SBZ7-SBZ11). The study involves dinocysts/ palynofacies analyses and bulk geochemistry to characterize PETM interval and to decipher palaeoecological and sea level changes related with this event. The PETM interval is demarcated by negative carbon isotopic excursion peak and *Apectodinium* dinocyst acme in the upper part of the succession. Climate, vegetation, sediment supply and sea level fluctuation play an integral role in the diversity and abundance of marine and terrestrial palynomorphs in the shallow marine region. Maximum distance cluster analysis was performed to identify palynomorph clusters of palaeoecological significance. Seven palynomorph clusters were identified in the present study. The rarefaction and detrended correspondence statistical analysis were used to assess the palynofloral diversity pattern as well as charcterization of various sub-environments of coastal marine region. The study reveals considerably low diversity of terrestrial palynoflora prior to PETM event and enhanced diversity pattern subsequent to the event. The depositional facies represent a shallow marine stratigraphic record reflecting sea level fluctuations, responsible for frequent facies related changes. Palynofacies studies were carried out to interpret palaeoenvironmental changes and to identify sequences, parasequences and systems tracts corresponding to 3rd and 4th order sea level cycles within a precise dinocyst and benthic foraminifera chronobiostatigraphic framework. The studies show that the high sediment supply as a result of excessive warm and humid climate of PETM in low equatorial zone during slowly

rising sea level resulted in the conversion of carbonate ramp into a clastic dominated coastal marine set up with extensive development of fresh water marshes brackish lagoons and estuarine and bay fill deposits within a Transgressive Systems Tract.

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PALYNOSTRATIGRAPHY AND PALAEOENVIRONMENTAL INTERPRETATION OF PALAEOGENE SEQUENCES OF TAPTI-DAMAN SECTOR, MUMBAI OFFSHORE, INDIA

NOTES

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Biostratigraphic and palaeoenvironmental studies on Panna, Belapur, Diu, Mahuva and Daman formations in the Tapti-Daman Block enabled identification of nineteen dinoflagellate biohorizons in the Panna, Belapur, Diu, Mahuva and Daman formations in ten wells drilled in Mumbai Offshore.

The significant dinoflagellate cyst events are LAD Impagidinium dispertitum, 26Ma (top of Chattian, Late Oligocene) to LAD Palaeoperidinium pyrophorum, 58Ma (Thanetian-Late Palaeocene), based on the globally recognized dinoflagellate biohorizons. Two hiatuses, one ca. 48-51 Ma between Panna and Belapur formations (Early and Middle Eocene) and another ca. 36-39.4 Ma between Diu and Mahuva formations (Middle-Late Eocene and Early Oligocene) are identified.

Fluvial environment was mainly prevalent during the deposition of Panna Formation. Subsequently, due to marine incursion in the area, it was under marginal marine to shallow inner shelf and inner shelf during the deposition of younger formations. During the deposition of Daman Formation, the area experienced mainly inner shelf to middle shelf condition due to transgressive phase. Palaeogeographic maps at the top of Panna, Diu, Mahuva and Daman formations helped in understanding depositional set-up in the Tapti-Daman area.

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MODERN POLLEN RAIN STUDY IN THE TROPICAL DECIDUOUS FOREST IN UMARIA DISTRICT, MADHYA PRADESH

NOTES

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Pollen analytical investigation of 6 surface samples from the tropical deciduous forest from Paudi, Umaria District, Madhya Pradesh has been executed in order to understand the modern pollen/ vegetation relationship in the region. The pollen assemblage, in general, demonstrates the dominance of nonarboreals (herbs) and relatively low frequencies of arboreals (trees and shrubs). Among the arboreals, *Madhuca indica*, *Holoptelea, Acacia*, etc. are retrieved very frequently in most of the samples and the representation of these taxa corresponds largely with their composition in the forest floristic. However, excessively high frequencies of *Madhuca indica*, particularly in some of the spectra (P-3 and P-6) could be attributed to its local preponderance around the provenance of the samples. On the other hand, *Shorea robusta* and other forest components, viz. *Terminalia, Mitragyna, Adina cordifolia*, *Aegle marmelos*, *Lannea coromandelica*, *Sterculia*, etc. were encountered very sporadically, despite their frequent presence in the forest. The under-representation of these taxa could be attributed to their low pollen production, since majority of the tropical trees portray a strong tendency of entomophilly. Grasses (Poaceae) followed by Tubuliflorae (Asteraceae), *Xanthium*, sedges (Cyperaceae), etc. are the prominent constituents of ground flora and their presence in appreciable frequencies in the pollen spectra compares more or less with their factual occurrence in the herbaceous complex. The record of pollen of cerealia and ruderal plants, viz. Brassicaceae and Cheno/ Am depicts the proximity of cultivated land and human habitation to the investigated site. The abundance of fern spores, though in fluctuating values, envisages their origin from the local sources as ferns and their allies flourish well in moist and shady depressions in the forests. Furthermore, a large number of arboreal and nonarboreal taxa occurring in good proportion in the extant vegetation are entirely untraceable in the sediments. This might have occurred due to selective preservation as well as microbial degradation of their pollen in the sediments. The comparative data base generated on pollen/ vegetation relationship will be used as modern analogue for the precise evaluation of fossil pollen spectra to be prepared from the region in terms of past vegetation and climate.

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DO DIATOMS FROM INDIAN SECTOR OF SOUTHERN OCEAN REFLECT SURFACE WATER HYDROGRAPHY?

NOTES

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The spatial distribution of different diatom species, their relationship with changing sea surface temperature (SST), salinity and nutrient availability, were studied in the Indian sector of Southern Ocean by using six core top sediment samples and 34 surface water samples collected during the austral summer 2004. Additionally, a comparison of surface water samples and sediment samples was carried out to understand past and present latitudinal distribution of different diatom species. In both surface water and sediment samples, *Fragilariopsis kerguelensis* dominates the diatom community. Other major species identified include: *Fragilariopsis separanda, Thalassiothrix* spp., *Thalassiosira lentiginosa, Eucampia antarctica Thalassionema nitzschioides* and *Azpeitia tabularis.* However, the species diversity and total diatom count in surface water samples is comparatively less than that of sediment samples. A total of 24 diatom species were identified in sediment samples and only 6 species were identified in surface water samples. The study revealed that in both cases the decreasing SST, salinity and increased nutrient availability in terms of nitrate, silicate and phosphate had a positive influence on the growth of diatoms, as deciphered by variation in distribution of diatoms from low to high latitudes.

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EFFECTS OF PETM IN SHALLOW INNER NERITIC ENVIRONMENT: DOMINANCE OF ACARININIDS AND ABSENCE OF MOROZOVELLIDS IN JAISALMER BASIN, RAJASTHAN

NOTES

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Jaisalmer Basin, the eastward extension of the Indus Basin has recorded a thick neritic early Palaeogene sequence. The Palaeocene/Eocene boundary global warming event, Palaeocene Eocene Thermal Maximum (PETM), has been recorded by a number of workers in the mid-outer neritic to bathyal environment. However, the evidence of PETM in inner neritic to middle neritic environments remains quite poorly recorded so far. The present study documents the planktonic foraminiferal changes across the Palaeocene/ Eocene boundary in a nearshore environment. The early Palaeogene sedimentary sequence in Jaisalmer Basin is recorded from the samples of RAM-1 well (Oil India Ltd.) near Ramgarh area (Lat. 27°23'N: Long. 70°30'E) and from boreholes SDC-49 near Sanu village (Lat. 27°15'N: Long.70°39'E) and JOGA-99 near Joga village (Lat. 27°20''N: Long. 70°42'E). The samples of the studied sub-surface sections are mainly composed of sandstone, clay and marl along with some limestone and shale. The basal sandy parts contain better preserved planktonic foraminiferal tests as compared to the carbonate rich beds. Planktonic foraminiferal assemblages are mainly dominated by low latitude acarininids (e.g. *Acarinina esnaensis, A. wilcoxensis, A. strabocella, A. nitida, A. mckannai, A. soldadoensis* and *A. pseudotopilensis*). The occurrence of the planktonic foraminiferal excursion taxa, viz. *Acarinina sibaiyaensis* and *A. africana* indicates the presence of Zone E1 which is related to the global Palaeocene/ Eocene boundary event known as PETM. The maximum diversity of the acarininids occurs in the Zone E1 and coincides with most of the Palaeocene/ Eocene sections world over. On the other hand morozovellids are rare to absent. In the studied areas, presence of *Morozovella praeangulata, M. angulata, M. conicotruncata* and *M. velascoensis* (Zone P2-P3) indicates an initial transgressional phase. Morozovellids are almost absent in the Zone P4-P5 and are completely absent in the *Acarinina sibaiyaensis* and *Pseudohastigerina wilcoxensis* subzones. In Tanot-1 well, a few kilometres away from the studied sections towards the sea, morozovellids are present throughout the Palaeocene-Eocene sequence, signifying an open marine environment. Thus the absence of the morozovellids can be referred as an indication of a shallow inner neritic deposition. Abundant larger foraminifers, dominated by *Nummulites, Assilina* and *Daviesina,* occur in

the argillaceous limestone along with the planktonic foraminifers, signifying an inner neritic shelf environment. The reappearance of the morozovellids (*Morozovella edgari*) at the top of the Zone E2 indicates another transgressional phase in the area.

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EARLY JURASSIC CALCAREOUS NANNOFOSSILS FROM PATCHAM ISLAND, KUTCH, WESTERN INDIA

NOTES

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The Patcham Island represents the westernmost highland of Island belt, containing oldest rocks in Kutch basin. The stratigraphic sequence of Patcham Island is divided into older Kaladongar Formation and younger Goradongar Formation. The Kaladongar Formation is exposed in Kuar Bet Islet about one km northwest of Patcham, which is the last outcrop within Indian Territory. The Kaladongar Formation is divided into Dingi Hill and Kaladongar Sandstone members. The Dingi Hill Member is exposed here as intermittently broken small escarpment sections starting from Indira Bridge to the outer periphery of the Island. The sections ehhibit thinly bedded alternations of green and red siltstones and hard calcareous sandstones with abundant ichnotaxa. At Point 16 in Kuar Bet (=Mori Bet) the exposures are seen in a hillock. The top of the hillock is full of pelycepods and rare gastropod shells and the lower part shows current and flaser bedding. In the middle of current lamination a sample (GPS location Lat. 23°59'40"N: Long. 69°42'28"E) has yielded calcareous nannofossils.

The following nannotaxa have been recovered: *Biscutum finchii, Biscutum* sp., *Bussonius prinsii, Crepidolithus crassus, C. pliensbachensis, Crucirhabdus primulus, Diazmatolithus lehmanii, Discorhabdus criotus, Ethmorhabdus gallicus, Lotharingius contractus, Mitrolithus elegans, Octopodorhabdus* sp., *Schizosphaerella* sp., *Triscutum* sp., *Tubirhabdus patulus, Watznaueria barnesae* and *W. fossacincta.*

Presence of *Biscutum finchii* (FAD NJ5, LAD NJ6), *Bussonius prinsii* (NJ5B), *Crucirhabdus primulus* (NJ5B) and *Discorhabdus criotus* (FAD NJ7) suggests the placement of assemblage in NJ5 to NJ7 zones of Pleinsbachian to Toarcian age. NJ5 represents upper Pleinsbachian whereas NJ6-7 indicates lower Toarcian. This has wide palaeogeographical implication as it suggests that after faulting the transgressive event in Kutch basin might have taken place during Pleinsbachian-Toarcian time, i.e. about ?6-8 MA, earlier than ?Bajocian, a view accepted by many workers. Record of upper Pleinsbachian nannofossils from Masirah Island of Sultanat of Oman, Arabia strengthens this finding. Reworked Pleinsbachian-Aalenian nannofossils were earlier recoverd from Callovian sediments of Jara Dome situated in the easternmost extremity of mainland. Besides, record of statigraphically leaked Albian, middle Eocene and Miocene fossils is intriguing.

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CALCAREOUS NANNOFOSSILS FROM OTTAKOIL FORMATION (LATE MAASTRICHTIAN), CAUVERY BASIN, SOUTH INDIA

NOTES

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The NE-SW trending rift type of Cauvery basin is located in the southeastern part of Indian peninsular shield. The exposed part of Ariyalur-Pondicherry depression of this basin encompasses more or less complete rock record of Barremian-Danian age. However, owing to very low dip, scanty undisturbed exposures for geological study and concealment of rocks under alluvial cover, systematic documentation of Maastrichtian-Danian rock and palaeontologic record have been rare in the literature. Documentation of stratigraphic variation of geochemical and isotopic characteristics of these rocks, in the sequence stratigraphic framework, particularly along K/ T section, has shown the occurrence of double peaked nature of $^{87}Sr/^{86}Sr$, $\delta^{18}O$, $\delta^{13}C$, Ba and Si anomalies preceding K/ T boundary indicating stressful conditions prevailing much before the exact KTB. The recent studies have also concluded that owing to poor age control in terms of K/ T section of this area, exact positioning of these anomalies is difficult. Given cognizance to this, a specific study has been undertaken to analyze the K/ T section of the exposed part of Cauvery Basin.

Fifty five samples collected from top most of Sillakkudi Formation (Campanian) to top most of Niniyur Formation (Danian) by logging exposures, mine and well sections utilized in previous studies were taken for study of nannofossils. Almost all the samples studied have abundant organic matter and calcareous material, suggestive of possible presence of nannofossils. Nevertheless, only one sample from middle of Ottakoil Formation had yielded Late Maastrichtian calcareous nannofossils. Although the assemblage showed limited diversity and overgrowth of the forms preservation of most of the species is found to be excellent. The list of calcareous nannofossil taxa recorded in this sample are *Ahmuellerella octoradiata, Arkhangelskiella cymbiformis, Braarudosphaera bigelowii, Ceratolithus aculeus, Chiastozygus litterarius, Cyclagelosphaera deflandrei, Cribrosphaerella ehrengergii, Cribrosphaera* sp., *Eiffelithus gorkae, E. parallelus, E. turriseiffeli, Microrhabdulus undosus, Micula decussata, M. staurophora, M. swastika, Petrobrasiella? bownii, Prediscosphaera cretacea, P. spinosa, Stradneria crenulata, Staurolithites crux, Zygodiscus minimus* and *Z. spiralis*.

Common occurrence of large sized *Arkhangelskiella cymbiformis,* the LAD of which marks the base of CC25a and the presence of *Ahmuellerella*

octaradiata the LAD of which indicates top of UC20a^{TP} suggests the zonal placement of the assemblage in CC 25 *Arkhangelskiella cymbiformis* Zone equivalent to UC 19 nannofossil Zone of Late Maastrichtian age. In the light of these observations and the requirement of systematic and detailed analyses of K/ T environmental transition, studies on other exposed sections covering Late Maastrichtian and Danian are being undertaken currently.

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SIGNIFICANCE OF CALCAREOUS NANNOFOSSILS IN BIOSTRATIGRAPHY AND PALAEOENVIRONMENTAL/ PALAEOCLIMATIC INTERPRETATION

NOTES

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Calcareous nannofossils are the fossil counterpart of coccolithophores (tiny, marine, golden brown algae) belonging to Phylum Haptophyta and Division Prymnesiophyceae. Coccoliths are formed of calcite plates, biomineralised by the cells which are preserved as fossils in marine sediments, either as complete coccosphere or as coccoliths after disaggregation. These are abundant in sea floor sediments above the Calcite Compensation Depth (CCD) and their fossil record is continuous from Late Triassic to Recent.

Nannofossils are ideal for biostratigraphy, since they are abundant, planktonic, rapidly evolving and largely cosmopolitan. Due to their small size (1-25ìm), they can be studied from minute rock chips, ditch cuttings and sidewall cores, etc. which are of great value in hydrocarbon exploration and development.

This fossil group is also useful for various palaeoenvironmental studies, e.g. some holococcoliths (Family Calyptrosphaeraceae) indicate shallow depth near shore, warm water environment of deposition. Presence of many coccospheres in the sediments, not overlapping each other, is indicative of deposition in a calm water conditions. Some nannofossil species are more common in marginal seas while some are restricted to open oceanic environments.

Nowadays, coccolithophores are greatly utilized in palaeoclimatic interpretations. In palaeoclimatic reconstruction from the study of calcareous tests of nannoplankton, basically three types of analyses take place: i. oxygen isotope composition of calcium carbonate, relative abundance of warm and cold water species; and morphological variations in particular species resulting from various environmental factors.

For interpreting palaeotemperature in Mass Spectrometer oxygen isotopes are used. The abundance of isotope O^{16} is very large over O^{18}. Oxygen isotopes are utilized in palaeothermometery. It works on principle that the temperature affects the relative abundance of the heavy and light molecules of oxygen in the water escaping the sea surface. If records of oxygen isotope ratios are built up from cores of ocean sediments and are accurately dated, the ratios may provide a method of palaeoclimatic reconstruction.

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PHYTO-TAPHONOMY OF KOTA FORMATION, EAST COAST

NOTES

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Eastern peninsular India lodges a large intra-cratonic Gondwana Graben, Pranhita-Godavari, formed as a result of failed rift, which plunges into the peri-cratonic Krishna-Godavari Basin in the east coast. The south eastern continuation of the Kota Formation extends up to the Krishna-Godavari Basin in the east coast, where it is unconformably overlain by the Raghavapuram Formation The tectono-sedimentary domain of the basin houses richest fossils embedded in the Kota Formation. The Kota Formation is characterized by coarse to fine grained pebble sandstones, yellowish green clays, mudstones, grey creamy bedded limestones, ferruginous clays, sandstones and siltstones. Recovery of ostracods, estherids, fishes, amphibians, reptiles, insects, stromatolites, mammals, charophytes, spore-pollen, leaves and woods makes the sequence unique in attempting an integrated analysis of palaeoecology. The Kota ecosystem was heterogeneous and diverse with faunal and floral components. In the lacustrine beds, the presence of limestone and alternating mudstone to very fine sand layers indicates little clastic input. The lacustrine facies contain well-preserved fish, vertebrate and insect fossils. Plant components are relatively not well preserved. Available evidences and newly generated data have been evaluated for taphonomic interpretation. Plant assemblage recovered was almost entirely composed of disarticulated parts. Preservation potential of plant parts recovered from the clays/thin bands of brittle shales/ sandstones in general was poor. Recovery of wood fragments, cuticle pieces, spore-pollen demonstrates a depauperated plant assemblage. Hard parts, like wood, bear relatively more fossilization potential rather than soft parts like leaves. Preservation of organs varies enormously between different taxa instituting an important bias in the plant fossil record. Conifer leaves being robust represented fairly well. Stem axes of pteridophytes too are well preserved. Small size of leaves indicate buoyant-potency and transportation flexibility. Small leaf forms recorded belong to pteridophytes, bennettitaleans and coniferales. Much of the phytomass during the deposition of Kota Formation was lost as evidenced from the plant part preservation. Non-recovery of underground parts like roots, rhizomes and root-like structures suggests an allochthonous deposition. The distance and mode of transportation probably failed to preserve rich phyto-fossil assemblage. Biological degradation agents were poor. Different plant parts

got segregated and the whole assemblage in the low energy lake beds is represented by fragmentary parts of low lying plants. Debris from shrubs and trees directly adjacent to the lake margins might have been subjected to filtering process. Since direct relation between deposited remains and source vegetation hardly exists, different suites should be analysed for taphocoenoses reconstruction. Co-occurrence of plant parts from the same plant happens when the settling velocity of the parts is similar. Leaves are transported greater distances than other denser parts. Relative abundance of source vegetation was not accurately reflected in the relative abundances of plants in the sediment samples. Plant data reflect local environmental and taphonomic conditions. Search for palaeosoil and leaf litter layers may help to derive precise palaeoenvironment. The age of Kota Formation has been variously dated as early Jurassic (Liassic), Middle Jurassic and Early Cretaceous. Both micro- and macro- plant fossil evidences were evaluated considering other related evidences for palaeoenvironmental and biostratigraphic analysis.

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OCCURRENCE OF FORAMINIFERA AND DEPOSITIONAL ENVIRONMENT OF THE ARCHAEOLOGICAL SITE, ATTIRAMPAKKAM, TAMIL NADU

NOTES

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As foraminifera are exclusively marine in habitat, their occurrence in inland deposits warrants an understanding of the geological processes that resulted in their presence in such contexts. In this respect the occurrence of foraminifera in sediments associated with Palaeolithic artifacts at the archaeological site of Attirampakkam, located around 40 km inland, is unusual and is discussed in this paper. Attirampakkam is currently being excavated under the direction of the second author, and is a well-known Palaeolithic site with deposits of Middle to Late Pleistocene age. Acheulian tools of the Early Palaeolithic period, assigned to the Middle Pleistocene, were discovered for the first time in deposits which were previously assigned to the Avadi Series of Cretaceous marine shales. These occurred in a deposit termed Layer 6, to depths ranging from 6-7 m below the surface. The density of tools was high, and they were noted throughout this unit. Research conducted till date, indicates that the tools are, to a large extent, in-situ with only some degree of reworking, pointing to the redeposition of the shales through localized fluvial processes. These deposits also contained agglutinated foraminifera of Early Cretaceous age. This occurrence is attributed to the reworking of Early Cretaceous sediments by the palaeo-Kortallaiyar river sometime during the Early to Middle Pleistocene and roughly contemporary with the deposition of tools left behind by prehistoric hominins. The fresh unabraded nature of the foraminifera indicates localized transport. Further the occurrence of Pleistocene deposits directly overlying the Cretaceous deposits is attributed to the rejuvenation of existing pre - Pleistocene faults in this part of the Cauvery basin.

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PERMIAN AMMONOID RECOVERED FROM THE LINGTI ROAD SECTION, GUNGRI FORMATION, SPITI VALLEY, HIMACHAL PRADESH

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An ammonoid was recovered from a nodule of the Gungri Formation (latest Late Permian) exposed along Lingti Road Section, near Irrigation and Public Health Guest House, Spiti Valley, Himachal Pradesh. The ammonoid bearing nodule was collected ~8.13m below the contact of the Gungri Formation with Lilang Formation (lower-most unit of Lilang group). The Gungri Formation (7-22m), is composed of black splintery shale, steel-grey silty bands, calcareous and arenaceous shale with occurrence of nodules varying in shape and size. The ammonoid specimen shows relationship with genus *Cyclolobus* Waagen. Though it is fragile, dimensions and suture, as seen in the broken specimen, reflect clear comparability with *Cyclolobus walkeri*. The occurrence of this ammonoid from the Lingti Road Section, suggests development of Dzhulfian Stage of Late Permian in Spiti Valley.

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LATE PERMIAN MARINE SIGNATURES IN RAIGARH GONDWANA BASIN, CHHATTISGARH

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Talchir, Karharbari, Barakar, Barren Measures, Raniganj and Kamthi formations of Gondwana Group are developed in Raigarh Coalfield (Lat. 21°45'00" to 22°42'00"N: Long. 83°25'00" to 83°45'00"E). The Gondwana sediments of this coalfield are characterized by fine grained sandstones, claystone, grey shale and carbonaceous shale with two coal seams. Palynological investigation on the bore hole MJB-1 (12.05 m depth) from the Dharamjaygarh area, Raigarh District, Chhattisgarh yielded rich palynoflora dominated by striate bisaccate pollen (*Faunipollenites, Striatopodocarpites* and *Crescentipollenites)* in association with *Densipollenites* and *Arcuatipollenites* indicating late Permian age and correlatable with Raniganj palynoflora. Many vase shaped organic walled microfossils, along with *Leiosphaeridia, Brazilea, Tasmanites, Peltacystia* and *Hemisphaerium,* were also recovered indicating marine influence. Vase shaped forms, closely resembling tintinnids, suggest association of members of Celiophora. The present finding constitutes first record of marine influence in Raniganj Formationlevel (Late Permian) in the Raigarh Gondwana Basin. A comparison with marine signatures known from the late Permian sediments of Godavari, Jaisalmer, Son Valley (Johilla/ Singaruli) Rajmahal and Salt Range has been made. Occurrence of organic walled microfossils during late Permian sequences in Gondwana basins of India were correlated with global marine regression.

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FIRST REPORT OF THE OCCURRENCE OF *OPHIOMORPHA IRREGULAIRE* FROM THE KALLANKURICHCHI FORMATION, ARIYALUR GROUP, SOUTH INDIA

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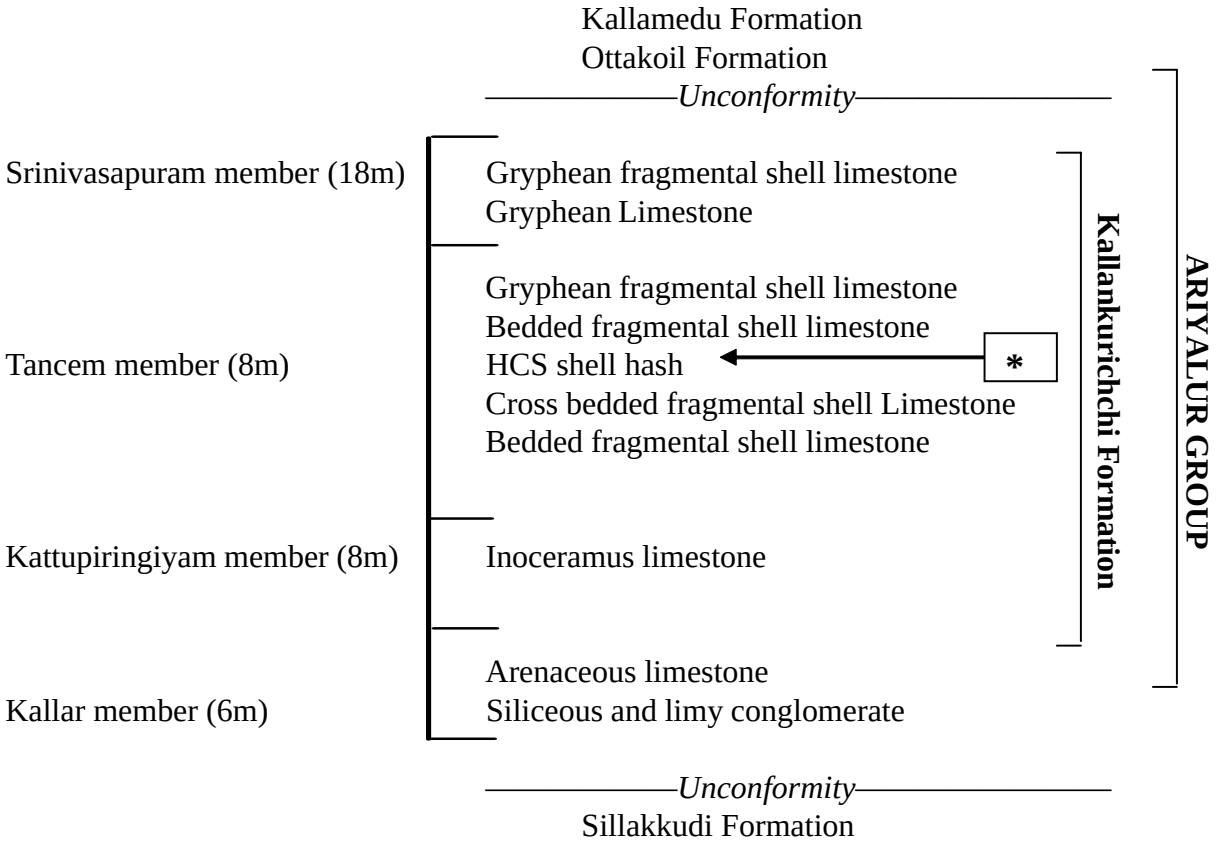
Owing to their insitu nature and resistance to post depositional alteration, the trace fossils offer reliable clues to palaeoenvironmental study than body fossils. Among trace fossils, the ichnogenus *Ophiomorpha* is best known to the palaeontologists and sedimentary geologists due to its abundance in Mesozoic and Cenozoic shallow and marginal marine deposits. The trace fossil *Ophiomorpha irregulaire* has been reported repeatedly from Blackhawk and Star Point formations of Utah. Occurrence of this fossil from other regions is found to be rare in literature despite its



* Stratigraphic position of *Ophiomorpha irregulaire* discussed in this paper.

striking morphology and large size. This paper reports, for the first time, occurrence of *Ophiomorpha irregulaire* colony, confined within storm beds of the Kallankurichchi Formation of the Ariyalur Group, Cauvery Basin, South India.

The Kallankurichchi Formation is part of Ariyalur Group and is a prominent carbonate unit exposed as isolated outcrops in the Cauvery basin of south India. The present study documents the occurrence of dense array of burrow systems that run horizontal to the bedding plane. The burrow system consists of straight horizontal tunnels with branching of "T" and "Y" shapes. The branches are located at right angles. The tunnels run for a distance of 3 – 11.5 cm with an average of 6.3 cm between swellings. The tunnels never cut through each other. The burrow systems are endogenic according to preservational classification as the burrows are within the sediment itself and the traces are found in full relief. Varying angle of branching of these tunnels from main tunnels is a typical characteristic of these burrows. Except in few places, there is no pentagonal interconnected tunnel. The material under study shows varied diameter of tunnels, varied shapes of nodes and increase of diameter at junctions and can be idetified as *Ophiomorpha irregulaire*. Similar to the characteristics of *O. irregulaire* at its type locality in Book Cliffs, U.S.A. the present specimens show smooth inner wall lining and sparse and irregularly distributed ovoid pellets and lumps of pellets on the outer wall. The Kallankurichchi Formation was first assigned a Maastrichtian age and later refined to Early Maastrichtian. Few workers have speculated the commencement of deposition of this formation during late Campanian-Earliest Maastrichtian. Recent study of this formation concluded that the Kallar member of the Kallankurichchi Formation was deposited during Latest of Campanian, the Tancem Member belong to Early Maastrichtian, from where present fossil find is being reported.

Occurrence of highly bioturbated layer of sediment immediately over storm deposits indicates colonization of burrowers on newly established favourable sites that were previously shallow shelf regions. Occurrence of *Ophiomorpha* typically in top bed of storm deposits and their absence in other deposits of the Kallankurichchi Formation is a peculiar phenomenon. Occurrences of such colonies over storm beds are interpreted to be omission surfaces and were considered to be important clues in recognition of stratal surfaces in sequence analyses of sedimentary basins.

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AGAMID LIZARDS FROM THE CAMBAY SHALE FORMATION (EARLY EOCENE), VASTAN LIGNITE MINE, WESTERN INDIA: PALAEOBIOGEOGRAPHIC IMPLICATIONS

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Terrestrial biotas offer good insight into dispersal and distribution of organisms in time and space. Lizards, in general, have been used for reconstruction of the origin, evolution and palaeobiogeographical importance since the Cretaceous. Gilmore established the utility of lizard assemblages in several sites in Central Asia (Mongolia) and North America and laid down the foundation of such studies.

In India, lizards are known from the Maastrichtian (Late Cretaceous) sediments associated with the Deccan Intertrappean beds and have recently been described in some detail. However, the fragmentary nature of the material has been a deterrent in establishing generic and specific identity. The lizards from the lower Eocene Vastan Lignite Mine (Cambay Basin, western India) have been recovered by bulk screening and washing of several tons of material from a main level located just above the lower lignite seam. Details of the collecting site are now available in several publications as the producing level has yielded a variety of other microvertebrates (fish, amphibians, snakes, turtles, crocodiles, mammals and birds).

The Vastan lizards are probably represented by two or three new species of agamids and work is underway to specifically diagnose the diverse assemblage. The affinities of the agamids in a geodynamic plate tectonic framework are hard to infer as it is difficult to quantify the degree of biotic cosmopolitanism and endemism although current research has shown that in the drifting isolated Indian Plate there are several records of origination and evolution of various lineages. The present paper, therefore, deals with the status of the lizard assemblage and its relationship to better worked out ones both in the northern and the southern continents.

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PALYNOLOGY AND ENVIRONMENTAL CONSTRAINTS OF EARLY CRETACEOUS UMIA FORMATION, KUTCH DISTRICT, GUJARAT

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The present paper embodies the results of palynological investigations of the Early Cretaceous Umia Formation exposed in Ghuneri Coal Mine Section and Korawadi River Section near Dharesi, Kutch District, Gujarat and its implications in assigning a precise age to the formation vis-à-vis environmental constraints of palynobiota. The palynological assemblage recovered from the Umia Formation of Kutch Basin comprises 88 species belonging to 48 genera. Of these, 3 genera, viz. *Venkatapollis, Aranyasporis* and *Pyrgopites,* and 9 species, viz. *Venkatapollis indica, Aranyasporis cretacea, Pyrgopites mesozoicus, Echninatisporis korawadiensis, Concavissimisporites trilobatus, Leptolepidites psilatus, Cingulatisporites intermedius, Taurosporites mesozoicus* and *Trilobosporites indicus* are new. The age diagnostic palynotaxa, viz. Crybelosporites, *Gabonisporis, Rouseisporites* and *Aequitriradites* which straddle Tithonian-Neocomian time plane are well represented in Bhuj sections of Umia Formation. However, the palynotaxa which do extend up to Aptian-Albian, viz. *Cyathidites, Klukisporites, Concavissimisporites, Taurocusporites, Schizosporis* and *Echinatisporis* form an integral part of the assemblage. Hence the miofloral assemblage, recovered in the present study, indicates an Early Cretaceous age ranging from Neocomian-Early Aptian for the Umia Formation. Since the palynological assemblage of the Umia Formation exposed at the Ghuneri Coal Mine Section and Korawadi River Section is dominated by pteridophytes followed by gymnosperms, bryophytes and fungi, a warm and humid climate is inferred on the basis of palynobiota.

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MORPHOLOGICAL CHARACTERS OF BENTHIC FORAMINIFERAL SPECIES *HYALINEA BALTHICA*: APPLICATIONS IN PALAEOCLIMATE STUDIES

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To understand the fluctuating pattern in monsoons, oceans are the best reserves as they have long undisturbed archives of monsoonal records in the bottom sediments and marine fauna therein. Oceans receive loads of fresh water and terrestrial sediment influx through rivers which impart localized changes in seawater properties. Most of the Indian peninsular rivers drain their water into Bay of Bengal. A change in the physico-chemical characteristics of seawater, in response to the changing monsoonal pattern leads to variation in the relative abundance of foraminiferal species. Different foraminiferal species have specific preference to a particular set of physico-chemical conditions.

In view of the above, we have studied the downcore variation in the abundance and morphological characters of benthic foraminiferal species *Hyalinea balthica.* In morphological features, maximum diameter, number of chambers and proloculus size has been measured. Based on known ecology of *Hyalinea balthica,* warmer environment can be described as an unfavourable habit. It is known that in most of benthic foraminiferal species, mean proloculus size has inverse proportional relation with temperature while dimorphic ratio has directly proportional relation with temperature. On the basis of these arguments it is concluded that core sections at ~40 cm with low abundance of *Hyalinea balthica* and high number of microspheric forms or low mean proloculus size indicates warmer climate. From radiocarbon dating, this core level show an age of ~6 Ka BP which corresponds to already established mid-Holocene warming phase, indicating that abundance and mean proloculus size or dimorphic ratio can be used as a proxy to study the palaeoclimate.

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WELL-SITE BIOSTRATIGRAPHY: A PILOT STUDY FROM THE CAUVERY BASIN

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Well-site Biostratigraphy is a modern biostratigraphic approach, widely used at well-site to generate 'real time' stratigraphic data that renders monitoring of well path with respect to target reservoir. This approach goes beyond establishing chrono-biozones and emphasizes recognizing bioevents which serve as steering points to help make quick decisions related to coring, maximizing reservoir penetration and sidetrack issues. This technique also known as "Biosteering" is long established tool that provides unique ability to discriminate between the individual mudstones that separate enveloping reservoir bodies. The nature of Cretaceous reservoir bodies present in the Cauvery Basin, are generally thin sandstone and shale units with restricted lateral geometry, thereby necessitates the use of well-site biostratigraphy for discriminating non-pay from the reservoir, to maximize reservoir penetration and to recognize unpredicted exits due to facies pinch outs or sub-seismic faults.

A pilot study has been attempted to establish possible (bio)steering points useful in local correlation in Ramnad and Nagapattinam sub-basins. By adopting microfacies technique four field scale biosteering points are identified in two different structures in Ramnad sub-basin. A brown shale lithology, which biostratigraphically designated to represent Late Palaeocene is correlatable in Kamalapuram field in the Nagapattinam sub-basin, and this characteristic lithofacies underlies the Kamalapuram reservoirs, limiting its vertical limit. The extinction level (=first down hole occurrence) of *Inoceramus*, which also marks K/ T boundary in the Cauvery Basin, is easily recognizable in even unwashed ditch cuttings, can serve as a significant steering point for Nannilam reservoirs.

Biostratigraphic correlation of the recognized steering points is attempted between well sections to provide the initial chronostratigraphic control on dating by the identification of the most regionally significant bioevents, viz. extinction level, flooding events and distinctive lithofacies. Thereupon, preliminary well-to-well correlations are drafted by identifying characteristic wire line log signatures correlatable between well and supported by biostratigraphic picks. These steering points also guide the geologist to steer the well bore back into the reservoir by integrating with "Logging while drilling" (LWD) coupled with lithologic data, whenever well path encounters non-pay packages due to offset by faults or pinching

out of reservoir facies. This restricted lateral extent of reservoir facies is an observable fact in Cauvery Basin at all stratigraphic levels due to debris flow/ mass flow depositional process of clastic reservoirs.

Therefore, well-site biostratigraphy can contribute significantly and help quick decisions related to sidetrack issues whenever well path passes out of target reservoir facies. This approach has become exceedingly important application bringing significant benefits in terms of saving money and time in hydrocarbon industry and is widely adopted in Joanne and Andrew fields in UK and in Danish sector in North Sea.

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OCCURRENCE OF CHAROPHYTES FROM THE HOLOCENE INTERTIDAL DEPOSITS OF THE GULF OF KUTCH AND THEIR IMPLICATIONS ON THE ENVIRONMENT

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The micropalaeonotological study of the Late Quaternary intertidal sediments of the Gulf of Kutch reveals the occurrence of well preserved gyrogonites. These gyrogonites, belonging to *Lamprothamnium*?, are recovered from the silty clay of the gulf of Kutch indicating the presence of fresh/ brackish water bodies in and around this region. The ^{14}C date of the silty clay is estimated to be 7.6 Ka BP. This period is characterized by the high lake levels in the northern hemisphere and thus the occurrence of charophytes in the gulf sediments is significant for climatic inferences for this part of the Indian peninsula.

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INTERTIDAL FORAMINIFERA FROM THE HOLOCENE DEPOSITS OF THE GULF OF KUTCH, WESTERN INDIA

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A rich and varied foraminiferal assemblage is being reported for the first time from the Holocene intertidal sediments of the Gulf of Kutch. It includes 252 foraminiferal species shared by seven orders, twenty five superfamilies and forty two families, one new subfamily Asipholageninae and ten new species. The overall foraminiferal assemblage indicates the dominance of calcareous group followed by porcellaneous forms. The forms belonging to agglutinated group are negligible. Besides, there occur planktic foraminifera in the sediments located far away from the mouth of the Gulf implying storm/ tsunami like situation in the recent past. The fauna in general exhibits Mediterranean and Atlantic affinity.

In addition, an attempt is made to study the modern fauna. The sediments from the Navalakhi port, located far away from the mouth, contain foraminifera characterized by thin and small transparent tests implying the influence of the fresh water. In the absence of any major river and gulf being the part of the semi arid zone the fresh water influence is attributed to the discharge of Indus River. This assumption strengthens the views expressed by previous workers about the migratory mechanism of the Indus discharge into the Gulf.

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MODERN FLORISTICS AND ETHNOBOTANY IN RELATION TO PALAEOBOTANICAL AND PALAEOETHNOBOTANICAL STUDIES

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Plant fossils occur as fruits, seeds, leaves, woods, cuticle, pollen and spores and generally possess diagnostic characters, with the help of which they are identified. Their comparison with modern equivalents helps to infer the botanical affinity. For accurate assessment of the composition of fossil flora and meaningful understanding of palaeoecological, palaeogeographical and palaeoethnobotanical knowledge, especially from Tertiary and Quaternary periods, the information from the present day flora and vegetation of different habitats along with their traditional uses survived among various ethnic societies in the selected areas are very essential. In view of this, a study was made on present day flora and ethnobotany of Shahdol forest division in Madhya Pradesh to record the natural habitats of each plant species and to document the multifarious utilities of plants being practised by various ethnic groups to meet their daily requirements. Shahdol district in Madhya Pradesh is tribal dominant district, situated in North-Eastern part of the state. Baiga, Gond and Panica are the major ethnic groups which are distributed in various remote localities in the forests of the district. The livelihood of all the tribes is based on minor forest produce. They collect leaves, roots, tubers and fruits of different species from the forest. Ragi (*Eleusine coracana*), Maize (*Zea mays*), rice (*Oryza sativa*), 'Kodo' (*Paspalum scrobiculatum*), 'Kutki' (*Panicum sumatrensis*), 'Sawan' (*Echinochloa crus-galli*) and several other minor millets are the staple food of these tribes. Botanically the area is very interesting. The available botanical literature indicates that no systematic floral investigation of the district has been done so far.

The floristic study of the area reveals that the vegetation of the district comes under sub-tropical deciduous type. However, some of the trees are evergreen and semi-evergreen. Sal and miscellaneous forests are found in almost entire area. The Sal forests are in the climax stage of the plant succession. The miscellaneous forest is of preclimax stage. The medium quality bamboo forests are also found at several places. While studying the flora and ethnobotany of Shahdol district, the author has compiled an account of about 1385 angiospermic plant species belonging to 983 genera and 193 families. Of these, 259 species are documented as medicine, 42 species as food, 23 species as timber, 62 species as dye, 18 species as tannin and gum, 12 species as oil, 89 species as fuel and 40 species as fibre and cordage.

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END-CRETACEOUS FLORAL CHANGE INDUCED BY DECCAN VOLCANISM: ECOSYSTEM RESPONSE TO ENVIRONMENT AND CLIMATE SHIFT

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Deccan Volcanic associated sediments (DVS) from different geographic locales, viz. Kutch-Saurashtra, Chhindwara-Mandla-Jabalpur (CMJ) and Nand-Dongargaon (ND), were extensively studied for the their palynofloral analysis. The study basically aimed to register the end-Cretaceous floral changes in the Indian subcontinent and for establishing a relationship, if any, between the observed palynofloral change and the Deccan volcanic activity (69-61 Ma). A majority of the DVS occurring onland represent terrestrial, non-marine sediments that occur at different stratigraphic levels. Considering the critical nature of the study and challenges involved we selected volcanic sequences having a well established stratigraphy. For a better time-constraint, the palynological studies were supplemented with Milankovitch based time series analysis of the sediments, magneto-stratigraphy and organic carbon isotope stratigraphy. The sedimentary beds at different stratigraphic levels were sampled at different intervals.

Our observations suggest that the floral change were triggered by advent of Deccan volcanic activity in different volcanic sectors. The first volcanic flow arriving locally proved more devastating for the existing flora. The ecosystem struggled to recover during the period of repose between the two successive flows. With the initiation of volcanism, the existing ecosystem of semi-arid climate having a strong seasonality (alternate wet-and dry spells) gradually changed to closed restricted small basins and lakes that enjoyed more of sub-humid to humid (dominating wet spells) climates. Events of first level of appearance of diatoms in 30 N chron and dinoflagellates-siliceous sponge spicules in the 29R chron in Maastrichtian freshwater ecosystem have been recorded. These events together with the floral change induced by volcanic activity, as evident, commenced much before the KTB, continued across the KTB and stabilized in the Palaeocene time during the waning stage of the Deccan volcanic eruption.

An overview of floral scenario of the DVS in CMJ and N-D sectors clearly indicates a marked floral change from Lameta to the intertrappeans of first level and addition of a few new forms (primitive polyaperturate

pollen and diversification Normapolles pollen) in the successive sedimentary layers occurring at higher stratigraphic levels. Overall, the floral changes are marked by drastic decrease in gymnosperm and dominance of angiosperms accompanied by appearance and gradual dominance of diatoms, dinoflagellates and siliceous sponge spicules. The appearance of diatoms and siliceous sponge spicules with the advent of Deccan volcanism is possibly related to the chemistry of the intertrappean lakes that enjoyed more acidic condition with a lot of silica mobilization from the provenance and precipitation in the basin. During the waning phases of the Deccan volcanic activity, i.e. Palaeocene time new palynoassemblage such as *Dandotiaspora* spp., *Lakiapollis ovatus,* etc. appeared as reported from the Lalitpur section and similar to the palynoassemblage of Matanomadh Formation of Kutch and Lakadong Sandstone of Meghalaya.

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DISCREPANCY IN THE REFLECTANCE OF LOWER GONDWANA COALS FROM TATAPANI-RAMKOLA COALFIELD, SURGUJA DISTRICT, CHHATTISGARH

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Tatapani–Ramkola coals have attained High Volatile Bituminous 'C' rank, the average reflectance of the units varying from 0.49% to 0.63%. It is now recognized that the vitrinite reflectance also depends on the depositional environment of coal. Therefore, when detailed studies on the trends of vitrinite reflectance are carried out, both environmental and thermal factors need to be taken into consideration. With the increase in depth, a number of significant departures from a continuous rise in reflectance have been observed in Tatapani-Ramkola Coalfield. It has been observed that the older units often have lower reflectance than the younger units. In borehole TRM-3, unit I has 0.53 % Ro max, Unit II has 0.63 % Ro max, Unit III has 0.54 % Ro max and Unit IV has 0.55 % Ro max. A characteristic gradation can be seen in the behaviour of each coal unit in the form of a negligible detrital content in the central part and in the occurrence of carbominerite dominant coal, which have minor organic content in the layers forming the roof and the floor of the unit.

The coals of Tatapani-Ramkola Coalfield show minor fluctuation from the Hilt's Law, which states that the volatile matter of coal decreases with increasing depth and the fixed carbon increases in the same direction. This has also been observed in the coals of Brazil, Gunnedah Basin of Australia, Godavari Graben and Singrauli Basin, Son Valley. The coals of Tatapani-Ramkola Coalfield can be used for liquefaction purpose as the Ro max ranges from 0.4 % to 0.6%.

ICMS - 118 **Key Note**

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RECONSTRUCTING QUANTITATIVE CHANGES IN SEAWATER PHYSICO-CHEMICAL PROPERTIES DURING GEOLOGIC PAST BY COUPLED ISOTOPIC AND ELEMENTAL ANALYSIS OF CALCAREOUS FORAMINIFERA

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Temporal changes in the abundance, species diversity and morphology of foraminifera have often been used for palaeoceanographic reconstruction. But almost all of these proxies provide only a qualitative estimate of the past oceanographic changes. The changes in the isotopic composition of the calcareous tests of selected foraminiferal species were suggested as potential proxy to reconstruct absolute changes in few of the oceanographic properties. The first major global effort to assess the absolute changes in the seawater temperature over glacial-interglacial period throughout the world oceans was made as part of CLIMAP, wherein change in the foraminiferal census count and oxygen isotopic ratio was used. Though the effort helped in assessing the lead-lag in the global ice volume induced seawater oxygen isotopic changes and the census count based sea surface temperature changes from various locations, even these estimates were marred by ambiguity as foraminiferal oxygen isotopic ratio is affected by both seawater temperature and salinity, whereas the census count faced a no analog problem. Therefore, it was felt to develop an independent proxy for seawater temperature and other bio-physico-chemical properties. As early as with the development of isotopic analysis of foraminifera as potential tool to estimate quantitative changes, elemental ratio was also suggested as an efficient technique to reconstruct absolute variation in seawater properties. The magnesium/calcium ratio was found to exponentially increase with the increasing seawater temperature. However, unavailability of instrumentation to measure the subtle changes in the elemental ratio, along with high degree of contaminant phases almost ruled out the application of elemental analysis of foraminifera to reconstruct palaeoceanographic changes.

Improved sample processing techniques for elemental analysis of foraminifera were developed in the early eighties. But the lack of proper instrumentation still hampered the routine measurement and application of elemental analysis for palaeoceanographic reconstruction studies. The development of accelerator mass-spectrometer paved the way for precise measurement of elemental ratio of foraminiferal tests during the late nineties.

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Thus, coupled oxygen and Mg/Ca analysis of foraminifera could be used for quantitative estimation of past seawater temperature and salinity changes. The first ever Mg/ Ca based sea-surface temperature reconstruction for the equatorial Indian Ocean showed a cooling of ~2.1°C and further that the surface of Indian Ocean was warmer during the isotopic stage 5e as compared to present. The absolute sea-surface temperature estimates from oceans of other parts of the world also helped in understanding the lead-lag relationship, in changes in seawater physico-chemical properties of low and high latitudes during the geologic past. Additionally, earlier the assessment of productivity changes from oceans of different parts of the world was mainly carried out by using foraminiferal census count, which again provided only qualitative estimates. Also, due to the availability of very few foraminiferal tests from certain regions, it was difficult to reconstruct productivity changes from such locations. Development of coupled carbon isotopic and cadmium/calcium ratio of the calcareous foraminifera helped in reconstructing the absolute changes in the phosphorous content of the oceans, a measure of oceanic productivity. Thus development of elemental analysis of foraminifera has immensely helped in assessing the absolute changes in seawater temperature, salinity and productivity of the world oceans during the geologic past.

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OXYGEN ISOTOPIC COMPOSITION OF *GLOBIGERINA BULLOIDES*: TOOL TO ESTIMATE ITS DWELLING DEPTH

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The water depth at which planktic foraminiferal species *Globigerina bulloides* calcifies its shells has been deciphered from the oxygen isotopic composition of the shells recovered from the surface sediment samples from the southwestern Indian Ocean. For stable oxygen isotopic analysis, 8-10 tests of *G. bulloides* were picked from a total of 19 surface sediment samples. The stable isotopic analysis was performed at the Alfred Wegener Institute for Polar and Marine Research (Bremerhaven) using "Finnigan MAT 251 isotope ratio gas mass spectrometer" coupled with an automatic carbonate preparation device (Kiel I) and calibrated via NBS 19 to the PDB scale. The seawater temperature for water depths ranging from 0 to 200 m was estimated from the *G. bulloides* oxygen isotopic composition by using palaeotemperature equation. In order to estimate the calcification temperature from the stable oxygen isotopic composition of *G. bulloides*, a regr lues between 5°N and 60°S latitude and 35°E to 100°E longitude, available at the global seawater oxygen isotopic composition database. Similarly the seawater salinity was estimated using the seawater oxygen isotopic composition calculated from the *G. bulloides* oxygen isotopic ratio and seawater temperature taken from Levitus database. Estimated seawater temperature at different water depths was plotted against the annual average seawater temperature taken from Levitus database and onboard CTD measurements. The plot of estimated and Levitus temperature and salinity for different water depths shows that the *G. bulloides* calcifies its test between 75-100 m water depth. Interestingly, this water depth in the study area falls within the range of thermocline.

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DEEP WATER CHANGES IN THE EQUATORIAL INDIAN OCEAN DURING THE LAST ~350 KA BP: THE NORTH ATLANTIC CONNECTION

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The changes in deep-water over the geologic time scales can be assessed by using various foraminiferal characteristics, including benthic foraminiferal assemblages, stable oxygen and carbon isotopic composition of selected species, elemental composition of few species, etc. Here we infer millennial scale deep water changes from the northern Indian Ocean over the last ~350 Ka BP based on the stable oxygen isotopic composition of the benthic foraminifera. The isotopic analysis was carried out on *Fontbotia wuellerstorfii* and *Uvigerina peregrina* recovered from a total of 300 samples of a core (Core SK 157/ 4, Latitude 02.67°N, Longitude 78.00°E, water depth 3450 m) collected from the equatorial Indian Ocean. Since none of the single benthic foraminiferal species was present throughout the core, stable isotopic analysis was performed on both *Fontbotia wuellerstorfii* and *Uvigerina peregrina*. The *F. wuellerstorfii* oxygen isotopic values were corrected by +0.64‰ to bring it in equilibrium with seawater oxygen isotopic value. The oxygen isotopic ratio shows a change of 2.0‰ over the last glacial-interglacial transition. These estimates are comparable with the CLIMAP estimates that reported an average benthic oxygen isotopic change of 2.0‰ for the Indian Ocean region, higher than the global mean of 1.9‰. Based on the benthic foraminiferal ä^{18}O changes over the last ~350 Ka BP, it is inferred that the glacial-interglacial deep water ä^{18}O changes in the equatorial Indian Ocean were comparatively more intense than the global average glacial-interglacial ä^{18}O variations. It is proposed that the Indian Deep Water was significantly cooler during glacial periods as compared to present. Additionally, the contribution of North Atlantic Deep Water to the Indian Deep Water was considerably reduced during the glacial periods whereas the contribution from the Southern Ocean water significantly increased.

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MULTIVARIATE MORPHOMETRIC DISCRIMINATION OF TOPOTYPES OF SOME DEBATED EOCENE SPECIES OF *NUMMULITES*

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In the tropical, shelf carbonates the foraminiferal genus *Nummulites* was most abundant and diverse during the Eocene. Kutch is the type area of several species of *Nummulites.* There have been differences of opinion among the taxonomists over the validity of some of the species reported from this region. In the present study, the taxonomic status of four such debated species, viz. *Nummulites acutus*, *N. vredenburgi*, *N. stamineus* and *N. neglectus,* is evaluated using multivariate morphometrics. The topotype materials were collected from Harudi Formation and Fulra Limestone of Middle Eocene age. Equatorial sections of fifteen to twenty five specimens of each of the species were prepared for morphometric measurements. The diameter and thickness of the test, length and height of chambers in the first and final whorls, diameter of the protoconch and thickness of the marginal cord were measured for multivariate analysis. The cluster analyses distinctly seperate *N. acutus* from *N. vredenburgi* and *N. stamineus* from *Nummulites neglectus*. Discriminant analyses of the respective pairs of debated species also discriminate them distinctly. The four analyzed species are found to be taxonomically valid on morphometric criteria and linear discriminant functions are proposed to differentiate them.

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COAL DEPOSITS FROM KAYAR AREA OF YEOTMAL DISTRICT, MAHARASHTRA AND THEIR BIOPETROLOGY

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Two coal seams intersected in two bore holes MJ-11 and MJ-12 of Kayar Block, 30-35 km south-east of Pandharkawada near Mukutban, in Yeotmal District, Maharashtra have been critically analyzed for their biopetrographic characteristics. The top seam ranges in thickness from 4.60 to 10.25m and the bottom seam attains maximum thickness of 1m. Coal deposits of this area represent a part of the main seam which runs across the Wardha Valley Coalfield. Vitric, fusic and mixed types of coal have been recorded. Vitric and fusic coal types are confined to a few representative seam samples, whereas mixed type of coal constitution is dominantly observed. Vitrinite reflectance study (R_o max %) reveals that the coal attained high volatile bituminous C stage of rank. It has been inferred that the basin of deposition was subjected to a prolonged spell of cold climate with reducing environment of deposition. Besides, signatures of a few interruptions of dry and oxidizing spells of shorter duration are also recorded.

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A ~625 KA CLIMATIC RECORD AS DECIPHERED FROM PLANKTONIC FORAMINIFERAL THANATOCOENOSE FROM DSDP CORE 219 LOCATED ON THE CREST OF LACCADIVE-CHAGOS RIDGE IN THE SOUTH-EASTERN ARABIAN SEA

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Planktonic foraminiferal assemblage from Upper 900 cm sediment section of DSDP core 219 located on the crest of Laccadive-Chagos ridge in the southeastern Arabian Sea offers an opportunity to understand the changes in climate during last ~625 ka. Fluctuation in pore water salinity between ~35‰ and 36‰ in the studied section indeed indicates towards temporal variation in the past climate. Earlier, in the present core the temporal variation in the absolute abundance of *Globorotalia menardii* and ä^{18}O of *Gr. menardii* along with the palaeontological time series (PTS) analyses done on these data helped in deciphering the warm and cold episodes prevailing during this time (~625 ka).

To document this change, the present study involves the study of temporal variation in absolute abundance of all the planktonic foraminiferal species present in the sediment. *Gr. Menardii,* being a deeper dwelling species, records the changes taking place at a depth ~100m. Temporal variation of the species thriving in shallower water, viz. *Hastigerina aequilateralis, Hastigerina murrayi, Hastigerina siphonifera, Globigerina bulloides, Globigerina conglomerata, Globigerinoides sacculifer, Globigerinoides quadrilobatus, Globigerinoides ruber and Orbulina universa* have been studied to understand the perturbation caused in the abundance of near surface dwellers because of the modifications in the environment resulted from changes in the climate.

Apart from the measurements on *Globorotalia menardii,* ä^{18}O and ä^{13}C measurements have also been done on *Globigerinoides sacculifer* and *Globigerinoides ruber* to compare the geochemical stratification present, if any, in the water column at a particular time. It is noteworthy that fluctuations observed in the abundance of near surface dwelling species is more than that of the *Gr. menardii*. This is probably because of the fact that while weak climatic perturbation affects only the near surface environment; strong climatic perturbation penetrates to deeper levels. This observation is corroborated by the similarity in the ä^{18}O between the *Gs. sacculifer* and *Gs. ruber* at all levels as both of these species share nearly the same depth habitat (ã = 0.8). On the other hand, ä^{18}O of *Gs. sacculifer* and *Gs. ruber*

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do not show much correlation with the same of *Gr. menardii* (ã = 0.29 and 0.27 respectively), which indicate that the perturbation caused in the water column are because of various reasons, viz. change in sea surface temperature, surface productivity, overhead precipitation, surface runoff, evaporation over precipitation, ice volume change, etc. These factors affect various levels in the water column differently, i.e. while *Gs. sacculifer* and *Gs. rubber,* being a dweller in the upper layers, precisely records isotopic changes in the surface water, *Gr. Menardii,* being a deeper dweller, is less affected by the above factors.

An attempt has been made to find out the resultant of the absolute abundance of *Gr. menardii* and the ä^{18}O measured on the tests of this species through time. Since these data depend on some independent factors, their resultant brings out the change in the palaeoclimate. Hence the present study helps in deciphering the cyclic climatic changes during last ~625 ka.

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MICROFOSSILS FROM EARLY EOCENE AMBERS FROM VASTAN LIGNITE MINE, GUJARAT

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Eocene ambers have been discovered from Vastan Lignite Mine, Gujarat. The age of the lignite has been estimated to be 55.2Ma (Ypresian). Several insect assemblages have been investigated in amber. So far, many organic inclusions such as arachnids, fly, mosquito, wasps, ants, pollen, and plant fragments have been investigated in India. These assemblages can be correlated with the Early Eocene assemblages from other parts of the world to know: i. whether these fossilized insects in pristine condition were endemic in nature; and ii. history of the drifting course of the continents.

The study of the ambers provides a wide range of organic data to reconstruct the Early Eocene scenario. It gives an insight into the existence of various insect groups that existed during that period and also about the biodiversity of that age. Study of these organic inclusions will give information about the course of their diversification from Early Eocene till today and will provide the missing links in the path of evolution. It would also tell about the various forms that were confined and are not found today.

The inclusions in the amber are distinct and are enhanced by the new techniques of preparing samples that in combination with new microscopic techniques gives an additional clarity to their visualization.

The amazing capability of preservation of amber is largely dependent on its chemistry. A lot of work on its chemistry is done in other parts of the world. Yet Indian amber has not been deeply analyzed chemically, its initial FT-IR spectra reveals the presence of chemical functional groups. The chemical analysis which is in process, may assist to determine the botanical affinity of amber.

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FUNGAL REMAINS FROM THE PALAEOGENE SEDIMENTS OF HIMACHAL PRADESH: PALAEOECOLOGICAL AND STRATIGRAPHIC IMPLICATIONS

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The Palaeogene succession of Shimla Hills, Himachal Pradesh consists of Kakara, Subathu, Dagshai and Kasauli formations, in ascending order of stratigraphy. The Kakara/ Subathu formations, which rest unconformably over the pre-Tertiary rocks, were deposited under shallow marine condition whereas the successively overlying Dagshai and Kasauli formations were deposited under coastal transitional and fluvio-deltaic conditions respectively. Occurrence of fungal remains from these sediments has been reported by earlier workers mostly as a part of the palynoflora. However, these remains did not receive due recognition for their utility in palaeoecological reconstruction. In the present communication, fungal spores, conidia, ascostromata and other fungal remains recorded from the Palaeogene sediments of Shimla Hills, as well as new data from the present palynological investigation have been analyzed critically in order to understand morphological variations as well as the ecological factors which influence their distribution in the Palaeogene sediments of Himachal Pradesh. An attempt has also been made to throw light on their role in the identification of various stratigraphic units in the area of investigation.

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PALAEOCENE-EOCENE CALCAREOUS ALGAE FROM LAKADONG LIMESTONE OF JAINTIA HILLS, MEGHALAYA: IMPLICATIONS FOR PALAEOENVIRONMENT

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The Palaeocene-Eocene shelf sediments of Shella Formation, exposed along the southern fringes of Meghalaya Plateau, represent one of the best developed Palaeogene shelf outcrops in India. The sequence in the study area is represented by alternate carbonate-clastic rocks. Lakadong Limestone is the lowermost unit of Shella Formation and contains smaller and larger benthic foraminifera, calcareous algae in association with few broken fragments of bryozoans, echinoid spines and mollusks. The presence of age diagnostic foraminifera suggests Late Palaeocene to Early Eocene age for this limestone unit of Shella Formation. The present thin section analysis reveals the occurrence of calcareous fossil algae belonging to Red Algae (Order: Corallinales) and Green Algae (Order: Bryopsidales) from the well bedded Lakadong Limestone exposed in the southern part of Jaintia Hills of Meghalaya. Based on the assemblage of the calcareous algae along with other benthic biota, attempts have been made to deduce the palaeoenvironmental significance during the deposition of Lakadong Limestone.

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NANNOFOSSILS FROM KUTCH – SAURASHTRA – MUMBAI – KERALA OFFSHORE ALONG WEST COAST OF INDIA

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In order to understand finer time slicing of the sedimentary record it is essential to understand the development of various age sequences, their environment of deposition and sedimentation history. It is in this context, calcareous nannofossil studies are taken up to facilitate deep water exploration programme of Oil and Natural Gas Corporation (ONGC) along the western margin of India. The utility of the calcareous nannofossils as precise age markers has already been established and is being practised in ONGC for quick dating purpose during drilling of exploratory wells in shallow/ deep/ ultra deep waters.

The present study stretches from Kutch Offshore in the north to Kerala Offshore in the south along western offshore of India. In the Kutch offshore, well A penetrated about 455m traps with intervening limestones of Late Santonian-Maastrichtian age. While in Saurashtra Offshore, well preserved and diverse early Palaeocene to Late Miocene calcareous nannofossils are recorded from the well B penetrating nearly 4.3 km thick clastics. Since the encountered lithology is a monotonous pelagic clay division of the sequence with the help of biostratigraphic tool becomes meaningful. Nanno-events are utilised for dating the sequence to the precision of <2 Ma. In Mumbai Offshore, basaltic basement forms the floor of the sedimentary succession and studied wells C, D, E encountered excellent development of Palaeocene to Oligocene nannofossils from deep marine Panna clastics, Devgarh, Bassein and Mukta formations after cessation of Deccan Trap volcanism. Kerala Offshore representing well F in the south records Late Cretaceous calcareous nannofossils. The study has brought out valuable subsurface biostratigraphic information for understanding evolutionary history of western margin of India. In view of recognition of Late Santonian - Maastrichtian sediments from deepwater area of Kutch Offshore and the absence of corresponding sediments in the wells of Mumbai Offshore, two depositional pods for Mesozoic (Late Cretaceous) sediments are envisaged while intervening Mumbai Offshore area remained possibly positive.

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BIOPETROLOGICAL CHARACTERIZATION OF PANANDHRO LIGNITES, GUJARAT

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Twenty selected samples of varied lignite seams were studied for biopetrological characterization to understand the genesis of these lignites. Panandhro lignites are characterized by huminite, liptinite and inertinite groups of macerals. Huminite group of maceral is formed under euxinic condition by the processes of humification and gelification of the vegetal debris and is represented by textinite, ulminite, attrinite, densinite, gelinite and corpohumite. Liptinite group of maceral constists of sporinite, resinite, cutinite, alginate, etc. whereas inertinite group of maceral is represented by charred or oxidized parts of vegetal mass, e.g. fusinite, semifusinite, sclerotinite, funginite, inertodetrinite. Typical algal bodies were recorded in these lignites besides, resinites. Biopetrographic compositions of these lignites show higher reflectance (0.39-4.05% in oil) and high calorific values in comparison to Neyveli lignite. Qualitative and quantitative distributions of these macerals, in time and space, suggest that these were formed under fluctuating euxinic condition.

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PALYNOLOGICAL STUDY OF THE REWAK FORMATION EXPOSED ALONG TURA-DALU ROAD, WEST GARO HILLS, MEGHALAYA

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A rich and diversified palynofloral assemblage has been recorded from the Rewak Formation (=Kopili Formation) exposed along Tura-Dalu Road, West Garo Hills District, Meghalaya. The assemblage is represented by dinoflagellate cysts, fungal remains, pteridophytic spores and gymnospermous and angiospermous pollen. Besides, reworked Permian palynofossils have also been recorded. Important palynotaxa of the assemblage are: *Monolites mawkmaensis, Polypodaceaesporites major, P. indicus, P. levis, Polypodiisporites mawkmaensis, P. ornatus, P. favus, P. speciosus, P. splendidus, P. tuberculensis, Striatriletes multicostatus, S. paucicostatus, S. susannae, Todisporites major, Araucariacites australis, Inaperturopollenites punctatus, Podocarpidites ellipticus, Densiverrupollenites eocenicus, Margocolporites sahnii, M. complexum, Palmaepollenites nadhamunii, Palmidites plicatus, Pellicieroipollis langenheimii, Proxapertites assamicus, Rhoipites nitidus, Spinizonocolpites echinatus, Tricolpites crassireticulatus, T. minutus, Tricolporopilites robustus, Tricolporopollis matanomadhensis, Verrucolporites verrucus, Phragmothyrites eocenicus,* etc. The palynoflora indicates prevalence of tropical to subtropical, warm-humid climate. Presence of coastal and mangrove elements, together with dinoflagellate cysts, suggests a coastal environment of deposition. The palynoflora has been compared with the Kopili palynoassemblage and Eocene palynoassemblages recorded from other sedimentary sequences of India. A Late Eocene age has been suggested to the presently studied sediments.

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POTENTIAL OF CHEMICAL STRATIGRAPHY AS A PROXY DATA FOR ENVIRONMENTAL RECONSTRUCTION OF LAKE SEDIMENTS

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Chemical analysis of sediments has been established as one of the proxy data to reconstruct past environmental changes in time and space. It occupies a special position in the catalogue of proxy data along with pollen, diatoms, macrofossils and other such analysis. In addition, this has gained much significance recently especially for the analysis of level of pollution in the environment. Its potential lies in understanding the variation of chemical constituents with time and space in relation to its natural state. It becomes the only source of proxy data when the sediments are devoid of pollen and other microfossils. In the present context, authigenic, biogenic silica and allogenic components of the lake sediments are of interest to us for deduction of past climate. In the past, environmental reconstruction of Tsokar Lake, Ladakh, Jammu and Kashmir, Didwana Lake, Rajasthan and Berijam Lake, Kodai Hills were attempted on the basis of elemental analysis as well as pollen data. Results of the above studies reveal that chemical analysis of lake sediments has become potential tool to reconstruct climate and to decipher the development of ecosystem. It can also supplement other proxy data based on pollen, diatoms, microfossils, etc.

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BENTHIC FORAMINIFERA AS INDICATOR OF CHANGING ENVIRONMENT DURING LAST THREE DECADES IN CUMBARJUA CANAL, GOA

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Estuaries are very important habitats being the most productive breeding grounds for diverse and large number of organisms. Thus they attract many studies on their bio-geo chemistry. In Goa, the Mandovi and Zuari Rivers connected via the Cumbarjua Canal forms an ecologically sensitive estuarine complex. This gave us an opportunity to study the ecosystem with reference to the effect of mining in its catchment area. Though the Cumbarjua Canal has been studied as a part of the Mandovi-Zuari estuarine complex, no studies have been done exclusively on it to estimate the effect of mining. The present study was aimed at determining the current distribution of foraminifera and comparing it with the previous distribution in 1972 reported by K. K. Rao. This would help us to estimate any change in environment over nearly 30 years. We collected sediment samples from 9 locations along the stretch of the canal and analyzed them for foraminiferal content. The results obtained by comparing the present data with the previous study show that the range of foraminiferal number has increased from 40-200 in 1972 to 168-9000 in 2006 in this canal over the years. Although the trend is similar to that seen before, i.e. decreasing from south to north, the foraminiferal numbers have increased considerably during this period. This indicates improved environmental conditions for foraminifera to flourish and therefore decreasing effects of mining in the region. We made a very peculiar observation at Station 5 (comparable with Station 6 of 1972). Field observations and previous reports suggest that the pharmaceutical companies release their treated effluents into the canal near this station. Previous studies on distribution of nutrients within the canal report higher concentration of phosphate at this station. Phosphate has been also reported previously as a nutrient for foraminifera. Consequently, it is postulated that higher concentration of phosphates at this location serves as nutrients for foraminifera and causes their increased abundance. Such an observation during the present work suggests continued effects of industrial waste at this station.

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PALYNOSTRATIGRAPHY AND PALAEOENVIRONMENTAL ANALYSIS OF PALAEOGENE SEQUENCE IN LIMBODRA - WASNA AREA OF AHMEDABAD BLOCK, CAMBAY BASIN

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The eastern margin of Ahmedabad block in Cambay Basin is among the thrust areas for hydrocarbon exploration. The present work incorporates the result of palynological investigation carried out in Limbodra-Wasna area to understand the palynostratigraphy and depositional environment of subsurface Palaeogene sediments to facilitate identification of further prospective areas for hydrocarbon exploration.

The palynological studies suggest presence of diversified palynoflora in Palaeogene sediments of the studied area. Based on palynofloral assemblage four assemblage zones, viz. *Pelliceroipollis langenheimii* Zone (Zone-I), *Proxapertites cursus-Polycolpites flavatus* (Zone-II) and *Palmaepollenites kutchensis-Proxapertites operculatus* Zone (Zone-III) and *Couperipollis rarispinosus-Striatopollis bellus* Zone (Zone-IV) have been identified. These zones are dated as Early Eocene, Middle Eocene, Late Eocene and Oligocene respectively, while the sediments corresponding to Olpad Formation (Palaeocene) exhibited poor palynofloral contents.

The depositional environmental interpretations are based on absolute pollen frequency and palynofloral associations. The coastal and back mangrove elements are common with sporadic occurrence of marine elements in Cambay and Kadi formations, represented by Zone-I, which is suggestive of near shore environment of deposition. The overlying Kalol and lower part of Tarapur Formation (Zone-II) has yielded rich back mangrove floral assemblage suggestive of littoral conditions of deposition. The presence of appreciable percentage of marine phytoplankton in middle and upper parts of Tarapur Formation (Zone-III and Zone-IV) is indicative of deposition under shallow marine environment.

The distribution of palynofloral assemblage zones in time and space have helped in understanding the lateral variations in depositional set-up through correlation and basin modelling for hydrocarbon exploration.

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GEOCHEMISTRY AND PHYTOLITH STUDY OF RAYKA SECTION, MAINLAND GUJARAT: IMPLICATIONS TO PROVENANCE AND QUATERNARY PALAEOCLIMATE

NOTES

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The Quaternary deposits of Mainland Gujarat have been studied for varied geological aspects and provide valuable background information to carry-out high resolution interdisciplinary studies. In the present study mineralogical, geochemical and grass phytolith investigations were conducted on a Quaternary type section exposed along Mahi River at Rayka to understand sediment characteristics, their provenance, depositional environment and palaeoclimate.

The exposed succession (~40m thick) shows two phases of fluvial aggradation, both started with deposition of gravel bed followed by finer sedimentary facies. Chronologically, the base of the exposed sequence is ~125 Ka old [equivalent to marine isotopic age 5 (MIS 5)] old and is of marine origin. The lower phase (age between MIS 5 to 74 ka) is dominantly comprised of silty sand and no significant pedogenesis has been found except the top which is comprised of highly mottled and pedogenised mud. The upper phase is alluvium comprising fine sand, silt and clay and intercalated with three weathered horizons identified as palaeosols (74-40 ka). The fluvial section is capped by aeolian sediments indicating setting up of arid phase ~22 Ka which also correlates with the dunal activity in the Thar Desert around LGM.

The mineralogical and geochemical investigations of the entire section show a more or less similar characteristics and the variation noticed in major and trace, including rare earth, elements is primarily linked to the intermittent deposition of calcium carbonate and less by weathering processes as indicated by low to moderate Chemical Index of Alteration (CIA) values. Significant match noticed in the inter-elemental ratios and their trends with sediment cores recovered from the Arabian Sea make these deposits very promising for depositional environment and palaeoclimatic studies. Palynologically the samples are either barren or show very poor preservation which could be a result of prevailing oxidizing conditions or became oxidized due to prolonged exposure or a result of subsequent diagenetic changes. However, rich grass phytolith assemblages were recovered from the palaeosol horizons which indicate palaeoprecipitation fluctuation between 70-40 ka.

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PLEISTOCENE RADIOLARIANS FROM ODP LEG 119, SITE 745

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Well preserved, abundant and highly diverse radiolarian assemblages were found in the Leg 119, site 745, sections 1H-6H. The radiolarian fauna belongs to typically of Antarctic assemblage. This paper deals with the systematic palaeontology and biostratigraphy. Forty five radiolarian taxa were identified from seventy samples (745B-1H-1, 13-15 to 745B-6H-7, 4-6). Common to few and well preserved species include *Antarctissa srelkovi, Cycladophora bicornis bicornis* and *Cycladophora amphora*. Based on first and last common occurrences, two radiolarian zones, viz. Psi and Omega, are established. Twelve new species were identified but they have not been formally named. It is also observed that the sections belong to Late Pleistocene and the zonal boundary is marked between Psi and Omega at a depth of 6.63 mbsf and not at a depth of 32.4 mbsf as reported by Caulet in 1991.

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ULTRASTRUCTURE STUDIES OF PRECAMBRIAN CARBONACEOUS REMAINS: A CASE STUDY FROM VINDHYAN SUPERGROUP

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Varied carbonaceous remains are known from different lithostratigraphic levels of the Vindhyan Supergroup of central India. The oldest record of carbonaceous discs is from Suket Shales of the Semri Group in Rampura locality of Madhya Pradesh. Since beginning, these discs were interpreted variously and later established as an acritarch-*Chuaria circularis.* Acritarchs are organic walled microfossils of unknown affinities. In addition, carbonaceous macrofossils, viz. *Tawuia,* helically coiled macrofossils described as *Grypania* are well known from the Semri Group. Commonly morphological characters of these macrofossils are determined by Light Microscopy. Ultrastructure studies on Precambrian carbonaceous remains are in its infancy. Such studies are required to gain additional information regarding their wall structures, affinities and status as prokaryotes/ eukaryotes. Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) have distinct advantage over transmitted Light Microscopy (LM). SEM provides details of surface morphology, microstructure and wall ornamentation whereas TEM provides insight into high resolution images of cell wall structures.

In the present paper, studies are confined to *Chuaria circularis* and helically coiled macrofossil *Katnia singhi* akin to *Grypania spiralis* to understand their nature with the help of LM, SEM and TEM. Earlier, circular discs from Suket Shales of Rampura were extensively studied by LM. Specimens of *Chuaria* are subjected to all the modes of microscopic examinations and those of *Katnia singhi* were studied under LM. Contrary to the previous study of *C. circularis* from Rampura under SEM and TEM, that reported no radial pores, our observations suggest the presence of distinct radial canals and single walled cell structure. Similar radial canals were also noted in Pendjari Formation of West Africa. But the conspicuous fact is that radial canals are not the universal character and are absent in the *C. circularis* reported from Visingsö Group, Sweden and Liulaobei Formation in China. In ultra thin sections of the well preserved specimens of *C. circularis* of the Rampura area, the thickness of the wall structure is almost same. The layers are continuous, parallel and very close to each

†Deceased

other. Both the parallel running layers have characteristic structural properties of organic matter, i.e. density, robustness and texture. The details on surface ornamentation and the cell wall structure of *C. circularis* are also provided in the paper. *Katnia singhi,* which has been correlated with *Grypania spiralis* and considered as one of the earliest evidence of eukaryotic remains, appears to be large size cyanobacteria closely comparable with Nostocalean cyanobacteria.

The case study presented here suggests that all the discoidal forms described in literature as *Chuaria* may not in fact be *Chuaria*. Among the circular discs, specimens with radial canals indicate that the populations of discs are constituted of at least two distinct biological entities. Our observations corroborate the studies on topotype material suggesting that the presence of radial canal, trabecular ultrastructure should be treated as an additional taxonomical attributes for *C. circularis*. Similarly there is no confirmatory evidence to consider *Grypania* as a eukaryote.

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FRESHWATER OSTRACODA FROM THE DECCAN INTERTRAPPEAN BEDS (PALAEOCENE) OF LALITPUR, UTTAR PRADESH

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A fairly diverse freshwater ostracod assemblage comprising 14 species has been recovered for the first time from the Deccan intertrappean beds near Lalitpur, Uttar Pradesh, on the eastern fringe of the Deccan Traps volcanic province of peninsular India. The probable Palaeocene age of the Lalitpur intertrappean make it potentially important in addressing the issue of faunal survivorship in fresh water aquatic systems across the Cretaceous-Tertiary boundary in the Deccan. The assemblage includes *Gomphocythere akalypton*, *G. paucisulcata*, *Mongolianella cylindrica*, *M. subarcuata*, *Cypridopsis hyperectiphos*, *Cypridopsis* sp., *Eucypris intervolcanus*, *E. catantion*, *Eucypris* sp., *Zonocypris spirula*, *Frambocythere tumiensis lakshmiae*, *Cypria cyrtonidion*, *Paracypretta* sp. and *Cyrois 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. 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 micro-organisms.

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THE GENUS *UVIGERINA* FROM THE NEOGENE OF ANDAMAN–NICOBAR: PALAEOENVIRONMENTAL IMPLICATIONS

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Uvigerinid foraminifera are now being recognized as potential and powerful tool available for palaeoenvironmental interpretations. Studies have revealed that Uvigerinids exhibit some of the best known trends in size and ornamentation with bathymetry. Also the fact that the morphology and distribution of *Uvigerina* species appear to be related to organic carbon content of the bottom waters, has led to increasing interest to study this group in detail for reconstructing palaeoecological models.

Uvigerina species are prominent and quantitatively important constituents of the Neogene benthic foraminiferal assemblages of Andaman – Nicobar. In this paper, thirteen species of *Uvigerina* from the Neogene of Andaman – Nicobar are illustrated and discussed systematically. Based on their surface ultrastructure the Uvigerinid foraminifera are grouped into: hispid – spinose, spinose – costae and platy – costae plus a species with smooth surface.

Stratigraphic ranges and abundance of *Uvigerina* in the Neogene of Andaman – Nicobar indicate three major bio-events. These bio-events are attributed to the Middle Miocene, Late Miocene and Early Pleistocene cooling events. Thus, the major fluctuations in deep sea environment during the Neogene have resulted in large part by climate that controls the distribution of benthic foraminifera in deep sea.

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LARGER BENTHIC FORAMINIFERAL INDICES OF THE INDIAN PALAEOGENE

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Larger benthic foraminifera of the Indian Palaeogene comprise diversified and complex foraminiferal assemblages belonging to several genera such as *Nummulites, Assilina, Miscellanea, Lockhartia, Daviesina, Actinosiphon, Discocyclina, Pellatispira, Spiroclypeus* and *Miogypsinoides*. Several species of these genera have index value in high impact biostratigraphy and are characterized by their short geological ranges which could be utilized for inter and intra-regional stratigraphic correlations. Precise larger foraminifer facies during the Palaeocene, Eocene and Oligocene could be recognized in several sedimentary successions in different petroliferous basins and exploratory acreages across the Indian Shelf. The event of larger foraminifera appearance on shelf is nearly spontaneous in all basins. During Palaeocene, this event is normally associated with P3/ P4 boundary (SBZ 2), about 59 Ma on geological scale and varying in the range of ± 1 Ma. No Tertiary larger foraminifera is apparent below this level in India and at the onset the larger foraminifera spurt includes seven genera – *Nummulites, Operculina, Alveolina, Lockhartia, Assilina, Daviesina* and *Miscellanea*. The diversity of the larger foraminifera assemblage reaches its acme during Middle Eocene which is followed by a short decline of the population and the number of genera touches the lowest level near the Eocene/ Oligocene boundary. Further up another acme along with diversity of species is witnessed during Oligocene.

The larger foraminifera are dominated by *Nummulites* in almost all the Indian sedimentary basins throughout the Palaeogene. There is not much difference in the larger foraminifer diversity of highest Palaeocene and Early Eocene excepting for the addition of *Orbitolites* and *Sakesaria* close to the Palaeocene/ Eocene boundary. Somewhat more striking change is observed in the larger foraminifera near the middle-late Eocene boundary. Usually the level is characterized by disappearance of *Assilina* and flosculine *Alveolina* in the stage P14 (= SBZ 17) to be followed by appearance of *Pellatispira* and new developments among nummulitids which fill the vacuum of last *Assilina*. The diversification of the *Nummulites* is rapid during the Middle Eocene when a number of new forms are added. The late Eocene shows lesser diversity with more extinction, although few new species distinguished by small proloculus, stellate ornamentation and sigmoid septa do appear. Notable among these are *N. pulchellus, N.*

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chavannesi and *N. stellatus*. Some of these along with *N. vascus* survive through transition bordering Eocene to Oligocene. Besides *Nummulites, Lepidocyclina* and rotaliids, the post Eocene younger nummulitids are dominated by *Operculina, Operculinoides, Grzybowskia, Hetrostegina* and *Spiroclypeus*, some of which continue almost up to recent times.

Serra-kiel et al. (1998) under the aegis of the International Geological Correlation Program (IGCP-286) provided a working tool comprising twenty shallow benthic zones covering Palaeocene-Eocene time span of 32 Ma and representing faunal assemblages of both concurrent and mutually exclusive species from key-levels and key-localities. Unfortunately, there were very little inputs from the Indian sedimentary basins and the only Indo-Pakistan area inputs to Serra-Kiel scheme were from South Shillong outcrop area representing the Palaeocene zonation (SBZ 2-4) and younger horizons in Salt Range, Pakistan representing the SBZ 4-8. In view of the extensive structural and stratigraphic trap exploration by the ONGC and a vast collection of data from all the sedimentary basins from India including the total occurrence, diversity and evolutionary changes are witnessed by the petroleum geoscientists rather than anyone else. Tethyan shallow benthic zones (SBZ) for 23 wells, spread across the Assam-Arakan shelf, covering areas from South Shillong, Dhansiri valley and Upper Assam, have been worked out by the author to provide basic framework for future biostratigraphic/ sequence stratigraphic studies. Indian equivalent species for each SBZ including both the Tethyan key foraminifera and concurrent shallow larger benthic species were presented and documented by the author to act as local reference for our sedimentary basins. Use of local bio-events and their mapping under different palaeoenvironmental setups during Palaeocene-Eocene provided finer biostratigraphic inputs to the stratigraphic modelling. Integration of such data with other geological information is immensely useful in the stratigraphic traps exploration. The stratigraphic ranges and the phylogenetic schemes suggested for *Nummulites, Assilina* and *Discocyclina* are largely based upon their diversity, occurrence in the sedimentary successions in one or several Indian basins.

The views expressed in the paper are author's only and not necessarily of the organization to which he belongs.

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FORAMINIFERAL AND PTEROPOD RESPONSE TO LATE QUATERNARY RAPID CHANGES IN THE INTENSITY OF OXYGEN MINIMUM ZONE IN THE EASTERN ARABIAN SEA

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The eastern Arabian Sea Indian margin is characterized today by the well developed Oxygen Minimum Zone (OMZ) between 200 and 1200 m water depth. The intensity of the OMZ, which is linked with the primary productivuity, oxygen consumption and ventilation condition in the water column has varied in the past as a consequence of rapid fluctuations in the monsoonal climate. High resolution foraminiferal (planktic and benthic) and pteropod census data from two sediment cores recovered from the central part of the western Indian margin (off Goa) within present day Oxygen Minimum Zone demonstrate major assemblage switches at millennial to centennial scales in the last 70 ka. Changes in the upper water column structure (temperature gradients, mixed layer and thermocline depth) linked with fluctuations in the monsoonal climate, inducing productivity variation, are recorded by planktic foraminferal assemblages and the organic carbon content in sediments. Pteropods (aragonitic composition) are suitable indicators for monitoring changes in oxygen concentration in the intermediate waters, as their occurrence in bottom sediments is controlled by the Aragonite Compensation Depth (ACD), which varies with changes in OMZ intensity. Our pteropod data clearly exhibit changes in preservational condition of solution susceptible species in response to the swings in the intensity of the OMZ. Benthic foraminiferal assemblages and abundance in marginal environments (upper continental slope) are related mainly to the sedimentary organic carbon and dissolved oxygen concentration. Benthic foraminiferal record demonstrates rapid fluctuations in abundances of oxic, dysoxic and suboxic assemblages at millennial to centennial scales in response to variations in primary productivity and the OMZ intensity. It is intriguing to record that benthic species inhabiting the region during climate instability were able to survive rapid changes in environmental conditions.

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ISOTOPIC DEPTH RANKING OF PLANKTIC FORAMINIFERA AS A PROXY FOR UPWELLING: A CASE STUDY FROM SOUTH-EAST INDIAN OCEAN

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Our research on stable isotopic composition of depth related planktic foraminiferal species resulted in detecting episodes of upwelling at several intervals during Pleistocene in the Southeast Indian Ocean off western Australia, which otherwise is unique in being the only eastern boundary region undergoing no upwelling in modern times. Stable isotope composition of planktic foraminifera has been utilized for ranking them according to their depth habitat in the ocean's upper water coloumn. The basic idea is the vertical variation in temperature and amount of organic carbon in the ocean's upper water coloumn. During upwelling, minimum differences have been observed in the the oxygen isotope record of surface dwelling species like *Globigerinoides ruber, Globigerinoides sacculifer* and thermocline dwellers *Globorotalia menardii*. This has been taken as a powerful tool in addition to the presence of upwelling indicators *Globigerina bulloides* or *Globigerinita glutinata* which sometimes show variation in abundance due to other reasons also including their water mass preference. We must stress here that the basic research material on which all our observations are based are microfossils and correct identification (avoiding phenotypic variants also) is the most necessary component.

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STRENGTHENING OF NORTH-EAST MONSOON WINDS DURING 8.0 KA- 5.4 KA BP: PLANKTIC FORAMINIFERAL AND STABLE ISOTOPE RECORDS FROM THE WESTERN ARABIAN SEA

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Earlier workers reported weak Southwest monsoon (SWM) winds during 8.0 to 5.4 Ka BP based on the ä^{18}O records of foraminiferal tests, speleothems and varve deposits. Sea surface temperature (SST) variation in the Arabian Sea has been affected by changing solar insolation during Holocene, in addition to local hydrological structure, glacial-interglacial events and changing ocean circulation patterns. The western Arabian Sea in particular is influenced by the seasonal Northeast monsoon (NEM) and Southwest monsoon (SWM) wind systems. Lowest SSTs occur during the SWM season due to the coastal upwelling of cold water, and highest SSTs can be found in the low-productivity inter monsoon season due to the stratification of ocean water. We have carried out micropalaeontological and stable isotopic studies on the sediment core SS 4018, taken from the western Arabian Sea in order to see the response of planktic foraminifera to SST variations during Holocene, which is a function of changing monsoonal strength. In the present study, planktic foraminiferal abundance has been observed as they are well established proxy for the monsoon intensity and also for the surface ocean productivity.

The present study has been carried out on a sediment core obtained from the Gulf of Aden, Western Arabian Sea, well above the Carbonate Compensation Depth (CCD). This region is considered as one of the most productive regions due to the SWM induced coastal upwelling. Based on planktic foraminiferal abundance, we have tried to decipher the strength of the SWM during the last 10 Ka BP. The chronology has been obtained by radiocarbon dating of selected planktic foraminifer species using Accelerator Mass Spectrometer (AMS). Enhanced abundance of Northeast monsoon (NEM) indicator planktic foraminiferal species (*Globigerinoides ruber*, *Globigerinoides* species and *Neogloquadrina dutertrei*) was observed which suggests the strengthening of NEM winds during ~8.0-5.4 Ka BP, as compared to that of the present day.

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MICROCONSTITUENTS OF PACHWARA COALS, RAJMAHAL BASIN

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The Rajmahal Basin consists of five coalfields, Hura, Chuperbhita, Pachwara, Mahuagarhi and Brahmani, exposed along the western flank of Rajmahal Hills in N–S direction in Jharkhand State. Pachwara Coalfield, lying in central part of the basin, houses 10 coal seams associated with Barakar Formation (Permian) of Lower Gondwana. The present paper deals with the nature and composition of microconstituents (macerals) in coals of this coalfield encountered in a bore-hole RJP-11 (representing seams I – IX). The coals contain variable proportions of vitrinite macerals (average 39%) with occasionally dominant inertinite (up to 76%, av. 32%) and poor liptinite macerals (av. 7%) associated with dispersed mineral matter, as observed under normal incident mode. Vitrinite, mainly comprising collotelinite and collodetrinite, occurs as finely divided regular/ irregular shreds, fragments and thin to thick microbands. Almost all the macerals of inertinite group, comprising chiefly of semifusinite and fusinite, are well-represented in the coals. Most of these inertinites have obscured cellular structure and occur as irregular, isolated fragments in thin to thick micro bands. Qualitative and quantitative observations under fluorescence mode (blue light excitation) show manifold increase in liptinite contents, chiefly constituted by sporinite (spores-pollen: up to 34%, with a wide range of preservational stages, liptodetrinite (detritus: up to 22%) and alginite (algae-*Botryococcus* and lamalginite: up to 8%). Cutinite (cuticles), fluorinite (essential oils), resinite (resin/ wax) and exsudatinite are in subordinate amounts. Sporinite chiefly consisting of microsporinite, occurs as thin to thick and sparsely to densely packed micro bands, with rather common macrosporinite.

The vitrinite reflectance ($R_{o\ max.}$ 0.40-0.58%) suggests that Pachwara coals are of sub-bituminous A to high-volatile bituminous C rank and are immature for thermogenic methane generation. The ratio between various reactive (vitrinite+liptinite) and non-reactive (inertinite) constituents indicates that these coals are normally rich in trimacerite association, i.e. predominance of mixed (vitrinite-rich: fusovitric + inertinite-rich: vitrofusic) coal types. High amounts of hydrogen-rich macerals (liptinite + perhydrous vitrinite: 24-75%) render these coals suitable for hydrogenation. Coal types, presence of well-preserved cutinites and macrosporinite indicate that the coal seams have originated dominantly from hypautochthonous to

autochthonous woody vegetation in rapid seasonal fluctuations with wet-reducing (anaerobic: vitrinite-rich) to dry-oxidative (aerobic: inertinite-rich) conditions. Occurrence of alginite indicates that the source (vegetal) material was deposited under the influence of brackish water conditions.

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EARLY–MIDDLE CAMBRIAN BIOSTRATIGRAPHY OF ZANSKAR BASIN, TETHYS HIMALAYA, INDIA

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Cambrian successions of the Zanskar region are well exposed in the Niri-Tsarap Chu and Kurgikah valleys of the southeastern part of Zanskar-Spiti basin. The Cambrian succession of the Zanskar region, belonging to Haimanta Group, comprises of Phe, Karsha and Kurgiakh formational units which unconformably or tectonically rests over the metamorphic complex of the Zanskar crystallines (HHC). Recently, a new Parahio Formation has been added by coupling of upper part of the Phe Formation and lower part of the Karsha Formation.

In order to revel the litho and biostratigraphy of the Cambrian succession three field expeditions (2002-2004) were carried out in southeastern part of the Zanskar Valley and three well preserved sections, i.e. Purni-Phuktal (P-P 219.5m), Tangze Yogma-Kuru (TY-K 80.5m) and Kurgikah-Surichun La (K-SL 715m), in Niri-Tsarap Chu and Kurgiakh valleys were studied. A geological map (1:10000) was also prepared to understand the disposition of the lower Palaeozoic rocks of these two valleys.

The Purni-Phuktal section contains well preserved forms of ichnofossils whereas no body fossils of trilobite have been collected along this section. Only fragments of trilobite cheeks were recovered from the loose rock material. Compared to Purni-Phuktal section, the Tangze-Yogma-Kuru and Kurgiakh-Surichun La sections are rich in agnostid and polymerid trilobites. The ichnofossils of arthropod and trilobite affinity are also recovered along these two sections. The composite section of these three well exposed sections indicates age range from Early to Middle Cambrian based on their faunal content. The recorded faunas of ichnofossils and trilobites represent Early Cambrian to Middle Cambrian age. The systematic palaeontology of collected fossils in composite section revealed 25 ichnospecies (19 ichnogenera) and 14 species (7 polymerid and 3 agnostid trilobite genera). The stratigraphic distribution of these fossils indicates four faunal assemblage zones in descending order, i.e. *Hundwarella* assemblage zone, *Peronopsis-Hundwarella* assemblage zone, *Diplichnites-Rusophycus* assemblage zone and *Skolithos-Planolites* assemblage zone.
In Early and Middle Cambrian successions, diverse assemblages of ichnofauna have been collected which includes *Skolithos* isp., *Planolites* isp., *Didymaulichnus* isp., *Trichophycus* isp. (*Trepitichnus* isp.), *Tapherhelminthopsis* cf. *circularis*, *Monomorphicnus* isp., *Dimorphichnus*

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isp., *Protichnites* isp., *Diplichnites* isp., *Teichichnus* isp., *Isopodichnus* isp., *Chondrites* isp., *Palaeophycus* isp., *Lockeia* isp., *Bifungites* isp., burrows, trilobite scratch marks, etc. The distribution of ichnofauna indicates that the simple ichnoforms evolve in the basal part whereas the complex forms evolve higher in the succession. So far, no body fossils of Early Cambrian age have been reported from the Zanskar region, therefore the ichnofossils are very significant at this level. The overall ichnofossil assemblages from the Zanskar region are represented by the lower *Skolithos-Planolites* assemblage zone and upper *Diplichnites-Rusophycus* assemblage zone.

The Tangze-Yogma-Kuru section is a well preserved section along the right bank of Kurgiakh Chu and contains various horizons of agnostid and polymerid trilobites. The major collection along this section shows the trilobite fauna belonging to Teta Member of the Karsha Formation. In Kurgikah-Surichun La section, the trilobites were collected from the Surichun Member of the Kurgikah Formation.

In general, the earliest Middle Cambrian fauna of Zanskar belongs to *Peronopsis-Hundwarella* assemblage zone. This zone includes *Hundwarella convexa*, *Hundwarella* sp., *Damesella* sp., *Ptychoparia* sp., *Fuchouia oratolimba, Anomocarella temenus, Parablackwelderia* sp., *Peronopsis* sp., *Peronopsis amplaxis*, *Peronopsis* cf. *tramitis, Acadagnostus scutalis, Baltagnostus ambonus,* etc. This zone is overlain by the *Hundwarella* assemblage zone represented by *Hundwarella convexa, Hundwarella* sp., *Ptychoparia* sp., *Proasaphicus* sp., *Kunmingaspis* sp., *Peronopsis* sp., *Acadagnostus scutalis,* etc. The distribution pattern of the recorded trilobite genera shows that they are dominant in Teta Member (Karsha Formation) and go above up to basal part of the Kuru Member (Kurgikah Formation). The collected fauna indicates the age ranges from Amgan to Mayan stages of the Middle Cambrian.

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RIVER DYNAMICS AND CLIMATE CHANGE IN GANGA PLAIN

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Ganga plain is one of the most important physiographic features of India. It is located between Himalaya in the north and peninsular plateau in the south. This alluvial plain was formed by the tectonic interplay of Indian and Tibetan plate during Middle Miocene. At present, Ganga plain is drained by a number of rivers like Ganga, Yamuna, Ghaghara, Great Gandak, Kosi, Gomti, Rapti, Chhoti Gandak, Jharahi, etc. which are snow-fed, groundwater-fed and rain-fed. These rivers have evolved various fluvial geomorphic features formed at different span of time. The fluvial geomorphic features are the result of tectonics and climate change and control the demographic distribution on the Ganga Plain. The energy (transporting capacity) of a river is its discharge, which varies, in direct response to the climate change. Energy of the river is high in humid climate and so the sediment size is coarser, whereas during arid climate the energy is low and so the sediment size is finer.

Chhoti Gandak River, a tributary of Ghaghara River, was selected to study the climate change in the Ganga Plain region. It is a ground water-fed river which originates in the terai area near Baithulia in Maharajganj District, Uttar Pradesh and meets with Ghaghara River near Ghothani in Siwan District, Bihar. This meandering river is about 295 km in length and flows essentially southwards.

The valley width, channel width, elevation of cliffs on both the banks and size of the point bars were calculated using SOI topographical sheets and satellite data. The granulometric and environmental magnetic studies were also carried out to describe the discharge and nature of monsoon. The valley of the river is wide (0.5-1.5 km) in which the channel is narrow (50-100 m). The wide valley was carved by the river in the past when the discharge was high and the climate was humid. At present the channel is narrow and the Chhoti Gandak River is a misfit stream. In the present paper sedimentological and magnetic data were analysed to describe the climate change in the Chhoti Gandak River in the Ganga plain region.

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EARLY LAND PLANT REMAINS FROM THE LATE SILURIAN OF LUDFORD CORNER, LUDLOW, SHROPSHIRE, ENGLAND

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Records of early land plants in Silurian and basal Devonian rocks are largely based on small fragmentary coalified forms (mesofossils) of simple morphology and lacking anatomical details. Fossil assemblages from Late Silurian and Early Devonian localities in and around the town of Ludlow in the county of Shropshire, England are of great importance to studies on early land plant vegetation. Ludford Corner is situated at the junction between Whitcliffe Road (Ludford Lane) and the A49 Leominster Road, ca. 80m to the south of Ludlow Bridge, Ludlow (SO 5124 7413). The Upper Silurian rocks exposed at Ludford Corner, including the Ludlow Bone Bed, have been extensively studied and their relevance to the Silurian-Devonian boundary has been vigorously debated over many years. Ludford Corner is a world famous locality of primary importance to the history and definition of Silurian stratigraphy, the evolution of the biosphere and the history of the Lower Palaeozoic Welsh Basin. The fossiliferous horizons occur in the Platyschisma Shale Member that forms the lower part of the Downton Castle Formation of the Prídolí Series. The Platyschisma Shale Member (up to 2m thick) comprises unlaminated to laminated mudstones and shales with subordinate siltstones. It was probably deposited in an intertidal environment. At Ludford Corner itself, complete hummocky cross-stratification sequences in the Sandstone member occur, indicating shallow marine, subtidal to intertidal storm-generated conditions. Land plants growing around rivers were probably uprooted during floods associated with storms, swept away and buried in intertidal sediments. The spore assemblages recovered from this section belong to the *Tripapillatus spicula* Sporomorph Assemblage Biozone and also confirm its Prídolí age.

New collections of exceptionally preserved coalified compressions and semi compressions belonging to early land plants have been made from the uppermost Silurian deposits at Ludford Corner. The fossils were obtained from siltstone horizons 1.6m and 1.8m above the main Bone Bed at this locality. The mesofossils were isolated by bulk acid maceration of grey siltstones using hydrochloric and hydrofluoric acids. The organic residues resulting from the maceration were washed through a 500 micron sieve and the fraction larger than 500 microns was put into a Petri dish in

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water. Cuticles were removed using a pipette and the remaining coalified residues were air dried. The macerate was examined using a stereomicroscope and 40 specimens were removed from the Petri dish using a fine paint brush and photographed with a digital camera. The specimens chosen for this study were circular in outline and suggestive of sporangia or spore masses. Both sides were photographed and they were then mounted on SEM stubs using water soluble glue. They were then coated with gold/ palladium and examined with the help of a scanning electron microscope. The light and scanning electron microscopy of the specimens reveals that the plant fragments of very small size have a variety of shapes, i.e. round, discoid, deltoid, oval, reniform, cordate and obcordate. They were identified as the remains of sporangia and sporangial sacs (some with in situ spores), spore masses, nematophyte cuticles and tubes. Some of the sporangia and sporangial sacs contain dyad spores, while some of the spore masses and isolated sporangia contain laevigate hilate cryptospores attributable to the dispersed spore taxon- *Laevolancis divellomedia*. The surface of many of the specimens is covered with an acellular sheet with irregular depressions interpreted as the remains of the sporangial cuticle.

The composition of the vegetation remains conjectural. Sporangia with trilete spores indicate the presence of vascular land plants and those discoidal in shape, possibly belong to *Cooksonia*. The dyads assigned to *Laevolancis* closely resemble those isolated from earlier Ordovician and Silurian rocks and are thought to derive from the pioneering embryophytes most likely with bryophyte affinities. More enigmatic remains, broadly encompassed by Lang's Nematophytales, may well represent hyphae or coverings of fungi or lichens. A fungal affinity has recently been proposed for *Prototaxites*. Thus even though the fossils isolated from these Late Silurian rocks appear very fragmentary, they can still provide important evidence in reconstructing early terrestrial ecosystems.

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LATE MIOCENE CALCAREOUS NANNOFOSSILS FROM EKTI BAY, LITTLE ANDAMAN ISLAND, BAY OF BENGAL

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Approximately 10m thick sequence, comprising of hard, light grey, highly calcareous silty mudstone grading into siltstone, is exposed at the southern portion of Ekti Bay, Little Andaman Island and is designated as Ekti Bay Section. Sixteen samples examined from this section have yielded 36 species of calcareous nannofossils. The nannofossil assemblage recovered from the section is poorly preserved. The nannofossil taxa are represented by the following ten genera: *Coccolithus, Calcidiscus, Discoaster, Helicosphaera, Pontosphaera, Cribrocentrum, Dictyococcites, Reticulofenestra, Sphenolithus* and *Thoracosphaera*.

The calcareous nannofossil assemblage, containing *Discoaster berggrerii* and *Discoaster quinqueramus,* suggests assignments to *Discoaster berggrerii* Subzone (CN9A) of Okada and Bukry (1980) and to *Discoaster quinqueramus* Zone (NNII) of Martini (1971) of Late Miocene age corresponding to the Neillian Stage of Andaman Nicobar Islands. The present age assignment to the Ekti Bay Section is in conformation with the earlier assignment based on planktic foraminifera.

Berggren et al. (1995) estimated an age range of 10.9 Ma-6.4 Ma for planktic foraminiferal Zones (*N. acostaensis* Zone N16-*Gr. plesiotumida* Zone N17A) and 8.6 Ma-7.2 Ma for the calcareous nannofossil zone (*D. berggrenii* Zone CN9A). A comparison of above estimated ages reveals the age data based on calcareous nannofossils to be more precise than the planktic foraminifera. Thus based on comparative age data the Ekti Bay section of Little Andaman Island represents the uppermost part of *N. acostaensis* Zone N16 and lower part of *Gr. plesiotumida* Zone N17A.

Reworked calcareous nannofossil species of Eocene – Oligocene and Early- Middle Miocene age are also recorded from the samples of Ekti Bay Section of Little Andaman Island. The reworked assemblage suggests uplift of Andaman Islands during the Late Miocene.

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RECONSTRUCTION OF NEOGENE-QUATERNARY PALAEOCLIMATE OF SIWALIK SEDIMENTS: MULTIPROXY APPROACH

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The proxy methods for reconstructing the palaeoclimate have been widely used in the last two-decades. The main factors that have been considered in proxy records to reconstruct palaeoclimate include the continuity of the record, accuracy to which it can be dated and its resolution. Siwalik deposits offer a reasonably complete and a high-resolution record of Neogene and Quaternary fresh water sediments. In order to reconstruct the palaeoclimate of Siwaliks we are using microvertebrates (rodents, insectivores, lagomorphs, otolith, etc.), microinvertebrates (mollusc, ostracods, decapods, etc.) and plant remains (pollen, spores and charophytes). The well dated sections, which we have studied so far, include, Kangra, Haritalyangar, Ghaggar river section, Nadah, Moginand, Khetpurali and Haripur Khol.

Among the microvertebrates, a diverse assemblage of micromammals, including rodents, insectivores and lagomorphs, has been recovered from these deposits. Our study shows that the replacement of survival-oriented cricetids by reproduction-oriented murid rodents in the Late Miocene is indicative of inter-annual seasonal variations (intensification of monsoon). Within the Pliocene (~2.5 Ma), among the rodents a significant change at generic level, leading to the appearance of modern forms (*Bandicota, Nesokia, Rhizomys,* and *Tatera*), probably indicates an intensification of monsoon. Further, presence of gerbil rodents associated with lizards in ~ 2 Ma deposits might indicate semi-arid conditions or intermittent dry periods. Beside rodents, fish otolith growth rings and their microstructure are being studied to understand environmental changes and seasonal variations.

We have recovered a diverse assemblage of microinvertebrate as well, which includes mollusc (gastropods and bivalves) and ostracods. A greater understanding of Quaternary palaeoclimates has accrued from the gastropod assemblage, in particular, which extrapolated towards the Recent comprise of second largest and most successful group. They are very sensitive to changing environments, and endowed with short-term basin residency times, provide a statistically strong significant population size from which to base environmental interpretations. The diversifications of viviparids and *Melanoides* are reflective of a lentic environment of lowland ponds with

around 2m depths. Most abundant are viviparids, which are subtropical viviparous communities. Other members of the pond communities comprise those of a unionid bivalve *Lamellidens* and *Corbula.* The distribution of freshwater ostracods is dependent on temperature for which they are most sensitive, light, substrate type, water chemistry, predation, and food supply. We have also recorded palynoassemblage from Nadah and Ghaggar River sections (Pinjor Formation), Haryana. The assemblage consists of algal and fungal remains, pteridophytic spores, gymnospermous and angiospermous pollen grains. The pteridophytic spores favor moist and shady habitats and fungal remains are indicative of warm and humid conditions. Based on modern equivalents, a tropical-subtropical humid climate has been inferred for the Pinjor Formation. The presence of zygospores of Zygnemataceae is indicative of stagnant shallow and more or less mesotropic fresh water habitats. This is also supported by the presence of charophyte genus *Lamprothamnium* that indicates an oligo-mesohaline environment. The presence of grass pollen indicates the existence of herbaceous flora. Based on the overall palynofloral assemblage, wet grassland with open mixed flora during the Pinjor sedimentation has been inferred.

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DIVERSIFICATION OF MEGASPORES CONSEQUENT TO THE DECCAN VOLCANIC EPISODE

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The present paper reports megaspores recovered from the Deccan intertrappean sediments (Maastrichtian) and attempts to correlate the palaeoenvironmental conditions suitable for heterospory vis-à-vis the volcanic activity. Among with the earlier known megaspores, three new genera, viz. *Hirsutiaspora*, *Acrolamellispora* and *Padwarispora* are described. All the above proposed genera are monotypic and are typified by *H. excellensa, A. reticulata* and *P. baculata* respectively. Reports of megaspores from the Deccan intertrappeans are scanty, when compared to equivalent Late Cretaceous deposits studied in other parts of the world. This is primarily due to the routine palynological procedures adopted for the recovery of miospores, where comparatively less amount for each sample (20 grams) is chemically processed and only the finer residue is studied. In this study, considerably large amount for each sample (500 grams) was processed without crushing and suitable sieving was done to retain the larger megaspores. Megaspores are well recognized for their use in correlating and assigning the age of the sedimentary sequences. Recovery of these megaspores reflects good possibility for further study in correlating sediments from other intertrappean deposits.

Heterospory is the first step towards the evolution of seed habit in land plants. It evolved during the Devonian, along with major groups of land plants, when volcanism, sea level rise and greenhouse effect were at their zenith. Somewhat similar climatic conditions again prevailed at the time of deposition of the Deccan intertrappean sediments during Late Cretaceous. This greenhouse stage resulted in the further diversification and prominence of heterosporous plants, as well as the angiosperms. Heterospory is in consequence to aquatic freshwater environment where cross fertilization of populations and drifting away to new areas occur, which allows new sporophytic generation to proliferate. This is in concurrence to the depositional environment of the studied sediments, which took place under freshwater lacustrine conditions. Megaspores being large and laden with nutrient; provide an additional advantage for the plants to grow in hot and periodically arid climate as in ephemeral habitats. During the terminal Cretaceous (Maastrichtian), Indian landmass was subjected to one of the largest episodes of volcanism in the earth's history. The enormous

outpouring of lava considerably increased the carbon dioxide content of the atmosphere, which further aided the already hot climate prevalent during that time. All these factors, along with the rise in sea level, were conducive for the diversification and proliferation of heterosporous plants on land. The Deccan intertrappean sediments, therefore, provide tremendous potential for extensive studies on megaspores.

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FUNGAL REMAINS AND POLLEN FROM THE NEOGENE SEDIMENTS OF MAHUADANR VALLEY, JHARKHAND AND THEIR PALAEOCLIMATIC IMPLICATIONS

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This paper deals with the record of fungal remains and pollen from the Neogene fossiliferous bed exposed along the Rampur Nala and Birha River in the vicinity of Mahuadanr (Lat. 23º23'15"N: Long. 84º06'40"E,) in Latehar District, Jharkhand and their significance in understanding the depositional environment. Pyroclastic rocks, conglomerates, sandstones and organic-rich shales have yielded rich pollen and fungal assemblage. In all, 22 well established forms, viz. *Tetraploa*, *Curvularia*, *Diplodia*, *Nigrospora*, *Cookeina* sp., *Alternaria*, *Helminthosporium*, *Meliola*, *Multicellaesporites elsikii*, *Trichothyrites*, *Microthyrites* sp., *Microthyrium* Type (fruiting body), *Monoporisporites koenigii*, *Phragmothyrites*, *Dictyosporium*, *Didymoporiporonites*, *Dicellaesporites*, *Staphlosporonites*, *Diporisporites*, *Diporicellaesporites* and *Spinosporonites* and 10 other fungal remains in the form of spores and fruiting bodies of uncertain affinities have been documented. In addition, the pollen of the tropical trees, viz. *Schleichera*, *Terminalia*, *Emblica officinalis*, *Dalbergia*, *Lannea coromandelica* and Melastomaceae together with herbaceous elements such as Poaceae, Asteraceae (Tubuliflorae), *Solanum* and ferns have also been encountered in this sedimentary bed. The retrieval of diversified fungal and pollen assemblages suggest that the region witnessed a humid climate during the course of sediment accumulation and supported the moist tropical deciduous forests. The prevailing favourable climatic conditions coupled with organic rich substrates on the forest floor were very conducive for the growth and proliferation of fungi. The palaeoclimatic inferences drawn from the present investigation are also in agreement with those deduced earlier from the recovery of a large number of megafloral remains such as leaf, fruit and seed impressions together with petrified woods belonging to tropical deciduous plants from this fossiliferous bed.

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PHYTOPLANKTON VARIABILITY IN HARSHAD ESTUARY, SAURASHTRA COAST AND ITS IMPLICATIONS IN PALAEOMONSOONAL FLUCTUATIONS

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Estuarine systems exhibit a complex interplay of both fluvial and marine processes that are responsible for the deposition of organic rich sediments, derived from terrestrial as well as from marine sources. Diatoms and dinoflagellate cysts forming the phytoplanktonic community are the primary producers, and are important constituents of organic matter deposited in the estuarine system. Hence their study is expected to provide clues to the quantity and quality of carbon available at the base of the food chain. The seasonal precipitation related runoff mainly controls the diversity and abundance of phytoplanktons in the estuarine system. The coastal region of Saurashtra in the semi-arid and arid zones of Western Indian region has various estuarine environments.

The Harshad estuary located in the semi-arid zone, near Porbandar, experiences low SW monsoonal activity. An attempt has been made to investigate fluctuations in the palaeoprecipitation by studying the runoff related environmental changes based on the distribution pattern of dinoflagellate cysts and diatom community along with other phytoclasts in the Harshad estuary. Sediment samples were collected from a 60 cm long core from the central part of the estuary. Fine sampling at one centimetre intervals was carried out in order to obtain high resolution palaeoclimatic data. Cysts of both gonyaulacoid and peridinioid dinoflagellates were studied for their ecological significance. Both centric as well as pennate diatom communities were studied. Maximum distance cluster and detrended correspondence analyses were performed to identify phytoplankton associations that corresponded to nutrient related environmental changes. Possible relationships between various palaeoecological groups amongst phytoplankton communities were drawn. The study shows that the diatoms and protoperidiniods dominate during periods of high river discharge (high SW monsoonal activity) however gonyaulacoid dinocyst predominates under the influence of marine tidal activity during low river runoff (low SW monsoonal activity).

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OCCURRENCES OF SILICIFIED MICROFOSSILS FROM THE NEOPROTEROZOIC BHANDER GROUP, VINDHYAN SUPERGROUP, SATNA DISTRICT, MADHYA PRADESH

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Carbonaceous cherts in Proterozoic sequences from various parts of the world represent vast storehouse of cellularlly preserved and diversified microfossils that existed in the form of microbial mat/ isolated dwellers (combination of single to multicelled organisms). These microfossils are significant to elucidate the evolutionary history of photosynthetic life in geologic past.

The microbial fossils dealt with, in this paper, are comprised of both filaments and coccoides detected from the inner and outer side of coated grains as well as beyond it. For the study of organic-walled microfossils, samples were collected from chert lenses (intercalated in dark grey limestone) of the Nagod Limestone Formation, Bhander Group exposed in Sijahata village, Satna District, Madhya Pradesh. The microfossils belong to planktic and benthic habitats. The microfossil assemblage is represented by 15 taxa of cyanobacterial remains belonging to Chroococcaceae and Oscillatoriaceae. These are categorized into three groups, viz. euendolithic, epilithic and clast bound.

Fossils of euendolithic groups are the most abundant in the assemblage and are identified as cylindrical, unbranched, nonseptate, deeply penetrating tortuous filaments *(Cunicularius halleri)* and small spherical, coccoids fossil *(Myxococcoides minor*. They show actively drilling habit from periphery towards centre of the ooids rock substratum through changing their physiochemical process accordingly. The epilithic group represents the micro-organisms that lived either in the interstices or on the outer margins of the stabilized pisoids/ ooids rings. These fossils are tightly packed sphaeroids in colonial habits with or without internal coalesced organic matter, viz. *Glenobotrydion aenigmatis* and *Parenchymodiscus endolithicus*. The micro-organism population, preserved in the carbonate clasts, includes helically coiled filaments *(Obruchevella parva),* long cylindrical smooth walled filaments *(Siphonophycus robustum)* and hyaline to granular solitary vesicles containing large number of inner spherical vesicles (*Perulagranum obovatum)*. The interstitial fossils are found in isolated manner in chert

†Deceased

matrix in form of solitary and colonial habits. The assemblage includes dyads and tetrads *(Eoentophysalis belcherensis)*, small to large, smooth coccoides *(Myxococcoides grandis, Myxococcoides cantabrigiensis)*, densely interwoven filaments *(Siphonophycus robustum)* and ribbon like thin filaments *(Archaeotrichion)*. The present assemblage shows close affinity with the assemblage from ~700 Ma old Eleonore Bay Group of Greenland. Excellent preservation of these microfossils indicates a unique property of auto-transformational phase for their protection from the unfavorable conditions caused by natural processes. It also suggests a heterogenetic and shallow marine depositional environment during sedimentation of the Nagod Limestone Formation.

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RESPONSE OF LATE QUATERNARY PTEROPODS TO THE OMZ FLUCTUATIONS IN NORTH-WESTERN ARABIAN SEA

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The present study is based on the examination of about 9m thick section at ODP site 728A situated at a water depth of 1428m near the Oman margin (northwestern Arabian Sea). This site is suitable to examine the variations in the strength of Oxygen Minimum Zone (OMZ) due to its location just below the OMZ. Variations in the strength of OMZ over the past ~175 Ka in the northwestern Arabian Sea were reconstructed on the basis of changing abundances of pteropod at this site. The down core abundance reveals pteropod spikes at the transitions of isotope stage MIS 6/ 5, MIS 2/ 1 and during glacial stages MIS 6 and MIS 2 reflecting lowering of Aragonite Compensation depth (ACD) and relatively less intense OMZ in this region possibly due to deep sea mixing and thermocline ventilation and the relative decline in the surface productivity during winter monsoon. In general, the interglacial periods are largely devoid of or marked with very low pteropod abundances indicating dissolution of aragonite due to increased intensity of OMZ in the northwestern Arabian Sea. The transition of MIS 6/ 5 is also marked with the prominent increase in abundances of *Limacina inflata* and mesopelagic forms indicating less intense surface productivity and more deep sea ventilation. However, MIS 2/ 1 transition is characterized by increased abundances of pteropod shells, *Limacina trochiformis* along with epipelagic forms reflecting more surface productivity and intense deep sea ventilation. Therefore, it is suggested that the accumulation of pteropod shells in the sediment is mainly influenced by the changing strength of OMZ in response to deep sea ventilation which is largely unaffected by the fluctuations in surface productivity. Thus, the reduced number of pteropod shells in the deep sea sediments of the high productivity regions like Oman Margin in the northwestern Arabian Sea may largely be due to dissolution and not because of the lack of supply.

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PRE AND POST MONSOON SEDIMENT PATTERNS, ECOLOGICAL DISTRIBUTION AND ENVIRONMENTAL CONDITIONS IN AND AROUND TAMBRAPARANI ESTUARY, SOUTHEAST COAST OF INDIA

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Tamiraparani basin is one of the major river basins and the second largest river in Tamil Nadu with a catchment area of around 6000 km^2. The study area Tamiraparani located between latitudes 8°25' and 9º25'N and longitudes 77°10' and 78°10'E along the south east coast of India. In order to identify the nature of sediment character, the mode of deposition in river, estuary and marine regions of Tamiraparani and adjoining coastal areas, grain size and ecological parameter studies for both the monsoon have been carried out. Sampling sites were determined with a grid overlain on a Survey of India 1: 50,000 scale base map of Tamiraparani estuary and adjoining coastal area. Ninety sediment samples were collected in two seasons using Van Veen grab sampler. The study of organic matter (OM) in the estuarine environment ranges from 0.3% to 4.7%. The content of calcium carbonate in the surface sediments is generally low. The strong positive association with fine sediments with organic matter (R2=0.0602) in pre-monsoon and (R2=0.0889) in post-monsoon respectively. Tamiraparani river samples indicate a unimodal and bimodal distribution in pre-monsoon. In Tuticorin, marine samples are also bimodal in nature with medium and fine sand where sediment is additionally deposited by the Tamiraparani River. In post-monsoon, the marine sediments are unimodal to bimodal with medium to very fine in nature. The fine sediments indicate the depositional environments either in the form of suspension or it can be transported by longshore current. In pre-monsoon, the mean values in the study area, river sediments range from 0.89 to 1.33 indicating the dominant presence of medium and coarse sand. In the marine sediments of Tuticorin sector, the sediments from Tuticorin itself are fine to medium (3.07, 1.09). This is due to the strong wave divergence or low energy conditions in that region. In post-monsoon, the mean values range from 1.69 to 2.01 with medium to fine sand. The fine sand in the riverine region indicates the depositional nature of the sediments.

Pre-monsoon, standard deviation ranges from 0.29 to 0.81 and falls in the very well sorted to moderately well-sorted. In post-monsoon, the rivers

are moderately sorted to moderately well-sorted in nature. In the study region, the river sediments account for fine skewed to very fine positively skewed (3.63 to 1.35). The fine skewed indicates the transport of fine sediments towards the estuary region. This positive skewness of the sediments strongly recommends the depositional activities in the area. In post-monsoon, the river sediments show symmetrical to very fine skewed whereas in estuary region it is symmetrical to very fine skewed in nature. From the sediment texture and ecological studies, it is clearly observed that in pre-monsoon the erosional activities are predominant than the post-monsoon. In both the monsoons, sediments transport from river and estuary towards the beach and marine. In pre-monsoon whatever sediment deposited were transported and shifted due to longshore current action. But, in the post-monsoon it is depositional environment where the sediments deposited due to the multi-source like riverine and marine influence is observed.

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THE PLIOCENE CLIMATIC TRANSITION: POSSIBLE CONSEQUENCES OF THE SEAWAY CLOSING

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The Pliocene has been one of the most crucial epochs in the geological history, for during this period two major ocean gateway closing events occurred. These are the closing of the Indonesian Seaway at about 5.6 - 4.2 Ma (early Pliocene) and the closing of the Central American Seaway at about 3 Ma (late Pliocene). Another key event that took place in the late Pliocene was the development of permanent ice sheets in the Northern Hemisphere at about 3 - 2.4 Ma. Closing of these two seaways caused diminishing equatorial circulation and brought profound oceanographic, biotic and climatic changes.

Prior to 3 Ma Polar ice sheets were restricted to Antarctica. Faunal and isotopic evidences suggest that early Pliocene (between 5.6- 3.5 Ma) is well known to have been an interval of global warmth greater than any time during the last 7 million years, including to-day. Therefore, the question whether the Antarctic ice sheets and climatic system withstood this early Pliocene warmth or did it experience major instability? This problem is of central importance in considering the consequences of global warming and the polar cryosphere and of changing global climate and sea level.

The opening and closing of major ocean gateways or seaways through plate tectonics can significantly change surface and deep ocean circulation, which in turn affect global heat transfer, and thus climate. Hence, the main focus of the study is to document possible repercussions arising from the seaway closing and to evaluate as to how far the evolution of the present earth system is largely a consequence of closing of seaways in the Pliocene?

The most significant aspect of the Pliocene is the major climatic transition from a warm early Pliocene to abrupt global cooling during late Pliocene, as a result of development of Northern Hemisphere glaciation and increase in Antarctic ice volume. Other striking features of the Pliocene are the diminishing equatorial circulation and the resultant palaeobiogeographic distribution pattern including major faunal turnover. These events appear to be largely the consequences of the closing of the Indonesian Seaway and the Central American Seaway during early and late Pliocene respectively.

The modern assemblage of foraminiferida although emerged in the middle Miocene but undergone perhaps the last major faunal turnover during the late Pliocene due to abrupt climatic cooling. Further, age determinations and correlations support the view that the late Pliocene closing of the Central

American Seaway and development of permanent ice sheets in the Northern Hemishphere are coeval events. Thus, these events led to establish a bipolar symmetry in climate change since 3 Ma, and set in motion the modern ocean circulation.

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MICROBIAL ASSOCIATION IN LOWER GONDWANA PLANTS

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Lower Gondwana succession of India is known for variety of leaf forms, fertile structures, dispersed seeds, sporangia and spore-pollen assemblages which are distributed in different geologic formations, viz. Talchir, Karharbari, Barakar, Barren Measures and Raniganj, of Permian Period. However, records of microbial organisms like algae, fungi, bacteria and their association/ activities are rare and random. Systematic approach has not been adopted to discover/ describe the microbes and microbial relationship in flora. However, careful search and compilation of scattered data indicate the presence of microbial association in plant fossils and algal and fungal spores in palynological assemblages.

Records of fungal hyphae and spores alongwith degraded cellular tissues in *Glossopteris* and *Noeggerathiopsis* leaves indicate the possible fungal parasitism in Glossopteris flora. The presence of rod-shaped bacteria over the surface of seed cuticle recovered from *Scutum*-type fructification demonstrates the evidence of bacterial degradation in the form of plaque/ pit-like structure. The epiphyllous fungi recovered from the cuticle of *Glossopteris*-leaves and cyanophycean algal filaments observed in cellular pulls obtained from the stem surface of *Phyllotheca indica* suggest the mutualistic relationship of microbes. Quite often associations of fungal hyphae and spores in fossil woods apparently do not demonstrate the activities of fungi, quite likely such association at later stage became a viable factor for the degradation of plant tissues.

Well preserved algal and fungal spores are known in dispersed condition and their presence is discussed in relation to palaeoenvironmental features during Lower Gondwana phase. Skeletonization of body exine/ saccus and presence of fungal colonies over the surface of degraded spores-pollen provide the direct evidence of microbial activities in biodegradation. The sporadic and occasional records of microbes and their association in Lower Gondwana flora are encouraging to study the taxonomic deliberation and role of microorganisms in fossil assemblages. Such studies are relevant to understand the microbial diversity and to make out the palaeoecological interpretations.

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A NEW FOSSIL WOOD FROM THE TIPAM GROUP OF HLIMEN, MIZORAM

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The Tertiary sediments in Mizoram are mainly represented by the Barail, Surma and Tipam groups. Though the state is rich in plant fossils, yet it is not fully explored as far as the megaremains are concerned. In order to enrich the palaeoflora of the region, a field trip was undertaken to collect the fossils. A new plant fossil locality was discovered near Builum, 6.5 km west of North Hlimen in the Kolasib District. The present fossil wood is described from the Tipam Group which is of Late Miocene in age. The main identifying features of the fossil wood are small to medium vessels, paratracheal banded parenchyma, mostly biseriate xylem rays, simple perforation plates, vestured pits, weakly heterogeneous xylem ray tissue and non-septate fibres which strongly indicate its affinity with *Cynometra*, especially with *C. ramiflora* of Fabaceae. This is the first record of *Cynometra* from this state. *Cynometra ramiflora*, to which the fossil wood shows maximum resemblance, is found in tidal forests of Andaman and Sunderbans. Fossil woods, resembling *Cynometra*, are generally placed under the genus *Cynometroxylon*. The present fossil is identical to *Cynometroxylon holdenii* which is very common during the Neogene of India. The occurrence of the fossil wood near Hlimen indicates warm and humid climate during the Late Miocene.

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PERMINERALIZED FUNGAL REMAINS IN THE FOSSIL WOOD OF *BARRINGTONIA* FROM THE DECCAN INTERTRAPPEAN SEDIMENTS OF YAVATMAL DISTRICT, MAHARASHTRA

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Fungal infection (parasitism and saprophytism) in the fossil flora of Deccan Intertrappean sediments is well documented from Chhindwara, Dindori, Mandla, Nagpur and Seoni areas of central India. Recently, a well preserved dicotyledonous fossil wood infected with fungus was recovered from Zhargad area of Yavatmal District, Maharashtra where cherts are flooded with gastropods and plant material. The characteristic features of the fossil wood are: vessels mostly in radial multiples, perforation simple, intervessel pits large; parenchyma abundant, both paratracheal and apotracheal, paratracheal vasicentric and apotracheal as diffuse-in-aggregate forming 1-2 seriate broken lines; rays 1-4 seriate, heterocellular and fibres nonseptate. These characters collectively indicate its close resemblance with modern woods of *Barringtonia* Forster and G. Forster of the family Lecythidaceae (=Barringtoniaceae).

Fungal spores are profusely found in the vessels of the fossil wood. They are dark coloured, circular, found as single grained or in clusters, 10-30µm in diameter, spore wall seemingly smooth and inaperturate. Few spores show germination at one or more points. Very fine mycelium is also seen at places but it is broken, ill preserved and difficult to reveal structural details. Interestingly none of the spores have been found in attachment with the hyphae. The present finding is the first record of dicotyledonous wood as well as fungal infection from Yavatmal area.

The genus *Barringtonia* Forster and G. Forster consists of 39 species of small and medium sized trees and is one of the characteristics of beach forests of India, Sri Lanka, Polynesia, Malaysia, Myanmar and northwest Australia. They also occur in Inland along streams and swamps. The marshy habitat and humid warm climatic conditions in Deccan Intertrappean times were unquestionably suitable for luxuriant growth of fungi as well as the genus *Barringtonia*. Presence of gastropods near the fossil locality further supports the humid conditions and water bodies in the area.

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POLLEN ANALYSIS OF LATE HOLOCENE CORES FROM RUSULCHERUVU, CENTRAL ANDHRA PRADESH

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Pollen remains are one of the best available biological proxies to reconstruct past vegetation and climatic changes. However, in South India, there is still a significant gap in terms of the number and spatial distribution of terrestrial sites. The studies currently available are from upper montane, offshore, mangroves and estuaries. One of the key factors that palaeovegetation studies in the tropics can help eventually unravel, in a combination of data and modelling approaches, is the dynamics of the Indian monsoon, crucial to the currently primarily agrarian economy that is dependent on it.

The present instrumental record of the monsoon candidly demonstrates that in South India it is characterized by a complexity and spatial variability that has an antiquity that probably goes back to the LGM (18000 BP) or at least early Holocene (11000 BP). This underlines the need for a spatially well distributed set of palaeovegetation reconstruction in this region in order to effectively understand its past performance at the regional scale of South India. Using the novel multidisciplinary approach, incorporating remote sensing we short-listed a number of potential sites in mainland South India. Here, we present the preliminary results of one of these sites, Rusulcheruvu, a rainfed reservoir (tank) at the foothills of the Achampet plateau, near the NSTR (Nagarjunasagar Srisailam Tiger Reserve), Central Andhra Pradesh. This tank currently supports an *ayacut* of ~ 300 acres.
Two cores were taken from this tank at different locations nearly 50 to 100 m apart. The first, at the centre of the tank yielded a core of ~1.5 m before reaching the rock bottom while the second core more towards the periphery was only around 80 cm after which a weathered layer was encountered. Two radiocarbon dates indicate that the site is around 1400 BP. Although the cores have been subsampled at 2 cm intervals, we present here only the broad pollen spectrum all along the cores at 5 to 8 cm intervals.

Some of the most significant pollen taxa encountered in the cores include deciduous tree taxa such as Melastomataceae/ Combretaceae, *Haldina*, *Ixora*, *Trema* and *Grewia* in addition to some evergreen elements such as *Syzygium*, *Elaeocarpus* and *Gnetum*. Poaceae and Cyperaceae are among the dominant herbaceous taxa, with other herbs such as

Chenopodiaceae/ Amaranthaceae and Compositae echinate also being encountered. The paucity of human impact markers such as *Casuarina*, *Polygonum plebium*, and *Eucalyptus* indicates that the site has remained relatively undisturbed. The spectrum as a whole reflects a decrease in the total tree pollen influx from the surrounding deciduous forests since the past 1400 years. The pollen percentage diagram as well as the quantitative diagram of pollen influx (pollen per gram of sediment) are presented and described in detail vis-a-vis the present day vegetation on the slopes providing the run off input to the tank.

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A REVIEW OF FORAMINIFERAL STUDIES ON JURASSIC ROCKS OF KUTCH

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Jurassic rocks of Kutch have been subjected to extensive palaeontological and stratigraphic studies since 1834. However, most of the studies are devoted to megafossils and relatively little has been published on microfossils. Since the first record of some foraminiferal genera from the Patcham rocks of Habo Hill in 1957, a number of studies have appeared. However, most of them deal with taxonomy and biostratigrahy with little emphasis on other aspects, such as palaeoecology, palaeobiogeography, and palaeoclimatology. The present study compiles and assesses the entire work done on the Jurassic foraminifera of Kutch and identifies areas for future foraminiferal investigations.

A total of 281 species have been recovered so far from Jurassic rocks of Kutch including 37 new and 80 indeterminate species as well as 27 species of *Epistomina*, an important genus for Jurassic biostratigrapy. Vaginulinids and nodosarids dominate the Kutch foraminiferal assemblage. Both calcareous and agglutinated forms were recorded and their ratio is about 2: 1. Most of the foraminiferal assemblages have been reported from Patcham and Chari formations, the overlying Katrol Formation yielded meagre foraminifera. Some well known Jurassic species are found to occur in nearly all the assemblages recorded from Kutch.

Most of the foraminiferal studies deal with systematics but foraminifera has also been used to date the sediments, delineate boundaries between stratigraphic units and preparation of microbiozonation scheme. Attempts have been made to interpret the depositional enivironment of these sediments mainly based on foraminifera but in combination with lithology, petrography, microfacies and field observations. Few studies also demonstrated the affinity of the Kutch foraminifera to those of neighbouring regions and assigned a Tethyan affinity to the Kutch foraminifera.

Although considerable systematic studies have been carried out on the Jurassic foraminifera of Kutch but most are confined to major domal outcrops in the Kutch Mainland viz. Habo, Jhurio, and Jumara domes. The smaller outcrops, viz. Jara, Kaiya, Keera, Chari, Ler, Fakirwari, and Walakhawas as well as the 'islands' of the northern belt, viz. Patcham, Khadir, Bela and Chorad are either totally neglected or subjected to cursory investigations. Detailed foraminiferal studies of these outcrops are vital for a complete picture of the systematics and distribution of foraminifera

in the Jurassic rocks of Kutch. It is also important to establish more marker species for precise dating of these sediments. Stage boundaries in all the exposed sections may also be marked and correlated.

Only preliminary studies on the palaeoecology and depositional environment have been carried out so far. A number of methods for palaeoecolgical interpretations using foraminifers are currently being used which may be applied for a more accurate and precise interpretation of depositional environment and palaeotectonism, characterizing the maximum flooding surfaces, marking the precise time of different transgressive and regressive episodes and identifying various orders of transgressive-regressive cycles and their number.

Palaeobigeographic affinity of Kutch foraminifera has not been conclusively established till date and only a few studies exist on foraminiferal affinity and palaeobiogeography. A thorough study of affinity of the Jurassic foraminifera of Kutch may help in arriving at a definite conclusion regarding their palaeobiogeography.

Foraminifers are currently being used as a reliable tool for palaeoclimatic interpretation. However, no such study is carried out so far on the Kutch Jurassic. Future foraminiferal studies on this aspect are desirable.

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ARCHITECTURAL RADIATION IN INDIAN GONDWANA MEGASPORES

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Architecture is a genetically determined morphology of an organism but may be often regulated also by ecological factors. Architectural patterns are of biological significance and strongly influence life history of an organism. These patterns have been studied in megaspores of Permian (Talchir, Karharbari, Barakar, Barren Measures and Raniganj formations), Triassic and Early Cretaceous of Indian Gondwana. Study of megaspores is not only significant in deciphering evolutionary history of land plants but also in biostratigraphy, interpretation of palaeoecology and of source vegetation. Indian Gondwana megaspores exhibit varied exine ornamentations, viz. grana, verrucae, bacula, coni, spines, setae, reticulum and a variety of mammilate, ribbon-like, hair-like and filiform appendages. These ornamentations display a distinct radiation from Early Permian to Early Cretaceous, thus reflecting on the specific diversity of their parent plants. Megaspores of Early Permian (Talchir, Karharbari and Barakar formations) exhibit almost all kinds of ornamentations, including laevigate and micropitted/ granulate, whereas those of Late Permian (Raniganj Formation) are by and large spinate and show various types of straight, hooked, stout, simple, bifurcate and multifurcate spines/ appendages. These sculptures also indicate aquatic and sub-aquatic environments. Alete, spinate seed megaspore *Kamthispora*, occurring in the Raniganj Formation, probably indicates an intermediate stage between a megaspore and a seed. In Mesozoic, the megaspores additionally show reticulate exosporia which are not recorded from Permian. Evidently, the outer layer of megaspores exhibits a distinct evolutionary trend. However, this is not the case with mesosporium/ inner layer which is either not distinct or is not recorded in Mesozoic megaspores. Probably, the palaeoecological factors were responsible for this discrepancy.

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MASS EXTINCTION DUE TO LARGE BOLIDE IMPACT ON EARTH AND ITS ASTROBIOLOGICAL IMPLICATIONS

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During its history, the Earth has been a target for numerous meteorite and asteroid impacts. Impactors over 10 km in diameter are relatively rare, but such an impact must have played influential roles in determining the nature and future of life on Earth. A projectile of only 10 to 15 km in diameter can cause a mass extinction, not only directly killing organisms by means of explosions and shock waves but indirectly, when dust collects in the atmosphere, blocking the Sun's light and suffocating all breathing organisms. Volcanic eruptions and rock showers can also follow, first killing large animals and plants and then autotrophs and other organisms because of a lack of oxygen and light. Evolution could also be halted for millions of years, for the time it takes to cool the Earth's atmosphere. The extraterrestrial bolide impact at the Cretaceous-Tertiary Boundary is the most widely accepted reason for the catastrophic mass extinction on Earth about 65 million years ago. Recently this asteroid has been recognized as Baptistina family asteroid. The dinosaurs were killed by broken up chunks of a bigger asteroid estimated as 170km wide. The Chicxulub crater, long thaught to be associated with the extinction of the dinosaurs is 180 km wide. The bolide impact theory is strongly supported by the impact derived spherules and the rich concentration of the rare earth element iridium and other platinum group elements in the boundary clay layer from Yucatan Peninsula (Mexico), Sugarite section in New Mexico (USA) Padriciano and Gubbio sections of Italy, Dolenja Vas section of Slovenia and Um Sohrynkew section of Meghalaya, North-East India. The mass extinction of dinosaurs and planktonic foraminifera at the K/ T Boundary is related to this impact. The benthic foraminifera show reorganization and resulted from the drop in biotic productivity after the asteroid impact in the end Cretaceous. The sedimentological and geochemical study of the carbonate rocks from the K/ T Boundary to Lower Eocene rocks in the Karst area of Italy (Padriciano), the Dolenja Vas and Sopada sections of the Slovenia in the NW Adriatic platform and Meghalaya, India also support the impact related extinction. The mass extinction in the oceans was world wide and about 90% of the planktonic foraminifera perished. The extinction event was also linked with the major change in the global carbon cycle. Stable carbon isotope studies of planktonic foraminifera show a negative excursion following the K/ T

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boundary mass extinction. The highly negative carbon isotope (-10 PDB) values have been reported from the stromatolitic limestone with microcodium in the Padriciano section following the K/ T Boundary. The extreme depletion of carbon isotope indicates a drop in marine primary productivity following mass extinction. The decrease in carbonate carbon and organic matter at K/ T Boundary is also interpreted to be the global cooling event and mass extinction. No life form could have survived locally at the impact site upon collision. However, after sometime, the Earth's surface temperature cooled down enough for hyperthermophiles and thermophiles to survive.

Astrobiology encompasses the origin and evolution of life on Earth; the range of habitats that carbon liquid water life occupies here, and that life on any basis might occupy elsewhere; the identification and exploration of possible habitats beyond the Earth; and ways of detecting extraterrestrial life, in whatever forms it occurs. **Astrobiology** is a term that has been popularised by NASA, the American Space Agency. Astrobiology has been recognized as science for extraterrestrial search for evidence of microbial life whether fossil or extant in the cosmos. In the search for life and the impact of extraterrestrial bodies (asteroids, comets, etc.) on them, we have to properly understand the earliest life on our planet Earth as best analogue. Comets and meteorites may have been a source of amino acids on the early Earth. Recently some new techniques have been devised to confirm the biogenicity of the Precambrian microfossils found in black cherts ranging in age from 3500 to 850 million years. Laser Raman imagery and spectroscopy has been used to analyse the molecular compositions of individual cellular microfossils from all over the world including the Indian Lesser Himalaya and the Peninsular shield. Ion microprobe analysis has been done to analyse the carbon composition of individual fossils in Precambrian rocks. Atomic force microscopy has been used to study the submicron scale kerogenous matter of the Precambrian microfossils. Mossbauer spectroscopic study of the iron biota and minerals in banded iron formation and stromatolites will be very useful about their origin. These techniques have been used in the Martian (ALH) meteorites recoverd from Allen Hill, Antarctica and the SNC group and other meteorites of Indian origin. The Vostok and Vanda lakes in Antarctica are being studied as a possible analogue for life on Europa (Jupiters icy moon). The concept of snow ball Earth, microbial life in extreme environments (Antarctica) has astrobiological significance. It is important to study the effect of impact on microorganisms particularly cyanobacteria experimentally on Earth. The effects of asteroid impacts on cyanobacteria and stromatolites produced by interaction of cyanobacteria with carbonate sediments can be experimentally examined using Plasma Induced Lasers (PIL). The Astrobiological studies would be useful in search for extraterrestrial life on frozen poles of Mars and Europa's subsurface since bacteria can survive in extreme cold environment.

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DISTRIBUTION OF RECENT DIATOMS IN THE SURFACE SEDIMENTS OF ALLEPPEY AND MARARIKULAM SOUTH, OFF KERALA COAST

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Diatoms are unicellular, photosynthetic algae that occur in the euphotic zone and biomineralize siliceous exoskeleton called frustule. The diatom frustule, composed of opaline silica, forms the basis of diatom taxonomy. In the present study, diatom assemblages were studied in 16 surface sediment samples collected from ~5 to ~12 m water depth for their distribution pattern along the depth transect along Alleppey and Mararikulam South, off Kerala coast. Alleppey has a tropical humid climate and is mainly influenced by seasonal heavy rains of southwest summer monsoon. The samples are composed of silty clay followed by sand-silt-clay and clayey silt.

The diatom assemblages are dominated by freshwater planktonic species *Cyclotella minighiniana* and *C. operculata*. A few specimens of *Actinocyclus ingens* and *Actinophytus undulates* are also present. The freshwater benthic diatoms includes *Navicula* spp. which are abundant in the sediments. A few forms of *Nitzchia palea, Cymbella silesiaca, Surirella* sp. 1, *Stauroneis* sp., *Triceratium* sp. and *Pinnularia gibba* have also been recorded. The marine diatoms, though few in number, are mainly planktonic *Thalassiosira* sp. (centric) and *Diploneis didyma* (pennate).

The occurrence of the planktonic freshwater centric forms, suggest fluvial discharge into the sea from adjacent region. The sediments at certain stations (st. 1 to st. 8, ~6 to ~11 m depth) show higher percentage of *Cyclotella* than *Navicula* species which is indicative of enhanced freshwater transport in the area, while in the rest of the stations the *Navicula* species dominates over *Cyclotella* forms. The abundance of low diversity diatom population in all the samples suggests enhanced primary productivity due to high nutrient availability. The benthic diatoms of *Navicula* species occur in abundance in certain horizons which are rich in organic matter content due to its high tolerance for sulphides. The abundance of *Cyclotella* and *Navicula* species from the coastal Arabian Sea is significant and intriguing as predominance of these taxa is suggests oligotrophic conditions in certain brackish estuarine/ lacustrine areas.

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ADDITIONAL CHAROPHYTES FROM LATE EARLY MIOCENE DHARMSALA HORIZONS OF KANGRA RE-ENTRANT IN HIMACHAL PRADESH

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Additional organ-taxa of charophytes (Order Charales; aquatic macrophytes), viz. *Chara rantzieni* (= *C. pappii*) and C*hara globularis* from a locality that yielded microfossils earlier and also from a new locality near Naddi are added to the Dharmsala biota; there is yet another unnamed *Tectochara* sp. Enlisting of C*hara globularis* in the assemblage is indicative of coldwater as its extant forms occur in clear coldwater ranging from 8-14°C with water hardness 100-200 ppm down to 25 metres in freshwater bodies.

With charophytes, typical freshwater cyprinid fishes and ostracodes, from dark grey mudstone horizons in Dharmsala sequence, we mark beginning of the Upper Dharmsala beds, characteristically corresponding to a permanent aquatic environment that is in contrast to the older levels deposited in ephemeral aquatic environment with prominence of red facies. This holds true as well to the coeval sequence of Dagshai/Kasauli in Simla Hills. The barren Dagshai has extreme thickness of cumulative red facies and younger Kasauli has fossil charophytes, flowers, leaves and indication of mammalian elements. Similarly, going by faunal content of Laren beds (in Palkhai Syncline) and younger levels of Murree in Jammu region we propose them to be coeval to Upper Dharmsala or Kasauli with corresponding barren horizons below in the regional sequence.

While the oldest Indian records of charophytic gyrogonites are from Gondwana Basin, Cenozoic occurrences begin with Deccan intertrappeans of Lalitpur, Uttar Pradesh (widely held as representing earliest Tertiary freshwater sedimentation) and then a continuum of charophytes in freshwater horizons of Subathu, Kasauli, Murree, Upper Dharmsala, Siwalik, Karewa, Ladakh Molasse, etc. towards north in the Himalayan region. This implies that charophytes harbouring water bodies have been around since then almost without any break. Further, the present record is from the earliest charophytes-bearing Dharmsala beds of Kangra re-entrant indicating it to be climatically at par with known biotas from homotaxial Kasauli Formation in Simla Hills.

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PALYNOLOGY OF COAL BEARING ROCK STRATA IN RAJMAHAL BASIN, JHARKHAND

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Extensive drilling programme for the exploration of the solid mineral fuel – coal resources by Geological Survey of India has proved large number of coal horizons in the coalfields of Rajmahal Basin. All the coal-bearing strata in Rajmahal Basin are considered to pertain to Barakar Formation of Early Permian age. The coal-bearing Barakar Formation is underlain by Talchir Formation and overlain by Dubrajpur Formation. The Barakar Formation is represented by pebbly and coarse grained sandstone (often with shale and coal clasts), medium-fine-grained sandstone (often felspathic, kaolinitic, ferruginous), siltstone, silty shale, arenitic clay, carbonaceous shale and coal seams.

The subsurface rocks have been analysed palynologically for the dating of the coal-bearing beds of Rajmahal Basin. On the basis of overall composition of palynoflora and distribution pattern of age marker taxa, seven palynological assemblage zones have been identified. The chronology of palynological assemblage zones recorded in Rajmahal Basin, in ascending order, are (i) *Parasaccites korbaensis* Assemblage Zone, (ii) *Crucisaccites monoletus* Assemblage Zone, (iii) *Scheuringipollenites barakarensis* Assemblage Zone, (iv) *Faunipollenites varius* Assemblage Zone, (v) *Densipollenites indicus* Assemblage Zone, (vi) *Gondisporites raniganjensis* Assemblage Zone and (vii) *Densipollenites magnicorpus* Assemblage Zone. The first four palynological zones indicate the Early Permian age while the last three palynological zones indicate Late Permian age for the coal-bearing sequence in Rajmahal Basin. Lithologically it is difficult to recognize the Late Permian coal horizon. The palynochronological evidences suggest a Late Permian age for the part of coal-bearing strata in the Rajmahal Basin.

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REWORKED PALYNOFOSSILS FROM THE SUBANSIRI FORMATION EXPOSED ALONG DOIMUKH-KHEEL- SAGALI ROAD SECTION, PAPUMPARE DISTRICT, ARUNACHAL PRADESH

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Recycling or reworking is a phenomenon when fossils of older age are found to occur in younger sedimentary sequences. Recycling is quite common in the Tertiary sequences of north-east India. The present study deals with the occurrence of Gondwana palynofossils along with Tertiary palynofossils in the Late Miocene sediments, i.e. Subansiri Formation, exposed along Doimukh-Kheel-Sagali Road Section, Papumpare District, Arunachal Pradesh. The reworked Permian palynofossils recorded are *Striatites*, *Striatopodocarpites*, *Platysaccus*, *Scheuringipollenites*, *Primuspollenites*, *Ibisporites*, *Verticipollenites*, *Plicatipollenites*, besides Cretaceous palynofossils, viz. *Callialasporites*, *Podosporites* and *Cicatricosisporites*. In the present assemblage Permian palynotaxa are better represented than the Cretaceous ones. The Gondwana sediments occur in the north of the presently studied Subansiri Formation (Late Miocene) and could have been source rock for the Subansiri sedimntation.

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GLOBAL BIO-EVENTS IN THE CRETACEOUS OF CAUVERY BASIN

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The studies of global bio-events largely focus on mass extinctions leading to abrupt changes in the global biota. The Cretaceous, encompassing four global mass extinctions (Jurassic-Cretaceous, Late Aptian, Cenomanian-Turonian, Maastrichtian-Danian), represents one of the most dynamic periods of earth's history. Bioevents occur at local, regional and global scales, reflecting short-term, extraordinary environmental changes.

Nearly 50 percent of world's giant oil fields have reservoirs in the Cretaceous rocks. Foraminifera, like other marine microfossil groups are affected by changes in the environment and palaeoceanographic conditions. They are globally used for biostratigraphic subdivision and correlation of sedimentary strata. The late Cenomanian extinction event is one of the major global bioevents ranking alongside the K/ T boundary and late Eocene events.

Most global scale bioevents are expressed as mass extinctions and as biotic turnovers associated with certain stage or sub-stage boundaries. Major extinction events, occurring at specific intervals, indicate a total change in the palaeoceanographic conditions. An analysis of Cretaceous bioevents from Cauvery Basin, India and their correlation with North and South America suggest that the majority of the global bioevents are associated with major changes of the oceanic anoxic events (OAE), rapid changes in sea level, temperature and in ocean and/ or atmospheric chemistry. From the author's view the Cretaceous sections in India still have a potential to represent as one of the Global Stratotype Section and Point (GSSP) on regional or global level.

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BIOSTRATIGRAPHY OF SYLHET FORMATION, JAINTIA GROUP, DILLAI PARBAT AREA, ASSAM

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Geological studies in the NE region have been greatly accelerated owing to the discovery of oil, particularly in Upper Assam. Most of the results are from subsurface wells by ONGC or OIL and the studies on the exposed sediments are limited due to various factors. The present study has been carried out in the Dillai Parbat area in Karbi Anglong District, Assam. The Dillai Parbat exposes the carbonate rocks of Sylhet Formation and the arenaceous-argillaceous sediments of Kopili Formation. As a result of quarrying activities, a number of sections are exposed. Three sections, which represent all the rock types in the area, have been measured, systematically sampled and studied. The area studied is covered in the Survey of India Toposheets no. 83F/ 12 and no. 83G/ 9 and located between Lat. 25°49'45" and 26°01'00"N and Long. 93°34'40" and 93°35'50"E.

A total of 62 species belonging to 43 genera have been recorded in the Sylhet Formation, Dillai Parbat area of Assam. On the basis of the distribution of foraminifera four biozones have been established along with two barren zones. The planktic foraminiferal biozone *Planorotalites palmerae* is established for the first time in NE region. It is based on the range of the latest Early Eocene marker species *Planorotalites palmerae* (Zone P9 of Berggren et al., 1995). This zone occurs in the lowest part of the Dillai Parbat sequence and is considered more or less equivalent to *Nummulites burdigalensis* Zone (Early Eocene). The other larger benthic foraminiferal zones established in this area are *Nummulites obtusus* Zone (early Middle Eocene), *Nummulites beaumonti - Assilina spira abrardi* Zone (middle Middle Eocene) and *Discocyclina javana- Nummulites* sp. Zone (latest Middle Eocene). Two barren zones are also recorded below and above *Discocyclina javana- Nummulites* sp. Zone. The biostratigraphy established is correlated with other parts of India and abroad.

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CLIMATE CHANGE IN HOMININ BEARING QUATERNARY SEDIMENTS OF CENTRAL NARMADA VALLEY THROUGH PROXY RECORDS

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The Narmada River of central India flows along an E-W lineament bounded by Vindhyans to the north and Satpuras to the south. The Quaternary deposits of Narmada Valley have recorded a variety of spore-pollen, diatoms, mammals, vertebrates which have been utilized in reconstruction of vegetation and climate change. These deposits are divided into Pilikarar, Dhansi, Surajkund, Baneta, Hirdepur, Bauras and Ramnagar formations ranging in age from Early Pleistocene to Holocene. Based on the pollen analysis, a broad inference of vegetation vis-a-vis climate change around this area could be drawn. The pollen proxy recorded from Surajkund Formation has revealed that the area in the vicinity was covered with sparse grassland vegetation, chiefly constituting Poaceae, Asteraceae, Chenopodiaceae and *Artemisia* and the sediments were deposited under arid climate.

On the basis of pollen/ spores recovered from the samples from the Baneta Formation inferred between 12460 to 25340 yrs BP, the area was covered with open vegetation constituting the grasses, Chenopodiaceae/ Amaranthaceae, Asteraceae and *Artemisia* along with sparsely distributed trees, viz. *Syzygium, Symplocos, Azadirachta, Diospyros, Emblica, Acacia and Holoptelea*. The record of marshy elements such as sedges (Cyperaceae) and *Polygonum* together with the aquatic elements *Potamogeton* and *Typha* and algal spores such as *Spirogyra* and *Zygnema* denotes the existence of water bodies/ ponds/ lakes in the close proximity of the site of investigation. Pteridophytic spores (*Selaginella*, Polypodiaceae) and other trilete/ monolete spores are also recorded. *Podocarpus* pollen grains have also been recorded sporadically. The overall vegetation assemblage is suggestive of the prevalence of a cool and dry climate regime during the period of sediment deposition. This vegetational scenario and corresponding climatic event is equivalent to the Last Glacial Maximum episode which has been globally documented between 18 and 22 Ka BP. Magnetic susceptibility studies also support the above view. At 8740±450 yrs BP, the area may have been covered with a dry deciduous forest represented by *Terminalia, Mimosa, Pongamia* and *Artemisia* under amelioration of climate when precipitation was somewhat higher than the earlier formations. *Potamogeton* and the frequent presence of algal spores also support the view.

This inference was also corroborated by the record of mammal assemblages comprising *Stegodon namadicus, Equus namadicus, Hippopotamus namadicus, Sus namadicus* and *Cuon alpinus*, suggesting a warm climate with intermittent arid-humid phases. Vertebrate assemblages, including cyprinid fishes, crocodiles, *Hippopotamus palaeindicus, Elephas hysudricus*, may indicate a warm climate but the terminal part of the Late Pleistocene may have become dryer as indicated by the presence of wild ass (*Equus hemionus khur*) and ostrich (*Struthio camelus*).

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PALYNOLOGICAL DATING OF SUBSURFACE COAL BEARING HORIZON IN EAST BOKARO COALFIELD, DAMODAR BASIN, WEST BENGAL

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The first stratigraphic borehole EBM-1 Muditole block, Eastern part of East Bokaro Coalfield, Damodar Basin, is worked-out for its spore-pollen content. Approximately 1185m thick Gondwana sediments (comprising green shales, carbonaceous shales, sandstones and coal seams) have shown many levels of changing patterns in spore-pollen groups. Abundance of monosaccate pollen between 1198.30 and 1095.25 metres depth is equated with Talchir Formation (Early Permian). Here, the palynotaxa are dark brown with distorted specimens. In up-section (13.00 to 1086.95 metres), the sequence is followed by the abundance of *Faunipollenites, Scheuringepollenites, Densipollenites* and striate bisaccates. The relative occurrences of these taxa delimit varied levels in the palyno-sequence of the studied strata. Hence, it is inferred that the Barakar Formation contains the representative palynoassamblages of Early to Late Permian. The FAD's of *Arcuatipollenites pellucidus, Playfordiaspora cancellosa,* (Early Triassic taxa) observed at 51.50 and 66.70 metres depths enhance the end-Permian level. Non-productive strata between the depths 310.00 and 344.35, 376.45 and 383.50, 571.90 and 640.00 and 982.65 and 1086 metres contain abundance of woody matter that might be the reason for changing depositional set-up within the sediments during Permian time.

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MICROFOSSILS FROM THE MARWAR GROUP, BIKANER, NAGAUR BASIN , RAJASTHAN.

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Fairly well preserved Organic walled microfossils are recorded in thin sections of the subsurface cores from Jodhpur Formation and Bilara Formation and the crude oil from the exploratory wells drilled by Oil India Ltd. These include an assemblage of *leiospherids*, *Micrhystridium tornatum*, *Leomarginata simplex* and *Granomarginata* sp. Presence *Skiagia* spp. is recorded only in the Upper Carbonate Formation. Calcareous algal fragments are common in the carbonates and *Obruchevella* sp.,*Renalcis polymorphus*, *Korilophyton sp.* and *Proaulopora* sp.are recognized in thin sections. The fossil assemblage indicates Nemakit Daldynian age for the Jodhpur and Bilara Formation whereas the upper carbonate is marked by the presence of Tommotian forms .In the absence of previous documantation of fossils, Marwar Group in Biakaner Nagaur Basin was generally regarded as unfossiliferous. Mixed carbonate evaporite-siliciclastic rocks deposited along the northern margin of Gondwanaland in rift grabens in India, Pakistan and Oman. The geochemical similarity of oils from these regions suggests their origin in the rocks of the same age. The evaporitic suite of rocks in Salt Range, Pakistan Oman, Iran correlates with Nemakit Daldynian in Siberia . Carbon isotope values of Oil generated in Bilara source rock are consistent with the globally recorded anoxia near the Pc/C.Boundary. The fossils recorded in the present study also suggest an Early Cambrian age for the Marwar Group, Rajasthan.

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A REPORT ON THE SILICEOUS DINOFLAGELLATES FROM SOUTH WESTERN INDIAN OCEAN SEDIMENTS.

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The subsurface marine sediments upto a depth of 30 cm, collected from the south western Indian Ocean sediments (Lat 44° 59.82' S Long 45° 00.83' E) at a water depth of 1423 meters have been analysed for siliceous dinoflagellates components. These interesting microfossils are significant as there is hardly any work done on them and are being reported in this paper along with calcareous nannofossils and other siliceous microfloras represented by diatoms, silicoflagellates, radiolaria and ebridians. Though the specimen are not abundant but their presence in all twenty-nine top samples with a sample difference of one centimeter each is noteworthy.

Such siliceous spicules of endoskeletal dinoflagellates constitute a very small fraction of siliceous microfossil assemblage from South western Indian Ocean. They are represented by a solitary genus *Actiniscus* with its type species *A. pentasterias.* They are bilaterally symmetrical. Though they do not have any biostratigraphical importance but are useful in deriving palaeoecological interpretations. Their association with diagnostic calcareous nannofossil blooms alongwith reworked Palaeogene nannofossils suggest transport of older age plankton laden current from close proximity.

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COILING DIRECTION: A TOOL FOR DECIPHERING THE PALEOCLIMATE IN THE SOUTHERN OCEAN REGION

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The coiling direction of foraminifera is influenced by the physico-chemical properties of the ambient sea water, such as temperature, salinity, nutrient availability, carbonate saturation, oxygen availability etc. With the change of any physico-chemical parameter of the ambient sea water the coiling direction changes from dextral (right-hand coiling) to sinistral (left-hand coiling) or vice versa. In this study, the effects of some of these factors on the coiling direction of planktonic foraminiferal species *Neogloboquadrina pachyderma* (Ehrenberg) from the surface sediments of south western Indian Ocean were investigated. Average 40 specimens of *N. pachyderma* from each of 26 surface samples were analyzed. It was noticed that dextral coiling is preferred towards higher latitudes. Near polar region, sinistral coiling predominates over dextral coiling. Hence, it was concluded that low temperature and/or salinity motivate the choice of coiling direction in this species. This data can be very useful to decipher paleoclimate if studied in subsurface sediments.

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Foraminifers and Otoliths -Tools to assess effects of natural and anthropogenic changes in climate on marine fisheries

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Fishes are the most sought after gift of the Sea to mankind'. India is the 6th largest producer of fish in the world and its fisheries industry contributes largely to the country's economy. However, growing population and industrialization causing stress on the environment, thus endangering marine fisheries. There are reports stating that excess use of fertilizers in coastal areas creating coastal hypoxia in certain areas which resulted in decline in fish catch. It is important to note that the diminution of fisheries is one out of several consequences of global warming associated with atmospheric pollution. In order to assess the adverse effect of environmental pollution on marine fisheries, microfossils especially foraminifera and otoliths can playas important and very useful tools.

Excessive supply of nutrients, production of increased amount of organic matter and its subsequent burial, coupled with restricted water circulation, leads to the depletion of dissolved oxygen in the water and development of oxygen minima zone. Such zones are detrimental for the survival of fisheries and result in low fish catch. Interestingly, the formation of such zones has recently been attributed to the spurt in anthropogenic activities in the coastal regions. However, the exact cause for the formation of depleted oxygen zones is debated. Tracing the intensity and extent of low-oxygen zones beyond the human presence can help in delineating the anthropogenic contribution. Foraminifera, whose several characteristics have been used for paleoceanographic and paleoclimatic reconstruction, are also helpful in inferring the changes in low oxygen zones throughout the geologic past. The relative abundance of rectilinear benthic foraminifera increases with decreased amount of dissolved oxygen. Several species are highly abundant in low-oxygen zones. However, the characteristic species assemblage varies from region to region. The distribution of foraminifera during the last few thousand years can indicate the change in distribution of fisheries in a particular region.

Otoliths, which form a part of the hearing apparatus of the fish, have been traditionally used by biologists to determine the age of fishes by counting the growth rings. Oxygen isotope studies on otoliths help the paleontologists in determining paleoclimate / paleotemperature. The one of the objectives of this presentation is to demonstrate the utility of otoliths in inferring extinction and / or migration of fish-stock due to temperature changes. It is widely believed that natural change in climatic pattern and global warming cause change in circulation pattern in coastal regions which effect the fish distribution on different time scales. Distribution of fossil otoliths if studied over the recent past (high resolution data) particularly during the Holocene can provide clues on how anthropogenic activities have caused changes in fish populations in the Indian waters. This can help in suggesting remedial measures for preventing/repairing the damage to the fish resources of India. Long term records could help in understanding the climatic effects on fisheries. However, to achieve this objective and to translate this knowledge for the benefit to all, otoliths of the modern commercial fishes need to be cataloged. A modest beginning is already made and as first attempt, cataloging otoliths in fishes off Goa is almost completed.

Thus, benthic foraminifers and otoliths characteristics can be used to assess the anthropogenic effect on marine fisheries.

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