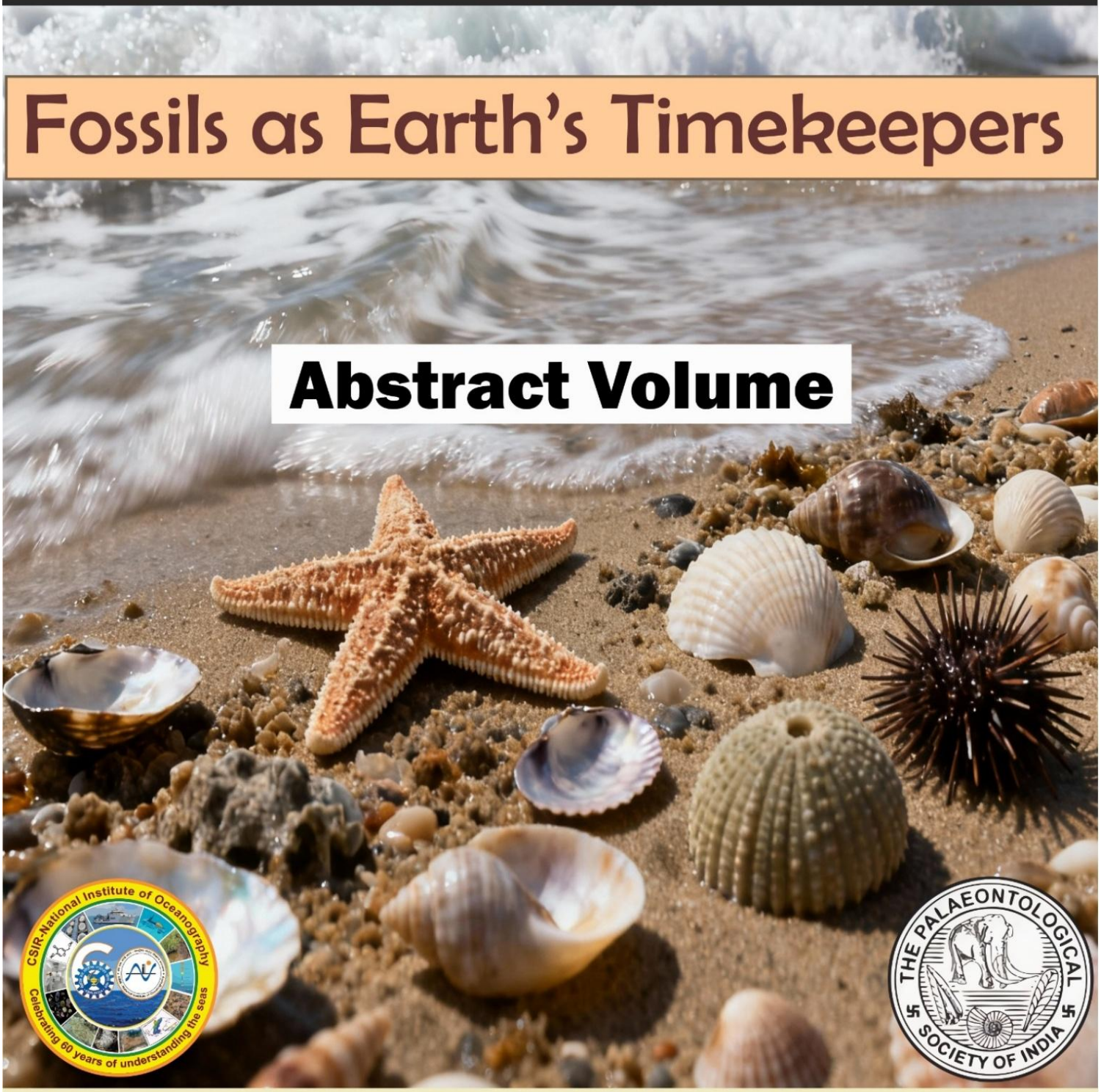
Palaeontological Society of India

Platinum Jubilee Conference

29th to 31st October 2025

Fossils as Earth's Timekeepers



Abstract Volume

CSIR-National Institute of Oceanography, Goa

THE PALAEONTOLOGICAL SOCIETY OF INDIA

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The Palaeontological Society of India

The Palaeontological Society of India (PSI) was established on January 26, 1950, by Dr. M. R. Sahni, Dr. Raj Nath, Dr. S. R. Narayan Rao, Dr. R. C. Misra, Dr. B. S. Tewari, Dr. S. N. Singh, Dr. G. W. Chiplonkar, and others. It was officially registered in Lucknow on August 12, 1950, under the Societies Registration Act, 1860 (XXI).

The Society has been continuously serving the palaeontological fraternity since its inception. It holds corporate membership in the International Palaeontological Association (IPA) and is a member of the Federation of Indian Geosciences Associations (FIGA). The Society is instrumental in organizing scientific meetings, conferences, and field workshops on contemporary issues in Geology and Palaeontology.

Its main activities center on the publication of its flagship, peer-reviewed journal, The Journal of the Palaeontological Society of India (JPSI), which is Scopus-indexed (ISSN 0552-9360). Published biannually at the end of June and December, the journal welcomes original, unpublished research communications and invited review papers on all aspects of Palaeontology (e.g., systematics, phylogeny, palaeoecology, biostratigraphy), Anthropology, and Archeology. It accepts manuscripts dealing with all fossil organism groups and ichnofossils. JPSI's publication is partially sponsored by grants from the Science and Engineering Research Board (SERB), Department of Science and Technology, Government of India.

Committed to the free dissemination of palaeontological knowledge, the Society makes all its publications, except for the current year's issues, available via open access on its website.

The Society also encourages and promotes the discipline nationally by organizing Memorial Lectures and establishing various awards, funded by donations. Registered with NITI Aayog, Government of India, the Society is authorized to receive and administer grants, donations, and charities under the Income Tax Act 1961 of India.

To commemorate 75 years of active service supporting palaeontological and stratigraphic research, the Society is organizing a Platinum Jubilee Conference, at the CSIR-National Institute of Oceanography, Goa. This event aims to be the first national gathering to foster collaborative discussion and knowledge exchange among academicians and researchers across the diverse disciplines of Palaeontology and Stratigraphy.

National Institute of Oceanography

The National Institute of Oceanography (NIO), headquartered in Dona Paula, Goa, is one of the 37 constituent laboratories of the Council of Scientific & Industrial Research (CSIR), New Delhi. It also operates regional centres in Cochin, Mumbai, and Visakhapatnam.

Established on January 1, 1966, following the International Indian Ocean Expedition (IIOE) of the 1960s, CSIR-NIO has since evolved into a multidisciplinary oceanographic research institute of international acclaim. The institute is celebrating sixty years of its glorius existence. Its primary research focuses on observing and understanding the unique oceanographic features of the Indian Ocean, with over 5,000 research publications to its credit.

The institute has a sanctioned staff strength of 200 scientists and 100 technical personnel. Its core research areas span biological, chemical, geological/geophysical, and physical oceanography, along with ocean engineering, marine instrumentation, and marine archaeology.

State-of-the-art laboratories are housed both at the Goa headquarters and across its regional centres. CSIR-NIO also operates two advanced research vessels, namely RV *Sindhu Sankalp* (56 m) and RV *Sindhu Sadhana* (80 m)—fully equipped for multidisciplinary oceanographic exploration.

The institute's library holds an impressive collection of 15,000 books and 20,000 journal back volumes, making it the most comprehensive printed resource on ocean sciences in India.

In addition to fundamental research, CSIR-NIO undertakes applied research projects sponsored by industry. These include oceanographic data collection, environmental impact assessments, and predictive modelling. The institute also provides consultancy services on marine environmental protection, coastal zone regulations, and related issues.

With the largest community of ocean scientists in the country and robust research infrastructure, CSIR-NIO also serves as a premier centre for ocean science education. It hosts a School of Oceanography under the Academy of Scientific & Innovative Research (AcSIR) and is recognized by numerous universities for doctoral research. Currently, over 100 Junior and Senior Research Fellows (qualified through CSIR/UGC) are pursuing their PhDs at the institute, while around 300 undergraduate and postgraduate students undertake project-based research each year.

Contents

Plenary Abstracts

Timing of India-Asia collision: Constraints from Eocene vertebrates

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Abstract

The collision between the Indian and Asian plates was one of the most profound tectonic events in the Earth's Phanerozoic history, significantly influencing Cenozoic topography, oceanography, climate and biodiversity. However, the exact timing of the initial India-Asia collision continues to be debated, with current estimates ranging from approximately 65 to 35 million years ago (Ma), based on diverse evidence such as the cessation of marine sedimentation, shifts in sediment provenance, paleomagnetic records, magmatic chronology, and the occurrence of high-pressure Himalayan metamorphic rocks. Fossil data play a crucial role in determining when India and Asia first collided and when they became finally sutured. In recent years, discoveries of vertebrate fossils have provided compelling evidence that India's northward drift and subsequent collision with Asia drove major changes in the region's communities, initiating significant faunal turnover and the rise of new mammalian lineages on the Indian subcontinent. A major recent finding supporting this scenario is the identification of an early Eocene (~55 Ma) terrestrial mammal fauna from the Vastan lignite mine in Gujarat, western India. This fauna, representing the oldest known record of Cenozoic land mammals in South Asia, contains basal representatives of several placental mammal groups such as artiodactyls, perissodactyls, and primates (collectively termed APP taxa). In the Holarctic (northern) continents, these taxa first appeared near the Paleocene-Eocene boundary (~56 Ma), a time marked by pronounced global warming. Several mammals from Vastan—such as tapiroid perissodactyls, nyctitheriids, and lagomorphs—show close biogeographical ties to Asian species. The Vastan tapiroid *Cambaylophus* is closely related to *Orientolophus* from the earliest Eocene (Bumbanian ALMA) of China, while the nyctitheriid Indonyctia from Vastan has notable similarities to *Voltaia* from the late Paleocene (Gashatan) of Kazakhstan. These and other taxa imply that India and Asia were connected around the Paleocene-Eocene boundary (56 Ma), or possibly earlier, allowing exchanges of terrestrial species. Such biotic exchanges likely took place via intervening crustal fragments, especially the Kohistan-Ladakh Island Arc, as further supported by recent discoveries of fossil palm remains in Tibet.

Recent Advancements in the application of fossils in oil and gas exploration

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Abstract

Application of palaeontological data in the human endeavour for understanding and tapping of the earth's natural resources is in vogue for the past more than two centuries. With the advent of the petroleum industry, wherein explorers had to decipher the relation between the host reservoirs, source rocks and their distribution in a milieu where the they unseen except through drill cuttings, micropaleontology was the first answer, before the advent of technologies like seismic data, which could remotely map the subsurface. The zenith of micropaleontological applications was witnessed in the four decades after the second world war. In the nineties of the last century petroleum exploration moved from the easy areas viz. onshore and shallow offshore into technologically difficult and high-cost area beyond the continental shelfs into deep waters (W.D. >200m). This led to another spurt in the application of microfossils for exploration and development of petroleum resources. The main microfossil groups used in these applications were marine fossils viz. foraminifera, calcareous nannofossils and dinoflagellates. Study of palynological fossils was related more to the understanding of source rocks and fluvial to transitional sediments. The most common applications were for the determination of age and correlation through biostratigraphy, paleontological facies analysis for paleoenvironments and source rock characterization (maturity and richness) through the study of microscopic macerals / organic remains. With the advent of drilling technology to drill horizontal wells and extended reach deviated wells, the technique of bio-steering of well trajectories was developed. In such conditions a micropalaeontologist would be deployed on the drill site, to constantly determining whether the trajectory of the drilled hole remained in the desired target interval or if it deviated away, the correction required. These category of wells resulted in saving of millions of dollars in the cost of wells. Presently one of the most focused application of microfossils is in the determination of high-resolution multi-proxy biostratigraphy, wherein isotope geochemistry of microfossils is used for deriving a variety of information regarding the subsurface sequences.

Radioactivity in Fossils: An unconventional approach to uranium exploration

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Abstract

Exploring for uranium, a key resource for nuclear fuel, often leverages multidisciplinary geological tools. One hitherto unrecognized but increasingly studied approach is the use of fossils (organic remains, fossil wood, shells, bones) in uranium exploration. Their role extends beyond biostratigraphy to influencing ore localization through their interaction with paleo-redox environments, diagenetic fluids and mineralising processes. In certain depositional settings, fossils can act as geochemical traps or even direct hosts for uranium mineralisation. Though this approach is not universally applicable, but may play a vital role in especially sandstone type uranium mineralisation. In sandstone-type uranium systems, organic- and phosphate-bearing fossils such as fossilized wood, bones and shells create micro-reducing zones that facilitate uranium precipitation. Uranium, transported as soluble uranyl ions (UO_2^{2+}) in oxidizing groundwater is restrained upon encountering reducing agents like carbonaceous matter or phosphate minerals. The cellular structure of fossil wood provides redox buffering, promoting the formation of uraninite and coffinite under reducing conditions, followed by carnotite and tyuyamunite in oxidizing regimes. Similarly, vertebrate bones and shells containing apatite can incorporate uranium into their lattice, retaining it during diagenesis and thus serving as natural concentrators of uranium. Global examples, including the Happy Jack uranium deposit (Utah, USA) and calcrete-type uranium systems of Namibia and Western Australia, demonstrate the influence of fossilized organic matter and root systems in ore nucleation. Recent investigations also demonstrate uranium uptake in ammonite and bivalve shells, showing alpha particle tracks correlated with apatite content in fossils, indicating that fossils themselves may record uranium accumulation histories. In India, vertebrate fossils within the Siwalik sediments exhibit significant uranium enrichment, indicating post-depositional uranium uptake under reducing conditions. Stable isotopic signatures of organic matter suggest that sediments in the Middle–Upper Siwalik transition zone were deposited under relatively semi-arid conditions are more conducive to uranium mineralisation. Likewise, in Tummalapalle uranium deposit (Andhra Pradesh), the patterns of alpha tracks obtained on mineralized dolostone of the Vempalle Formation reveal evidence of uranium entrapment from seawater by filamentous organo-sedimentary structures. At the microscale, microbial mats, conodonts and other phosphatic fossils record uranium and rare-earth element substitution, showing REE fractionation and Ce anomalies that trace paleo-redox gradients. Such features mark fossil-rich horizons as valuable indicators of past uranium migration and concentration zones. Trace fossils, rhizoliths and burrows also reveal depositional and redox conditions, distinguishing potential mineralisation zones from leached or oxidized intervals. Integration of fossil occurrences with radiometric, geochemical and sedimentological datasets significantly enhances uranium exploration by delineating paleo-hydrological pathways and mineralizing fronts. Fossil assemblages, being stratigraphically confined, aid in correlation of favourable horizons across basins and improve the predictive precision of exploration models. Fossil-rich horizons (e.g. petrified wood, fossil logs, shell beds) within permeable sandstones serve as potential redox traps and can be prioritized as exploration targets. Their spatial distribution not only marks sites of uranium precipitation but also helps reconstruct paleo--fluid migration patterns, thereby guiding drill targeting and anomaly follow--up

strategies. In essence, fossil-based exploration represents an interdisciplinary bridge between palaeontology and economic geology. When coupled with modern analytical, geophysical and geochemical tools, it strengthens our understanding of the interplay between biological evolution and ore-forming processes, thereby advancing atomic mineral exploration and contributing to the sustainable discovery of nuclear resources. Nonetheless, the method requires judicious approach, appropriate geological settings and integration with other exploration data to be effective.

Comprehensive study of Permian plant assemblages from lower Gondwana basins: Implications for palaeovegetation, climate, and floristic evolution

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Abstract

The Permian Period (298.9–251.0 Ma) represents a key epoch in terrestrial plant evolution, characterized by the diversification and dominance of Glossopteris flora across Gondwana. The Lower Gondwana stratigraphic sequence preserves exceptional terrestrial plant records within India's major Gondwana basins, such as Damodar-Koel, Son-Mahanadi, Pranhita-Godavari, Satpura, and Rajmahal. Systematic examination of megafossils from key formations (Talchir, Karharbari, Barakar, Barren Measures, Raniganj) reveals progressive evolutionary trajectory from post-glacial recovery to peak floristic diversity, culminating in extensive coal-forming swamp forests dominating late Paleozoic Gondwanan landscapes. 3D graphical reconstructions provide comprehensive visualization of forest canopy structure and understory composition, yielding parameters essential for palaeovegetational reconstruction. Permian flora encompasses extraordinary taxonomic diversity across major plant groups. Bryophytes, characterized by fragile nature and limited cuticularization, provide insights into hydrological conditions and atmospheric humidity during deposition. Pteridophytic assemblages demonstrate architectural complexity, with lycopodiaceous forms (*Cyclodendron leslii*) occupying understory niches, while equisetaceous taxa (*Schizoneura gondwanensis, Raniganjia bengalensis, Phyllotheca indica*) dominated wetland margins with articulated stems and whorled leaves. Sphenophyllalean taxa (*Trizygia speciosa, Sphenophyllum speciosum*) exhibited climbing habits, while filicalean ferns (*Neomariopteris polymorpha, Dichotomopteris lindleyii*) displayed diverse architectures adapted to varying light regimes. Gymnospermous taxa constituted the dominant arborescent component, with Glossopteridales representing the most significant evolutionary radiation. *Glossopteris* species, characterized by reticulate venation, formed primary canopy elements of coal swamp forests. Gangamopteris taxa dominated earlier assemblages with parallel venation systems. Cordaitalean conifers (*Noeggerathiopsis hislopii, Euryphyllum whittianum*) occupied upland habitats, exhibiting foliage adapted to moisture stress. Emerging coniferous lineages (*Buriadia heterophylla*) and cycadalean forms (*Macrotaeniopteris*) contributed to gymnospermous diversification. Glossopterids were the primary hosts of insect herbivory in the Permian, with broad-leaved gymnosperms and sphenopsids moderately affected, and ferns, lycophytes, and some conifers less so. The diverse damage types—ranging from margin, surface, and midrib feeding to oviposition scars, galls, and leaf mines—reveal preferential feeding strategies, host specificity, and complex plant–insect interactions. Specialized traces such as galls, blotches, and oviposition marks highlight reproductive behaviour, microbial associations, and ecological niches under humid temperate conditions. These records highlight the ecological complexity of Permian ecosystems, where plants not only sustained insect communities as food but also as shelter and reproductive sites, shaping the structure and function of terrestrial landscapes.

The genetic tapestry of our past

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Abstract

The genetic landscape of India is complex. Population genomic studies and archaeological records suggest that present-day Indians source their ancestry to multiple ancestral components. However, several questions remain contested and unresolved. What are the sources of the genetic components found among present-day Indians? When did these components enter the region and to what extent did, they admix? Additionally, there is no consensus on the levels of archaic (Neanderthal/Denisovan/other) ancestry in India. Due to the paucity of ancient genomics datasets, we have a restricted understanding of the processes that have driven the present-day genetic profiles of the region. The ancient DNA is emerging as a powerful complementary tool that can reveal a lot about individual and population origins and the relationship between ancient and modern humans in a region. Ancient DNA research has recently witnessed an explosion in studies on ancient human population histories, primarily from Europe and the Americas. India has very little representation in the ancient genomics literature despite the wealth of archaeological samples that exist in collections all over the country, in addition to new excavations. We aim to lay a foundation of ancient DNA research in India and using new genome data we focus to understand the paradigm-shifting in the Indian sub-continent, i.e. from Mesolithic to Neolithic/Chalcolithic/Megalithic with adoption of farming, and emergence of new technologies such as megalith-building (Megalithic), metal-working (Chalcolithic) and writing (Early Historic onwards). By generating the first large-scale ancient genomic dataset for India, we are reconstructing the past and present demographic processes that shaped the present- day gene pool in India over the last 10 millennia.

Theme 1

Evolutionary trends in various fossils groups

Challenging issues in organic evolution: From tiny foraminifera to giant vertebrates

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Abstract

The central theme of the Conference "Fossils as Timekeepers" stems from the fact that Organic evolution is largely a non-repetitive process and thus parallels the nature of time, which moves from future to past with a momentous stay in the present. Evolution depends on random mutations, natural selection, genetic drift, and environmental influences, all of which are subject to chance. The combination of these factors produces a unique evolutionary path that is not exactly repeatable. The celebrated book by William Smith, "Strata Identified by Organized Fossils," was published in 1816, about four decades earlier than Darwin's famous book, "The Origin of Species," published in 1859. Smith's book can be considered the first systematic scientific presentation recognizing the non-repetitive nature of the fossil record, the basis for "fossils as timekeepers." However, the fossil record is often marked by reversed traits in some organisms, putting our beliefs in unidirectional evolution in question. The microfossil world, particularly planktic foraminifera, presents many such examples. The evolutionary trend in *Globorotalia crassaformis* (Galloway & Wissler) is one such example. *Globorotalia crassaformis* with a distinct keel shows morphological gradation to *Globorotalia tosaensis* Takayanagi & Saito, with loss of keel in the Late Pliocene. However, the later evolution of *Globorotalia truncatulinoides* from non-keeled *Gr. tosaensis* in the Early Pliocene once again involves the acquisition of a keel. This points towards the acquisition of old, shed traits in phyletic gradualism. Another type of evolution is exhibited by the *Globorotalia menardella* group. Normally, the members belonging to the *Globorotalia menardii* group (menardines) have five to six chambers in the outer whorl (Kennett & Srinivasan, 1983). In the Atlantic Ocean, the group experimented by increasing the number of chambers in the final whorl to eight to ten (*Globorotalia multicamerata, Globorotalia mioceinica*, and *Globorotalia pertenuis*) during the Pliocene. However, all these multichambered forms became extinct before the Pleistocene, while the five-six-chambered menardiform continues. This is another example where an evolutionary trend was shed by the group. Though the microfossil world is flooded with so many examples where the exact pressure of the ambiance and its response to changing morphologies is uncertain, the large vertebrate and invertebrate fossil record is also loaded with many examples that do not fit the ambiance-animal evolution doctrine. While Darwin could not initially explain the wasteful tail of the peacock using his theory of natural selection, he later advanced the concept of sexual selection to explain it. Darwin found the peacock's tail puzzling because it seemed to hinder flying and thus should have been eliminated by natural selection. However, Darwin proposed that the peahens preferred males with more attractive tails, and this preference drove the evolution of the peacock's tail through sexual selection. However, there are examples from the living world where large, giant vertebrates have even defied this concept. Many examples, like the Komodo dragon (*Varanus komodoensis*), which is the world's largest lizard,

have an amazing ability to clone themselves as part of asexual reproduction. However, such offspring are all males. This is a sophisticated reproductive backup system where the pressure is not from the environment, but pressure is from the imbalanced population. Like the Komodo dragon, which can reproduce both sexually and asexually, Foraminifera, too, have alternate generations of sexual and asexual reproduction, giving rise to megalospheric form, which is associated with sexual reproduction and has a larger initial chamber (proloculus), and microspheric form, associated with asexual reproduction and a smaller proloculus. Many species of whiptail lizards, Python, bdelloid rotifers, hydras, and female hammerhead sharks have evolved to peculiar reproductive strategies where they can colonise a niche without needing any male or sexual reproduction. Their survival strategies are an enigma for biologists and palaeontologists. If our fossil record could have had these attributes, our interpretation of the population dynamics of the fossil species needs to be revisited. Many workers tried to relate foraminiferal morphologies to their depth habitat. For example, they proposed that globular chambers, rounded forms, thrive in the mixed layer due to buoyancy, while flat forms thrive in the thermocline. Similar interpretations were made for angular asymmetric forms and rounded symmetric forms. Here we take one example from planktic foraminifera, *Pullenia obliquiloculata*, which is very much globular (almost spherical) but does not live in the mixed layer, but thrives in the thermocline. Surprisingly, *Pullenia bulloides*, which is somewhat similar to *Pulleniatina obliquiloculata*, lives in the abyssal depth and is a benthic foraminifer, living with the same morphology from the Thanetian (Late Palaeocene) to the Recent. When we look at the fossil record, particularly of the extinct species without any modern representative, it is usual to infer their population dynamics by relating their abundance to the ambiance, food, chemistry of the surroundings, etc. But as the case discussed here, from microscopic foraminifers to large reptiles, the fossil record may be holding many mysteries, and the organic evolution has to be re-examined, revisited with more data on genetics and molecular palaeontology. Another interesting aspect of Darwin's evolutionary doctrine stems from the discovery of James Watson and Francis Crick of their 1953 model of DNA's double helix structure, for which both were awarded the Nobel prize. The ambiance-organism relation, stresses, and transmission of the information to the DNA level are something we need to understand. The examples given of large vertebrates regarding their bizarre reproductive strategies to survive have hardly any environmental climate relationships. A central debate within Darwinism concerns the unit that is selected, what kind of entity is it that survives, or does not survive, because of natural selection? That unit will become, more or less by definition, "selfish." The critical question is at which level in the hierarchy of life, which unit will turn out to be the inevitably "selfish" level, at which natural selection acts? The selfish species, the selfish Group, the selfish Organism, or the selfish ecosystem? Another interesting book, "The Selfish Gene," by Richard Dawkins, published in 1976, on evolution, promotes the gene-centred view of evolution as opposed to views focused on the organism and the group. With the advancement of techniques in molecular biology, molecular palaeontology, the future is full of challenges to explain all that has happened, is happening, and will happen with a unified theory of organic evolution.

Evidence of the occurrence of a possible sponge fossil community from the Ediacaran Mahi Formation, Krol Belt of the Lesser Himalaya, India

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Abstract

Precambrian palaeobiological records include members of archaea, cyanobacteria, single to multicellular eukaryotic remains, a few higher algal forms, and some early animal forms. Many of the algal forms are unequivocally accepted as representatives of modern-day living clades. These discoveries of Precambrian life forms have significantly enhanced our understanding of the emergence and evolution of different clades of life; however, the sudden or instantaneous appearance of metazoans in the Cambrian remains a fascinating and intriguing phenomenon. The antiquity of animal life has not yet been established with confidence. We report unique and well-preserved specimens representing various phases of the life cycle of possible sponge fossils (*Porifera*) from the Ediacaran Mahi Formation (also known as Krol 'A') succession in the Lesser Himalaya, India. These remains resemble various parts/stages of the life cycle of the demospongiae vegetative body and are recorded from the nodules of chert. Recorded specimens are comparable with the well-established Phanerozoic and living sponges in their morphology and dimensions, showing sponge body bauplan like a sessile adult, reproductive sexual cells, viz., spermatic cysts, eggs, and asexual reproductive bodies, viz., Gemmules. The present study is likely to contribute to the knowledge of a solution to the "inexplicable" absence of a metazoan fossil record preceding the Cambrian explosion in geologic time. The study also implies the existence of a Porifera-like community in the Ediacaran Period.

Evolution and ecological perspectives of calcareous nannofossils and silicoflagellates: a case study from late Neogene sediments of northeast Indian Ocean

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Abstract

Evolution and adaptation of organisms are directly linked to ecological attributes. Size variations and morphotypic alteration are often referred to genetical or environmental factors. The deep sea sediments of the geologic past archive a wide array of microfossils that are important constituents that document evolution of marine organisms. Some of the preserved microfossils are not only potential for accurate dating of the marine sediments but also play a significant role in deciphering past climatic conditions in which they successfully continued their existence in extremities by the process of evolution. On this aspect the present contribution hovers on variations of morphotypes and size or vigor alongside unusually preserved rare features as observed during the study of calcareous nannofossils and silicoflagellates from the onshore and offshore sediments of northeast Indian Ocean ranging in age from early Middle Miocene (Burdigalian) to Pliocene (Zanclean). Amongst these microfossils, calcareous nannofossils are globally used for dating of marine sediments owing to their world wide horizontal distribution and restricted vertical distribution in high, mid and low latitudes though there are a number of diachronisms. Taxonomic and morphometric analyses on evolutionary perspective reveal that certain species belonging to calcareous nannofossil genera namely, *Ceratolithus, Calcidiscus, Nicklithus, Reticulofenestra* along with some common nannofosil taxa like *Discoaster*. Variations in size also have been observed in certain nannofossil taxa. One of the most important characteristics of an organism is its size and this can be readily used to interpret ecology and evolution. The size variation patterns can be interpreted in a variety of ways, e.g. size variation represents the effect of change in ecological factors on a genetically unchanging population or size variation reflects evolutionary change without environmental change. However, both these statements are not conclusive. Silicoflagellates, the flagellate, marine algae belonging to Class Dictyochophyceae are very common in the deep sea sediments. However, this group of siliceous microfossils was not attractive to the micropalaeontologists as their biostratigraphic significance is comparatively subtracting. However, several silicoflagellate biozones have been proposed from deep sea sediments of various oceans. One of the rarest features of the silicoflagellates is presence of double skeleton. Double skeletons have been documented from the Tortonian sequence of northeast Indian Ocean namely *Dictyocha calida, Dictyocha fibula* subspecies *ausonia* and *Stephanocha speculum* (6-sided). The double skeletons possess significance for phylogeny and palaeoecology. Moreover, relative abundance of *Dictyocha* and *Stephanocha* can relatively estimate the palaeotemperature. From the evidences of these two groups of microfossils the major scientific question is "Why evolution, size variations and morphotypic alteration in an organism is needed?

Pachyosteosclerosis in extinct Indian Hippopotamus (Hexaprotodon sp.) as evidence of aquatic adaptation

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Abstract

The taxonomic position of Hexaprotodonts in the Late Pleistocene of the Indian Subcontinent finds importance due to its implications on palaeoenvironment during the MIS-3 to MIS-2 transition. Out of the two extant groups of Hippopotamus, African hippos (*Hippopotamus amphibius*) spend a far greater time in water, exhibiting evolutionary adaptations in the cortical tissue in the form of pachyosteosclerosis, a set of modifications down to the microscopic level that result from prolonged movement underwater. On the other hand, dwarf hippopotami (*Choeropsis liberiensis*), spending a considerably lesser amount of time in water, exhibit very limited bone modification of this manner. The present work looks at the tissue structure of cortical bone in the fossils of *Hexaprotodon* from contexts in peninsular India, identifying patterns of pachyosteosclerosis (especially in comparison to modern examples of *H. amphibius*) and re-examining the evidence of aquatic behaviour in the chronological and environmental context of the late to terminal Pleistocene of the Indian Subcontinent.

A preliminary comparative study on diversity patterns, palaeobiogeographic distribution and evolutionary tempo of two superfamilies of ammonite from the Aptian to the Cenomanian (Cretaceous)

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Abstract

Two superfamilies, Desmoceratoidea and Acanthoceratoidea of the class Cephalopoda, had started their evolutionary journey from the Early Cretaceous and became extinct during the Maastrichtian age. Representatives of these two superfamilies survived a time span of ~80 Ma. How these two superfamilies distributed spatiotemporally and how they evolved in terms of body size and diversity, are the main focussed on this present study. The study has been made across the Lower and Upper Cretaceous boundary. For this preliminary study, we have gathered extensive global paleobiologic and paleobiogeographic data from the Wright et al. (1996) and have only considered the genera and their type species in most of the cases. We have measured the maximum diameter of each representative species from the provided illustrated figures and also recorded their paleobiogeographic distribution, i.e., mainly three latitudinal zones—Polar, Temperate, and Tropical—spaced 30° apart in the both hemispheres. For body size distribution, specimens were classified into seven size classes [S1(0-25mm), S2(26- 50), M1(51-75), M2(76-100), L1(101-125), L2(126-150), and L3(150)]. Specimens having a diameter larger than 450 mm have not been considered in this present endeavour because they are statistically insignificant (such outliers add to the skewness). Five families and six subfamilies of Desmoceratoidea were distributed from the Aptian to the Cenomanian. Likewise, eight families and 12 subfamilies of Acanthoceratoidea were distributed from the Albian to the Cenomanian. For our study, we have considered 53 genera/subgenera of Desmoceratoidea and 66 genera/subgenera of Acanthoceratoidea, as they are two most diverse superfamilies during this studied interval. Among 71 representative species of the Superfamily Desmoceratoidea, 17 species appear in the Aptian, 49 (of which 42 new) in the Albian, and 16 (of which 12 new) appear in the Cenomanian. Only 2 species survived all three ages. In term of body size, small (S2) representatives are dominating during the Aptian, while a mixed pattern of abundance containing both S2 and M1 size with the dominance of M1 are observed during the Albian-Cenomanian time. The abundance of small-sized (S2) and medium-sized (M1) forms distributed in temperate zone irrespective of their size classes while considering the biogeographic

distribution of the Superfamily Desmoceratoidea throughout the Aptian to Cenomanian time. On the other hand, we have studied 102 species of the Superfamily Acanthoceratoidea, of which 51 species restricted themselves within Albian age and an entirely new set of 51 species appeared at the Albian-Cenomanian boundary. The dominance of S2 size class observed at their first appearance in the Albian while a steady decrease in number of species from small size to large size is observed in the Cenomanian. Like Desmoceratoidea, most of the species of the Superfamily Acanthoceratoidea also distributed in the temperate zone irrespective of their size class. Several reasons, e.g., Oceanic Anoxic Events (OAE) during Early Aptian, Global warming, etc may be responsible behind the restriction in the temperate zone of most of the species of both the superfamilies, will need further detailed study.

Idiographic and nomothetic: The role of novel Indian Meso-Cenozoic marine invertebrate data

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Abstract

The causes of evolution have been philosophically attributed to several views, e.g., materialistic, vitalistic, and deterministic. To formally test the validity of these nomothetic, there should be enough spatio-temporal coverage of 'global' raw data, representing unique events (idiographic). Here, we have been tempted to show a few examples to highlight that Indian Meso-Cenozoic marine invertebrate data indeed represents unique eco-evolutionary events, and the inclusion of the same in the global database are essential to identify/defy the aforementioned nomothetic: (1) the records of several Middle-Late Jurassic endemic taxa from the western India have redefined the global Jurassic gastropod paleobiogeography, suggesting that Indian gastropod assemblage was, to some extent, distinct from the European and African assemblages, at least in the Bajocian and Oxfordian; (2) many of the Cretaceous-Paleogene echinoids, endemic to India, are not included in the global database, precluding the validation of any meaningful 'global' nomothetic; (3) the Pleistocene coral reef and other associated fauna from the western India have been proven to be an exception to the general rule of a Pleistocene Acropora world hypothesis, which is commonly observed even in the nearby ecoregions; (4) novel faunal data from the Cambay Basin suggests a regional pattern of environmental switching from an early Eocene mollusc-dominated shallow marine siliciclastic facies to the middle Eocene larger benthic foraminifera-dominated deeper shelfal carbonate facies, identifiable both in Kutch and Cambay basins; (5) bulk sample based analyses of unique Recent Indian molluscan assemblages have negated the presence of any latitudinal diversity gradient along the Indian coasts, which is otherwise assumed to be a 'rule' in other parts of the world; and, (6) numerous novel reports of drilling predation on molluscs from India in the recent decades have redefined the global Mesozoic predator-prey interaction nomothetic, in terms of intensity and long-term patterns.

Diachrony of planktic foraminiferal events and bochronologic refinement in the Southeast Atlantic: Evidence from ODP Site 1085A

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Abstract

Diachrony in planktic foraminiferal bioevents—where the timing of first (FO) and last occurrences (LO) varies across regions—has long complicated biostratigraphic correlation. However, when carefully calibrated, such diachronies offer critical insight into paleoceanographic processes and evolutionary dynamics. This study presents a detailed investigation of planktic foraminiferal events from Ocean Drilling Program (ODP) Site 1085A in the Cape Basin, Southeast Atlantic, spanning the late Neogene to Quaternary. A total of 33 foraminiferal events were identified and integrated with magnetostratigraphic data to construct a high-resolution biochronology. Shaw's graphic correlation method was applied between ODP Site 1085A and DSDP Sites 588 and 590 in the Southwest Pacific to assess the extent and pattern of diachrony among key taxa, including *Gr. inflata, Gr. puncticulata, Gr. truncatulinoides* and *Gr. tosaensis.* Results reveal significant diachronous behavior, attributed to both intrinsic factors (evolutionary lineage shifts, population dynamics) and extrinsic controls such as variations in the Benguela Current, upwelling intensity, and interoceanic exchange via the Agulhas Leakage. The combined bio- and magnetostratigraphic approach enhances chronological precision and improves our understanding of planktic foraminiferal evolution in response to major paleoceanographic changes. This study not only fills a regional gap in biostratigraphic data from the Southeast Atlantic but also highlights the importance of diachronous events as proxies for ocean circulation and climatic variability during the late Neogene–Quaternary.

Survival in the shadows: How marine anoxia reshaped naticid-bivalve arms races in ancient India

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Abstract

The fossil record from the Indian subcontinent offers crucial insights into the co-evolutionary dynamics of naticid gastropods and their bivalve prey, especially during major marine anoxic events. These events severely impact benthic ecosystems by altering oxygen availability, nutrient cycling and habitat viability, leading to widespread mollusc mortality, reduced growth and impaired burrowing. Oxygen depletion can make prey more vulnerable by hindering avoidance and predator sensing, while hypoxia-tolerant predators may gain an advantage. Fossil assemblages provide concrete statistical evidence of these impacts. Analysis with fossil assemblages from the Indian subcontinent reveals a complex response of naticid gastropods (drilling predators) and their bivalve prey to deoxygenation in the Indian subcontinent, establishing links between environmental stress and ecological shifts. Anoxic episodes caused significant turnover in both naticid and bivalve assemblages, characterized by selective extinctions, shifts in dominant species and subsequent recoveries. Notably, drilling predation intensity was suppressed during peak anoxia, followed by adaptive radiations in the recovery periods. Two anoxic events, Cenomanian-Turonian Oceanic Anoxic Event (OAE 2, ~94 Ma) and Paleocene-Eocene Thermal Maximum (PETM, ~56 Ma) which have considerable imprint on the sediments in the Indian sub-continent have been analysed from this perspective. Redox proxies (Mo/Al, U/Th, and V/Cr ratios) from the Cauvery Basin confirm euxinic conditions during the Cenomanian-Turonian Oceanic Anoxic Event (OAE 2, ~94 Ma). This period was marked by extremely low oxygen levels across significant portions of the global oceans. During OAE 2, there was a sharp decline in naticid drilling frequency, indicating a severe suppression of their predatory activity. This coincided with a significant shift in bivalve dominance from infaunal species (e.g., Cardium), which were likely more sensitive to oxygen depletion in the sediment to epifaunal taxa (e.g., *Ostrea* and *Pycnodonte*), which may have had better access to limited oxygen. Post-OAE 2 recovery saw a robust radiation of naticid genera like *Euspira* and *Gyrodes*, and a substantial increase in drilling intensity from approximately 15% to 35% on bivalve specimens. This demonstrates a significant rebound in predation pressure as environmental conditions improved. Similarly, $\delta^{13}C$ excursions in Kutch correlate with the Paleocene-Eocene Thermal Maximum (PETM, ~56 Ma), an interval of rapid global warming and associated ocean deoxygenation. During the PETM, significant ~40% drop in bivalve diversity have been noted in Kutch basin. Opportunistic chemosymbiotic lucinid bivalves, known for their ability to thrive in low-oxygen environments by utilizing sulfide-oxidizing bacteria, became dominant during this period. Naticids (*Neverita sp*.) showed a lagged recovery in drilling predation. This extended recovery period highlights the more pronounced and lasting impact of

the PETM on naticids compared to bivalves. This period also saw changing affinities of the Kutch fauna to coeval faunas from the Mediterranean-Iranian and Eastern African-Arabian provinces, primarily driven by the development of shallow water habitats, suggesting regional faunal shifts. Rarefaction analysis confirms that this diversity loss was non-random, disproportionately affecting deep-infaunal bivalves, which were particularly vulnerable to the anoxic conditions. Overall, drilling frequencies dropped during peak anoxia due to environmental stress and low oxygen, but showed intensified prey selectivity and frequency during recovery intervals, indicating renewed trophic pressures and a re-establishment of predator-prey dynamics. Therefore, the positive correlation between redox-sensitive elements and community-level turnover points to anoxia as a major ecological filter, fundamentally reshaping these marine communities. The OAE 2 and the PETM in India highlights how large-scale environmental changes, including severe anoxia, can fundamentally reset coevolutionary arms races. While anoxia acted as a significant bottleneck for benthic communities, pre-existing traits like burrowing efficiency and metabolic flexibility likely facilitated differential survival among species. This research underscores the resilience and adaptability of marine benthic ecosystems to extreme environmental changes and provides a crucial framework for understanding modern biodiversity crises in the context of ongoing deoxygenation trends in our oceans.

Ovum-in-ovo egg pathology in Titanosaur eggs

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Abstract

Pathological eggs are infertile eggs caused due to egg within another egg, unusually sized or shaped eggs, and extra eggshell layers. A type of pathologic egg, known as "ovum-in-ovo" egg, has been documented from a titanosaur clutch from the Upper Cretaceous Lameta Formation of western Central India. This kind of pathologic egg has only been known from extant birds; hence the finding makes it the first to ever exist in dinosaurs and any other reptile. Study of the micro-, ultra-structure, and thin section of the eggshells under binocular, Scanning Electron, and petrological microscopes suggest that the eggshells belong to the oospecies Fusioolithus baghensis. In the absence of diagnostic osteological remains in the clutch, macro- and micro-structure observations indicate that the clutch belongs to that of the titanosaur. The macro-morphology of the pathologic egg shows an egg within an egg with a considerable gap which indicates it to be ovum-in-ovo egg known from birds. This is unlike another pathologic egg type which is common in fossil reptiles and is called as multi-shelled egg with additional eggshell layers. The cause of the ovum-in-ovo egg could be due to extrinsic factors such as illness, lack of resources, floods etc. which caused stress in the mother dinosaur. Once the stress was caused, the mother titanosaur would have pushed her egg back up the oviduct where it may have met another unshelled egg and then the pair would have travelled down to receive calcitic eggshell layers, thus getting entombed together. Birds have a specialized uterus where membrane and eggshell are produced in different regions and they release their eggs one by one. Crocodiles also have a specialized uterus but they release all of their eggs together in the form of a clutch. However, ovum-in-ovo pathology is not known from crocodiles' eggs. Hence, it is hypothesized that titanosaurs laid their eggs sequentially like birds. The study also suggests that this pathology may not be unique only to birds, as was previously considered, and that reproductive biology of sauropods shared similarities with other archosaurs.

Paleobiogeographic evidences suggest that the Middle to Late Jurassic gastropod assemblages of western India were faunistically distinct

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Abstract

The Tethys was one of the most dynamic gastropod realms during the Jurassic, being actively involved in faunal exchange both within the Tethyan as well as with other non-Tethyan provinces. Among several Tethyan gastropod provinces, the Ethiopian Province (EP) – of which western India was a part – was one of the taxonomically diverse provinces, which came into existence during the Toarcian (Early Jurassic). Discoveries of numerous Bajocian-Tithonian endemic gastropod taxa from the western Indian basins (e.g., *Bhujnerita, Euspira, Gyrodes, Helicacanthus, Indomaria, Jumaramaria, Megatylotus, Solarioconulus,* and *Turbinea*) in the last three decades reveal that the degree of endemicity (both at the genus and species level) of western Indian gastropod assemblages started increasing from the Bajocian. During the Bathonian-Callovian, western India clustered either with the European or with the Ethiopian localities, but endemicity increased further at this time: 79 out of 108 species were endemic. However, in the Oxfordian, species-level endemicity reached its acme (70 out of 83 species were endemic), as supported by the lower similarity coefficients of western India with several Tethyan and East Pacific provinces. As a consequence of these endemic faunal assemblages, western India was an outgroup of EP, as also revealed in the Cluster Analysis (CA). The overall low similarity between western India and different EP localities during the Bajocian-Tithonian claim that the western Indian basins (Kutch and Jaisalmer) had a distinct faunal assemblage compared to the European and African faunal assemblages during most of the Middle-Late Jurassic.

Taxonomic and ecological changes during the Coniacian- Campanian: A diversity study on gastropods from the Cauvery Basin, southern India

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Abstract

The Cauvery Basin, situated at the southern margin of the Indian plate, represents a nearly continuous Cretaceous marine sediment succession ranging from the Aptian to Maastrichtian, with a hiatus during the Santonian. The Basin, with the periodic deposits of shale, sandstones and limestones, has yielded diverse assemblages of microfauna, ammonites, gastropods, bivalves, brachiopods and echinoderms which offer a glimpse at the thriving biological communities of the Cretaceous period. Although gastropods are quite abundant, this group has received less attention in comparison to other fossil molluscan groups. In this study, we provide the diversity and ecological changes of the marine gastropod faunas in response to the environment. The specimens were collected from the Coniacian and Campanian horizons, situated nearly 12 km, 6 km and 9 km from the Ariyalur town, respectively. The new collections have been made from the Coniacian horizons (medium-to-coarse grained sandstones), which belong to the upper part of the Garudamangalam Formation. The assemblage includes 260 specimens belonging to 40 species, 30 genera, and 18 families. Among these 18 families, ten families crossed into the Campanian with an extinction rate of 44% at the family level and 18 (64%) new families originated in the Basin during the Campanian. Consequently, a total of 28 families (672 specimens; 51 species and 41 genera) were reported from the Campanian horizon, which consists of coarse-grained calcareous sandstones of the Sillakudi Formation. This increase in diversity signifies considerable changes in the environmental conditions in the Campanian of the Cauvery Basin. This diversity increase is also evident in the dietary habits of the gastropod communities, where an increase in the herbivorous grazers (which feed on plants and algae) and decrease in carnivore predators is noticed during the Campanian, while the suspension feeders did not face significant changes. This indicates fairly stable nutrient supply rates in the environment, with the possible introduction of a macroalgal or sea-grass dominated environment in the Late Cretaceous marine habitats of the southern Indian biosphere.

Phanerozoic morphological evolution in Class Bivalvia: insights into patterns and processes from model-based approaches

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Abstract

Quantifying patterns of morphological diversity (i.e., disparity) from the fossil record has had a long lineage in evolutionary studies, however, the integration of modelling-based approaches is essential in understanding the underlying driving mechanisms. Among marine organisms, the general ecologic and morphologic diversity trends in marine Class Bivalvia are reasonably well-known: bivalves have undergone multiple episodes of pronounced morphological diversification, specifically during the early Paleozoic and Mesozoic, associated with significant innovations and modifications in both hard- (e.g., shell outline, dentition) and soft-part (e.g., foot, siphons) morphologies, although the anatomy of this disparity trajectory and the evolutionary processes driving the megatrends is poorly constrained. Here, using geometric morphometrics, we analyse the Phanerozoic disparity trends of marine bivalves. To infer the underlying evolutionary processes behind these patterns, standard time-series-based evolutionary models – Unbiased Random Walk (URW), Stasis, Generalised Random Walk (GRW), and Ornstein-Uhlenbeck (OU) – are fitted. Our results reveal that the Phanerozoic bivalve disparity evolved in three distinct episodes: during the Cambrian-Devonian, the origination of several orders, coupled with morphological innovation, resulted in a sharp rise in disparity, as evident by the highest model support in favor of URW. The Carboniferous-Permian records the second interval of morphological evolution, when disparity reaches its acme, emerging from the expansion of the morphospace as some of the newly-originating families occupy the peripheral parts of the morphospace, as a consequence of morphological constraint-driven niche partitioning, as supported by the GRW model. During the third interval (Triassic-onwards), a long-term stasis in disparity is observed, reflecting morphological convergence among diverse groups, due to morphological constraint-driven stabilizing selection. The findings highlight the importance of model-based analyses for understanding macroevolutionary trends and deciphering their driving mechanisms.

Miocene sea-cows of Kutch, Gujarat: Role of sea level and paleoclimatic changes in diversification

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Abstract

Sirenia (dugongs, manatees) is an order of herbivorous marine mammals, whose geological record spans the last 50 million years. Their fossil remains are well- documented across tropical and subtropical regions, including Europe, the Mediterranean, North Africa, the Caribbean, the North-Pacific, the Indian subcontinent, Madagascar, and Java. Increase in sea levels and global temperatures during the Eocene and Miocene are strongly correlated with a rise in sirenian diversity in these regions. These shifts also likely affected the proliferation of seagrass meadows, which provided essential habitats, supporting both population expansion and diversification of Sirenia. The Kutch Basin in western India, has particularly revealed a remarkable diversity of fossil sirenians, having a multi-dugongine community in the Khari Nadi Formation of Miocene (Burdigalian) age. Studies of these fossils from Kutch have revealed significant diversification and morphological adaptations closely related to past climatic changes, sea-level fluctuations, tectonic activitiy, and evolving coastlines along the Indian Ocean. These findings have contributed significantly to our understanding of the relationship between faunal evolution and paleoenvironmental changes, highlighting the dynamic environmental conditions that shaped the evolutionary history of Sirenia.

The utility of landmark-based 2D and 3D geometric morphometry in palaeontological studies: case studies based on extinct aquatic snakes

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Abstract

Morphometry is an established tool in the palaeontologists' arsenal and has frequently been utilized to understand the relationships between taxa and elucidate phylogenetic relationships. It has especially been useful for systematic studies when the fossil dataset under scrutiny is poor or dominated by a single part of the animal's anatomy, e.g. isolated teeth or vertebrae. Recent advances in landmark-based geometric morphometry have let the technique surpass traditional morphometrics in terms of sophistication and error reduction. This technique allows for the complete elimination of the size of the fossil elements belonging to disparate groups, which is the largest source of error in morphometric analyses. The utility of landmark-based 2D and 3D geometric morphometries at different taxonomic levels is demonstrated here with the help of two case studies. Aquatic snakes belonging to the families Palaeophiidae and Nigerophiidae originated during the Early Cretaceous, surviving the K-Pg mass extinction, and surviving until at least the end of the Eocene. While nigerophiids had a higher diversity during the Cretaceous, including taxa like the Cenomanian genus Nubianophis from Sudan and Indophis from the Maastrichtian of India, palaeophiids primarily diversified during the Cenozoic, with ~20 known species distributed worldwide. Both families, their interrelationships, and their relations to extant snake families are poorly known, as the constituent taxa are based on rare, isolated vertebrae. It is crucial to understand these relationships to track the evolutionary history of these aquatic snakes. In the first case study, landmark-based 2D and 3D geometric morphometric is utilized to evaluate the morphometric relationships between the family Palaeophiidae and modern alethinophidian snakes. CT-scans of modern snakes were obtained from the online CT repository Morphosource TM. The scans were processed, and the precloacal vertebrae of the snake specimens were modelled at an interval of 20% of the total precloacal length of the specimen. The palaeophiid dataset was using photographs and sketches from the literature, which were used to manually generate 3D models. Both 2D and 3D landmarks were ascribed to the dataset, and Canonical Variates Analyses (CVA) were performed to understand the "morphometric affinity" of Palaeophiidae amongst modern alethinophidian groups. The evaluation showed that the family Palaeophiidae has a stronger morphometric affinity to the modern families Acrochordidae, Boidae and Pythonidae. The second case study utilizes landmark-based morphometry at a lower taxonomic level. This dataset includes palaeophiid and nigerophiid fossil

vertebrae, along with modern snake taxa including boids, pythonids, acrochordids, and elapids. 2D landmarks were ascribed to this dataset, serving as a training dataset for the CVA. The morphometric affinities of a snake vertebra from the Paleocene of Alabama, USA, along with the enigmatic taxa *Tuscahomaophis* and *Woutersophis*, were evaluated based on the training dataset. The results of this analysis showed that the Paleocene vertebra and the two taxa plot between the clusters of Palaeophiidae and Nigerophiidae, indicating a complex, possibly non-monophyletic relationship between the two families. The case studies presented here demonstrate the utility of landmark-based geometric morphometry in understanding relationships amongst extinct taxa with a limited fossil record.

A new Late Permian emydopoid (Synapsida, Dicynodontia) from India

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Abstract

Dicynodonts, a clade of non-mammalian herbivorous quadrupedal synapsids of the Permo- Triassic, were cosmopolitan, especially during the Triassic. These became extinct by the end of Triassic and are used as important biostratigraphic markers. The dicynodonts are characterized by distinct skull morphology that helped in propalinal action of the lower jaw, and most of the genera were edentulous and had keratinized epithelium in place of dentition for mastication. India documents a high abundance of dicynodonts that comprised varied genera and species. A Late Permian dicynodont-dominated multitaxic vertebrate assemblage is known from the Kundaram Formation of the Pranhita-Godavari Basin. The assemblage is dominated by large to medium *Endothiodon mahalanobisi*, *Oudenodon* and *Dicynodontoides*, and several small forms such as *Cistecephalus microrhinus*, *Pristerodon mackayi*, and *Sauroscaptor tharavati*. Here we report a new emydopoid dicynodont taxon, represented by a nearly complete, small skull associated with a lower jaw, which was originally encrusted by hard ferruginous host rock masking its original shape and size. The specimen was prepared manually and iron encrustations removed with the help of engravers, and electric microdrills. The new taxon is characterized by a unique combination of features that included a small toothed skull having short and wide snout, large orbit, large pineal foramen, embayment of palatal rim anterior to caniniform process, shovel-shaped symphyseal region of lower jaw with a rounded or squared-off edge, and distinct lateral dentary shelf. The study showed that the specimen belonged to a new taxon of the superfamily Emydopoidea and family Emydopidae. This finding is further corroborated by X-Ray micro computed tomography. The addition of another new dicynodont taxon in the highly diverse Late Permian dicynodont assemblage of India suggests a close similarity with that of the South African assemblage, though a certain degree of endemism in terms of generic and species diversity is evident.

A review of the complexities in Hexaprotodon evolution, distribution, and extinction with reference to the Indian Subcontinent

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Abstract

Hexaprotodon is an extinct genus of the Hippopotamidae family. The fossils remain of the *Hexaprotdon* genus is found in South Asia and Southeast Asia during the Plio-Pleistocene period. Various isotopic studies have concluded that the *Hexaprotodon* genus survived on C4 dominated diet in arid and seasonal habitats. The *Hexaprotodon sivalensis* fossils was first discovered by Falconer and Cautley in 1836 and it was initially described as a sub- genus. Eventually several different species such as *sivalensis, iravictus, palaeindicus, namadicus, sinhaleyus* were found in different temporal and spatial zones. The present study addresses the research on *Hexaprotdon* fossils to understand the evolution, distribution and role of *Hexaprotodon* genus in the megafaunal extinction debate. By employing a systematic and thorough literature review, the study aims to explore the various complexities and contradictions in our understanding of the *Hexaprotodon* fossils from the Indian Subcontinent.

Meso-Cenozoic disparity dynamics of the Class Echinoidea from India

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Abstract

The Class Echinoidea is one of the most diverse macroinvertebrate groups in the marine benthos, first appearing in the Ordovician, with subsequent diversification from the Mesozoic-onwards, specifically after the origination of irregular (infaunal) echinoids. Although the taxonomic diversity dynamics of echinoids are known in detail, there have been very limited works on the spatio-temporal change in the morphologic diversity (i.e., disparity) dynamics in this group, both at global and regional scales. For India – which has a rich Meso-Cenozoic record of echinoids, distributed across multiple sedimentary basins (e.g., Kutch, Cauvery, Assam, Mizoram) – no such attempts on disparity have been made till date. In the present study, we quantify disparity of Indian Meso-Cenozoic echinoids by using 83 discrete hard-part morphological characters of 184 Meso-Cenozoic species to achieve the aforementioned goal. To analyse disparity evolution during the Meso-Cenozoic, a morphospace was constructed using the Principal Coordinates Analysis (PCoA), with Gower distance. Furthermore, disparity was measured using Sum of Variances (SoV) and Sum of Ranges (SoR) metrics. Our results reveal higher variability in disparity in the Mesozoic, following which a Cenozoic drop was observed. However, on the PCoA morphospace, no such change in disparity is observed through time. The disparity trajectory does not correlate well with species richness – the Cenozoic species richness was higher than that of the Mesozoic, suggesting that disparity and diversity were decoupled, at least for the Indian Meso-Cenozoic echinoids.

Evolutionary mechanisms and dynamics of marine biodiversity hotspots during the Cenozoic

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Abstract

Marine biodiversity hotspots are regions of exceptionally high species richness relative to surrounding areas. Fossil and molecular data show that these hotspots have shifted both spatially and temporally throughout the Cenozoic Era. Understanding the mechanisms behind their formation, persistence, and movement is essential for reconstructing macro-evolutionary patterns and the biogeographic history of marine clades. In this study, we examined the key drivers of marine biodiversity hotspots using genus-level fossil occurrence data spanning the Cenozoic Era for four taxonomic groups: Mollusca, benthic and planktonic Foraminifera, and Cnidaria. The dataset was regionally subdivided and standardized, and we generated regional and global diversity curves to identify provinces of high biodiversity. We identified 29 distinct biodiversity hotspots across the Cenozoic for the studied taxa. Ancient paleo-hotspots, such as the Western Tethys, were primarily driven by high origination rates and low extinction, whereas more recent hotspots—like the Indo-Australian Archipelago and the Caribbean—were shaped predominantly by migration. Among the different hotspot dynamics, the Centre of Survival emerged as the most common mechanism, followed by the Centre of Origination and the Centre of Accumulation (Migration). Generalized Linear Models (GLMs) revealed contrasting drivers among the taxonomic groups. Planktonic foraminiferal hotspots were associated with low migration, higher sea surface temperatures, and greater habitat availability. In contrast, benthic hotspot formation showed no consistent biotic predictor and was only weakly influenced by abiotic factors—with higher temperatures reducing the likelihood of hotspot presence. Our findings underscore that marine biodiversity hotspots are not uniform across clades, but are shaped by a combination of taxon-specific traits and environmental conditions.

A note on taxonomic implications and evolutionary trends of recent Ostracodes from Kihim beach, Alibagh, west coast of India

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Abstract

Ostracodes have long geological history as they are known since Cambrian. They develop distinct morphological features in order to adapt to the variations in ecological parameters which are crucial in understanding evolutionary history and decipher climate change. There exists very close resemblance of some of the Recent Ostracodes with that of fossil counterparts recorded by Khosla and Nagori (1989, 2019) from the Quilon beds (Lower Miocene) of Kerala and Early Eocene Ostracoda from the Akli Formation of Barmer Basin, Rajasthan. The taxa included for the study purpose belong to the genera *Bairdoppilata, Actinocythereis, Alocopocythere, Keijella, Lankacythere* and others, recorded from Recent sediments of Kihim beach, Alibagh which show close resemblance with that of fossil counterparts belonging to the same genera. An attempt has been made to understand the evolutionary history of Recent Ostracodes with that of fossil counterparts which in turn help us to frame a linkage between "Present is key to the Past"- James Hutton. Further, looking forward to identify significant Recent Ostracodes which are comparable to fossils to construct the predictive model.

Evaluating species invasion using time-averaged dead assemblage of shallow marine bivalve community

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Abstract

Urban coastal environments are changing due to various factors such as pollution, habitat destruction, species invasion, etc. The effect of this is seen in the marine species community and its change over time. Invasion, being a large-scale phenomenon, is observed across various ecosystems, including marine, at varying degrees, and this leads to a change in the composition of the current species community. Invasive species are a subset of established non-native alien or naturalized species that are a threat to native species and biodiversity. These invasive species are often introduced by human activities, either intentionally or accidentally. Data about past species composition can help us better understand species invasion. Skeletal remains of dead organisms can serve as a good archive representing the past composition. The Dead Assemblage (DA) is a time-averaged dataset and can cover centuries of bivalve shells and their richness. Live assemblage (LA), on the other hand, gives the species richness at a very recent time point. In this study, we collected LA and DA of shallow marine bivalves from the coastal and creek area of Mumbai city. We tried to identify the alien species and evaluate their impact on the native community. We have observed the presence of two invasive species: *Mytella strigata* and a *Mytilopsis* species, of which the latter is already reported from Mumbai as invasive in previous studies. Primary findings suggest that the presence of invasives is changing the substrate character indicated by the low abundance of DA compared to LA, which is not expected under normal conditions. High richness in DA compared to LA also suggests a combined negative impact of pollution on the natives. Establishing this will open up the scope for further analysis, where DA will be the primary reference point. Considering DA as the baseline, we can evaluate the recent changes and their potential causes. Incorporating recent ecology with the dead assemblage/fossils is a very innovative idea to study population evolution over time, and to study the change in the habitat and its impact on the species community.

The Deccan Traps' role in Indian Dinosaur extinction vs. global Impact

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Abstract

The Deccan Traps constitute a vast large igneous province (LIP) in west-central India characterized by extensive basaltic lava flows, which commenced around 66.25 Ma. The most voluminous phase of volcanism, accounting for 80-90% of the total lava volume, occurred between 65-66 Ma which undergoes the K-Pg mass extinction period. The Cretaceous-Paleogene (K-Pg) boundary, dated to approximately 66 Ma, represented one of the most profound mass extinction events. This catastrophe led to the abrupt disappearance of non-avian dinosaurs and an estimated 75% of global plant and animal species. The primary cause of the K-Pg mass extinction revolves around two major contemporaneous geological phenomena: (i) the colossal volcanic eruption of the Deccan Trap in India, (ii) the impact of the Chicxulub asteroid on the Yucatan Peninsula in Mexico. The Chicxulub impact and Deccan Trap volcanism were identified by the presence of iridium at the K-Pg boundary and U-Pb dating and Ar/Ar dating, respectively. The Trap complex is predominantly composed of multiple layers of theolitic basalt, which eruption is widely associated with a deep mantle plume, specifically linked to the Reunion plume head, as evidenced by the high 3He/4He ratios observed in the magmas and notable acceleration in the motion of the Indian plate. The Deccan Traps region holds significant paleontological importance, with the discovery of dinosaur remains within its intertrappean and intratrappean beds. Some genera like *Rajasaurus*, *Barapasaurus*, *Isisaurus* are majorly founded. Now slowly a great debate starts upon the relative contribution and interplay of both Chicxulub and Deccan Traps action. Many things are considered, like the timing of impact and dating of rocks. At last, it confirms that both are taking part in global warming, acid rain, and different devastating activities, which helps in the large extinction. The research explicitly states that understanding the K-Pg extinction informs the present-day human-driven climate change and rapid CO_2 emissions from the Deccan Traps are similar to what is happening today.

Silicious microfossils from the Late Cretaceous Anjar Intertrappean beds of Katchchh, Gujarat

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Abstract

A rich assemblage of siliceous microfossils—comprising sponge spicules, diatoms, and phytoliths of palms—has been recovered from the Late Cretaceous (Maastrichtian) Anjar intertrappean beds in the Kachchh region of Gujarat. This articulated dinosaur fossil-bearing and iridium-rich intertrappean occurs between Flow III and Flow IV of the Deccan trap volcanic sequence (Bhandari et al., 1995; Khadkikar et al., 1999). The magnetostratigraphy (Courtillot et al., 2000; Hansen et al, 2001) of the bracketing lava flows and intertrappean bed shows that (i) the lower three flows in this area are of normal polarity (Maastrichtian Chron 30N), (ii) the immediate overlying intertrappean bed of reverse polarity (Maastrichtian Chron 29R). The freshwater sponge spicules from the Anjar intertrappean beds are represented by siliceous fossil biorotule spicules (gemmuloscleres) and megascleres belonging to asexual resting stages typical of the order Spongillida of family Palaeospongillidae. The presence of new species of sponge spicule, along with Palaeocorvospongilla cretacea, has provided evidence of the presence of diversified groups of freshwater sponges during the Late Cretaceous. In addition to sponge spicules, the freshwater diatoms, both centric (*Aulacoseira*) and pinnate types, are present in the sediments. An equally significant discovery is the presence of phytoliths attributable to palms (Arecaceae) and grasses (Poaceae), along with silicified tracheids, leaf cuticles, previously reported dicot wood remains (Srivastava and Gularia, 2001), and pollen grains of *Proxapertites spp*. sp., *Palmidites sp*., *Racemonocolpites maximus*, *Triorites sp*., *Proteacidites spp*., and *Aquilapollenites indicus* (Dogra et al., 2004) indicates good vegetation. Together, the floral and faunal assemblages reflect favourable ecological conditions both within the paleolake and in its surrounding landscape during deposition of the sediments.

Theme 2

Recent advancements in ichnofossils' origin and applications

First report of dinosaur highways from the lower Jurassic Limestone of India

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Abstract

Early Jurassic witnessed diverse groups of dinosaurs globally that became ecologically dominant. Most of our knowledge on the skeletal morphology on the clade Dinosauria are known from the recovered body fossils. However, dinosaur ichnology, that deals with the study of single fossilized impression of hand or foot or sequences of hand and foot impressions made by the dinosaurs during their lifetime, has gained little popularity although dinosaur tracks are so far reported from almost all the continents. Also, it is important to note that dinosaur footprint / track / trackways are direct evidences to infer the palaeobiology of the trackmakers such as the posture, gait, locomotion, palaeobehaviour, along with palaeoecology and dinosaurian diversity. Lower Jurassic Dinosaur ichnites are common in the siliciclastic sediments of North America, United Kingdom, South America, Africa and China. The report of Lower Jurassic dinosaur ichnites in carbonates are scanty and are known only from the shallow marine carbonates. This study is based on the only dinosaur track sites preserved in Lower Jurassic freshwater carbonates of Palustrine environment. Current study reports presence of dinosaur highway in the form of hundreds of different Lower Jurassic dinosaur footprints involving multiple bedding planes of the freshwater carbonate of the upper Kota Formation of the Pranhita-Godavari Gondwana basin of India, with the main bedding plane uncovering three extensive trackways of 10-20 meters in length and numerous other foot print/tracks. Outline drawings of trackways, track sizes and preliminary gross track morphology have revealed presence of several dinosaurian taxa including large, obligate, quadrupedal herbivores to relatively small sized bipedal herbivores along with large apex predators sharing the Lower Jurassic terrestrial ecological niche.

Coprolite ichnofossil records from India: An overview

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Abstract

The history of coprolite research in India spans over 150 years and reflects the limited existence of the five major types of research gaps, i.e., evidence, empirical, knowledge, theoretical, and methodological. As presently understood, the microcoprolites from the Terminal Proterozoic - Ediacaran Krol Group's 'Mussoorie phosphorite' are the oldest coprolite ichnofossil records from India (Patwardhan and Ahluwalia, 1971). Additionally, the Late Triassic (Carnian-Norian) Tiki and Maleri formations have yielded the taxonomically most diverse coprolite assemblage, to date, from India (Rakshit and Ray, 2022; Kapur et al., 2024a and references therein). Further, the latest Maastrichtian 'Morphotype-A' coprolite ichnofossils from the Deccan Volcano-Sedimentary Lameta Formation (Infratrappean) deposits at the Pisdura locality (central India) have been emphasized in research on Indian coprolites for their biotic inclusions (Khosla et al., 2025 and references therein). The only published record of vertebrate coprolites from the Deccan Volcano-Sedimentary 'Intertrappean' deposit, to date, has been reported from Lotkheri, Central India (Kapur et al., 2024b). The last decade or more has witnessed a renewed interest in the Paleogene (particularly, the Paleocene and Eocene) and the Neogene (Miocene) vertebrate coprolites from the sedimentary basins of western India (Sagar et al., 2024 and references therein), owing to the recovery of diverse vertebrate orders (including mammals) from the region, while the Oligocene coprolite records from India are presently non-existent. The above-mentioned coprolite records have assisted in providing direct evidence on the dietary habits of prehistoric fauna and have contributed towards our understanding of prey-predator interactions in an ecosystem framework. Additionally, geochemical investigations on the abiotic inclusions have highlighted their importance in understanding the chemical nature, mechanism of formation, and depositional environment (Kapur et al., 2024a and references therein), apart from the palaeoecological significance of the external surface traces, e.g., dentalites, burrows (Kapur et al., 2024b and references therein). Investigations incorporating both morphometry and geochemical techniques in a statistical framework should be encouraged to establish a classification (ichnotaxonomy) scheme on the coprolite ichnofossil records of India. However, the sporadic occurrences of coprolites in distant localities in India hamper our understanding regarding any change(s) in the dietary habits of extinct fauna as a consequence of changes in the ecosystem(s) linked to climatic change(s) in the geological record.

Differential epi- and endobiontic recruitment upon inflated and compressed bioclasts of *Nummulites vredenburgi* Prever Form B (Foraminiferida): A case study from the middle Eocene Harudi Formation of Kutch, India

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Abstract

Differential organic activity upon bioclasts of contrasting morphotypes of middle Eocene *Nummulites vredenburgi* Prever Form B (Foraminiferida) from Kutch, India provides valuable insight on sclerobiont-bioclast relation. The inflated morphotype of *N. vredenburgi*, characterized by a thicker and more robust test, consistently exhibits a higher incidence of domichnia-type endobiont colonization, notably by ichnotaxa such as *Gastrochaenolites dijugus* Kelley and Bromley, *Meandropolydora sulcans* Voigt, *Trypanites helicus* Nielsen & Görmüş and *T. solitaries* Hagenow. These endobionts are typically absent in the compressed test of *N. vredenburgi*. The compressed morphotype instead shows predominance of epibiont colonization by annelids, bryozoa, corals and bivalves as reported early. The inflated morphotype plausibly facilitated the endobionts to bore deep into the foraminiferal substrate, while the compressed morphotype offered increased scope for the surface settlement of the epibionts.

New Sauropod footprint from the Lathi Formation (Jurassic), Jaisalmer Basin, western Rajasthan, India

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Abstract

The present study reports a new set of sauropod dinosaur tracks from the Early Jurassic Lathi Formation of the Jaisalmer Basin, Western India. The discovery of sauropod footprints within the Lathi Formation, marks a significant advancement in the understanding of dinosaur distribution in western India. This find adds to the limited ichnological record of the Indian subcontinent and provides valuable insights into the distribution and palaeoecology of early Jurassic sauropods. The footprint exhibits characteristic features of a sauropod track, including a rounded heel impression and prominent digit impressions. The sedimentological context indicates deposition in a fluvio- deltaic to marginal marine environment, supporting the hypothesis that these large dinosaurs traversed diverse habitats. This discovery contributes to the growing body of evidence for widespread sauropod activity in Gondwanan terrains during the Early Jurassic and underscores the palaeobiogeographic significance of the Jaisalmer Basin in understanding dinosaur dispersal patterns in Western India.

The Asthenopodichnium trace fossil from the Barmer Basin, western Rajasthan, India

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Abstract

The present study reports the occurrence of the wood-boring trace fossil *Asthenopodichnium* from the Early Eocene (Paleocene) of the Barmer Basin, Western Rajasthan, India. *Asthenopodichnium* consists of five ichnospecies. These are *A. lignorum*, *A. lithuanicum*, *A. xylobiontum*, *A. ossibiontum*, and *A. fallax*. Their shape are almond, J, and U, respectively. These trace fossils, discovered in fine to medium-grained sediments, were most likely generated by wood-rotting fungi and mayfly nymphs and larvae in a freshwater environment. These Asthenopodichnium species suggest a biological origin associated with decomposing woody substrates. Their presence in the Barmer basin indicates the presence of a freshwater depositional environment. It provides valuable insights into the palaeo- ecological and palaeoenvironmental conditions during the Early Eocene in this region.

Assessing biotic recovery and environmental perturbations through ichnofabric analysis at the Permian-Triassic transition in the Spiti Valley, Tethys Himalaya India

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Abstract

The Permian-Triassic boundary (PTB) marks the most severe biotic crisis in Earth's history, resulting in the extinction of nearly 90% of marine species. This interval also marks a significant ecological transition, closely linked to widespread environmental perturbations. Following the PTB, a stepwise recovery of ichnogenera is postulated for the Early Triassic, characterized by a gradual, multi-phase re-establishment of benthic infaunal activity and bioturbation intensity. Globally, bioturbation diminished significantly during the Griesbachian interval and began to increase in the Dienerian. In the Spiti Valley of the Tethyan Himalayas, the Permian–Triassic succession is well-exposed, offering a near- continuous marine stratigraphic record across the boundary. Detailed field and Ichnological observations were conducted across three sections, including Mud, Gungri Village, and the Atargoo Bridge–Pin River transect. The Gungri Formation (Djulfian to Early Dorashmian) and the overlying Mikin Formation (Induan) preserve this transition in exceptional detail. The present study conducts ichnofabric analysis to examine the responses and recovery dynamics of the trace making benthic community across the PTB. The upper Permian interval comprises black shales and calcareous sandstones with moderately diverse trace fossil assemblages, including *Zoophycos*, *Teichichnus*, *Chondrites*, *Planolites*, and *Palaeophycus*, indicative of stable, oxygenated bottom-water conditions. These trace fossils display intense bioturbation and complex tiering structures. However, towards the top of the upper Permian succession, near the PTB, the shales become laminated, nodular and pyrite- rich, showing a marked decline in both bioturbation intensity and ichnodiversity. Across the boundary, the bioturbation index indicates a significant reduction in trace fossil activity, followed by the gradual reappearance of simple, horizontal traces in the overlying Lower Triassic beds. These observations reflect colonization by opportunistic tracemakers within a stressed, low-diversity ecosystem. While the Ichnological database from Himalayan regions, including Spiti, supports the stepwise pattern, other studies report persistent suppression of bioturbation throughout much of the Early Triassic or suggest spatially heterogeneous recovery trajectories. The ichnological record preserved in the Gungri and Mikin Formations documents a stepwise, yet delayed and regionally incomplete, recovery of benthic communities following the PTB. This study therefore provides new insights into the paleoecological dynamics of trace-making organisms during one of Earth's most critical biotic transitions.

Theme 3

Vertebrate through ages and their use in palaeogeography

First rodent and additional mammals from Piram Island, Kathiawar, India: A biochronological implication

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Abstract

Piram (Perim) Island of Kathiawar (Gujarat) is well known for its preserved wealth of fossil vertebrates since the early 18th century. Broadly, these vertebrates have been considered to be equivalent to the Dhok Pathan stage of the Middle Siwaliks. However, our knowledge about the precise age, stratigraphic context of this important fossil assemblage is still limited. Recent field work conducted at this Piram Island is yield additional mammalian faunal record comprising of Cf. Anancus, Stegolophodon cautleyi, Sivalhippus perimensis, Brachypotherium perimense, Bramatherium perimense and Selenoportax cf. vexillarious. Based on earlier finds and recent field work, we describe additional fossil mammals, including first report of a rodent, Democricetodon fejfari, from these sediments and discuss their biostratigraphic significance in the light of latest available Siwalik mammalian. We can now precisely place these highly fossiliferous sediments at ~8.7 Ma based on the first occurrence (FO) of the hipparionine equid Sivalhippus perimensis and last occurrence (LO) of the rodent Democricetodon fejfari. The discovery of a well dated cricetid rodent Democricetodon fejfari and first occurrence date of Sivalhippus perimensis overlap at ~8.7 Ma providing a precise age to Piram Island sediments and faunal assemblages.

The co-occurrence of alpheid shrimps and gobiid fishes in the fossil records: Insights into the timing(s) of the development of mutualistic relationship(s) within these groups

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Abstract

The fossil records of the co-occurrence of alpheid (genus Alpheus) shrimps (dominantly based on the strongly calcified claw fingertips) and gobiid (family Gobiidae) fishes are quite rare. In India, published records suggest the co-occurrence of these groups within the early Miocene (Aquitanian) Khari Nadi Formation (Kutch Basin, western India) and the early Miocene (Burdigalian) Quilon Formation (Kerala Basin, southwest India) (Kapur et al., 2022; Carolin et al., 2023; Amal et al., 2025). Considering the cryptic ecological behaviour observed in modern alpheids, the morphological variations observed within the fossil records of alpheid fingertips have been argued to favour the idea of Hyžný et al. (2017) that a complex snapping claw developed within alpheids before the Aquitanian (~23 Ma). In addition, it possibly reflects the taxonomic diversity within the genus Alpheus in the geological past. Thus, any future integrated biological and palaeontological investigations (in a phylogenetic framework) incorporating (i.e., scoring and analyses) of morphological characters displayed by the calcified fingertips of the major chelae of the pereiopod 1 'P1' claw in alpheid shrimps may assist in gaining inferences in an evolutionary context. The global data on the historical geographic distribution of alpheids and gobiids (including in co- occurrences) argues in favour of the persistent dwelling of these groups in a mutualistic relationship within the shallow coasts (mainly inter-tidal zone) of the Paratethys Sea and the Indian Ocean region during the Neogene, i.e., from the Aquitanian to the Burdigalian. The Indian fossil records on these groups also support the idea of Hyžný et al. (2017) that the mutualistic relationship(s) within these groups had developed prior to the Burdigalian. Palaeontological data from the early Paleogene of India reveal that the subcontinent was a biodiversity hotspot for numerous terrestrial and marine faunal groups (Kapur et al. 2022; Kapur, 2024 and references therein). These records include the globally oldest record on gobiid fishes (based on otoliths) from the early Eocene (~54.5 Ma) Cambay Shale, western India (Bajpai and Kapur, 2004). In view of the above, it has been

A new species of bush rat from the Early Pliocene Upper Siwaliks with implications for a South Asian origin of the genus Golunda

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Abstract

The Indian Bush Rat (Golunda ellioti) is the only extant representative of the genus Golunda. The genus, however, was much more diverse and widely distributed (in the past with fossil specimens recovered in West Asia, East Africa and the Indian subcontinent). In this study, we report a new species of Golunda from Mohand (ML1), Saharanpur District of Uttar Pradesh, India. We describe morphological differences in the dentition between this new species and other members of the genus, and discuss the implications of its evolutionary history. The new species is characterized by comparatively small molars, with less elongated and moderately inclined cusps. The fossils come from the upper part of the section at the level of 1760 m, which corresponds to the time frame between the chrons C3n.3r (4.997 Ma) and C3n.3n (4.896 Ma) based on previous paleomagnetic correlations. Therefore, the fossil locality falls in the Tatrot Formation of the Upper Siwaliks, suggesting an Early Pliocene age rather than the Late Miocene age of the Middle Siwaliks as suggested by earlier workers. The newly discovered species of Golunda predates the African species. This finding supports the earlier hypothesis that Golunda might have originated in the Indian subcontinent rather than in Africa.

Unveiling Eocene snake diversity from Kutch, western India: Insights into post-K-Pg evolution and biogeography

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Abstract

Snakes are among the most successful squamate lineages, that first appeared in the Early Cretaceous (~113–100 Ma) and are among the few non-mammalian vertebrates to have survived the Cretaceous–Palaeogene (K–Pg) mass extinction (~ 66 Ma). Here we report an exceptionally diverse snake assemblage from the Eocene deposits (56–42 Ma) of Kutch, western India, providing key insights into snake diversification on the Indian subcontinent across the K–Pg boundary. This interval coincides with extensive Deccan Traps volcanism during India's northward drift as an isolated landmass. The assemblage includes both aquatic and terrestrial/semi-aquatic snakes. Aquatic taxa comprise palaeophiids and nigerophiids, including a new palaeophiid species, Pterosphenus rannensis, which represents one of the youngest records of the family from India. The nigerophiid specimen marks one of the earliest Cenozoic occurrences of the group. Terrestrial forms include large-bodied madtsoiids, notably Vasuki indicus gen. et sp. nov., with estimated lengths of 11–15 m, making it one of the largest snakes known. Palaeotemperature reconstructions based on body size suggest warm Eocene tropical conditions (~28 °C). Biogeographic considerations indicate intercontinental dispersal, with India potentially serving as a center for the radiation of aquatic palaeophiids.

Dispersal routes of early dinosaurs from an Indian perspective

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Abstract

India has a rich dinosaurian record with the early taxa reported from the Upper Triassic Gondwana horizons, that included various saurischian remains from the lower and upper fauna of the Maleri Formation and Lower Dharmaram Formation. Multiple partial and small femora recovered from two bonebeds of the Upper Triassic Tiki Formation revealed co-occurrence of varied early dinosaurs that included a herrerasaurid and a possible ornithischian (silesaurid). A comprehensive phylogenetic assessment showed that these new taxa were early-diverging members of their respective clades, where Herrerasauridae is resolved as the sister-taxon to the Sauropodomorpha-Theropoda dichotomy, and Silesauridae is positioned as a stem taxon to the core ornithischians. Paleobiogeographic analysis using a time calibrated phylogenetic tree reveals that the herrerasaurids originated from the mid-latitude regions of western Gondwana whereas the silesaurids origination was more from the central Gondwana and the clades underwent significant diversification in the aftermath of Carnian Pluvial Event (CPE). Dispersal of herrerasaurids were in eastward and northward directions though the former commenced much earlier than the latter. The paraphyletic array ancestral to the typical ornithischian, i.e., the silesaurids dispersed into Laurasia immediately after the CPE, though its time of migration to the Indian landmass remains uncertain. These dispersal routes highlight the early dinosaurian diversity and underscores a continuous record of all major dinosaurian clades in the Indian subcontinent during the Late Triassic.

First evidence of dental elements of Pycnodontiformes from the Kachchh Basin, India

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Abstract

Pycnodontiformes is an extinct order of mostly marine bony fishes, with a few freshwater and brackish water forms too. Their range spanned from Late Triassic to Paleogene and they were a major component of the marine ichthyofauna, with an almost worldwide distribution. The members (called pycnodonts) were characterized by their laterally compressed and deep bodies, large posteriorly placed median fins and short jaws, which adapted them for maneuverability in reef environment. These fishes are particularly characterized by their heterodontous dentition made up of incisiform teeth in the premaxilla and dentary bones, and molariform teeth in the prearticular and vomer bones which were used for crushing the hard shells of their invertebrate prey. The molariform teeth, whether isolated or attached to toothplates, are an important part of the pycnodont fossil record and are often the only elements of these fishes that are found preserved. Numerous taxa have been created solely on the basis of pycnodont isolated dental elements; a majority of the pycnodont species known in the fossil record are known from isolated dentition or teeth. The Early and Middle Jurassic fossil record of pycnodonts is extremely poor with only twelve nominal species reported. Pycnodonts in the fossil record of Jurassic of Gondwana are even more scarce, with either isolated dentitions or very incomplete specimens discovered. In India, occurrence of a pycnodont was reported based on a fragmentary prearticular dentition as well as several isolated teeth from the shallow marine Middle Jurassic (Bathonian) strata of the Fort Member of Jaisalmer Formation, in the Jaisalmer Basin of Rajasthan, western India, which is currently the oldest record of a pycnodont in India as well as across the East Gondwana. Here, we report the first fossil evidence of this group in the form of dental elements including a partial jaw and isolated dentitions from the late Early Jurassic to Bajocian of the Dingy Hill Member of Kaladongar Formation as well as numerous isolated teeth from the late Bathonian of the Raimalro Limestone Member of the Goradongar Formation in the Kachchh Basin, western India. The taxonomical identification of these dental elements was attempted by utilizing landmark-based 2-D geometric morphometries to compare their morphology to the dental elements of known pycnodonts. This was done by creating a dataset which included the pictures of molariform teeth from numerous accepted taxa of pycnodonts as well as from our own collected specimens, which was then evaluated using Canonical Variates Analysis (CVA). The results were then plotted to understand the morphometric affinities between the known and unknown teeth and it was observed that the unknown teeth were closer to the clusters of members from the families Pycnodontidae and Gyrodontidae. This study therefore marks the first occurrence of pycnodonts from the Jurassic of the Kachchh Basin, India, as well as the oldest occurrence of this group

across the East Gondwana and fills an important knowledge gap of the Middle Jurassic vertebrate fauna, while also showcasing the remarkable potential of landmark-based geometric morphometrics to test the taxonomical relationships between extinct taxa.

An integrated spatial analysis of Hyperodapedon taphonomy from the Late Triassic Maleri Formation

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Abstract

The Late Triassic Maleri Formation of the Pranhita-Godavari (P-G) Basin, India, is notable for its diverse terrestrial vertebrate assemblage, primarily preserved in red mudstones that are interbedded with sandstones, calcirudites, and calcarenites—indicating low-energy floodplain deposition with episodic high-energy channel activity. Hyperodapedon huxleyi, a herbivorous rhynchosaur, is restricted to the lower Maleri Formation and found mostly within the thick red mudstone unit and mixed mud-sand lithologies. While earlier taphonomic studies on vertebrates from various Gondwana basins have largely relied on qualitative descriptions, this study introduces an integrated spatial statistical analysis—applied for the first time—to better understand bone preservation patterns linked to burial and fluvial energy regimes. Three geospatial techniques—Kernel Density Estimation (KDE), Average Nearest Neighbour (ANN) analysis, and Getis-Ord Gi* hotspot analysis— are employed within an integrated taphonomic framework to examine four key variables: Voorhies Group (VG), weathering stage (WS), abrasion stage (AS), and breakage orientation, measured from 202 Hyperodapedon specimens of Maleri Formation of the P-G Basin. The spatial coordinates of each of these specimens have been measured in field using hand held GPS. KDE created a continuous map of fossil density, while ANN measured clustering and Getis-Ord Gi* identified hotspots and cold spotsfor the taphonomic features. These spatial analyses of taphonomic features across the basin shows clear clusters, suggesting different patterns of fossil preservation in different areas. KDE revealed five distinct accumulation zones characterized by high kernel peaks, interpreted as localized bone-rich sub-areas within the basin. ANN confirmed strong, statistically significant clustering (NNR =1; p = 0.0001) across the taphonomic variables, including Voorhies Groups, VG1 (Z = –16.67), VG2 (–11.64), and VG3 (–16.01); Weathering Stages, WS1–WS4 (–12.72 to –6.02); Abrasion Stages, AS1–AS4 (–15.57 to –3.99); and transverse (–14.82), oblique (–16.70), and longitudinal breakages (–9.14), highlighting basin-wide clear spatial organization in fossil preservation, driven by varying energy regimes and burial processes. Pie chart distribution of the four taphonomic features in each sub-area reflect varying taphonomic patterns. Sub-area 1 displays hotspots for all Voorhies groups, weathering, abrasion stages, and transverse–oblique breaks (90–99% confidence), with pie chart dominance of VG3, WS3, AS3, and transverse breaks, indicating a high-energy fluvial reworking zone likely representing an active channel. Sub-area 2 has hotspots for VG2, WS2, AS2, and oblique– longitudinal breakages (95–99%), matching local dominance of directional breaks and moderate weathering/abrasion, consistent with episodic reworking and burial in a distal levee or flash

flood channel. Sub-area 3 shows coldspots for VG3, WS3, AS3, and transverse–oblique breaks (99% confidence), despite dominance of these features in pie charts, indicating slow burial in a low-energy floodplain. Sub-area 4 exhibits coldspots for all taphonomic variables, yet pie charts show moderate representation of WS1 and AS2, suggesting low-energy area where bones were gently buried without much disturbance. Sub-area 5 shows a WS1 hotspot (99%) but coldspots for VG3, WS3, AS1, and longitudinal breakage, with localized WS1 and AS1 abundance—indicating brief exposure followed by rapid burial, likely along a levee margin. Together, these indicates a clear gradient from low- energy, stable depositional settings to high-energy, reworked bonebeds, shaped by localized exposure and hydrodynamics. Variations in taphonomic patterns across the Lower Maleri outcrop— from high- energy reworked channels to quieter floodplain—thus, indicate distinct taphonomic pathways for the rhynchosaur population. These patterns align well with sedimentary indicators for a meandering to anastomosing river system influenced by occasional sheet floods on floodplain settings, offering valuable insights into the Late Triassic depositional setting of the P-G Basin. The study, thus, highlights the value of spatial statistical tools in vertebrate taphonomy by applying an integrated GIS-based approach combining ANN, KDE, hotspot analysis, and pie chart evaluation.

New Goniopholididae from the lower Jurassic Kota Formation of India: Palaeobiogeographic significance

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Abstract

The earliest ancestors of the modern-day crocodiles appeared on earth during the Carnian Age of the Late Triassic Period as small gracile animals, except for a few anomalous forms from North America. Today crocodiles are known by twenty-seven species pertaining to nine genera and exhibit a global distribution. They are amphibious in nature, occupying semi- aquatic habitat in tropical to subtropical regions, except some alligatorids which are found from temperate regions. Neosuchia, the ancestors of all the modern-day crocodiles, appeared on earth during the Early Jurassic and recorded the first habitat shift from land to freshwater aquatic realm within the clade Crocodylomorpha. During the Early Jurassic, the breakup of the supercontinent Pangea was initiated, marking a significant shift in the earth's tectonic configuration. With the drift of Lauresian and Gondwanan continents, newer passageways were created and shallow seas emerged globally, which possibly helped the neosuchians to explore the empty aquatic niche. These new spaces were occupied by marine and semi-aquatic taxa all over the world. Among the Neosuchia, a group of crocodiles evolved during Sinemurian-Pliensbachian of the Early Jurassic with a marked depression in their maxillary region and are known as the Coelognathosuchia. It includes the flat-snouted goniopholidids and tubular-snouted pholidosaurids. Goniopholidids existed till the age of the Late Cretaceous. Biogeographic distribution of this clade shows a robust representation from Laurasia with earliest report from USA. However no confirmed report has been made from the Gondwana till date. The distribution shows three distinct clusters in Laurasia— a) North America, b) Europe and c) Asia. A new goniopholidid fossil from the Early Jurassic (Toarcian to Aalenian Age) of India enriches the extent of the currently known biogeographic distribution of this taxon in Gondwana. This new Indian fossil exhibits morphological similarities with that of the North American forms from Early and Late Jurassic age, and the Late Jurassic form from Asia (NW China), indicating a strong Laurasian affinity. In turn, this also indicates towards a basal form within this clade. Further study is needed to resolve the Lauresian affinity of the new Indian basal form during the Early Jurassic.

Sharks and batoids (Chondrichthyes, Elasmobranchii) from the late Miocene deposits of Piram Island, Gujarat, India: Paleobiogeographic implications

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Abstract

The recent field work at the Late Miocene Piram Beds of Southeastern Saurashtra of Bhavnagar, Gujarat could recover certain shark teeth, batoid teeth and other vertebrates. The fossiliferous conglomerate bed of Piram Island yields teeth of sharks, batoids, certain invertebrates and microfossils. The Miocene epoch marks a significant phase in Earth's history characterized by dynamic climatic shifts and oceanographic reorganizations that profoundly influenced marine biodiversity and distribution. Among marine vertebrates, elasmobranchs (sharks, rays, and skates) serve as critical indicators for reconstructing past environments and biogeographic patterns due to their widespread distribution and excellent fossil preservation, especially of teeth. The elasmobranch fauna from study area comprises of *Carcharadon carcharias, Sphyrna zygaena, Carcharhinus perseus, Hemipristis serra, Rhizoprionodon* sp., *Isurus oxyrinchus, Isurus desori, Isurus pagoda, Myliobatis* sp., and crocodilian tooth. The collected fossils are correlated with the other Neogene elasmobranch bearing site of India such as Baripada Beds in the eastern coast of India, Kutch in the western site, and Mizoram in the Northeastern India. The majority of the reported fauna shows the prevailing of tropical to sub-tropical climatic conditions. The faunal similarity index of the late Miocene elasmobranch of India is closer toward South Pacific Ocean and Indo-Pacific region suggesting the shifting of migration path from the Mediterranean region after permanently closing the Tethys Sea ways. Most of the collected species of the late Miocene sharks and batoids are also presently found today in the Indian Ocean.

First Evidence of Ziphodont Crocodilian from the Eocene of Kutch, India: Tracing their biogeographic radiation

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Abstract

The Naredi Formation of Kutch, Gujarat, India, represents an early to middle Eocene depositional system associated with the first marine transgression overlying the Deccan Traps. This formation, particularly well exposed in the Panandhro Lignite Mine, records sedimentation in a shallow inner shelf setting ranging from brackish lagoonal to marginal marine environments. Recent field investigations in the Panandhro lignite field have led to the discovery of a rich assemblage of fossil vertebrates preserved within grey silty shale deposits near the top of the lignitic sequence. These ossiferous backswamp deposits, part of the Naredi Formation, have yielded a diverse vertebrate fauna comprising fishes, turtles, snakes, crocodilians, and mammals. Among the recovered materials, isolated crocodilian teeth exhibit distinct ziphodont morphology characterized by sub-conical shapes with serrated carinae, where the serrations are more pronounced along both the mesial and distal edges. Although no cranial or postcranial elements were found to permit definitive taxonomic identification, the dental morphology is comparable to that of Planocraniidae (formerly Pristichampsine) crocodylomorphs, are previously reported from the Eocene Subathu Formation of northwest India. Planocraniids are known to be hypercarnivores, inhabiting primarily terrestrial environments but are also capable of surviving in coastal and brackish conditions. This ecological adaptability aligns with the paleoenvironmental context of the Naredi Formation. The presence of ziphodont crocodilian remains in the middle Eocene of western India supports the hypothesis that Planocraniid could have dispersed across coastal ecosystems during the Middle Eocene Thermal Maximum, a period marked by elevated global temperatures and diverse reptilian assemblages, including giant snakes such as *Vasuki indicus.* However, further discoveries of associated skeletal elements are required to confirm the taxonomic identity of these remains and to better understand the biogeographic patterns and ecological adaptations of Eocene non-crocodilian crocodylomorphs in the Indian subcontinent.

Early Eocene (~55 Ma) "insectivores" from Vastan, Gujarat: Biogeographic connections during India's northward drift

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Abstract

The early Eocene period in Earth's history had a profound influence in three fundamental aspects, namely evolution, climate, and geography. This period witnessed the rise of the modern mammals, such as the APP taxa (artiodactyls, perissodactyls, and primates), the intense warming episodes (hyperthermals), most notably the Paleocene-Eocene Thermal Maximum (PETM) at the Paleocene-Eocene boundary (56 Ma), and the collision of the Indian landmass with Asia. The early Eocene fauna of the Indian subcontinent is crucial for understanding the causes and consequences of these phenomena. Biogeography, in particular, offers a valuable tool for studying the interplay of these processes. Fossils from the open-cast lignite mines of Vastan, Tadkeshwar, and Mangrol, in Gujarat, have provided a wealth of data on early Eocene land mammals. Whereas much of this mammal fauna shows Holarctic signatures, certain groups, such as the "insectivores", a polyphyletic assemblage of small-sized mammals, remain poorly known. Elucidating the affinities of these small mammals is essential for understanding the complex biogeography of India during the final stages of its northward drift and the subsequent India-Asia collision, which had profound implications for faunal migrations.

Theme 4

Isotopic and elemental geochemistry applications in palaeoclimate and archaeology

Isotope evidence for diet of extinct primates of India

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Abstract

We are what we eat! Diet has been central to our evolution. The tooth enamel is the hardest tissue in vertebrates and it remains unaltered for millions of years, preserving the dietary and climate signature in the form of $\delta^{13}C$ and $\delta^{18}O$ values. Enamel in turn grows incrementally on daily or weekly basis and faithfully records dietary and ecological changes an individual undergoes in its life time. in the tooth enamel of all the mammals including those of primates. Application of non-invasive X-Ray Synchroton microtomography combined with laser ablation based stable carbon and oxygen isotope analyses of growth layers show very interesting results including high resolution dietary, ecological and climate data. I present here some of the studies carried out on Indian extinct primates, including *Sivapithecus, Sivaladapis, Indopithecus* and *Theropithecus,* indicating a dietary shift from a pure C3 browsing to pure C4 grazing *vis a vis* ecological shift in the subcontinent.

Paleontological proxies in the rock art and archaeology of the eastern Vindhyas: Assessing the relevance of Rock art

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Abstract

The rock art of Mirzapur and Sonbhadra districts of Southern Uttar Pradesh has been the focus of our field investigations and documentation since 2009. The Vindhyan uplands, falling in the area between Rivers Sone and Belan, the Rewa-Drummondganj Plateau has two very large concentrations of rock art traditionally called the Morhana Pahar and Lekhahia Pahar groups of sites. Several early to late Holocene rock art sites and clusters are at Mukkha Dari Waterfalls, Chaan Pathari, on the Shahganj escarpment on the Belan; Kandakot and Panchmukhi hilltop sites on the Markundi Plateau, near Robertsganj, in Sonbhadra district; Likhaniya Dari, Chuna Dari, and Bhaldaria Dari, on the Garai River, on the Sukrit escarpment, and Wyndham Falls on the Khajuri River/Barkachcha escarpment in Mirzapur. All these sites were enclosed by dense forests and sported many game animals, of which hunting-gathering communities made prehistoric drawings of the early to late Holocene periods. Predominantly, Rhinos, Elephants, Buffalo, Gaur, Wild Cattle, Nilgai, seven species of Deer and Antelopes, and smaller wild aquatic, avian, and terrestrial fauna are also drawn. Palaeontological notices about fossil prehistoric fauna like Rhinos found in Mirzapur, and those depicted in rock art, were written by A.C.L. Carlyle and John Cockburn (both colonial officers working on rock art) in the Journal of the Asiatic Society of Bengal, and other notable 19th-century world journals. Many Holocene faunal specimens have been excavated at Raja Nal ka Tila, Raipura, Morhana Pahar, Bagahi-Khor, and Lekhahia Pahar, which also confirm the presence of most of the species occurring in the rock art. This article is based on two field projects to document rock art of Southern Uttar Pradesh (2009-12 and 2021-24) and highlights the correspondence between palaeontological and archaeological findings in the Eastern Vindhyas.

Elephants to Ostriches: current status of Quaternary vertebrate palaeontology in South Asia

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Abstract

Quaternary paleontology in South Asia has been traditionally dominated by vertebrate fossil assemblages recovered mostly from river valleys across India. Abundant assemblages have also been recovered from the the Siwalik Hills of India, Pakistan and Nepal and the Karewa deposits of northern India. However, this has led to geographic and temporal dichotomy of fossil evidence across the Indian subcontinent. This paper reviews the current status of Quaternary paleontological research in South Asia and implications for paleoanthropology and related issues. Special scientific distinctions as well as key lacunae, problems and challenges in the subject are discussed and potential research directions are underscored. One of the most prominent lacunae is inadequate fossil hominin specimens as known from other parts of the Old World. This issue, along with the decline in research and lack of absolute dates for key fossil assemblages and associated contexts, has led to critical knowledge gaps resulting in comparative hindrances and interpretations with global datasets. Therefore, concerted efforts through multi-pronged collaborations between all stakeholders are urgently required to revive the subject, recover additional fossil assemblages and protect/display evidences at select sites and zones (especially due to imminent destruction through various factors).

Prehistory and human origin during Pleistocene in South Asia

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Abstract

The Pleistocene age on Earth is dated between 2.58 to 0.0117 MYA. Oldest stone tools dated 3.3 MYA were reported from Lomekwi in Kenya. Tool makers in South Asia must have arrived before *Homo erectus*, P. Chouhan (2007, p. 257). The hominid group that produced mode I pebble tools in Riwat, Pakistan, central and S.E. Asia did not disperse into peninsular India, and he supported the movious observation. The author of the Mode ll Acheulean tool in South Asia came in two successive migrations? This requires confirmation from the P. Chauhan side. Mode l pebble pre 1.8 million years dates from Damanisi in Georgia in central Asia, and Mode ll Acheulean tool tradition from Ubeidya in Israel. Which records date to 1.4 million years, as indicated by Baryosef & Goren Indar (1993)? This Ubeidya Acheulian site in Israel Jordan Valley is the oldest evidence of Acheulean in the entire Europe, the Middle East, and Asia. Recently, S. Pappu (et al, 2011) published a date of 1.5 million years for the Acheulean site of Attirampakkam in Tamil Nadu. D.K. Bhatacharya (2012) suggested that the origin of Asia, *Homo erectus*, occurred anywhere between North Deccan India and the highlands of Israel, as indicated by the tools found. Archaic *Homo sapiens* evolved in North East Africa, and one branch of this migrated through the Horn of Africa and Saudi Arabia to China and South Asia. Thus, India acted the main corridor to populate Southeast Asian, Australia, and New Zealand; another branch moved to Europe through Mount Sinai. Narmada *Homo erectus* was dated around 76 million years by A. Sonakia (2007). Its cranial capacity is estimated to range between 1200-1400 B.C. (de Lumley 1985). Kennedy (2007) called it the Narmada Skull as an early Sapien on an evolved *Homo erectus*. We may conclude lower Paleolithic chopper chopping stage began around 2.7 M +- BP, and the early Acheulean began in South India around 1.6 M BP P and *Homo erectus* was the author of the Acheulean tradition. The family of *Homo erectus* was reported from Hathnora and Attirampakkam. The Middle Paleolithic stage began in South India around .35 M+- B P. The upper Paleolithic stage began earlier than .05 M+- BP. Dr A R. Sankayan, called Hathnora, Narmada Valley skull as Archives *Homo sapiens* because its cranial capacity of skull ranges between 1155cc to 1480cc, but we prefer to call it a developed form of *Homo erectus*. According to Shilla Mishra, *Homo erectus* was the manufacturer of Acheulean in South Asia and South East Asia. Around 400 *Homo erectus* fossils were reported from sites in Indonesia and 3 sites in India. and we have the oldest dates from India and African sites, and she confirmed South Asia or Africa could be the beginning of the Acheulean and the oldest *Homo erectus* fossil. The oldest *Homo erectus* cranium, dated 2.04 to 1.95 millennium old, was reported from Drimolen, South Africa was the birthplace of *Homo erectus* and Acheulian tools.

Hippopotamus as the palaeoecological proxy in Archaeology

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Abstract

Hexaprotodonts (*Hexaprotodon spp.*) or six incisored hippopotami in Peninsular India are one of the most common associational occurrences with palaeolithic artefacts and the biostratigraphy confirms its contemporaneity. There are three known species viz. *H. palaeindicus*, *H. namadicus* and *H. deccanensis*, (dated to from 34k to 22k years B.P.), whose fossilised skeletal and dental remains have been discovered along with other megafauna like elephants, rhinos, cattle, buffaloes, zebrine horses and deer and constitute a significant representation in the fossil record. The anatomy and physiology of these artiodactyls point to their dependence on water bodies commonly known as their living spaces. This renders hippopotamus as an ideal candidate for palaeoecological interpretations for their fossil occurrences in the Late to Terminal Pleistocene deposits across Peninsular India. The study has amply demonstrated that the hippos are very useful proxies for ecological interpretations for the period that also includes the prehistoric man who shared the landscape along with them. Using modern methods of ecological, dietary and taphonomy, the present paper highlights the importance of this taxon in prehistoric archaeology as an ecologically sensitive megafauna which finally succumbs to the post LGM impact, commonly known as Late Quaternary extinction window globally.

Evaluation of organic matter genesis and its significance

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Abstract

The palaeodepositional environment and present-day significance of the Paleogene lignite-bearing sequence of the Jalipa Mine were assessed using a multiproxy approach. This study investigates the genesis and nature of organic matter, source floral composition, depositional setting, and utilization potential of the deposit through geochemical and visual kerogen characterization. Petrographic analysis reveals a dominance of huminite macerals (average: 66.36 vol.%), followed by liptinite (average: 16.59 vol.%) and inertinite (average: 12.35 vol.%) groups. The mineral matter content in the samples ranges from 2.12 to 20.20 vol.%. A substantial higher-plant contribution to the palaeopeat is indicated by the abundance of telohuminite, mainly as ulminite, further supported by a high terrigenous/aquatic ratio (TAR) and a high carbon preference index (CPI). The presence of oleanane and lupane compounds suggests a dominant angiosperm source, while the diterpenoids indicate gymnosperm vegetation in the catchment area. Additionally, cadinanes and bicadinanes in fossil resins (amber) point to an input from Dipterocarpaceae. The n-alkane distributions, peaking at n-C_{17} and n-C_{29}, reflect a contribution from both algal communities and higher plants, although alginite was rarely observed. Various petrographic indices suggest that peat-forming vegetation was deposited in a limno-telmatic environment under fluctuating (ombrotrophic to mesotrophic) hydrological conditions. The presence of higher plant terpenoids (diterpenoids, oleanane- and lupane-type triterpenoids), and bacterial-derived hopanoids, indicates a mixed floral assemblage flourishing under a tropical warm and humid climate. This is further supported by the significant proportion of detrohuminite subgroup macerals (7.3 vol. %). The lignite samples are characterized by low moisture content (1.2–18.86 wt. %), moderately high ash yields (dry basis: 2.57–60.24 wt.%), volatile matter (dry-ash-free basis: average 41.96 wt.%), and fixed carbon content ranging from 10.63 to 44.95 wt.% (daf). They also exhibit high carbon content (average: 70.72 wt. %), low hydrogen (average: 9.62 wt. %, daf), nitrogen (average: 3.12 wt.%), and sulfur (average: 1.98 wt.%). Geochemical screening using Rock-Eval pyrolysis reveals that the Jalipa lignite contain 10 wt. % total organic carbon (TOC) and are thermally immature (T max 435 °C). Various plots (e.g., HI vs. OI; S_2 vs. TOC) suggest that the studied samples comprise mixed kerogen Types III–II, making them primarily suitable for gaseous hydrocarbon generation. Elemental analysis (on a dry ash-free basis) shows average carbon content at 83.45 wt.%, hydrogen at 3.73 wt.%, nitrogen at 0.95 wt.%, and oxygen at 11.15 wt.%, while sulfur content (on a dry basis) averages 0.50 wt.%. The atomic H/C and O/C ratios also suggest that the organic matter is dominated by Type III kerogen. The vitrinite reflectance values (Rr% up to 0.45%)

suggest that the samples have reached a near-mature stage of thermal evolution. The maceral composition, low mineral matter content, and geochemical characteristics classify these lignite deposits as clean coal resources, with high suitability for unconventional hydrocarbon generation and conversion.

Interglacial productivity increase in the Bay of Bengal driven by monsoon-enhanced runoff during the last ~52 kyr

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Abstract

An increase in primary productivity in the Bay of Bengal during interglacial periods is attributed to enhanced nutrient supply driven by intensified Indian Summer Monsoon (ISM), which promotes both riverine runoff and upwelling. As a critical modulator of air-sea CO_2 exchange, primary productivity plays an essential role in regulating past climate. However, a large regional variability exists in terms of glacial-interglacial productivity changes. This variability arises from multiple factors influencing oceanic primary productivity, such as nutrient availability, turbidity, light, and wind intensity. The ISM governs approximately 80% of annual precipitation over the Indian subcontinent, contributing to a substantial riverine influx of ~1.5×10^{12} m^3/y into the Bay of Bengal. This input delivers ~1.74 Tg of nitrate, 0.08 Tg of phosphate, and 0.91 Tg of silicate annually, supporting a primary production of ~11.5 TgC. However, the long-term impact of monsoon-driven changes in nutrient delivery on productivity remains unclear due to conflicting reconstructions from both modern and paleo- records. To address this, we present a ~52 kyr multiproxy record of surface runoff, productivity, and carbonate preservation using sediment samples from Site U1446, recovered during IODP Expedition 353. Our record, based on proxies including sea surface temperature, sea surface salinity, *Globigerina bulloides* abundance, and Ba/Ca ratios in *Globigerinoides ruber*, reveals intensified runoff during interglacial periods, reflecting a stronger ISM. In contrast to earlier interpretations, our productivity proxies—*G. bulloides*/*G. ruber* ratio and Cd/Ca in G. ruber—indicate elevated productivity during interglacials. We argue that previous suggestions of glacial productivity maxima likely reflect enhanced carbonate preservation rather than true productivity increases. We have used the absolute abundance of planktic foraminifera and Li/Ca ratios in G. ruber as preservation indicators. These results suggest that intensified monsoonal activity during interglacials increased nutrient delivery to surface waters, driving higher productivity. This study underscores the importance of multiproxy approaches in disentangling productivity signals from preservation effects in paleoceanographic reconstructions.

Stable isotope evidence for long-Term ecological stability and adaptation of mammalian fauna in the Indian subcontinent during the middle to Late Pleistocene

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Abstract

The global pattern of mammalian extinctions during the Late Pleistocene has often been attributed to climate shifts and anthropogenic pressures. While such hypotheses have been extensively tested in the Americas, Europe, and Australasia, South Asia remains relatively underrepresented. In this study we present stable carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotope data from dental enamel of fossil mammals from Middle to Late Pleistocene deposits of Central Narmada Valley in India. The $\delta^{13}C$ values reveal a persistent dominance of C_4 grass-based diets throughout the sequence, with limited variability suggesting fluctuating access to mixed C_3-C 4 vegetation by some taxa. This data imply relatively stable open grassland and savannah-like habitats with interspersed wooded patches over at least 100,000 years. The $\delta^{18}O$ values exhibit moderate shifts consistent with regional palaeoclimatic reconstructions, indicating variations in monsoonal intensity and aridity but no evidence for prolonged or extreme environmental stress. Together, these isotope results support the idea that many mammalian taxa were able to endure ecological pressures through behavioural or dietary plasticity. Scholars have demonstrated faunal continuity in the region for over 200,000 years suggesting long-term adaptation rather than widespread extinction of herbivore communities in India.

Estimating heating events and temperature using phytoliths and pottery of the Kohla Iron Age archaeological site, Nagpur district, Maharashtra

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Abstract

The recently excavated Iron Age archaeological site at Kohla in Nagpur District, Maharashtra, has yielded abundant phytoliths recovered both from pottery and sediment samples. The phytoliths are derived from grasses and woody plants. Autofluorescence study of the phytoliths from the pottery indicates strong green and red fluorescence, indicating exposure to temperatures between 400 °C and 1000 °C. Notably, there is no evidence of paleofire events in the area. Fourier transform infrared spectroscopy (FT-IR) and X-ray Diffraction analysis of the pottery and soil samples have also provided interesting results about the firing temperatures of the pottery and diagenetic changes due to burial. This multidisciplinary study highlights the utility of phytolith analysis in reconstructing past heating events, assessing anthropogenic fire use, and estimating the firing temperature of archaeological pottery.

New fossil discoveries from the Karewas of Kashmir: Preliminary findings, implications, and future work

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Abstract

The Pleistocene record of the Indian subcontinent is vibrant, making it a hotspot for fossil activity and leaving several palaeoanthropological and archaeological investigations within the region to be explored. The Karewas of Kashmir is one such affluent locality to explore for all such studies. The current research plan includes a multiproxy approach to systematically reconstruct the past environment based on several seasons of fieldwork that have been performed in the Kashmir Valley. The site of Samboora in the Upper Karewas has been identified, where various vertebrate fossils have been recovered and sediment samples collected. The aim is to create a holistic record via multiple proxies, including microfossils and macrofossils, palynology, sediment geochemistry, and dating techniques. This reappraisal could place the region in a possible corridor to corroborate the 'Out-of-Africa' hypothesis and provide strong evidence for faunal and hominin entry into the subcontinent. The aim of this study also includes a conservation aspect, keeping in mind the geological, palaeontological and archaeological importance of sites that are being lost to anthropogenic activity. Modern techniques, such as 3D photogrammetry, geotagging and map creation using GIS, and digital recording of various specimens (be it artefacts, fossils, or sediments), are necessary for future research. With the Karewa sediments being valuable for saffron cultivation and the recent ban on sand quarrying that was disturbing the sections, the necessity for a dying agricultural practice and archaeological research to go hand-in-hand is crucial. The Galander fossil site in Pampore, first excavated in 2000, only came to the media in 2024, even though the scientific body informally knew about the site's situation and activity. The aforementioned techniques can help visualize the stratigraphy and geology of the area, and the use of photography and videography to display in public forums and 'geomuseum/geoheritage creation' can help the locals to see the importance of their land. Knowledge dissemination, therefore, is vital for research to progress and conversations to occur. Future prospects for the site also include a robust taxonomic description of the fossils, taphonomic analysis of all diagnostic specimens, and a correlative study that involves the use of said proxies such that their context can be put into perspective, and specific questions such as how the fauna survived (and thrived) in the valley, and if hominins followed suit, can be attempted to answer.

Quaternary review of Ostrich eggshells

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Abstract

The Quaternary period, encapsulating the Pleistocene and Holocene epochs, unfolds over a vast stretch of 2.6 ma. This period is hallmarked by multiple glacial-interglacial cycles that carved the face of the earth, as well as the evolution, migration, and growing dominance of the hominids. Yet, alongside these expanding human ancestors, the earth teemed with diverse forms of life — animals and birds of every kind asserted their presence. Of particular note within this ecological tapestry were the ostriches, whose eggshells have emerged as invaluable paleoenvironmental and archaeological artefacts. These eggshells offer profound revelations about ancient human-environmental dynamics, especially within arid and semi- arid territories. Preserved across epochs, ostrich eggshells (OES) found in varied prehistoric sites throughout Africa and South Asia hold the keys to reconstructing long-lost environmental conditions, as well as decoding the symbolic behaviours and intricate human-environment interactions of early populations. The occurrence of these eggshells alongside Pleistocene-aged deposits articulates a narrative wherein early humans not only encountered but intricately utilized ostrich eggs across multifaceted dimensions. Meticulous analysis of these eggshells unravels pivotal information regarding past climates and floral patterns, which, in turn, shaped the adaptive movements and resource management strategies of ancient hominids. Moreover, the discovery of OES fragments adorned with perforations or incised designs unveils their transformation into beads, containers, or even ritualistic artefacts, providing a glimpse into the cognitive ingenuity and cultural depth of early societies. As a resilient artefact that interconnects biological, environmental, and cultural threads, ostrich eggshells stand as a rare and unique evidence, crucial for comprehending the intricate relationship between humans and their habitats throughout prehistory. Appreciating the underestimated role that these eggshells played will alleviate the sphere of cognitive advancement in the life of hominids, offering not only a fresh perspective on their intellectual capabilities and resourcefulness but also insights into how they adjusted to the variations in climate.

Phytoliths, a tool to decipher paleoclimate, paleofire, and Heating events: a case study from the pachkhed iron age archaeological site, Yavatmal district, Maharashtra

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Abstract

Phytoliths are an important proxy for the reconstruction of past climate, environment, and agricultural activities, and also for reconstructing paleofire events. This study presents a comprehensive paleoenvironmental reconstruction of the Iron Age archaeological site Pachkhed, Yavatmal District, Maharashtra, India, using phytolith analysis. A total of 32 Iron Age soil samples were analysed for this study. Standardized maceration, microscopic analysis, and fluorescence microscopic analysis were conducted, along with the calculation of different paleoenvironmental indices such as aridity index, water stress index, dicot index, and climate index. Seventeen different morphotypes were recovered from the soil samples. Overall, C 4 Panicoid grasses dominated the landscape for most of the sequence, which indicates warm and humid climatic conditions. The shifts in the abundance of woody (dicot) and grass (monocot) phytoliths, along with calculated indices for water stress and aridity, highlight significant changes in vegetation, climate, and land use over time. A key finding is the detection of high-water stress but low aridity during the Late Iron Age, suggesting that human activities placed additional pressure on local water resources even when the climate was relatively moist. The study also reconstructs the region's fire history by combining visual identification of burned phytoliths with advanced autofluorescence microscopy and chromatism. Burned phytoliths and strong green and red fluorescence signals point to repeated high-temperature fire events, especially during periods of settlement and agricultural expansion. These findings demonstrate the value of phytolith and fluorescence analysis for uncovering the intertwined stories of climate, fire, and human impact in central India. The research not only fills a major gap in the environmental history of Vidarbha but also provides a framework for future archaeological and paleoenvironmental studies in the region.

Climate-induced shifts and agricultural adaptation during the Harappan civilization: Synthesizing from archaeobotanical and palaeoenvironmental records

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Abstract

Climatic variability during the mid to late Holocene significantly influenced the agricultural systems and settlement dynamics of the Harappan Civilization. Following the cultural sequence outlined by Fuller and Madella (2001) and Possehl (2002), this review synthesizes published archeobotanical and palaeoenvironmental data to examine the relationship between shifting monsoonal patterns and agricultural adaptation across the Early (~5200–4600 cal yr BP), Mature (~4500–3900 cal yr BP), and Late Harappan (~3900–3000 cal yr BP) phases. Archaeobotanical data from sites such as Kunal, Banawali, Kanmer, and Rojdi, along with palaeoclimatic evidence from lakes including associated with Black and Red Ware ceramics, these communities maintained a mixed farming economy, while the Iron Age and Early Historic periods (c. 1000–200 BCE) remain less understood due to the limited number of excavated sites, except Manjhi. The present study focuses at Uren (25°10'3"N; 86°13'11"E), a multi-cultural settlement in the Lower Ganga Plain. Archaeobotanical evidence spanning six cultural phases—Black and Red Ware, (BRW), Black Slipped Ware, (BSW), Northern Black Polished Ware, (NBPW), Sunga–Kushana, Gupta, and Pala Period, offers a unique opportunity to trace long-term agricultural practices and human response to environmental changes. Systematic analysis reveals that rice (*Oryza sativa*) cultivation was a consistent staple from the Neolithic onwards, often accompanied by barley (*Hordeum vulgare*) and various pulses. By the Early Historic phase, however, barley had significantly declined in prominence, reflecting a shift in crop priorities that resonates with modern agricultural patterns. This study highlights the central role of cereals, pulses, oilseeds, and fibre crops in sustaining ancient food economies, while also drawing attention to the sophistication in plant usage for vegetables, culinary, and medicinal purposes during early historic. By integrating archaeobotanical data within a robust chronological framework, this research provides new insights into the diversification of crops across the vast landscapes of the Ganga Plain. These findings, coupled with the presence of agricultural weeds and wild plant resources, highlight the resilience and adaptability of ancient farming communities in response to environmental and cultural changes. Uren thus provides critical data for understanding Agrarian economies and their role in supporting emerging urbanism in early historic Ganga plain. Renuka, Khajjiar, and Wadhwana, provide insights into changing crop regimes in response to regional climate fluctuations. The Early Harappan phase coincided with intensified Indian Summer Monsoon (ISM) activity, supporting a diverse winter cropping system including early rice cultivation. In contrast, the Mature and Late phases reflect a gradual to pronounced shift towards drought- tolerant crops like

millets and their associates, aligning with evidence for declining monsoon strength and increasing aridity. The 4.2 ka BP event, associated with abrupt climate change, appears to mark a critical transition in both environment and subsistence. The aforesaid findings suggest that long-term climatic stress, coupled with fluctuating water availability, played a crucial role in shaping agrarian strategies and population dispersal. This work underscores climate as a major driver in the cultural transformation of the Harappan Civilization.

Archaeology, macrobotanics and dates: Decoding 3000 yrs agricultural history in Lower Ganga Plain

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Abstract

Archaeobotanical research in the Ganga Plain has illuminated the intricate relationship between ancient communities and their plant resources, tracing the evolution of subsistence strategies from the Neolithic to Chalcolithic periods. Excavations at prominent sites such as Chirand (Saran district) and Senuwar (near the Kaimur hills) reflect a gradual transformation from simple stone-and-bone tool cultures to increasingly complex agricultural systems. During the Neolithic phase (c. 2500–1800 BCE), communities practiced mixed farming, cultivating cereals and pulses such as hulled barley (*Hordeum vulgare*), dwarf wheat (*Triticum sphaerococcum*), rice (*Oryza sativa*), lentil (*Lens culinaris*), field pea (*Pisum sativum*), and grass pea (*Lathyrus sativus*). The subsequent Neolithic–Chalcolithic transition (c. 1800–1500 BCE) marked a diversification of the crop with the introduction of bread wheat (*Triticum aestivum*), chickpea (*Cicer arietinum*), green gram (*Vigna radiata*), and horse gram (*Macrotyloma uniflorum*), indicative of cultural exchanges and the eastward diffusion of West Asian domesticates. During the Chalcolithic phase (c. 1500–1200 BCE), associated with Black and Red Ware ceramics, these communities maintained a mixed farming economy, while the Iron Age and Early Historic periods (c. 1000–200 BCE) remain less understood due to the limited number of excavated sites, except Manjhi. The present study focuses at Uren (25°10'3"N; 86°13'11"E), a multi-cultural settlement in the Lower Ganga Plain. Archaeobotanical evidence spanning six cultural phases—Black and Red Ware, (BRW), Black Slipped Ware, (BSW), Northern Black Polished Ware, (NBPW), Sunga– Kushana, Gupta, and Pala Period, offers a unique opportunity to trace long-term agricultural practices and human response to environmental changes. Systematic analysis reveals that rice (*Oryza sativa*) cultivation was a consistent staple from the Neolithic onwards, often accompanied by barley (*Hordeum vulgare*) and various pulses. By the Early Historic phase, however, barley had significantly declined in prominence, reflecting a shift in crop priorities that resonates with modern agricultural patterns. This study highlights the central role of cereals, pulses, oilseeds, and fibre crops in sustaining ancient food economies, while also drawing attention to the sophistication in plant usage for vegetables, culinary, and medicinal purposes during early historic. By integrating archaeobotanical data within a robust chronological framework, this research provides new insights into the diversification of crops across the vast landscapes of the Ganga Plain. These findings, coupled with the presence of agricultural weeds and wild plant resources, highlight the resilience and adaptability of ancient farming communities in response to environmental and cultural changes. Uren

thus provides critical data for understanding Agrarian economies and their role in supporting emerging urbanism in early historic Ganga plain.

Preliminary geochemical insights into Late Triassic bonebeds from India based on trace element study

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Abstract

Trace elements, typically present in very low concentrations in natural systems and living organisms, often become significantly enriched in fossilized remains because of diagenetic uptake during the fossilization process. This study investigates the diagenetic pathways of four contemporaneous bonebeds from the Upper Triassic Tiki Formation of India, whose biostratinomic aspects have been well-documented by previous authors. More than 100 fossil specimens representing three most abundant tetrapod taxa and their associated host rocks were analysed to deduce concentration of 15 trace elements using inductively coupled plasma-mass spectrometry. The analysis revealed similar patterns of mean trace element concentrations between the fossil specimens and their enclosing rock matrices, suggesting comparable diagenetic and burial conditions implying that the fossil assemblages were not reworked post-burial. However, the overall disparity in average trace element concentrations between the fossil specimens and host rocks indicate likely enrichment from external sources. The reducing nature of the early diagenetic micro-environment is evidenced from differential elemental concentrations that resulted from decomposition of organic matter within the bones. This study offers insight into the taphonomic pathways of the four Tiki bonebeds through trace element analysis and underscores the value of such geochemical approaches in reconstructing provenance, early diagenetic micro-environments, and palaeoclimatic conditions. While the findings are preliminary, they provide a foundation for more detailed future studies.

Palynological and geochemical evidences of climatic changes from ice house to greenhouse conditions during the Late Paleozoic Ice Age

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Abstract

Earth's penultimate icehouse period, the late Paleozoic ice age (LPIA), was a time of dynamic glaciation characterized by glacial–interglacial climatic cycles, large-scale glacioeustasy, and repeated ecosystem changes. In India, this late Palaeozoic glaciation is well documented in the southern temperate high palaeolatitude Gondwana sequences especially in the Permo-Carboniferous Talchir Formation, which is the oldest stratigraphic unit of the Gondwana Supergroup. Its transition into the greenhouse conditions are documented in the overlying Barakar Formation. The responses to these climatic changes are shown by the changes in the compositions of terrestrial flora, marine fauna, sedimentary facies and geochemical signatures. Here we present the changes in the palynological and geochemical trends observed in the Talchir and Barakar formations in the Wardha Basin, Maharashtra state, Central India. The palynoflora of the Talchir Formation are characterized by dominance of cold and arid upland pollen of cordaites and conifers and are least diversified, whereas the Barakar Formation show advent and establishment of proliferous humid taxa. This is substantiated by geochemical signatures where Talchir sediments showed low CIA and low TOC values due to glacial climate, whereas Barakar sediments showed high CIA and TOC values which indicates increased weathering under increased precipitation and high organic input from luxuriant vegetation. These analyses let us interpret the linkage between vegetation and climate shifts in response to transition from icehouse to greenhouse conditions during the LPIA.

Theme 5

Applications of fossils in demarcating stratigraphic boundaries

Marine invertebrate diversity and extinction in the Indian Himalayan regions

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Abstract

The fossil record of the Indian Himalayan region provides important evidence of the evolutionary history and extinction patterns of marine invertebrates from the Cambrian (~538 Ma) to the Cretaceous (~66 Ma). The Cambrian–Ordovician interval witnessed the "Cambrian Explosion," a phase of rapid diversification marked by the rise of trilobites, brachiopods, archaeocyathids, graptolites, and early corals in the Tethyan Himalayan belt. The Silurian and Devonian periods maintained relatively stable marine ecosystems dominated by brachiopods, ammonoids, and crinoids, with continued sedimentation in the Tethys basins. During the Carboniferous and early Permian, marine biodiversity reached its peak in these basins; however, the Permian–Triassic boundary (~252 Ma) saw the largest mass extinction in Earth's history, eliminating nearly 90% of marine species. The Triassic period marked a slow recovery with the reappearance of ammonoids, bivalves, and gastropods, while the Jurassic period showed a robust resurgence of marine ecosystems, including reef-building organisms and cephalopods. The Late Cretaceous fossil record from the Himalayas indicates high diversity, particularly of echinoids and gastropods, but this ended with the Cretaceous–Paleogene (K–Pg) extinction event, which, combined with regional tectonic changes and global climatic shifts, led to a decline in marine biodiversity. Overall, the Himalayan fossil record is crucial for reconstructing the paleogeography of the Tethys Ocean, as it reflects the combined effects of global extinction-recovery cycles and local tectonic events, including the northward drift of the Indian Plate toward Eurasia that influenced sedimentation patterns and ecological dynamics in the region.

Permian brachiopod diversity from Arunachal Pradesh and its palaeobiogeographic implication

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Abstract

During the Permian Period, extensive palaeogeographic restructuring and environmental shifts played a pivotal role in shaping patterns of global provincialism, with a pronounced impact on marine invertebrate communities. In India, Early Permian brachiopods are well known from northern to northeastern Himalaya and also Peninsular India, but the Late Permian brachiopods are only well established from north India. The Gondwana in Arunachal Pradesh are represented lithologically by alternations of shale, siltstones and sandstones and at places with coal lenses and having Lower Gondwana plant impressions. Early Permian marine fossils have also been recorded with predominant presence of brachiopods and next to it, molluscs. The Lower Permian rocks in and around Tatamori, Gensi, Rilu, Daring, Kimin, and Littemori areas record six families of brachiopods, the dominant genera being *Costatumulus*, *Cyrtella*, *Tivertonia*, *Linoproductus*, *Trigonotreta*, *Neospirifer* and *Subansiria*. In the east of Siang river, a marine fossiliferous shale unit has been recorded in the Dalbuing hill near Mariyang in the Upper Siang district, that hosts a strikingly different brachiopod assemblage. The brachiopod fauna hosted in the shale unit designated as the Yamne Formation indicates Middle to Late Permian age and it is sandwiched between the underlying Geku Formation and the overlying Dalbuing Formation, both Paleogene in age. The brachiopod and bivalve diversity is restricted within the upper part of the Yamne Formation. The Dalbuing brachiopod fauna represent six families -- Productelliidae, Rugosochonotidae, Spiriferellidae, Linoproductidae, Margininferidae, and Trigonotretidae in the order of abundance. Though the fossil preservation is bad, posing hindrance in detail taxonomy required for species designation, the dominant genera observed in the Yamne Formation are *Spiriferella*; *Neospirifer*; *Neochonetes*; *Costiferina*; *Rectimarginifera*; *Fusichonetes*; *Transennatia*; *Tethychonetes*; *Cathaysia*; and *Anidanthus*. Late Permian marine fauna in eastern Arunachal Pradesh is significant from the perspective of Permian palaeobiogeography of the Himalayan Province, which stretched from Pakistan in the west through the Himalayan area of North India, Nepal, Southern Tibet, to western Australia in the Permian. Recent studies indicate that the Himalayan brachiopod fauna is biogeographically 'complex' because of an admixture of cold and warm water fauna in the Upper Permian and by the presence of Cathaysian taxa. In the southern part of the Himalayan Province (i.e., W. Australia, S. Tibet, and Spiti), there are more

typical Gondwanan genera, whereas in the northern part (i.e., Salt Range, Kashmir, Chitichun, and Timor), faunas show similarities with Cathaysian Province. Such faunal affinity was due to southerly invasion of Cathaysian faunas in response to climatic change due to northward drift of Gondwana. Paleobiogeographically, the Arunachal Pradesh fauna show a mixed assemblage of Gondwanan and Cathaysian taxa and is similar to southern Tibet. Interestingly, the Zhongba Micro-terrane is characterised by several typical Gondwanan/bipolar cool-water brachiopods and bivalves that appeared as early as the Late Cisuralian, apart from several Cathaysian warm-water brachiopods, bryozoans, fusulines and compound corals.

Coral from Hamira Member (Early Jurassic to Bajocian), Jaisalmer Formation, Jaisalmer Basin

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Abstract

The Jaisalmer Basin is a pericratonic shelf basin. It is a part of the Rajasthan shelf, situated on the western part of the Indian Craton. The basin contains sediments ranging from Precambrian to Quaternary in age and exhibits rapid temporal changes in facies. The Mesozoic sedimentation started in the basin during the Triassic/Early Jurassic period with the rifting of Gondwanaland. The Jaisalmer sedimentary basin is very significant for its fossiliferous Jurassic sedimentary rocks. Lithostratigraphically, Jurassic rocks within the Jaisalmer Basin are further divided into four formations: the Lathi, Jaisalmer, Baisakhi, and Bhadasar formations, spanning from the Early Jurassic (Pliensbachian) to the Late Jurassic (Tithonian). The Jaisalmer Formation, spanning the Bajocian to Oxfordian ages, is further subdivided into six distinct members: Hamira, Joyan, Fort, Bada Bagh, Kuldhar, and Jajiya. Hamira member of the Jaisalmer Formation shows a intertonguing relationship with the underlying Lathi Formation, which dominantly consists of brown calcareous sandstones or sandy limestones, at places coquinoidal with fragments of bivalve shells. This is the basal member of the Jaisalmer Formation, overlying the Lathi Formation consists of greyish, brownish, yellow, low-angle cross-bedded, fine- to medium-grained calcareous sandstone and limestone with scattered bivalves (heterodonts, oysters, Trigonia, etc.), brachiopods, trace fos- sils (*Rhizocorallium*, *Chondrites*, *Taenidium*, *Planolites*, *Skolithos*, etc.), colonial corals, crinoid fragments, solenopo- racean algae and wood fossils. This member is exposed at the top of the Thaiyat scarp, north of the village Thaiyat along the right-hand side of the road going to a railway crossing near the village of Hamira and near the Tamre Rai temple about 28 kms SE of Jaisalmer city. On the basis of fossil records in the overlying Joyan Member, the Hamira Member can be safely assigned to the interval from Early Jurassic to Bajocian. Corals occur in the Jaisalmer Formation (Upper Bajocian–Oxfordian) as scattered, rewor- ked specimens of both solitary and colonial corals, and in the Bhadasar Formation (Upper Tithonian) they mostly consist of parautochthonous, monospecific solitary corals. Prior to this work, oldest corals from Jurassic rocks are reworked coral-heads of *Isastrea bernardiana* (D'Orbigny) from late Bajocian fossiliferous rudstone of the Joyan Member. Corals from Hamira Member of the Jaisaler Basin has not been described. Present work records the solitary coral for the first time from fosiliferous limestone of Hamira Member of the Jaisalmer Formation exposed at the Tamre Rai temple about 28 kms SE of Jaisalmer city.

Non-marine vertebrate faunal diversity and biostratigraphic re-evaluation of the Upper Triassic Gondwana horizons of India

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Abstract

The Late Triassic is a major transition in the Earth's history when many new biotas first appeared, others became extinct and fragmentation of the supercontinent Pangaea was initiated. There is a plethora of work globally on the Late Triassic biostratigraphy and biochronology, which provide a framework for understanding these biotic changes, especially in absence of radioisotopic dating and magnetostratigraphy. The Late Triassic in India is best represented by the Gondwana successions exposed in the Pranhita-Godavari (PG), and Son-Mahanadi (SM) basins that are rich in highly diverse vertebrate fossils that constitute important biostratigraphic markers on a global scale. These horizons included the Maleri and Lower Dharmaram formations of PG Basin and the Tiki Formation of the Rewa Basin, a sub-basin in the northern part of the Son-Mahanadi Basin. Based on current advances in the knowledge of Late Triassic vertebrates of India, an attempt is made to designate biozones based on multiple taxa that are bounded by the lowest and highest known occurrences, and ascertain biochronology or relative ages of the fossil-bearing horizons. The study resulted in several new biostratigraphic insights that included assigning Carnian and Norian biozones based on distinct faunal assemblages, absence ofsynchronicity between faunal and lithological boundaries, and absence of well-designatedRhaetian vertebrate index fossils. However, caution is necessary for determination of age based only on temporal range of the fossils because of preservation loss and collection bias that may lead to underestimation of relative age, and the boundaries of these eubiozones may change because of new fossil recoveries and changes in identification of pre-described taxa.

Lagerstätte of *Shaanxilithes ningqiangensis* and their taphonomic variants from the Krol E Formation of the Nigalidhar Syncline, Lesser Himalaya, India

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Abstract

The co-evolution of life and environment can be encountered during the transition of the Ediacaran-Cambrian Period. During this phase, the simplest forms of the metazoan and metaphytes have evolved and become complex and diversified. In the present study, an index fossil, *Shaanxilithes ningqiangensis*, has been documented from the terminal Ediacaran-aged Krol-E Formation of the Nigalidhar Syncline, Lesser Himalaya, India. These are carbonaceous in nature and preserved as compression. They are characterized by serially arranged discoidal, lensoidal, or crescentic-shaped nested units found preserved on the top of the bedding planes. The present study documents four types of taphonomic variants of *Shaanxilithes ningqiangensis*, having different morphological artifacts preserved on the different bedding planes of the micritic earthy dolomite unit. These fossils have been considered a potential biostratigraphic marker of the terminal Ediacaran age. Laser Raman Spectroscopic (LRS) analyses of all four taphonomic variants have also been carried out to understand their biogenic origin. The LRS results show the graphitization level in the form of the D and G bands of organic carbon. The fossil-bearing horizon is all together a new locality within the Nigalidhar Syncline, which holds the terminal Ediacaran fossil remains from the Indian subcontinent.

Understanding the Ediacaran-Cambrian transition in the Bilara Group, NW India: Paleontological and geochemical constraints

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Abstract

The calcareous tubular fossil has been discovered for the first time in the Bilara Group of the Marwar Supergroup (MSG) in NW India. The carbonate facies of the Bilara Group are positioned between the underlying siliciclastic Ediacaran Jodhpur Group and the overlying Cambrian Nagaur Group. A 23-meter-thick mining section (Barna II) of the Bilara Group was examined for palaeontological investigation, combining results with U-Pb detrital zircon geochronology and previously documented stable carbon isotope stratigraphy. The outcrop section of the Barna II includes the upper part of the Gotan Limestone and the lower part of the Pondlo Dolomite. The skeletal tubular fossils discovered at the top of the Gotan Limestone. These fossils were identified in a bed that lies eight meters above the base of the mine section, and two meters below the silty layer with a maximum depositional age of ca. 544 Ma constrained by detrital zircon U-Pb dating. Stable carbon isotope stratigraphy signatures demonstrated most likely trace of BACE and the Ediacaran-Cambrian (E–C) boundary as it moves upward in the outcrop, approximately 10 meters above the dated horizon. Furthermore, the underlying Jodhpur Group has yielded Ediacara-type macrofossils, and the overlying Nagaur Group contains Cambrian trace fossils. Therefore, the occurrence of calcareous tubular fossil along with available stable carbon isotope data, and maximum depositional age estimate that the lower part of the Pondlo Dolomite (Bilara Group) witnessed BACE and the E-C boundary within the Barna II mine section of the Bilara Group, Marwar Supergroup.

Carnian pluvial event: Resolving vertebrate biostratigraphy and endemism in India's critical Gondwanan record

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Abstract

This study addresses significant gaps in understanding the Carnian Pluvial Event (CPE), a pivotal global extinction and diversification boundary marking profound climatic upheaval and faunal turnover, within the terrestrial Triassic of India—a crucial Gondwanan context bridging southern continents. We present a comprehensive alpha-taxonomic revision of Indian metoposaurids, resolving longstanding uncertainty through first-hand morphometric analysis (elliptical Fourier, PCA) and cladistics (TNT) of global specimens. Results demonstrate the Indian taxon (*Buettneria maleriensis/Metoposaurus maleriensis*) is morphometrically and phylogenetically distinct, occupying an intermediate position between European *Metoposaurus* and North American *Koskinonodon,* supported by biogeographic isolation, warranting the new genus *Panthasaurus maleriensis.* Furthermore, we report the first chigutisaurid skull from the Tiki Formation, identified as a new *Compsocerops* species distinct from the Maleri Formation's *C. cosgriffi* based on key autapomorphies (inward-curved quadratojugal process, vomerine foramina, vacuities morphology). Critically, this novel chigutisaurid provides the first biostratigraphic correlation, confirming synchronicity between the Tiki Formation and the Lower Maleri Formation during the mid-Carnian/Norian transition coeval with the CPE. These findings reveal CPE-driven patterns: the establishment of endemic taxa (*Panthasaurus, new Compsocerop*s) underscores significant provincialism and vertebrate diversification within isolated Indian basins, directly linked to Carnian humidification. This research resolves critical Indian vertebrate taxonomy, establishes essential intra-basinal correlations, and highlights India's unique Gondwanan record in elucidating the CPE's global impact on terrestrial ecosystems.

Late Cretaceous calcareous nannofossil biostratigraphy and paleoenvironmental changes in the Mannar Basin, Sri Lanka

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Abstract

We present the results of a calcareous nannofossil study carried out on 57 drill-cutting samples from the Barracuda well, Mannar Basin in the Indian Ocean. The study reveals a well-diversified, moderately preserved nannofossil assemblage (60 species, 35 genera) in the Mannar Basin with Tethyan affinities. The studied section spans UC14d TP - UC18 subzones representing the Campanian and Maastrichtian stages. The abundance changes in the ecologically significant taxa such as *Biscutum constans*, *W. barnesiae*, *Zeugrhabdotus spp*., and the total absolute abundance of nannofossil reveal distinct paleoenvironmental changes during early Campanian, late Campanian, and early Maastrichtian. Nannofossil indicators of fertile taxa, together with the previously published geochemical data, reveal high productivity in the early Campanian (till UC15d at 76.8 Ma) under cooler conditions and upwelling, followed by low productivity in the late Campanian and increased warm and humid conditions and terrestrial inputs. The Campanian-Maastrichtian boundary event 'CMBE' is characterised by a sharp decline in productivity, which is synchronous with the global records revealing global cooling during the Campanian-Maastrichtian boundary and early Maastrichtian. This study reveals that productivity is governed by the climate and sea level changes in the Mannar Basin.

Trace Fossils as key stratigraphic markers sans body fossils: Insights from the Cambrian of Kinnaur, Tethyan Himalaya

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Abstract

The Cambrian biostratigraphy in Spiti, Zanskar, and Kashmir (Tethyan Himalaya) is based on trilobite zonation from well-preserved fossiliferous strata. The Cambrian sediments of the Kinnaur region belong to shallow marine to fluvial environments and in general, lack body fossils. In these areas, trace fossils (ichnofossils) are critical for delineating stratigraphic boundaries, especially when interpreted within multi-proxy frameworks. Ichnological studies of the Cambrian Kunzam La Formation in the Tidong and Hojis valleys (Kinnaur) reveal a low-diversity yet biostratigraphically significant trace fossil assemblage comprising *Psammichnites gigas gigas*, *Psammichnites gigas circularis*, *Bergaueria spp*., *Monomorphichnus*, and *Dimorphichnus* in nearshore settings. The *Psammichnites gigas gigas*, and *Bergaueria* and *Monomorphicnus ichnozones*, indicative of Cambrian Series 2–Stage 4, are well represented in the uppermost parts of the Kunzam La Formation, occurring above and below the Redlichia biozone, respectively. This association, thus, is used for correlating with the Redlichia biozone in Kinnaur, despite the absence of its diagnostic trilobites. This interpretation follows the evolving ichno-stratigraphic framework comprising *Treptichnus pedum*, *Monomorphichnus*, *Psammichnites gigas circularis*, and *Psammichnites gigas gigas* for correlating the Cambrian sections (Series 2) for the Himalaya, where trilobite-bearing horizons (e.g., *Redlichia noetlingi, Haydenaspis*) are absent. Additionally, associated microbially induced sedimentary structures (MISS) suggest a photoautotrophic, shallow-marine ecosystem. The integration of ichnological and sedimentological data underscore the utility of trace fossils in refining Cambrian stratigraphy, particularly where taphonomic or depositional factors hinder preservation of shelly faunas.

Demarcation of Lower Cambrian (Cambrian Series 2) biostratigraphically significant ichnozones in Himalaya

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Abstract

The Lower Cambrian successions of the Tethyan and Lesser Himalaya are subdivided into five ichnozones, each defined by distinctive trace fossil assemblages recorded from precisely measured stratigraphic sections. The Treptichnus pedum ichnozone represents a low-diversity association dominated by *T. pedum*, accompanied by long-ranging forms such as *Planolites* and *Palaeophycus*. Above this lies the Bergaueria ichnozone, positioned well below the first trilobite- or arthropod-origin traces and recognised widely across both regions. The Monomorphichnus–Cruziana ichnozone is marked by a sudden increase in ichnodiversity, with characteristic arthropod/trilobite traces (*Cruziana*, *Monomorphichnus*, *Rusophycus*, *Dimorphichnus*) alongside persistent facies-crossing forms (*Diplocraterion*, *Lockeia*, *Planolites*, *Palaeophycus*); it occurs just below the *Drepanopyge gopeni* level in the Lesser Himalaya and the *Paokannia magna* level in the Tethyan Himalaya. Higher in the sequence, the *Psammichnites gigas circularis* ichnozone is dominated by its eponymous form with subordinate *Planolites* and *Palaeophycus* and is overlain by the *Psammichnites gigas gigas* ichnozone, which contains abundant and varied traces. This upper ichnozone lies below the *Haydenaspis parvartya* trilobite level in the Tethyan Himalaya and the *Redlichia noetlingi* zone in the Lesser Himalaya. While these ichnozones provide useful biostratigraphic resolution, the presence of long-ranging forms across multiple zones limits precision in some intervals. Lower Cambrian ichnozones in the Tethyan and Lesser Himalaya provide reliable stratigraphic markers where body fossils are scarce, aiding correlation across the Himalayan arc. These zones bridge gaps between trilobite biozones. Changes in ichnodiversity reflect ecological expansion after the Cambrian Explosion, offering both chronostratigraphic precision and paleoenvironmental insights.

Differences in the lithological and palynological associations of the east and west Gondwana and their paleogeographic, paleoclimatic and taphonomic implications

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Abstract

Correlation of the Indian Gondwana late Paleozoic palynoassemblages with their coeval counterparts across Gondwana revealed that the late Carboniferous and early Permian palynoassemblages from the Talchir and Barakar formations of India showed gross similarities with minor differences which is due to phytogeographic provincialism. These similarities are attributed to the fact that during this interval, Gondwana occupied high southern palaeolatitudes invariably resulting in late Carboniferous to early Permian glacial and periglacial deposits. Deglaciation occurred in early Sakmarian time, evidenced by a typical, commonly transgressive facies. After deglaciation the basic depositional theme was modified, depending on postglacial adjustments of climate and on the type of regional tectonic regimes. Thus, the pre deglaciated sequences could be correlated across Gondwana. However, during the late Permian, the post deglaciated sequences in east Gondwana comprising India, Antarctica and Australia located south of 55-60°S were covered by the southern humid belt, and was characterized by coal-bearing basins with alluvial, lacustrine, floodplain and boggy sediments; India had close proximity to the Paleotethys Ocean resulting in coastal plain to fluvio deltaic environment which had favored the formation of extensive coal and associated sediments, whereas, during the Guadalupian-Lopingian southern South America occupied paleolatitudes approximately 30-45°S falling in the semiarid-arid belt and showed progressive continentalization formed by long volcanic barrier obstructing humid winds thus resulting in eolian deposits.

The Amravati Formation, overlying the Cambay Shale, in the Cambay Basin, western India: Lithological and paleontological accounts

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Abstract

The early Eocene Cambay Shale of the Cambay Basin, western India, has been extensively studied from sedimentological, geochemical, and palaeontological perspectives. The Cambay Shale – an alternation of lignite, variegated shales, and limestones – was deposited in a restricted marginal marine environment, and is dominated by molluscs (gastropods, bivalves, and scaphopods), and contains several age-diagnostic foraminifera. In contrast, the overlying middle Eocene rocks of this basin remained relatively unexplored. In the present study, we provide a brief account of the lithology and fossil content of this unit, belonging to the Amravati Formation, overlying the Cambay Shale, exposed in the Tadkeswar lignite mine. The presently studied overlying unit is especially significant for having a few prominent foraminiferal limestone units within an otherwise monotonous sequence of essentially yellow clay with marls and sandstones. These fossil-bearing units are dominated by Large benthic foraminifers (LBF), with relatively less abundant molluscan fauna. Notable age-diagnostic benthic foraminifera include *Nummulites beaumonti*, *Nummulites discorbinus*, *Discocyclina dispansa dispansa*, and *Discocyclina nandori*. This foraminiferal assemblage broadly suggests a Bartonian age, although no absolute dates are available from these rocks. Along with LBFs, abundant oysters are found in these rocks, with associated Carditidae, Nuculidae and Mytilidae. Well-preserved remains of gastropods belonging to Conidae, Cypraeidae, and Olividae are also present. Worm tubes and scaphopods are abundant. A detailed study of the fossils and the fossil- bearing beds of the Amravati Formation is forthcoming. The Amravati Formation was deposited in a significantly different environment from the Cambay Shale, as indicated by the lithology and its fossil content. Based on the lithologies and faunal content, the Amravati Formation appears to have been deposited in a warm, shallow shelf environment, with more open-marine conditions than those of the underlying rocks, as suggested by previous workers.

Recovery of vertebrate fauna from the Palaeogene Formation of Kutch, Gujarat

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Abstract

This study details the recovery of diverse shark taxa from the Harudi Formation and Khadi Nadi Formations in Kutch, Gujarat. From the Harudi Formation, we identified Lutetian (Middle Eocene) species including *Carcharhinus balochensis*, *Tethylamna dunni*, and *Galeocerdo eaglesomei*. Their presence indicates a Lutetian age for the Harudi Formation. The fauna predominantly comprises free-swimming taxa, suggesting deposition in a coastal shallow marine inner shelf environment. This interpretation was also supported by the previous foraminiferal evidence that the Harudi Formation was deposited in shallow marine inner shelf environment. The Khadi Nadi Formation yielded species like *Galeocerdo cuvier*, *Galeocerdo mayumbensis*, *Hemipristis serra*, and *Carcharhinus priscus*. The occurrence of early Miocene species such as *G. mayumbensis* and *Hemipristis serra* indicates an early Miocene age for the Matanomadh site within this formation. The Khadi Nadi fauna is largely composed of pelagic sharks, adapted to warm temperate to tropical conditions. Biogeographically, the Middle Eocene selachian fauna from the Harudi Formation shows strong affinities with contemporary African Eocene faunas, suggesting faunal exchanges across the southern margin of the Tethys Sea into the Indo-Madagascan province. Similarly, the wide distribution of Lower Miocene chondrichthyan faunas (e.g., *Hemipristis serra*, *Galeocerdo mayumbensis, Galeocerdo cuvier, Sphyrna, Carcharhinus priscus*) across the Atlantic, Tethys Sea, and Madagascar indicates continued free faunal exchanges between the Western Tethys and the Indo-Pacific region during the early Miocene.

Charophyte assemblage from the Deccan intertrappean beds of the Malwa Plateau lower Narmada Valley, Central India: Age and palaeoecology

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Abstract

Five charophytes taxa Platychara perlata, Nemegtichara grambastii, Microchara sp.1 and sp.2, and Chara cf. changzhouensis are reported from the intertrappean beds of Gujri, Gandhwani, and Bada Bheralya located in the vicinity of Manwar town, Madhya Pradesh, falling within the Malwa Plateau sub-province of Deccan Volcanic Province, Central India. The recovery of Chara cf. changzhouensis from the study area is the first such report of the taxon from the Deccan Volcanic Province of India. On the other hand, the other four taxa were previously known from the various infra and intertrappean beds of peninsular India. Gyrogonites of Chara changzhouensis were earlier described from the Cretaceous-Paleocene boundary of the Songliao Basin, China (Li et al., 2019). In addition to these charophyte remains, previously known from other Upper Cretaceous intertrappean sedimentary beds, typical Maastrichtian pollen Aquilapollenites bengalensis and non-avian dinosaur remains are also recovered from the presently investigated intertrappean localities. In view of these multiple sources of evidence, a Maastrichtian age is assigned to the investigated intertrappean sites. The occurrence of non-marine ostracods, freshwater fishes, and a terrestrial plant Sahnipushpam in the studied intertrappean sections further indicates the presence of a freshwater body enriched in calcium under warm and humid climatic conditions during the deposition of the intertrappean sedimentary layers.

Ediacaran fossils from the sonia sandstone, jodhpur Group, india: new discoveries and interpretations

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Abstract

The Sonia Sandstone of the Jodhpur Group, Marwar Supergroup in western Rajasthan has unveiled a remarkable array of fossil assemblages, significantly advancing our comprehension of the Ediacaran biotic diversity and paleoecological dynamics. Recent discoveries within the Sonia Sandstone include a diverse suite of Ediacaran fossils assemblage such as *Tirasiana qingzhenensis*, *Mawsonites sp*., *Pteridinium sp*., *Finkonella ukrainica*, *Finkonella oblonga*, *Arumberia banski,* coiled form, bizarre forms "A and B" and jellyfish-like impressions. These fossils preserved predominantly as positive epirelief on the bedding plane, exhibit an extraordinary range of morphological intricacies, suggesting a multifaceted and dynamic Ediacaran ecosystem. This unprecedented paleontological record sheds light on the ecological complexity and evolutionary trajectories during the Ediacaran Period, contributing to the broader understanding of early metazoan diversification and sedimentary biogenic processes.

Early Eocene ostracodes from the Subathu group of Jammu Region, NW Himalaya: biostratigraphy and palaeoenvironmental implications

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Abstract

Ostracods are characterized by their diminutive size, typically around 1 mm, though some marine species like *Gigantocypris* can reach up to 25 mm. Their bodies are encased in a bivalve-like carapace made of chitin and often calcium carbonate, resembling the shell of a clam. This protective shell encases their head and thorax, leaving their abdomen rudimentary and their body segmentation obscured. It helps in determining the relative dating and correlation of biostratigraphy as well as palaeoenvironmental and palaeoclimatic proxies as it is found in all types of aquatic environment. Its age ranges from early Ordovician to recent. Subathu Formation in the Northwest Himalaya received much attention for its molluscan and formaniferal fauna as compared to ostracods although they are important microfossil group. Ostracods possess most complete fossil record among the arthropods. Their rapid evolutionary rates and broad geographic distribution make ostracods valuable for biostratigraphy. By investigating the ostracods assemblages in the sediments shows the researchers to rebuilt the ancient ecosystems and the changes in the environmental conditions. It helps in the biozonation of the marine strata and provides the valuable information about the palaeoenvironmental conditions. A preliminary work records 9 species from the middle Subathu Formation of Jammu region in the present study viz. *Aglaiocypris indica, Alocopocythere longilinea, Bairdia kutchnesis, Bairdopillata sp, Bairdopillata kalakotenis, Bythocypris biswasi, Hornibrookella jaisalmerensis, Annomocythere indica and Bythocypris westi* of Early Eocene age. These species and other further ongoing findings will help to document Ostracods occurrences which have been very limitedly documented till date (mainly Juyal & Mathur, 1992). No modern re-evaluation or detailed study of ostracod assemblages is available from Jammu region of Subathu Group. Modern taxonomic reanalysis could enhance biostratigraphic and paleoecological resolution and indicate the collisional tectonics of the Himalaya.

Fossil assemblages from the Siwaliks of NW Himalaya exposed in the Saharanpur areas of Uttar Pradesh: Biostratigraphy and palaeoecological implications

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Abstract

The Neogene Siwalik deposits have long been considered for their rich fossil record, yet many localities within the Siwaliks remain unexplored. The Mohand Rao (MR) section of the Siwalik, located near Dehradun, primarily consists of sandstone, mudstone and conglomerate, representing braided streams with frequent avulsion and sheet flood events in a sandy alluvial fan regime. So far, fossils recovered from this section have been limited. However, recent expeditions have uncovered a variety of fossils, including microvertebrates such as rodents, insectivores, and fishes. Besides, freshwater ostracods, charophytes, and gastropods are also being recovered. Notably, the rodent materials are identified as a new species of *Golunda mohandensis* n. s. along with isolated teeth of *Mus sp*. Additionally, the insectivore has been identified as Soricidae indeterminate. The recovered fish otoliths include three taxa *Channa* (Channidae), *Trichogaster fasciata* (Osphronemidae), and Gobiidae indet. Among these, *T. fasciata* represents the second known fossil record of Osphronemidae globally and the first based on otoliths. Biostratigraphically, the fossil locality falls in the Tatrot Formation of the Upper Siwaliks, suggesting an Early Pliocene age rather than the Late Miocene age of the Middle Siwaliks. The fossil fish assemblages Osphronemidae, a family to which the current living gouramies belong and *Channa* species in the area indicate that there was a calm and stable freshwater body surrounded by dense vegetation during the Pliocene. The existence of a stagnant water body is further supported by the occurrence of other fossil assemblages, including charophytes dominated by *Chara globularis,* ostracods such as S*tenocypris sp*., and gastropods like *Lymnaea, Gyraulus*, and *Bithynia*. The recovered micromammals, especially rodent species *Golunda* and *Mus*, likely thrived in an area adjacent to water bodies, mainly floodplain area.

New record of Ediacaran complex Acanthomorphic Acritarchs from the Krol-A formation of Kamlidhar syncline of Krol-Tal belt, Lesser Himalaya, India

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Abstract

The Ediacaran Period (ca. 635–538.8 Ma) represents a critical interval in Earth's history, marking the rise of macroscopic multicellular life, significant shifts in ocean chemistry, and a prelude to the Cambrian Explosion. The Krol–Tal belt of the Lesser Himalayas, extending from Solan (Himachal Pradesh) to Nainital (Uttarakhand) in North India, hosts a well- recognised sedimentary succession of Ediacaran-Cambrian age. This region represents an extensive archive for understanding the Precambrian–Cambrian transition. The Neoproterozoic successions within this belt, exposed in a series of eight synclines, host organic-walled microfossils, including acanthomorphic acritarchs - key biostratigraphic markers for Ediacaran-age sediments. These ECAPs are widely preserved in early diagenetic chert and black carbonaceous shales. Well-established Ediacaran Complex Acanthomorphic Palynomorph (ECAP) assemblages from the sedimentary succession of Australia, China, and Russia are well-documented; however, the Indian counterparts remain underexplored. This study presents the first documented occurrence of acanthomorphic acritarchs from the Kamlidhar Syncline in the Krol Group situated in parts of Himachal Pradesh. The identified species of ECAPs, namely *Appendisphaera clava, Appendisphaera longispina*, *Appendisphaera tenuis*, *Cavaspina acuminata*, *Cavaspina basiconia*, *Cymatiosphaeroides forabilatous*, *Tanarium conoideum*, *Leiosphaeridia spp* including cyanobacterial microfossil *Barogophycus symmetricus*, S*iphonophycus robustum*, *Salome huebeinsis*, *Botominella lineatua*, *Polythichedum lineatus*, representing major fossil groups similar to those from the Pachmunda, Rajgarh and Khanog synclines, India and Ediacaran Doushantuo Formation, China. These acritarchs have potential for intercontinental correlation of Ediacaran strata and contribute significantly to our understanding of the spatial and temporal distribution and diversification of early eukaryotic life. Additionally, the present finding of acanthomorphic acritarchs from the Krol A Formation contributes to filling this gap and establishes a foundation for refining the Ediacaran biostratigraphy of the Indian subcontinen

Assessment of organic matter preservation and thermal alteration in P/T Boundary carbonaceous shales of east Bokaro Coalfield

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Abstract

The Permian–Triassic (P/T) boundary in the East Bokaro Coalfield is well exposed at Lugu Hill, Lalpania, Bokaro, Jharkhand. Rock samples, including shale, sandstone, and carbonaceous shale, were collected from just below the P/T boundary within the Raniganj Formation. The carbonaceous shale was analyzed for spore and pollen recovery. The palynomorphs are well preserved and exhibit characteristics of overmature organic matter, displaying a dark brown color corresponding to a Thermal Alteration Index (TAI) of 3 to 3.5. The recovered microfloras show affinities with Late Permian assemblages. Technological characterization of the samples indicates high ash content, ranging from 66.89 to 88.92 wt.%. The volatile matter content is highest in sample LR-4, with a yield of 20 wt.%, while the moisture content across samples ranges from 2.25 to 3.59 wt.%. Palynological analyses confirmed low spore and pollen yields in most samples. The data suggest that the carbonaceous shale of the Raniganj Formation is over mature, supported by a Spore Color Index (SCI) of 8 (equivalent to TAI 3.5). Except for sample LR-4, which shows relatively higher organic richness with a fixed carbon content of approximately 10 wt.%, the remaining samples exhibit low organic yield and are considered organically lean zones. The combination of low organic content and high thermal maturity across the majority of samples indicates poor hydrocarbon potential in this region—except for LR-4, which may still hold promise and requires further detailed investigation.

Morphotaxonomy of fossilised eggshells from the inter-trappean beds of India

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Abstract

Fossilised eggshells from the volcanic landscapes of Anjar, Gujarat, unfold a unique and personal account of dinosaur nesting behaviour from the very beginning of extinction. [1,2] These delicate artefacts, wedged in between powerful lava flows of the Deccan Traps, transport us back to the final days of the Cretaceous period. By studying them, we gain insight into how life survived extreme volcanic turbulence and environmental shifts, providing valuable clues about survival, resiliency, and overall environment that dinosaurs once inhabited in India. [2] In this work, we examine the fossilised eggshell pieces from inter-trappean beds to determine their composition and state of preservation. We map the internal crystal orientation using Electron Backscatter Diffraction (EBSD) [3] and then analyse pores and fine surface features using Scanning Electron Microscopy (SEM). [4] Combining these cutting-edge techniques offers us a fresh look at prehistoric life beyond skeletal remains by shedding light on the microstructure of eggshells and thus aiding in the identification of the potential dinosaur species that laid them.

When odisha was antarctica: Fossils, flora and the Gondwana secrets of the Talchir basin

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Abstract

The Talchir Basin in Odisha, India, is a significant geological formation that preserves a rich record of fossils and flora from the Gondwana period (about 300-250 million years ago). The basin's sedimentary rocks contain an array of fossilized plant remains, including *Glossopteris*, a characteristic Gondwanan flora. These fossils provide valuable insights into the paleoclimate, paleoecology, and evolution of life on Earth during the Permian period. The Talchir Basin's fossil record also sheds light on the breakup of the supercontinent Gondwana and the geological history of the Indian subcontinent. This abstract highlight the importance of the Talchir Basin as a key site for understanding the Gondwana secrets and the evolution of life on Earth.

Marine incursion and pathways in Baripada Beds of Odisha, India: A review

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Abstract

Odisha is recognized not only for its magnificent architectural marvels like the Konark Sun Temple but also for being home to significant paleo-shields that offer invaluable information about shaping our interpretation of prehistoric life. Baripada, located at latitude N 22°54'9 and longitude E 86° 44'39 is situated in the northern region of Odisha, approximately 60 km (about 37.28 mi) from the coastline. Prior research indicates a possible marine incursion in the region, evidenced by the presence of marine fossils from the Cenozoic. Many workers have depicted a correlation between fossil assemblages of Baripada deposits and those from other parts of India. The age of the fossiliferous marine deposits of the Baripada Beds is still a topic of discussion due to the absence of significant index fossils. These fossiliferous beds contain remains of diverse vertebrate groups, signifying a diverse ecosystem during that period. Based on biostratigraphy, it is mostly believed to be Eocene to Pleistocene in age. The Miocene is characterized by two significant geological events: the uplift of the Tibetan Plateau and the desiccation of the Mediterranean Sea, which contributed to the establishment of monsoon patterns in Asia. Additionally, it is suggested that during the Late Miocene, Baripada may have experienced marine transgression. This study thoroughly examines the various viewpoints expressed by previous workers and offers a perspective to analyse the academic pursuits on the fossils of Baripada Beds.

Theme 6

Fossils as proxy in palaeoclimate and palaeoceanography

Fossils from Kasauli and Ladakh: Decoding the closure of Tethys, the Tectonic Tango, and the birth of the Himalaya

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Abstract

The closure of the Tethys Sea and the consequent rise of the Himalaya represent one of Earth's most dramatic geological transformations, triggered by the monumental collision between the Indian and Eurasian plates. Fossil assemblages from the Sub-Himalayan Kasauli Formation and the Indus–Tsangpo Suture Zone in Ladakh provide crucial biostratigraphic and paleoenvironmental clues that refine our understanding of the timing, velocity, and mechanisms behind this tectonic convergence. A central question emerges: How fast did India actually move to collide with Asia? If the Indian plate advanced at the often-cited rate of ~10 cm/year, it would have taken over 20 million years to traverse the 2400 km from its Lower Miocene (~20 Ma) position near the equator (4°–11°N) to its current latitude beneath the Himalayas. Such a pace would likely have created a long isthmus-like landform—similar to the modern Central American corridor—rather than the imposing Himalayan orogeny we observe today. Yet, the Himalayas rose. This discrepancy demands a deeper investigation into the dynamics of plate movement. This presentation explores fossil evidence from two pivotal regions. In Kasauli, freshwater charophytes such as *Lychnothamnus kasauliensis sp*. nov.—which anchors the Kasauli Formation to the Lower Miocene—along with tropical plant fossils including *Garcinia, Gluta, Syzygium, Combretum*, and palms, point to a rich equatorial flora. While these taxa have vanished from the Himalayan region, their close relatives survive in Southeast Asia (Malaysia, Indonesia) and the Andaman Islands, implying an equatorial paleolatitude during deposition. In contrast, Ladakh's Indus Molasse yields marine molluscan fossils from Stok and Nyoma that closely resemble those from the Subathu Formation in the Sub-Himalayas, indicating lingering marine connections during the waning stages of the Tethys Sea. By integrating biostratigraphy, paleogeography, and tectonic reconstructions, this work proposes a revised timeline for the India–Asia collision—one involving episodic accelerations or tectonic reorganizations, rather than a uniform drift. Fossils serve here not just as biological remnants, but as geological chronologers—preserving the tempo of tectonics and the story of mountain-building. Finally, this study underscores the urgent need to preserve fossil-rich outcrops. As rapid development threatens these natural archives, many specimens—now housed at the Tethys Fossil Museum—offer irreplaceable insights into the birth of Earth's youngest mountain system.

Assessing floral response to Late Cretaceous-Early Palaeocene Deccan volcanism induced climatic changes

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Abstract

The End Cretaceous Deccan volcanic eruptions, spreading over 500,000 km² in different sub-provinces with an eruptive volume of 1.3 × 10 3 km³ over a span of 4-5 million years, triggered a major environmental crisis through the emission of gases like SO_2, Cl, CO_2, and halogens (Nava et al, 2021). Recent studies (Schoene et al. 2015; Renne et al. 2015) suggest that 50-75% of this eruptive volume occurred in the early Danian, raising the question: which phase of the volcanism, pre-K-Pg or post-K-Pg boundary, had the most severe impact on terrestrial flora? Detailed chronostratigraphically controlled palynofloral analysis of the infra and intertrappean sediments across the Late Cretaceous-early Palaeocene indicates a distinct shift in floral diversity and composition in the Deccan volcanic province. The palynological data from the Late Cretaceous (Maastrichtian Chron 30N) indicated an increase in the diversity and abundance of flora with the onset of Deccan volcanic eruptions. The onset of volcanism changed the climate, which proved favourable for the proliferation of flora and fauna. The Maastrichtian period also witnessed emergence of several angiosperm families and subfamilies, including Arecaceae (tribe Borasseae), Malvaceae (Malvoideae), Phyllanthaceae (Malpighiales), Torricelliaceae, and Zingiberales. Notably, the affinity of recovered palynomorphs, fruits, seeds, and flowers can often be established at the family level, but identification at the genus or species level remains mostly ambiguous. This taxonomic uncertainty may reflect the unique climatic and environmental conditions of the Indian subcontinent during Deccan eruptions, where angiosperms likely adopted varied morphological adaptations to survive under ecological stress. While many taxa evolved and persisted through this period, others either went extinct or experienced a sharp decline, such as *Aquilapollenites bengalensis, Gabonisporis vigourouxii*, *Crybelosporites*, and *Proxapertites sulcatus* across the Cretaceous-Paleogene boundary. The early Danian (Chron 29R) witnesses a sharp decrease in overall floral diversity along with the prolonged dry spells in central India. This decline is potentially attributed to increased volcanic activity and tempo of eruptions resulting in long episodes of mock aridity. Notably, the latter part of the Danian (64 Ma) indicates a transition to more humid conditions, accompanied by a resurgence in plant diversity. This study highlights the complex and phased response of the flora to Deccan volcanism, offering insights into ecosystem resilience and extinction mechanisms across the K–Pg transition.

Was there a permanent El Niño (El Padre) like condition in the Pliocene? Insights from variations in depth-stratified planktic foraminiferal assemblages from Western Pacific Warm Pool and Eastern Indian Ocean deep-sea cores

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Abstract

There have been considerable debates on whether the Pliocene Warmth was characterised by a permanent El Niño-like condition termed El padre. El Niño is a phenomenon depicting coupled ocean (El Niño) and atmosphere (Southern Oscillation) interaction occurring every 3-7 years (low frequency) and 2-3 years quasi-biennial, affecting global climate by the release of a large amount of heat, which is distributed worldwide via meridional atmospheric cells. The occurrence of a permanent El Nino-like condition in the Pliocene has been championed by a number of researchers, like Fedorov et al (2006) and Wara et al (2005). These studies revealed that during 5-3 Ma, the average global temperatures were higher, and there was permanent El Niño-like conditions. Wara et al. (2005) estimated the west-to-east sea surface temperature difference across the equatorial Pacific to be similar to that during a modern El Niño event. However, Watanabe et al. (2011) refuted such claims based on oxygen isotopic studies of the corals from the Philippines in the Western Tropical Pacific. These authors believed that the studies of Fedorov et al. (2006) and Wara et al. (2005) had coarse resolution, not sufficient to resolve ENSO variability, while the coral records had high-resolution variability. The Earth's climate has many rhythms and pulses and behaves differently on longer and shorter scales, depending on the changing boundary conditions. Contrasting climatic shifts on short time scales often characterize the long-term mean state of the Climate. The debate still is centred around whether the tropical Pacific mean state climate was more like an El Niño or otherwise. The Tropical Pacific Mean State climate has been alternatively dominated by El Niño-like and La Niña-like conditions. Many authors termed long-term El Niño-like conditions as "permanent El Niño, El Niño State, or El Padre (EP), spanning several thousand years. The Western Pacific Warm Pool (WPWP) responds to El Padre conditions by changing upper ocean hydrography. We used depth- stratified planktic foraminiferal relative abundance to characterise the changing hydrography of the WPWP over the last 6 million years and its impact on the variability of the strength of the Leeuwin Current in the Eastern Indian Ocean, which the WPWP influences via the Indonesian throughflow. The study has identified several El padre which are bridged by La Niña State. The effect of the El Padre event in the Eastern Indian Ocean has been transmitted through the Indonesian throughflow, affecting the strength of the Leeuwin Current. The most influential El Padre events affecting the Eastern Indian Ocean have been EP-3, EP-4, EP-5, and EP-6. In general, the Eastern Indian Ocean responds to the El Padre Events by a general reduction in the strength of the Leeuwin

Current. The Pliocene El padre event was not continuous and was interrupted by La Niña-like conditions revealed in our study.

Understanding the world of ocean through the lens of a single-cell marine microorganism - Foraminifera

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Abstract

Oceans, which account for about 97% of Earth's available water and cover 71% of the Earth's surface, form an important component of Earth's system. Oceans not only govern the world's climate but also provide food, energy, minerals, employment, livelihoods, and routes for trade and commerce. Despite being the shared heritage of mankind, oceans are severely impacted by human activities in pursuit of unmindful growth and development. The major issues facing the world's oceans in recent times include habitat destruction, coral bleaching, rising sea temperatures, reduction in fish catch, ocean acidification, pollution, etc. Oceans serve as a storehouse for present and past environmental changes. Marine microorganisms which constitute 70% to 90% of the oceanic biomass and significantly contribute to the marine food chain, have proven to be among the most important tools for investigating changes in paleoenvironments and monitoring current environmental shifts. Among marine microorganisms, 'Foraminifera', a unicellular marine microorganism that is highly sensitive to ambient environmental changes and has a good preservation potential, is widely used to examine paleoclimate, palaeo-productivities, sea level changes, palaeo-tsunami, marine archaeology, marine pollution and sediment movement, among other things. Based on the study conducted, the paper highlights the role of "foraminifera" as an inherent marker to study the oceanic water masses of the Indian Sector of the Southern Ocean, and past and present changes in environments along the Indian Coasts.

Reconstructing the Middle Pleistocene to Recent paleoceanographic variability in the Agulhas System driven by Antarctic Circumpolar Current fluctuations

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Abstract

The Agulhas System in the southwestern Indian Ocean is a crucial component of the global circulation system. The Agulhas Current (AC) transports warm, saline Indo-Pacific waters to the Atlantic Ocean through the Agulhas Leakage (AL). The AL feeds the returning arm of the global ocean conveyor belt and its intensity is strictly related to position of the subtropical front (STF) and the northward fluctuations of the Antarctic Circumpolar Current (ACC). Although crucial to oceanic circulation, the evolution and dynamics of the Agulhas system over time still remain poorly constrained. In this study, we conducted detailed quantitative, statistical and isotopic investigations of planktic foraminiferal assemblages recovered from 185 samples spanning Middle Pleistocene to Recent, from IODP Hole U1474A. The position of the hole is ideal as it is situated in an area directly influenced by the AC. The resulting dataset offers a high-resolution record of Agulhas system variability over the past 1.5 million years. The composition of the foraminiferal assemblages provided new insights on the interplay between the AC and the ACC, in turn closely tied to shifts in both the seasonal and permanent thermocline. Additionally, we reconstructed Pleistocene-scale fluctuations in the ACC and assessed their relationship to variations in the AL intensity across glacial-interglacial transitions. Prior to 900 kyr, the AC exerted dominant control throughout both glacial and interglacial periods, with minimal ACC influence. After 900 kyr, however, glacial intervals experienced a notable increase in the frequency and intensity of ACC incursions, which subsequently notably intensified following the Mid-Brunhes Transition (~400 Kyr). We suggest that these temporal shifts in ACC strength are linked to evolving patterns in the amplitude and pacing of glacial-interglacial cycles during the Pleistocene.

Southern Ocean deep-water cooling across the Eocene-Oligocene boundary: Clumped Isotope Insights from ODP Site 744A

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Abstract

One of the most significant shifts in Earth's Cenozoic climate was the transition from a global warmhouse to a coolhouse state. This major climatic reorganization began with the onset of large-scale continental glaciation on Antarctica during the Eocene-Oligocene transition (EOT), approximately 34 million years ago. However, reconstructions of deep ocean temperatures and global ice volumes across this critical interval remain uncertain, largely due to limitations in proxy records that are sensitive to changes in seawater chemistry. To overcome these challenges, we present robust estimates of deep-sea temperatures across the EOT using clumped isotope thermometry on benthic foraminifera. Our study utilizes sediment cores from the Southern Ocean ODP Site 744A (Leg 119; 61.5790°N, 80.5950°S; 2318 mbsl), a key archive of high-latitude ocean history. The clumped isotope-derived temperatures indicate an approximate 5°C decrease in bottom water temperatures across the EOT. Importantly, our results reveal that this cooling occurred in two distinct, transient steps, highlighting the complex nature of climate change during this transition. These findings suggest that traditional reconstructions of deep-ocean temperatures and seawater oxygen isotope ratios ($^{18}O/^{16}O$) may require re-evaluation. By providing more accurate temperature estimates, our data contribute to a better understanding of the timing, magnitude, and dynamics of the EOT and offer improved constraints on the co-evolution of Earth's cryosphere and ocean systems during this pivotal period in Earth's climatic history.

Regional changes in carbon burial from the north-western Bay of Bengal during the last glacial-interglacial transition

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Abstract

An unprecedented increase in the atmospheric carbon dioxide concentration since the industrialization has been detrimental to our environment. Marine productivity and its associated processes sequester a large part of the carbon and aid in its burial in the sediments. To understand this long-term regional variation in carbon burial from the western Bay of Bengal, we studied sedimentary characteristics (coarse fraction (CF), $CaCO_3$, C_{org}/N and % C_{org}) in core SK308 GC13 collected from a water depth of 260 m off Mahanadi. A large variation in CF, $CaCO_3$, $\%C_{org}$, and C_{org}/N is observed during the last ~25 kyr BP. CF mainly comprised of biogenic carbonates, and co-varied with $CaCO_3$. The higher $\%C_{org}$ and $CaCO_3$ during the last glacial interval was largely due to the increased productivity and better preservation. However, a large drop in $\%C_{org}$ and C_{org}/N is observed between ~21 - ~24 kyr BP, suggesting very low productivity. During the early Holocene, a decrease in $\%C_{org}$ at ~10 kyr BP is marked by a sharp decrease in $CaCO_3$ too, likely because of the heavy terrigenous dilution, since the initiation of Holocene when the south west monsoon strengthened. During this interval, the preservation potential of $\%C_{org}$ dropped drastically. Overall, carbon burial increased during glacial times and interglacial was marked by low carbon burial. However, the opposite has been reported from the Arabian Sea where interglacials are marked by high productivity and vice versa. This defines the strong influence of regional settings which dominate and modulate productivity in the Bay of Bengal.

Monsoon-induced productivity variations since the Last Glacial Maximum: Evidence from planktic foraminiferal abundance in the eastern Arabian Sea

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Abstract

The abundance of planktic foraminifera from Core SK291/GC17 (water depth 182 m) suggests surface oceanographic shifts between ~25,000 and 3500 calibrated years before Present (cal yr BP) in the eastern Arabian Sea. During the Last Glacial Maximum, between ~21,000 and 19,000 cal yr BP, the oligotrophic and mixed-layer planktic foraminifera such as *Globigerinoides ruber* and *Trilobatus* spp. show high relative abundance. In contrast, the eutrophic species like *Globigerina bulloides* and *Globigerinita glutinata* show a decreasing trend in relative abundance. *Pulleniatina obliquiloculata*, a deep thermocline-dwelling species, shows distinct low abundance in the same interval. These trends in planktic foraminiferal abundance suggest a decline in upwelling-induced productivity linked to a weak phase of the Indian summer monsoon (ISM) during the LGM. In the early Holocene, the lower abundances of oligotrophic planktic foraminifera, and an increasing trend in eutrophic species and thermocline-dwelling planktic foraminifera indicate the influence of strong ISM in the EAS. Between ~6,000 and 3,500 cal yr BP, the relative abundance of *G. bulloides* and *P. obliquiloculata* conspicuously decreased, suggesting a possible weakening of the ISM winds and deepening of the thermocline.

The biostratigraphic correlation and paleoenvironmental reconstruction of the Mid-Eocene Siju Formation, Western Garo Hills, South Shillong Plateau, India: Evidence from dinoflagellate cysts and calcareous nannofossils

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Abstract

One of the defining global features of the Eocene epoch is the widespread development of carbonate platforms across various regions of the Tethys Ocean. In the Shillong Plateau of northeastern India, Paleogene sedimentary sequences are exposed along the steep Garo, Khasi, and Jaintia hills, extending from west to east. In the Khasi and Jaintia hills, these successions comprise alternating carbonates and siliciclastics, yielding datable micropaleontological fossils. In contrast, the Paleogene succession in the southwestern Garo Hills is dominated by siliciclastics with fewer carbonate layers, which are often marly and thus yield limited carbonate microfossils, complicating biostratigraphic age determination. To refine age correlations among the time-transgressive and lithologically variable sequences of the Khasi, Jaintia, and Garo hills, a detailed palynological study was conducted on 65 samples from a 25-meter-thick section of the Siju Formation in the western Garo Hills. The analysis revealed a diverse and well-preserved assemblage of organic-walled dinoflagellate cysts and calcareous nannofossils. Key taxa identified include dinoflagellate cysts such as *Heteraulacacysta porosa* and *H. leptalea*, and calcareous nannofossils including *Discoaster barbadiensis*, *D. saipanensis*, *Reticulofenestra bisecta*, *R. erbae*, and *R. reticulata.* These assemblages collectively indicate a middle Eocene (Bartonian) age for the studied interval. Correlation of these findings with records from other parts of India and Australia supports the recognition of a significant late Bartonian marine transgression across the Indo-Pacific region.

Impact of southern polar front migration in the eastern equatorial pacific during Quaternary: insights from planktic foraminiferal evidences

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Abstract

The paleoceanographic configuration of the Eastern Equatorial Pacific (EEP) has been the subject of extensive investigation due to its pronounced upwelling conditions, which result from the Ekman transport of coastal waters. The strength of the Humboldt Current is a primary factor influencing the large-scale La Niña phenomenon, which is intermittently disrupted by short- to long-term quasi-periodic El Niño events. These events can be explained through variations in passive dweller planktonic foraminifera assemblages. This study examines planktonic foraminiferal census count data from ODP Hole 846B, strategically located at the terminus of the Humboldt Current at 3°S latitude, coinciding with the eastern boundary of the South Equatorial Current (SEC). Planktonic foraminiferal species were categorized into mixed layer oligotrophic species, thermocline dwelling species, and upwelling indicator species. Seven distinct upwelling events (2.42 to 0.2 Ma) were identified, characterized by an increased relative abundance of *Globigerina bulloides*, which inversely correlates with a decreased relative abundance of *Globigerinoides ruber*, a mixed layer species. Notably, the abrupt invasion of the temperate species *Globorotalia* (*Globoconella*) *inflata* at 3°S latitude was observed during four intervals between 2.07 and ~0.2 Ma, indicating a habitat migration towards lower latitudes. The unique co-occurrence of cold-water species alongside *Neogloboquadrina dutertrei*, a thermocline-dwelling species, at the study site strongly suggests a northward migration of the Southern Polar Front along with strong trade winds. This migration led to an expansion of the Antarctic Circumpolar Current, subsequently intensifying the Humboldt Current and expansion of the cold-water tongue.

Foraminiferal diversity and paleoenvironmental reconstruction of marsh sediments from Piram Island, Gujarat, India

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Abstract

This study systematically analyzes benthic foraminiferal assemblages from lower and upper marsh sediments of Piram Island, situated in the Gulf of Khambhat, Gujarat, India. A total of 217 foraminiferal specimens representing 18 species (8 Miliolida, 10 Rotaliida) were recovered from the lower marsh, while 362 specimens representing 25 species (12 Miliolida, 12 Rotaliida, and 1 Lagenida) were identified from the upper marsh. *Pararotalia nipponica* and *Nonion commune* dominated the lower marsh assemblage, whereas *Pararotalia nipponica*, *Triloculina sp.* A and *Nonion asterizans* were prevalent in the upper marsh. Rotaliida, the dominant order overall, suggests stable salinity and oxygen conditions typical of open to marginal marine environments. The co-occurrence of Miliolida, tolerant of elevated salinities and reduced circulation, supports interpretation of a marginal marine to inner shelf depositional setting. The relative abundance of *Nonion spp*. (7.91% in lower marsh; 3.34% in upper marsh) and angular serial forms (RAF: 1.38% and 0.84%, respectively) points to localized low-oxygen conditions, especially in the lower marsh. A minor presence of Lagenida indicates occasional influence from deeper or lower-energy marine conditions. Overall, the foraminiferal assemblages reflect a dynamic yet ecologically favourable environment with moderately variable salinity and energy conditions, consistent with a marginal marine to inner shelf setting.

Unraveling past ocean productivity through foraminiferal proxies: A tale of two species in the tropical northern Indian Ocean

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Abstract

Planktic foraminifera are essential tools in paleoceanographic reconstructions due to their sensitivity to changes in surface ocean conditions. *Globigerinoides ruber* is a symbiont-bearing, spinose species inhabiting the upper ~50 m of the mixed layer, thriving in warm (21–28°C), saline (34.5–36.0 psu), and oligotrophic waters of tropical to subtropical oceans. In contrast, *Globigerina bulloides* is a non-symbiotic species typically associated with sub-polar waters but also abundant in the Arabian Sea during periods of summer monsoon-induced upwelling and winter monsoon-driven convective mixing, both of which enhance nutrient availability and primary productivity. Traditionally, the abundance of *G. bulloides* has been used as a qualitative indicator of surface ocean productivity. However, in this study, we assess the ratio of *G. bulloides* to *G. ruber* as a more reliable proxy, due to their contrasting ecological preferences and similar dissolution susceptibility and burial efficiency. Records from different hydrographic regimes of the tropical northern Indian Ocean were compared for foraminiferal assemblages and total organic carbon (C^{org}) content. Our results show that the *G. bulloides*/*G. ruber* ratio correlates strongly with spatial variations in C_{org}, capturing modern productivity gradients. Furthermore, down-core records across the late Quaternary period demonstrate that this ratio reflects significant changes in upper water-column structure and monsoonal forcing. This study highlights the potential of the *G. bulloides*/*G. ruber* ratio, when used in conjunction with geochemical proxies, as a refined tool for reconstructing past surface ocean productivity in monsoon-influenced regions of the northern Indian Ocean. It offers improved sensitivity to hydrographic variability and enhances our understanding of past ocean-climate interactions in low-latitude marine environments.

Hydro-climatic variability and corresponding vegetation dynamics during CE 1219–1942 from the Western Ghats, India

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Abstract

Pollen proxy record of hydro-climatic variability in the Somwarpet area of Karnataka State (Western Ghats), India, receiving monsoon rainfall from both the southwest summer monsoon (SWM; June to September: JJAS) and the northeast winter monsoon (NEM; October to December: OND) is presented. This record covers the last 723 years (CE 1219–1942) and is based on high-resolution lacustrine sediment pollen proxy data. The pollen evidence indicates that between 731 and 576 cal yr BP [CE (AD) 1219–1374], the landscape was dominated by mixed moist/semi-evergreen–dry tropical deciduous forests under a warm and moist climate, possibly indicating increased monsoon rainfall. This phase is globally correlated with the Medieval Climate Anomaly (MCA; CE 750–1200). Between 576 and 279 cal yr BP (CE 1374–1671), dense mixed moist/semi-evergreen–dry tropical deciduous forests came into existence and transformed the existing forests of the previous phase under a warm and moist climate with further increase in monsoon rainfall. Finally, between 279 and 8 cal yr BP (CE 1671–1942), mixed moist/semi-evergreen–dry tropical deciduous forests again came into being, replacing the existing dense mixed forests of the previous phase under a warm and comparatively less moist climate with increased monsoon (may be NEM) rainfall, corresponds to the global Little Ice Age (LIA; CE 1550–1850). The hydro-climatic variability during CE 1219–1942 offers valuable insights into the impact of monsoonal variability and human activities on ecosystems in the Western Ghats (India), which are subject to dual monsoon systems (SWM and NEM).

Holocene calcareous dinoflagellate cyst record from the northern Indian Ocean

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Abstract

Calcareous dinoflagellate cysts are one of the rarely studied microfossil groups across the world. Surficial distribution of Calcareous dinoflagellate cyst (dinocyst) is generated from the eastern Arabian Sea to evaluate the sea surface parameters that govern their distribution. In addition, a sedimentray core from the eastern Arabian Sea is studied to decipher paleoenvironmental changes using calcareous dinocysts. Coccoides (vegetative stage of calcareous dinoflagellates) of *Thoracosphaera heimii*, *Leonella granifera* shows a dominance of 82–92% of the total assemblage suggesting a eutrophic environment throughout the studied period. Calcareous dinoflagellate cysts shows distinct changes in the environmental conditions driven by changes in the monsoon variability. Early Holocene (prior to 10 ka BP) shows warm and low productivity environment compared with the late Holocene. A strengthening trend in the monsoon during the Holocene since 10 ka BP is reflected by the gradual increase in *L. granifera*, which is a runoff/terrestrial nutrient indicator. The high relative abundance of *L. granifera,* eutrophic taxa, and TOC since 6 ka BP reveals high primary productivity during middle to late Holocene compared with the early Holocene in the eastern Arabian Sea. This record reveals the potential of calcareous dinoflagellate cysts to reconstruct monsoon variation, particularly runoff changes, in the Arabian Sea.

Influence of Mid-Brunhes transition on the deep-sea benthic foraminifera under different settings

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Abstract

The Mid-Brunhes Event, also known as the Mid-Brunhes Transition (MBT), that occurred around 430 ka, is characterised by a warmer interglacial climate compared to other interglacials prior to MBT. Various studies suggest that insolation variations, along with feedback mechanisms among sea ice dynamics, evaporative fluxes, salinity distributions, and Antarctic Bottom Water (AABW) formation, caused the warmer interglacials during and after the MBT that influenced deep water characteristics. Benthic foraminifera abundance of particular species or species associations and diversity are influenced by varying deep water characteristics. Hence, this study analysed the benthic foraminifera from different oceanic settings such as a closed basin (the Japan Sea), an open ocean (the central South Pacific; CSP), and a near-coast setting (the southeastern Pacific). Our study suggests variable responses of benthic foraminifera modulated by the above-mentioned forcing factors and local oceanographic settings. The influence of MBT was minimal in the closed basin, like the Japan Sea, while maximum in the open ocean setting, like the CSP. The prevalence of vigorous cold bottom-water currents after the MBT is evidenced by the continuous occurrence of benthic foraminifera associations, suggesting expansion of sea ice and persistent occurrence of strong cold bottom-waters and decreased abundance of associations, suggesting high productivity in the Japan Sea, whereas at CSP, there is a decline in both sea-ice and productivity. The near-coast setting benthic foraminifera assemblages are influenced by a switch in the source of sediments and other factors, and have an increased abundance of high productivity indicator benthic foraminifera associations in contrast to the other two settings. Our study suggests a major reduction in the volume of AABW formation and enhanced coastal weathering during and after the MBT, which might be a major forcing factor that increased atmospheric CO 2 concentration in the interglacials after the MBT.

Shell Beds from Nodular Limestone Formation of Bagh Group, central India

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Abstract

Shell beds are one of the characteristic features often observed in sedimentary succession of a marine system. These are composed of shell fragments of different shapes and sizes. The orientation of these shells is quite helpful in observing the current velocity and direction. In Nodular Limestone Formation, these shell beds occur at 8 to 10 levels as a part of sections. The nature of the shell beds particularly in lower, middle and upper part of the succession of Nodular Limestone Formation are quite different especially in shell concentration these coincide with macrofauna typical of Lower, Middle and Upper Turonian collected with them. The shell concentration are of both types' mono and pauci, latter dominated. Shells are mostly of bivalves, followed by gastropods, brachiopods and unrecognizable fauna. These shells are a part of the sedimentary history of the Nodular Limestone; it is quite helpful as one of the tools of the evolutionary history of the basin. Besides, in the present case it can be used as supplementary evidence in stratigraphic division of Nodular Limestone Formation.

Quantification of eastern Arabian Sea climate change during the Mid-Pleistocene Transition

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Abstract

The Mid-Pleistocene Transition (MPT; ~1.2–0.7 Ma) represents a climatic shift in Earth's Quaternary history, marked by a transition from 41-kyr to quasi-100-kyr glacial-interglacial cycles without concurrent changes in orbital forcing. Understanding the mechanisms governing this transition, particularly its impact on regional hydroclimate such as the South Asian Monsoon (SAsM), remains incomplete due to limited high-resolution oceanographic reconstructions. This study quantifies the oceanic temperature, salinity, productivity, and denitrification variability from the Eastern Arabian Sea spanning Marine Isotope Stages (MIS) 28–18, thus capturing a major portion of the MPT. We analysed paired Mg/Ca and $\delta^{18}O$ measurements from the mixed-layer dwelling planktic foraminifer *Globigerinoides sacculifer* obtained from IODP Site U1457. Mg/Ca paleothermometry, combined with $\delta^{18}O$-based salinity reconstructions, provides quantitative estimates of mixed-layer temperature (MLT) and salinity variability. Our results indicate pronounced variability in MLT (19–28°C; mean ~23°C) and salinity (32–39 PSU; mean ~36 PSU), with warmer interglacial periods generally corresponding to enhanced monsoon strength and higher salinity. Spectral analyses, including continuous wavelet transform (CWT) and REDFIT, reveal dominant periodicities of ~65 kyr and ~24 kyr, consistent with precessional cycles, alongside higher-frequency signals (~15 and ~7 kyr) suggestive of internal climatic feedbacks. Comparison with orbital forcing parameters and southern hemisphere insolation indicates that precession-driven insolation changes modulated SAsM variability during the MPT. Our findings support the hypothesis that southern hemisphere warming and thermohaline circulation variability played critical roles in amplifying monsoon dynamics and reorganising glacial cycles.

A study on total organic carbon and benthic forminifera from shallow sediment core of Odisha coast- implication for paleoenvironmental analysis

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Abstract

A 4.28 m shallow gravity core was retrieved from a drill site GC - 94 at a water depth of 272m (19°46.778N latitude; and 86°35.586E longitude) in the Bay of Bengal, off Odisha during the 308th cruise of the ORV Sagar kanya. The core is predominantly consists of silt lithology. The silt content varies from 99-99.5%, except at the depth interval (100-75) cm, wherein the silt content is 92.4% and sand is 6%. The core displays no definitive physical structures and it is massive with no visible laminations. The study has revealed the presence of the total of 159 species. Among these, 106 species are benthic foraminifera belonging to 67 genera 33 families, 20 Super families and 7 orders. The rest 53 species are planktonic foraminifera belonging to 16 genera, 5 families, 1 super family and 1 order are reported. Through Biostratigrapy, we identified 3-biozones *Globigerinoides extremus* IRZ (bottom 428 to 88 cmbsf), *Globigerinoides fistulosus* IRZ (88-36 cmbsf), and *Globorotalia tumida* flexuosa PRZ (36 cmbsf to top of the core), based on these results we identified the age Pliocene-Pleistocene. The comparison of benthic foraminifera (*Uvigerina peregrina*) δ18O data to the composite global stack curve "LR04" enabled to establish a precise orbital-scale age model from 1.815 – 2.67 Ma, and we have identified the consistency of the benthic δ18O stratigraphy with biostratigraphy confirms the reliability of both methods for constraining age. The changes in TOC content in core GC-94 (present study), show positive correlation with both sedimentation rates and BFOI. The BFOI values of <30 throughout the core abundantly suggest the prevalence of suboxic/disoxic conditions at the deposition surface. The co-occurrence of *Gl. adamsi* with index taxa of zone N21 in the present core further validates the geological range of this species from late Pliocene to Holocene in the Bay of Bengal province. Therefore, report of well-preserved *Gl. adamsi*, although sparse, but frequent in the present core, resolves its true stratigraphic range from Late Pliocene to Holocene in the Bay of Bengal.

Paleovegetation changes across the Paleocene–Eocene boundary at low latitudes: a palynological perspective from western India

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Abstract

The Paleocene-Eocene (P-E) boundary corresponds to a period of global warming that was instrumental in driving the widespread ecological changes during the early Paleogene. While early Paleogene sedimentary records from mid- and high-latitudes demonstrate significant changes in biotas, the low latitudinal vegetation dynamics remain largely unexplored. The Indian Plate, with its paleoequatorial position during the early Paleogene, is a potential natural laboratory to investigate changes in vegetation patterns at low latitudes in response to the warming event. On account of the well-demarcated P-E boundary within the early Paleogene succession of Sonari Lignite Mine, Barmer Basin, Rajasthan, western India, the study employs quantitative and qualitative palynological investigations, and demarcates the Paleocene and early Eocene palynoassemblages with varying palynofloral compositions across the boundary. Both palynoassemblages comprise fossil pollen belonging to similar ecological groups, structured with mangroves/back mangroves (*Spinizonocolpites* and *Proxapertites*), ferns (*Acrostichum*), palms (Arecaceae- *Arenga*, *Korthalsia*, *Oncosperma*, etc.), and inland tropical rainforest taxa (Ebenaceae, Euphorbiaceae, Myristicaceae, etc.), but differ in their floral diversity and composition across the boundary. The Paleocene palynoassemblage and P-E boundary, with predominating mangrove/back mangrove taxa, suggests the prevalence of widespread brackish swamps under the well-established low saline conditions, which most likely resulted from high precipitation and increased runoff on the paleoequatorially aligned Indian Plate during the early Paleogene warming. The early Eocene (early Ypresian) assemblage, on the other hand, displays rich and diverse palms as well as inland tropical rainforest elements, and fern spores that account for the expansion of rainforest ecosystems under a warm and humid climate of the warming event. A decline in seasonal taxa (e.g., *Lepidocaryum*) and an increase in moisture-dependent palms and rainforest taxa further suggest a possible transition from high-seasonal tropical rainforests tolow seasonal (perhumid) tropical rainforests during the early Eocene. With these palynoassemblages, this study underscores how variations in seasonality and climate associated with equatorial positioning and early Paleogene warming facilitated the vegetation transitions across the P-E boundary on the Indian Plate. The similar ecological groups with varying richness across the boundary also suggest that low-latitude vegetation transitions were gradual, in contrast to the more abrupt changes observed at higher latitudes.

Ancient microbial imprints in the Proterozoic sediments of Himachal Pradesh, Lesser Himalaya, India

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Abstract

In the Lesser Himalayas of Himachal Pradesh, the mixed siliciclastic-carbonate Simla and Jaunsar Groups were synchronously deposited in a rifted basin during the Neoproterozoic. The present study gives a detailed report on the diversity of stromatolites and microbially induced sedimentary structures (MISS) which are abundant in the two rock groups. This was done to understand the relation of the microbial buildups with the palaeoenvironment and palaeoclimate during the coeval deposition of the sediments. Both Simla and Jaunsar Groups exhibits a bottom carbonate succession deposited during transgression while the upper siliciclastic successions were deposited during a phase of sea regression with increasing sediment input. The stromatolite types which are common in both the Simla and Jaunsar Groups are wavy and domal stromatolites. These stromatolite morphotypes indicate deposition under high energy in reefs of intertidal to shallow subtidal settings. Additionally, the Simla Group also exhibits columnar and conical stromatolites and profuse development of ooids. Columnar stromatolites reflect deposition in calm subtidal environment while conical stromatolites are indicative of reef-slope deposition. Ooids are usually deposited under high energy conditions in intertidal setups. The common microbially induced sedimentary structures in the siliciclastic of the two rock groups are wrinkle structures, patchy ripples and palimpsest ripples. These microbially induced sedimentary structures indicate sediment deposition in intertidal flats. Stromatolites and MISS structures indicates deposition under warm and humid climatic conditions. SEM analysis of the stromatolites and MISS suggest a biotic origin. The Simla Group exhibits more abundance and morphological diversity of carbonate stromatolites and microbially induced sedimentary structures (MISS) than the Jaunsar Group. Presence of less carbonates and stromatolite precipitation in Jaunsar Group may be related to its proximity to the hinterland. This closeness to the provenance may have supplied more siliciclastics over the Jaunsar carbonate shelf which hindered the generation of stromatolites and MISS. The Simla carbonate shelf being further towards the sea had suitable conditions for stromatolitic carbonate precipitation and also for the generation of more microbially induced sedimentary structures. Further, the deposition of Simla and Jaunsar Groups took place during a time of active volcanism which was related to disintegration of Rodinia Supercontinent. Weathering of these volcanics increased the nutrients in the sea which increased microbial growth leading to more development of stromatolite and MISS.

Freshwater fish otoliths from the upper Siwaliks of Mohnad: New insights into Pliocene Himalayan aquatic ecosystems

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Abstract

The Neogene Siwalik Group is well-known for its diverse terrestrial vertebrate assemblages. However, its freshwater ichthyofauna has remained poorly known. The fossil freshwater fish otoliths were recovered for the first time from the Upper Siwalik Pliocene deposits at Mohand, Saharanpur district of Uttar Pradesh, in the northwestern Himalaya. Bulk sampling from this area yielded otoliths belonging to three taxa: *Channa* (Channidae), *Trichogaster fasciata* (Osphronemidae), and Gobiidae indet. *T. fasciata* is notably the second fossil record of Osphronemidae globally, and the first one based solely on otoliths. The assemblage indicates a structured trophic web with both mid-level prey and apex predators, suggesting a calm, possibly lentic freshwater system with dense vegetation. Such an environment is suitable for the spawning ecology of labyrinth fishes and supports the ambush predation behavior of snakeheads. Although limited in sample size, these findings provide important new insights into the aquatic ecosystems of the Pliocene Siwaliks and highlight the significance of ichthyofaunal data in reconstructing paleoecological and biogeographic histories in South Asia.

The bearing of amber microbiota from the Eocene lignite sequences of Gujarat on palaeoenvironmental reconstruction

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Abstract

Over the last two decades, there has been significant progress in identifying the biotic diversity recorded in Eocene amber nodules from the Cambay and Kutch Lignites of Gujarat. The study reconstructs a Dipterocarpaceae dominated broad-leaved dense tropical angiosperm forest, in the light of amber micro-biota fossils, which existed during the Eocene, and in this paper demonstrates its palaeoecological relevance. Amongst the recorded micro-biota, nearly forty taxa of fossil arthropods preserved in amber nodules have been reported, dominated by 55% of tree canopy, 32% xylophagous and terrestrial, 3% litter-dwelling and sub-soil, and 10% of aquatic palaeoenvironments. Amongst the canopy biota, the most dominant group of insects are taxa of true flies including non-biting and biting midges (Families Chironomidae, Cecidomyiidae and Ceratopogonidae) that constitute the major proportion of flying biota. True flies are indicators of water habitats near the vicinity of resinous trees and biting midges suggest the mutual relationship between parasitic arthropods and diversifying mammalian hosts. The canopy biota also includes interesting flowers like the Apocynaceae, and inclusions like bees and wasps which are possible sources of pollen dispersal. The bark-dwelling taxa of social insects comprises of ants (Family Formicidae) and some unidentified groups of termites. Arachnid fossils include spider taxa and a new pseudoscorpion taxon *Geogaranya* in Cambay amber, the first ever phoretic taxa recorded from Indian amber from a warm-temperate biome. Spider genus *Rugathodes* exhibits traits of parental care with evidences of unidentified egg sacs. The egg sacs are multilayered and complex structures. *Baalzebub* in amber represents the oldest representative of Family Theridiosomatidae and is unique due to the exceptionally round and globose palpal bulbs. Of special significance is the occurrence of phytophagous Alticinae beetles and sarcoptid mites as representatives of the litter-dwelling sub-soil biota. The mites thrive well in humid semi-aquatic habitats, and represent common parasites of mammals. The aquatic biota includes freshwater ostracod families which are uniquely preserved, varying in size with soft parts intact. These globally rare ostracod occurrences are in fact recorded from three mines: Valia, Tarkeshwar and Umarsar and suggest the common presence of water bodies. Euhedral quartz crystals in amber nodules from the Vastan and Umarsar mines, respectively, have intriguing features that point to an aerosol component of origin. The discovery of euhedral crystals of quartz may provide important insights into extraordinary volcanic events post the Deccan volcanic eruptions. The micro-biota assemblage is an indicator of dispersal in and out of India with affinities to Europe, Asia and Gondwana. India lay as an island subcontinent at the equator at a time when the earth was experiencing episodic thermal heating. The Eocene saw an intense biotic radiation with many of the lineages surviving upto the present day.

Ostracod-bearing Middle-Late Jurassic facies of Fakirwari Dome, Kachchh: Deciphering shallow marine depositional environments

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Abstract

Total 14 sediment samples were collected from the shale beds of Gypsiferous Shale Member and oolitic limestone of Dhosa Oolite Member of Jumara Formation, exposed at Fakirwari Dome, Mainland Kachchh, and numbered as FD01 - FD14 (From bottom to top). Of these, 12 samples are consisting of ostracode fossils. A diversified assemblage consisting of forty-four ostracode species have been recovered. The sampled part is proved to be productive with respect to ostracode fauna belonging to genera *Bairdoppliata, Cytherella, Cytherelloidea, Cytheropteron, Eucytherura, Fastigatocythere, Galliaecytheridea, Glabellacythere, Lophocythere, Majunagella, Mandwacythere, Micropneumatocythere, Paracypris*, and *Trichordis*. The familial composition of the ostracode assemblage consists of seven families such as Progonocytheridae, Cytherellidae, Candonidae, Cytheruridae, Cytherettidae, Cytheredeidae and Bairdiidae. The occurrence of ostracode shows distinct fluctuations in abundance and diversity throughout the section. The frequent occurrence of the genera *Galliaecytheridea* Oertli, 1957, *Cytherella* Jones, 1849 and *Cytherelloidea* Alexander, 1929 as abundant taxa in most of the assemblages of the section along with deep water taxa like *Paracypris* Sars, 1866 and *Cytheropteron* Sars, 1866 suggests an open marine environment within the shelf, most preferably a sublittoral zone. Early diagenetic dissolution of fossil shells is frequently observed in this unit, which may be the potential cause for the absence of ostracods in this interval. One sample (FD 04) is derieved from the fossiliferous limestone bed, which is a hard substrate, representing a time-averaged transgressive unit, which is rich in fragmented and altered shells, and devoid of identifiable ostracode shells (Fürsich *et al.,* 1991). In the section, the species richness varies from 3 in both FD 08 and 09 to maximum of 31 in FD 05. Similarly, the species abundance varies from 6 in FD 09 to 197 in FD 05. The species richness and species abundance are fairly correlated in case of all the samples. The maximum Shannon diversity index (H' = 3.038) is observed in FD 01, which comprises 30 species, followed by FD 05 (H'= 2.2845) (figure 7.13). This observation is attributed to the fact that the Shannon diversity index accounts for both species' richness and the evenness. The taphonomic analysis of the recorded fauna suggest a moderate energy autochthonous thanatocoenosis; and CBCC Plot for paleodepth analysis (Dingle, 1980, 1981) suggests a shelf platform during the deposition of the sediments not exceeding 200m.

Glacial–interglacial CO_2 exchange in the tropical Indian Ocean over the last 38 Kyr

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Abstract

The role of the tropical Indian Ocean in driving glacial–interglacial atmospheric CO_2 variability remains poorly understood compared to the Atlantic and Pacific Oceans. In this study, we present a 38 kyr high-resolution reconstruction of surface ocean pCO_2 from marine sediment core SSD004 GC03, retrieved from a depth of 1540m in the tropical central Indian Ocean. We utilized boron isotopic composition ($\delta^{11}B$) and trace element analysis of the planktic foraminifera *Globigerina bulloides* to reconstruct past seawater pH and pCO_2, thereby assessing ocean–atmosphere CO_2 exchange through the ΔpCO_2 (seawater–atmosphere pCO_2 difference). Our results indicate that the region acted as a significant CO_2 source during Heinrich Stadial 1 (HS1) and as a minor source during the Last Glacial Maximum (LGM), evidenced by positive ΔpCO_2 values. Conversely, negative ΔpCO_2 during the Bølling-Allerød (BA) and Younger Dryas (YD) intervals reflect periods of net CO_2 uptake. These variations are closely linked to changes in monsoon-driven upwelling intensity, upper-ocean stratification, and thermocline ventilation. The study underscores the important but spatially variable role of the tropical Indian Ocean in regulating atmospheric CO_2 over the last glacial–interglacial cycle.

Assessment on the response of Foraminifera due to the impact of urban pollution under changing climatic condition in the marginal marine environment

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Abstract

In last decades, the sediment in the Ennore creek has been intensively studied in numerous environmental studies focused on elemental (heavy metal) distribution in relation to anthropogenic impacts. The integrative approach we propose to assess the potential anthropogenic impacts (port activities, industry, municipal activities) on the Ennore creek is based on the benthic foraminifera assemblages. Benthic foraminifera are useful ecological indicators of depositional dynamics owing to their abundance and adaptations to different environmental conditions. This study evaluates the impact of the anthropogenic influence on benthic foraminifera and geochemical proxies. It is focused on the spatio-temporal comparison of geochemical properties (element concentrations) of sediments and benthic foraminifera from the surface and subsurface sediments in the creek with different degrees of anthropogenic load. 12 surface sediments and one core samples were collected to assess the trace metal distribution and its impact of the foraminiferal tests in Ennore creek. Based on the foraminiferal studies, 25 genera / species have been identified. Various sedimentological parameters such as $CaCO_3$, organic matter and sand-silt-clay ratio were determined for the samples in order to study the relationship between substrate and foraminiferal populations, and to evaluate the favored substrate of dominant species populations. All the samples are dominated by coarse fraction of the sediments. In general, all the core samples have higher concentration of OM and are depleted in $CaCO_3$ concentration. Foraminiferal assemblages are more in the silty sand and sand substrate environments. Based on the foraminiferal distribution, in the western part of the creek, species diversity are very rare in abundance due to the tidal fluctuation. In the middle and eastern part of the creek the species diversity is slightly higher due to the salinity influence. Sediment samples were analyzed for a range of heavy metals using Inductively Atomic Absorption Spectrometry (AAS). The results reveal elevated concentrations of these metals, exceeding natural background levels, indicating substantial anthropogenic input. Spatial distribution patterns of heavy metals were mapped to identify hotspots of contamination, closely associated with industrial discharges, urban runoff, and port activities. Enrichment factor (EF), Contamination Factor (CF) and geo-accumulation index (Igeo) calculations were employed to quantify the degree of pollution and assess the potential ecological risk. The study also incorporates multivariate statistical analyses, such as Principal Component Analysis (PCA) and Cluster Analysis (CA), to distinguish between natural and anthropogenic sources of contamination. It was found that the benthic foraminifera respond to elevated concentrations of certain heavy metals by changes in their test

morphology and size. This work contributes to detect anthropogenic stress against a background of natural conditions in the Ennore creek.

Zonal hydrographic asymmetry in the equatorial Indian Ocean and its link to Indian monsoon variability over orbital timescales

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Abstract

Understanding zonal variability in surface hydrography across the equatorial Indian Ocean (EIO) is crucial for deciphering the role of Indian monsoon dynamics in modulating tropical ocean-atmosphere interactions over glacial-interglacial timescales. This study presents new insights based on high-resolution records of planktonic foraminiferal abundance and stable isotopic compositions ($\delta^{18}O$ and $\delta^{13}C$ of *Globigerinoides ruber*) from core RC14-037PC in the Eastern Equatorial Indian Ocean (EEIO), in conjunction with comparable abundance data and published isotopic records from core VM29-045PC in the Western EIO (WEIO). Our multiproxy analysis reveals coherent patterns of monsoon-driven hydrographic changes, marked by distinct east-west gradients in isotopic composition and species abundance. Interglacial periods, notably Marine Isotope Stages (MIS) 7, 5, 3, and 1, are characterized by depleted $\delta^{18}O$ values in *G. ruber*, reflecting intensified summer monsoon activity, enhanced precipitation, and the development of a shallow thermocline. These conditions were likely promoted by stronger equatorial easterlies and enhanced upwelling in the eastern basin. Conversely, glacial intervals (MIS 6, 4, and 2) exhibit enriched $\delta^{18}O$ signatures, indicative of weakened monsoonal influence, reduced convective rainfall, and deepening of the thermocline associated with diminished surface wind forcing. Cross-basin comparisons further highlight that zonal asymmetries in hydrographic properties were especially prominent during transitional intervals such as late MIS 7, late MIS 6, and mid to late MIS 5 (substages 5b and 5a), as well as across major glacial terminations (TI, TII, and TIII). These phases coincide with enhanced Indian Ocean Walker Circulation (IWC) and intensified equatorial westerlies (IEW), potentially coupled with a reduction in the Indonesian Throughflow (ITF), resulting in significant alterations to thermocline structure, nutrient dynamics, and water mass stratification. Spectral analysis of the $\delta^{18}O$ time series reveals dominant periodicities at ~100 kyr, ~40 kyr, and ~22 kyr, corresponding to eccentricity, obliquity, and precession cycles, respectively. This strongly supports an orbital forcing of monsoon-driven oceanographic variability in the equatorial Indian Ocean.

Late Holocene paleoceanographic and climatic changes and their Impact on Indian socio-economic condition: Benthic foraminiferal Evidence from the Bay of Bengal

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Abstract

The present work is pursued on the benthic foraminiferal groups obtained from NGHP core samples of the western Bay of Bengal to understand the variations of paleoceanography and Indian Summer Monsoon (ISM), as well as socio-economic changes in ancient India. Benthic foraminiferal AMS 14 C dating reveals that the studied interval spans between 335 BC and 1355 AD, covering the history of the last 1690 years. We compared foraminifera group counts with published isotopes, sunspot number, summer monsoon index, hematite-stained grain, Al/Ca, 14 C data sets. Angular Asymmetrical Benthic Foraminifera, infaunal, and dysoxic groups exhibit declining trends with warm, humid intervals with intensified ISM signature from 335 BC to 406 AD (Roman Warm Period) and from 787 AD to 1202 AD (Medieval Warm Period). The Increasing trend of the above foraminiferal groups captures the signature of weak ISM from 406 AD to 787 AD (Dark Age Cold Period) and from 1202 AD to 1355 AD (Medieval Warm Period and Little Ice Age Transition). Whereas Rounded Symmetrical Benthic Foraminifera, epifaunal, and oxic groups show a reverse relation with the abovementioned groups. Spectral analysis of foraminiferal groups shows significant periodicities of 563/561, 450, 321, 281/250, 22/27, and 17/16/15 years, corresponding to various solar cycles. This research uncovers the relationship between solar activity and monsoonal changes, which influenced India's economic growth and played a crucial role in the establishment and demise of successive dynasties throughout the Indian subcontinent during the late Holocene.

Benthic foraminifera as indicator of environment: A case study from Sunderbans, West Bengal

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Abstract

The Sunderban is the largest mangrove delta in the world having a vast, low-lying archipelago comprising countless mudflats, islands, and a dense, intricate network of tidal waterways (creeks, rivers, and estuaries); all shaped by daily tides and seasonal freshwater flows. The Sunderbans represents a vast, dynamic wilderness located in one of the world's most significant and complex river deltas. The delta is formed by the confluence of the Ganges, Brahmaputra and Meghna Rivers in the Bay of Bengal. Core samples from two different locations from Sundarbans National Park located in West Bengal, India have been collected. The first core sample was collected from Bally Island (Bijay Nagar) [22˚06'53'' N, 88˚47'41'' E]. A total of fifteen foraminiferal species has been identified from the sediments of the core samples of the Gomti and Bidyadhari River, collected during the pre-monsoon season. Highest foraminiferal assemblage from this core sample is five which is found from the top layer of 20 cm core-pipe. Approximately zero abundance is found from thirteenth layer till the end. Average moisture content of the sediments in first core is 25.8 percent, whereas average sand percentage is 84 percent. *Miliammina petila* and *Quinqluloculina boschiana* is the most abundant species found. The species are having mainly agglutinated to porcelaneous tests. The second core sample is collected from Sona Gaon [22˚06'39'' N, 88˚46'36'' E]. A total of fourteen foraminiferal species have been identified from the sediments of the core samples of the Gomti and Bidyadhari River, collected during the pre-monsoon season. Highest foraminiferal assemblage from this core sample is seventy-three which is found from the top layer of 20cm core-pipe. Approximately zero abundance is found from tenth layer till the end. Average moisture content of the sediments in first core is 22.8 percent, whereas average sand percentage is 92.65 percent. *Ammonia tepida* and *Ammonia parkinsoniana* are the most abundant species found. The species are having mainly hyaline to agglutinated tests. TFN suggests low abundance of foraminifera in the first core station, which is in the east of the second core sample station. This condition is possibly due to harsh environment where foraminifera are sparse due to physical stress, poor preservation and limited food resources. Foraminifera from the first core suggests more saline, shallower and marsh conditions than the second core which is probably having high energy open marine environment. In first sample station porcelaneous or hyaline forms are absent from 8 cm top till bottom only agglutinated forms are present whereas in second core station abundance of hyaline forms are more in the top layers but below 8cm from top till end hyaline forms are approximately nil. So, it might indicate a local sea level rise in this areas.

From coastal onset to inland expansion: understanding the evolution of monsoonal seasonality in India through enamel (phosphate) oxygen isotopes in megaherbivores

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Abstract

The Indian monsoon system, provider of the majority of annual rainfall in the Indian subcontinent, is one of the most prominent climate systems in the South Asian region. Wide- ranging estimates regarding the timing of its inception, ranging from 55 to 7.5 Ma, have led to a fierce temporal debate. While many of these studies converge around Middle/Late Miocene subepoch, little to no consensus exists regarding the precise timing. To help resolve this chronological disagreement, herein we offer an age estimate of ≥ ~14 Ma for its development along the western coast of India based on the robust enamel phosphate oxygen (δ18Op) isotopic record from fossilised mammal tooth enamel. Furthermore, we also evaluate Siwaliks) during similar times, using the same geochemical proxy. Oxygen in water dependent large herbivore mammals is known to reflect the isotopic composition of ingested and hence, meteoric water (δ18O mw). Intra-tooth sampling along the growth axis reveals the variation in the rainfall signature over the course of mineralisation, a powerful tool for detecting patterns of seasonality in the ambient rainfall regime. In search of such patterns, pristine rhinocerotid, proboscidean and equid enamel remains ranging from Middle Miocene to Early Pleistocene localities from western Indian (Gujarat) as well as Siwaliks were serially sampled. Analyses revealed sinusoidal-like curves with an amplitude of up to 4.6 ‰, a strong signal for the presence of rainfall seasonality, for the Miocene Kutch samples. However, for the Siwalik specimens, curves with much weaker amplitudes of upto 2.9‰ were obtained. A comparison of the reconstructed Miocene Kutch $\delta^{18}O$ mw signals with the ones from modern- day Indian localities indicate the prevalence of present-day Mumbai (Bombay)-like rainfall dynamics in western India during the time. Additionally, a comparison of the Miocene Kutch rainfall regime with that reconstructed for the contemporaneous Siwalik region reveals a relatively significantly weaker monsoonal seasonality in the latter. This, in turn, implies that the expansion of monsoonal dynamics over the subcontinent was a gradual process, initially strengthening over the coastal regions before progressively expanding over the northern landmass.

A study on benthic foraminifera from the Bhitarkanika marshes, Odisha, India

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Abstract

Foraminifera, a unicellular amoeboid marine protist, are considered a significant biological proxy for paleoclimate reconstruction. The hard mineralized shells of foraminifera are highly responsive to various physicochemical changes in the aquatic environment, including temperature, salinity, pH, turbidity, and freshwater discharge. Research findings indicate significant environmental variations along the Bay of Bengal coastal region, influencing foraminiferal distribution and abundance. This report examines the spatial variability of foraminiferal assemblages in Bhitarkanika National Park, India's second-largest mangrove forest, focusing on species diversity and abundance. 18 surface samples were collected from Bhitarkanika marshes (20˚44'09'' N to 20˚43'07'' N and 86˚49'51'' E to 86˚52'06'' E) during the post-monsoon season along the banks of the Brahmani and Baitarani rivers. Total Foraminiferal Number (TFN) ranges from 1 to 175 across different sampling stations. The identified calcareous species from the surface samples include *Ammonia tepida*, *Elphidium advena*, *Nonion umbilicatulum*, and *Nonion sp*. Agglutinated forms in surface samples comprise *Trochammina inflata*, *Haplophragmoides wilberti*, *Haplophragmoides canariensis*, *Miliammina fusca*, and *Srinivasania sunderbanensis*. Microscopic observations reveal an abundance of more than 80% of the agglutinated species, while the other two forms, calcareous hyaline and porcelaneous cover the remaining sections. The dominance of agglutinated species over calcareous forms suggests sea level fluctuations, reduced salinity, and freshwater discharge by major river channels in this study region. During the post-monsoonal sampling season, the environment is less favourable due to fluctuations in salinity, temperature, pH, nutrient availability, and dissolved oxygen level. As a result, less than 10% living foraminifera were identified compared to dead specimens. Murray's Ternary Diagram indicates a dominance of agglutinated forms, with a lesser amount of calcareous hyaline forms and the least abundance of calcareous porcelaneous tests. Fisher's alpha index (α =0-1) represents an overall low species diversity from the low marshy environment of the Bhitarkanika region. An increase in species richness, with an approximation of 3-4 species in the west to 6-7 species in the east, has been observed, likely due to shifting environmental settings.

Assessing southwest Indian Ocean thermocline structure during the Late Quaternary using *Globorotalia truncatulinoides* as a proxy

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Abstract

The planktic foraminifer *Globorotalia truncatulinoides* has been widely utilized as a reliable proxy for reconstructing thermocline depth variability owing to its distinct habitat preferences. Previous isotopic studies have established *G. truncatulinoides* as one of the deepest-dwelling planktic foraminiferal species. Its preferred depth habitat, particularly in the Southern Ocean and adjacent regions, centers around ~400 meters, making it a critical indicator of subsurface paleoceanographic conditions. This study reconstructs thermocline structure over the past ~350,000 years by integrating stable isotope analysis and relative abundance data of *G. truncatulinoides* from sediment cores collected at IODP Site U1475, situated on the Agulhas Plateau in south west Indian Ocean. The relative abundance of *G. truncatulinoides* and oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) isotopic records were used to infer subsurface water mass properties and changes in thermocline depth. The results reveal the increased prevalence of *G. truncatulinoides* (sin.) during late MIS 9, early and late MIS 7, late MIS 5, early and late MIS 3 and MIS 1, as well as during glacial terminations (I, II, III, and IV), suggests deepening/expansion of thermocline and/or the presence of thick Subantarctic Mode Water (SAMW) thermostads during these periods. The higher abundance of *G. truncatulinoides* (sin.) during warm MIS stages, and glacial terminations likely reflects the advection of warm subtropical waters into the region, driven by a southward shift of the Subtropical Front (STF). These shifts coincide with warmer SSTs and reduced upwelling, the conditions that promote a thickening and expansion of the thermocline. These findings underscore the utility of *G. truncatulinoides* as a robust indicator of past thermocline dynamics.

Glacial-interglacial dynamics of organic carbon burial in the southeastern Arabian Sea

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Abstract

Organic carbon burial in marine sediments is a critical part of the global carbon cycle. Where, variations in both primary productivity and sedimentary preservation potential can significantly influence atmospheric carbon dioxide level. To explore this further we made use of a gravity core (SSD004 GC11) retrieved from the southeastern Arabian Sea, spanning the last 175,000 years. To reconstruct changes in surface productivity and sedimentary carbon preservation, we measured Total Organic Carbon (TOC), *Globigerina bulloides* (%), $\delta^{13}C$ of organic matter, TOC/TN ratios, benthic foraminiferal morphological assemblages and $\delta^{13}C$ of *Cibicidoides wuellerstorfi*. Our results suggest that productivity in the region is mainly driven by precession-controlled insolation changes, indicated by *G. bulloides* abundance and TOC. In contrast, bottom water conditions follow a glacial–interglacial pattern. During the last two glacial maxima, the basin saw enhanced influx of oxygen-depleted Antarctic Bottom Water (AABW), suggested by lower δ^{13} C Cibicidoides values and higher abundance of Angular Asymmetrical Benthic Foraminifera (AABF). This influx promoted sedimentary organic matter preservation, marked by unusually high TOC peaks during both glacial maxima, even though surface productivity was lower than during their following interglacials. These findings highlight the nonlinear nature of organic carbon preservation, shaped by the interplay between surface productivity and deep-water ventilation, and underscore the role of ocean processes in regulating carbon sequestration and global climate.

A Late Pleistocene coral reef from western India as a proxy for reconstructing local-scale paleoenvironment and sea-level fluctuations

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Abstract

Studies on fossil coral reefs and their associated faunal assemblages provide valuable proxies for reconstructing past ecosystems and environments. However, records from Pleistocene reefal ecosystems, which have the closest temporal proximity to modern coral reefs, remain understudied, even from the Indo-Pacific—a region of biodiversity hotspots throughout the Cenozoic. The Late Pleistocene fringing coral reef of the Aramda Reef Member (ARM), situated in the Western Indo-Pacific (WIP) Realm, bordering the Arabian Sea, along the western coast of Gujarat, India, represents one such underexplored reefal ecosystem. Paleoecological and paleoenvironmental analyses of the reef-building corals and reef-associated macro- and microfauna suggest that the ARM paleoreef was formed in a nearshore, low-nutrient, and low-to-moderate detritus-laden setting, fringing a narrow and shallow lagoon. Assessment of the temporal longevity of the paleoreef based on our reconstructed reef profile and the inferred lifespans of coral and coralline algae suggests that the paleoreef was short-lived, i.e., of sub-millennial span. Furthermore, integrating these estimates with previously published age constraints of the paleoreef and a literature-based compilation of lithological, biological, and archaeological sea-level proxies, a relative sea-level (RSL) curve of this region has been reconstructed, which suggests that the formation of the paleoreef likely resulted from a brief, local sea-level rise during the Late Pleistocene, the contemporaneous regressive sea-level trend across the WIP. The results, thus, indicate that coral reefs are precise archives of local environmental variability, offering more nuanced paleoenvironmental insights at smaller spatial scales, which can often deviate from large-scale environmental patterns.

Southern Ocean palaeoceanography across the Eocene-Oligocene period: A review

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Abstract

Recent climate models predict an ice-free polar region due to an unprecedented increase in the atmospheric greenhouse gases. To understand this shift, we examine the paleoceanography of the Southern Ocean from the Paleocene to Oligocene period (~56-23 Ma), from an ice-free period to a time with major ice-sheets formation. The Early Eocene (~53-49 Ma) was marked by extreme warmth and high atmospheric CO_2 levels, with Southern Ocean surface temperatures reaching 24-26°C, as shown by Mg/Ca and δ18O proxies from foraminifera. This resulted in strong upper water column stratification and poorly oxygenated deep waters. Cooling began after 49 Ma, improving ocean ventilation and increasing productivity, as indicated by biogenic sedimentation and δ13C values. This period saw the first signs of Antarctic cooling, as ice started accumulating on the continental highlands. This secular cooling trend was interrupted by a brief warming, the Middle Eocene Climatic Optimum (MECO) ~40 Ma, caused a ~4°C rise in in surface and deep-water temperatures, reducing Benthic and planktic foraminiferal production and export productivity. Following MECO, the Priabonian oxygen isotope maximum (PrOM) event (~37.3 Ma) indicated possible ice sheet expansion. The major climatic shift occurred at Eocene-Oligocene Transition (EOT; ~34 Ma) marked significant Antarctic glaciation, cooling both surface and deep waters by 3-5°C. Gateway openings like the Tasmanian and Drake Passages enhanced circulation, establishing the Antarctic Circumpolar Current (ACC), which isolated Antarctica and promoted global cooling. By the Oligocene, the Southern Ocean had transitioned to a cooler and more ventilated state. The ACC was fully established, reinforcing the thermal isolation of Antarctica and the maintenance of its ice sheets. The Southern Ocean's role as a significant driver of global heat transfer and CO_2 regulation was heightened during this period, with biological productivity contributing to atmospheric CO_2 drawdown. In conclusion, the Southern Ocean's paleoceanography from the Eocene to Oligocene reflects significant shifts in temperature, circulation, and biological activity. The key drivers of these changes were the climatic cooling events, oceanic gateway formations, and the onset of Antarctic glaciation.

Reconstructing shallow marine environmental change during the Middle Miocene climate optimum using Foraminifera: evidence from the Kerala Basin, India

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Abstract

The Middle Miocene Climate Optimum (MMCO), dated to approximately 17 to 14.7 million years ago, was one of the warmest intervals of the Cenozoic era. Global surface temperatures were 3 to 5 °C higher than present (~4-6 °C above than pre-industrial levels), and atmospheric carbon dioxide levels were similar to those of today, around 450 ppm (Zachos et al., 2001; Holbourn et al., 2015). Positioned within the tropics during this interval, the Indian subcontinent offers a valuable setting to investigate the environmental and ecological impacts of sustained global warmth on shallow marine systems. This study presents micropaleontological and geochemical data from Middle Miocene onland sections exposed at Paravoor and Channakodi in the Kerala Basin. Sediment samples were collected and analyzed at the Indian Institute of Technology Gandhinagar to generate foraminiferal assemblage records and clay mineral profiles. These datasets are used to reconstruct paleoenvironmental conditions in tropical shallow marine environments during the MMCO. Preliminary results reveal significant changes in foraminiferal diversity and size distribution across the studied sections, suggesting a transition from open marine to restricted environments. This shift is consistent with increased nutrient input and terrestrial influence, likely associated with a warmer and wetter climate. Clay mineralogical data support enhanced weathering and runoff during this interval (Clift et al., 2008). The Kerala Basin record provides new insights into the response of tropical coastal systems to prolonged climate warming. These findings offer useful analogs for understanding how present-day shallow marine environments may respond to future climate trajectories.

Eastern North Atlantic productivity dynamics across the Miocene–Pliocene Boundary: Insights from IODP expedition 401 Site U1609A

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Abstract

The Miocene–Pliocene boundary (~5.97–5.0 Ma) marks one of the most dynamic paleoceanographic intervals in Earth's history, prominently shaped by the Messinian Salinity Crisis and the subsequent Zanclean Flood. This study investigates the changes in ocean productivity and surface water conditions across this transition using sediment core samples from IODP Expedition 401 Site U1609A, located on the Portuguese continental slope. A multi-proxy approach involving planktic foraminiferal assemblages, benthic/planktic ratios, and grain-size distribution was employed to reconstruct paleo-productivity and oceanographic variations. Key indicator species—*Globigerina bulloides*, *Globigerinita glutinata*, and *Globorotalia inflat*a—were used to infer nutrient levels, upwelling activity, and temperature regimes. Results reveal significant shifts in productivity and water mass structure in response to climatic and tectonic events, particularly Mediterranean–Atlantic water exchange. The study underscores the eastern North Atlantic's sensitivity to regional and global environmental changes and highlights the utility of microfossil-based reconstructions in understanding past marine ecosystems. These insights are critical for refining paleoclimatic models and improving predictions of future ocean-climate dynamics.

A Study on the assemblage of benthic foraminifera in the Lothian Island of Sundarbans, India

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Abstract

The Sundarbans is the largest mangrove forest and marsh delta region located where the Ganges and Brahmaputra rivers meet the Bay of Bengal, stretching across India and Bangladesh. Topographically, Lothian Islands, a relatively small low-lying area known for its mangrove forests, low tide mudflats and influencing ecosystem variability. The surface sediment samples were collected across eight sites during pre-monsoon (March) and post-monsoon seasons (August) for identifying species diversity, differentiating on basis of test composition, and seasonal population trends from marsh zones. The samples were stained using Rose Bengal and stored for three days. The stained sediment samples are then processed in the Micropaleontology laboratory. The dried sediment samples are observed under Stereozoom microscope for sorting and identification. The preliminary findings indicated the total foraminifera number (TFN) declined from the southernmost location to the northernmost location, and the majority of the foraminifera were alive (stained). The high marsh samples, identified by agglutinated tests, are separated from the low marsh samples, which have calcareous tests. The agglutinated species, such as *Haplophragmoides spp*. And *Trochammina spp*., were dominant, whereas the calcareous test-rich species included *Cribroelphidium sp*. and *Haynesina spp.* The results also suggest that the pre-monsoon periodsupports growth because of stable marine environments, while the post-monsoon period leads to a decline in the foraminifera population due to changed environmental conditions, such as sediment load, freshwater input, and salinity. The benthic foraminiferal assemblages serve as effective bioproxies for interpreting marsh ecological dynamics, reflecting past variations in salinity, tidal influence, and sedimentation patterns. Their fossil record aids in reconstructing the palaeoecological history of intertidal marsh environments like those in the Sundarbans.

Decoding the role of the Arabian Sea in carbonate burial and atmospheric CO_2 regulation through foraminiferal records

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Abstract

The ocean plays a fundamental role in regulating Earth's climate by facilitating interactions among the atmosphere, hydrosphere, lithosphere, and biosphere. These interconnected systems drive the exchange of energy between hemispheres, contributing to the dynamic equilibrium between land and ocean climatic processes. Carbon dioxide (CO_2), in particular, has historically exerted significant influence on Earth's energy balance—acting as a driver of both warming and cooling trends across decadal to millennial timescales. Given the importance of CO_2 in climate dynamics, this study aims to investigate its historical variability and ocean-atmosphere interactions by examining the shell weight of planktic foraminifera as a proxy for carbonate ion concentration (CO_3^{2-}) and calcite saturation. Despite progress in understanding the oceanic calcium carbonate cycle, several uncertainties remain—especially regarding (1) how past changes in atmospheric CO_2 can be accurately interpreted, and (2) how the ocean system may respond to current increases in CO_2 levels. An inverse relationship between atmospheric pCO_2 and carbonate ion concentration implies that the saturation state of calcite in the ocean—and the associated preservation and dissolution of calcium carbonate—could have played a significant role in regulating past atmospheric CO_2 and climate. To explore this, we analyze a sediment core (SK-240/505) retrieved from a depth of 261m in the northeastern Arabian Sea. This study employs carbonate preservation/dissolution proxy based on foraminiferal species such as *Globigerinoides ruber*, *Pulleniatina obliquiloculata*, and *Neogloboquadrina dutertrei* as indicators of carbonate burial processess. By reconstructing past changes in calcite preservation/dissolution, this research contributes to a better understanding of how the oceanic carbon cycle has influenced climate variability in the historical past—and offers insights into potential future responses of marine systems under ongoing anthropogenic CO_2 rise.

First Report of fossil wood from the Lower Siwalik Formation near Tipra village (Himachal–Haryana Border): Implications for fluvial deposition and Miocene paleoenvironment

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Abstract

This study presents the first report of fossilized wood remains from the Lower Siwalik Formation near Tipra village, located along the Himachal–Haryana border. The discovery was made during a field expedition organized by the Tethys Fossil Museum to commemorate the 75th anniversary of the Paleontological Society of India.The fossiliferous horizon comprises yellow sandstones interbedded with grey and maroon mudstones, characteristic of a fluvially dominated foreland basin setting during the Middle Miocene. The site hosts 8–10 well-preserved silicified wood logs, some exceeding one meter in length. Their random orientation, varying dimensions, and associated sedimentary structures suggest deposition by high-energy flood events within a meandering river system, followed by rapid burial and silicification. Comparative analysis with fossil wood occurrences from the Lower Siwalik strata in Jammu, Dehradun, and Surai Khola (Nepal) indicates the presence of widespread humid subtropical forests and dynamic riverine landscapes across the Himalayan foreland prior to significant orogenic uplift. The Tipra assemblage provides new insights into regional stratigraphic correlations, vegetation dynamics, and sedimentological processes during the Miocene. Samples have been sent to Lucknow, for taxonomic identification. This report contributes significantly to our understanding of Siwalik paleoecology, taphonomy, and the evolution of Himalayan foreland fluvial systems.

Benthic foraminiferal morphogroups in Savitri River, west coast, Maharashtra, India: Palaeoenvironmental implications

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Abstract

The present contribution constitutes the first morphogroup analysis of foraminiferal assemblages of the Savitri River. Benthic foraminifera are classified into five morphogroups based on the external test morphologies of 32 species of intertidal benthic foraminifera: tapered, elongate flattened, milioline, planoconvex, and rounded-planispiral. The analysis of morphogroups indicates a promising approach for identifying both past and present environments in cases where the autoecology of the species remains unclear or where uncertainties exist concerning their taxonomic classification. The foraminiferal population in 36 surface sediment samples, located along the southern coast of the Savitri River, was examined at Velas, Bankot Jetty, Vesavi, Vesavi Jetty, Kante, and Umroli. The 19,372 classified specimens are distributed among the morphogroups as 77.9% planoconvex (PC), 9% milioline (MI), 6.6% elongate-flattened (EF), 5.5% tapered (TA) and 1% rounded-planispiral (RP). The PC morphogroup is present in all 36 samples; MI is in 20 samples, and absent only from Vesavi Jetty and Kante locations; EF occurs in 12 samples from the Velas and Bankot Jetty but is absent from all other samples; TA is in 12 samples from the Velas and Bankot Jetty but is absent from all other samples; RP is in eight samples from the Bankot Jetty and Vesavi. Planoconvex (PC) morphogroups exhibited by agglutinated and calcareous foraminifera predominated throughout the study area. Morphogroups PC and RP, lacking a dominant axis in their morphology, can be regarded as symmetrical. In contrast, those such as TA and EF, which possess a dominant axis, are classified as asymmetrical. Undisturbed sediments promote the emergence of asymmetrical forms due to their ability to sustain a preferential position, whereas disturbed sediments tend to exhibit more symmetrical forms, which can readily adjust their positions following disturbance. Utilising morpho-groups rather than species offers numerous benefits. Since morpho-groups operate independently of species-level taxonomy, they remain unaffected by variations in the habitat of specific species or by taxonomic discrepancies among different researchers. There is no requirement to identify species, allowing for rapid sorting of samples in the laboratory. The processes of data reduction and analysis are significantly more straightforward when employing a limited number of morpho-groups compared to a vast array of species. Furthermore, analyses that incorporate morpho-groups can be tailored for compatibility with computer image processing.

Storm-driven reworking in Eocene Carbonates: A taphonomic study of foraminifera and Echinoids

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Abstract

This study documents distinct fossiliferous horizons dominated by Orthophragminid packstones, characterized by a micritic matrix and sparry cement, but with unique sedimentary and taphonomic features that suggest short-lived episodic high-energy local events. These horizons display widespread burrows and concretions embedded within otherwise planar-laminated rocks. While the host sediment preserves foraminiferal tests in relatively consistent orientations with moderate fragmentation (~57%), the burrows and concretions show significantly higher fragmentation levels (~81%) and a completely disoriented arrangement of tests. A total of 917 fossil specimens were examined from these horizons using both thin section analysis and hand specimens. Fragmented *Discocyclina*, *Nummulites*, *Asterocyclina*, *Assilina*, and large irregular echinoid fragments dominate the assemblage, with echinoid test sizes ranging from 2.56 cm to 5.23 cm. The sharp contrast in fossil preservation between the laminated host rock and the burrow/concretion zones suggests two distinct taphonomic overprints: an initial bioturbation event that reworked and fragmented earlier deposits, followed by a subsequent high-energy event, likely storm- induced, that caused further fragmentation, reworking, and infilling of pre-existing structures. Similar structures are also found in other parts of the world. Some burrows preserving less fragmented foraminifera may have been filled prior to the storm event. These observations collectively point to episodic, high-energy depositional local events interrupting otherwise lower-energy sedimentation, and underscore the complexity of post-depositional processes in shaping fossil assemblages in carbonate shelf environments.

Distribution of reef associated benthic foraminifera in the Kalpeni Atoll, Lakshadweep Archipelago

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Abstract

The Kalpeni Atoll, part of the Lakshadweep Archipelago of the southeastern Arabian Sea, lies in a climate-sensitive region within the Indian Ocean Warm Pool (IOWP). This coral atoll, situated ~220-240 km off the Kerela coast, features a reef-lagoon system formed over the Laccadive-Chagos Ridge. Despite its ecological significance, detailed studies on the reef associated benthic foraminiferal assemblages in the surface sediments of this atoll remain scarce, limiting its paleoenvironmental interpretations. Previous studies have documented the dominance of calcareous benthic foraminifera, particularly symbiont-bearing taxa such as A*mphistegina, Calcarina*, *Neorotalia*, etc. However, a systematic assessment of the spatial distribution, particularly for symbiont-bearing large benthic foraminifera (LBFs) across different habitats remains lacking. The primary objective of this study was to analyze the spatial variations in foraminiferal assemblages, to investigate the influencing factors and mechanisms related to monsoon currents, and local physicochemical factors on the foraminiferal distribution. Twenty- Five surface sediment samples from key environmental zones have been analyzed using microscopic identification, grain size classification, and statistical evaluation of foraminiferal assemblages. Grain size analysis reveals a grain-stone dominated texture with sand size fractions prevailing. The sediment texture exhibits bimodal to polymodal distributions, supporting the influence of hydrodynamic processes. The prevalence of LBFs suggests their utility as indicators of reef vitality. This study provides the first detailed information regarding the distribution of reef associated benthic foraminifera in Kalpeni. It also demonstrates how foraminiferal distributions reflect both local hydrodynamic processes and regional oceanographic influences, offering a framework for comparative studies across tropical reef systems.

Middle Jurassic calcareous nannofossils from the Kachchh Basin, western India

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Abstract

Middle Jurassic serves as an important period during which plankton evolution occurred in the marine environments. This can be attributed to the opening of large oceanic pathways. Over the course of this period the carbonate production, particularly from the nannofossils, increased and this subsequently led to a significant contribution to the pelagic carbonate sedimentation in open oceans. The present biostratigraphic study is based on calcareous nannofossils from the section near Jara village (Gujarat). Quantitative estimates of total nannofossil and single taxa abundances showed that calcareous nannofloras are rare to common and their preservation is poor to moderate. On the basis of the recovered calcareous nannofossil taxa, the broad age bracket for the samples is delineated as Aalenian-Bajocian. Index calcareous nannofossils species recovered from the base of the section includes the first occurrence (FO) of *Watznaueria britannica* and *Watznaueria fossacincta* along with the last occurrence (LO) of *Lotharingius barozii*. This indicates that the base of the section lies at ~170 Ma. The top of the section is marked with the first occurrence (FO) *Cyclagelosphaera margerelii* and *Watznaueria barnesiae* in addition to the last occurrence (LO) *Triscutum sullivanii.* Hence, the age of the topmost sample is designated as ~168.5 Ma. The calcareous nannofossil taxa viz., *Watznaueria*, is recorded as the dominant taxa during this time slice. It is already well established that *Watznaueria* dominated the calcareous nannofossil assemblage from the Middle Jurassic to the end of the Early Cretaceous, and was ubiquitous in Upper Cretaceous assemblages. Diversification of the genus *Watznaueria* also coincided this time period (Giraud et al., 2016). The overall high abundance percentage of *Watznaueria spp*., indicates that there was gradual eutrophication in the system which is correlatable to the trend of increasing carbonate $\delta^{13}C$ values, and a rise in biogenic silica production and deposits in different basins of the Western Tethys over the Early Bajocian (Aguado et al., 2016).

Reconstructing past oxygen minimum zone variability in the eastern Arabian Sea using multi-proxy records

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Abstract

Reconstructing past bottom-water oxygenation (BWO) is important for understanding the strength and variability of Oxygen Minimum Zones (OMZs) and the influence of intermediate water circulation on OMZ dynamics. The Arabian Sea hosts one of the most intense Oxygen Minimum Zones (OMZs), yet its long-term variability and driving mechanisms remain poorly understood. To address this gap, we present the changes in the strength of the OMZ of the Eastern Arabian Sea (EAS) over the past ~15.5 kyrs using a novel approach - epifaunal benthic foraminiferal porosity (*Planulina dayi* and *Elphidium excavatum*), content, alongside other oxygenation proxies (molybdenum (Mo), uranium (U)) from sediment Core SK-376/GC-02 (core length: 4.12m, water depth: 614 m). This study attempts to understand how past shifts in intermediate-water circulation and monsoonal variability influenced OMZ intensity since the last deglaciation. Epifaunal benthic foraminiferal porosity, a proxy for bottom-water oxygenation, increases in low-oxygen conditions and decreases in well-ventilated waters. Porosity was measured on the dorsal side of the penultimate chamber of *Planulina dayi* and *Elphidium excavatum* using SEM imaging and ImageJ analysis, following Petersen et al. (2016). Geochemical analysis was conducted using a Q-ICPMS. The reduced U and porosity data reveal a weaker OMZ during Heinrich Stadial 1, likely due to enhanced ventilation from increased Antarctic Intermediate Water (AAIW) incursion into the EAS (Jung et al., 2009) and reduced monsoon-driven productivity as evidenced by Singh et al. (2007). Whereas, the Bølling-Ållerød hosted a moderately strengthened OMZ coinciding with strengthened summer monsoon-driven productivity (Singh et al., 2007). During the Younger Dryas, reduced U and Mo data suggest a weakened OMZ owing to a strengthened winter monsoon resulting in vertical mixing (Singh et al., 2007). The U and porosity data showed an increasing trend throughout the Holocene suggesting a transition towards an intensifying OMZ, associated with intensified summer monsoon-driven productivity (Singh et al., 2007). Our results suggest that OMZ fluctuations possibly follow the incursion of oxygenated AAIW during deglaciation and monsoonal strength fluctuations highlighting the role of monsoonal dynamics and intermediate-water circulation in OMZ fluctuations offering insights into future deoxygenation trends.

Morphological evolution of microbialites in Late Pleistocene Hawaiian drowned reefs (MIS 7-6): Insights from IODP Expedition 389 core analyses

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Abstract

Microbialites are organosedimentary deposits formed by microbial communities and represent a major component of the reefal framework alongside corals and algae in the drowned Hawaiian reef system. These structures have the potential to serve as proxies for paleoenvironmental conditions. However, their growth architecture and variability in response to climatic fluctuations during the late Pleistocene remain poorly constrained. This study focuses on the morphology, and architectural evolution of microbialites across the glacial-deglacial cycle in the Late Pleistocene, utilizing datasets from the IODP Expedition 389 – Hawaiian Drowned Reefs. Specifically, we examine microbialites offshore Big Island of Hawaii from sites M0097 A, B, C, and D on the leeward side and M00102-C and M00104- A on the windward side of the drowned terrace H2 (~400 m depth), dating to Marine Isotope Stages (MIS) 7-6 (~243–130 Ka). This interval has received comparatively little attention and thus provides a fresh perspective on Late Pleistocene reef dynamics. We utilized high-resolution digital line scan images of cores from these sites to identify and characterize microbialite morphologies and growth patterns. A systematic interpretation of these images, supported by chronological constraints from the IODP Expedition 389 team, enabled reconstruction of temporal and spatial variability in microbialites. Our findings reveal seven distinct mesoscale microbialite classes visible at the centimeter scale: laminated, laminated columnar, structureless, structureless columnar, digitate, microbialite-coated debris (MCD), and IBFM (Intraskeletal Boring and Filling Microbialites). Manual segmentation of the line scan images using ImageJ allowed differentiation of coral, algae, and other reef components from microbialites, enabling quantification of the 2D surface area occupied by each microbialite morphology. This approach facilitates the semiquantitative assessment of microbialite dominance and abundance through the cores. Future work aims to integrate compositional analysis from thin sections, SEM imaging, and lipid biomarker studies to evaluate temporal and successional changes in morphology and explore potential links to environmental factors such as nutrient levels and light availability during glacial-interglacial transitions. This study advances our understanding of the morphological diversity and distribution of microbialites within the Late Pleistocene Hawaiian drowned reefs, particularly across a previously understudied interval (MIS 7-6). Our integrated imaging and quantification approach establishes a basis for interpreting microbialite responses to climatic fluctuations and environmental variability. The ongoing and future compositional and biomarker analyses will provide critical insights into their

paleoenvironmental significance, enabling better reconstruction of reef ecosystem dynamics through glacial-deglacial cycles.

Pteropod dissolution and foraminiferal preservation: Indicators of past oxygen stress and diagenesis in the Arabian Sea

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Abstract

The Southeastern Arabian Sea contains one of the world's most extreme Oxygen Minimum Zones (OMZs), particularly at intermediate depths. The low oxygen environment at the core site core SK 291-GC05 (10°24.85'N; 75°17.26'E; water depth 1000 m) has significantly influenced the preservation and post-depositional modification of microfossils throughout time. The OMZ here is closely connected to monsoon-driven productivity and inadequate subsurface ventilation, resulting in oxygen depletion, aragonite undersaturation, and a shallow Aragonite Compensation Depth (ACD) of around 550m. Our research looks into how these circumstances have affected the process of pyritization—a type of diagenetic alteration in which the original shell material is replaced or covered with iron sulphide minerals, mainly pyrite. We examine the microfossil assemblage in this sediment core, focusing on aragonitic pteropods, which are particularly susceptible to dissolution, as well as more resilient planktic foraminifera, which maintain surface water conditions. The presence or lack of pyrite in these fossils offers important information on redox conditions, the strength of the OMZ along with iron availability in the region. This study demonstrates how microfossil preservation in the Southeastern Arabian Sea may be used not only to track productivity and water mass changes, but also as a sensitive indication of oxygen stress and early diagenetic processes. This technique aims to increase our understanding of how monsoon variability has affected ocean chemistry and fossil preservation during Late Quaternary periods.

Aggregation origin and usability of marine bivalves and gastropods as indirect paleo-seagrass indicators (IPSIs)

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Abstract

Seagrass ecosystems are important today as hosts of marine biodiversity hotspots, providing ecosystem services worth trillions in USD annually and an estimated global extent of at least 277,000 square kilometres. However, global seagrass ecosystems face major threats in the face of present-day climate fluctuations with a significant research gap in the impact of temperature, salinity and ecosystem turnover on the global and regional distribution of seagrass meadows. Paleontological records of seagrass distributions can act as natural observations over climatic upheavals, but the fossilization potential of seagrass in marine ecosystems is rare. Ecological studies show marine molluscs such as gastropods and bivalves as strong potential indirect paleo seagrass indicators. Using the probabilistic framework of co-occurrence, we identified molluscan aggregative association with modern seagrasses using data from repositories such as OBIS and WORMS. Comparing these aggregative molluscs, we demonstrated that they occur more often in paleoseagrass assemblages and aggregative families of gastropods in particular emerge to be a reliable seagrass proxy. The molecular phylogentic relationship shows that the aggregative nature of gastropods emerged after the advent of seagrass ecosystems in Early Cretaceous. However, some of the aggregative molluscs in bivalves as well as gastropods appear to come from clades that existed before Early Cretaceous implying that biological associations can be developed even in older groups as and when the new niches are built. This is the first quantitative approach to develop a proxy for paleobiological association using a multi-direction approach combining recent occurrence data, fossil association, probabilistic modeling and molecular phylogeny. Such an approach can be used for developing other similar paleo-proxies and tracking the timing of acquiring the associative trait in the evolutionary history of taxa comprising similar marine ecosystems.

Influence of Indonesian Throughflow on the Indian Monsoon during Pliocene based on planktic foraminiferal studies from ODP Hole 716A, Equatorial Indian Ocean

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Abstract

The Indian Ocean is unique because of its reversing surface circulation due to changing wind stress, due to differential heating of the continent and oceans. During Northern summer, this wind stress combined with northward migration of the Intertropical Convergence Zone (ITCZ) results in intense Southwest Monsoon. The changing sign of the Coriolis force as a result of the northward migration of the ITCZ causes the powerful Somali Current associated with upwelling and enhanced surface water productivity (eutrophic condition), resulting in a reduced thickness of the warm mixed layer. The location of ODP Hole 716A is such that the migrating ITCZ sweeps the region while moving north or south during the summer monsoon and winter monsoon, respectively. However, during Northeast Monsoon, when ITCZ migrates southward once again, sweeping the Hole 716A, such upwelling is not seen, and this results in a well-stratified ocean upper water column and thick mixed layer, causing oligotrophic conditions in the upper water column. Planktonic foraminifera, which live in the upper ocean water column in the mixed layer and thermocline, accordingly, show the variation in their abundance in response to the processes discussed above. The present work comprises core samples from the Pliocene interval of ODP Hole 716A located in the equatorial Indian Ocean at a water depth of 554.8 meters. The site contains undisturbed carbonate oozes comprising foraminifera and calcareous nannofossils. Planktic foraminiferal census counts were made by splitting the samples into an aliquot of 300 individuals. All specimens were mounted in slides, and their relative abundance was calculated. Species groups were created, including Mixed Layer Dweller, Thermocline Dweller, and Deep Dweller. This study presents the comparative analysis of the relative abundance of Mixed Layer Dweller (MLD) versus Thermocline Dweller Species (TDS) and Oligotrophic Indicator Species (OIS) versus Upwelling Indicator Species (UIS) versus Productivity Indicator Species (PIS) during the Pliocene at ODP Hole 716A in the equatorial Indian Ocean. The overall trend of MLD exhibits four increasing trends bridged by three decreasing trends within the examined interval. Specifically, the increase in MLD indicates the strengthening of the NE Monsoon, during which no upwelling occurs at ODP 716A. In addition, the flow of less saline Bay of Bengal water into the Arabian Sea through ODP 716A strengthens the stratification of the ocean water column. Conversely, a decrease in MLD indicates strengthening of the SW monsoon, and an increase in productivity is indicated by an increasing PIS trend whenever MLD decreases. The UIS exhibits a major declining trend in the later part of the early Pliocene, which might be due to the closing of the Indonesian throughflow during the Early Pliocene. This closing of the ITF during the Early Pliocene is also indicated by the deepening of the thermocline and a decreasing trend in TDS species.

Equatorial Indian Ocean Chalk intervals at IODP Site U1443A: Insights into diagenesis, productivity, and carbonate preservation

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Abstract

IODP Site U1443A (Ninetyeast Ridge) provides a unique record of equatorial Indian Ocean conditions spanning the transition from greenhouse to icehouse climates. Three discrete chalk intervals in the core reflect changes in formation processes, paleoceanographic context, and diagenesis, each linked to global and regional events. (1) The deepest chalk (204–249 m; Paleocene–early Oligocene) formed under extremely low sedimentation (~0.36 cm/kyr; Clemens et al., 2015) and intense early diagenesis, evident from overgrown nannofossils below ~110 m (Clemens et al., 2015). This interval coincided with a major deepening of the calcite compensation depth (CCD) at the Eocene–Oligocene transition, when Antarctic glaciation drove CCD depths from ~3.2 to ~4.4 km (Rea & Lyle, 2005). The result was enhanced carbonate preservation despite slow accumulation, yielding a condensed chalk layer during global CCD deepening. (2) The early Miocene chalk (142–154 m; ~19–20 Ma) reflects improved carbonate preservation under a deep CCD in an established icehouse world. Moderate biogenic productivity and minimal terrigenous dilution at U1443 maintained carbonate-rich sediments (Clemens et al., 2015), allowing thick nannofossil chalks to accumulate. This interval aligns with early Miocene oceanographic changes, including the initial restriction of the Tethyan Seaway (closure beginning in the early Miocene; Chattopadhyay et al., 2025), which altered circulation and helped sustain a deep CCD and high carbonate saturation. (3) The upper chalk (55–86 m; late Miocene–early Pliocene) records the late Miocene biogenic bloom, a period (~7–5 Ma) of surging productivity and carbonate accumulation documented globally (Diester-Haass et al., 2004). At Site U1443, elevated bioproductivity and reduced dissolution during this interval led to well-preserved chalk deposition. This timing overlaps with intensification of the South Asian monsoon in the late Miocene, which likely boosted nutrient supply and productivity (Kochhann et al., 2021), as well as broader global climatic shifts (e.g., late Miocene cooling and ocean gateway changes). Together, these three chalk intervals demonstrate how CCD fluctuations, Antarctic glaciation, seaway reconfigurations, and monsoon evolution governed carbonate deposition and diagenesis in the equatorial Indian Ocean, making Site U1443 a valuable archive of paleoceanographic change from the Paleocene greenhouse to the Neogene icehouse.

Late Holocene benthic foraminiferal response to bottom water oxygenation in the western Bay of Bengal

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Abstract

Bay of Bengal is characterized by high riverine sediment influx, strong freshwater-driven stratification, and an intense yet shallow Oxygen Deficient Zone (ODZ), making it a key region for paleoceanographic studies. To assess variations in the paleo ODZ during the Late Holocene, a preliminary multiproxy study was undertaken on a sediment gravity core (SK308 GC-13), retrieved from a depth of 260 m in the Mahanadi Basin, which spans the last ~600 years BP. Sedimentary characteristics, including coarse fraction (CF), organic carbon content (%C_{org}), and C_{org}/N ratios, were analyzed along with benthic foraminiferal assemblages. These included the Total Benthic Foraminiferal Number (TBN), morphogroups of rounded symmetrical benthic foraminifera (RSBF) and angular asymmetrical benthic foraminifera (AABF), and the relative abundances of the genera *Uvigerina, Bolivina, Bulimina,* and *Buliminella*, to infer past bottom water oxygenation. TBN, CF and RSBF exhibited similar variation, during the last ~600 yrs BP. The high CF mimicking the TBN and RSBF indicates that the coarse fraction was primarily derived from benthic foraminifera, suggesting minimal terrigenous dilution. Moreover, high RSBF can be attributed to low saline, well oxygenated bottom water suggesting the preference of high energy conditions. In contrast, AABF showed inverse relation with TBN, and was highest during the ~200-300 yrs BP. %C_{org} was positively correlated to AABF and vice versa to RSBF implying the affinity of morphogroups of AABF with high organic carbon and low bottom water oxygen conditions. Furthermore, the prominent peaks of relative abundances of *Bulimina, Bolivina, and Buliminella* within the AABF morphogroups during the last 100 yrs and between ~200 and 320 yrs BP indicate period of elevated organic carbon under low bottom water oxygen conditions in the study area. Collectively, these proxies marked a strong monsoonal influence over the last ~600 yrs BP, punctuated by a weakened phase between ~200 and 300 yrs BP, associated with sluggish bottom-water circulation. Thus, patterns of benthic foraminifera assemblages reflect episodic shifts in bottom-water oxygenation and energy conditions during the Late Holocene in the western Bay of Bengal.

Monsoon-driven paleoceanographic variability in the Northeastern Arabian Sea: Insights from planktic foraminiferal assemblages

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Abstract

The Arabian Sea plays a critical role in the climatic and oceanographic dynamics of the northern Indian Ocean, being profoundly influenced by the seasonally reversing Indian monsoon system. In order to reconstruct the paleoclimatic conditions along the western continental margin of India, a detailed micropaleontological investigation was conducted on sediment core SK- 240/505, retrieved from the northeastern Arabian Sea off the Saurashtra coast. This study primarily utilizes planktic foraminiferal assemblage data to infer variations in monsoonal wind strength and its associated impact on surface oceanographic conditions and productivity over time. The results reveal significant fluctuations in the abundance and composition of foraminiferal taxa, indicative of alternating monsoonal regimes. Periods of enhanced productivity are interpreted to coincide with intensified Northeast (NE) monsoon phases, typically occurring during winter months. These intervals likely reflect strong convective mixing and increased nutrient availability in the upper water column, leading to favorable conditions for foraminiferal proliferation. In contrast, phases dominated by the Southwest (SW) monsoon, prevalent in the summer, appear to be associated with a decline in productivity. This may be attributed to substantial freshwater influx from the nearby land, which leads to stratification of the water column and limits vertical nutrient mixing. Furthermore, the study highlights the role of monsoon-driven seasonal wind systems in modulating the regional hydrography through the regulation of the West India Coastal Current (WICC). The reversal in current direction, influenced by monsoonal circulation, alters coastal upwelling patterns and surface salinity gradients, thereby significantly affecting the ecological and biogeochemical dynamics of the region.

Calcareous nannofossil response to the Mid-Pleistocene transition in the Central South Pacific Ocean

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Abstract

The Mid-Pleistocene Transition (MPT, ~1.2–0.78 Ma) marks a pivotal climatic reorganization characterized by a shift in glacial-interglacial periodicity from a dominant 41 kyr cycle to a more pronounced 100 kyr rhythm. To investigate the biotic response to this climatic evolution, we analyzed calcareous nannofossil assemblages from International Ocean Discovery Program (IODP) Expedition 383, Site U1540, located in the central South Pacific. The study interval spans from 1.20 to 0.80 Ma, encompassing the full extent of the MPT. Six major nannofossil taxa suggest shifts in assemblage composition across key Marine Isotope Stages (MIS). Pre-MPT samples, particularly between MIS 38 and MIS 27, reveal low-amplitude 41 kyr variability, with the notable exception of MIS 31, a super interglacial marked by elevated abundance of *Gephyrocapsa spp.*, which coincides with the intensification of the Antarctic Circumpolar Current (ACC). A similar *Gephyrocapsa spp*. dominated peak is observed during MIS 19, another interglacial-maxima within the study interval. Between the two interglacial maxima (MIS 31 and MIS 19), the intervening glacial and interglacial periods are characterized by alternating dominance of *Coccolithus pelagicus*, a cold-water indicator, and other intermediate to warm-water species, reflecting shifting oceanographic conditions through the MPT. Across the MPT transglacial anomaly (0.95–0.80 Ma, MIS 24–22), a significant shift in community structure is recorded where assemblages exhibit a co-occurrence of *Coccolithus pelagicus*, with *Reticulofenestra asanoi*, a warm-water opportunistic species. This unusual assemblage mix reflects oceanographic instability associated with the Thermohaline Circulation (THC) crisis during the MPT, indicating disrupted water mass stratification and nutrient dynamics. Mixed glacial and interglacial assemblages, especially during the THC crisis, highlight the sensitivity of marine producers to rapid oceanographic transitions.

Cretaceous fossils of Trichinopoly: paleo shoreline reconstruction and basement structure analysis

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Abstract

The Cretaceous sedimentary sequences of the Trichinopoly region in Tamil Nadu, India, represent one of the most fossiliferous marine deposits of the Indian subcontinent, providing crucial insights into paleoenvironmental reconstruction and basement structural evolution. This study examines the exceptional fossil assemblages from the Ariyalur Group, investigating their significance in determining Cretaceous paleoshorelines and understanding the underlying basement rock architecture through systematic fossil distribution analysis. The Ariyalur region's remarkable fossil abundance stems from its unique paleogeographic position during the Cretaceous period, when the area experienced optimal marine conditions for fossil preservation. Unlike other contemporaneous formations in southern India, Ariyalur's exceptional exposure and fossil richness result from specific structural controls and depositional environments that favored both accumulation and preservation of marine fauna. The distinctive badland topography of Ariyalur, characterized by deeply incised ravines and exposed sedimentary sequences, provides unparalleled access to complete stratigraphic sections spanning the entire Cretaceous period. The tectonic evolution of this region is intrinsically linked to the Indian plate's northward drift from Gondwana during the Mesozoic era. The anticlockwise rotation of the Indian plate, driven by asymmetric spreading along the mid-oceanic ridges and differential mantle convection patterns, created significant structural modifications in the basement rocks. This rotational movement induced extensional stresses that developed characteristic horst and graben structures in the Precambrian basement, fundamentally controlling sedimentary basin architecture and subsequent depositional patterns. Five major transgressive-regressive cycles are documented within the Cretaceous succession, reflecting eustatic sea-level fluctuations superimposed on regional tectonic subsidence. These cyclic marine incursions and retreats created diverse depositional environments, from shallow marine carbonate platforms to deeper basinal conditions, each characterized by distinct fossil assemblages that serve as precise paleoenvironmental indicators. The spatial distribution of fossil localities correlates strongly with basement structural trends, suggesting that pre-existing fault systems controlled sedimentary facies distribution and preservation potential. Areas of maximum subsidence, typically associated with graben structures, accumulated thicker sedimentary sequences with enhanced fossil preservation, while uplifted horst blocks experienced erosion or non-deposition. Several fundamental questions remain unresolved regarding the Cretaceous evolution of Trichinopoly: the precise mechanisms controlling differential fossil preservation between Ariyalur and adjacent regions, the detailed relationship between basement structure and sedimentary architecture, and the specific paleoceanographic conditions that facilitated exceptional fossil accumulation. Future research

integrating high-resolution biostratigraphy, sequence stratigraphy, and structural analysis will be essential for comprehensive understanding of this globally significant Cretaceous succession and its implications for Indian Ocean evolution.

Paleoceanographic insights from Pteropods: Aragonite dissolution and ventilation patterns in western Bay of Bengal

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Abstract

The present study investigates the downcore variation of pteropods from the western Bay of Bengal, off Godavari River basin. Pteropods are marine gastropods with their test composed of aragonite, a metastable polymorph of $CaCO_3$ which is more susceptible to dissolution than calcite in acidic conditions. They are calcareous micro-gastropods that inhabit the pelagic zone of the upper ocean. They are highly abundant in shallow marine regions of the tropical northern Indian Ocean. The preservation and accumulation of the pteropods on the seafloor is controlled by the Aragonite Compensation Depth (ACD), intermediate water masses and associated ventilation. The Bay of Bengal hosts sediments brought by the Himalayan rivers in the north and the peninsular rivers. Along with this, it experiences seasonal reversal in the monsoon winds and surface currents. This makes the Bay of Bengal a highly stratified basin (Thermal/ Salinity). It also influences the surface primary productivity in the entire basin. Variation in the primary production leads to the development of a prominent Oxygen Deficient Condition (ODC) here, though there is a spatial distribution of ODC in the Bay of Bengal. Water studies from various workers have reported the role of tropical cyclones and mesoscale eddies in altering the ODC strength in the Bay of Bengal, the cyclonic eddies (CEs) increase the primary productivity due to upwelling, intensifying the ODC whereas anticyclonic eddies (ACEs) ventilate dissolved oxygen rich water at intermediate depths weakening of the ODC resulting in absence of denitrification in the Bay of Bengal. The results (Down core abundance of pteropods) indicate a correlation between the pteropod population and ODC strength at intermediate depths along with the monsoon strength, intermediate (oxygen) ventilation and surface primary productivity. Thus, the ODC, ACD and monsoon driven productivity have proved a phenomenal link between modern day global warming and ocean acidification.

The role of fossils as proxies in paleoclimate and paleoceanography

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Abstract

Fossils are powerful tools that provide us insights into past climatic conditions and development of ancient ocean systems. The theory of Uniformitarianism suggests that the geological processes that we observe today have also operated in the past, at essentially the same rate and intensity. Fossils, being remnants of past life, provide us evidence for various processes and events and let us compare them to modern organisms and ecosystems. The poster will cover the role of certain key fossil groups such as foraminifera, coccolithophores, and diatoms. They serve as reliable proxies for past ocean temperatures and salinity. Their chemical signatures (stable isotopes and trace elements) allow us to reconstruct fluctuations in temperature, salinity, ocean circulation and atmospheric composition spanning millions of years.

Study of benthic foraminiferal assemblages from Sushnichar, Indian Sundarbans

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Abstract

Foraminifera, single-celled marine protists, exist in almost all marine environments. Foraminifera shells are either calcareous, made of calcium carbonate ($CaCO_3$), or agglutinated, made of cemented sediment particles. The preservation of foraminifera test makes them ideal for studies on environmental monitoring. Sundarbans, with its vast, marshy deltas, is located in West Bengals southeastern region. It is home to the world's largest mangrove ecosystem, a UNESCO world heritage site. Sushnichar is a tidal floodplain with marshes and swamps, enriched with sediment. This study involved collecting 12 surface sediment samples from Sushnichars marsh zones in August 2019 and March 2020. We stained the sediment samples with Rose Bengal solution to identify living versus dead. This study aimed to assess seasonal environmental changes using species diversity, test composition, and seasonal population trends in both low and high marshy zones. The preliminary results show that the agglutinated forms are abundant with the species - *Haplophragmoides sp.*, *Miliamina fusca* and *Trochamina sp.* in the high marsh zones whereas the species of calcareous forms consist of *Cribroelpidium sp*., *Hyanesina sp*. and *Ammonia parkinsoniana* in the low marsh zones. The total foraminiferal number (TFN) is high during the months before the monsoon. The south Sushnichar site has high count of foraminifera after the monsoon. These foraminiferal assemblages serve as valuable proxies for reconstructing past climate and oceanographic conditions. Their species composition and test types reflect variations in salinity, temperature, and sedimentation, aiding palaeoclimate and palaeoenvironmental interpretations.

Theme 7

Applications of palaeobotany in reconstructing Earth's past

Against the ash: Late Maastrichtian Indian tropical flora shows high resilience to Deccan Volcanism

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Abstract

The late Maastrichtian Deccan Volcanism associated Lameta and intertrappean sedimentary deposits provide critical insights into ecosystem dynamics during. Despite their potential, interpreting biologically driven floral responses remains challenging due to stratigraphic ambiguities and a lack of high-resolution, well-dated terrestrial records. In this study, we integrate palaeobotanical, palaeoclimatic, and palaeobiogeographic evidence from pre-eruptive (Lameta) and syn-eruptive (intertrappean) deposits, supplemented by new palynological data from a magnetochron C29R sequence in Yavatmal, central India. These data reveal episodic floral turnover patterns corresponding with distinct phases of volcanic activity. We identify three ecological stages within C29R. Initial eruptions led to large-scale vegetation loss and the dominance of aquatic and herbaceous taxa in Stage I. A subsequent quiescent interval (Stage II), coinciding with India's passage through the Intertropical Convergence Zone, supported the exponential proliferation and diversification of lowland megathermal angiosperm forests under warm (~26 °C) and humid (~2270 mm MAP) conditions. Renewed volcanic activity in Stage III triggered widespread wildfires and forest knockdown. However, the resilience and recovery observed during Stage II highlight the short-term nature of volcanic ecological disruption. Palaeoclimatic trends indicate a shift from drier seasonal conditions supporting mixed gymnosperm–angiosperm communities during the Lameta phase to wetter, angiosperm dominated environments during intertrappean sedimentation. Biogeographic analysis suggests a complex interplay of floristic dispersal and endemism. Dispersals from South America and Africa via the Kohistan–Ladakh Arc likely contributed to the observed diversity, but the presence of ~41% endemic taxa underscore significant in situ radiation of tropical angiosperms. Our findings suggest that Indian late Maastrichtian vegetation exhibited high ecological resilience, shaped by multiple interacting factors: episodic rather than sustained volcanism, migration of the Indian Plate into equatorial humid zones, elevated atmospheric CO_2, legacy effects of seed and spore banks, and adaptive plasticity of angiosperms. These results emphasize the importance of Deccan

Volcanism as both a driver of ecological stress and a catalyst for evolutionary innovation in tropical plant communities.

Palaeoenvironmental reconstructions based on coralline red algae in Palaeocene-Eocene limestones of Meghalaya, northeastern India

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Abstract

Palaeocene-Eocene limestone successions outcropping in Meghalaya, northeastern India provide an excellent natural laboratory for carrying out quantitative study of various marine fossil groups and their response to climate change. In order to examine changes in shallow marine depositional environments during late Palaeocene to middle Eocene limestones in several parts of Jaintia and Khasi Hills, application of biofacies analysis is used with a detailed study of coralline red algae. Changes in the relative abundance of both non- geniculate and geniculate coralline red algae are interpreted by examining the morphometric alterations in response to the Palaeogene hyperthermals and also making comparative accounts with data from their living analogues, except the extinct forms like Distichoplax. Based on these integrated datasets, three coralline red algal associations are identified: (1) a Distichoplax-Sporolithon dominant association restricted to the upper photic zone in very warm, tropical oligotrophic environments, (2) a Mesophyllum-Sporolithon dominant meso- oligotrophic association corresponding to the upper to lower photic zone, and (3) a Lithothamnion-dominant association with high abundance of crustose coralline growth- forms associated with lower photic zone in warm tropical meso-oligotrophic environments. Three major warm intervals are recognized within the late Palaeocene to middle Eocene successions of the examined limestones in Meghalaya. The algal assemblages from different Palaeogene time slices and varying localities show considerable divergence based on factors like sedimentary regime, environmental settings, and the predominant taxa.

Early Permian palaeoenvironment and vegetation dynamics from East Bokaro Coalfield, Damodar Gondwana Basin, India: A multiproxy approach

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Abstract

The present study deals with the Early Permian floral diversity, palaeoenvironment, palaeoclimate and depositional setting using a multiproxy approach that include morphotaxonomy, palynology, and organic geochemistry of Karo OCM (Open Cast Mine), East Bokaro Coalfield, Damodar Gondwana Basin, India. The Permian sediments of peninsular India are widely regarded as fluvial, along with some marine incursions. The macroplant fossil assemblage exhibits the presence of Glossopteridales, comprising *Glossopteris*, *Gangamopteris*, and *Vertebraria*, as well as Coniferales, which includes *Noeggerathiopsis*. The palynological assemblage encompasses the dominance of the striate bisaccate pollen *Faunipollenites sp*. and the sub-dominance of the non-striate bisaccate pollen *Scheuringipollenites sp.* with Glossopterid affinities. The megafloral and palynofloral assemblage confirms the biostratigraphical age to be Upper Barakar palynoflora of Kungurian affinity. The studied morphological characteristics, including small to large *Glossopteris* leaves exhibiting a lanceolate shape, acute apices, and acute cuneate or tapering bases, as well as entire margins with narrower lamina and narrow meshes, suggest the existence of a dense forest with the prevalence of a warm and humid climate during their deposition. The organic geochemical characterization based on functional group and biomarker analyses reveals the diagenetic effects on organic matter. Aliphatic symmetric (~2865–2855 cm^{-1}) and asymmetric stretching (~2930–2910 cm^{-1}) peaks are identifiable in coal samples, whereas they are absent in carbonaceous shale. The A-factor vs. C-factor plot suggests that the kerogen type is Type III, which can generate mainly gaseous kerogen. The vitrinite reflectance studies (Rr av. 1.1%) show increased maturity of the samples, which is supported by the n- alkane distribution pattern and the absence of hopane terpenoids. The Indian floral assemblages in contemporary of southern Gondwana continents reveal a stronger inclination/affinity with the flora of Africa than that of South America, thereby supporting the age to be of Artinskian-Kungurian.

India's first green village-Khonoma, experiencing natural and human induced vegetation changes during late Holocene: An insight from palynological perspective

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Abstract

Villages in an agrarian economy like India are the prime focus points for transforming the country's developmental journey. Clean and Green villages are the key to rural development and the transformation to Viksit Bharat by 2047. Adoption of natural farming, organic farming, biogas and waste management practices can influence the circular economy in rural ecosystem and accelerate objectives of clean and green villages. Khonoma-Nagaland, a part of Indo-Malayan biodiversity hot spot region, is well known for its rich biodiversity, diverse ecosystems, and historical significance as the first green village of India, where sustainable practices are deeply rooted in the local culture. The area lies within the monsoon belt, and is characterized by a unique mosaic of tropical and temperate forest types, vegetation transitioning from grasslands and tropical broadleaf forests at lower altitudes to montane forests and temperate woodlands at higher elevations. During the past two decades the region has witnessed a change in its biodiversity and landscape due to several natural and human driver changes. Thus, there is a dire need to look for the remedial measures of conservation, restoration. This can only be achieved by understanding the pattern of climate-vegetation-human relation at spatial and temporal scale. Thus, to understand the extant and extinct state of vegetation climate relationship and extent of humans' influence on natural environment, surface and sub surface samples were analyzed. Palynological investigation carried out from surface samples sediments, moss cushion, honey samples etc broadly shows distribution of present day vegetation viz., pollens of *Alnus, betula*, *Rhododendron*, *Prunus*, *Shorea robusta*, *Pterocarpus*, and *Dipterocarpus* wild and cultivated Poacaea memebers, Chenopodiacae and Asteraceae were found in dominance along with non-pollen palynomorphs like *Glomus*, *Sordaria, Gelasinospora*, *Nigrospora* etc with micro charcoal of varying size suggesting fire activity in and around the study site. Palynological analysis of sub surface sediment samples of a 100cm trench from Khonoma village shows four phases of vegetation and climatic shift during the last 1342 cal yr BP. The first zone covered the period from 1351 -1305 cal yr BP. In this zone initially the recovery of pollen taxa was not good but further amelioration in climatic conditions resulted in increase in pollen taxa suggesting a cooler and drier climatic conditions prevailing in the region. Further, in the zone-II extending from 1282 to 1159 cal yr BP an increase in the arboreal pollen (trees+shrubs) viz., *Alnus, Betula*, *Myrica*, Rutaceate, Rosaceae, *Prunus, Quercus* and *Pinus* and an increase in the micro charcoal concentration indicating towards good monsoonal conditions. In the zone-III extending from 1159-683 cal yr BP there was a decline observed in the arboreal taxa while an increase in the non-arboreal period suggesting a period of decreased rainfall and drier condition. Even a decline in the representation of

non-pollen palynomorphs also supports similar conditions. In the zone IV, from 683 cal yr BP to present, initial period from 683 cal yr BP a decline in the aquatic taxa, disappearance in the testate amoeba ferns and arboreal taxa was noticed along with the rise in the representation of pollens of cultivated plants indicating favorable conditions for their growth. A good recovery of micro-charcoal suggests a recent fire activity in the vicinity of the study area. Further ahead around 383 cal yr BP onward the arboreal taxa (grasses) increased, rise in the representation of pollens of cultivated taxa and an increase in micro-charcoal pieces (100µ) suggest human interference in the environment in the form of slash and burn, agriculture etc.

Was the Little Ice Age reflected in Equatropical Regions? Multiproxy evidence from the southwest coast of India

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Abstract

A multi-proxy analysis of a 70 cm sediment core retrieved from Mundrothruthu (MT) in the Ashtamudi wetland, Kollam, Kerala, southwest India, reveals three distinct climatic phases spanning the Little Ice Age (LIA). The first phase (1507–1518 CE) is marked by elevated agricultural activity, evidenced by high diatom diversity, enhanced terrestrial input, and significant freshwater runoff. Elevated total organic carbon (TOC%) and more negative $\delta^{13}C$ TOC values suggest increased organic matter influx under warm and humid climatic conditions, likely driven by intensified terrestrial runoff. The second phase (1519–1548 CE) reflects a transition to increased marine influence, as indicated by a rise in marine palynomorphs, higher mud content, mixed terrestrial-marine organic matter, and less negative $\delta^{13}C$ TOC values. This shift may correspond to changes in sea level or intensified tidal activity. The final phase (1548–1804 CE) is characterized by further enhancement of marine indicators, a decline in TOC%, and more depleted $\delta^{13}C$ TOC values, consistent with a reduction in atmospheric CO_2 concentrations and a ~1°C decline in temperature. This cooling trend is likely linked to reduced solar insolation and a southward displacement of the Intertropical Convergence Zone (ITCZ). The findings suggest a transition from warm, humid, and agriculturally productive conditions to increasingly marine-dominated environments, reflecting both local hydrodynamic changes and broader global climatic shifts. The study underscores the complex and potentially asynchronous climate behavior of the southwest Indian coast in relation to global LIA dynamics.

Report of *Desmiophyllum* from Lower member of Bhuj Formation (Early Cretaceous) of Kachchh Basin, Western India

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Abstract

A fossil leaf assigned to the genus *Desmiophyllum* (Lesquereux, 1878) emend. Miller et Hickey, 2010, has been discovered in a sedimentary bed of the Bhuj Formation of Early Cretaceous age located in the southern part of the Tapkeshwari Section of the Kachchh Basin, western India. The specimen occurs within a sandstone unit of Bhuj Formation of Early Cretaceous age. This fine-grained sandstone exhibits an interlaminated structure characterized by flaser and lenticular bedding, based on alternate sand and mud layers. Symmetrical ripple marks are also seen. The sequence of this area shows a coarsening upward or thickening upward trend, marked by high energy sedimentary features such as steeply inclined trough cross- stratification and herringbone cross-stratification, which is an indicative of tidal influenced depositional environment. The presence of skolithos is also noted in the sequence. In some areas, where sedimentation was limited, these trace fossils formed colonies within the intercalated sandstone and shale units. The leaf fossils are found as isolated specimens. Some fragments are relatively large and display well-preserved, intact margins, while others are poorly preserved. Notably, intermediate veins are absent in fossil specimens. There are only parallel thick veins which show the resemblance of leaves from *Desmiophyllum* type 1 from Galve locality of Mexico which is of Early Barremian age (Luis M. Sender, 24). These are detached and ribbon-shaped leaves of approximately 4.3–7.5 cm in width and 18.9–24.5 cm in length, with rounded to obtusely pointed apices and tapering base. The venation is dense (8-10 veins per cm), consisting of numerous simple, unbranched, parallel veins denoting a reduction or carbon-di-oxide rich environment. The leaf surface is marked with linear striations and lacks a distinct mid rib. The present specimens can be readily distinguished from the Indian Jurassic species *D. indicum* by their elongated, ribbon-shaped morphology and the significantly higher number of parallel, predominantly simple veins. On other hand in terms of their bluntly rounded apices and linear, elongate shape, these leaves bear resemblance to certain specimens identified as *Phoenicopsis elongatus* from Mesozoic deposits of South Africa (Seward, 1903), Australia and Tasmania (Walkom, 1917, 1925), and Argentina (Kurtz, 1921). While the veins in these specimens are mostly parallel, occasional evidence of vein dichotomy is observed, distinguishing them from true *Phoenicopsis*. These leaf fossils provide concrete evidence of onset of Bhuj formation of Early Cretaceous.

Late Holocene climatic changes and anthropogenic activities in the higher-western Himalaya, India: Palynological implications

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Abstract

The high-altitude Himalayan regions serve as excellent natural archives for studying Holocene climate variability and anthropogenic activity, as the relatively pristine environment preserves the signatures of climatic changes and human impact exceptionally well. Studies on past climatic changes are important because these help us to understand how the different components of the climate interact with one another and how our climate might change in the future as a result of natural and human-induced forcings. The present work is from the Chopta-Tungnath region, Uttarakhand, Western Himalaya; characterised by temperate mixed forests and alpine meadows. The development of modern analogues has been done by the surface soil samples that were collected along an altitudinal transect (2700-3680 m). This was primarily undertaken to interpret how well the surrounding vegetation is represented in the pollen records, or not. The palynological assemblages revealed relatively high frequencies of arboreal (trees and shrubs) pollen over the non-arboreals (herbaceous taxa), along the altitudinal transect, and show an over-representation of extra-local Pinus pollen, across all the vegetation zones. Based on available radiocarbon (^{14}C) dates, climate fluctuations during the Late Holocene (around 5070 yr BP) have been inferred through variations in the ratio of arboreal to non-arboreal pollen (AP/NAP). Interpretation of the palynological data, in the Higher Himalayan region, is based on the basic principle fact that high AP/NAP ratio indicates the warm and humid conditions, while low AP/NAP ratio reflects cold and dry climatic conditions. The palaeopalynological assemblages from the Chopta-Tungnath region have not only recorded the Late Holocene climatic and vegetation changes, but also identified the impact of anthropogenic activities. The evidence of human impact in the region is manifested by the rapid increase in the frequency of Asteroideae and Cichorioideae pollen, the declining trend of Quercus and Rhododendron taxa and presence of coprophilous (dung-loving) fungi in the palynological assemblages of sub-surface sediments.

Floral diversity of the Devonian and Carboniferous successions of the Spiti Basin, Himachal Pradesh, India: Biostratigraphical, phytogeographical and palaeoenvironmental implications

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Abstract

Spiti Basin (Himachal Pradesh) along with Zanskar Basin (Ladakh) constitutes the largest marine sub-basin of the Tethyan Himalayan Basin and is the repository of excellent and complete successions of Palaeozoic Era. Study of late Palaeozoic sequences is of great interest as it provides insights into the evolution and subsequent diversification of various floral groups. The present paper focuses on the floral diversity of Devonian and Carboniferous sequences (Lipak, Po and Ganmachidam formations) of Spiti Basin and their biostratigraphical, phytogeographical and palaeonvironmental significance. While, several studies have reported faunal biodiversity from these sequences, the studies pertaining to plant remains both macro- and mioflora are meagre. The palynological study of Lipak Formation, exposed around Loasr village has revealed dominance of spores- Verrucosisporites, Dictyotriletes, Lophozonotriletes, Convolutispora followed by subdominance of Rugospora, Cymbosporites and Knoxisporites along with reworked pollen grain Plicatipollenites. The procured palynoassemblages are corroborated with Retispora lepidophyta-Verrucosisporites nitidus (LN) and Vallatisporites verrucosus-Retusotriletes incohatus (VI) Assemblage zones of Western Europe and Cordylosporites-Verrucosisporites Biozone of Argentina which indicates that studied section of the Lipak Formation is upper Famennian to early Tournaisian in age. Spores have affinities with Zygopteridiales, Marattiales, Botryopteridales, Equisetales/Sphenophyllales group of plants. A rich and diversified macro and miofloral remains have been recorded from the Lower Carboniferous Po Formation. The macrofloral assemblage comprises *Triphyllopteris peruviana*, *Nothorhacopteris* (Rhacopteris) *kellaybelenesis, Fryopsis sp.*, *Sphenopteris cf. elegans*, *Flabellofolium sp*., *Archaeocalamites*, and *Diplothemema sp*., along with some undetermined poorly preserved fronds, conifers shoots and stem axes/rachis. Phytogeographically the procured fossil floral remains are of Visean to Serpukhovian in age, with other Gondwanan floras of this age and flora that existed on the shores of the Palaeotethys that have been assigned to the Paraca floral realm, and are taken to indicate relatively warm climatic conditions that existed just prior to the onset of the Carboniferous–Permian ice-age. Palynological studies of the sequences belonging to Po Formation exposed near Tabo, Losar and Poh villages have revealed well preserved and diversified palynoflora. The palynofloral composition comprises predominantly trilete spores (Dictyotriletes, Vallatisporites, Prolycospora, Calamospora, Spelaeotriletes, Cyclogranisporites

and Verrucosisporites) and monosaccate pollen grains (Potonieisporites, Plicatipollenites and Cannanoropollis). These assign the age bracket of the Po Formation within Viséan to Serpukhovian (early Carboniferous) age. Palynological analysis of a sequence of Ganmachidam Formation exposed in Lingti valley has yielded excellent mioflora; which was hitherto considered as unfossiliferous, and has been subject to contentious age assessment. Palynocomposition shows dominance of monosaccate pollen grains, namely Parasaccites, Crucisaccites, Divarisaccus, Maculatasporites, followed by diverse bisaccate pollen grains mainly Scheuringipollenites, Crescentipollenites, Faunipollenites and the spores Callumispora and Calamospora along with woody fragments and fungal spores. Based on the recovered palynoassemblages, detailed palynocorrelation, the palynostratigraphic status of the studied section of Ganmachidam Formation has assessed to be of late Pennsylvanian to Early Permian. Occurrences of palynomorphs from the Carboniferous sequences having a glossopterid affinity further strengthen the idea that glossopterids might have originated in Carboniferous time. Additionally, the rich floral diversity during early Carboniferous led to envisage excellent growing conditions for abundant and luxurious pteridophytes; and reasonable decrease in the spore diversity with frequent occurrence of monosaccate pollens Serpukhovian onwards, indicate that the palaeoclimatic conditions became relatively drier.

Quaternary palynological studies from the Higher and Trans Himalaya: Implications and applications

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Abstract

The great Himalayan range is unique due to its climatic, topographic, geological and altitudinal variations. The Higher Himalaya is affected by both the Indian Summer Monsoon (ISM) and Western Disturbances (WDs), whereas the Trans Himalaya is mostly arid and under the influence of the WDs. Palynology, the science of pollen and spores, has proved to be an indispensable tool for Quaternary climatic reconstructions, especially in the terrestrial realm. Pollen-spores are produced in bountiful abundance and are readily preserved in the sediments. Owing to their characteristic morphological features, pollen-spores can be readily linked to respective plant groups, and thereby represent the vegetation growing at a particular point of time. Palynological analysis provides the basis for temporal and spatial vegetation reconstruction and significantly helps in understanding the long term climatic changes. Palynological studies have been carried out from the Higher and Trans Himalayan regions of Western Himalaya (Hamta Glacier: Lahaul-Spiti; Chopta-Tungnath and Kedarnath: Uttarakhand) to reconstruct the vegetation and deduce the concurrent climatic changes during the Holocene. To understand the pollen-vegetation relationship, palynology of the surface soil samples was undertaken, to develop the modern analogues for a better interpretation of the sub-surface fossil pollen assemblages. Different climatic phases have been reconstructed, based on the changing frequencies of arboreal and non-arboreal pollen (AP/NAP ratios). The global Holocene climatic events, such as the Holocene Climatic Optimum, 4.2 ka event, Roman Warm Period, Dark Ages Cold Period, Medieval Warm Period, Little Ice Age and Current Warm Period are well marked in the studies undertaken. Other than climatic reconstruction, palynological records have also provided insights about the human activities in the respective study areas. In this regard, the increased/decreased frequencies of certain pollen taxa, anthropogenic pollen indicators (API) and coprophilous (dung) fungi have shed light on the inception, intensification and impact of anthropogenic activities in the high-altitude regions.

Palaeoenvironmental and biostratigraphic significance of Microbial-Induced Sedimentary Structures (MISS) of the Semri Group, Vindhyan Supergroup

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Abstract

The unmetamorphosed sedimentary rocks of the Vindhyan Supergroup preserve a broad array of palaeobiological signatures, including microfossils, macrofossils, and organo-sedimentary structures. These fossils have served as crucial indicators for constraining both the age and the palaeodepositional history of the Vindhyan succession. Numerous microfossil types have been documented from both argillaceous and carbonate lithologies of the Vindhyan Supergroup. In this study, a diverse range of Palaeoproterozoic microbial-induced sedimentary structures (MISS) have been identified within the Rohtashgarh Limestone Formation of the Semri Group. The biostratigraphic implications of the MISS assemblages and their significance in understanding depositional environments are analyzed. The Proterozoic biosphere was primarily composed of microorganisms, and the fossil record from this era is dominated by stromatolites (finely laminated organo- sedimentary structures), resulting from microbial mat activity that facilitated sediment binding and carbonate precipitation. In the Precambrian, these microbial mats colonized most surfaces in the absence of grazing or competing organisms, as evidenced by widespread stromatolites and microbial laminites in carbonate successions A broad spectrum of Mat-Induced Sedimentary Structures (MISS) have been reported (Noffke et al., 2001; Schieber, 2004), which are sometimes complex and may be mistaken for trace fossils (Seilacher, 1999). The abundance of these structures in Proterozoic sequences introduces a unique perspective to the field of biosedimentology. These MISS are formed through the interaction of microbial processes with physical sedimentary dynamics, and their morphology is governed by parameters such as: intrinsic biological properties, microbial responses to physical disruption of substrates, sediment trapping and binding, secondary deformation of biogenic structures, post-burial modification, and potential bioturbation or grazing. Unlike stromatolites, microbial mats exhibit distinct features due to their unique microbe-physical formation mechanisms, and thus are categorized separately among primary sedimentary structures. MISS were recorded in the sandstone sequences, but the microbial buildups in the Lower Vindhyan carbonates have received limited attention in previous research. Earlier studies have primarily described stromatolites in the Kajrahat and Salkhan Limestones of the Semri Group, with no such structures documented in the Rohtasgarh Limestone. This study aims to fill that gap by documenting microbial features within the Rohtasgarh Limestone exposed in the Maihar region of Madhya Pradesh and Rohtas district in Bihar. These structures, formed through the interaction of microbial mats with sedimentary

processes, offer crucial insights into the palaeoenvironmental conditions of the Palaeoproterozoic Era. This study investigates the distribution, morphology, and types of MISS identified in key outcrops of the Semri Group, including wrinkle structures, mat cracks, and microbial laminites. Through detailed field observations and petrographic analyses, we infer that these structures developed in shallow marine to intertidal settings under low-energy depositional regimes. The presence of MISS in the Semri Group has significant biostratigraphic implications, as it provides indirect evidence of microbial life in pre-Cambrian ecosystems, aiding in the reconstruction of early biospheric conditions. Moreover, the spatial and stratigraphic occurrence of MISS contributes to refining the depositional history and stratigraphic correlation within the Vindhyan Basin. This research enhances our understanding of early Earth surface processes, microbial-sediment interactions, and the environmental conditions that prevailed during the early Proterozoic. This research enhances our understanding of early Earth surface processes, microbial-sediment interactions, and the environmental conditions that prevailed during the early Proterozoic.

Palaeofloristic studies from the early Permian Barakar sediments of Singrauli Coalfield, Son Basin, India

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Abstract

The present study deals with the reconstruction of early Permian floral diversity, palaeoenvironment, palaeoclimate and depositional setting using a multiproxy approach involving morphotaxonomy, palynology and FTIR analysis of a coal bearing sequence of Jayant Colliery, Singrauli Coalfield, Son Basin, India. The megafloral assemblage is of low diversity is characterized with the presence of only two groups, i.e. *Glossopteridales and Equisetales,* represented by leaf forms of *Glossopteris*, scale leaf-Pantolepis and stem axes- Paracalamites respectively. The genus Glossopteris is represented by thirteen species namely *G. arberii, G. communis, G. emarginata, G. gigas, G. indica, G. major, G. mohudaensis, G. nautiyalii, G. recurva, G. spatulata, G. stenoneura, G. tenuifolia and Glossopteris sp.* Most of these species have narrow to intermediate meshes which indicate prevalence of warm and humid climatic condition with sufficient sunlight. The palynological analysis has revealed only one assemblage, having the dominance of the non-striate bisaccate pollen Scheuringipollenites and the sub-dominance of the striate bisaccate pollen Faunipollenites; The assemblage is equated with Scheuringipollenites barakarensis palynoassemblage of the lower Barakar Formation. The palyno composition have affinities with Glossopteridales, Cordaitales and Coniferales. The megafloral and palynofloral composition elucidates the biostratigraphical age as early Permian (Artinskian). The Glossopteris leaf of various size along with other floral entities from a terrestrial ecosystem suggest the preponderance of small to large size deciduous trees with annual leaf fall and providing organic detritus for peat formation during Artinskian age. The FTIR study also reveals that sediments contain quartz and clay minerals with some organics representing fluvial sedimentation during lower Permian.

Pollen-based reconstruction of Late Holocene vegetation and climate dynamics in Bhandavgarh Tiger reserve, Central India

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Abstract

A comprehensive understanding of the ecology and the concurrent climate dynamics over the past ca. 2600 cal yr has been proposed from the Bhandavgarh National Park, Umariya District in Madhya Pradesh, central India, using pollen as a proxy. The climate during this period exhibited varying characteristics, initially being warm and humid with more precipitation between 2600-2400 cal years BP, recording a. high density of mixed forest types, with intermittent grasslands and other herbaceous comprehensive palaeoecological reconstruction of vegetation and climate dynamics over the past ~2600 calibrated years before present (cal yr BP) has been carried out from Bhandavgarh National Park, Umariya District, Madhya Pradesh, central India, using fossil pollen analysis. The study reveals significant shifts in ecological and climatic conditions driven by variability in the Indian Summer Monsoon (ISM). Between 2600–2400 cal yr BP, a warm and humid climate with enhanced precipitation supported dense mixed forests interspersed with grasslands and herbaceous elements, suggesting a moderately strong ISM. A notable climatic transition occurred thereafter, with the period 2400–350 cal yr BP characterized by reduced humidity, punctuated by a brief wet phase between 1950–1850 cal yr BP. This interval witnessed the dominance of *Shorea robusta*-led wet deciduous forests, indicating a stronger and more reliable ISM, aligning with the Roman Warm Period. From ~1850 to 1170 cal yr BP, the expansion of grasslands and mixed deciduous taxa marks a weakening ISM phase, synchronous with the Dark Ages Cold Period. A subsequent climatic shift between 350 cal yr BP and the present reflects a return to warm and humid conditions, with increased monsoonal rainfall—likely corresponding to the Medieval Climate Anomaly. This high-resolution pollen record underscores the sensitivity of central Indian ecosystems to monsoon variability and offers valuable insights into long-term climate-vegetation interactions.

Deciphering Holocene fluvial dynamics and environmental shifts in Majuli Island, Assam (Indo-Malayan region) through palynofacies and grain size analysis

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Abstract

Majuli Island, the world's largest inhabited river island situated in the Brahmaputra River of Assam, India, presents a unique setting for palaeoenvironmental and flow regime reconstruction. Owing to its geomorphologically dynamic and ecologically sensitive nature, the island offers valuable insights into past climatic and depositional processes shaped by the fluvial dynamics of the Brahmaputra and its tributaries. This study focuses on a 2 m deep sedimentary sequence from the Lohit River section of Majuli Island in the Upper Brahmaputra Valley. Through multiproxy analysis—primarily palynofacies and grain size, we investigate temporal patterns of organic matter deposition and preservation to unravel the depositional history over the past ~13,880 calibrated years BP. Palynofacies analysis, which evaluates the composition and preservation state of organic matter (phytoclasts, palynomorphs, and amorphous organic matter or AOM), is employed to overcome the biases associated with pollen/spore-based reconstructions, especially in highly dynamic fluvial environments. These proxies not only reflect source vegetation but also respond sensitively to transport, oxidation, and degradation processes after deposition. CONISS (Constrained Incremental Sums of Squares) cluster analysis delineates five distinct palynofacies zones. Notably, the most recent phase (2940 cal. yrs. BP to Present) exhibits higher degrees of degradation and alteration, likely reflecting intensified anthropogenic and hydrological disturbances. In contrast, the earliest phase, corresponding to the onset of post-glacial warming (~13,880–12,730 cal. yrs. BP), shows relatively well-preserved organic components, indicating minimal human interference and more stable depositional conditions. Grain size data, analyzed alongside palynofacies through Principal Component Analysis (PCA), further elucidate sedimentary energy regimes across these zones. Zone I (13,880–12,730 cal. yrs. BP) displays poorly sorted fine to medium sands with skewed distributions, suggesting moderate to slightly higher energy conditions typical of braided channel systems. Zone II (12,730–6,300 cal. yrs. BP) marks a transition to lower energy conditions, characterized by dominant fine silt and very fine sand. Zone III (6,300–4,500 cal. yrs. BP) reveals a peak in energy, indicated by the prevalence of coarse sand, poor sorting, and leptokurtic to platykurtic distributions. Zone IV (4,500–2,940 cal. yrs. BP) again reflects mixed but slightly stagnant conditions, followed by further energy fluctuations in Zone V (2,940 cal. yrs. BP to Present), which includes mixed muddy-sand deposits, possibly linked to increased human impact and changing hydrodynamics attested with palynofacies data. Overall, the sedimentary archive from Majuli Island reveals alternating phases of energetic fluvial activity and relative quiescence, intricately linked with shifts in climate and human-environment interactions. These findings contribute significantly to our understanding of Holocene

depositional environments in the Brahmaputra floodplain and provide a valuable palaeoecological framework for managing the island's fragile geomorphic system under modern climatic stressors.

Lessons from floral turnovers across the early Paleogene hyperthermal events

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Abstract

The Indian plate exemplifies a drifting, isolated island continent moving through the equatorial zone during the Palaeocene–Eocene. Its collision with the Eurasian plate significantly impacted global climate and was crucial in shaping biodiversity and biogeographic patterns. Alongside geodynamic activity, the several hyperthermal events of the early Paleogene promoted widespread growth of tropical plants and animals across the Indian subcontinent. Although the Palaeocene–Eocene interval has been widely studied in mid- and high-latitude regions, data from low equatorial latitudes are still comparatively scarce. In this context, the age-constrained lignite deposits and associated sedimentary sequences of western India provide a valuable archive for examining climate-vegetation dynamics in equatorial regions. Using palynological data and isotopic analyses, the study identified several major Paleogene hyperthermal events—including the Eocene Thermal Maximum 2 (ETM-2), the Early Eocene Climate Optimum (EECO), and the Middle Eocene Climate Optimum (MECO)—and reconstructed regional palynofloral turnovers, ecological transitions, and hydrological shifts associated with these events. During ETM-2 (~53 Ma) and MECO (~40 Ma), decreased average annual rainfall and prolonged dry periods led to a shift in vegetation from evergreen forests to more drought-resistant, deciduous communities. Possibly, brief periods of increased atmospheric CO_2 levels triggered the hydrological cycles, evidenced by greater seasonal rainfall fluctuations and an increase in deciduous plant species. In contrast, the EECO (~52–49 Ma) marked an extended period of warm and humid conditions under high CO2 levels that supported the luxuriant growth of tropical evergreen forests, which were characterised by megathermal families such as Arecaceae, Bombacaceae, Ctenolophonaceae, Dipterocarpaceae, and Meliaceae. The study is indicative of the extensive expansion of evergreen tropical flora, highlighting a divergence in floristic resilience between short-term hyperthermals and sustained warming phases. The study highlights India's role as a natural laboratory for examining the impacts of global warming on the tropical floral biodiversity and ecological shifts during the early Paleogene, offering valuable analogues for contemporary climate change scenarios.

Tree-ring inferred drought records from cold-arid Lahaul-Spiti, Himachal Pradesh, western Himalaya

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Abstract

Lahaul-Spiti is a cold desert region in the north-western part of Himachal Pradesh. Over the Lahaul Himalaya, 2/3rd of the annual precipitation occurs due to western disturbances (winter monsoon) from December to April. Thus, the failure in precipitation during winter causes drought conditions over the region. Tree-ring samples of Himalayan cedar (*Cedrus deodara*) and Himalayan pine (*Pinus wallichiana*) were collected from seven open forest sites in Lahaul-Spiti, Himachal Pradesh. All the samples were analysed together, and a multi-century-long moisture-sensitive regional chronology was developed. Using an annually resolved, well-replicated tree-ring chronology, the robust 11-month Standardised Precipitation Index of July (SPI11-July) was reconstructed and extended back to the mid-fifteenth century. The most important finding of the reconstruction is extensive drought conditions during the Little Ice Age. The extreme annual drought was recorded in 1626, followed by 1554, 1705, 1971, 2008, and 1785, and the wetting phase was recorded in the later part of the reconstruction. Extreme droughts and pluvial phases in the reconstruction are comparable to other hydrological reconstructions across the western Himalaya. Such drought reconstruction from the data- scarce cold desert region is significant for understanding climatic upheavals and the agrarian economy in the long-term perspective.

Paleoclimate reconstruction of the Heruka Sector, Birbhum, west Bengal during the Late Paleocene–Early Eocene: evidence from palynological Studies

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Abstract

The palynological investigation of lignite-bearing clay sequences from the Heruka sector, part of the Rajmahal–Birbhum Master Basin offers an insight into the paleoclimate and depositional settings prevailing during the Late Palaeocene to Early Eocene time period in the study area. Subsurface samples from two boreholes, BHK-6 and BHK-7, were studied to characterize the palynofloral assemblages retrieved from the undifferentiated Cenozoic sediments present above the Rajmahal Trap formation. A total of 20 palynologically productive core samples yielded diverse spore-pollen assemblages. Across both boreholes, a total of 39 angiosperm species (23 genera) and 12 pteridophyte species (8 genera) were recorded, with members from plant families like Arecaceae, Liliaceae, Clusiaceae, Euphorbiaceae, Schizaeaceae and Polypodiaceae being prominent. Fungal remains and dinoflagellate cysts (*Oligosphaeridium, Operculodinium, Cordosphaeridium*) were also identified. In borehole BHK-6, 63% of total recovered palynomorphs belong to angiosperm pollen grains. Dominance of angiosperm pollen of Arecaceae and Gunneraceae family like *Proxapertites*, *Tricolporopollenites* and *Tricolpites* has been identified. Pteridophytic spores viz. *Todisporites*, *Laevigatosporites*, and *Dandotiaspora* of Osmundaceae, Polypodiaceae and Matoniaceae family and fungal remains (*Inapertisporites, Notothyrites*) with dinoflagellate cysts (*Oligosphaeridium*) have been recorded. Angiosperm plants having affinity with the Arecaceae (*Proxapertites, Spinizonocolpites, Longapertites*) and Clusiaceae (*Polybrevicolporites*) family were the main contributor in the recovered palynoflora from borehole BHK-7. Presence of pteridophytic plant families like Schizaeaceae (*Lygodiumsporites*), Polypodiaceae (*Polypodiisporites*) and Cyatheaceae (*Cyathidites*) were also marked. In this borehole, fungal remains were represented by *Monoporisporites* and *Inapertisporites*. Based on floristic dominance and stratigraphic positioning from older to younger, three major palynoassemblage zones were classified. Assemblage Zone I is characterized by *Proxapertites*, *Longapertites*, *Margocolporites*, *Palmaepollenites*, and *Spinizonocolpites*, indicative of warm, humid lowland rainforests dominated by Arecaceae and other tropical angiosperms. Assemblage Zone II reveals abundant pteridophytic spores such as *Lygodiumsporites* and *Cyathidites*, suggesting a more hydrophilic vegetation cover linked to fern-dominated swamp habitats. Assemblage Zone III is dominated by fungal spores (*Inapertisporites, Monoporisporites*) and amorphous forms like *Notothyrites*, which indicates forest litter and epiphytic fungal activity under high humidity. Presence of dinoflagellate cysts in the identified assemblage, points towards a near-shore depositional setting with an irregular marine influence. The dominance of tropical-subtropical floral taxa, high diversity of fern spores, and presence of mangrove-related elements

altogether suggest a humid megathermal climate with high precipitation and proximity to coastal environments that prevailed during Late Paleocene-Early Eocene in the study area.

Macrofloral diversity from the Talchir Formation, Son Basin, India: biostratigraphical and palaeoenvironmental implications

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Abstract

The lowermost non-coaliferous sedimentary unit of the Lower Gondwana Group, Talchir Formation, holds vital importance for understanding the evolution and spread of the Glossopteris Flora across Gondwanan continents. Following the Carboniferous deglaciation, this distinct flora emerged during the beginning of the Permian in high southern palaeolatitudes. In India, this flora is widely distributed in the Permian successions of Peninsular regions and occurs sporadically distributed in extra Peninsular (Himalayan) regions. Therefore, the floral evidence from the Talchir Formation is essential for tracing the early evolution and diversification of Glossopteris Flora. The present study investigates the early Permian floral diversity, palaeoenvironment, and palaeoclimatic conditions as interpreted from the Talchir deposits of the Chirmiri area, Son Basin, Chhattisgarh, India. A rich and diverse macrofloral assemblage has been procured from the reddish siltstone and grey shale units of two sections of the Talchir Formation, representing the largest floral assemblage documented so far, from this formation. The recovered floral assemblage is dominated by Cordaitales (*Noeggerathiopsis* and *Euryphyllum*), followed by Equisetales (*Paracalamites*), and Glossopteridales (*Gangamopteris, Glossopteris*, scale leaves, and seeds). The prolific occurrence of Cordaitales suggests that this plant group, alongside glossopterids, thrived on elevated terrains during the early Permian. The characteristic *Euryphyllum-Noeggerathiopsis-Gangamopteris* assemblage indicates that the studied strata belong to the Upper Floristic Zone of the Talchir Formation, equivalent to the Rikba beds, and is Asselian in age. Moreover, the presence of thick reddish siltstone units suggests the development of localized 'Red Beds', indicating a climatic shift from cool-humid to more arid conditions. The recovered floral assemblage has been correlated with coeval floras from other parts of India and Gondwanan continents to better understand the palaeogeographic distribution of these plant groups. Overall, the floral composition reflects the existence of a terrestrial marshy ecosystem under cooler climatic conditions during the early Permian.

Early Paleogene Figs: A paleobiogeographically significant and a pre-eminent model for deep time climate-vegetation relationships

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Abstract

Ficus (Moraceae) is a diverse woody plant genus found in all lowland tropical rainforests encompassing ~750 species of what are commonly called, and are grouped into six subgenera *Pharmacosycea*, *Sycomorus*, *Sycidium*, *Ficus*, *Synoecia* and *Urostigma*. To date, fossils belonging to *Ficus* have been retrieved from Asia, Europe, Africa, and America and are interpreted to have had either Eurasian (around the Tethys Seaway) or Gondwanan origins (primarily on the Indian subcontinent). We report the well-preserved foliage of three fig (*Ficus*) species from the late Paleocene-early Eocene succession of the Gurha Mine, Bikaner, Rajasthan (India), inferring their systematic relationship and their relevance to the evolution and diversification of the modern genus *Ficus*. The present study supports a Eurasian origin for figs, and it also suggests the Indian subcontinent was an integral part of fig diversification during their early contact phase with Eurasia. These new fossils show that *Ficus* was well established in South Asia by the early Paleogene, and has inhabited low latitude areas since then. In the light of recent findings, along with earlier recorded fossils of *Ficus*, we trace the evolution and paleo-dispersal pattern of this genus. Together with other elements described from the Gurha lignite mine, a humid tropical forest is reconstructed in the region during early Paleogene time.

Plant fossils trace the role of Himalayan uplift and climate change in shaping Western Ghats endemism

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Abstract

The Western Ghats of peninsular India are renowned for their exceptional levels of plant endemism, yet the deep-time evolutionary and biogeographic drivers of this biodiversity are not fully understood. Endemism, shaped by long-term geological and climatic transformations, defines many of the world's biodiversity hotspots. Fossil discoveries from these regions offer crucial insights into the evolutionary history and past distribution of endemic taxa. A recent finding from the late Oligocene (~24 Ma) sediments of the Makum Coalfield in Northeast India has revealed exceptionally preserved fossil leaves assignable to the genus *Nothopegia* (Anacardiaceae). These fossils represent the earliest known global record of the genus and show remarkable morphological affinities with two extant species—*Nothopegia travancorica* Bedd. Ex Hook.f. and *N. castaneifolia* (Roth) Ding Hou —which are now restricted to the tropical evergreen forests of the southern Western Ghats. Paleoclimatic and paleolatitudinal reconstructions suggest that during the late Oligocene, Northeast India had an equable, perhumid climate, closely resembling present-day conditions in the Western Ghats. This would have supported thermophilic taxa such as *Nothopegia*. However, subsequent Himalayan orogeny and associated climatic shifts—particularly a sharp decline in cold month mean temperatures (CMMT)—rendered much of northern and northeastern India inhospitable for such taxa. As a result, *Nothopegia* populations became extinct in the northeast, surviving only in the climatically buffered refugia of the southern Western Ghats. This discovery adds to growing palaeobotanical evidence for deep-time floristic connectivity between Northeast India and the Western Ghats, likely maintained by Paleogene evergreen forest corridors. It highlights the pivotal role of geological processes and climate change in driving biotic contractions, extinctions, and modern patterns of endemism in South Asia. Moreover, the findings underscore the significance of fossil data in identifying ancient refugia and informing conservation strategies for relictual and range-restricted taxa under current and future climate change scenarios.

Echoes of deep time: Pollen and fossil records from the Jaisalmer Basin

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Abstract

The Mesozoic sedimentary successions of the Jaisalmer Basin, spanning from the Early Jurassic to the Early–Middle Albian, are stratigraphically divided into the Lathi, Jaisalmer, Bhadasar, Pariwar, and Habur formations. Fossil and rock samples were collected from 14 stratigraphic sections across these formations, including Nara Singh Ki Dhani, Tamira Rai Temple, Bhojka, Suleiman Pir, Thaiat Ridge, Rewata Singh Ki Dhani, Badabag, Bhilo Ki Basti, Kuldhar Nala, Bhadasar Ridge, Mokal Nala, Serawa, Kanoi Fault, and Habur- Kuchri Road sections. Among these, the Tamira Rai Temple (Lathi Formation), Bhadasar Ridge and Mokal Nala (Bhadasar Formation), and Serawa (Pariwar Formation) sections yielded significant palynological and megafossils data. Palynofacies analyses identified two assemblages (PA-I and PA-II) in the Tamira Rai Temple, Bhadasar Ridge, and Mokal Nala sections. These assemblages are characterized by a dominance of opaque phytoclasts and limited amorphous organic matter, indicating marginal marine depositional environments with strong terrestrial input. PA-II in Mokal Nala also shows signs of a shallow marine, low-energy environment, based on preserved palynomorphs and trace fossils. Palynomorph analysis from the Bhadasar Ridge and Mokal Nala sections yielded 41 species, including 33 newly recorded from the Late Tithonian–Neocomian interval. Noteworthy taxa include Araucariacites, Callialasporites, and Goubinispora indica, the latter of which now has its known stratigraphic range extended from the Early–Middle Triassic to the Neocomian. The palynological assemblages suggest a warm, coastal climate with conifer- dominated vegetation, while rare upland pollen types imply drier conditions inland. The systematic study of plant megafossils identified one family (Williamsoniaceae), one genus (Ptilophyllum), and two species (P. cutchense and P. acutifolium), with P. cutchense reported for the first time from the Pariwar Formation. The abundance of Ptilophyllum leaves, fossil wood, and trace fossils suggests a lush, lowland coastal forest dominated by bennettitalean plants, possibly in swampy conditions. The prevalence of bennettitalean flora in the Lower Cretaceous of the Jaisalmer Basin indicates warm climatic preferences, with foliage possibly adapted to a deciduous or semi-deciduous habit.

Grain size distribution and pollen deposition in Mona Lake of Kaziranga National Park: implications for palaeoenvironment and palaeoflood analysis

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Abstract

The primary aim of this study is to investigate the relationship between sediment grain size and pollen dispersal and deposition in Mona Lake, located within Kaziranga National Park (KNP). A total of twenty surface sediment samples were collected to assess spatial variation across different depositional settings. Specifically, seven samples were collected from the central basin of Mona Lake, seven from its periphery, and six from the adjacent forestland within the park. To understand the depositional environment, both grain size fractions (sand, silt, and clay) and pollen assemblages were analyzed. Variations in pollen composition and sediment texture across the three zones - lake center, lake periphery, and forestland were examined to infer the influence of hydrodynamic conditions on pollen transport and sedimentation patterns. Canonical Correspondence Analysis (CCA) was employed to explore the relationship between grain size distribution and pollen deposition, highlighting spatial differences in depositional regimes within and around the lake. The findings offer insights into sedimentary processes and pollen taphonomy in a floodplain lake setting, contributing to the reconstruction of past ecological conditions and palaeoflood events. This study serves as a reference framework for understanding depositional environments and ecological history in flood-prone wetlands and may support palaeoflood and palaeoecological interpretations in similar geomorphic and ecological settings across the Indian subcontinent.

Pollen and non-Pollen palynomorphs diversity from surface samples of central India, India: insights for palaeoenvironmental interpretation

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Abstract

Pollen and non-pollen palynomorphs (NPPs) recovered from surface sediment samples collected across five sites in Madhya Pradesh (M.P.), Central India, India. The five study sites viz., Deogarh, Chhindwara, Jaitpur Narsinghpur, Rangabari and Patparwari represent varied ecological settings shaped by regional vegetation dynamics, water availability and anthropogenic impact. The recovered pollen grains include Madhuca indica, Acacia, Cassia spp., Capparis decidua followed by Poaceae, Cerealia, Cyperaceae and Asteraceae, along with notable occurrences of Amaranthaceae/Chenopodiaceae, Brassicaceae, Fabaceae and other less frequent taxa. Notable aquatic taxa such as Lemna, Potamogeton and Typha are also present. Algal forms such as Botryococcus, Zygnema zygospores, Desmid, Trachelomonas and other chlorophytes, along with Sphagnum, were recovered. These algal forms indicate freshwater productivity, intermittent waterlogging and localized ecological shifts, making them valuable indicators for palaeoenvironmental interpretation. The assemblages recovered include a wide range of fungal spores, such as Glomus, Curvularia, Valsaria, Nigrospora, Arthrinium, Sporormiella, Alternaria, Fusarium, Scleroderma, Tetraploa, Cookeina, Chaetomium, Arcella, Smut, Teliospores and various conidial and amoeboid cyst types. The integrated analysis of pollen and non-pollen palynomorphs (NPPs) from modern surface sediments reveals multi-proxy evidence of local vegetation composition, anthropogenic disturbance, fungal diversity, aquatic ecology and faunal presence. This palynological dataset serves as a modern analogue for palaeoecological calibration and offers critical baseline data for the reconstruction of past vegetation and climate variability in Central India.

Palaeovegetational and palaeoclimatic interpretation of Dibrugarh District, upper Brahmaputra region of Assam, Eastern Himalayan Foothills: Using a multiproxy approach

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Abstract

The Eastern Himalayan Foothills serve as a critical archive for reconstructing past vegetation dynamics and climatic variations, owing to their distinct geographic and tectonic setting. This study presents a multiproxy analysis of a 150 cm sediment profile from the Madhupur region in Dibrugarh district, Upper Assam, northeast India. Both biotic and abiotic proxies, including grain size, palynofacies, and pollen, were examined. Pollen was generally sparse throughout the section; however, the upper part showed a higher abundance of cultural taxa (e.g., Poaceae, Chenopodiaceae, Amaranthaceae) and exotic taxa (e.g., *Pinus*, *Symplocos*, and *Castanopsis*), indicating anthropogenic activity and upstream fluvial transport. Additionally, the middle portion of the section exhibited an increased presence of arboreal taxa such as Impatiens and Acanthaceae pollen, suggesting warm, humid conditions with active monsoonal influence. Toward the lower section of the profile, abundant arboreal taxa like *Schleichera*, *Syzygium*, *Lagerstroemia*, and *Duabanga* indicate the evidence of consolidated vegetation in the region. Palynofacies were well represented and categorized into opaque phytoclasts, degraded brown organic matter (OM), amorphous organic matter (AOM), palynomorphs, and zoomorphs. Grain size analysis, a key proxy for discharge energy and depositional environment, identified five distinct zones (Zone I to Zone V), reflecting a shift from low to moderate to high hydrodynamic conditions. Zone I (oldest deposits) exhibited low to moderate energy, with a unimodal, leptokurtic distribution of heterogeneous sediment types. Zone II was dominated by coarser silt under moderate to high energy conditions. In Zone III, muddy, moderately sorted sediments were deposited under fluctuating energy conditions in a unimodal pattern. Zones IV and V (recent deposits) featured moderately sorted, very coarse silt deposition with unimodal, leptokurtic type of distributions, indicating moderate to high energy depositional environments.

Preliminary evidence of megathermal tropical forest of the early Eocene warm world: Palynological record from the Valia lignite deposit, Cambay Basin, India

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Abstract

The early Paleogene period, particularly marked by several transient global warming events, was a time of intense geodynamic and climatic transformation. Geodynamically, significant tectonic events such as the India-Asia collision, rifting in the North Atlantic, and enhanced volcanic activity reshaped continental positions and ocean circulation and facilitated carbon release. Climatically, during this period, the Earth experienced global warming due tomassive greenhouse gas emissions, possibly from methane hydrates and volcanic activity. This led to ocean acidification, altered hydrological cycles, and intensified weathering. Polar regions warmed, sea levels rose, and tropical ecosystems expanded. These combined effects caused significant faunal and floral turnover, making this period vital for understanding Earth's climate sensitivity and tectonic-climate interaction. The Cambay Shale is a significant Paleogene-aged sedimentary unit in the Cambay Basin of western India. It is an important source rock, rich in organic matter, and plays a key role in petroleum generation and hydrocarbon exploration. The Cambay Shale also preserves diverse fossil biota, providing clues to palaeofloristics and palaeoenvironments. The present study deals with the Valia Lignite Mine (Gujarat, India), a part of the Cambay Basin, which holds significant potential for advancing our understanding of early Paleogene terrestrial palynofloristics and ecosystems. Preliminary palynological studies have identified a wide range of pollen taxa, including those belonging to megathermal families such as Arecacea, Bombacaceae, Dipterocarpaceae, Meliaceae, Ctenolophonaceae and the most dominant family, Araceae. The palynoassemblage indicates the dominance of tropical megathermal forests in the region, providing clues of extreme warm and humid climate conditions during the deposition of the Valia lignites.

Depositional environment, hydrodynamic condition, and paddy field diatom for Lahuradewa Lake, central Ganga Plain, India

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Abstract

A 2.8 m deep trench was dug on the eastern dry part of the Lahuradewa lake, Uttar Pradesh, India, where 28 samples at 10 cm intervals were collected for the study of the diatom. Planktic diatoms thrive within the lake's aqueous environment, contrasting with benthic diatoms, which inhabit the sediment bed. Lake expansion fosters a surge in planktic forms, whereas contraction prompts an upsurge in benthic types. Diatoms influenced by human activity flourish amidst rising organic pollution. Paddy field diatoms populate the lake periphery, carried into deeper waters by sediment and organic material from nearby agricultural lands. Shifts in their abundance are closely tied to human agricultural practices. Over the past 10,000 years, changes in diatom populations have served as indicators of climate fluctuations impacting the lake's hydrological dynamics and human interference. Various phases of diatom dominance correspond to periods of shallow or deep lake conditions, influenced by both precipitation patterns and human interventions. The Early Holocene Climatic Optima, approximately 7000 cal years BP, witnessed a surge in monsoonal activity, reflected in heightened diatom populations. Conversely, diminished rainfall between approximately 5800 and 3000 cal years BP resulted in diminished lake volume but expanded areas under paddy cultivation. Fluctuations in rainfall on a centennial scale, spanning from 2300 to 500 cal BP, led to oscillations in diatom abundance and diversity. Weakened monsoon seasons correlated with reduced lake levels and increased human activity. From around 500 cal years BP to the present, increased rainfall has spurred a resurgence in diatom populations and diversity, encompassing species associated with paddy fields and human influence. Similar patterns of intensified monsoonal activity were observed around 400 years BP.

Early Eocene fossil fruits from Khadsaliya clay formation of western India and its phytogeographical significance

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Abstract

The recent geological exploration at the Surkha lignite mine, Bhavnagar district in Gujarat, India, yields more than 30 samples of fossilized fruit belong to the Early Eocene age. The samples were collected from the mining area having the succession consisting of ferruginous sandstone, fossiliferous carbonates, grey clays, bentonite, laterite, and variegated shales with gypsum. The highly carbonized and petrified fossil fruits described here were collected from the Khadsaliya clay formation of the Surkha Lignite Mines and studied for their descriptive morphological characteristics. The specimens are categorized under 4 genera: *Combretum*, *Terminalia*, *Ziziphus*, and *Lagerstroemia*, belonging to the families Combretaceae, Lythraceae, and Rhamnaceae, which have distinct phytogeographical and paleoclimatical significance. Indian species of the genus *Combretum* have a close resemblance to modern African and Southeast Asian species, which supports the theory of endemism. The availability of *Terminalia* fossils in different continents like Africa, Asia, and the Indian subcontinent suggests the migration route of this flora and the connection between these landmasses. It also indicates the climatic shift of this genus from humid tropical climatic conditions to more seasonal and arid environments. These plants are more sensitive towards soil moisture and water availability. The presence of *Ziziphus* species on the Indian subcontinent and other continents of the world supports the intercontinental floristic exchange during the Cenozoic, and it also supports the boreotropical hypothesis during the Paleogene. The earlier fossil record and the present-day distribution of *Lagerstroemia* species indicate its origin in Gondwana during the Late Cretaceous, then dispersed across Asia and other continents. The systematic study of these dicotyledonous fruit fossils suggests the existence of dense tropical moist forests that were deciduous in nature during the Paleocene-Eocene interval and are similar to present-day coastal deciduous forests of Southern India. After comparison of these fossils with their Indian and global counterparts, these fossil records support the northward movement of Indian subcontinent towards mainland Asia after drifting from Gondwana Land and the adaptation of the genus with changing landscapes and climates. The fossil record from western India shows that the tropical forests were already present before the collision with the Eurasian plate. It also indicates a tropical & humid climate during India's isolation, i.e., as a drifting island. Overall, this fossil assemblage supports theories about India acting as a biotic ferry that carried Gondwanan flora to Asia.

Recent palynological and multiproxy evidence from surface soils of the central Ganga Plain: Indicators of vegetation dynamics, anthropogenic impact, and Holocene environmental change

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Abstract

This study presents a detailed multiproxy analysis of pollen and non-pollen palynomorphs (NPPs), phytolith, and diatom assemblages from surface soil samples collected at Masada Lake in Ambedkar Nagar, Uttar Pradesh, situated within the Central Ganga Plain. This region remains largely underexplored in palynological and palaeoclimatic research, despite its potential to provide important insights into past environmental and climatic conditions. Eight surface soil samples were analyzed to examine microfossil deposition patterns in relation to modern vegetation, agricultural practices, and anthropogenic impact. Palynological analysis identified dominant arboreal pollen (AP) taxa such as *Acacia* and Blumea, along with majority of non-arboreal pollen (NAP) types including Cerealia, Poaceae, *Alternanthera* and Tubuliflorae, reflecting active agriculture and land-use modification. Aquatics such as *Botryococcus* and Amoeboid cyst and NPPs such as *Glomus, Nigrospora*, *Ascospores* and bicelled fungal spores suggest organic matter input and moderate ecological stress. Phytolith analysis revealed diverse morphotypes including sedge-type, Cyperaceae achene, bilobate forms with varying shank thicknesses, gemmoscleres with birotules, saddle types, two-horned rondels, spicules, bulliform cuneiform, and sinuate types, suggesting mixed vegetation cover and climatic variability. Diatom taxa, including *Navicula*, *Amphora, Tabularia, Eunotia*, and *Pinnularia*, indicate eutrophic freshwater environments with fluctuating water levels. The integration of all three proxies highlights human influence, seasonal farming activity, and regional climatic variability. This integrative approach underscores the utility of multiproxy datasets in reconstructing late Holocene palaeoenvironmental conditions and anthropogenic influence in understudied lacustrine settings of the Central Ganga Plain.

Early Permian climate dynamics and vegetation evolution in the Indian Gondwana sub-continent-a study from West Bokaro Coalfields, Damodar basin, India

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Abstract

The melting of Gondwana ice sheets and the subsequent progressive warming played a pivotal role in the evolution of terrestrial biota. To explore this climatic and ecological transition, we examined the Talchir and Barakar formations of the Lower Gondwana succession from the Damodar Basin, India. These formations provide a valuable sedimentary repository to examine the Artinskian Warming Event and its impact on terrestrial plant evolution during the Early Permian. The Talchir Formation preserves evidence of Late Paleozoic glaciation, while the overlying Barakar Formation reflects a transition to warmer and more humid fluvio-deltaic environment. This climatic shift is often attributed to rising atmospheric CO_2 levels, possibly linked to extensive volcanic activity associated with the Panjal Traps of India and the Tarim Large Igneous Province in northwestern China. Although climatic changes across Gondwana have been reconstructed using ichnofossils, plant macrofossils, and sporomorphs, the relative scarcity of the former in the Damodar Basin (India) necessitates a focus on sporomorphs as the primary proxy for interpreting climatic and biotic shifts.Sporomorphs are more accurate markers of broad-scale climatic and vegetational changes than macroplant fossils because they follow distinct taphonomic paths and are less affected by local depositional constraints. Shifts in sporomorph diversity, abundance, and morphology across the Talchir–Barakar transition. reflects a significant biotic turnover likely driven by warming of the climate. To reinforce these climatic interpretations, geochemical proxies such as the Chemical Index of Alteration (CIA) and Total Organic Carbon (TOC) are utilized to assess degrees of chemical weathering and paleo-productivity, respectively. Together, these multidisciplinary approaches provide an integrated framework to reconstruct palaeoecological and palaeoclimatic trends and to enhance our understanding of terrestrial ecosystem dynamics during the Permian.

Quantifying modern pollen analogue for understanding vegetation and climate dynamics in Majuli Island (World's largest river island), northeast India: Insights into palaeoecological assessment

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Abstract

This study presents an extensive palynological analysis from different depositional settings (wetland and river margin) of Majuli Island, Assam, to establish modern pollen-vegetation relationships for understanding palaeoecology and assessing climatic impacts on present vegetation. Majuli Island is known for its rich biodiversity, as it lies on the mighty Brahmaputra River within the Indo-Burma biodiversity hotspot. The present study focused on two major wetlands, Garamur, Pharam, and the Lohit River margin. A total of 26 surface sediment samples were analyzed palynologically to establish a modern pollen reference, aiding the understanding of the present vegetation–climate relationship. Multivariate statistical analysis was conducted using regional climatic variables, including Land Surface Temperature (LST), and Normalized Difference Vegetation Index (NDVI), to examine the climate-induced vegetation response. The Garamur wetland pollen assemblage displayed a tropical semi-evergreen to moist deciduous forest, along with riparian and grassland vegetation, indicating warm and humid climatic conditions with intense monsoon activity. Pharam wetland showed a significant presence of anthropogenic markers, pollen like *Cereal*, *Brassica*, *Apiaceae*, and *Solanaceae*, and abundant terrestrial herbs, suggesting human settlement and agricultural activity. The Lohit River margin showed dominance of extra-regional arboreals like *Pinus*, *Ulmus*, *Symplocos*, etc, pointing to an intense fluvial regime. The regional climatic variable, like NDVI, is negatively correlated with arboreal pollen, attributed to bias in pollen preservation due to recurring fluvial activity. A significant negative correlation between LST and arboreal pollen challenges the previous assumption that temperature universally enhances tree pollen productivity, instead indicating that excessive heat may impose physiological limitations on tree growth and pollen production. The observed decline in aquatic pollen with rising LST further highlights the impact of thermal stress on aquatic vegetation on the Island. Statistical methods, including the Bray-Curtis method, Principal Component Analysis (PCA), and Box-Whiskers Plot, were applied to evaluate the similarities and dissimilarities in pollen frequency across different depositional environments within the island. This comprehensive modern pollen dataset offers insights into vegetation patterns, agricultural practices, forest degradation, and climatic factors influencing regional vegetation changes.

It also aids in predicting future pollen distribution shifts under climate change and understanding past ecological transitions in the upper Brahmaputra Valley, Assam.

A palynological insight into the present vegetation and climate scenario of Hollongapar Gibbon Wildlife Sanctuary, Assam

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Abstract

We present here the results of a palynological study conducted in the Hollongapar Gibbon Wildlife Sanctuary of Jorhat, Assam; situated within the verdant expanses of the Eastern Himalayan Biodiversity Hotspot to unveil the contemporary pollen-rain, existing vegetation and climatic conditions of the area. The study was done by surface soil samples collected from various ecological zones within and nearby the sanctuary viz., core forest, forest edge, and adjacent agricultural areas which reveals distinct vegetation patterns and ecological indicators linked to specific sites. The identified assemblage of palynomorphs includes pollen from tree families such as Dipterocarpaceae, *Mesua ferrea* and *Elaeocarpus*, in addition to species from marshy herbaceous groups, pteridophytes, fungal spores and taxa carried by highland drift. There is also a significant representation of terrestrial herbaceous pollen types, particularly from Poaceae, Amaranthaceae, Tubuliflorae and Liguliflorae. Moreover, marked prevalence of monolete spores compared to trilete spores indicates a gradual deterioration of forest cover due to changing climatic conditions. The relatively higher representation of non-arboreal pollen (from marshy and herbaceous taxa) over arboreal pollen (from trees and shrubs) highlight ongoing migration of the forest towards the open-land and declining trend forests within the sanctuary. These findings are consistent with the trends of forest cover loss documented for Jorhat district by Global Forest Watch (World Resources Institute, USA). Notably, the common presence of coprophilous fungal spores such as *Cercophora, Sordaria*, *Podospora* and *Sporormiella* suggests the existence of rich organic materials, which support a thriving wildlife population in the sanctuary. Collectively, these results also emphasise the urgent need for conservation efforts to maintain the ecological integrity and biodiversity of the Hollongapar Gibbon Wildlife Sanctuary.

Deciphering the Past: Palynofacies and grain size analysis of Tuman Lake sediments, Korba, Chhattisgarh in core monsoon zone (CMZ) of India

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Abstract

The Core Monsoon Zone (CMZ), covering parts of Madhya Pradesh, Chhattisgarh, and Maharashtra, is a climatically sensitive region essential for understanding past monsoon variability in India. This study presents a high-resolution multiproxy palaeoenvironmental reconstruction based on a 120 cm sediment trench from Tuman Lake in Korba District, Chhattisgarh. Using palynofacies and grain size analysis of 30 sediment samples spanning ~7300 to 240 calibrated years BP (cal BP), three distinct zones reflecting changing monsoonal dynamics were identified. Zone I (~7300–4380 cal BP; TNT_22–TNT_30) represents a transitional phase from moderate-energy fluvial to low-energy wetland conditions. The early part of the zone (TNT_22, TNT_26, TNT_30) displays coarse sediments, suggesting episodic high-energy events, likely linked to strong monsoonal precipitation and flooding. In contrast, the middle part (TNT_25–TNT_27) is dominated by high grass oxidized organic matter (OM), fungal remains, and amorphous organic matter (AOM), reflecting stagnant, ephemeral wetland settings with microbial activity under reduced drainage. Peak silt and clay in TNT_27 hint at a lacustrine or more persistent waterbody. Aquatic indicators like *Botryococcus* reappear toward the end, suggesting renewed water availability. This zone captures a weakening monsoon interspersed with periodic intensifications. Zone II (~4380–240 cal BP; TNT_09–TNT_21) corresponds to a relatively stable floodplain or swampy environment, characterized by low-energy sedimentation dominated by fine-grained clays and silts. The basal samples show moderate oxidation conditions revealed by structured OM, and fungal remains, indicating seasonal lowering of water levels. TNT_13 suggests localized flooding or floodplain reactivation with increased finer sands. Marsh-like conditions with high AOM dominate TNT_14–TNT_15, reflecting stagnant and anoxic depositional settings. TNT_16–TNT_18 show brief energetic phases with aquatic indicators and coarser sediments, before returning to calm, wet floodplain conditions in TNT_19–TNT_21. This zone reflects fluctuating but generally subdued monsoon activity, marked by intermittent waterlogging and vegetation stability. Zone III (~240 cal BP–present; TNT_1–TNT_8) highlights a shift from stable floodplain to increasingly dynamic fluvial conditions. Samples (TNT_1–TNT_3) indicate vegetation-rich, oxygenated floodplains. Rising AOM and aquatic indicators in TNT_4–TNT_6 suggest swamp formation and anoxia. TNT_7 and TNT_8 reveal increased sand input and aquatic microfossils, indicative of episodic

channel activity or flood events, possibly tied to late Holocene monsoonal intensification reflecting the current warming period. Thus, the Tuman Lake record reflects late Holocene monsoonal fluctuations in the CMZ, alternating between stable floodplain, stagnant marsh, and high-energy fluvial phases in response to shifting rainfall patterns and hydrological variability.

Pollen rain/vegetation relationship and its implication in fossil pollen records in the core monsoon zone of India

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Abstract

Understanding past vegetation dynamics is critical to reconstructing long-term monsoonal and ecological variability, particularly in the Core Monsoon Zone (CMZ) of India, which is highly sensitive to changes in the Indian Summer Monsoon (ISM). One of the most effective ways to reconstruct palaeovegetation is through palynology—the study of fossil pollen—and this requires a robust understanding of the relationship between modern pollen rain and the existing vegetation. This modern analogue serves as a baseline for interpreting fossil pollen records from sediment cores. A palynological investigation of surface soil samples from the Raigarh District, Chhattisgarh (Central India) was conducted to assess the relationship between modern pollen rain and existing vegetation. The analysis revealed a rich assemblage of palynomorphs, including pollen from tropical deciduous forest taxa (trees and shrubs), aquatic and marshy herbs, pteridophytes, algae, fungi, and a few long-distance drifted pollen grains from Himalayan taxa. The arboreal pollen (trees and shrubs) was underrepresented (average 13.39%), comprising species such as *Madhuca indica*, *Shorea robusta*, *Tectona grandis*, *Terminalia*, and *Emblica officinalis*. Shrubby taxa like *Rungia* and *Strobilanthes* contributed around 3.04%. In contrast, non-arboreal pollen (NAPs) dominated, indicating an open, mixed tropical deciduous forest in the region. Grasses (*Poaceae*, 14.59%) and cultivated cereal taxa (Cerealia, 58.04%) were abundant, reflecting both natural and anthropogenic influences. Other cultural and ruderal herbaceous taxa, such as *Amaranthaceae*, *Brassicaceae*, *Cannabis sativa*, and *Tubuliflorae*, collectively formed 21.86% of the pollen sum. Marshy and aquatic taxa, including *Cyperaceae*, *Nymphoides*, and *Typha*, were also well-represented (18.71% and 10.58%, respectively). Pteridophytic spores (12.81%) and algal remains (7.5%) indicated wet and humid microenvironments. Himalayan drifted taxa like *Pinus*, *Alnus*, and *Ephedra* were negligible (<0.5%). Fungal spores, including *Glomus*, *Diplodia*, and *Alternaria*, occurred frequently (average 14.94%). The study highlights that modern pollen rain in the Charkhapara area reflects a dominance of herbaceous and cultural taxa over arboreal elements, indicating an open tropical deciduous forest influenced by both natural and anthropogenic factors. Despite underrepresentation of insect-pollinated and low-preservation taxa, the modern pollen assemblage provides a valuable reference framework for interpreting fossil pollen records and reconstructing past vegetation and monsoonal dynamics in the Core Monsoon Zone.

Reconstructing Herbivore Diets and Vegetation Shifts through Scat-Based multiproxy Evidence

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Abstract

Scat-based multiproxy analysis has emerged as a powerful approach in biogeosciences, offering fine-scale insights into animal diet, vegetation composition, and habitat conditions through time. By examining modern faunal dung using palynology, phytoliths, diatoms, and non-pollen palynomorphs (NPPs), researchers are able to reconstruct real-time ecological interactions and feeding strategies. These proxies together provide high-resolution data on seasonal foraging patterns, trophic behavior, and vegetational shifts. Importantly, this method not only sheds light on Quaternary environments but also contributes significantly to understanding the dietary adaptability of extant endangered species, thereby informing conservation efforts under current climate pressures. In India, dung-based studies across varied ecological regions—from tropical forests to alpine steppes—have yielded critical insights into the foraging ecology of threatened herbivore. Notable research on species such as the red panda (*Ailurus fulgens*), Sangai deer (*Rucervus eldii eldii*), one-horned rhinoceros (*Rhinoceros unicornis*), hog deer (*Axis porcinus*), wild Ass (*Equus hemionus*), and wild yak (*Bos mutus*) has documented seasonal shifts in the preference of C3 and C4 plant, dependence on secondary plants, and vegetation-climate interactions. Globally, dung-based multiproxy studies have been applied to a wide range of large mammals—including South American camelids, North American bison (*Bison bison*), Alaskan brown bears (*Ursus arctos*), and European cave bears (*Ursus spelaeus*) etcetera, to reconstruct vegetation dynamics, trophic strategies, and paleodietary shifts. Multiproxy analyses of *Bos mutus* dung from the Trans-Himalayan alpine zones have revealed a cold- tolerant, high-fiber diet dominated by sedge phytoliths, alpine dicot pollen, and coprophilous fungi—reflecting a specialized foraging pattern within high-altitude vegetation mosaics. These dietary signals are in consonance with the palaeobotanical records from the scat of extinct megaherbivores such as the woolly mammoth (*Mammuthus primigenius*), woolly rhinoceros (*Coelodonta antiquitatis*), and giant elk (*Megaloceros giganteus*). The plausible cause of extinction in these species was not a singular climatic shift, but a progressive reduction in diverse, palatable plant communities, combined with reduced foraging flexibility, ecological stress, and landscape fragmentation during the transition from Pleistocene to Holocene. While cataloguing dung-derived proxies across central India, an unanticipated encounter with omnivore scat revealed a dyschronity with the herbivore's microfossil record. The dominance of *Helicoon*—saprotrophic fungi indicate swampy, moist, organic-rich substrates—replacing the typical herbivore-associated *Podospora*,

Sporormiella, and *Sordaria* assemblage. The pollen and phytolith records reflect a flexibility in dietary and ecological range. Thus, investigation of both herbivores and omnivores scat is vital for understanding the conservation strategies of wild faunas, as well as reconstructing palaeo-landscapes, forecasting ecosystem resilience and trophic adaptability in future climate scenarios.

Plant biodiversity of Mahanadi Master Basin during Gondwana period: Inferences on biostratigraphy and palaeoenvironment

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Abstract

The Mahanadi Gondwana Basin stretches across eastern and central India, primarily covering the states of Chhattisgarh and Odisha. Originating in the Central India Hills and flowing through the Eastern Ghats, the Mahanadi River ultimately drains into the Bay of Bengal. The basin's rich sedimentary strata contain fossilized remains of extinct plants and marine life, offering valuableinsights into past ecosystems. Over geological time, layers of deposition within the basin provide critical evidence of tectonic activity and climatic changes. Fossil records from the region reflect a diverse ecological history, making the Mahanadi Basin an important site for understanding biostratigraphy, palaeoenvironmental conditions and the evolution of plant life. Notable fossil taxa such as *Glossopteris* and *Gangamopteris* represent the diverse flora of the Permian period, forming a significant part of the basin's fossil assemblages. The coal-bearing regions of the Mahanadi Basin are particularly rich in macro- and microfloral content, especially from the order Glossopteridales. Palynological studies have identified distinct palynoassemblage zones, revealing a complex but systematic evolution of flora across different geological periods. The *Glossopteris* floral diversity plays a crucial role in reconstructing the ecological dynamics and climatic conditions of the Permian ecosystems. The current work reviews existing scholarly research on biodiversity reconstruction in the Mahanadi Basin and explores avenues for future studies and advancements in the field.

Whispers beneath the waters: A palynological reconstruction of chilika lagoon's ecological past

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Abstract

Chilika lake is the largest lagoon in Asia.The ecosystem of chilika lagoon has remained unique throughout its existence. ln the year 2000 many surface samples were taken. This study presents the lithological results and especially those of the pollen analysis. The oldest sediments of core CHI9 were dated 13500 cal years B.P. At this time the area of chilika lake was a river delta with fresh water vegetation. with the increase in sea level after about 9500 cal years the area has become an estuary with mangrove vegetation. Small variations in the sea level between about 5000 and 2500 cal years are B.P. are not visible in our pollen profile. However, the regression after about 2000 cal years B.P. caused the formation of a barrier spit and sand ridges with the consequence that a big lagoon was formed. Hence marine influence diminished and fresh water impact from river increased. Mangrove vegetation disappeared and was replaced by fresh water vegetation. The data generated from the analysis of surface sediments can be used for interpretation of palynological results in terms of past vegetation and climate around Chilika lagoon.

Aerial pollen diversity in Lucknow district and their clinical significance in allergic disease: A pilot study

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Abstract

A detailed information of Pre- and Post-monsoon of different particulates in the atmosphere. Lucknow city with increasing population, experiences a high number of allergic diseases, which may be attributed to its diverse aerial pollen. This pilot study is aimed to investigate the density of pollen and NPPs and explore their clinical significance in allergic diseases. Aerial pollen samples were collected from Five different sites in Trans- Gomti area, Lucknow district using a microscopic slide coated with glycerine for pollen trap. Pollen and NPPs (*Alternaria, Nigrospora, Curvularia, Pleospora*, Penicillium-type, and *Tetraploa*) were identified and counted, and their clinical concentration were calculated. As total of 34 types of pollen were identified, with dominant aerial pollen from tress, herbs and shrubs (Poaceae, *Madhuca indica*, *Moringa oleifera*, *Pinus sp*., *Acacia, Emblica officinalis*, *Syzgium cumini*, *Betula*, *Eucalyptus globulus*, *Prosopis spicigera*, Rutaceae, Anacardiaceae, *Ilex sp.*, B*ombex ceiba*, *Tinospora cordifolia*). Poaceae pollen was dominant throughout all months but showed peaks in April or May and being the most consistent and clinically significant allergens.

Theme 8

Recent advancements in palaeontology and its applications

Additional Eocene echinoids from Assam, NE India: implications for Tethyan paleobiogeography and Himalayan orogeny

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Abstract

Additional echinoid fossil comprising of *Eupatagus faurai* (Lambert, 1927) and *Echinolampas vilanovae* Cotteau, 1890 is recorded from the Sylhet Limestone of Mikir Hills, Assam (NE), India. The two species from middle Eocene of Assam are well recognized and placed under the genus Eupatagus and Echinolampas associated with echinoid fossil spine from NE India. This single specimen of *Eupatagus faurai* in our collection is denoted by large, oval test with petaloid ambulacral petals. Further, the single specimen of *Echinolampas vilanovae* is denoted by a large test and elliptical in outline. The length of test is more than width and greatest width towards posterior to centre. These are recorded for the first time from the sediments of Sylhet Limestone, Mikir Hills of Assam. The horizon containing the echinoid faunas described here is recorded from SBZ Zone 16–18, which corresponds to late Lutetian to Bartonian of middle Eocene age from the previous study of larger benthic foraminifera. The discovery the present additional echinoid fossils in the Sylhet Limestone of Assam of Mikir Hills provides fascinating evidence for a direct marine Tethys Seaway connection that existed between Northeast India, NW India and the NW Himalaya, the Middle East and Europe during the Eocene Epoch (56 to 34 Ma). These fossils enhance the ancient distribution of marine life and refine our understanding of the geological events leading to the formation of the mighty and youngest mountain of the Himalaya.

Documentation and extension of mid-depth MTD in the K-G basin: benthic foraminiferal evidence

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Abstract

The Bay of Bengal is a three-sided landlocked basin surrounded by India, Bangladesh, and Myanmar, which typically receives a vast amount of terrestrial sediment through the different riverine networks (Irrawaddy, Meghna, Brahmaputra, Ganga, Subarnarekha, Mahanadi, Krishna, Godavari, Pennar). The input of enormous sediments from all these continents allows the Bay of Bengal to accommodate rapidly and witness a rapid sedimentation rate. This higher sedimentation rate, diapiric movement related to high sedimentation rate, and the tectonic events are responsible for the creation of Mass Transport Deposits (MTD) within the Bay of Bengal. Several studies documented MTD in Bay of Bengal (Ramprasad et al., 2011; Hong et al., 2014; Rogers et al., 2015; Yamamoto et al., 2019; João et al., 2021; Bhaumik et al., 2024). All of these are inferred either from 2D or 3D seismic data acquisition. The Krishna-Godavari Basin is situated along the eastern continental margin of India within the Bay of Bengal. Using a seismic study, Ramprasad et al. (2011) showed an MTD structure on the surface sediments in the Krishna Godavari basin. The study of Collett et al. (2008) also showed a signature of surficial MTD in the seismic profile at the KG basin. However, a mid-depth MTD has recently been identified by Bhaumik et al. (2024) using benthic foraminiferal distribution. Here, we present our findings on this mid-depth MTD and its extension in the nearby region. We have studied benthic foraminifera from three nearby sites (NGHP-01 3B, 5C, and 10D) cored around 1000m water depth. Our study documented a threefold benthic foraminiferal distribution in all the sites. The mid- depth sediments (between 90 and 155 mbsf) in all the sites recorded increased abundance (up to 100%) of *Ammonia spp*., *Bolivinita subangularis*, L*oxostomum amygdalaeformis* etc. This clearly signifies the presence of transported outer shelf benthic foraminifera (200m water depth) at the middle bathyal zone as well as the development of a mid-depth MTD layer. The MTD shows maximum thickness (63m) at Holes 10D and 5C, whereas only 15m at Hole 3B.

Integrative reassessment of benthic foraminiferal genus *Ammonia* from the Indian coastline using combined morphological and ribosomal DNA barcoding approaches

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Abstract

The genus *Ammonia,* a widely distributed group of benthic foraminifera, plays a pivotal role in paleoenvironmental reconstructions and ecological monitoring. However, its species-level identification is complicated by morphological plasticity and cryptic diversity. This study presents a comprehensive reassessment of *Ammonia* diversity along the Indian coastline by integrating traditional morphology-based taxonomy with ribosomal DNA barcoding approaches. Specimens were collected from multiple ecologically distinct coastal habitats, and morphospecies were initially identified using established taxonomic keys. Genetic analyses targeting the partial 18S rRNA gene was employed to delineate lineages congruent or incongruent with morphological classifications. DNA sequencing of samples uncovered a higher level of new genetic diversity, endemism in benthic foraminifera, and highlighted habitat-specific assemblages which were previously undetected by conventional methods. This inter-disciplinary approach underscores the limitations of morphology-based identification, and demonstrates the impact of combined morphological and DNA sequencing techniques in resolving species complexes. This reassessment significantly refines the understanding of *Ammonia* diversity in Indian coastal ecosystems and provides a foundation for improved ecological monitoring and biogeographic studies.

Fossil and molecular evolution of tropical rainforests

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Abstract

Tropical rainforests (TRF) are the most abundant terrestrial ecosystems that support half of the global plant species, necessitating to understand their origin and evolutionary history. TRF of Southeast Asia are ecologically distinct by having 80% of their emergent trees belonging to plant family Dipterocarpaceae. The present study reports the oldest known fossils of *Dipterocarpus* type pollen from the Maastrichtian of Africa and eight pollen types corresponding to six extant genera of Dipterocarpaceae from the Paleocene-Eocene of India. The paleobiogeographic investigation of morphology of the recovered fossils coupled with the molecular sequences of comparable extant species suggests the origin of Dipterocarpaceae in the seasonally wet regions of tropical Africa during mid-Cretaceous (~102 Ma), and subsequent evolution as an adaptation to seasonal to perhumid climate in the Late-Cretaceous. The family further dispersed to India via Kohistan-Ladakh Island Arc during Maastrichtian-Paleocene leading to the diversification of aseasonal dipterocarps on the Indian Plate. The India-Asia collision promoted the spread of Dipterocarpaceae from India to similar climatic zones in Southeast Asia during Eocene, supporting "Out-of-India" dispersal hypothesis. The family rapidly diversified around 20 Ma in Southeast Asia giving rise to the Southeast Asian TRF. On the other hand, most of the genera disappeared from India owing to the strengthening of the Indian monsoon.

Shades of grey: A pleasant surprise in the Early Pleistocence

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Abstract

Reconstruction of past-sea surface temperature (SST) has been considered a vital component for understanding past climate dynamics and monsoon variability. A precise evaluation of the magnitude and timing of SST variability are therefore crucial for the assessment of general circulation models (GCM). Given the importance of tropics in modulating the global climate, past SST records from Arabian Sea will enable us to understand Indian monsoon in the context of global climate change. Today, the availability of large modern calibration datasets combined with environmental parameters from satellites, buoys and floats have facilitated the development of Machine Learning models for precise SST estimation from microfossil assemblages. Application of Machine Learning (ML) models for predicting environmental parameters have gained tremendous popularity owing to their robustness in handling large complicated data. In order to assess the potential differences among the SST reconstruction techniques when applied to a large fossil data set, the SST variation during the late Pliocene/early Pleistocene was reconstructed from the foraminiferal census counts in eastern Arabian Sea cores of Site U1457 using ANN, SVM and RF. Annual, Summer and winter SSTs were generated employing OISST V2 dataset. Although the general pattern of variation is similar for all three SST reconstruction techniques, there are significant differences. In addition, this study also aimed at evaluating the response of ecologically sensitive planktic foraminiferal species to seasonal SST variations during the early Pleistocene in the eastern Arabian Sea.

Large-sized dung beetle brood balls and ant traces from the alluvial sediments of the Purna basin, Central India: Palaeoenvironmental and palaeoclimate implications

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Abstract

Coprinisphaera has been regarded as a continental ichnofacies that comprises trace fossils of various insect taxa including bees, wasps, ants, termites, beetles and other unidentified groups. The trace fossils of this ichnofacies exhibit diverse morphologies and sizes. These traces have been widely studied in South American countries, particularly within hard rock formations ranging from the Cretaceous to the Pleistocene. The present investigation, for the first time in the Indian Subcontinent, reports the preservation of *Coprinisphaera* ichnofacies trace fossils from alluvial sediments of the Purna River Basin, Maharashtra, Central India. These fossils were recorded either individually or in groups of two to five calcium carbonate bodies, primarily within the paleosol succession that occupies the base of the river basin. Based on their morphologies, sizes and associated features, the trace fossils have been identified into three types: i) *Coprinisphaera akatanka*, ii) *Coprinisphaera lazai* and iii) *Attaichnus kuenzelii*. *C. akatanka* specimens are spherical to sub-spherical, compact to hard and may occasionally be pear shaped. They reveal two separate chambers—a main chamber and a secondary chamber—interconnected by a passage. The main chamber is relatively larger than the secondary chamber, which is often eroded and therefore difficult to identify. In contrast, *C. lazai* is characterized by a rounded to sub-rounded morphology, a compact structure and a cavity located on the upper part of the main chamber. This cavity is connected to the main chamber by a gallery, suggesting that it functioned as a secondary chamber for the insect community. The morphologies of both *C. akatanka* and *C. lazai* indicate that they are likely dung brood balls formed by beetle communities using the excrements of herbivore animals. The presence of beetle communities in the area reflects an open environment with a wet to humid climate and low to moderate vegetation at the time of trace fossil formation. In contrast, *A. kuenzelii* specimens are sub-spherical, flattened to pear shaped and contain open complete chambers. Internally, they reveal burrows and a mottled appearance, while externally they display surfaces ranging from rough to smooth surface, often performed with holes. *A. kuenzelii* traces are characterized by surrounding external and folded rims. Based on their unique morphology and appended features, they were likely produced by leaf-cutting ant communities, indicating open habitats with savannah to shrub

vegetation around the peripheries of closed water bodies such as lakes in the basin area, under a dry to hot climate.

The story of a large disabled middle triassic dicynodont from India: evidence of cancer?

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Abstract

It has been a few decades since Palaeopathology, the study of past traumas and diseases that affected the extinct life forms, has become an emerging topic in the world of Palaeontology. Deduction of such illnesses helped in reconstructing the behavioural patterns, physiology, paleoecology, and paleoenvironmental conditions in which the animal survived. The Gondwana sediments of India acted as a rich storehouse of vertebrate fossils, which included the various Permo- Triassic dicynodonts. The dicynodonts are an extinct clade of quadrupedal, herbivorous, often tusked, non-mammalian therapsids, which could masticate its food in the form of propalinal action of the lower jaw. Because of their high diversity and short range, dicynodonts are often used as biostratigraphic tool. One such notable dicynodont is *Wadiasaurus indicus* known from the Middle Triassic Yerrapalli Formation of the Pranhita-Godavari basin, which is represented by multiple individuals that lived in herds like the extant artiodactyls. We report for the first time a pathology / disease suffered by *Wadiasaurus* based on an adult femur bearing small and irregular abnormal bone overgrowths. Its bone microstructure revealed presence of aggressive periosteal reactive bone tissue in the form of crescentic zone of radial fibrolamellar bone. Comparison with similar abnormality in extant and extinct animals revealed strong resemblance to osteosarcoma, a type of bone cancer that affected the adult *Wadiasaurus* individual during its advanced age, restricted its movement and hampered the day-to-day life before its demise. The study presents the earliest evidence of cancer in from India and highlights the importance of examining bone microstructure of extinct animals.

Palynofacies and geochemical characterization of particulate organic matter for hydrocarbon potential study in the Andaman Backarc Basin

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Abstract

The present study investigates the characteristics and hydrocarbon generation potential of organic matter in marine sediments from the Andaman Backarc Basin through an integrated approach combining palynofacies analysis and Rock-Eval pyrolysis. An 82-cm sediment core was collected from a depth of 1395 m (10°18.909'N; 93°33.078'E) during ORV Sindhu Sankalp cruise SSK 145, forming the basis for this preliminary assessment. Palynofacies analysis reveals a predominance of labile organic constituents, including unstructured amorphous organic matter (AOM), along with marine organic-walled microfossils such as acritarchs, prasinophytes, dinoflagellate cysts, and various zoomorphs. Terrestrial inputs are also significant, represented by spores, pollen grains, cuticular fragments, tracheids, and resinous material (Tyson, 1995; Batten, 1996). The assemblage is dominated by AOM and oxidized terrestrial plant fragments (e.g., recycled wood and plant debris), indicating a major contribution from continental sources, likely transported by fluvial systems (Irrawaddy River in addition to the Salween and Sittang Rivers flowing from Myanmar) draining into the basin (Chernova et al., 2001). Rock-Eval pyrolysis results indicate a moderate total organic carbon (TOC) content ranging between 0.2 and 0.8 wt%, with kerogen predominantly of Type III (terrestrial amorphous organic), consistent with gas-prone characteristics (Espitalié et al., 1985; Behar et al., 2006). Overall, this study provides a preliminary evaluation of organic matter abundance and type in the Andaman Backarc Basin. However, more detailed, high-resolution studies across deeper and more geographically extensive core samples are essential to fully understand the hydrocarbon potential of this understudied region.

Dinoflagellate Cysts and the hydrocarbon potential of the Langpar formation of the Jaintia hills, Meghalaya (India)

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Abstract

Diversified palynofloral assemblages have been observed in the rocks of the Langpar Formation of Jaintia Hills, Meghalaya, from shales exposed along the Ladshobar-Therriaghat road section about 3 km towards the Therriaghat village. All the shale samples have revealed rich and well-preserved dinoflagellate cysts and spore-pollen with fungal remains. However, most of the palynomorphs are dinoflagellate cysts. The palynofloral assemblages mainly comprise *Homotryblium*, *Lingulodinium*, *Operculodinium*, *Spiniferite*, *Thalassiphora*, etc., with other dinocysts. *Operculodinium centrocapum*, which is highly abundant in *Operculodinium*, occurs in a wide variety of sedimentary settings ranging from restricted marine to open-marine and neritic water masses. The *Homotryblium* complex includes *Homotryblium floripes* and *H. plectilum*, indicating restriction to inner neritic settings with increased salinity. *Lingulodinium sp*. is most abundant in nearshore estuarine environments and deposited in nearshore, shallow marine environments having open marine influence. *Thalassiphora sp*., which is characterized by the brackish water dinocyst taxa. Based on the occurrence of palynofloral assemblages, the prevalence of tropical–subtropical humid climatic conditions can be inferred, and the depositional environment has been interpreted to be of neritic setting. Rock-eval pyrolysis of the selected shale samples occupied on the margin of type III and type IV kerogen. The studied samples represent the mature stage of the organic matter and suggest poor hydrocarbon source potential.

Looking inside the skull: First non-invasive imaging of a late Triassic reptilian braincase from India and its significance

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Abstract

The braincase houses the brain, inner ear and cranial nerves, aids in the articulation of the neck with the skull, and provides attachment sites for several jaw and neck muscles. Although, the braincase anatomy is well known for extant vertebrates, lack of preservation due to morphological complexity and fragility hinders their study in extinct animals. The Late Triassic Gondwana sediments of India possess a rich storehouse of vertebrate fossil remains that included the well-preserved, often articulated remains of an extinct, semi-aquatic, apex predator, the phytosaur, that shared similar ecological niches to that of the modern-day crocodiles. These phytosaurs are known from the Middle and Upper Triassic sediments of Europe, North America, Asia and India and the late Triassic forms are characterized by a long and elongated rostrum/snout, and dorsally and posteriorly placed nostrils. Even though there exist detailed studies on the taxonomy, lager, phylogeny and palaeobiological attributes of the Indian phytosaurs, knowledge on their braincase and internal anatomy is still lacking. The current study focusses on an isolated, well-preserved braincase of a Late Triassic phytosaur, Volcanosuchus statisticae, recovered from the Upper Triassic Tiki Formation of the Rewa Gondwana Basin of India. The braincase preserves the endocranial cavity and passages for several cranial nerves. The specimen was analyzed using X-ray micro-computed tomography, followed by the construction of a three-dimensional virtual model of the endocranium and its associated neurovascular structure. The model revealed an elongated brain of the extinct reptile similar to the modern-day crocodiles. The 3D representation of the endocranium also aided in the interpretation of the morphology of the inner ear partially. The present work thus incorporates traditional as well as new non-invasive techniques for 3D reconstruction of the endocranium and sensory capabilities of a fossil taxon to understand their neuroanatomy with regard to reptilian evolution.

Assessing spatial variations in shallow marine molluscan communities under anthropogenic stressors through live-dead assemblages

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Abstract

Tracking changes in shallow marine community structure due to human activities is challenging because of rapidly shifting baselines. Near-time archives, such as Dead Assemblages (DA), which consist of the skeletal remains of dead organisms, can be invaluable tools for establishing a baseline for changes that occur over a millennial timescale. DAs are time-averaged and represent past pre- impact conditions, contrary to Living Assemblages (LA), which represent the present-day community structure. Comparing these assemblages can give us information about the extent as well as direction of variation that occurred due to anthropogenic stressors. We investigated the spatial variation of anthropogenic impacts on shallow marine bivalve communities by examining locations in the coastal region of Maharashtra. Our samples were collected from various sites of polluted areas of Mumbai and Thane districts, and we compared them to pristine locations in Raigad district. We calculated abundance-based similarity between LA and DA using the Jaccard-Chao Index and evaluated the rank-order correlation of species abundances between them using Spearman's rho. Our results indicated that pristine sites exhibited higher similarity and a positive correlation between LA and DA. In contrast, polluted sites demonstrated variable responses across both parameters. Notably, the LA of polluted sites was dominated by sensitive filter-feeding bivalve groups, which was consistent with their DA. Conversely, pristine sites were predominantly characterized by bivalve groups that tolerate low oxygen levels and degraded environments, leading to an inconsistency with their DA. The dead assemblage (DA) embodies the original composition of the community, and its comparison with the living assemblage (LA) can reveal the degree of human impact. While ecological studies are often conducted in isolation, incorporating recent archives, such as time-averaged dead assemblages, is vital for establishing accurate baselines. This integration is essential for crafting effective conservation policy strategies.

Morphological variability of *Neogloboquadrina pachyderma* (Ehrenberg) in the Southeast Atlantic Ocean: Insights from ODP Hole 1085A

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Abstract

Neogloboquadrina pachyderma (Ehrenberg) is a planktic foraminifera residing in the polar waters in both hemispheres. It plays a vital role in paleoceanographic studies due to its sensitivity to water mass properties and distinct morphological variability. This study presents a comprehensive morphometric investigation of *N. pachyderma* specimens recovered from ODP Hole 1085A in the Southern Benguela Upwelling System. As the Southern Benguela Upwelling System experiences shifts in the subtropical and subpolar fronts, *N. pachyderma* exhibits corresponding variations in its morphological features. In the present study, we have observed at least eight morpho variants of *N. pachyderma* (NP1-NP8), which were identified based on the variations in their chamber configuration, coiling direction, aperture morphology, test compactness, and the surface ultrastructure. These morphotypes show significant variations in their test size, with the largest morphotype (NP2) reaching a test size of ~90835.49 μm^2 while the smallest morphotype (NP6) shows a test size as low as ~16994.02μm^2. Furthermore, all the morphotypes (NP1-NP8) were classified as normal, kummer, and quadrate test by measuring the ratio of the total size of the final 2 chambers (X) to the total size of the 2nd and 3rd last chamber of the final whorl (Y). In doing so, we could identify whether the final chamber has increased (Normal), decreased (Kummer), or remained the same (Quadrate) sized as the previous chambers, i.e, X/Y>1, X/Y<1, and X/Y ~1, respectively. High-resolution Scanning Electron Microscope photographs reveal variations in the pore size, pore density, and calcification patterns in the morpho variants of N. pachyderma (NP1-NP8), which might be related to the variation in the oceanic conditions of this Southern Benguela region. The larger morphotypes of N. pachyderma (NP2) show the highest average pore density with the smallest pore size (~1.37 µm). The larger morphotypes are accompanied by higher pore concentrations. Our findings underscore the taxonomic as well as the ecological significance of these morphotypes and suggest their use as refined proxies for reconstructing the paleoceanographic conditions.

Machine Learning driven Fossil Pollen analysis using a Convoluted Neural Network Ensemble

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Abstract

Palynofloral analysis is an integral part of any microfossil assemblage. However, it is difficult to identify the fossil/living palynomorphs to an untrained eye. Assigning proper nomenclature to any palynomorph in a classical manner requires expertise and is also time-consuming. To facilitate this, a computer program to classify pollen has been developed. The program trains an assembly of three Convoluted Neural Networks (CNNs) on a database with images of pollen collected from the Late Cretaceous -Early Palaeocene Deccan Intertrappean beds, arranged according to their taxonomic hierarchy. The database can be updated or modified in the future to potentially contain images of all major fossil pollen. The program can then classify any pollen images based on its training. The program tries to classify images at the Species level but moves to higher levels if it has low confidence. The low-confidence images are classified into a different folder on each level. This will help researchers to classify pollen with ease in an objective manner.

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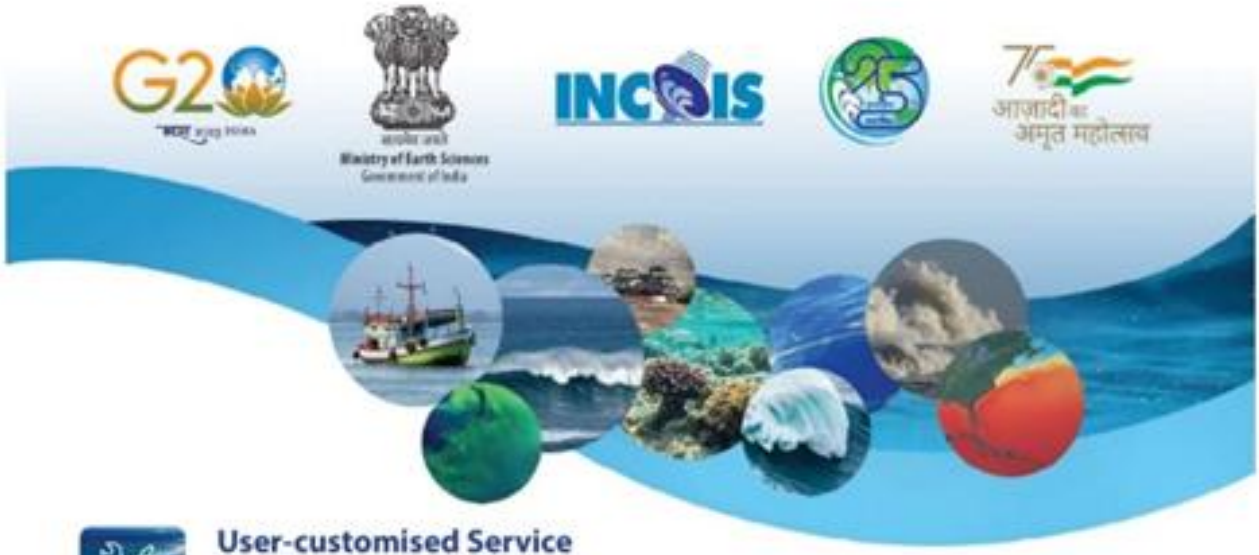

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