

Section –I Peer Reviewed Articles

Geo heritage and Geo tourism in Odisha

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Abstract: The state of Odisha is unique for its geological panorama with a span of oldest rock of Archaean to Recent and endowed with vast mineral resources. Many of the geological features through length and breadth of the state are notable for its aesthetic and scientific value. The state since nineteenth century has remained as a paradise for the geologist for the search of potential minerals. But the neo revolution of concretization of the available land has left little scope for preservation of these geologic marvels. In spite of several such isolated geological and associated cultural heritage sites the state has a lone geological monument, ‘Nomira pillow lava’ of Keonjhar District as identified by GSI. The objective of this write up is to create an awareness of the significance of some of the geoheritage sites of the state which not only needs the attention of geoscientists fraternity of the state but also regularization for its preservation and maintenance, by promulgation of necessary act and law by the State and Central Government authority. It is needless to stress that there could be many such geosites, which might have been noticed or studied by the geologist that need to be focused and brought forward for the knowledge of common man.

Keywords: Geoheritage, Geotourism, Nomira pillow lava, Monolithic granite, Chilika lagoon, Guptheswar caves

Introduction

The provision of enabling tourists to understand the geology and geomorphology of sites beyond mere aesthetic appreciation by the tourism industry is known as “Geotourism”, a term coined by Dr Thomas Hose in 1995. Geotourism is knowledge-based tourism, an interdisciplinary integration of tourism industry with conservation and interpretation of abiotic natural attributes, besides considering related cultural issues. (Sadry, 2009). The state of Odisha comprises dominantly Pre-cambrian rocks (73% of area) ranging in age from Mesoarchaeon to Neoproterozoic. Phanerozoic rocks, represented by the Gondwana Supergroup (Late Palaeozoic – Middle/Late Mesozoic) and minor Tertiary patches, constitute about 8% of the state. Remaining 19% is covered by Quaternary formations, including deltaic sediments of Mahanadi - Brahmani-Baitarani river system. The Precambrians of the state comprises two major cratonic domains, the Eastern Indian Craton and Bastar Craton and bordering mobile belts, Eastern Ghat Mobile Belt (EGMB) and the Singhbhum - Gangpur segment of the Satpura Mobile Belt. The cratons have supra-crustal rocks being enclaves within vast expanses of granite gneiss. This in turn is overlain by sedimentary and volcanic of several generations. EGMB comprises high grade granulitic rocks such as Khondalites and charnockite etc. The Proterozoic Kolhan and Chhatisgarh groups mostly sedimentary successions rest over the cratons. The Phanerozoic rocks are characterised by both Gondwanas (Upper Palaeozoic–Upper Mesozoic) and Baripada Marine beds of Tertiary period. The plateau bauxites laterites and sandstone-shale sequences of coastal sedimentary basins of Mahanadi represent Quaternary formations of the state.

Few Geosites of the state of Odisha can be enumerated as follows;

Pillow Lava of Nomira, Keonjhar District

Geological Survey of India (GSI) has declared twenty-nine (29) geologically prominent sites, located in different parts of the country, as **National Geological Monuments (NGM)**. Nomira in Keonjhar District, Odisha is the lone NGM in the state with well preserved pillow lava structures in Archaean Malangtoli volcanic sequence. The pillow lava is a significant geological structure formed by subaqueous volcanism. Individual pillows are roughly ellipsoidal having distinct ring formed due to sudden chilling of hot lava coming in contact with water and radial cracks confined to its interior. The size of individual pillows varies from 1.5 X 0.6 m and smaller. The closely packed pillows often preserve a V-shape which is taken as a way-up criteria for identifying younger sequences. The basaltic lava is fine to medium grained, green to bluish green in colour with abundant round to ellipsoidal vesicles filled with secondary minerals like quartz, epidote and calcite. These vesicles are formed due to escape of hot vapour from the lava flow. The area is located about 18 km south of Joda town lying on Keonjhar – Barbil – Lahunipada state highway. The monument can be approached from Joda by following Joda-Nayagarh road upto Bamebari and then following a 2 km unmetalled road leading eastward up to Nomira. (Source GSI).

The Simlipal Complex

The Simlipal Complex of Mayurbhanj district is popularly known as Simlipal National Park spread over an area of 2750 sq km area. This park is also declared as Simlipal Biosphere Reserve containing rich flora and fauna, including the rare Black Panther being the main attraction. Innumerable ephemeral springs and waterfalls (Joranda and Barehipani) multiply the natural flavour. In addition to the above this has typical mode of rare rock emplacement which is of interest both to the academicians and tourists. Geologically this national park contains a rounded to elliptical shaped Palaeoproterozoic volcano-sedimentary sequence of rocks often giving an impression of an *astrobleme (remnant bolide-impact structure)*. The spectacular circular map pattern of the Simlipal basin, an unique geological structure in whole of Peninsular India exposes a basal conglomerate and a dark phyllite succeeded by a zone of volcanic breccia, spilitic lavas and tuffs intercalated with quartzites. The effusives alternating with

siliciclastic sediments are intruded by mafic-ultramafic intrusive. Three bands of quartzite alternating with three bands of spilitic lavas form a prominent ovoid structure with inward dips. The volcanic pile is mostly tuffaceous, and the lavas are submarine and vesicular. These are intruded by sills and dykes. A highly differentiated ~ 800 m thick sill (Amjhuri sill) comprising dunite - peridotite - picrite - gabbro - quartz diorite occurs at the centre of the complex. Geological dimension can be added to the existing national park.



Fig.1: Pillow lavas at Nomira, Kendujhar District



Fig 2 Circular and dome shaped Simlipal Complex (Google Earth)



Fig 3 Joranda Waterfall
(Photo: courtesy Dr. M.Mohanty)



Fig. 4 Amygdular Metabasalt of Simlipal Complex

Granite Dome at Sitabinji, Keonjhar

Sitabinji, a paradise for history lovers is a well-known tourist attraction in Keonjhar district, Odisha because of unique fresco paintings on a Rock Shelter called Ravan Chhaya. It is situated at a distance of 32 km from Kendujhar Township. It is also considered a prime heritage of the state. Legend has it that Sita, Rama's wife, gave birth to the twins, Lava and Kusha, at this place. The attraction gets its name from a nearby stream, Sita. A magnificent 150 ft high upright massive rock at this place, is one of the prime attractions. Sita, along with her sons, is worshipped by the devotees under the huge rock. Besides, there are two more boulders measuring (6.7 m in height and 4.7 m in depth). There's also the rock of Ravana Chhaya (shadow of Ravana, the demon king of Sri Lanka who kidnapped Sita), which is quite famous. A series of rock inscriptions can be noticed nearby, which are still a mystery for modern historians. It is believed that once upon a time, a civilisation flourished here.

The additional geological dimension is the porphyritic granite outcrop that stands out as tors, also known by geomorphologists as either a **castle koppie** or **kopje**. **One monolithic granite at Sitabinji** is a large, free-standing residual mass that rises abruptly from the surrounding hill crest. The place is characterised by typical granitic exposure which is weathered in natural environment to have a domal shape. It is well polished due to natural abrasion and looks like a huge Siva Lingam from a distance. The other aspect of the granitic cave could be ascribed to natural joint plains and the interface of two such plains to give rise to caves where ancient paintings are housed.

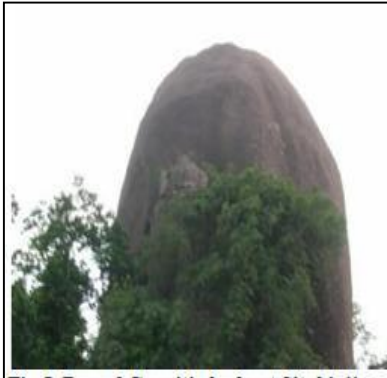


Fig 5 Domal Granitic body at Sitabinji



Fig. 6 Large K-feldspar phenocrysts showing magmatic alignment.



Fig 7 and 8 Fresco paintings on a Rock Shelter called Ravan Chhaya and in other places

Sand Volcano of Angul

A unique and rare feature of sand volcanoes is exposed along the Nandira Jhor river about 6 km from Angul Town, Odisha. These circular to elliptical features with diameter of 125 to 145 cm has crater of 30cm diameter. These volcanogenic structures represent rare events associated with seismicity or earthquakes with the Gondwana Beds of Mahanadi Valley. These sand volcanoes are cone of sand much similar to the volcanic vents of any common volcanoes but formed by the ejection of sand onto a surface from a central point. A crater is commonly seen at the summit. These rare features are regarded as the finger prints of ancient earthquakes, when the subsurface sand behaves as a liquid due to a process called liquefaction and flows along weak planes or fractures (Van Loon, and Maulik, 2011).

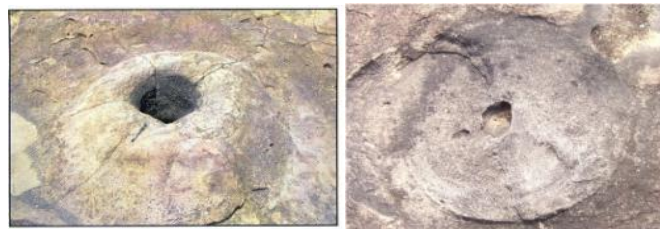


Fig. 9 Sand volcanoes near Angul

Glacial Boulder Bed, Kuturia, Dhenkanal District

During the geologic past, (Palaeozoic) India was near the south-pole conjoined with other continents such as Antarctica and Australia. Late Palaeozoic, Permian glaciations has its imprint in lower lithostratigraphic unit of Gondwana as Talchir Formation. The eminent British geologists Blanford in 1856 was first to describe the coal bearing Gondwana succession of the Talchir Basin of Orissa and designated its lower part as the Talchir Group of rocks. This basal formation has its stratigraphic position in other Gondwana Basins such as Godavari, Raniganj Damuda etc. The evidence of such glaciations is still preserved at Kuturia village (Lat. 21°02", Long. 85°22"; in Toposheet No. 73G/8) in Dhenkanal district. It occurs at the central part of the junction area of

Toposheet 73 G/8 and 73 H/5 and about 1 km. south of Kuturaia village. The boulder bed occupies higher ground (ridges and small hillocks) with an east-west extension and about 5km x 2km in aerial spread. Boulder bed consists of large rounded boulders measuring maximum of one metre to smaller sizes that occurs in the east-west running hills a kilometres south of Kuturaia village. The Talchir Formation of the Satpura Gondwana basin of central India shows features diagnostic of deposition under glacial regime such as the presence of diamictites, boulder pavements, bedding plane striation, faceted/striated gravels, bullet-shaped clasts, dropstone, cryoturbation, etc. Chakraborty and Ghosh (2008).

The boulder bed sits over the local Precambrians consisting of amphibolites, pink granite gneisses and quartzites of the Palaeoproterozoic Rengali Province. The boulder bed is succeeded by green shales, mudstones and fine soft sandstones of Talchir Formation. The boulder bed contains small to large boulder, the bigger ones measuring 2/3 of a metre. Majority of boulders are coarse grained quartzites. They are very well rounded. Interestingly there is a very prominent cave within the Boulder Bed and boulders are seen all around the cave. The cave is an archaeological site with Buddhist connection. A locally famous deity is worshipped here and tourist comes to visit the site.



Fig 10 Talchir Boulder aggregate and boulder with striation

Gondwana Plant Fossils

Gondwana plant fossils viz. *Glossopteris*, *Vertebraria* etc are best seen at Madhupur in Talcher Basin within Barakar and Kamthi Formations. These plant fossils are indicative of a climate which prevailed nearly 300 million years back and was congenial for the formation of coal during that time. A warm condition with low humidity is interpreted from some of these *Glossopteris* fossils. The evidence of plants, leaves and stems of plant fossil, *vertebraria* more than 300 million years past shall be of inquisitiveness to a common man when explained in the occurrence at site itself. These fossils also indicate that the Southern Hemisphere around the beginning of the Permian Period (298.9 million years ago) when the continents of Australia, Antarctica and India were once amalgamated into a single supercontinent – Pangea. The *Glossopteris* was restricted to the middle- and high latitude parts of Gondwana during the Permian and responsible America towards the vast Permian coal deposits. However, such fossils are markedly absent in northern parts of South and Africa.



Fig.11 Plant Fossil:Vertebraria.



Fig.12 Plant Fossil: Glossopteris

Caves of Gupteswar, Koraput District

Due to water action in calcareous rocks of the Eastern Ghat Mobile Belt huge caves are formed at Gupteswar on the bank of Kolab River situated about 55 km away from Jeypore, Koraput District. Inside the cave, there exists the famous holy Lingam of Lord Gupteswar, typical structures of stalagmite within this calc-granulite complex and precipitated from calcium carbonate bearing water dripping onto the floor of a cave. Most stalagmites have rounded forms formed by percolating water action in a calcareous rock. A stalagmite is an upward-growing mound that have or flattened tips. Owing its name for being remained concealed in the cave for a long time (Gupteswar) this sacred place is believed to be associated with Shri Rama of the epic Ramayana. The nearby hill named as "Ramagiri" and its scenic beauty finds its mention in Kalidas's Meghadutam. According to mythology, the lingam was first discovered by Lord Rama during his *Vanavas* (stay in forest) in the Dandakaranya during his exile. Similar caves with similar set up, are noted at Ampavalli near Sunki Village and at Bora-caves in Andhra Pradesh. Bora-caves in Ananta Giri Hills of Araku, Andhra Pradesh have been developed as a tourist centre that attracts thousands of tourists in a year.



Fig.13 Gupteswar shrine and cave

Chilika Lagoon, Associated Beach and The Unique Rock Exposures Of Anorthosites

The Chilika lagoon, the biggest brackish water lagoon in Asia has been developed as a tourist centre and could find a place in the world heritage sites. This lagoon is bestowed with another significant geological aspect hitherto unknown to common tourist. The lake is abounding with a unique and rarely occurring igneous rock 'Anorthosites'. Those unique rocks are exposed adjoining to the National Highway (NH 16). Some of these exposures are the Solari hill, Mamubhanaja hill (on the north west of the lake), Banpur hills on the west and the Ghantasila hills at Rambha on the South-western end of the lake. The well-known hill within the lake 'Chadeihaga' is composed of such type of mantle derived anorthositic rock. Anorthosite, is an intrusive igneous rock comprising calcium-rich plagioclase feldspar. The rocks from the moon also have similar composition as anorthosite. These magmatic activities emplacing the anorthosite is dated to be 983 ± 2.5 Ma (Chatterjee et al. 2008).



Fig 14 Solution Cavities in coastal rock (Photo courtesy Dr BM Faruque.)



Fig:15 Picturesque Chilika lagoon and a sample of Anorthosite

Geosites in Khorda Balugaon stretch (Nanda J.K, Personal Contact)

In this stretch, some of the well-studied and type areas for the litho-tectonic ensemble of the Proterozoic orogen of the EGB are included. These include (i) the ~950 Ma massif-type anorthosite pluton well exposed in Balugaon, Banpur and Rambha areas, (ii) type localities of ultra-high temperature (>1000°C) granulite facies metamorphism between Khordha and Balugaon and (iii) coastal geomorphology between northern part of the Chilka lagoon through Puri up to Konark.

1. **Rambha:** The contact of gabbroic anorthosite and a highly folded calc-silicate with well documented **UHT contact aureole near Mathamukundpur**, 3km south of Rambha.
2. **Banpur:** large exposures of coarse grained anorthosite on Barbara road near Kolathia village.
3. **Balugaon:** Well studied ANORTHOSITE EXPOSED IN THE WELL KNOWN MAMU-BHANJA HILLOCKS.
4. **NACHUNI:** A HILLOCK EXPOSING UHT SAPPHIRINE-CORDIERITE-OPX-GARNET ASSEMBLAGE IN QUARRY SECTION. THIS IS CONSIDERED ANOTHER contact aureole with metapelite

5. Tapang and nearby region: Numerous quarry sections expose aluminous granulites, cordierite ± sapphirine bearing gneisses, leptynite with patchy (metamorphic) charnockite. This is the type section of the Chilka domain of the EGB and has its deformation and metamorphic history very well documented by modern technique in recent works and its significance in EGB-Rayner (Antarctica) orogen highlighted.
6. Konark-Puri-Satapada: The tract is ideal for studying evolution of coastal geomorphology, marine science and neotectonics

Platinum Bearing Magmatic Breccia, Baula-Nuasahi, Keonjhar District

Discovery of Platinum Group Elements (PGE) in the Baula Nuasahi ultramafic belt in Keonjhar District during nineties has attracted earth scientists from all over the world as the oldest Platinum deposit (> 3.1 billion years). Baula - Nuasahi mafic-ultramafic Complex (BNUC) (Lat. 21° 15" and 21° 20" and Long. 86° 18" and 86° 20", Toposheet no. 73 K/7) in Keonjhar district is exposed in the southern slope of the Baula hills. The 3km long NNW-SSE trending Baula-Nuasahi mafic-ultramafic complex is known for rich deposits of high grade lumpy chromites which is associated with the platinum group of elements(PGE). The Magmatic breccia zone being geologically most important and well exposed on the hanging wall in FACOR, IMFA mining lease areas contains **economically enriched platinum minerals and is one of its kind in India, This breccia zone need to be preserved and declared as National monument for its intrinsic academic value.**



Fig.16 Palladium and Platinum Rich Magmatic breccia in Hangingwall of Shankar Chromite lode in FACOR Mines, Baula



Fig. 17 Location of OMG & OMTG in Baitarani river bed, Champua

Oldest Metamorphic Rocks of Peninsula India, Keonjhar District

Within the vast granitic terrains of Keonjhar District, in the Baitarani River Bed near Champua the typical metamorphic assemblage of Tonalite Gneiss has been dated to be oldest one with an age of 3600 million years. These enclaves are hosted within the granitic rocks dating to 3300 to 3100 million years. The Singhbhum craton of Odisha contains one of the oldest rock successions in the world and only is comparable in age with similar cratons of Greenland, and Canada. The basement rocks within the craton occur as enclaves within batholithic granite comprising the Older Metamorphic Group and the Older Metamorphic Tonalite Gneiss. These granites from the core of the Singhbhum craton and have intruded in phases at 3.3 Ga to 3.1 Ga. The Older Metamorphic Group and Older Metamorphic Tonalite Gneiss are considered to be around 3.6 to 3.4 Ga old. **Recently, 4.0 Ga old zircons dates from tonalite gneiss considered oldest rocks of India and has significant potential to unravel the Hadean (>3.0 Ga) geological history of the earth.**

Vesicular or Amygdaloidal Basalt In Keonjhar District

Basalt is a dark coloured volcanic rock formed from a lava flow of basic composition erupted on the Earth's surface. Magmas generally contain dissolved gas, which can form bubbles in the magma as the pressure is released on eruption. These bubbles can get trapped in the solidified rock. After some time, groundwater or hot solutions connected with the volcanic activity pass through the porous lava and deposit crystals in the open cavities, which gradually fill up with quartz, calcite (calcium carbonate) or other minerals called zeolites. Filled cavities in lavas are called *amygdales*, and a rock full of them can be called *amygdaloidal*. The amygdales are usually white in colour. As the magma flows from underground to the surface of the earth, there is fall in pressure that allows water and gases to form bubbles. These bubbles are frozen in the lava as vesicles. Amygdaloids are the vesicles filled with secondary minerals long after the lava gets cooled. This type vesicular rock occurs at Kanjipani ghati (NH-6) and within Baitarni River Bed of Keonjhar District, These rock exposures are considered as a typical field for the hunt of zeolite, commonly used as commercial adsorbents and catalysts.



Fig.18 Amygdular metabasalt at Rugudi, Keonjhar District

Few of the sites could be of interest to the earth scientist community for academic and knowledge based purpose. Those are;

Nepheline Syenites of Odisha (Koraput, Khariar, Rairakhol)

Nepheline Syenite is an alkaline rocks that are crystallised from under- saturated magma, produced by partial melting of lower crust-mantle. These magmas are emplaced in a weaker zone when there was severe tectonic movement of the Eastern Ghat over north lying Singhbhum craton. Age of this tectonic movement is inferred 1.5 Ga. In Odisha these rocks occur at Koraput, Khariar, Rairakhole, and Poipani areas.

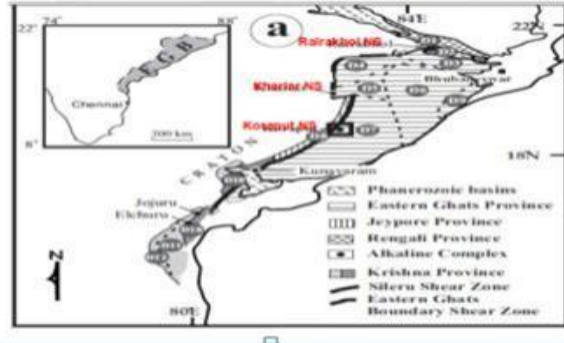


Fig.19 Location of Nepheline Syenites of Odisha (Koraput,Khariar,Rairakhol)

Khondalite Rocks of Odisha

It is interesting to note that the master piece of architectural marvel of Konark, the Black Pagoda of Odisha is exclusively onstructed by this type of rock. Khondalite is a quartz,-feldspar,-sillimanite gneiss with garnet, +/- coordiarite, hosting graphite, manganese, bauxite, produced by regional metamorphism of pelittic sediments. It is named after *Khond / Khandha* tribes of Odisha.(Koraput & Phulbani). These rocks are found in India, Srilanka, Vietnam, China, New York, Antarctica. The best exposure of khondalite can be seen near Kubhikota hill section along Rayagada-Koraput road.

Baripada Marine Bed

The Baripada beds of Odisha are the marine Tertiary exposures of east coast, distributed in parts of Mayurbhanj and Balasore with further extension to west Bengal. These beds are named after the town Baripada and are very well developed in the river cuttings of Budhabalang namely, Mahulia, Satpautia and Mukurmatia. The studies have helped to infer the age, environment of deposition bio-assemblage with their Palaeoecological significance, also It is quite interesting to know that Baripada Town, the District Headquarters of Mayurbhanj was once upon time under the sea. This place has yielded fossiliferous limestone beds which are exposed in the banks and other erosional sections of Budhabalanga river at Mahulia and Mukurmatia in Baripada town. Fossils of fish, crocodile, crab, shark, gastropod, pelecypod, foraminifers etc. are found in the sediments (Rath, 2004). The fossiliferous marine deposits of Baripada Beds are well known for their Mio-pliocene vertebrate and invertebrate fauna. The fossil fish assemblage recorded in this contribution from these beds comprise of sharks (48%), batoids (31%) and teleosts (20%). Rhyncobatus genera is the first discovery of Batoids in Indian subcontinent (Sharma and Pattnaik,2013). Deposition of sediments has occurred in shallower part of shore environment, as a result of marine transgression and regression episodes in tropical to subtropical climate during Tertiary period. The presence of a diverse fossil fish fauna corroborates well with an overall increase in the global biodiversity during the Miocene, due to a change in the climate caused by widespread tectonism leading to the rise of the Alpine-Himalaya and closure of the Tethys Sea.

The organic facies is characterised by type-IV kerogen with major contribution from near shore terrestrial plants. This also suggests deposition in shallow, oxygenated environments that did not promote significant accumulation and preservation of organic content in sediments. The organic facies is characterised by type-IV kerogen with major contribution from near shore terrestrial plants. This also suggests deposition in shallow, oxygenated environments that did not promote significant accumulation and preservation of organic content in sediments. (Bhaumik et al. ,2017).



A



B

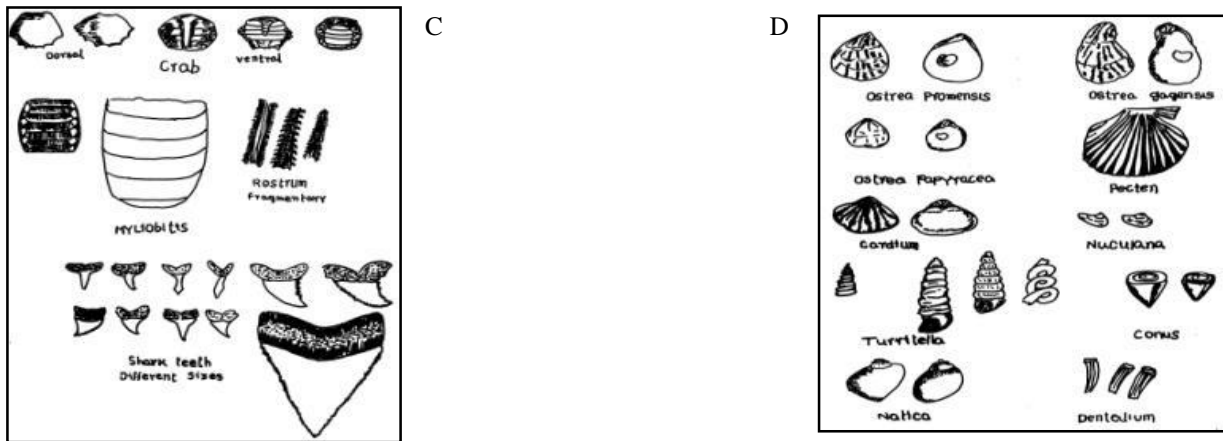


Fig.20 A. Location of Baripada Bed B. Fossiliferous limestone beds on the bank of river, Budhabalanga C and D. Fossil findings (both vertebrate and invertebrate) in Baripada Bed (Courtesy: Prof. M.Mohanty, B.D.Rath and Dr B.Mishra).

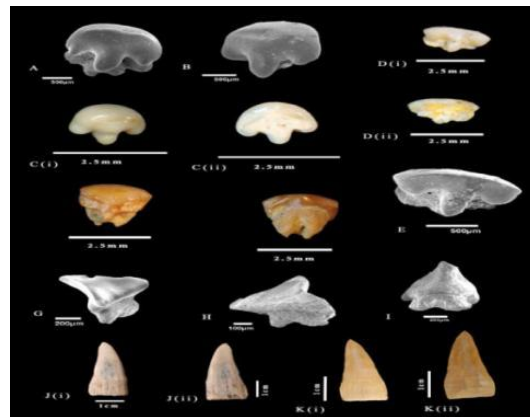


Fig.21 Photographs of some specimens of the Genus Rhinobatos, Rhynchobatus, Gymnura and Pristis. A. Rhinobatos sp. indet. 1 (Mks/pal/pu. 2195) in lingual view; B, C. Rhinobatos sp. indet. 2 (Mks/pal/pu. 2196, 2197), B & C (i) in lingual view, C (ii) in labial view; D, E. Rhinobatos sp. indet. 3 (Mks/pal/pu. 2198, 2199) D (i) & E lingual view, D (ii) in labial view; F. Rhynchobatus sp. (Mks/pal/pu. 2000), F (i) in lingual view, F (ii) in labial view; G, H, I. Gymnura sp. (Mks/pal/pu. 20204, 20205, 20206), (Courtesy: K.M.Sharma and R.Pattnaik)

Conclusion

Although our endeavor is to stress on the significance, identification and preservation of geosites in Odisha, a systematic approach on the following lines as recommended has to be taken over by the fraternity of geoscientists, before it is destroyed by invasion for human habitation. A. Identification and deliberations on the important geosites of Orissa. B. Classification of the suggested sites into scientific / educational / recreational (geotourism) at Local / Regional / National / International level of importance. C. Ascertain the present status of the suggested geosite including ownership (Public. private land), potential threats (Natural (weathering, floods, cyclone, earth quakes etc) / anthropogenic (Real estate, urbanization, mining etc). D. Suggest the possible remedies to the perceived problems and the likely agency which can willingly take up / be persuaded to take up the responsibility of protection and conservation. E. Evaluation and prioritization: All the suggested sites can be evaluated for their importance under various heads and can be prioritized.

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