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Additional Fossil Batoids (Skates and Rays) from the Miocene Deposits of Baripada Beds, Mayurbhanj District, Orissa, India

K. Milankumar Sharma and Rajeev Patnaik
Centre of Advanced Study in Geology
Punjab University, Chandigarh-160014, India
Email: milankumar.sharma@gmail.com; rajeevpatnaik@gmail.com

Abstract

The Miocene Baripada Beds of Orissa are well known for their rich assemblages of sharks and batoids. The Batoid assemblages of Baripada Beds are represented by nine genera comprising of *Myliobatis, Aetobatus, Rhinoptera, Dasyatis, Raja, Rhinobatus, Rhyncobatus, Pristis* and *Gymnura*. Our record of *Rhyncobatus* sp. is significant as it is the first such report from Indian subcontinent. Presence of *Gymnura* sp. is also being described for the first time from the eastern coast of India. We also describe additional specimens and skeletal remains that were not discovered earlier. Our findings, combined with earlier finds of crocodilian coprolite, fish fauna, gastropods, bivalves, pelecypods, and foraminifers, suggests that the Baripada Beds were deposited in a shore environment, probably in the shallower part of the inner neretic, tropical to subtropical environment, well connected to the open seas.

Keywords: Batoids, Baripada Beds, Miocene, Palaeoenvironment, Neretic.

Introduction

Baripada Beds are well known for their diverse fossil assemblages of sharks and batoids (Ghosh, 1959; Bhalla and Dev, 1972; Mehrotra *et al*., 1973; Sahni and Mehrotra, 1981; Mondal *et al*., 2009). The fossil fish fauna of Baripada Beds include sharks teeth, Skates and Rays teeth and spine and certain micro teleost (Modak, 1952; Gosh, 1956, 1959; Sarma, 1956; Tiwari and Awasthi, 1960; Sahni *et al*., 1971; Mehrotra *et al*., 1973; Sahni and Mehrotra, 1981; Mondal *et al*., 2009). This fossiliferous assemblage is considered to be deposited as a consequence of marine transgression during Middle to Late Miocene.

The study of Baripada Beds has been carried out since 1904 when Bose discovered richly fossiliferous limestone beds exposed at Mahulia. Hora (1939) recorded the first detailed account of the fossil fish including sharks and rays from the Miocene deposits of Orissa from the borings at Balasore, Orissa. However, Jena (1942) for the first time described the fossil fish teeth from Baripada Beds. Earlier fossil records of batoids faunas were described by various workers from these fossiliferous deposits (Modak, 1952; Ghose, 1956, 1959; Tewari and Awasthi, 1960; Mohanty, 1980; Sahni, *et al*., 1971; Sahni and Mehrotra, 1981; Mondal *et al*., 2009). Besides the batoids and sharks, remains of turtle and crocodiles, pelecypods, gastropods, foraminfers and mammalian teeth have also been reported from these beds (Chauduri, 1958; Tewari and Awasthi, 1960; Mohanty, 1980; Bhalla and Dev, 1972; Milankumar and Patnaik, 2010; Milankumar and Patnaik, in press). Earlier, Tertiary selachians including batoids have been recorded from different parts of India including Kutch, Gujarat (Mehrotra *et al*., 1973; Sahni and Mishra, 1975; Sahni and Mehrotra, 1981), (Tiwari *et al*. 1964; Sahni and Mishra, 1975; Mishra, 1980; Bajpai and Thewissen, 2002;

Rana *et al*, 2004, etc.), Rajasthan (White, 1952; Jolly and Loyal, 1985; Rana *et al*., 2006; Kumar *et al*. 2007, etc.), Mizoram (Ralte *et al*., 2011; Tiwari and Ralte, 2012) and from lesser Himalayas (Loyal, 1983, 1984; Kumar and Loyal, 1987; Kumar, 1989, 1996).

Geology and Lithostratigraphy

Baripada Beds, exposed in the erosional cut section of Burbhalang River were deposited as a result of marine transgression and regression episodes (Modak, 1952; Sahni and Mehrotra, 1981; Mondal *et al*. 2009; Milankumar and Patnaik, in press) over the Precambrian basement which is not exposed in any of the sections (Bose, 1904). It is conformably overlain by conglomerate a bed which is again overlain by lateritic and alluvial deposits.

The present fossil batoids were collected from the Miocene deposits of Baripada Beds of Orissa, India exposed along the banks of Burabhalang river at Mukurmatia (21^0 54': 86^0 44'15"), Itamundia ($21^0$53'35.9': $86^0$43'35") (Fig. 1). This fossiliferous marine sedimentary deposit exposed around the Baripada town lies conformably over the Precambrian metamorphic basement (Blanford, 1872) and it is cited as an example for marine transgression and regression history in the peninsular India during the Miocene time (Modak, 1953; Sahni and Mehrotra, 1981; Mondal *et al*. 2009). The lithological unit comprises of Miocene fossiliferous marine deposits which is ~12 m thick and is overlain by fresh water lateritic sediments of Quaternary age. The Quaternary pebbly lateritic deposit is unfossilifereous. The lowermost bed comprises of green shales, base of which is not exposed in this section. Greenish grey shales are in turn overlain by a thin hard limestone bed of about 1.5 m. The limestone bed is then overlain by bluish white coprolite bearing shale (Milankumar and Patnaik, 2010) of about 10 m thickness. This shale bed is greenish in colour at the base, and as it becomes sandier towards the top, the colour of the sediment changes from greenish to yellowish. The shale is thinly laminated and has yielded abundant shark teeth and foraminifers. The limestone bed is dominated by fossil oysters, whereas, the greenish shale is characterized by the presence of foraminifers (Bhalla and Dev, 1972, 1975).

Methodology

The currently described specimens were collected from the shale and the limestone beds of the localities Mukurmatia and Itamundia. The micro size batoids fossils have been collected after maceration of about 150 kilogram of sample using water, water and acetic acid and with kerosene and water depending on the hardness of the samples. The disintegrated and loose macerates of the above samples were subjected to wet sieving process in which the macerates were passed through sieves ranging from 40-200 mesh. The residues collected from the sieves were made to dry at first and then it is seen under the binocular microscope for picking the fossils contained in it. They are found to be associated with fossil sharks, teleost, mollusc and foraminifers. The collected fossils were studied under the Leica S8 APO stereo zoom binocular microscope and JEOL 6490 Scanning Electron Microscope housed at the Department of Geology Panjab University, Chandigarh.

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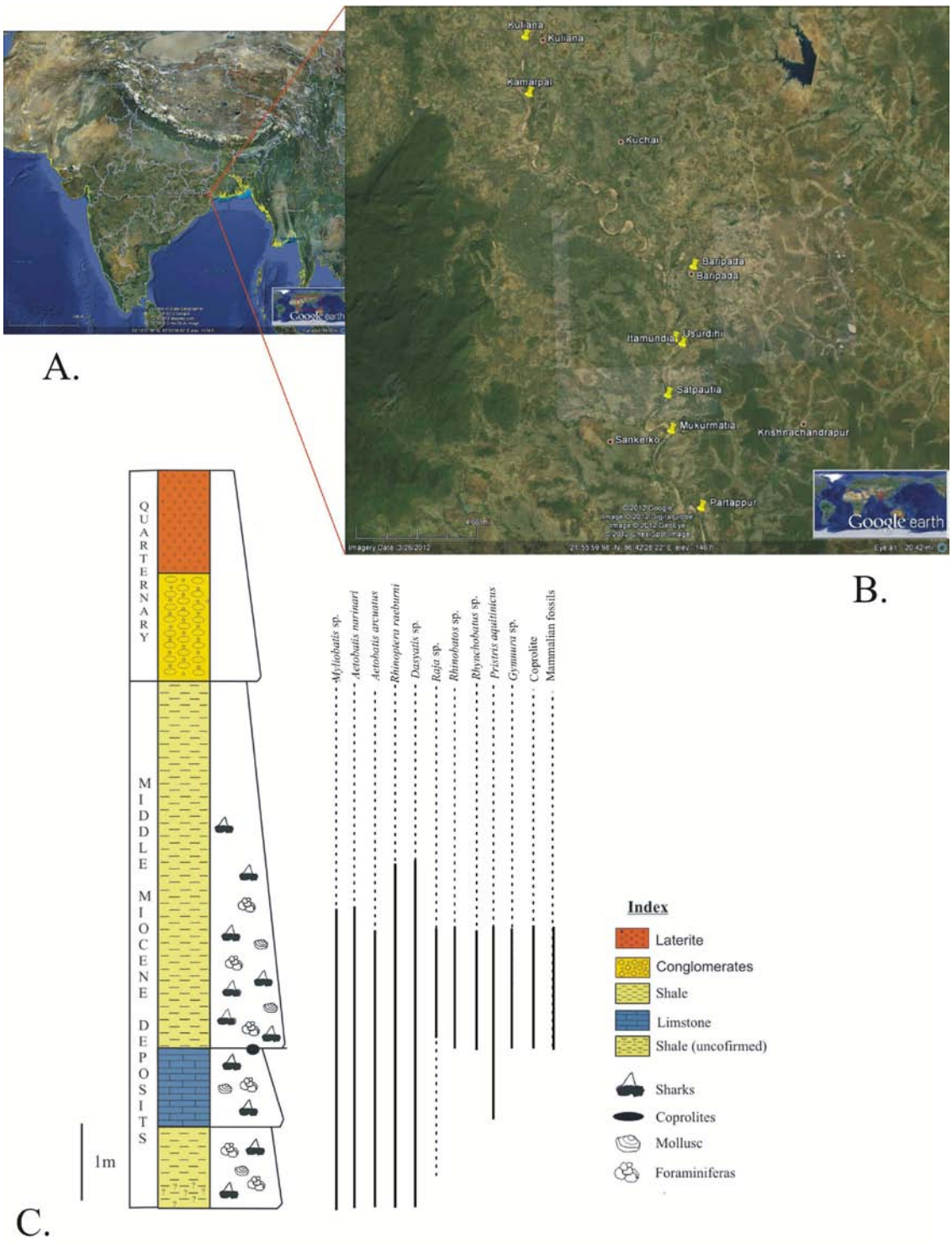

Fig. 1: A. Physical Map of India (Source, Google Earth image, 2012); **B**. Location map of study area (Source, Google Earth image, 2012); **C**. Generalized stratigraphy of Baripada Beds, Orissa, India.

Most of the fossil teeth were preserved completely, however some of them were rather poorly preserved often missing the roots, enamel or having fractured enamel, etc. These occurred mostly as tiny specimens. The terminology of the teeth used herein is that of Cappetta, 1987. All the specimens carry requisition number Mks/pal/pu and are deposited at the micropalaeontological laboratory of the Centre of Advance Study of Geology, Punjab University, Chandigarh-160014 (India).

Systematic Palaeontology

Class: Chondrichthyes Huxley, 1880
Order: Rajiformes Berg, 1940
Family: Myliobatidae Bonaparte, 1838.
Genus: *Myliobatis* Dumeril (In Cuvier, 1817: 137)
***Myliobatis* sp. indet. 1**
(Fig. 2: A, B, C, D)
Morphotype 1 (Fig. 2: A, B)

Materials and Horizon: Isolated dental plates, Mks/pal/pu. 2001 and 2002 of from the greenish yellow shale of Mukurmatia.

Description: - Mks/pal/pu. 2001, 2002 (Fig. 2: A, B) are dental plate; Mks/pal/pu. 2001 (Fig. 2: A) consists of six rows of median teeth; the lateral teeth are not preserved as the specimens are incomplete; Mks/pal/pu. 2002 (Fig. 2: B) is incomplete and large in size comprising of seven rows of median teeth. Crown thin, the hexagonal median teeth are transverse, longer than broad, dorsal surface of the plate is flat and the basal surface is convex. Small ornamented tubercles are present at the coronal surface and the root is marked by antero-posterior ridge and furrows.

Remarks: - The present specimen is closely similar to *Myliobatis tewarii* (Mishra, 1980; p. 81, pl. 1, Fig. 1), the same specimen was described earlier as *Myliobatis* sp. by Sahni and Mishra (1975; p. 6-7, pl. 1, Fig. 1), described from the Middle Eocene shale and limestone of Babia stage, Kutch. However, the present specimens are longer than broad unlike their specimen which is nearly as long as broad. The incomplete nature of preservation makes it difficult to described and assign it to a particular species. Dental plate of *Myliobatis* had also been described from the Eocene deposits of Kutch by Lydekker (1886). The dental plates are very rare as the median and the lateral teeth in a dental plate gets easily detached during fossilization and are commonly found isolated (Mishra, 1980). This is for the first time that a dental plate of *Myliobatis* is described from the Miocene deposit of Baripada Beds.

Morphotype 2
(Fig. 2: C, D)

Materials and Horizon: - Two isolated dental plates, Mks/pal/pu. 2003, 2004 of *Myliobatis* sp. from the greenish yellow shale of Mukurmatia.

Description: - Mks/pal/pu. 2003 (Fig. 2: C) is incomplete dental plate shows six rows of median teeth. The straight rows of the median teeth are hexagonal, longer than broad and

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anterio-posteriorly arched. The occlusal surface is flat (Fig. 2: C) or slightly concave (Fig. 2: D). In Mks/pal/pu. 2003 (Fig. 2: D), five anterio-posteriorly arched median teeth are present; lateral denticles are not preserved. The basal surface of root of each median tooth possesses the numerous distinguished ridges and grooves. The coronal surface is smooth but bears numerous micro-tubercles. The inner lateral teeth are diamond shaped, small and nearly as long as broad.

Remarks: - Many species of the genus *Myliobatis* have been described from the Tertiary deposits of India, however, the scarcity and fragmentary nature of the material collected makes it difficult to assign the specimen up to the species level. *Myliobatis* sp. has been described from the Middle Eocene of Kutch (Mishra, 1980), Miocene of Baripada Beds, Orissa (Sahni *et al*., 1981), Eocene of Subathu Formation, Bilaspur area (Singh, 1985), Eocene of Subathu Formation, Himachal Pradesh (Kumar and Loyal, 1987), Eocene Vastan lignite Mine of Cambay Shale, Gujarat (Rana *et al*., 2004), Lower Eocene Panandro lignite field, Gujarat (Bajpai *et al*., 2002), Early Eocene Kapurdi Formation of Rajasthan (Rana *et al*., 2006).

***Myliobatis* sp. indet. 2**
(Figure 2: E, F, G)

Materials and Horizon: - Mks/pal/pu. 2005, 2006 and 2007 are pieces of the caudal spine of *Myliobatis* sp. collected from the limestone bed of Itamundia and from the greenish shale of Mukurmatia.

Description: - The spines are long and become wider towards the base, hook shape denticles are present at the lateral edges which are directed distally, upper surface of spine are curve and the lower surface are more flattened, and longitudinal striations are present (Fig. 2: E, F, G). Mks/pal/pu. 2007 (Fig. 2: G) have broader base as compared to the other specimens. The sharpness of the lateral hook shape denticles also decrease from the bottom towards the top.

Remarks: - The spines resemble to that of *M. meriodionalis* (Leriche, 1957). However the designation of the specimens into a particular species by studying only its spine remains is very difficult. *Myliobatis* spines had been earlier described from the tube well boring between 30 to 60 m below the surface of the ground from Balasore, Orissa by Hora (1939), and from Baripada Beds by Ghosh (1959) and Sahni *et al*. (1981). The caudal spine of *Myliobatis* sp. has also been reported from the Tertiary deposits of Kutch (Sahni and Mishra, 1975, Bajpai and Thewissen, 2002).

***Myliobatis* sp. indet. 3**
(Fig. 3: A)
Materials and Horizon: An isolated tooth, Mks/pal/pu.1228, from the greenish shale of Mukurmatia, Baripada Beds.

Description: - Mks/pal/pu. 1228 is an isolated tooth, hexagonal in shape with rectilinear outline; the crown is as thick as the root. The crown and the root are well separated by a minor groove (Fig. 3: A i, A iii). The basal surface of the root is flat with 23 root lobes separated by grooves (Fig. 3: A iii). The tooth is much broader than long. The specimen

represents the tooth of median file as the teeth of lateral file are longer than broad. The crown is flat, bears minor tubercles in occlusal view (Fig. 3: A ii).

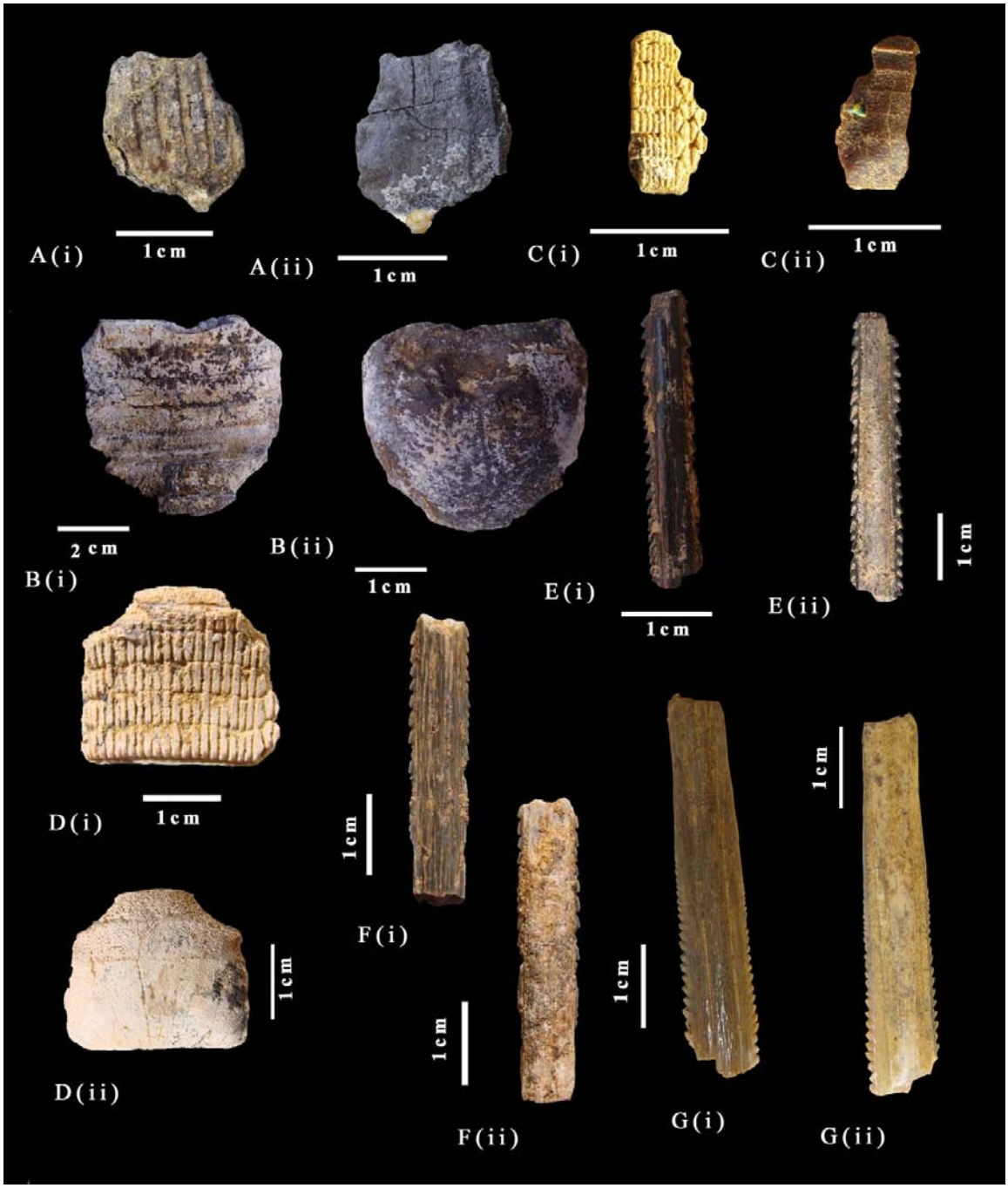

Fig. 2: Photographs of some specimens of the Genus *Myliobatis*. **A, B, C, D.** *Myliobatis* sp. indet. 1; A, B. *Myliobatis* sp. indet 1, Morphotype 1 (Mks/pal/pu. 2001, 2002), **A (i), B (i)** in basal view**, A (ii), B (ii)** in the occlusal view; **C, D.** *Myliobatis* sp. indet. 1, Morphotype 2 (Mks/pal/pu. 2003, 2004), **C (1), D (i)** in basal view and **C (ii),** , **D (ii)** in the occlusal view; **E, F, G**. *Myliobatis* sp. indet.2 (Mks/pal/pu. 2005, 2006 and 2007) in lateral view.

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Remarks: The present tooth is comparable to that of *Myliobatis* sp. of Welton (1972, Plate 1, p. 167, Fig. 8) from the Miocene Coaledo Formation along the Oregon coast. Though the author didn't describe the specimen, the hexagonal shape, flat surface of root, flat crown and separation of the root and crown by a minor depression is apparent from the illustrations. However, Coaledo specimen posses a thicker crown as compared to the present specimen. Gillette (1984) distinguished *Myliobatis* teeth from the closely similar *Rhinoptera* teeth in having a transverse diameter at least four times greater than the anterio-posterior diameter, which is having transverse diameter no more than three times greater than the antero-posterior diameter in the later case.

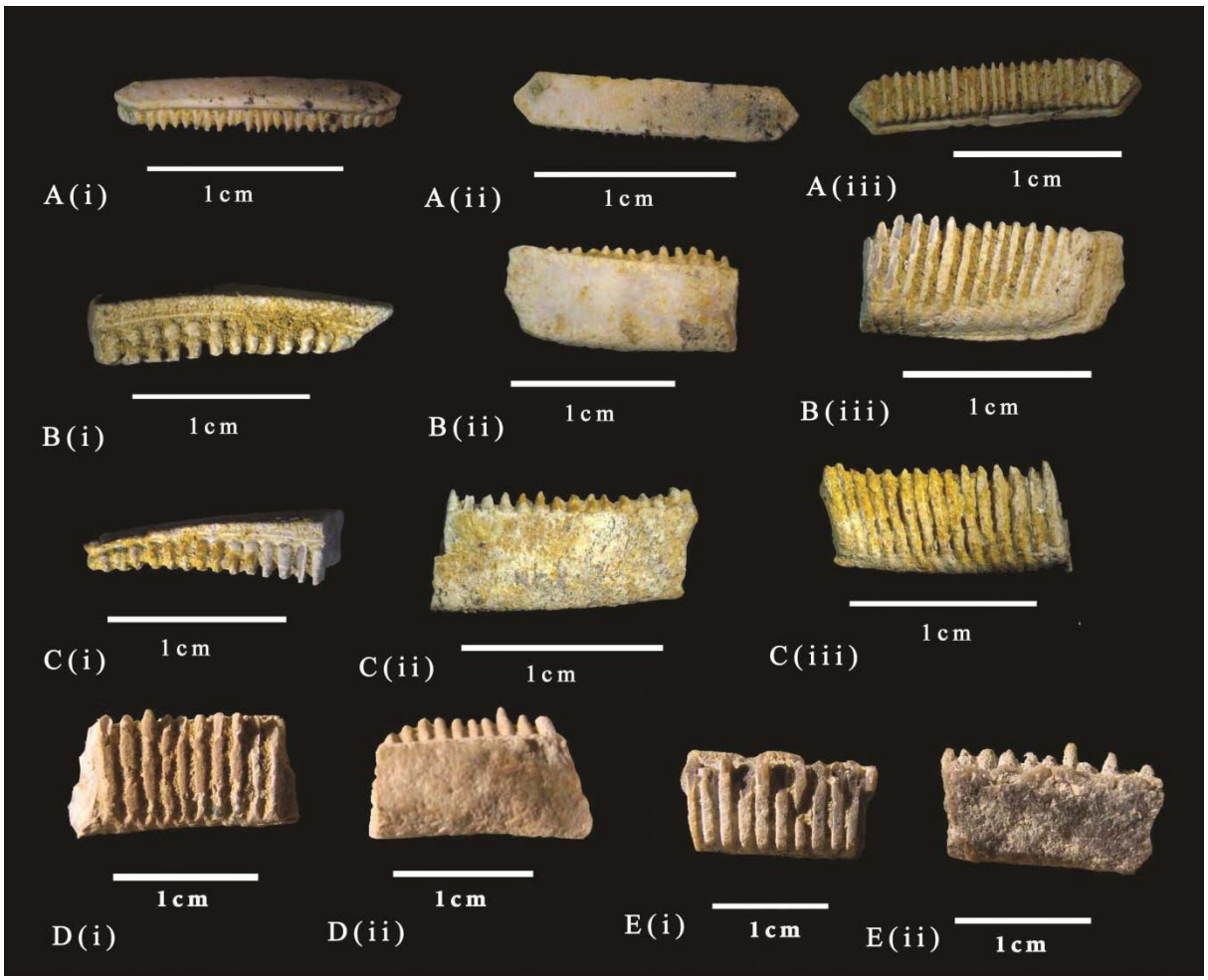

Figure 3: Photographs of some specimens of the Genus *Myliobatis*. **A.** *Myliobatis* sp. indet. 3 (Mks/pal/pu. 1228), **A (i)** in lingual view, **A (ii)** in occlusal view, **A (iii)** in basal view; **B, C.** *Myliobatis* sp. indet. 4 (Mks/pal/pu. 1229, 1230), **B (i), C (i)** in lingual view, **B (ii), C (ii)** in occlusal view and **B (iii), C (iii)** in basal view; **D, E**. *Myliobatis* sp. indet. 3 (Mks/pal/pu. 1231, 1232), **D (i), E (i)** are in basal view and **D (ii), E (ii)** are in occlusal view.

***Myliobatis* sp. indet. 4**
(Fig. 3: B, C)

Materials and Horizon: Mks/pal/pu. 1229, 1230 from the greenish shale of Mukurmatia, Baripada Beds.

Description: - Mks/pal/pu. 1229, 1230 are the median file of pavement like jaw teeth, arched in the coronal plane, representing upper teeth (Fig. 3: B, C). All the teeth are incomplete at the lateral ends and thus the hexagonal morphology is not evident. Teeth are wider than long. These are considered as the teeth of median file as the lateral file teeth are narrower and smaller. These teeth are considered as those of *Myliobatis*, rather than *Aetobatus*, because the thickness of the crown is equal to or slightly greater than the thickness of the root. However, *Aetobatus* teeth have roots much thicker than the crown (Cappetta, 1987). As the specimens are incomplete, the exact numbers of root elements of the specimen are not known; in the current state the root file have more than 13 elements in Mks/pal/pu. 1229 (Fig. 3: B iii) and 15 elements in the current fragment of teeth, Mks/pal/pu. 1230 (Fig. 3: C iii).

Remarks: - The present teeth are closely identical to the *Myliobatis* sp. of Stevens *et al.* (2011, p. 293, Fig. 3.1) recorded from the Palaeocene of Imo Formation of Nigeria in which they compare their specimen with *Myliobatis bothriodon* (White, 1926, pl. 10, Fig.12). However, the incomplete nature of preservation of the specimen makes it difficult to assign them to a particular species.

***Myliobatis* sp. indet. 5**
(Fig. 3: D, E)

Materials and Horizon: Isolated teeth, Mks/pal/pu. 1231 & 1232 from the greenish shale of Mukurmatia, Baripada Beds.

Description: The teeth are poorly preserved, incomplete; height of the crown is nearly equal to the height of the root (Fig. 3: D, E). In the basal view all the teeth show roots with prominent ridge and groove, the loblets are generally extending slightly beyond the lingual edge of the crown (Fig. 3: D i, E i). The crowns are smooth.

Remarks: - The present specimens are comparable with the *Myliobatis* sp. 1 of Case and Cappetta (1990; p. 19-20, pl. 9, Fig. 216) which presents a deep transverse lingual groove between the root and the crown. As the dental plates are poorly preserved, it is difficult at the moment to describe and compare the morphology of the teeth with other already described species.

Genus: *Aetobatus* Blainville**,** 1816
***Aetobatus narinari* Euphrasen**
(Fig. 4: A, B, C, D)

Aetobatus arcuatus baripadensis Ghosh, 1959, p. 678, pl. 88, Fig. 12, 17, 18.
Aetobatus narinari Euphrasen in Mondal *et al*., 2009, p. 148, pl. 3, Fig. 5, 6.

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Material: Mks/pal/pu. 1233, 1234, 1235, 1236 and several unnumbered specimens from the bluish shale bed of the Mukurmatia and limestone bed of locality Itamundia, Baripada Beds, Orissa.

Comments: This species has been described by Mondal *et al.* (2009) from gritty sandstone bed of Mahulia. As similar to their species the tooth of the present species also meets the arcuate root acutely both in labial and lingual view. *Aetobatus arcuatus baripadensis* which Ghosh (1959) described from the Baripada Beds is different in having bifurcated ridges near the root and two side of the crown meeting at a broad obtuse angle. *Aetobatus narinari* is different from *Aetobatus* sp. (Sahni and Mishra, 1975) described from the gypseous shales of Khari series (Lower Miocene) at Matanomadh of Kutch in which the slightly curved root of the tooth is divided longitudinally into ridges and grooves. His specimen also differs from the present specimen being smaller in size and less arched.

***Aetobatus* sp.**
(Fig. 4: E, F, G)

Materials and Horizon: Isolated teeth, Mks/pal/pu. 1237, 1238 & 1239 from the greenish shale of Mukurmatia, Baripada Beds.

Description: Mks/pal/pu. 1240, 1241 & 1242 are incomplete teeth, the root is quite distinctive with the strong lingual displacement of the laminae and the sloped labial and lingual root faces (Fig. 4: E i, F i). The crown lacks the hexagonal shape which is usually associated with myliobatids (Fig. 4: G); the lateral margins are smoothly curved and directed rearward (Fig. 4: G ii). The occlusal surface is smooth. The root is nearly as high as the crown and is divided into longitudinal ridges and grooves.

Remarks: As the teeth are poorly preserved, distinctive comparison of the specimen with other species is difficult. Earlier tooth of *A. arcuatus baripadensis* has been described from the Miocene of Mayurbhanj, Orissa in eastern India (Ghosh, 1959; Sahni and Mehrotra, 1981; Mondal *et al*., 2009). *Aetobatus* teeth have also been described from the western coast of India (Sahni and Mishra, 1975) from the Lower Miocene Khari Series of Matanumadh, Kutch. At present in India, the Family Myliobatidae (Eagle Rays) is represented by only two genera, *Aetobatus* and *Myliobatis* and only two species *A. flagellum* and *A. ocellatus* of *Aetobatus* (Duck-Billed Ray) are presently found in the Indian region (Sahni and Mishra, 1975).

Order: Myliobatiformes Compagno, 1973
Family: Rhinopteridae Jordan and Evermann, 1896
Genus: *Rhinoptera* Cuvier, 1829
***Rhinoptera* aff. *sherburni* Arambourg 1952**
(Fig.4: H, I)

Material and Horizon: Two isolated teeth under the specimen no. Mks/pal/pu. 1240 & 1241 from the limestone bed of Itamundia.

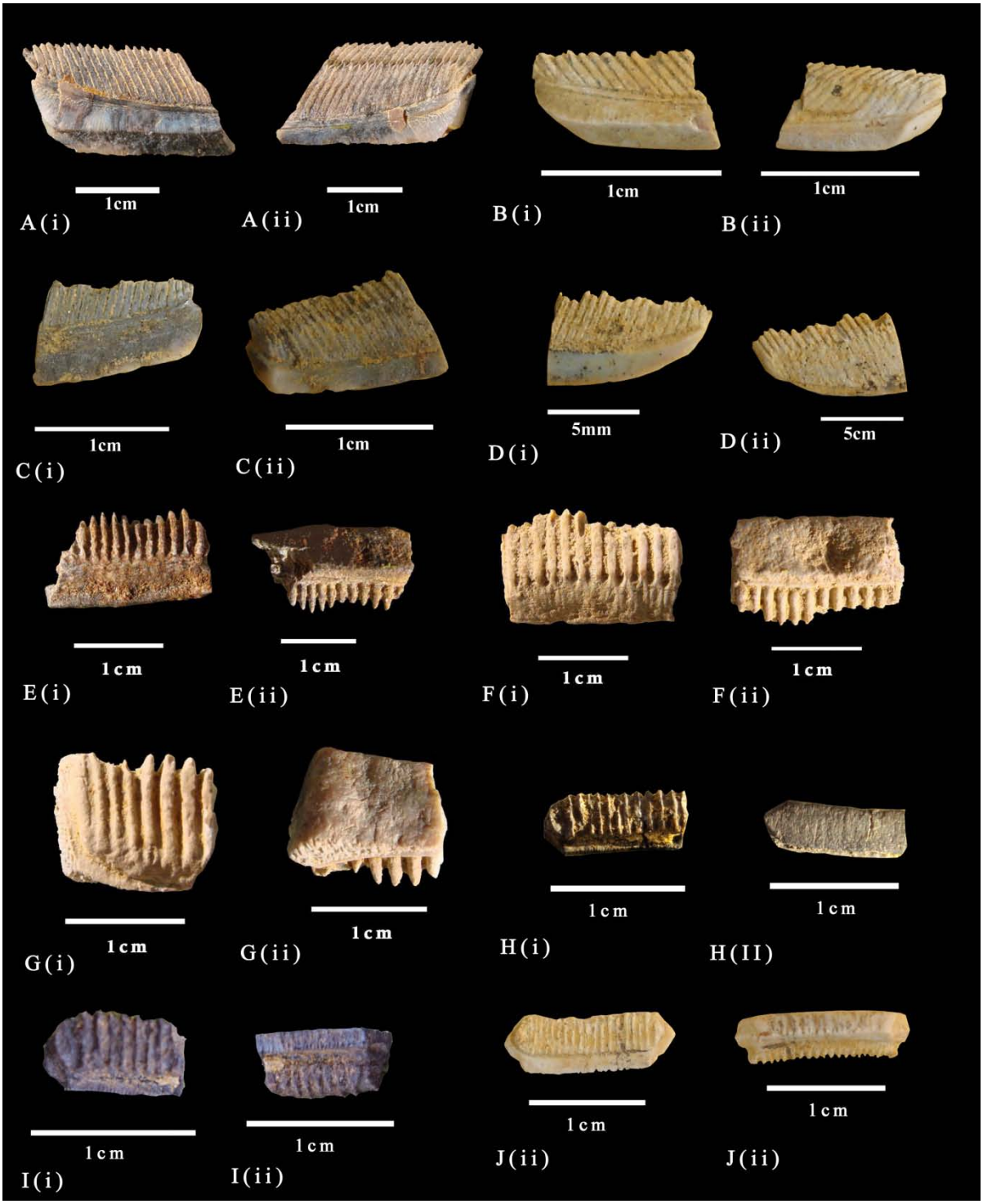

Fig. 4: Photographs of some specimens of the Genus *Aetobatus and Rhinoptera*. **A, B, C, D.** *Aetobatus narinari* (Mks/pal/pu. 1233, 1234, 1235, 1236), **A (i), B (i), C (i), D (i)** in the lingual view and **A (ii), B (ii), C (ii), D (ii)** in the labial view; **E, F, G.** *Aetobatus* sp. (Mks/pal/pu. 1237, 1238, 1239), **E(i), F(i), G(i)** are in basal view and **E(ii), F(ii), G(ii)** in lingual view; **H, I.** *Rhinoptera* cf. *studeri (*Mks/pal/pu. 1240, 1241**), H(i), I(i)** in basal view, **H(ii)** in occlusal view, **I(ii)** in lingual view; **J.** *Rhinoptera raeburni* (Mks/pal/pu. 1242), **J(i)** in basal view and **J(ii)** in lingual view.

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Descriptions: Mks/pal/pu. 1240 & 1241 are medium size teeth, hexagonal in shape; teeth posses a prominent but thin lingual shelve; labial face is more upright, the lingual root overhangs the crown by a distinct margin, the crown is thick (Fig. 4: H, I). The root structure shows evidence of some damage.

Remarks: The present teeth are closely identical to *Rhinoptera* aff. *sherburni* Arambourg (1952, Plate XXXII, Figs. 15-24). As the specimens are incomplete, it is difficult to work out the ratio between the width and the length of the crown which in case of *Rhinoptera sherburni* the crown width is nearly thrice the length. These specimens are distinguished from the teeth of *R. raeburni* (Ghosh, 1959) which is having a slanting anterior and posterior face, a thick crown which is sloping forward. *Rhinoptera* sp. of Mehrotra (1979) differs from the present specimen in having much wider crown in which the width is nearly six times its length. *Rhinoptera sherborni* has been reported from the early Eocene of Virginia (Kent, 1999); the Middle Eocene of England (Kemp *et al*., 1990), Nigeria (White, 1926), Morocco (Arambourg, 1952) and Uzbekistan (as *Rhinoptera* cf. *sherborni*, Case *et al*., 1996) and the late Eocene of Egypt (Murray *et al*., 2011). Fossil record of *Rhinoptera* extends back upto the Late Palaeocene (Cappetta, 1987, 2006).

***Rhinoptera raeburni* White, 1934.**
(Fig. 4: J)

Material and horizon: Mks/pal/pu. 1242 and four fragmented unnumbered specimens from the greenish shale horizon of Baripada Beds from the locality Itamundia and Mukurmatia.

Description: Mks/pal/pu. 1242 (Fig. 4: J) is a medium size tooth; hexagonal, anterior and posterior faces slant; crown very thick and sloping forward, the anterior and posterior faces are seldom vertical; the root coarsely ridged and grooved; in having flat enamel surface which is sloping distally in the occlusal view and prominent longitudinal groove in between the root and crown.

Remarks: The presence of *Rhinoptera raeburni* from Baripada Beds had already been described by Ghose (1956; 1959) and Mondal *et al*. (2009). *Rhinoptera raeburni* had been described from the Early Eocene of Nigeria and Angola (White, 1934; Dartevelle and Casier, 1959). At present, the family *Rhinopteridae* consists of the single genus, *Rhinoptera*, which includes at least seven species (Compagno, 1999, 2005; Nelson, 2006). It can be distinguished from other batoids by the concave anterior contour of their chondrocranium and their bilobed subrostral fin (Cappetta, 1987; Nelson, 2006). These, semi -pelagic and gregarious, rays can be found today in tropical to warm temperate waters of the Atlantic, Indian and Pacific Oceans (Nelson, 2006) feeding mostly on bivalve molluscs and crustaceans (Smith and Merriner, 1985; McEachran and Fechhelm, 1998). *Rhinoptera raeburni* has been reported from the Early Eocene of Nigeria and Angola (White, 1934; Dartevelle and Casier, 1959).

Suborder: Rhinobatoidei Fowler, 1941
Family: Rhinobatidae Muller and Henle, 1838
Genus: *Rhinobatos* Linck, 1790
***Rhinobatos* sp. indet. 1.**
(Fig. 5: A)

Material and Horizon: One isolated tooth, Mks/pal/pu. 2195, from the bluish grey shale bed of Itamundia, Baripada Beds, Orissa.

Description: - Mks/pal/pu. 2195 (Fig. 5: A) is a globular shape tooth, occlusion surface smooth with strong transverse crests which rise slightly at the median region; teeth's enameloid smooth; anterior face is convex, the crown is arched; three prominent uvulae (enamel prolongations) overhang the root in lingual view of which the lateral uvulae are shorter than the median uvula; equal in length and slightly pointed towards the median uvula. Roots are massive, sub-triangular and root lobes becoming narrower lingually on both the sides of the deep nutritive groove; the roots extend beyond the lingual face of the crown, the basal face of the root lobes are nearly flat making a triangular outline.

Remarks: The present *Rhinobatos* tooth of Baripada Beds is closely similar to the *Rhinobatus* sp.1 from the Early Eocene Kapurdi Formation of Rajasthan (Rana *et al*., 2006, fig 3.4 a-d; pl. 2, Fig. 1-4) and the *Rhinobatus* sp. from the Early Eocene Khuliana Formation of Rajasthan (Kumar *et al.*, 2007, fig 2; 27-32). However, the present specimen posses less prominent uvulae and smoother crown face as compared to that of *Rhinobatus* sp. from Kapurdi Formation and Khuiala Formation of Rajasthan. It differs from *Rhinobatus casieri* from the Campanion to Maastrichthian of New Jersey (Cappetta and Case, 1975, p. 25, pl. 6, Figs. 22-25, Figs. 7) in which the teeth posses a much longer and pointed uvula. *Rhinobatus* sp. from the green shaly limestone of lower Subathu Formation (Kumar and Loyal, 1987) possess wider crown which is sub-elliptical and slightly convex with more prominent transverse ridge and uvulae. *Rhinobatus* sp. from Carlile shale (Turonian) of South Dakota (Cappetta, 1973) differs from the present specimen in having deeper notch in between the contacts of uvulae and presence of wide and flattened terminal end of the median uvula.

***Rhinobatus* sp. indet. 2**
(Fig. 5: B, C)

Material and Horizon: Two isolated incomplete teeth of *Rhinobatos* sp. 2 under the specimen no. Mks/pal/pu. 2196 and Mks/pal/pu. 2197 from the bluish grey shale bed of Mukurmatia, Baripada Beds, Orissa.

Comment: The teeth are similar to that referred as *Rhinobatos* sp. indet. 1. But they differ from the previous ones and the *Rhinobatus* sp. from the Early Eocene Rajasthan (Rana *et al.*, 2006; Kumar *et al.*, 2007) in having more globular shape, smoother crown surface, very weak transverse ridge and a prominent depression on the lingual surface of the crown and median uvula; the crown is convex, lateral uvulae are equal in length (Fig. 5: B, C). Roots are not preserved well making it difficult to compare with the other specimens. *Rhinobatus sahni*, the only single species of *Rhinobatus* which have been reported from Baripada Beds (Sahni and Mehrotra, 1981) differs from the present specimens in having equilateral triangle anterior margin of the crown, more projected lateral uvulae and flattened terminal edge at the median

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uvula; and in lacking the prominent depression on the lingual surface of the crown and median uvula.

***Rhinobatus* sp. indet. 3**
(Fig. 5: D, E)

Material and Horizon: - Two isolated incomplete teeth, Mks/pal/pu. 2198 & 2199, from the bluish grey shale bed of Mukurmatia, Baripada Beds, Orissa.

Description: - Mks/pal/pu. 2198 & 2199 are small teeth; crown cusp smooth, crown is low, convex and slightly arched, its inferior edges are well developed; much wider than long; the transverse crest is sharp; the lower edges of the anterior margin of the crown are curved; the median uvula is prominent and the lateral uvulae are much shorter than the median uvula (Fig. 5: D, E). The roots are not well preserved in the present specimens.

Remarks: - The present specimens are very closely similar to those of the *Rhinobatus incertus* from the Carlile shale (Turonian) of South Dakota (Cappetta, 1973; p. 509, plate 2, Figs. 26, 27); however, lack of sinuosity at the posterior outline of the crown in the present specimens make it different from *Rhinobatus incertus*. It also differs from *Rhinobatus sahni* described from the Miocene limestone bed of Baripada Beds Orissa (Sahni and Mehrotra, 1981) in which the anterior margin of the crown makes an equilateral triangle with a coloration line and lateral uvulae more projected than the median uvula which is flattened out at the terminal edge. In the present day Indian Ocean, six species of *Rhinobatus* including *R. annandeli, R. granulates, R. linotus, R. obtusus, R. thouin* and *R. typus* are known to occur (Mishra, 1969).

Superorder: Batomorphii Cappetta 1980
Order: Rajiformes Berg, 1940
Family: Rhynchobatidae Garman, 1913
Genus: *Rhynchobatus* Muller and Henle, 1837
***Rhynchobatus* sp.**
(Fig. 5: F)

Material and horizon: One isolated tooth, Mks/pal/pu. 2000, from the bluish shale bed of Itamundia, Baripada Bed, Orissa.

Description: Mks/pal/pu. 2000 (Fig. 5: F) is a small tooth; crown enamel is having a granular texture**,** the lingual face is flat, concave on each side separated by a moderate medial uvula, the terminal end of the median uvula is pointed, lateral uvulae absent; root massive and extends beyond the lingual face of the crown; root lobes divided on both the sides by a deep nutritive groove and a small foramina.

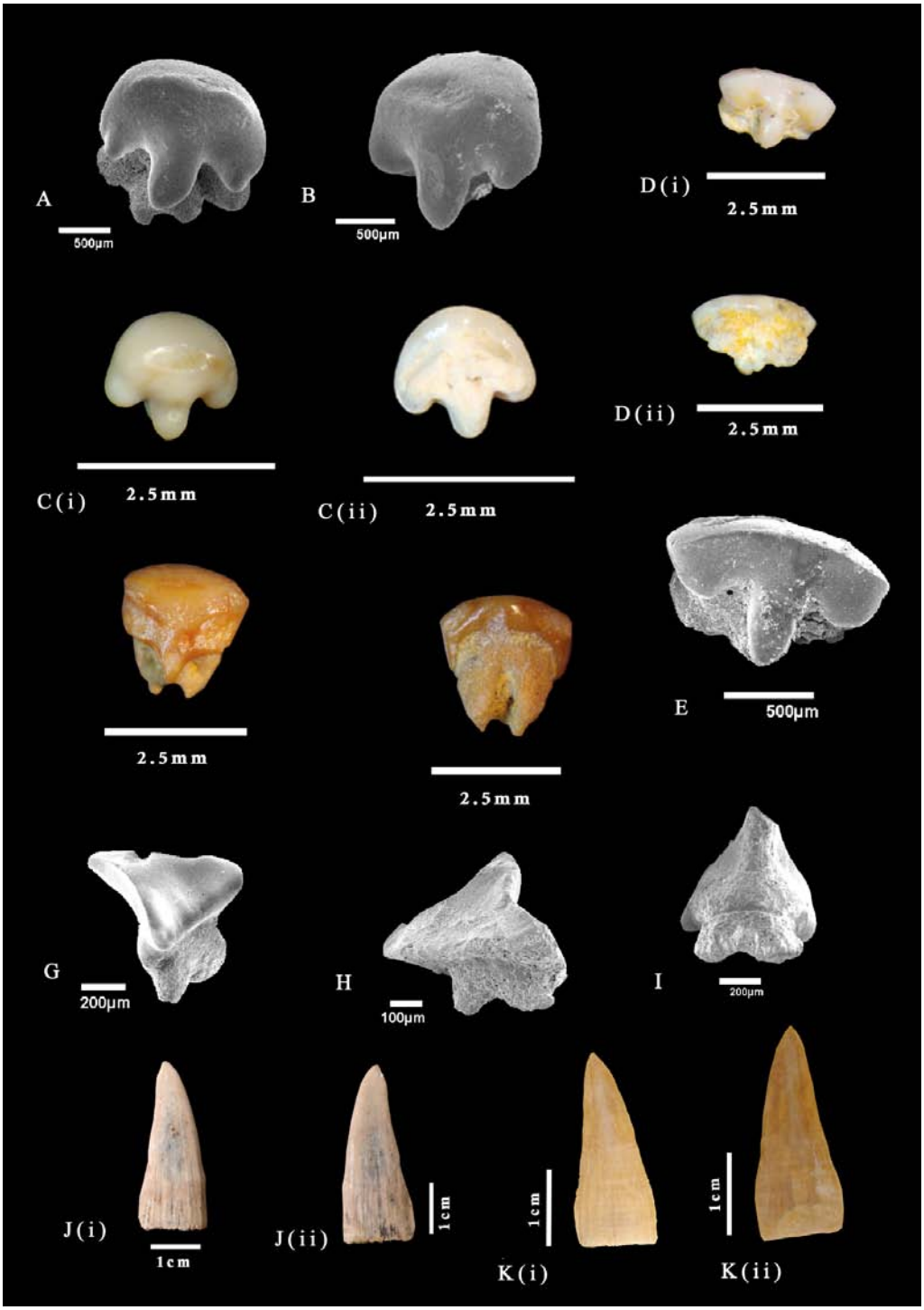

Fig. 5: Photographs of some specimens of the Genus *Rhinobatos*, *Rhynchobatus*, *Gymnura* and *Pristris*. **A.** *Rhinobatos* sp. indet. 1 (Mks/pal/pu. 2195) in lingual view; **B, C.** *Rhinobatos* sp. indet. 2 (Mks/pal/pu. 2196, 2197)**, B & C (i)** in lingual view, **C (ii)** in labial view; **D, 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), **G & H** are in labial view and **I** is in lingual view; **J, K.** *Pristis aquitanicus* (Mks/pal/pu. 20201, 20202, 20203) in lateral view.

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Remarks: The present tooth is the first report of *Rhynchobatus* sp. from the Indian subcontinent. Teeth of *Rhynchobatus* Muller and Henle (1837) can be distinguished from *Rhinobatos* Link (1780) in that the crown enameloid has a granular texture and the elongated medial lingual uvula is not flanked by lateral uvulae (Cicimurri and Knight, 2009). *Rhynchobatus* sp. of Baripada Beds is comparable to *Rhynchobatus pristinus* from Langhian of Loupian, Herault, Southern France (Cappetta, 1987) and from Oligocene Chandler Bridge Formation of South Carolina, U.S. (Cicimurri and Knight, 2009), however, the present tooth is having a more granular texture and concave lingual faces on the side of medial uvula. *Rhyncobatus* teeth have also been reported from the Maestrichtian of Morocco (Arambourg, 1952), and the Miocene of Japan (Itogawa *et al*., 1985).

Superorder: Batomorphii
Order: Myliobatiformes
Superfamily: Dasyatoidea
Family: Gymnuridae Fowler 1934
Genus: *Gymnura* Van Hasselt 1823
***Gymnura* sp. indet.**
(Fig. 5: G, H, I)

Materials and Horizon: Three isolated teeth, Mks/pal/pu. 20245, 20246 & 20247, from the bluish grey shale bed of Mukurmatia, Baripada Beds, Orissa.

Description: Teeth are triangular; symmetrical with a long, upright, and narrow cusp. Crowns are moderately high with a lingually directed cusp, lateral angles are well-developed and rounded; the labial face of the cusp is more or less flattened (Fig. 5: G, H, I), the acute lateral angles join and directed labially forming a margin labial protuberance. The lateral angles are well-developed and rounded; the labial face of the cusp is flat but quite depressed between the lateral angles. In lingual view, the cuspidate part of the crown is laterally compressed (Fig. 5: I), the latero-posterior faces are well-developed and the crown is narrower at its base than at the lateral angles. The mesial part of the crest is long and virtually rectilinear, while the distal part is shorter (Fig. 5 I). The labial face becomes more prominent due to the widening of the cuspidate part of the crown. The root is high, massive, and laterally-extended (Fig. 5: I). The basal face of the lobes flattens with the crown contour becoming triangular (Fig. 5: G, H, I). The groove is deep and clearly wider in the anterior region. The roots are clearly separated from the crown all along its perimeter by a narrow depressed zone, analogous to the neck. The primary foramen is in a central anterior position. In the more lateral files due to the transverse expansion of the teeth, the anterior notch tends to become shallower and the labial face of the crown becomes very flat (Fig.5: G, H).

Remarks: Prior to this record, *Gymnura* sp. has not been recorded from the Eastern coast of India. This is for the first time that the family *Gymnuridae* has been documented not only from Baripada Beds but also from the Eastern coast of India. Earlier, *Gymnura* sp. had been described by Rana *et al.* (2005) from the late Palaeocene- Early Eocene Akli Formation of Barmer district and by Kumar *et al.* (2007) from the Early Eocene Khuiala Formation of the Jaisalmer basin. The *Gymnura* sp. from Baripada is different from the *Gymnura* sp. from Akli Formation and the *Gymnura* sp. of the Thanetian, Morocco (Cappetta, 1984) in having median protuberance in addition to the margin-labial protuberance on the labial contour of

the crown. *Gymnura* sp. has also been reported from the Neogene (Aquitanian to the Middle Pliocene) of southern France (Cappetta *et al*., 1967; Cappetta, 1970), from the Early Eocene of England (Ward, 1983) and from the Middle Eocene of Belgium (Winkler, 1874; Cappetta, 1982).

Order: Rajiformes, Berg, 1940
Superorder: Pristoidea
Family: Pristidae, Bonaparte, 1838
Genus: *Pristis* Link, 1790.
***Pristis aquitinicus* Delfortrie1872**
(Fig. 5: J, K)
Pristis aquitinicus, Ghosh B.K., 1959, p. 67, pl. 88, Figs. 7, 8.

Materials and Horizon: Three isolated rostral teeth bearing the specimen numbers Mks/pal/pu. 20201, 20202 & 20203 and four unnumbered specimens from the bluish grey shale bed Mukurmatia and limestone deposit Itamundia Baripada Beds from the locality Itamundia.

Remarks: The fossil remains of the genus *Pristis* ranging in age from Lower Eocene to Recent. In most of the cases the deposits have yielded complete rostra, rostral spine and rarely oral teeth. Ghosh (1959) described rostral tooth of *Pristis aquitinicus* from the limestone bed of Baripada Beds in which the anterior surface is tapering gently towards the tip thereby increasing the curvature while the posterior surface is straight and has a broad sulcus. He also commented on the difficulty of identifying the species by only studying the rostral tooth. The species is having some similarity with *P. bisulcatus* and *P. lathami*, however the relatively broad sulcus and gradual slope of the tooth towards the tip shows a closer similarity to *P. aquitanicus* of Delfortrie (1872) described from the Lower Miocene of south-western France. Cappetta (1970) also reported *P. aquitanicus* from the Middle Miocene of Southern France.

Order: Myliobatiformes Compagno 1973
Family: Dasyatidae Jordan 1888
Genus: *Dasyatis* Rafinesque, 1810
***Dasyatis sylvestris* White 1931**
(Fig. 6: A)

Materials and horizon: Mks/pal/pu. 20248 and certain unnumbered specimen from yellowish grey shale bed Baripada Beds, Orissa.

Comments: *Dasyatis sylvestris* has been described from the Lower Miocene limestone of Baripada Beds by Sahni and Mehrotra (1981). *D. sylvestris* is distinguished by possessing an arched smooth coronal surface with a transverse ridge in both the margins sloping backward at an acute angle, smooth coronal surface and single vertical root in marginal tooth. Besides this, marginal angles are more acute and the root lobes are vertical in *D. sylvestris*. *Dasyatis rafinesquei* described from the Eocene of Subathu Formation, northwest Himalaya (Kumar and Loyal, 1987) and Subathu Formation of Garwal Himalaya near Nilakanth (Kumar, 1989) differs from the present species in having subelliptical to subovate lingual visor.
***Dasyatis mahuleinsis* Sahni and Mehrotra, 1981**

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(Fig. 6: B, C, D)

Material and Horizon: Mks/pal/pu. 20249, 20250 & 20251 seven unnumbered specimens from the yellowish gray shale bed of Mukurmatia, and bluish grey shale of Itamundia, Baripada Beds, Orissa.

Comments: Teeth of *Dasyatis mahuleinsis* have been described from the limestone bed of Mahulia, Baripada Beds, Orissa (Mehrotra, 1979; Sahni and Mehrotra, 1981). *Dasyatis mahuleinsis* is comparable with *Dasytis sylvestris* in having hexagonal shape, crown without prominent ridge. However, it differs from *Dasyatis sylvestris* in having crown ornamented with pits forming a sieve like structure and the root is obliquely oriented towards the crown. The present specimens are closely similar to *Dasyatis* sp. from the Early Eocene of Kapurdi Formation, Rajasthan (Rana *et al*., 2006)*;* however it differs from the later in having a more elliptical shape and shallower lip.

***Dasyatis menoni* Sahni & Mehrotra, 1981**
(Fig. 6: E)

Material and horizon: - Isolated teeth, Mks/pal/pu. 20252, from the yellowish gray shale bed of Mukurmatia, Baripada Beds, Orissa.

Comments: - Sahni and Mehrotra (1981) compared the teeth of *Dasyatis menoni* with the teeth of *D. bleekeri* (Mishra and Menon, 1955) flourishing in the Indian Ocean. It differs from *D. bleekeri* in having transverse ridge which is not running upto the lateral edge of the crown and the ridge also divides the crown into two equal convex surfaces in the latter, which is not found in *D. menoni. Dasyatis menoni* is also distinguished from *D. marginatus* in not having the strong transverse ridge with marked concavity on the surface in front of it (Sahni and Mehrotra, 1981).

***Dasyatis* sp. 1**
(Fig. 6: F, G, H)

Material and Horizon: Mks/pal/pu. 20253, 20254, 20255 unnumbered specimens from the yellowish gray shale bed of Mukurmatia, and bluish grey shale of Itamundia, Baripada Beds, Orissa.

Description: Mks/pal/pu. 20253, 20254 & 20255 are small teeth, longer than wide; crown more or less spherical, a wide, transverse and slightly bulged crest is present. A small sub circular depression is present in the labial face of the crown (Fig. 6: G i). The labial visor is subcircular to angular showing a median protuberance (Fig. 6: F, G). The marginal angles are well marked. The crown is ornamented by median lingual ridge which divides the crown into two unequal halves (Fig. 6: G i), the lingual zone is ornamented with longitudinal wrinkles. The lateral angles of the crown are acute in all the specimens; marginal-lingual surfaces are slightly concave. The lingual visor outline is convex to slightly concave in its middle part. The crown's lingual visor is clearly over the median sulcus of the root thereby concealing the root lobes (Fig. 6: F i, G i, H i). In all the specimens, the roots are lingually arched; median nutritive grooves are wide and deep. Each lobe is triangular in outline. A foramen in the

middle of the sulcus is present in all the specimens. Labial faces of the root are deeply depressed (Fig. 6: F ii, G ii, Hii).

Discussion: The present teeth are comparable to those of *D. cavernosa* Probst (1877) and *D. probsti* Cappetta (1970) in the presence of the crown' s middle-lingual depression (Cappetta, 1970: p. 88-91, pl. 22, Figs. 1-13 and pl. 21, Figs. 15-23). However, the characteristic features like larger size, wider transverse crest, more marked marginal angles, more developed lower edge of the labial visor, convex crown, lingual visor with a middle depression, and more developed root lobes makes it different from their specimen. These specimens are also comparable to *D. g. centroura* (Balbino and Antunnes, 2006) in having depressed labial faces of the root, wide crown, lingually arched root but differ from the latter which are having well marked marginal angles, more concave lingual face of the crown. The specimens are also different from *D. menoni* (Sahni and Mehrotra, 1981) which is having a hexagonal shape crown, convex lingual visor, flattened lower part of labial visor.

***Dasyatis* sp. 2**
(Fig. 6: I)

Material and Horizon: Mks/pal/pu. 20256 from the yellowish gray shale bed of Mukurmatia Baripada Beds, Orissa.

Description: Tooth small, longer than wide; crown is low, thin enameled, non cuspidate, the lateral edges of the tooth are sharp (Fig. 6: I). The labial visor of the crown is convex; labial face of the crown bears minute wrinkles, the lingual face is smooth, flat; lingual visor is elliptical to sub elliptical in shape. The crown is ornamented by median lingual ridge which divides the crown into two unequal halves. The median lingual ridge is absent and bears a lingual lip. Median lingual visor is distinct and hangs over the root. The roots are massive, bilobate with a wide root canal. A central foramen present on the labial side; labial face of the root is depressed, root lingually displaced, root lobes are more deviated from each other.

Remarks: The present specimens are closely similar to *Dasyatis* sp. from the Early Eocene of Kapurdi Formation, Rajasthan (Rana *et al.*, 2006; pl. 2, Fig. 11). However, the teeth of the present species are more elliptical in shape and the lip is also shallower. It also differs from *Dasyatis* sp. 1 described here which is having a lingual zone ornamented with longitudinal wrinkles; beside this the present specimen is also having root lobes more deviated from each other.

Order: Rajiformes Compagno 1973
Suborder: Rajoidea
Family: Rajidae Blainville, 1816
Genus: *Raja* Linnaeus, 1758
***Raja tewarii* Sahni and Mehrotra, 1981**
(Fig. 6: J, K)

Material and Horizon: - Mks/pal/pu. 20257 & 20258 from the yellowish grey shale bed of Mukurmatia, Baripada Beds, Orissa.

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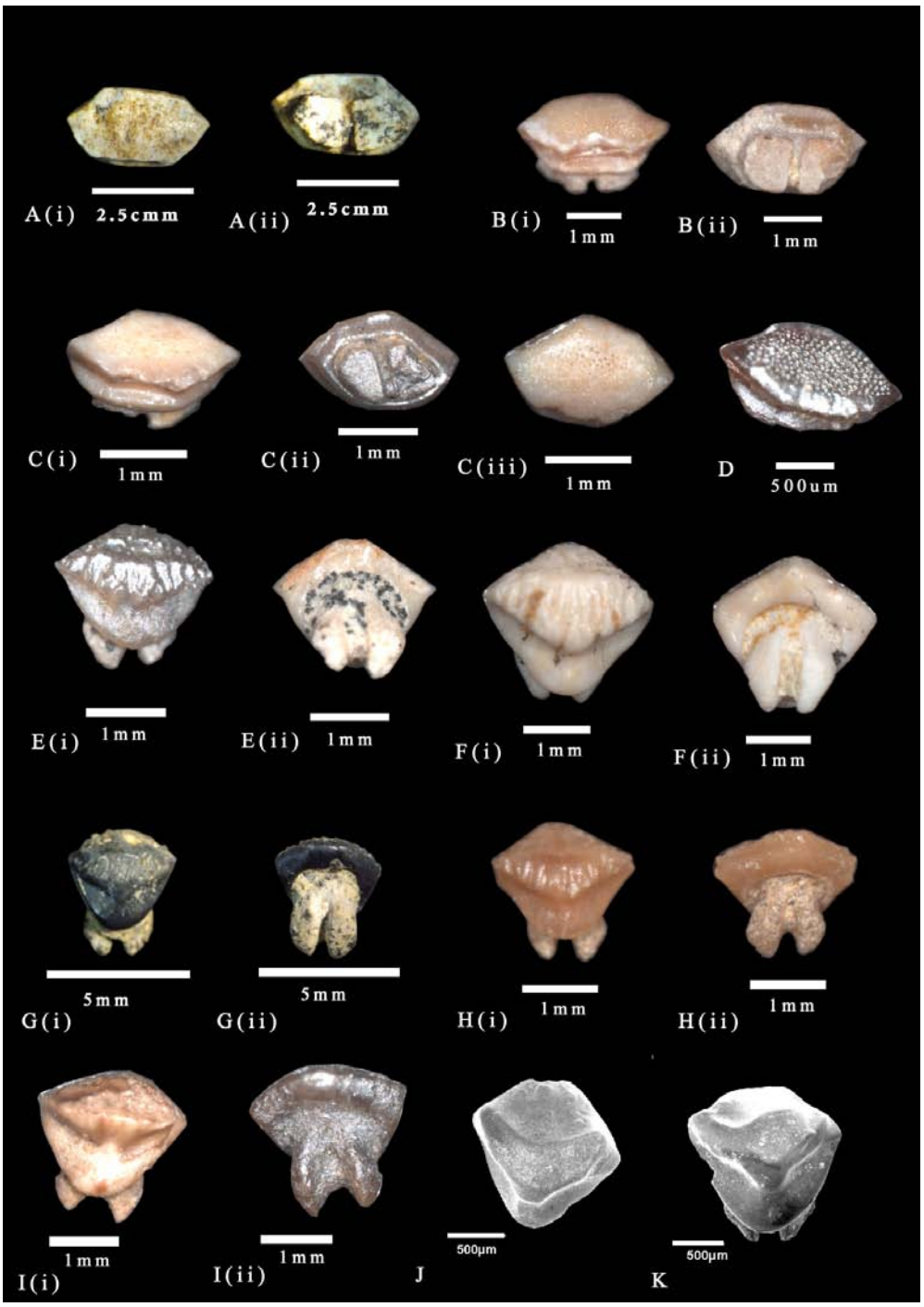

Fig. 6: Photographs of some specimens of the Genus *Dasyatis* and *Raja*. **A.** *Dasyatis sylvestris* (Mks/pal/pu. 20248), **A (i)** in lingual view, A(ii) in labial view; **B, C, D.** *Dasyatis mahuleinsis* (Mks/pal/pu. 20249, 20250 & 20251), **B (i), C (i) & D (i)** in lingual view, **B (ii), C (ii)** & **D (ii)** in labial view; **E.** *Dasyatis menoni* (Mks/pal/pu. 20252), E(i) in lingual view, E(ii) in labial view; **F, G, H.** *Dasyatis* sp. 1(Mks/pal/pu. 20253, 20254, 20255), **F (i), G (i), H (i)** in lingual view, **F (ii), G (ii), H (ii)** in labial view; **I**: *Dasyatis* sp. 2 (Mks/pal/pu. 20256), **I (i)** in lingual view, **I (ii)** in labial view; **J, K.** *Raja tewarii* (Mks/pal/pu. 20257, 20258), **J, K** in lingual view.

Description: Mks/pal/pu. 20257, 20258 are small teeth, rhombohedral in shape, height of the crown is nearly the same as the height of the root is very low not extending much in lingual view. The crown lacks tubercles, wrinkles and not ornamented. The crown enamel is recurved and slightly raised towards the anterior margin and the enamel makes a wing like structure. The median transverse ridge is present; labial face of the crown is smooth; labial visor is making an obtuse angle at the middle; both the labial and lingual face of the crown are concave (Fig. 6: J, K); median lingual ridge is absent in all the specimens; lingual visor is convex. The root is small, low, bilobate, two lobes which have been corroded are separated by a median root canal; lower part of the labial visor is flat, labial face of the root is slightly depressed.

Remark: The present teeth are identical to those of *Raja tiwarii* of Sahni and Mehrotra (1981, pl. 4, Fig. 6) which have been described for the first time from the limestone beds of Baripada. They compared their specimen with the closely similar teeth of *Raja fallax* and *Raja falla*e described by Bigelow and Schroder (1948) from the western North Atlantic. It differs from the latter in the absence of transverse ridge across the masticatory face of the tooth. The presence of recurved enamel making a wing like appearance and small root penetrating deep below the crown makes it easier to assign the present specimens as teeth of *Raja tiwarii.*

Discussion and Conclusion

The batoids are well known as bottom dwellers, but usually do not live at great depths. Majority of the specimens are isolated, complete to slightly incomplete, usually found in association with shark teeth, isolated vertebrae of fish which are well cemented in the shale and limestone beds. Myliobatids live close to the coast in depths of 1 to 30 m and in exceptional cases they are found at places as deep as 300 m. The three existing species of *Myliobatis* sp. in India namely *M. nichoffi, M. milvus* and *M. maculates* are also found near the mouth of river Ganga and Chilika lake and also along the eastern and western coasts (Satsangi and Bora, 1980). The genus is also found inhabiting the present day tropical and subtropical seas (Satsangi *et al*., 1980). They are most commonly found in shallow bays, estuaries, over sandy flats and mud bottoms as a benthic form in the littoral conditions of both the east and west coast of India feeding chiefly on the large crustaceans and molluscan shell and accordingly their dentitions are also adapted (James, 1984; Sahni and Mehrotra, 1980; Satsangi and Bora., 1980; Bigelow and Schroeder, 1948). The genus is found at considerable depths upto 110 m (Bigelow and Schroeder, 1948). The present specimens are well adapted to the tropical/subtropical to temperate climate (See, Table-1).

Aetobatus narinari is restricted to tropical and subtropical waters (Compagno, 1999). It is a coastal and semi pelagic species living over the continental shelf from the surface to 60 m depth. Sometimes it enters lagoons and estuaries and often associated with coral-reef ecosystems (Michael, 1993; Homma *et al.,* 1994; Last and Stevens, 1994). *Aetobatus narinari* is found as solitary or as several hundred individuals (McEachran and de Carvalho, 2002) in central Atlantic and East Pacific ocean. Although primarily observed near the coast and around islands and reefs, the species is likely to be capable of crossing ocean basins (Compagno and Last, 1999). Diet consists of a wide variety of benthic species including

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polychaetes, bivalves, gastropods, cephalopods, crustaceans and teleost fishes (Homma and Ishihara, 1994; Last and Stevens, 1994, Compagno and Last, 1999; McEachran and de Carvalho, 2002) with fish being an important prey items for adults (Michael, 1993).

Table- 1: Palaeoclimatic and palaeoecological data of certain fishes based on their recent distribution (Source, Sahni and Mehrotra, 1981; Compagno, 1984 and 1999; Rana *et al*., 2004).

Genera	Tropical/ Subtropical	Temperate	Cold	Littoral/ nereritic	Pelagic	Bathyal	Benthonic
Dasyatis	(+)	(+)		(+)			(+)
Aetobatus	(+)	(+)		(+)			(+)
Rhinoptera	(+)	(+)		(+)			
Pristis	(+)	(+)		(+)			
Rhinobatos	(+)	(+)		(+)			
Rhynchobatus	(+)			(+)			
Gymnura	(+)			(+)			
Myliobatis	(+)			(+)			(+)

Rhinoptera, which represents as a littoral genus, is found in the mean annual isotherm of 20^{o}C in the Indian Ocean. It is represented in all the oceans and prefers sandy or muddy bottoms of shallow waters where it forages for various mollusks and large crustaceans. It is a littoral genus found in the mean annual isotherm of 20^{o}C in the Indian Ocean. The genus *Dasyatis* is found distributed in the east coast of India on the Orissa coast in the mean annual isotherm of 20^{o}C (Sahni and Mehrotra, 1981). *Dasyatis* is also a littoral genus represented in India by a number of species. *Rhinobatus* are benthic batoids inhabiting warm waters of the continental shelf, deeper water of the upper slope, sandy beaches and muddy bay from the region of intertidal to the depth of 366 m. The genus *Pristis* is mostly found in tropical and subtropical shallow water coastal seas which are occasionally found in freshwater also. The genus *Pristis* and *Rhyncobatus* are most common in warm and tropical climate whereas the genus *Rhinobatus* and *Gymnura* are most common in warm to temperate waters.

The genus *Rhynchobatus* are coastal (shallow waters to 64 m) bottom dwelling batoids normally inhabiting tropical waters of the Eastern Atlantic, Indian Ocean and Western Pacific. They feed most commonly on crustaceans, mollusks, squids and small fishes. The genus *Gymnura* are circum global batoids found in warm temperate and sub-tropical waters of the continental and insular shelf, inshore water of sandy beach, enclosed bays and lagoons, offshore bank down to a depth of 110 m.

The present assemblage combined with crocodilian coprolites (Milankumar and Patnaik, 2010), fish faunas comprising of selachian, batoids, teleost (also see Mehrotra, 1981; Sahni and Mehrotra, 1981), invertebrate fossils including gastropods, bivalve, pelecypods, etc (also see, Modak, 1952; Sharma, 1956; Mohanty, 1980) and foraminiferal assemblages (Singh *et al*, 1976 a,b; Bhalla and Dev, 1975), clearly points towards a depositional shore environment most likely in the shallower part of the inner neretic, tropical to subtropical conditions, which was probably well connected to the open seas.

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