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Fossil batoid and teleost fish remains from Bhuban Formation (Lower to Middle Miocene), Surma Group, Aizawl, Mizoram

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Intraformational conglomeratic horizon within the Upper Bhuban unit of Bhuban Formation, Surma Group (Lower to Middle Miocene) exposed at two localities in the vicinity of Aizawl, Mizoram has yielded fish remains mostly in the form of isolated teeth, dental plates and spines. Majority of these belong to diverse selachians and have already been described. We describe here dental plates and a cau-

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dal spine belonging to two species of *Myliobatis*, one of *Aeteobatus* (batoids) and four of *Diodon* (teleosts) from the same fossil localities. These fish remains together with associated selachians and mega-invertebrates suggest the existence of a tropical to subtropical climate and a warm shallow marine set-up near to the shoreline in a high-energy environment during the deposition of the fossiliferous horizon.

Keywords: Batoids, caudal spine, dental plates, fish remains, fossiliferous horizon, teleosts.

MIZORAM is a part of the Tripura–Mizoram accretionary belt and is considered as the southern extension of the Surma basin[1–3]. It is covered by a huge pile of Cenozoic sedimentary succession with a total exposed thickness of around 8000 m. This succession has been divided into three groups, namely the Barail, the Surma and the Tipam Groups in an ascending order[4,5]. The Surma Group is divisible into a lower Bhuban Formation and an upper Boka Bil Formation. The Bhuban Formation is further divisible into lower, middle and upper Bhuban Units[6]. The Bhuban Formation consists of a rhythmic alternation of arenaceous and argillaceous facies of lower to middle Miocene. Sandstone, siltstone, shale, mudstone and their admixture in varying proportions along with a few pockets of shell-limestone, calcareous sandstone and intraformational conglomerates commonly constitute the main lithology of the Bhuban Formation. The Bhuban succession is thrown into a series of approximately N–S trending, longitudinally plunging anticlines and synclines[4,7].

Fish remains described here are from two localities situated on the western limb of the Aizawl anticline and were found in association with poorly preserved bivalves, gastropods, decapods and monogeneric form of a foraminifer (*Ammonia* sp.). Although the fossils are well preserved, recovery is rather poor due to hard and compact nature of the host rock. Identification at a specific level could not be attempted due to inadequate information. All the fossil materials described and illustrated here are housed at the Palaeontology Laboratory of the Department of Geology, Mizoram University, Aizawl.

The first fossil locality, Bika quarry (23°45′184″N–92°40′792″E) is located on the western fringe of Aizawl city about 2 km from Mizoram University on the right side of Mizoram University to Aizawl road (Figure 1). At this locality, fossils were collected from the two intraformational calcareous conglomeratic bands at 0.95–1.30 m and 8.50–8.65 m levels respectively, of the studied stratigraphic section. Bulk of the fossils from this bed are from the lower conglomeratic horizon and the faunal assemblage consists of isolated fish teeth[8] and poorly preserved bivalves, gastropods, decapods and a monogeneric form of a foraminifer (*Ammonia* sp.).

The second locality, Ruata quarry (23°45′143″N–92°40′631″E) is located about 12 km west of Aizawl city on the right side of Aizawl to Sakawrtuichhun road. It is in the strike continuation of Bika quarry. At this locality also, there are two fossiliferous intraformational calcareous conglomeratic bands, the lower one at 0–0.33 m and the upper one at 4.5–4.9 m level of the stratigraphic section (Figure 1). The bed is highly bioturbated with numerous worm burrows of different types. The bulk of the fish remains was collected from the upper conglomeratic band associated with poorly preserved bivalves, gastropods and decapods.

Myliobatis indet. (Figure 2; **1**) This species is represented in the collection by a fragmentary caudal spine, which is about 5 mm wide, longitudinally striated with some striations deep enough to form grooves. The anterior aspect is straight with denticles on the lateral edges which are directed distally at angles of 30°–40° from the central axis. These denticles impart a saw-tooth character. Identification of Myliobatids spines at specific level is not possible as all of them are nearly alike. Moreover, the present specimen is poorly preserved.

Myliobatis sp. 1 (Figure 2; **2–5**): All the four specimens represent the median teeth, which are medium-sized, transversely elongated, more or less straight with perfect hexagonal outline. The coronal surfaces of their crowns are wide and smooth, whereas the ridges and grooves of the basal surfaces of the roots appear to be feeble. Morphologically, these specimens have a close resemblance with the specimens of *Myliobatis* sp. from the Lower Miocene of Matanomadh and Lakhpat localities in Kachchh, Gujarat[9], and from the Eocene Subathu Formation of the Northwestern Sub-Himalaya[10].

Myliobatis sp. 2 (Figure 2; **6a** and **6b**): The median tooth of this species differs from that of *Myliobatis* sp. 1 in having a sub-oval outline and a crown with narrow and smooth coronal surface. The basal surface of its root is divided into 19–20 prominent ridges and grooves at right angle to the transverse axis of the crown. A straight ridge or shelf-like projection is present at the junction of coronal and basal surfaces on both the anterior and posterior sides. This specimen differs from *Myliobatis straitus* of Selsey Formation of Lee-on-Solent (Eocene), Hampshire, UK[11] on account of its small size, less prominent ridges and narrow coronal surface.

Aetobatus sp. (Figure 2; **7–8**): Isolated teeth are medium-sized, rectangular in outline and arched laterally with smooth occlusal surface and root divided longitudinally into 20–25 ridges and grooves, which continue from the underside to the posterior borders of the enamelled surface. The present specimens resemble well the *Aetobatus irregularis* known from the Braklesham Group (Eocene) in UK[11]. These can also be compared reasonably well with *Aetobatus arcuatus baripadensis* from the Tertiary deposits of Mayurbhanj[12]. However, the materials collected are too meagre and poorly preserved to assign them any of the known species.

Diodon sp. 1 (Figure 2; **9–13**): Dental plates medium to large in size, each consisting 4–9 oval to sub-rounded

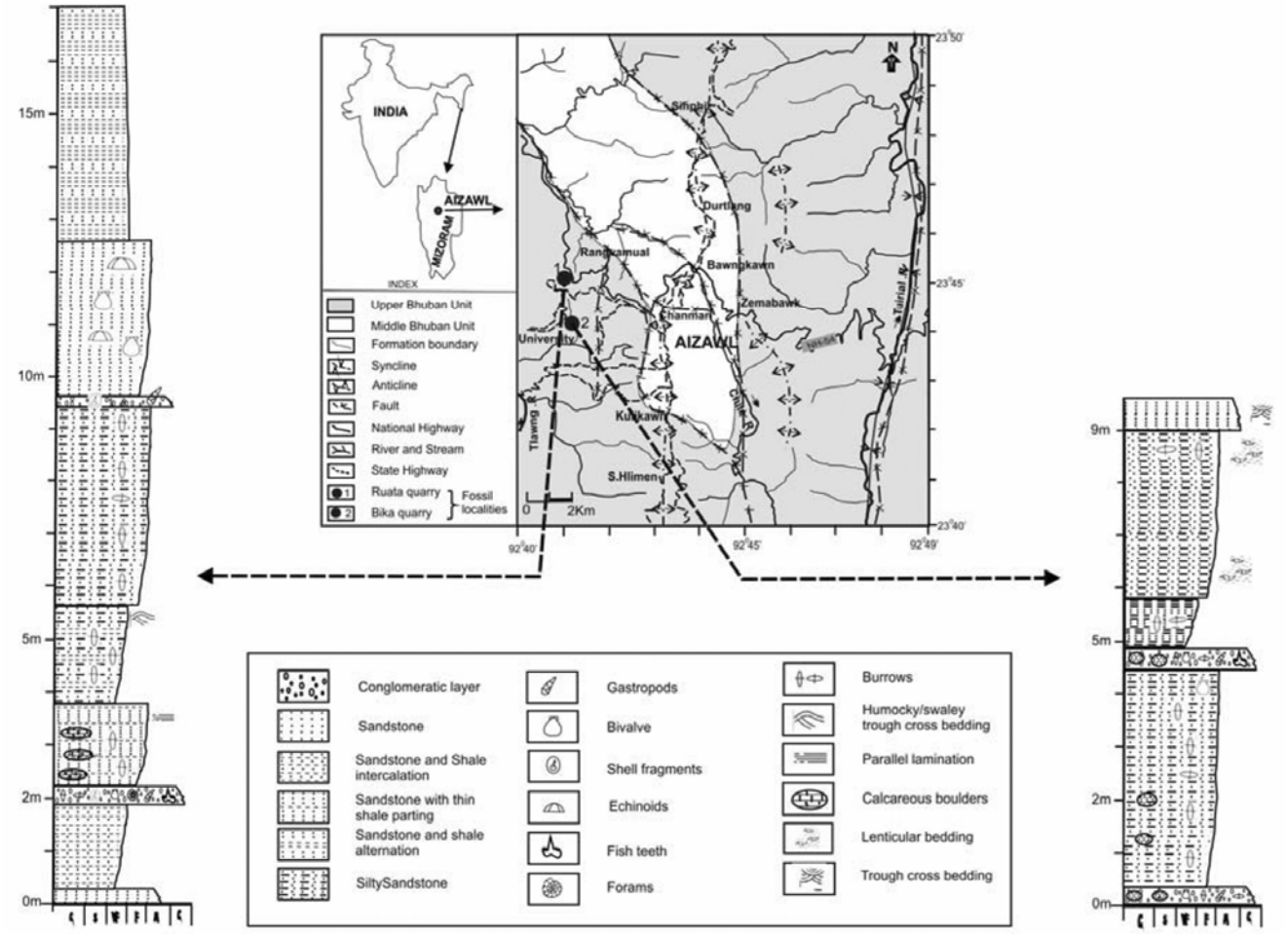

Figure 1. Geological and location map of the study area[33] and litho-columns of the fossil-yielding horizon.

lamellar plates of varying size and piled one upon the other. The first plate on the apical side in all the specimens is smallest and their size increases towards the base. All the dental plates are vertically divided into two more or less similar halves. The record of the fossil diodontids from India is meagre and the specimens could not be compared with any of the collections made by earlier workers.

Diodon sp. 2 (Figure 2; **14–15**): The dental plates differ from those of *Diodon* sp. 1 and other known species in being smaller and sub-triangular. Lamellar plates are smaller towards the apex and become larger towards the base. Both halves of the dental plate consist of four lamellar plates.

Diodon sp. 3 (Figure 2; **16a, 16b**): Dental plate medium to large in size, sub-triangular or 'heart shaped', consisting of six lamellar plates. The lamellar plates at the apex and base are thin compared to those placed in between, but all are more or less equal in size. A vertical line divides the plates into two asymmetrical halves. The outer edge of the plate is somewhat crenulated. The dental plate is slightly concave at the apex and slightly convex at the base. The marked difference between this species and *Diodon* species 1 and 2 is with respect to shape, size, number of lamellar plates and feebly crenulated plate margin.

Diodon sp. 4 (Figure 2; **17**): The dental plate is medium-sized, laterally elongated, sub-rectangular to sub-oval formed by more or less oblique piles of 6–7 lamellae of unequal size; the largest one lies at the base and the smallest one at the apex. The lamellar plates are divided into two similar halves. Margins of the plates are smooth. The elongated nature of the dental plate of the present specimen distinguishes it from the previously described species. Though *Diodon* is reported from many fossil localities of Eocene and Miocene sediments of the Indian subcontinent, the material described here is too meagre to allow any detailed comparison and specific identification.

The teeth, dental plates and spines of *Myliobatis* sp. are known to occur from the Late Palaeocene to Recent strata of India from several localities like the Late Palaeocene to Early Eocene of Rajasthan[13] and NW Sub-Himalaya[10,14], Eocene of Kachchh[9,15,16], and Surat in Gujarat[17], Miocene of Myanmar[18], Balasore in Odisha[19], Sri Lanka[20] and

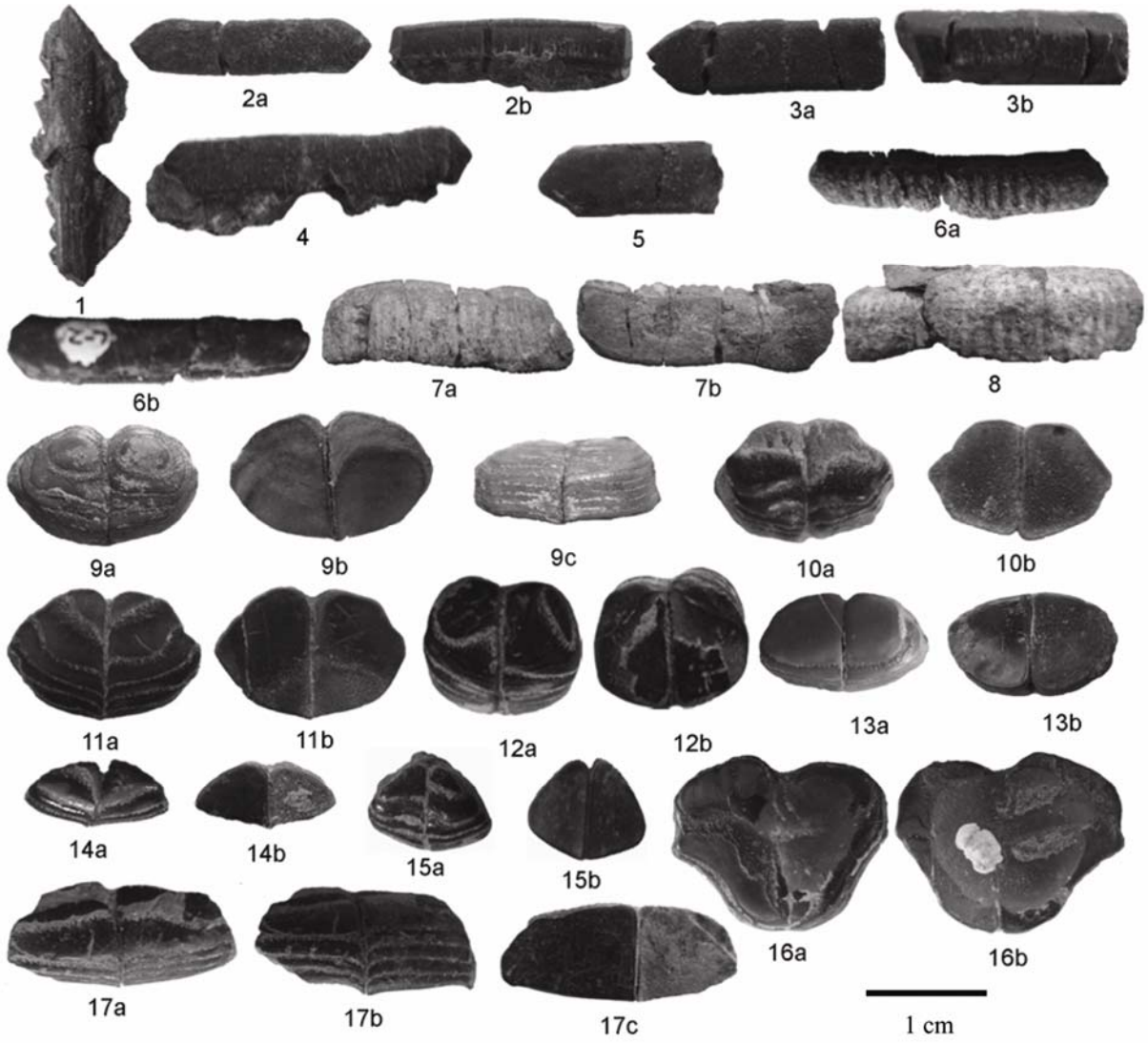

Figure 2. **1**: *Myliobatis* sp., caudal spine, (V/F/R–5b). **2–5**: *Myliobatis* sp. 1. Oral view (**2a**), (V/F/B -91); side view (**2b**), (V/F/B-91); oral view (**3a**), (V/F/B-92); side view (**3b**), (V/F/B-92); oral view (**4**), (V/F/B-93); oral view (**5**), (V/F/B-93). **6**: *Myliobatis* sp. 2. side view (**6a**), (V/F/B-5a); Oral view (**6b**), (V/F/B-5a). **7**, **8**: *Aetobatus* sp. Basal view (**7a**), (V/F/B-95); oral view (**7b**), (V/F/B-95); basal view (**8**) (V/F/B-96). **9–13**: *Diodon* sp. 1. Anterior view (**9a**), (V/F/B-12); posterior view (**9b**), (V/F/B-12); side view (**9c**), (V/F/B-12); anterior view (**10a**), (V/F/B-97); posterior view (**10b**), (V/F/B-97); anterior view (**11a**), (V/F/B-98); posterior view (**11b**), (V/F/B-98); anterior view (**12a**), (V/F/B-99); posterior view (**12b**), (V/F/B-98); anterior view (**13a**), (V/F/B-100); posterior view (**13b**), (V/F/B-100). **14**, **15**: *Diodon* sp. 2. Anterior view (**14a**), (V/F/B-101); posterior view (**14b**), (V/F/B-101); anterior view (**15a**), (V/F/B-102); posterior view (**15b**), (V/F/B-102). **16**: *Diodon* sp. 3, Anterior view (**16a**), (V/F/B-13); posterior view (**16b**), (V/F/B-13). **17**, *Diodon* sp. 4. Anterior view (**17a**), (V/F/B-103); side view (**17b**), (V/F/B-103); posterior view (**17c**), (V/F/B-103).

Pliocene of Piram Island[21,22]. *Myliobatis* are found to inhabit the estuarine and shallow to deep tropical seas[13]. Dental plates of *Aetobatus* have been reported from the Eocene deposits of Odisha[12]. The extant species of *Myliobatis*, viz. *Myliobatis tobijei* is a common inshore and offshore species[23], occurring on sandy and muddy bottoms from intertidal habitats to depths of at least 220 m. *Myliobatis longirostris* is a distinctive eagle-ray fish[24] occurring between the surface to a depth of at least 64 m. It is often found in areas with sand or soft bottoms. *Myliobatis californica* – a bat ray, prefers shallow intertidal waters and sandy areas in bays and estuaries. They can also be found near reefs and kelp beds. The bat ray lives in sandy and muddy bottoms in relatively shallow waters of beaches as well as in bays, channels and inlet[25]. Australian bull ray (*Myliobatis australis*) or southern eagle ray is commonly found off beaches and in shallow water over sand flats. It is also found[26] in water as deep as 85 m. The longheaded eagle ray (*Aetobatus flagellum*) inhabits open seas, shallow seas, subtidal aquatic beds and estuarine waters[27]. The spotted eagle ray, *Aetobatus narinari* or bonnet ray is found in shallow coastal waters by coral reefs and bays in depths down to 80 m. They are found globally in tropical regions[28].

Diodon has a geological range from Lower Eocene to Recent[13]. In the Indian subcontinent dental plates of *Diodon* species have been reported from Lower Eocene sediments of the Subathu Formation, NW Sub-Himalaya[10], Cambay Formation in Gujarat[17], and from the Jaisalmer basin in Rajasthan[29] and also from the Miocene beds of Kachchh[30], and Baripada in Odisha[30]. Diodontids are generally found in environments ranging from estuarine, shallow marine to deep marine in tropical climate[13]. The present-day *Diodon* species like *D. holocanthus* are frequently found in the muddy sea bottom, or in lagoons or seaward and reefs around the world[31]. The juvenile *Diodon hystrix* are pelagic up to the time that they are about 20 cm in length. Adults favour lagoons and seaward reefs, sheltering under ledges or in caves during the day. Although classified as benthic, they may sometimes be found hovering high in the water[32].

The extant species of *Myliobatis*, *Aetobatus* and *Diodon* are mainly found thriving in shallow intertidal waters and sandy areas in bays and estuaries. Based on the above information it can be inferred that the fish-yielding horizons of the study area may have been deposited in a tropical to subtropical shallow marine environment. On the basis of selachian remains and associated mega-invertebrate assemblage from these localities, a warm, shallow, marine set-up near the shoreline in a high-energy environment has been inferred to the fish-yielding horizons[8], which is in conformity with the present findings.

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