JOURNAL GEOLOGICAL SOCIETY OF INDIA
Vol.77, April 2011, pp.328-348

Selachian Fishes from Bhuban Formation, Surma Group, Aizawl, Mizoram

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Abstract: An interesting selachian fish assemblage having stratigraphic and palaeoecological significance is being described from the two intraformational calcareous conglomeratic horizons within the Upper Bhuban unit of Bhuban Formation, Surma Group (Lower to Middle Miocene). The assemblage consists of eighteen species of selachian fishes including two new ones (*Carcharhinus bhubanicus* and *Hemipristis unidenticulata*) belonging to thirteen genera and another thirteen forms have been identified up to generic level. It is dominated by the families Carcharhinidae and Lamnidae, and is one of the most diversified Miocene assemblages from the Indian subcontinent. The fish fauna and the associated mega-invertebrates suggest Lower Miocene (Aquitanian – Burdigalian) age for the Upper Bhuban unit of Bhuban Formation. These further suggest that the fish yielding horizons were deposited under a warm shallow marine set-up near to the shoreline in a high-energy environment.

Keywords: Selachian fauna, Lower Miocene, Bhuban Formation, Surma Group, Mizoram.

INTRODUCTION

Tripura - Mizoram accretionary belt is the southern extension of the Surma Basin - an outer arc basin - within the greater Bengal Basin (Mannan, 2002; Rahman and Faupl, 2003). Cenozoic rock record is excellently preserved in this basin. Bhuban Formation of the Surma Group is the major lithostratigraphic unit in Mizoram and it comprises alternating arenaceous and argillaceous succession. Though studied extensively for invertebrate biota (Tiwari and Satsangi, 1988; Tiwari et al. 1997; Tiwari and Kachhara, 2000, 2003; Tiwari and Mehrotra, 2000, 2002; Tiwari, 2001, 2006; Jauhri et al. 2003; Lokho and Raju, 2007; Mehrotra et al. 2003; Srivastava et al. 2008; Ralte et al. 2009; Lalmuankimi et al. 2010), the fish fauna of Bhuban Formation from Mizoram have not yet been fully explored. Earlier records of fishes are in the form of unpublished reports from the Bhuban rocks of Kolasib area that include *Alopias* sp., *Odontaspis* cf. *contortidens*, *Carcharhinus nicaraguensis* (sharks) and *Sparus cintus* (teleost) (Mehrotra, 1984) and *Hemipristis serra*, *Carcharodon* cf. *carcharias*, *Carcharhinus* sp., *Odontaspis cuspidata*, *Negaprion* sp., ? *Isurus* sp., *Dasyatis* sp. and siluroid tooth (Satsangi and Mehrotra, 1986). The first detailed systematic study of fish teeth from Bhuban rocks of Mizoram is by Tiwari (1992) who described three shark teeth *viz*. *Carcharhinus* (*Prionodon*) *gangeticus*, *Isurus spallanzanii* and *Carcharodon carcharias* from the Upper Bhuban rocks of Sairang area. Subsequently, Tiwari et al. (1998) described six species of selachians – *Hemipristis serra*, *Negaprion* sp., *Sphyrna zygaena*, *Carcharodon carcharias*, *Isurus spallanzanii* and *Pristophorous suevicus*; one each of batoids – *Dasyatis* sp. and teleost – *Dentex* sp. Tiwari and Bannikov (2001) also described three new species of fishes namely, *Decapterus*? *mizoramensis*, *Pentaprion sahnii* and *Bothus* ? *bhubanicus* from the skeleton of fishes recovered from the Bhuban rocks of Mizoram.

During the course of fieldwork in the western limb of Aizawl anticline in Ramrikawn and Tuivamit areas of Aizawl, two new calcareous conglomeratic horizons were delineated. These horizons are exposed at the two localities – Bika Quarry, Tuivamit and Ruata Quarry, Ramrikawn (Fig. 1) and are rich in fish fauna. A large number of fossil fish teeth were collected from these localities. The pebbles in both the conglomeratic horizons are extensively bored indicating the presence of hard ground in the neighbourhood. Eighteen species of selachian fishes including two new ones belonging to thirteen genera have been identified from the collection from both the localities. Another thirteen forms have been identified up to generic level. These are: *Lamna* sp., *Carcharodon carcharias*, *Carcharodon angustidens*, *Carcharodon* sp., *Isurus spallanzanii*, *Isurus pagoda*, *Alopias* sp., *Odontaspis* cf.

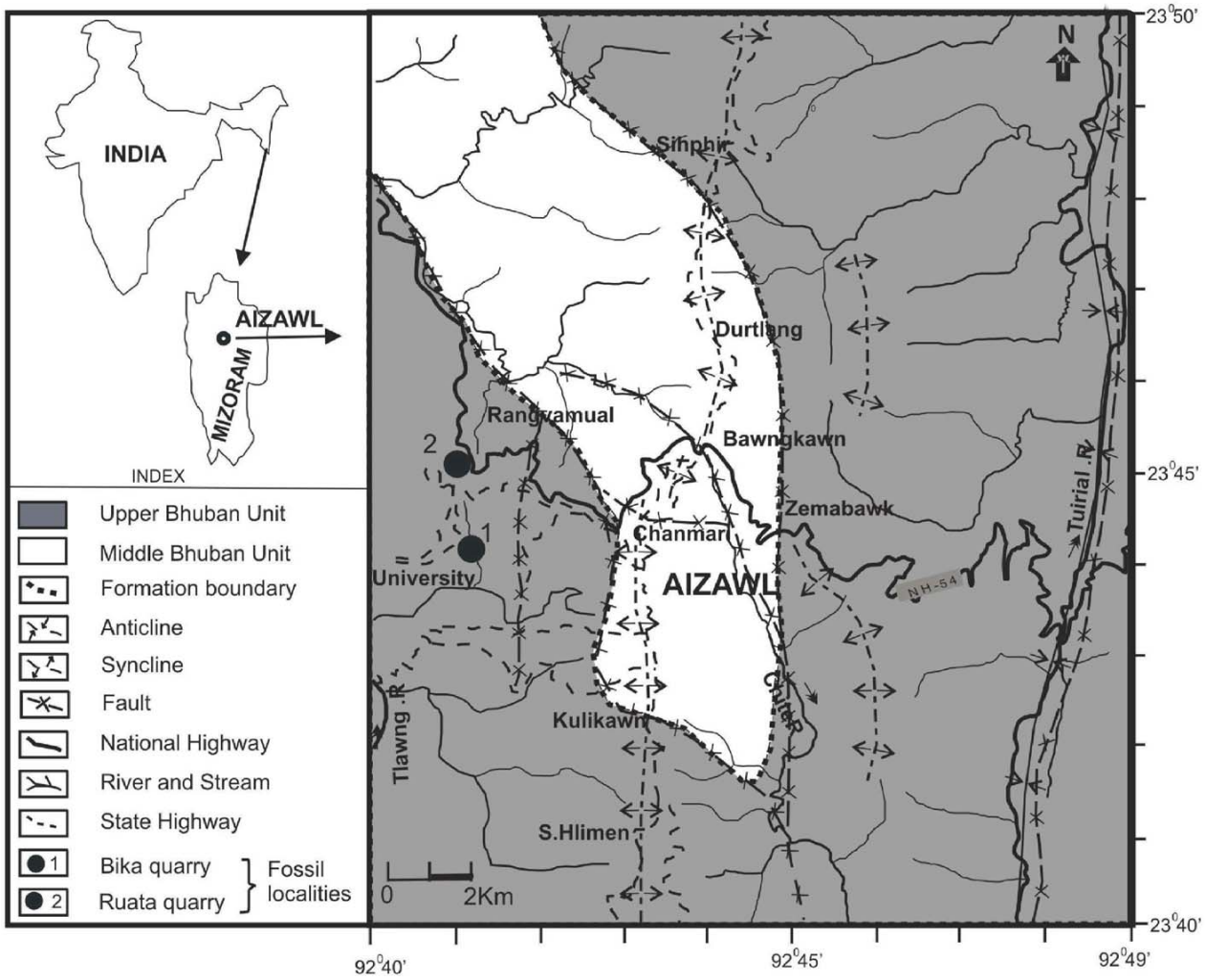

Fig.1. Geological map of Aizawl showing fossil fish localities.

taurus, *Odontaspis* cf. *tricuspidatus*, *Odontaspis* sp., *Carcharhinus egertoni*, *Carcharhinus priscus*, *Carcharhinus* cf. *macloti*, *Carcharhinus bhubanicus* n. sp., *Carcharhinus* (*Prionodon*) sp., *Carcharhinus* sp. A (indet), *Carcharhinus* sp. B (indet), *Carcharhinus* sp. C (indet), *Carcharhinus* sp. D (indet), *Galeocerdo aduncus*, *Negaprion brevirostris*, *Negaprion* cf. *eurybathrodon*, *Scoliodon sorrakawah*, *Hemipristis serra*, *Hemipristis unidenticulata*, *Sphyrna diplana*, *Sphyrna zygaena*, *Galeorhinus* sp., *Squalus* sp., Carcharhinidae gen. et sp. indet., and indeterminate vertebral centra of a selachian. Out of thirty one forms described in this paper, thirteen belong to the family Carcharhinidae and six to family Laminidae.

Fish remains are in the form of teeth and parts of vertebral columns. Although the fish teeth are well preserved, recovery is rather poor due to hard and compact nature of the host rock. The fish assemblage is found in association with poorly preserved bivalves, gastropods, decapods and mono generic form of a foraminifer (*Ammonia annectens*) (Ralte et al. 2009). This paper deals with the systematic description of selachian fish fauna collected from these two localities and palaeoecology of the fishes and depositional environment of the entombed rocks has also been discussed.

GEOLOGICAL SETTING

Geologically, Mizoram is a part of Tripura - Mizoram depositional basin and it has been considered as the southern extension of Surma Basin. The entire sedimentary column of the area is a repetitive succession of arenaceous and argillaceous rocks of Palaeogene and Neogene ages. It consists of sandstone, silty-sandstone, siltstone, shale, mudstone and their admixture of varying proportions along with a few pockets of shell-limestone, calcareous sandstone and intraformational conglomerates. This succession is thrown into a series of approximately N-S trending,

longitudinally plunging anticlines and synclines (Ganju, 1975). The general strike of the rock formation is N-S with dip varying from 20°- 50° either towards east or west. Sequentially, the Tertiary succession of Mizoram has been grouped into the Barail (Oligocene), the Surma and the Tipam Groups (Upper Oligocene to early Pliocene) in the ascending order. Surma Group has been subdivided into Bhuban and Bokabil Formations. Bhuban Formation is further divisible into lower, middle and upper Bhuban units. The stratigraphic succession of the state and the lithological characteristics of each litho unit as worked out by Karunakaran (1974) and Ganju (1975) with slight modification is given in Table 1. The modification pertains to assigning formation status to the Bhuban and Bokabil of Surma Group which were earlier assigned to Subgroup and also unit status to Lower, Middle and Upper Bhubans.

LOCALITY DESCRIPTION

Fish fauna described in this paper comes from the two localities in the western limb of Aizawl anticline in Mizoram. The description of the localities is as follows:

Locality 1

Bika quarry (23°45'184"N –92°40'792"E) is located ~12.5 km west of Aizawl city on the left side of Aizawl – Mizoram university road. Two fossiliferous beds have been delineated in this locality in the Upper Bhuban unit of Bhuban Formation (Fig. 2). The lower one consists of 8.9 m thick bluish grey coloured, fine grained, moderately hard and compact silty-sandstone. This bed contains two intra-formational calcareous conglomeratic bands at 1.7 to 1.95 m and 8.75 to 8.9 m levels. These bands contain pebbles that are extensively bored. Bulk of the fauna comes from the lower conglomeratic horizon and the assemblage consists of fish teeth and poorly preserved bivalves, gastropods, decapods and a foraminifer (*Ammonia annectens*). The upper bed is 2.9 m thick fossiliferous brown, fine to medium grained, well bedded, moderately hard and compact sandstone. Poorly preserved bivalves and echinoids occur sporadically in this bed.

Locality 2

Ruata quarry (23°45'143" N –92°40'631" E) is located ~12 km west of Aizawl city on the right side of Aizawl – Sakawrtuichhun road. It is the strike continuation of locality 1. In this locality also two fossiliferous beds are exposed. The lower one is grey coloured silty-sandstone (4.9 m thick) and upper one is brown silty-sandstone (3.1 m thick) (Fig. 2). These two fossiliferous beds are separated

Table 1. Stratigraphic succession of Mizoram (modified after Karunakaran, 1974; Ganju, 1975)

Age	Group	Formation	Unit	Lithology
Recent	Alluvium			Silt, clay and gravel
~ Unconformity ~				
Early Pliocene to Late Miocene	Tipam (+900 m)			Friable sandstone with occasional clay bands
~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ Conformable and transitional contact ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~				
Miocene to Upper Oligocene	Surma (+5950 m)	Bokabil (+950 m)		Shale, siltstone and sandstone
		~ ~ ~ ~ ~ ~ ~ ~ Conformable and transitional contact ~ ~ ~ ~ ~ ~ ~ ~		
		Bhuban	Upper Bhuban (+1100 m)	Arenaceous predominating with sandstone, shale and siltstone
			~ ~ ~ ~ Conformable and transitional contact ~ ~ ~ ~	
			Middle Bhuban (+3000 m)	Argillaceous predominating with shale, siltstone-shale alternations and sandstone
			~ ~ ~ ~ ~ Conformable and transitional contact ~ ~ ~ ~ ~	
			Lower Bhuban (+900 m)	Arenaceous predominating with sandstone and silty-shale
~ Unconformity obliterated by faults ~				
Oligocene	Barail (+3000 m)			Shale, siltstone and sandstone
~ Lower contact not seen ~				

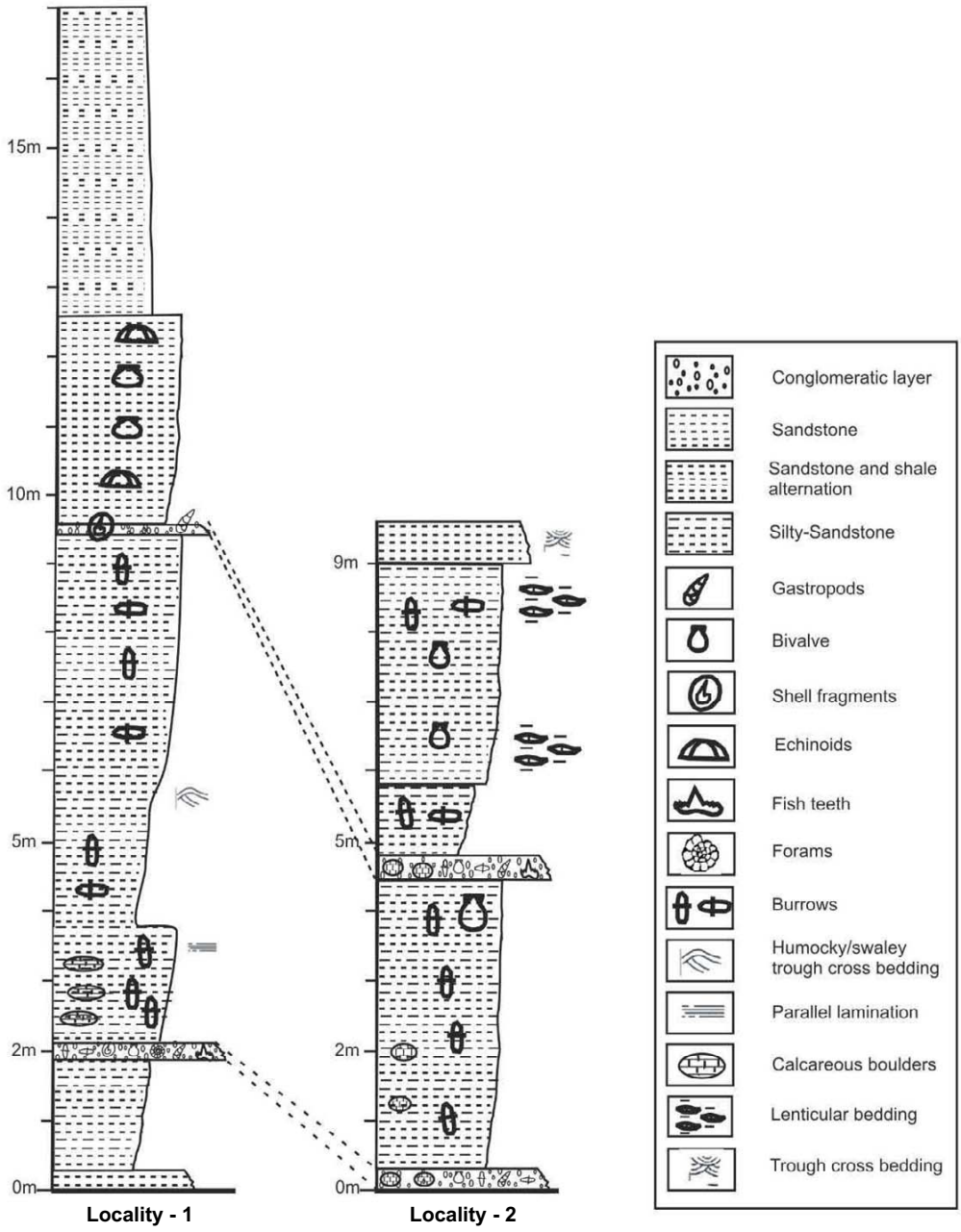

Fig.2. Lithocolumn at fossil localities. Locality: 1– Bika Quarry; 2 – Ruata Quarry.

by ~1 m thick bed of sandstone-shale alternation. The lower bed at this locality also contains two intraformational calcareous conglomeratic bands, the lower one at 0 – 0.33 m and the upper one at 4.5 – 4.9 m levels. The bed is highly bioturbated with a large numbers of worm burrows of different types. The bulk of the fauna from this locality has been collected from the upper conglomeratic band within the lower bed and the faunal assemblage consists of fish teeth and poorly preserved bivalves, gastropods and decapods. Upper bed has yielded only poorly preserved bivalves and burrows. Intervening bed yield burrows only.

SYSTEMATIC DESCRIPTION

The higher classification of Chondrichthyes followed in this paper is after Cappetta (1987). All measurements are in millimeters. All the fossil materials described and illustrated in this paper are archived in the Palaeontology Laboratory of the Department of Geology, Mizoram University, Aizawl.

Class	CHONDRICHTHYES Huxley, 1880
Subclass	ELASMOBRANCHII Bonaparte, 1838
Cohort	EUSELACHII Hay, 1902
Subcohort	NEOSELACHII Compagno, 1977
Order	LAMNIFORMES Berg, 1958
Family	LAMNIDAE Muller & Henle, 1838

Genus: *Lamna* Cuvier 1817
Species: *Lamna* sp.
(Pl 1, figs.1a, b and 2a, b)

Material: Two isolated teeth with broken roots.
Location: Locality 1: Bika Quarry.
Horizon: Lower intraformational conglomeratic band.
Measurements (mm):

Sp. no.	Height of Tooth	Breadth of Tooth	Height of crown
V/F/B-32	9.50	-	6.50
V/F/B-33	8.20	-	6.00

Description: Teeth medium in size; crown erect, high, narrow with pointed apex, broader at the base, sharp cutting edges without serrations, internal surface highly convex whereas external one is nearly flat or little convex; small denticle found on one side of the lateral cusp in one of the specimens (plate 1, fig 2a) while denticle on the other side is not preserved. Root poorly preserved but the preserved portion appears to contain median groove on the highly convex internal surface.

Remarks: The specimens can be compared with the species *Lamna* sp. figured and illustrated by Mishra (1980) from the Ossiferous limestones of Babia stage, Middle Eocene at Nareda, Kachchh. But due to the incomplete nature of the present specimens, the characteristic information needed for identification to the species is lacking. These specimens appear to be the first record of *Lamna* sp. from the Tertiary rocks of the northeastern region of India.

Genus: *Carcharodon* Muller & Henle, 1838
Species: *Carcharodon carcharias* Linnaeus, 1758
(Pl 1, figs. 3a, b; 4a, b; 5a, b and 9a, b)

The partial synonymy of the species is:
Carcharodon carcharias Linnaeus 1758: Mehrotra et al. 1973, p.190, Pl.2, figs. 2, 6a, b.
Carcharodon carcharias Agassiz: Sahni and Mehrotra, 1981, p.121, Pl.1, figs. 3, 4, 5, 6.
Carcharodon carcharias Linnaeus, 1758: Tiwari et al. 1998, p.17, Pl.1, figs. 5, 6.

Material: Three isolated teeth.
Location: Locality 1: Bika Quarry.
Horizon: Lower intraformational conglomeratic band.
Measurements (mm):

Sp. No.	Height of Tooth	Breadth of Tooth	Height of crown	Height/Breath Ratio
V/F/B-16	10.00	9.00	8.00	1.1
V/F/B -20	11.00	-	9.00	-
V/F/B -43	10.00	9.00	7.00	1.1
V/F/B -79	15.00	-	9.00	-

Description: Teeth medium in size, nearly as high as broad; crowns compressed, triangular in outline with pointed apex, thick in the middle and becoming thinner towards edges, erect or slightly inclined towards posterior or distal side, sharp cutting edges with fine regular serrations that are bigger at the base of the cusp; both mesial and distal margins almost straight; external surface flat, internal one slightly convex. No lateral denticles present at the cusps. Roots broader than high, basal margin of the roots feebly to moderately concave. Root canal or median furrow at the internal surface of the root is clearly visible in of the specimens (Plate 1, fig. 3b).

Remarks: The present specimens are identified as *Carcharodon carcharias* by their medium sized crown, triangular shape, serrated cutting edges and moderately bilobate roots. These bear close resemblance with the same species reported from the Miocene sediments of Kachchh described and figured by Mehrotra et al. (1973). These also resemble well with the teeth of the same species collected from the Miocene beds of Baripada (Sahni and Mehrotra, 1981) and Piram Island (Prasad, 1974). This species is also recorded from the Bhuban Formation of Mizoram (Tiwari et al.1998).

Species: *Carcharodon angustidens* Agassiz, 1843
(Pl 1, figs. 6 and 7)
Carcharodon angustidens Agassiz, 1843: Stuart, 1910, p.300, Pl.26, fig. 3 a, b, c.
Carcharodon angustidens Agassiz, 1843: Mehrotra et al. 1973, p.190, Pl.2, fig. 3.
Carcharodon angustidens Agassiz, 1843: Sahni and Mehrotra, 1981, p.121, Pl.1, fig. 11.

Material: Two isolated fragmentary teeth.
Location: Locality 1: Bika Quarry and Locality 2: Ruata Quarry.
Horizon: Lower intraformational conglomeratic band of Locality - 1 and upper intraformational conglomeratic band of Locality 2.
Measurements: One tooth (specimen No. V/F/B-07) cannot be measured and another (V/F/B-08) measures 30 mm in height. Height of the crown is 25 mm.

Description: Teeth large in size; crowns erect, thick, broad and having the shape of an isosceles triangle; sharp cutting edges having uniformly coarse serrations; both mesial and distal edges are straight; generally with two denticles on either side of the cusp, but only one denticle is preserved in one of the specimens (Plate 1, fig. 7). This denticle is finely and uniformly serrated. A series of prominent longitudinal striations extend from base to apex at the enamel surfaces of the cusps. Crown thickens or bulges at the center and gradually tapers towards edges. Internal surface strongly convex while the external surface flattened or slightly convex. Collar is prominent between root and cusp at the internal surface in one of the specimens (Plate 1, fig. 6). Roots not well preserved but seem to be broad, low and weakly bilobate.

Remarks: Two specimens presently described show close resemblance with the *Carcharodon angustidens* described and figured by Stuart (1910) from Miocene sediments of Pagan Hills, Burma. Both can also be compared well with the species collected and figured by Mehrotra et al. (1973) from the Lower Miocene shales of Lakhpat (Kachchh). They are also more or less similar with the same species reported and collected from the Miocene sediments of Kachchh (Sahni and Mehrotra, 1981).

Species: *Carcharodon* sp.
(Pl 1, figs.8a, b)

Material: One isolated incomplete tooth (Specimen no. V/F/R-27).

Location: Locality 2: Ruata Quarry.

Horizon: Upper intraformational conglomeratic band.

Measurements: Height of tooth and crown measures 22 mm and 18 mm respectively, breadth of tooth could not be measured because it is incomplete.

Description: Tooth large in size; crown thick, somewhat broad, acute triangular in shape and directed posteriorly or distally with pointed apex, sharp cutting edges bearing serrations that are coarser towards the base and finer towards the apex; mesial edge slightly convex and distal edge straight or slightly concave; internal surface strongly convex and external surface flat; collar preserved at the internal surface near the junction of crown and root; root low, appear to be broader and with a shallow bifurcation.

Remarks: The lone specimen resembles closely with the species *Carcharodon carcharias* from the Upper Miocene of Senhata Formation, Boso Peninsula, Central Japan (Yabe and Hirayama, 1994, p.41, figs.8 a-c). The material described is too meager and incomplete to allow any detailed comparison. However, on the basis of the morphological characters and geometry of the crown, it undoubtedly belongs to one of the species of the *Carcharodon*.

Genus: *Isurus* Rafinesque, 1810
Species: *Isurus spallanzanii* Bonaparte, 1839
(Pl 1, figs. 11a, b; 12a, b; 13a, b, c and 14a, b)

Oxyrhina spallanzanii Bonaparte: Noetling, 1901, p 372, Pl.25, fig. 4, 5, 6.

Oxyrhina spallanzanii Bonaparte: Stuart, 1910, Pl-25, fig. 9; Pl.26, figs. 1, 2.

Isurus (oxyrhina) spallanzanii Bonaparte: Mehrotra et al. 1973, p.182, Pl.1, fig. 10a, b.

*Oxyrhina spallanzanii*Bonaparte: Sahni and Mehrotra, 1981, p.120, Pl.1, fig. 1.

Isurus (oxyrhina) spallanzanii Bonaparte: Kumar and Loyal, 1987, p.121, Pl.1, Fig.7.

Isurus spallanzanii Bonaparte: Tiwari et al. 1998, p.17, Pl.1, figs. 7, 8.

Material: Four isolated teeth- one complete and 3 broken ones.

Location: Locality 1: Bika Quarry and Locality 2: Ruata Quarry.

Horizon: Lower intraformational conglomeratic band of Locality 1 and upper intraformational conglomeratic band of Locality 2.

Measurements (mm):

Sp. no.	Height of Tooth	Breadth of Tooth	Height of crown
V/F/B -43	8.00	6.00	6.00
V/F/B -44	-	-	9.00
V/F/R -28	-	14.00	-
V/F/B -53	-	-	8.00

Description: Teeth small to medium in size; crowns erect, narrow, slender and lanceolate in shape with pointed apex; median teeth (Plate 1, figs. 12 a, b) easily distinguished by narrow, deeply bifurcated roots, and cutting edges of crowns being sharp only for the upper two thirds and rounded at the base; sub-rounded or almost circular shape in cross-section; cutting edges without serrations; crown slightly curved inward at the base and outwards at the apical part; internal surface convex, external surface nearly flat; Roots thick and low, externally flat, internally strongly convex. Lateral teeth (Plate 1, figs. 11 a, b) is characterized by a broad bifurcated roots with sharp cutting edges of crowns from base to the apex; crown in general has more or less similar morphological characters with that of median teeth, but the cross-section at the base is elliptical; Roots are low but broad, forming deeply bifurcated lateral branches; externally flattened and internally strongly convex.

Plate 1. 1a. *Lamna* sp., internal view, x 3.00 (V/F/B-32); **1b.** *Lamna* sp., external view x 3.00 (V/F/B-32); **2a.** *Lamna* sp., external view x 3.00 (V/F/B-33); **2b.** *Lamna* sp., internal view x 3.00 (V/F/B-32); **3a.** *Carcharodon carcharias* Linnaeus, external view x 3.00 (V/F/B-16); **3b.** *Carcharodon carcharias* Linnaeus,internal view x 3.00 (V/F/B-16); **4a.** *Carcharodon carcharias* Linnaeus, external view x 3.00 (V/F/B-20); **4b.** *Carcharodon carcharias* Linnaeus, internal view x 3.00 (V/F/B-20); **5a.** *Carcharodon carcharias* Linnaeus, internal view x 3.00 (V/F/B-43); **5b.** *Carcharodon carcharias* Linnaeus, external view x 3.00 (V/F/B-43); **6.** *Carcharodon angustidens* Agassiz, internal view x 1.5(V/F/B-7); **7.** *Carcharodon angustidens* Agassiz, internal view x 1.5(V/F/B-8); **8a.** *Carcharodon* sp. external view x 2.00 (V/F/B-27); **8b.** *Carcharodon* sp. internal view x 2.00(V/F/B-27); **9a.** *Carcharodon carcharias* Linnaeus, external view x 2.00 (V/F/B-79); **9b.** *Carcharodon carcharias* Linnaeus, internal view x 2.00 (V/F/B-79); **10a.** *Isurus pagoda* Neotling, internal view x 3.00 (V/F/B-49); **10b.** *Isurus pagoda* Neotling, external view x 3.00(V/F/B-49); **11a.** *Isurus spallanzanii* Bonnaparte, internal view x 3.00 (V/F/B-44); **11b.** *Isurus spallanzanii* Bonnaparte, external view x 3.00(V/F/B-44); **12a.** *Isurus spallanzanii* Bonnaparte, internal view x 3.00 (V/F/B-43); **12b.** *Isurus spallanzanii* Bonnaparte, external view x 3.00(V/F/B-43); **13a.** *Isurus spallanzanii* Bonnaparte, internal view x 1.50 (V/F/B-28); **13b.** *Isurus spallanzanii* Bonnaparte, profile view x 1.50 (V/F/B-28); **13c.** *Isurus spallanzanii* Bonnaparte, external view x 1.50 (V/F/B-28); **14a.** *Isurus spallanzanii* Bonnaparte, internal view x 3.00(V/F/B-53); **14b.** *Isurus spallanzanii* Bonnaparte, external view x 3.00 (V/F/B-53); **15a.** *Odontaspis* cf. *taurus*, internal view x 2.00(V/F/B-59); **15b.** *Odontaspis* cf. *taurus*,, profile view x 2.00 (V/F/B-59); **15c.** *Odontaspis* cf. *taurus*, external view x 2.00(V/F/B-59); 16a. *Odontaspis* sp., external view, x 3.00 (V/F/B-58); **16b.** *Odontaspis* sp., internal view x 3.00 (V/F/B-58); **17a.** *Odontaspis* sp., internal view x 3.00 (V/F/B-30); **17b.** *Odontaspis* sp., external view x 3.00 (V/F/B-30); **18a.** *Odontaspis* cf. *tricuspidatus*, external view x 1.50 (V/F/B-61); **18b.** *Odontaspis* cf. *tricuspidatus*, internal view x 1.50 (V/F/B-61); **19a.** *Carcharhinus egertoni* Agassiz, external view x 2.00 (V/F/B-24); **19b.** *Carcharhinus egertoni* Agassiz, internal view x 2.00 (V/F/B-24).

Remarks: These specimens can be identified as *Isurus spallanzanii* based on the above mentioned morphological features of the crown and root. They have close resemblance with *Oxyrhina spallanzanii* of Noetling (1901) and Stuart (1910) from the different localities of Miocene beds of Myanmar. It can also be compared with the same species reported by Mehrotra *et* al. (1973) and Sahni and Mehrotra (1981) from the coastal Miocene sediments of Peninsular India. The same species is recorded and described by Tiwari *et al.* (1998) from the Bhuban Formation but from a different locality i.e. Chanmari, Aizawl.

Species : *Isurus pagoda* Noetling, 1901
(Pl 1, figs. 10a, b)

Oxyrhina pagoda Noetling: Noetling, p 372, 1901, Pl.25, figs. 1a-e; 2a-e; 3a, b.

Isurus pagoda Noetling: Mehrotra *et al.*, 1973, p 182, Pl.1, fig. 10a, b.

Isurus pagoda Noetling: Sahni and Mehrotra, 1981, p.120, Pl.1, fig. 1.

Material: One isolated tooth; part of root broken.

Location: Locality 1: Bika Quarry.

Horizon: Lower intraformational conglomeratic band.

Measurements: The crown measures 8 mm in height and 3.50 mm in width.

Description: Teeth small in size; crown erect, narrow, slender and lanceolate in shape with a broad arrow head-like apex; crown much higher than root; margins unserrated, sharp in the apical and rounded in basal part, internal surface strongly convex and external one somewhat flat. Root seems to be low and thick, bifurcated with short lateral branches.

Remarks: The lone specimen at hand though smaller in size closely resembles with the species *Oxyrina pagoda* (Noetling, 1901, Pl.25, figs. 1-3) in its broad arrow-head shape of the upper part of the cusp. It can also be compared with the same species reported by Mehrotra et al. (1973) and Sahni and Mehrotra (1981) from the coastal Miocene sediments of peninsular India.

Family: ALOPIIDAE
Genus: *Alopias* Rafinesque, 1810
Species: *Alopias* sp.
(Pl 3, figs. 8a, b and 9a, b)

Material: Two isolated teeth; roots are missing.

Location: Locality1: Bika Quarry.

Horizon: Lower intraformational conglomeratic band.

Measurements: The height of two crowns is 6 mm (Plate 3, figs. 8a, b) and 7 mm (Plate 3, figs. 9 a, b).

Description: Teeth small in size; crowns narrow, elongated with pointed apex, oblique towards inner edge; the cutting edges are sharp and without serrations.Both the surfaces of crown convex, internal one more so. Anterior edges nearly straight whereas posterior edges somewhat concave and with a notch towards base. Roots not preserved.

Remarks: The specimens resembles *Alopias vuples* described from the Lower Miocene shales of Matanumadh, Kachchh reported by Mehrotra *et al.* (1973). However, the materials described herein cannot be compared with the former due to the absence of the root parts. The presence of this genus is reported for the first time in the Surma sediments of Mizoram.

Family: ODONTASPIDIDAE
Genus: *Odontaspis* Agassiz, 1843
Species: *Odontaspis* cf. *taurus* Rafinesue, 1970
(Pl 1, figs. 15a - c)

Odontaspis taurus Rafinesque: Antunes and Jonet, 1970, Pl.IV, figs. 5-11.

Material: One isolated tooth.

Location: Locality 1: Bika Quarry.

Horizon: Lower intraformational conglomeratic band.

Measurements: Height of tooth (Specimen no. V/F/B-59) is 14 mm; breadth 10 mm and height of crown is 10 mm.

Description: Tooth medium in size; crown narrow, erect, elongated, slender and lanceolate in shape with pointed apex; cutting edges throughout from apex to the base of the crowns and without serrations; crown much higher than the root, curved inward at the base and outward at the apical part; internal surface highly convex and external surface flat or little convex. Root broader than high, deeply forked in the middle and only one denticle could be seen on the mesial edge of the cusp.

Remarks: The lone specimen described above is comparable with the species *Odontaspis taurus* figured and described by Antunes and Jonet (1970) from the Miocene beds of Algrave Coast, Portugal. However, crown of the latter is erect and the root is strongly bifid. Hence, present specimen is referred to as a comparable form of *Odontaspis* cf. *taurus* Rafinesque.

Species: *Odontaspis* cf. *tricuspidatus* Day, 1888
(Pl 1, figs. 18a, b)

Cacharias tricuspidatus Day, 1888: Mehrotra et al. 1973, p.190, Pl.2, fig.9.

Odontaspis tricuspidatus Day, 1888: Sahni and Mehrotra, 1981, Pl.1, fig.14.

Material: One isolated incomplete tooth.

Location: Locality 1: Bika Quarry.

Horizon: Lower intraformational conglomeratic band.

Measurements: The crown of specimen no. V/F/B-61 measures 21 mm in height and 7 mm in width.

Description: Tooth large; crown erect or slightly oblique towards inner edge, lanceolate in shape, higher than broad, inner and outer margins without serrations and sharp. Internal and external surfaces of crown convex. Root seems to be low and broad with prominent medial projection on internal side.

Remarks: The crown of the available specimen bears close resemblance with the species *Odontaspis tricuspidatus* reported and figured by Mehrotra et al. (1973) and Sahni and Mehrotra (1981) from the Lower Miocene shales of Matanumadh, Kachchh, Gujarat, in terms of its large size and nearly erect and lanceolate outline, edges without serrations and convex internal and external surfaces. But the presence of lateral denticles and deeply forked nature of the root could not ascertain due to the ill preserved nature of the present specimen. Hence, it is referred to as bearing affinity with the *Odontaspis* cf *tricuspidatus* Day.

Species: *Odontaspis* sp.
(Pl 1, figs. 16a, b and 17a, b)

Material: Two isolated broken teeth.

Location: Locality 1: Bika Quarry.

Horizon: Lower intraformational conglomeratic band.

Measurements (mm):

Sp. no.	Height of Tooth	Breadth of Tooth	Height of crown
V/F/B -58	-	-	8.00
V/F/B -30	-	-	10.00

Description: Teeth small in size; crowns narrow, erect, elongated, slender and lanceolate in shape with pointed apex, edges of the crown sharp throughout and without serration; crowns curved inward at the base and outward at the apical part; lateral denticles not preserved; internal surface highly convex and external one flat or little convex. Root is not preserved.

Remarks: The morphological features and outline of the crowns is typical of the Odontaspids. But the ill-preserved or incomplete materials especially the root parts do not allow precise identification of the specimens.

Family: CARCHARHINIDAE Jordan and Everymann 1896
Genus: *Carcharhinus* Blainville, 1816
Species: *Carcharhinus egertoni Aga*ssiz, 1843
(Pl 1, figs. 19a, b and Pl 2, figs. 1a, b)

Carcharias (Prionodon) egertoni, Agassiz: Stuart, 1910, p.300, Pl.26, figs. 8, 8a.

Carcharhinus egertoni Agassiz: Sahni and Mehrotra, 1981, p.122, Pl.2, figs.4, 5.

Carcharhinus egertoni Agassiz: Antunes et al. 1981, Pl.2, figs. 14, 16.

Carcharhinus egertoni Agassiz: Karasawa, 1989, p.55, Pl.VII, figs. 12-15.

Material: Two isolated teeth.

Location: Locality 1: Bika Quarry and Locality 2: Ruata Quarry.

Horizon: Lower intraformational conglomeratic band of Locality 1 and upper intraformational conglomeratic horizon of Locality 2.

Measurements (mm):

Sp. no.	Height of Tooth	Breadth of Tooth	Height of crown	Height/Breath Ratio
V/F/B-64	24.00	22.00	20.00	1.09
V/F/B-24	13.00	16.00	11.00	0.80

Descriptions: Teeth medium to large in size; crowns with pointed apex, obliquely triangular in outline, broad, slightly oblique towards distal side, cutting edges sharp with fine serrations at the apex becoming slightly coarser towards the base, mesial or outer margins moderately convex and distal margins straight or slightly concave; internal surfaces or lingual faces moderately convex and external surfaces or labial faces nearly flat or little convex, collar present between root and cusp in one of the specimens (Plate 2, fig. 1b). Root broader than high with moderately bilobed nature.

Remarks: Specimen no. V/F/B-64 (plate 2, figs. 1 a, b) has a close resemblance with the upper tooth of *Carcharhinus egertoni* described and figured by Karasawa (1989) from the Miocene sequences of Hokuriku district, Central Japan excepting that the former are slightly larger in size. These are also more or less similar with the same species described and illustrated by Antunes and Jonet (1970) from the Miocene Formations of Algarve coast, Portugal. These also tally well with *Carcharhinus egertoni* described and figured by Stuart (1910) from the Pegu beds exposed in the Singu Oilfield (Miocene), Pakokku district, Myanmar. Specimen no. V/F/B-24 (Plate 1, figs. 19a, b) can be well compared with the lower tooth of the same species described and illustrated by Karasawa (1989) from the Miocene beds of Hokuriku district, central Japan.

Species: *Carcharhinus priscus* Agassiz, 1970
(Pl.2, figs. 2a, b and 3a, b)

Carcharias priscus, Agassiz: Antunes and Jonet, 1970, Pl.XVII, figs. 120-131.

Carcharhinus priscus Agassiz: Antunes et al. 1981, Pl.II, figs. 18 a, b.

Carcharhinus priscus Agassiz: Karasawa, 1989, p 55, Pl.VII, figs. 9-11.

Material: Two isolated teeth.

Location: Locality1: Bika Quarry.

Horizon: Lower intraformational conglomeratic band.

Measurements (mm):

Sp. no.	Height of Tooth	Breadth of Tooth	Height of crown	Height/Breadth Ratio
V/F/B-25	11.00	-	9.50	-
V/F/B-26	8.00	9.00	6.50	0.88

Description: Teeth medium in size; crown narrow, pointed apex, acutely triangular in shape, and oblique distally or posteriorly; cutting edges sharp bearing fine and uniform serrations at the base of cusps while upper part of cusps are with a few or no serrations; mesial or outer margins moderately convex and distal or inner margins straight or little concave; internal surface convex and external surface flat; crowns slightly higher than roots and cover entire roots. Roots broader than high and the lateral branches of roots are moderately bifurcated.

Remarks: The specimens presently described can be compared reasonably well with the upper tooth of the same species described and figured by Karasawa (1989) from the Miocene sequences of Hokuriku district, central Japan and Miocene Formations of Algarve coast, Portugal (Antunes and Jonet 1970; Antunes et al. 1981).

Species: *Carcharhinus* cf. *macloti* (Muller and Henle, 1841)
(Pl 2, figs. 4a, b)

Material: One isolated teeth.

Location: Locality 1: Bika Quarry.

Horizon: Lower intraformational conglomeratic band.

Measurements: Height and width of tooth (V/F/B -78) is 12 mm; height of crown is 8 mm and height/width ratio is 1

Description: Tooth small; crowns thick, oblique posteriorly with pointed apex, both inner and outer edges straight and without serrations, moderately deep notch near the base of cusp. Internal surface strongly convex while external surface flattened. Root low, broader than high, internal surface convex, external one flat, basal margin of root slightly concave.

Remarks: The specimen resembles *Hypoprion macloti* now referred to as *Carcharhinus macloti* reported from the Lower Miocene sediments of Baripada, Orissa and Matanumadh of Kachchh (Sahni and Mehrotra, 1981). However, the specimen at hand is too meager to draw conclusion for precise assignment of species. Hence, it is considered to be the comparable form of this species.

Species: *Carcharhinus bhubanicus* n. sp.
(Pl 2, figs. 5a, b)

Etymology: The species name refers to its occurrence in the Bhuban Formation.

Type material: One tooth (Holotype; specimen no. V/F/R-77).

Type locality: Locality 1: Bika Quarry.

Type horizon: Lower intraformational conglomeratic band.

Measurements: A single but well-preserved specimen (holotype) measures 12 mm in height, 14 mm in width; height of crown is about 7 mm.

Diagnostic characters: Prominent and uniform serrations at both the margins, higher convexity of the outer edge, strongly concave nature of the inner cutting edge and rectangular root without bifurcation.

Descriptions: Tooth medium in size, thick at the centre and becoming thinner towards the edges as well as the apex and base of the tooth; crown broad, strongly oblique distally with pointed apex, cutting edges sharp with fine and more or less uniform serrations from apex to base, outer edge strongly convex, inner edge strongly concave; internal surface highly convex, external surface flattened. Root low, broader than high, internal surface convex while external one flattened. Basal margin of root straight or little concave.

Remarks: The lone but well preserved specimen undoubtedly belong to the genus *Carcharhinus* owing to the overall geometry of the tooth and prominent and uniform serrations at both the margins. It can be easily distinguished from the other species of *Carcharhinus* hitherto reported on account of higher convexity of its outer edge and strongly concave nature of the inner cutting edge. In addition, unlike other species its root is more or less rectangular and is without bifurcation.

Species: *Carcharhinus* (*Prionodon*) sp.
(Pl. 2, figs. 6a, b; 7a, b and 8a, b)

Material: Three isolated teeth.

Location: Locality 1: Bika Quarry.

Horizon: Lower intraformational conglomeratic horizon.

Measurements (mm):

Sp. no.	Height of Tooth	Breadth of Tooth	Height of crown
V/F/B-83	8.00	9.00	5.50
V/F/B-84	6.00	9.00	4.50
V/F/B -90	-	-	7.00

Plate 2. 1a. *Carcharhinus egertoni* Agassiz, external view x 1.00 (V/F/B-64); **1b.** *Carcharhinus egertoni* Agassiz, internal view x 1.00 (V/F/B-64); **2a.** *Carcharhinus priscus* Agassiz, internal view x 2.00(V/F/B-25); **2b.** *Carcharhinus priscus* Agassiz, external view x 2.00(V/F/B-25); **3a.** *Carcharhinus priscus* Agassiz, internal view x 3.00(V/F/B-26); **3b.** *Carcharhinus priscus* Agassiz, iexternal view x 3.00(V/F/B-26); **4a.** *Carcharhinus* cf. *macloti* Muller and Henle, internal view x 2.00 (V/F/B-78); **4b.** *Carcharhinus* cf. *macloti* Muller and Henle, internal view x 2.00 (V/F/B-78); **5a.** *Carcharhinus bubanicus* n. sp., external view x 2.00 (V/F/B-77); **5b.** *Carcharhinus bubanicus* n. sp., internal view x 2.00 (V/F/B-77); **6a.** *Carcharhinus* (*Prionodon*) sp., internal view x 3.00 (V/F/B-83); **6b.** *Carcharhinus* (*Prionodon*) sp., external view x 3.00 (V/F/B-83); **7a.** *Carcharhinus* (*Prionodon*) sp., internal view x 3.00 (V/F/B-84); **7b.** *Carcharhinus* (*Prionodon*) sp., external view x 3.00 (V/F/B-84); **8a.** *Carcharhinus* (*Prionodon*) sp., internal view x 3.00 (V/F/B-90); **8b.** *Carcharhinus* (*Prionodon*) sp., external view x 3.00 (V/F/B-90); **9a.** *Carcharhinus* sp. A, internal view x 1.50 (V/F/B-74); **9b.** *Carcharhinus* sp. A, external view x 1.50(V/F/B-74); **10a.** *Carcharhinus* sp. A, internal view x 2.00 (V/F/B-107); **10b.** *Carcharhinus* sp. A, external view x 2.00(V/F/B-107); **11a.** *Carcharhinus* sp. B, external view x 3.00(V/F/B-88); **11b.** *Carcharhinus* sp. B, internal view x 3.00 (V/F/B-88); **12a.** *Carcharhinus* sp. C, external view x 1.50(V/F/B-75); **12b.** *Carcharhinus* sp. C, internal view x 1.50(V/F/B-75); **13a.** *Carcharhinus* sp. C, internal view x 2.00 (V/F/B-76); 13b. *Carcharhinus* sp. C, external view x 2.00(V/F/B-76); **14a.** *Carcharhinus* sp. D, external view x 1.00 (V/F/B-80); **14b.** *Carcharhinus* sp. D, internal view x 1.00 (V/F/B-80); **15a.** *Galeocerdo aduncus* Agassiz, external view x 2.00 (V/F/B-67); **15b.** *Galeocerdo aduncus* Agassiz, internal view x 2.00 (V/F/B-67); **16a.** *Galeocerdo aduncus* Agassiz, external view x 2.00 (V/F/B-68); **16b.** *Galeocerdo aduncus* Agassiz, external view x 2.00 (V/F/B-68); **17.** *Galeocerdo aduncus* Agassiz, internal view x 2.00 (V/F/B-9).

Description: Tooth medium in size, broader than high; crowns compressed, sub triangular in outline, directed posteriorly with pointed apex, outer edges slightly convex, inner edge straight or little concave, cutting edges sharp bearing fine serrations, somewhat coarser at the base. Internal surface slightly convex while external surface flattened. Root low, broader than high, internal surface weakly convex, external one flat, basal margin of root straight or slightly concave.

Specimen no. V/F/B-90 (Plate 2, figs. 8 a, b) differs from the others by its erect nature of crown, triangular outline with somewhat blunt apex.

Remarks: The materials described above have close resemblance with the *Prionodon* sp. described and illustrated by Hora (1939) from the Eocene sediments of Balasore, Orissa. However, the genus *Prionodon* was established as the sub-genus of *Carcharhinus* under the family Carcharhinidae (Ghosh, 1959).

Species: *Carcharhinus* sp. A (indet)
(Pl 2, figs. 9a, b; 10a, b)

Material: Two isolated incomplete tooth.

Location: Locality 1: Bika Quarry.

Horizon: Lower intraformational conglomeratic band.

Measurements (mm):

Sp. no.	Height of Tooth	Breadth of Tooth	Height of Crown
V/F/B –74	20.00	-	15.00
V/F/B –107	12.00	-	8.50

Descriptions: Tooth medium to large in size; crowns erect or slightly oblique towards posterior, sub-triangular in shape with pointed apex, higher than broad; sharp cutting edges bearing fine serrations throughout; serrations coarser at the base becoming finer towards the apex, crowns thicken in the middle and thinner towards the edges; outer margins slightly convex and distal or inner margins somewhat straight or fairly concave; Surface strongly convex internally and flattened externally. Roots are poorly preserved.

Remarks: Both specimens can be compared well, on the basis of the morphological features and geometry of the crown, with the upper tooth of the species *Charcharhinus egertoni* by Antunes and Jonet (1970, plate-xv, fig. 111) from the Miocene beds of Algrave coast of Portugal. Since the present specimens are incomplete and poorly preserved, specific assignment is not attempted and these are referred to as *Carcharhinus* sp. indet.

Species: *Carcharhinus* sp. B (indet)
(Pl 2, figs.11a, b)

Material: One complete tooth (Specimen no. V/F/B-88).

Location: Locality 1: Bika Quarry.

Horizon: Lower intraformational conglomeratic band.

Measurements: Height of tooth 6 mm, breadth: 8 mm; height of crown: 4.50 mm.

Descriptions: Tooth small; crown erect, triangular in shape with somewhat blunt apex, broader than high, sharp cutting edge with fine serrations only at the base of the crown; crown runs all over along the root, outer edge moderately convex, inner edge straight or slightly concave; internal surface convex while external surface flatten. Root low, broad and weakly bifid with a median groove in its inner surface.

Remarks: The lone specimen at hand can be grouped under the genus *Carcharhinus* on the basis of morphological characteristics of the tooth and geometry of the crown. This can be distinguished from *Carcharhinus* sp. A described above on account of its small size, erect nature, serrated margins at the base, somewhat blunt apex and weakly bifid root.

Species: *Carcharhinus* sp. C
(Pl 2, figs. 12a, b and 13 a, b)

Material: Two isolated teeth; one complete and another one with broken root.

Location: Locality 1: Bika Quarry.

Horizon: Lower intraformational conglomeratic band.

Measurements (mm):

Sp. no.	Height of Tooth	Breadth of Tooth	Height of crown	Height/Breath Ratio
V/F/B-75	24.00	18.00	16.00	1.33
V/F/B-76	14.00	-	10.00	-

Descriptions: Specimen (Plate 2, figs.12 a, b) is large in size; crown directed posteriorly with pointed apex, sharp cutting edges with fine and more or less uniform serrations from base to apex, outer or distal margin convex and inner or mesial margin straight; crown curved inward at the base and outward at the tip; internal surface strongly convex while the external is flattened. Root high, broad and thick, internally strongly covex and externally flattened with strong bifid nature.

Specimen (Plate 2, figs. 13 a, b) is medium in size; crown erect, thick, higher than broad, pointed apex, cutting edges sharp, fine and uniformly serrated throughout, both outer and inner margins slightly convex; internal surface strongly convex while external is flattened. Root broader than high, lateral branch of root is weakly bifurcated.

Remarks: On account of medium size, almost equilateral triangular outline, regularly serrated margins and thick and bifurcated root, these specimens are assigned to

Carcharhinus sp. C. However, additional specimens and information would be desirable in order to have a precise determination. These specimens differ from *Carcharhinus* sp. A and B on account of the slender nature of crown and more bifid root.

Species: *Carcharhinus* sp. D
(Pl. 2, Figs.14a, b)

Material: One isolated teeth.

Location: Locality 1: Bika Quarry.

Horizon: Lower intraformational conglomeratic horizon.

Measurements: Height of tooth and crown (specimen no. V/F/B -80) is 12 mm and 8 mm, respectively.

Description: Tooth small to medium; crowns thick and erect with pointed apex, both inner and outer edges straight or little convex, cutting edges sharp bearing fine and uniform serrations from base to tip of cusp. Internal surface strongly convex while external surface flattened; no lateral denticles observed at the base of cusp. Root low, broader than high, internal surface convex, external one flat, basal margin of root slightly concave.

Remarks: The specimens, in spite of being small in dimensions, bear resemblance with the shape of crown and root with *Hypoprion minidenticulata* described and figured by Sahni and Mehrotra (1981) from the Lower Miocene gypseous shales of Matanumadh, Kachchh and unconsolidated conglomerates of Akwara, Bhavnagar. The only observable difference is the absence of small denticles on the lateral cusp.

Genus: *Galeocerdo* Muller and Henle, 1873
Species: *Galeocerdo aduncus* Agassiz 1843
(Pl. 2, Figs. 15a, b; 16a, b and 17)

Galeocerdo aduncus Agassiz: Antunes and Jonet, 1970, Pl-XI, figs. 59 -62.

Galeocerdo aduncus Agassiz: Antunes et al. 1981, Pl-II, figs. 10,13.

Galeocerdo aduncus Agassiz: Sahni and Mehrotra, 1981, Pl-2, fig. 15.

Galeocerdo aduncus Agassiz: Karasawa, 1989, p 55, Pl-VII, figs. 7, 8.

Material: Three isolated teeth; two complete and one broken and embedded in the matrix.

Location: Locality 1-Bika Quarry and Locality 2-Ruata Quarry.

Horizon: Lower intraformational conglomeratic band of Locality 1 and upper intraformational conglomeratic band of Locality 2.

Measurements (mm):

Sp. no.	Height of Tooth	Breadth of Tooth	Height of crown	Height/Breadth Ratio
V/F/B-09	10.00	16.00	9.00	0.62
V/F/B-67	12.00	16.00	9.00	0.75
V/F/B-68	11.00	-	9.00	-

Description: Teeth medium in size; upper part of the crowns obliquely triangular in shape with pointed apex and thicker at the centre, lower part compressed and broad covering entire roots, strongly oblique posteriorly; cutting edges sharp with fine and uniform serrations at the mesial or outer margin excepting near the apex that is smooth, serrations prominent at the inner margin with largest serrations in the proximity of the notch thereafter these gradually become smaller towards posterior end of the crowns, serration absent from the notch towards the apical end; outer margins moderately convex and distal or inner margins strongly concave giving a V-shaped geometry with a deep notch at the centre. External surface nearly flat and internal surface moderately convex. Root low and broad, strongly bilobed excepting in one of the specimen, Plate 2, fig. 17, appear to be sub- rectangular in outline.

Remarks: Galeocerdo aduncus Agassiz has been recorded and described by many workers from within the country and abroad. The presently described specimens can be compared reasonably well with the collections made by Antunes and Jonet (1970) and Antunes *et al.* (1981) from the Miocene beds of Portugal. Sahni and Mehrotra (1981) also described and figured this species from the Miocene sediments of Gogha coast of Orissa. Karasawa (1989) has also reported the presence of this species from the Miocene sequences at Hokuriku district of central Japan.

Genus: *Negaprion* Whitley, 1940
Species: *Negaprion brevirostris* Poey, 1868
(Pl. 3, Figs. 1a, b)

Negaprion brevirostris Poey, 1868: Antunes and Jonet, 1970, Pl.XIII, fig.80.

Material: One isolated tooth.

Location: Locality 1: Bika Quarry.

Horizon: Lower intraformational conglomeratic horizon.

Measurements: Height of tooth (specimen no. V/F/B-71) 6 mm, breadth is 7.50 mm whereas height of crown is 5 mm and height/breadth ratio is 0.80.

Descriptions: Tooth small, broader than high; crown oblique posteriorly with pointed apex, nearly as high as broad, outer margin slightly convex and inner margin straight, cutting edges sharp without serration except few ones at the base of the cusp. Internal surface convex and

external surface flattened. Root low, broader than high, convex on internal side while little concave on external side. Root straight or poorly bilobed.

Remarks: Though, the specimen presently described is little smaller in size, it can be compared reasonably well with the one described and figured by Mehrotra et al. (1973) from the Lower Miocene shales of Lakhpat and Matanumadh, Kachchh.

Species: *Negaprion* cf. *eurybathrodon*
(Pl. 3, Figs. 2 a, b)

Material: One isolated tooth with apical part broken
Location: Locality 1: Bika Quarry.
Horizon: Lower intraformational conglomeratic band.
Measurements: Height of tooth and crown cannot be ascertained due to broken apical part. Breadth of tooth is 24 mm.

Descriptions: Tooth medium sized; crown erect or slightly oblique posteriorly, broader than high, outer cutting edge convex and inner one straight or slightly concave, irregularly serrated, serrations bigger at the middle and decrease towards the basal and apical portion of cusp, crown goes all over along the root. Internal surface convex and external surface flattened or little convex. Root low, broader than high, internal surface convex while external one concave. Basal part of root straight or poorly bilobed.

Remarks: The specimen at hand has a close affinity with the species *Negaprion* cf *eurybathrodon* described and figured by Antunes et al. (1981) from the Miocene beds of Algarve coast, Portugal. Though the appearance and geometry of the above two are quite similar, the serrated margins and smaller size of the present specimen makes it different from the species described by Antunes et al. (1981).

Genus: *Scoliodon* Muller and Henle, 1837
Species: *Scoliodon sorrakawah* Cuvier, 1829
(Pl. 3, Figs. 3 a, b)

Scoliodon taxandriae Leirche: Antunnes and Jonet, 1970, Pl.XIV, figs. 82-91
Scoliodon sorrakawah Cuvier, 1829: Mehrotra et al. 1973, p.182, Pl.1, figs.-9a, 9b

Material: One isolated tooth with parts of root broken.
Location: Locality 1: Bika Quarry.
Horizon: Lower intraformational conglomeratic band.
Measurements: Height of tooth and crown (specimen no. V/F/B -73) is 7 mm and 5.50 mm respectively.

Description: Tooth small; crown narrow, oblique posteriorly with pointed apex. Inner and outer edges straight and without serrations, moderately deep notch near the base of cusp. Internal surface convex while external surface flattened. Root low, broader than high and its basal margin is weakly concave.

Remarks: The diagnostics characters of the species such as its small size, posteriorly oblique crown, unserrated cutting edges, low root allow it to be assigned to *Scoliodon sorrakawah.* The specimen also resembles with *Scoliodon sorrakwah* reported from the Lower Miocene shale and limestone of Matanumadh, Kachchh and Bariapad bed of Orissa (Mehrotra et al. 1973).

Order CARCHARINIFORMES Compagno, 1973
Family HEMIGALEIDAE Hasse, 1879 (1885)

Genus: *Hemipristis* Agassiz, 1843
Species: *Hemipristis serra* Agassiz, 1843
(Pl. 3, Figs.4a, b, 5a, b and 6a, b)

Hemipristis serra Agassiz, 1843: Noetling, 1901, p. 83, Pl.xxv, figs. 9 a-e and 10.
Hemipristis serra Agassiz, 1843: Stuart, 1910, p.300, Pl.26, fig. 14.
Hemipristis serra Agassiz, 1843: Gosh, 1959, Pl.88, fig. 1.
Hemipristis serra Agassiz, 1843: Mehrotra et al. 1973, p 182, Pl-1, fig. 5.
Hemipristis serra Agassiz, 1843: Antunes et al. 1981, Pl-II, figs. 7, 8 and 9.
Hemipristis serra Agassiz, 1843: Sahni and Mehrotra, 1981, p 122, Pl-2, figs. 16, 17.
Hemipristis serra Agassiz, 1843: Tiwari et al. 1998, p17, Pl-1, fig. 1.

Material: Three isolated teeth; two specimens with broken apex and one with parts of root embedded in the matrix.

Location: Locality 1: Bika Quarry and Locality 2: Ruata Quarry.

Horizon: Lower intraformational conglomeratic band of Locality 1 and upper intraformational conglomeratic band of Locality 2.

Measurements (mm):

Sp. no.	Height of Tooth	Breadth of Tooth	Height of crown	Height/Breadth Ratio
V/F/B-01	17.00	14.00	15.00	1.20
V/F/B-02	15.00	14.00	13.00	1.10
V/F/B-03	-	20.00	-	-

Description: Teeth large and broad; crowns obliquely triangular to lanceolate in shape, higher than broad with pointed apex and directed towards posterior end, thicker at the base and center portion, thinning out towards

Plate 3. 1a. *Negaprion brevirostris* Poey, internal view x 3.00 (V/F/B-71); **1b.** *Negaprion brevirostris* Poey, external view x 3.00 (V/F/B-71); **2a.** *Negaprion* cf. *eurybathrodon* Blake, internal view x 1.00 (V/F/B-72); **2b.** *Negaprion* cf. *eurybathrodon* Blake, external view x 1.00 (V/F/B-72); **3a.** *Scoliodon sorrakawah* Cuvier, internal view x 3.00 (V/F/B-73); **3b.** *Scoliodon sorrakawah* Cuvier, external view x 3.00 (V/F/B-73); **4a.** *Hemipristis serra* Agassiz, external view x 1.50 (V/F/B-1); **4b.** *Hemipristis serra* Agassiz, internal view x 1.50(V/F/B-1); **5a.** *Hemipristis serra* Agassiz, internal view x 1.50 (V/F/R-2); **5b.** *Hemipristis serra* Agassiz, external view x 1.50 (V/F/R-2); **6a.** *Hemipristis serra* Agassiz, external view x 1.00 (V/F/R-3); **6b.** *Hemipristis serra* Agassiz, internal view x 1.00 (V/F/R-3); **7a.** *Hemipristis unidenticulata* n. sp., internal view x 2.00 (V/F/B-70); **7b.** *Hemipristis unidenticulata* n. sp., profile view x 2.00 (V/F/B-70); **7c.** *Hemipristis unidenticulata* n. sp., external view x 2.00 (V/F/B-70); **8a.** *Alopias* sp., internal view x 3.00 (V/F/B-86); **8b.** *Alopias* sp., external view x 3.00 (V/F/B-86); **9a.** *Alopias* sp., internal view x 3.00 (V/F/B-87); 9b. *Alopias* sp., external view x 3.00 (V/F/B-87); **10.** S*phyrna diplana* Springer, internal view x 3.00 (V/F/B-40); **11.** S*phyrna zygaena* Linneaus, external view x 3.00(V/F/B-39); **12a.** *Galeorhinus* sp., *external* view x 3.00 (V/F/B-23); 12b. *Galeorhinus* sp., internal view x 3.00(V/F/B-23); **13.** *Squalus* sp., internal view x 3.00 (V/F/B-91); **14a.** Indeterminate vertebral centra of selachians, cranial or caudal view x 3.00(V/F/B-104); **14b.** Indeterminate vertebral centra of selachians, dorsal or lateral view x 3.00 (V/F/B-104); **15a.** Carcharhinidae. gen. et sp. indet. (Vertebra), cranial or caudal view x 1.00(V/F/B-105); **15b.** Carcharhinidae. gen. et sp. indet. (Vertebra), dorsal or lateral view x 1.00 (V/F/B-105).

apex and edges. Internal surfaces of crowns strongly convex, external surfaces flat or little convex. Both the edges sharp, bearing irregular and obtuse serrations excepting near the apex where they end abruptly; serrations at the inner margin smaller at the base and become larger towards the apex whereas at the outer edges these are smaller and somewhat uniform. Inner edges strongly concave, outer edges convex. Roots very low, swollen in the middle forming prominent bilobed structure on the internal side and is very prominent in one of the specimens (Plate 3, Figs. 6 a, b).

Remarks: The specimens under study resemble *Hemipristis serra* reported and described by many workers from within and outside the country. Specimen no. V/F/R-01 (Plate 3, Figs. 4 a, b) and V/F/R-02 (Plate 3, Figs. 5a, b) can be compared reasonably well with the same species reported and described by Stuart (1910) from the Pegu beds exposed in the Singu Oilfield of Burma. Specimen no. V/F/R-03 (Plate 3, Figs. 6a, b) bears close resemblance with the *Hemipristis serra* recorded and figured by Sahni and Mehrotra (1981) from the Miocene sediments of Kachchh (Gujarat) and Gogha coast (Orissa). They can also be well compared with the same species collected and described by Tiwari *et al*. (1998) from the Middle Bhuban Formation of Mizoram (Lower Miocene).

The present specimens are identified as *Hemipristis serra* on account of their large sized, stout and awl-shaped crown, differently serrated margins i. e. smaller at base, becoming larger towards apex, abruptly ending a little before reaching apex, and low, swollen and bifid root.

Species: *Hemipristis unidenticulata* n. sp.
(Pl. 3, Figs. 7a, b and c)

Etymology: Specific name is derived from the presence of a prominent denticle near the base of the cusp at the outer edge.

Type material: One complete isolated tooth (Holotype; specimen no. V/F/B -70).

Type locality: Locality 1: Bika Quarry.

Type horizon: Lower intraformational conglomeratic band.

Measurements: Height of tooth – 10 mm, Breadth of tooth – 08 mm; Height of crown – 08 mm.

Diagnostic characters: Somewhat blunt apex, 5-6 serrations in the inner margin, unserrated outer margin with a prominent denticle and weakly bilobed root.

Description: Tooth medium in size; crown triangular in shape with somewhat blunt and posteriorly directed apex, higher than broad, thicker at the base and central portion, thinning towards the apex and edges. Internal surface strongly convex, external surface flat or with slight convexity. Internal edge bears 5-6 obtuse serrations which are smaller at the base and larger towards apex and end abruptly leaving nearly one-third of crown unserrated. Only one large serration or denticle present near the base of the cusp at the outer edge. Inner margin slightly concave, outer margin straight or slightly convex. Root low and thick, swollen in the middle, and the lateral branches weakly bilobed.

Remarks: The lone but well-preserved specimen at hand is distinct from the *Hemipristis serra* in the lesser number of serrations in the inner margin and in the unserrated outer margin bearing a prominent denticle near the base of the cusp. It also differs from *Hemipristis simplex* Stuart (1901, pl. 26, figs. 13a-b) that has unserrated marginal edges, stout and narrow outline and convex outer and inner faces.

Family: SPHYRNIDAE Gill, 1872

Genus: *Sphyrna* Rafinesque, 1810
Species: *Sphyrna diplana* Springer, 1941
(Pl. 3, Fig. 10)

Sphyrna diplana springer, 1941: Mehrotra et al. 1973, p 192, Pl-2, figs. 8a-b.
Sphyrna diplana springer, 1941: Sahni and Mehrotra, 1981, p 192, Pl-2, figs. 8a-b.
Sphyrna diplana springer, 1941: Mehrotra, 1982, p 402, Pl-1, figs. 1a-b.

Material: One isolated tooth with external surface embedded in matrix (Specimen no. V/F/B -40).

Location: Locality 1: Bika Quarry.

Horizon: Lower intraformational conglomeratic band.

Measurements: The tooth (Specimen no. V/F/B -40) measures 7 mm in height and 9 mm in breadth.

Description: Tooth small; crown as high as root with pointed apex and strongly directed posteriorly, apical portion of cusp narrow and the base goes all along over the root; cutting edges without serrations; inner cutting edge straight, outer cutting edge little convex; internal surface somewhat convex, external surface not observable. Root as high as broad, internal surface strongly convex with prominent bilobed structure. It is bifurcated by a deep median furrow at the internal surface of the root.

Remarks: A single but well preserved specimen described herein is more or less similar with the one figured by Sahni and Mehrotra (1981) from the Miocene sediments of Baripada, Orissa and Lakhpat and Matanumadh of Kachchh.

Species: *Sphyrna zygaena* Linneaus, 1758
(Pl.3, Fig. 11)

Sphyrna zygaena Linneaus, 1758: Antunnes et al. 1981, Pl.III, fig.16.

Sphyrna zygaena Linneaus, 1758: Sahni and Mehrotra, 1981, p.122, Pl-2, fig.-21.

Sphyrna zygaena Linneaus, 1758: Tiwari et al. 1998, p.17, Pl-1, fig.-4.

Material: One isolated tooth with external surface embedded in matrix (Specimen no. V/F/B -39).

Location: Locality 1: Bika Quarry.

Horizon: Lower intraformational conglomeratic band.

Measurements: Height of tooth – 6 mm; Breadth of tooth – 7 mm; Height of crown – 4.50 mm.

Description: Tooth small; crown narrow, sharp, erect or slightly oblique with pointed apex. Inner margin nearly straight while outer margin slanted with slight convexity. Edges are without serrations. Base of the crown goes all along over the root. Crown much higher than root. The internal surface little convex, thickened in the middle and becoming thiner towards the edges. Root low, broader than high, sub-rectangular in shape.

Remarks: The present specimen compares well with the collection and description made by Tiwari et al. (1998) from the Upper Bhuban Formation of Mizoram. It also has a close resemblance with the lower lateral anterior tooth of *Sphyrna zygaena* described and figured by Antunnes et al. (1981) from the Miocene beds of Algarve Coast, Portugal.

Family: TRIAKIDAE

Genus: *Galeorhinus* Blainville, 1816
Species: *Galeorhinus* sp.
(Pl. 3, Figs. 12a, b)

Material: One incomplete isolated tooth.

Location: Locality 1: Bika Quarry.

Horizon: Upper intraformational conglomeratic band.

Measurements: Height of the crown (specimen no. V/F/B –23) is 6 mm.

Description: Tooth very small, about 6 mm in height; crown thick, as high as broad, sub-triangular in shape, labiolingually compressed with pointed apex and slightly directed distally; four to five obtuse serrations at the inner or distal cutting edge decreasing in size form the apex to the base of crown; mesial margin smooth and little convex; internal surface more convex than the external one.

Remarks: Although the root part is not fully preserved, the present specimen belongs to genus *Galeorhinus* by its small size, well developed cusp, absences of mesial serrations and sub-erect mesial margin. It has a close resemblance with the species *Galeorhinus* sp. described and figured by Kumar and Loyal (1987) from the Subathu Formation, (Lower Eocene), Northwestern Himalaya, and Yabe and Hirayama (1994) from the Upper Miocene sediments of Sehhata Formation, Boso Peninsula, Central Japan.

Order: SQUALIFORMES Goodrich, 1909
Family: SQUALIDAE

Genus: *Squalus* Linnaeus, 1758
Species: *Squalus* sp.
(Pl. 3, Fig. 13)

Material: One isolated tooth with external surface embedded in matrix.

Location: Locality 1: Bika Quarry.

Horizon: Lower intraformational conglomeratic band.

Measurements: The tooth (Specimen no. V/F/B-91) measures 3.50 mm in height and 8.50 mm in breadth.

Description: Tooth small; crown as high as root and strongly inclined towards the inner edge, apical portion of cusp narrow and the base goes all along over the root; cutting edges without serrations, inner cutting edge straight, outer cutting edge little convex; internal surface slightly convex, external surface embedded in the matrix. Root much broader than high, basal margin not observable.

Remarks: The specimen resembles with *Squalus* sp. reported and figured by Sahni and Mehrotra (1981) from the Miocene sediments of Baripada, Orissa.

Carcharhinidae gen. et sp. indet.
(Pl. 3, Figs. 15a, b)

Material: One vertebra.

Location: Locality 2: Ruata Quarry.

Horizon: Upper intraformational conglomeratic band.

Measurements: Vertebrae plate 15 mm in thickness, 40 mm in diameter or breadth (Specimen no. V/F/R-105).

Descriptions: Cranial and caudal surfaces with scripted ring groups, nearly rounded and concave; canals of haemal arches at dorsal surface and neural arches at ventral surface not observable; lateral faces nearly flat; vertebrae plate 15 mm in thickness, 40 mm in diameter or breadth.

Remarks: These vertebrae belong to the vertebrae of the family Carcharhinidae because cranial and caudal surfaces are round with concentric ring groups and with lateral surface nearly flat. The same species is reported from the Miocene sediments of the Hokuriku district, central Japan by Karasawa (1989). The features of this specimen are also

similar to one of *Carcharhinus egertoni* from the Higashibessho Formation, Hokuriku Group of Miocene age from Central Japan (Nishimoto et al. 1980).

Indeterminate vertebral centra of selachians
(Pl. 3, Figs. 14a, b)

Material: One vertebra. (Specimen no. V/F/R-104).

Location: Locality 1: Bika Quarry.

Horizon: Lower intraformational conglomeratic band.

Measurements: Thickness of vertebra is 10 mm and diameter or breadth is 8 mm.

Descriptions: Vertebra small in size; both anterolateral (cranial and caudal) surfaces concave with numerous concentric growth lines; lateral and dorsal surface concave with smooth surface.

Remarks: The presently described specimen is too meager and poorly preserved not to allow precise determination.

DISCUSSION

A check-list of fish fauna from the study area along with their geographic distribution is shown in Table 2. Among the eighteen species of selachians described in this paper, two namely, *Carcharhinus bhubanicus* and *Hemipristis unidenticulata* are new species. Only four species *viz*. *Isurus spallanzanii*, *Carcharodon carcharias*, *Hemipristis serra* and *Sphyrna zygaena* were recorded from the Bhuban Formation of Mizoram by the earlier workers (Mehrotra, 1984; Satsangi and Mehrotra, 1986; Tiwari et al. 1998). Remaining species are being described for the first time from

Table 2. Check-list of selachians from Bhuban Formation of Mizoram with geographic distribution

Genera and species recorded from the study area	Gujarat			Orissa	Myanmar
	Piram Island	Gogha Coast	Kachhch	Baripada	
Lamna sp.					
Carcharodon carcharias	✓	✓	✓	✓	
Carcharodon angustidens					✓
Carcharodon sp.					
Isurus spallanzanii	✓	✓	✓		✓
Isurus pagoda	✓	✓		✓	✓
Alopias sp.					
Odontaspis cf. *taurus*					
Odontaspis cf. *tricuspidatus*		✓	✓		
Odontaspis sp.					
Carcharhinus egertoni		✓			✓
Carcharhinus priscus					
Carcharhinus cf. *macloti*			✓	✓	
Carcharhinus bhubanicus n. sp					
Carcharhinus (*Prionodon*) sp.					
Carcharhinus sp.A					
Carcharhinus sp.B					
Carcharhinus sp.C				✓	
Carcharhinus sp.D					
Galeocerdo aduncus		✓			
Negaprion brevirostris			✓	✓	
Negaprion cf. *eurybathrodon*					
Scoliodon sorrakawah			✓	✓	
Hemipristis serra		✓	✓	✓	✓
Hemipristis unidenticulata n. sp					
Sphyrna diplana			✓	✓	
Sphyrna zygaena			✓		
Galeorhinus sp.					
Squalus sp.					
Carcharhinidae gen. et sp. indet.					
Indeterminate vertebral centra of selachians					

the Miocene of Mizoram. Further, *Carcharodon angustidens* Agassiz, *Isurus pagoda* Bonnaparte, *Odontapis* cf. *tricuspidatus*, *Carcharhinus egertoni* Agassiz, *Carcharhinus* cf. *macloti, Galeocerdo aduncus* Agassiz, *Negaprion brevirostris* Poey, *Scoliodon sorrakawah* Cuvier, and S*phyrna diplana* Springer, *Odontapis* cf. *taurus* and *Negaprion* cf. *eurybathrodon* Blake; and *Carcharhinus priscus* Agassiz and *Galeorhinus* are being reported for the first time from the Miocene succession of Northeastern region and Indian subcontinent respectively.

Miocene fish fauna have been extensively studied from the several localities of the Indian subcontinent viz. Myanmar (Noetling, 1901; Stuart, 1910), Baripada bed, Orissa (Bhalla and Dev, 1975; Sahni and Mehrotra, 1981; Mondal et al. 2010), Kachhch, Piram island and Gogha coast (Mehrotra et al. 1973; Sahni and Mehrotra, 1981). A close scrutiny of the selachian fauna reported earlier from the Indian subcontinent indicates that five species from the present assemblage are common with Miocene of Myanmar, eight with Baripada bed of Orissa, nine with the Miocene of Kachchh, seven with the Gogha coast (Kathiawar) and three with the Piram island (Table 2). This supports the earlier held view that the diversification of selachians reached its peak during the Miocene time (Adnet et al. 2007; Mondal et al. 2010) coinciding with the global marine transgression during Lower Miocene and the selachians became truly cosmopolitan during this epoch (Theodor, 2005). It further supports the view that the sub-tropic regions are the hot spots of selachian diversity.

The presence of *Galeocerdo aduncus* in the intraformational conglomeratic bands of the study area along with other typical Miocene forms like *Hemipristis serra, Sphyrna zygaena, Sphyrna diplana* and *Isurus spallanzanii* suggests a Lower Miocene age (Aquitanian - Burdigalian) to these beds whereas the occurrence of *Carcharodon carcharias* indicates that these are not older than the Burdigalian (Sahni and Mehrotra, 1981). *Carcharhinus egertoni* has been reported only from the upper Burdigalian of Portugal and is conspicuously absent in the Helvetian (Sahni and Mehrotra, 1981). Further, the foraminifer *Ammonia annectens*, present in both the localities, broadly indicates Miocene age for the horizon (Singh and Nayak, 2004). Thus the present assemblage has stratigraphic significance and indicates the Lower Miocene (Aquitanian-Burdigalian) age for the Upper Bhuban unit of Bhuban Formation. This supports the inference drawn by earlier workers with the help of the invertebrate fauna (bivalves, gastropods, decapods and echinoids) from the study area and also from the adjoining areas (Tiwari and Kachhara, 2000, 2003; Tiwari, 2001, 2006).

Described fish fauna bears a close relationship with the present day fauna of the Indian Ocean. Almost all the genera of fossil selachian fishes from the Miocene of Mizoram excepting *Carcharodon* and *Lamna* still inhabit the Indian Ocean. *Carcharodon* is very common in Indian Miocene beds but surprisingly absent in the present day Indian Ocean (Mishra, 1969; Mehrotra et al. 1973). Sahni and Mehrotra (1981) opined that the sharks underwent only a minimal structural change from the Miocene onwards and are the direct ancestors of recent Indian sharks. All the selachian species are nekton forms, dwelling mainly in the neritic to epipelagic regions of tropical to subtropical seas having mean annual isotherm of about 20^0C. *Carcharodon*, a neritic nekton, is a cosmopolitan fish inhabiting the seas around the globe ranging from tropical to temperate regions. Typical *Carcharodon carcharias* is an active and strong swimming species found in tropical to hot temperate belts of all oceans excepting the Indian Ocean. It prefers surface waters but descends to considerable depths. *Lamna* is also not found presently in Indian Ocean. It is widespread in boreal to warm temperate belts of both the hemispheres and not known from tropical seas. It is an active, strong swimming fish in a depth range from surface to 70 – 80 fathoms. *Isurus*, an epipelagic to neritic nekton, is a cosmopolitan fish inhabiting the seas around the globe ranging from tropical to temperate regions. *Alopias* represented by *Alopias vulpinus* in the Indian Ocean is a common thresher shark and occurs a few kilometers off shore in warm temperate and subtropical areas. It is practically absent in very warm waters. *Odontaspis* is a nekton shark dwelling in the neritic zone of the tropical and subtropical seas and is found in the Indo-Pacific and Atlantic Ocean. *Odontaspis tricuspidatus*, found in present day waters, is a typical temperate water species. It is generally found near the coast in warm and shallow waters. Bigelow and Schroeder (1948) stated that *Odontaspis tricuspidatus* and *Odontaspis taurus* of Atlantic withdraws from the area where temperature falls below 19° - 20°C. *Galeocerdo*, a tiger shark, is also a nekton dwelling in the neritic zone of the tropical and subtropical seas and found in the mean annual isotherm of 20°C. *Carcharhinus* is a neritic to epipelagic nekton in the tropical to subtropical seas. It is one of the most common sharks found all along the Indian coastline. A typical neritic nekton – *Hemipristis*, is widely distributed in the tropical seas around the globe. *Scolidon*, a typical Indian shark, is found all along the east and west coasts. *Scoliodon sorrakawah*, the most common species, is always found up to a few kilometers from the land. *Negaprion* is represented equally on the shores of Atlantic Ocean and warm water of Pacific and Indian Oceans (Antunes and Jonet, 1970). *Negaprion brevirostris* is typical

of very warm waters of tropical and subtropical seas and it is strictly an inshore species. *Sphyrna* is represented by four species in Indian waters. The most common species *Sphyrna zygaena* is found in tropical to warm temperate water of Pacific, Atlantic and Indian Oceans. It does not prefer temperatures below 20^0C. *Sphyrna* is presently found in Bay of Bengal and off Bombay Coast. *Galaeorhinus* is found in open pelagic conditions. Dominance of carcharhinids in the assemblage indicates tropical near shore environment (Mondal et al. 2010)

The fish fauna and the associated bivalves, gastropods, decapods and foraminifer are suggestive of a warm shallow marine set-up near to the shoreline in a high-energy environment of deposition for the fish yielding horizons of the Bhuban Formation.

Acknowledgements: This paper is a part of the Ph.D. thesis of the first author. We are thankful to Dr. V.P. Mishra, Director, Geological Survey of India, Northern Region, Lucknow for his valuable comments on the manuscript. Constructive suggestions received from the anonymous reviewer have helped improve the manuscript enormously and the same is gratefully acknowledged. Financial assistance received from the Department of Science and Technology, Govt. of India, New Delhi vide grant no. ESS/16/254(3)/2005 is gratefully acknowledged.

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(Received: 29 September 2009; Revised form accepted: 31 January 2011)