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ACKNOWLEDGEMENTS. We thank Dr V. P. Dimri, Director, NGRI, Hyderabad for permission to publish this paper. N.C.M. thanks the Council of Scientific and Industrial Research, New Delhi for financial support to carry out this work and Dr M. Thangarajan, NGRI for valuable discussions. We also thank the anonymous reviewer for valuable suggestions.

Received 10 January 2005; revised accepted 13 July 2005

Lower vertebrates from the Late Palaeocene–Earliest Eocene Akli Formation, Giral Lignite Mine, Barmer District, western India

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The first assemblage of lower vertebrates comprising fish, crocodilians and snakes is recorded from subsurface beds of the Akli Formation sampled from the Giral Lignite *Mine* about 40 km NNW of Barmer in Rajasthan. The fish comprise sharks, rays, lepisosteids, osteoglossids, pycnodontids and enchodontids and include among others *Squatina, Ginglymostoma, Jaekelotodus,* and *Gymnura,* which previously were not known from the subcontinent, an unnamed new species of *Dasyatis*, and two unidentified ?pycnodontid-like teleosteans. Reptiles are represented by crocodilians and ?boid snakes. The fauna supports a Late Palaeocene–Lower Eocene age and a coastal marine deposition under tropical-temperate conditions.

Keywords: Akli lignite, Palaeocene–Eocene, Rajasthan, vertebrates.

IN western Rajasthan, the Lower Tertiary successions of shallow marine sediments occur in vast peneplained, sand covered tracts in three major basins, namely Jaisalmer, Barmer and Palana-Ganganagar[1–3]. These shelf sediments have attained great importance during the last four decades in view of encouraging prospects of occurrence of hydrocarbon, bentonite, and fuller's earth deposits. Despite this, their biotic content in general and vertebrates in particular remain inadequately studied apparently because of paucity of surface exposures. Open cast mines of lignite, bentonite and fuller's earth in several areas of Rajasthan and neighbouring Gujarat offer an easy alternative to this handicap though collecting sites often vanish by the next field season. Recently we sampled subsurface beds of the Akli Formation in a lignite mine at Giral and recovered rich vertebrate fauna that formed the basis for this contribution and is significant on four counts: (i) it is the first systematic record of vertebrate fossils from the Akli Formation, (ii) it includes four selachian taxa previously unknown from the subcontinent, (iii) it provides corroborative evidence on age and palaeoenvironment of Akli lignites, and (iv) it expands

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our database of Palaeocene–Eocene vertebrates, which are important for palaeobiogeographic appraisal in the context of India–Asia convergence and widespread formation of lignite coals.

The Akli Formation comprising sandstone, clays, lignite seams and bentonite is about 265 m thick. It overlies the Fatehgarh Formation, which was earlier considered as of Cretaceous age with a hiatus as long as the Late Cretaceous[1–3]. The nature of contact and the extent of hiatus, if any, between these two formations is not clear, but a fauna of lower vertebrates suggests a Palaeocene age for the Fatehgarh Formation[4]. The Akli Formation is overlain by the Mandai Formation, where no vertebrates are known. The Kapurdi Formation (fuller's earth) with a varied Lower Eocene selachian fauna overlies the Mandai Formation[5–8]. The Akli Formation forms plains of the Barmer Basin and its outcrops are rare. A lignite mine at Giral–Thumbli (lat. 26°04′N: long. 71°16′E) provided a good representative section and our sampling was limited to this (Figure 1).

The Giral mine is situated about 40 km NNW of Barmer and 13 km NW of Barakha, which lies on the Barmer–Fatehgarh road (Figure 1). The dug-out thickness of the Akli Formation in the mine is about 52 m. It consists of bentonite, variegated clay, carbonaceous clay, dark grey-green clay, and several grey-green clay bands alternating with up to 1.5 m thick lignite seams and containing chert nodules. So far 10 seams have been dug through and the eleventh is being worked over. A 7 m thick grey-green clay band lying between the seventh and eighth seams yielded the whole collection of fossils treated in this paper.

The vertebrate remains recovered by screen-washing of bulk samples are all well preserved and comprise mostly isolated teeth, but also include spines, scales and vertebrae. Twenty genera belonging to six selachian (Squatinidae, Ginglymostomatidae, Odontaspidae, Dasyatidae, Gymnuridae, Myliobatidae), five teleostean (Lepisosteidae, Pycnodontidae, Osteoglossidae, Enchodontidae, Siluriformes indet.), two crocodilian (Crocodylia indet., Crocodylidae) and one snake families have been identified. Several of these have been known from elsewhere in the country hence only representative specimens are documented here. All specimens referred herein are registered (GV/R/GU Giral Vertebrates/Rajasthan/Garhwal University) and housed in the Department of Geology, HNB Garhwal University, Srinagar, India.

Squatina sp. (Figure 2; ***1–4***): Teeth wider than high with a stout cusp; labial face cambered with a distinct apron; heels long with low cutting edges; lingual protuberance distinct; root massive, basal face flat with a triangular outline. Teeth compare well with those of *Squatina* cf. *S. prima* from the Eocene of Uzbekistan[9], but differ in having smaller cusp. *Squatina* is widely known in Mesozoic-Cenozoic deposits and presently occurs in all tropical and temperate seas[10].

Ginglymostoma sp. (Figure 2; ***5–6***): Lateral teeth have a posteriorly bent main cusp flanked by broad robust dis-

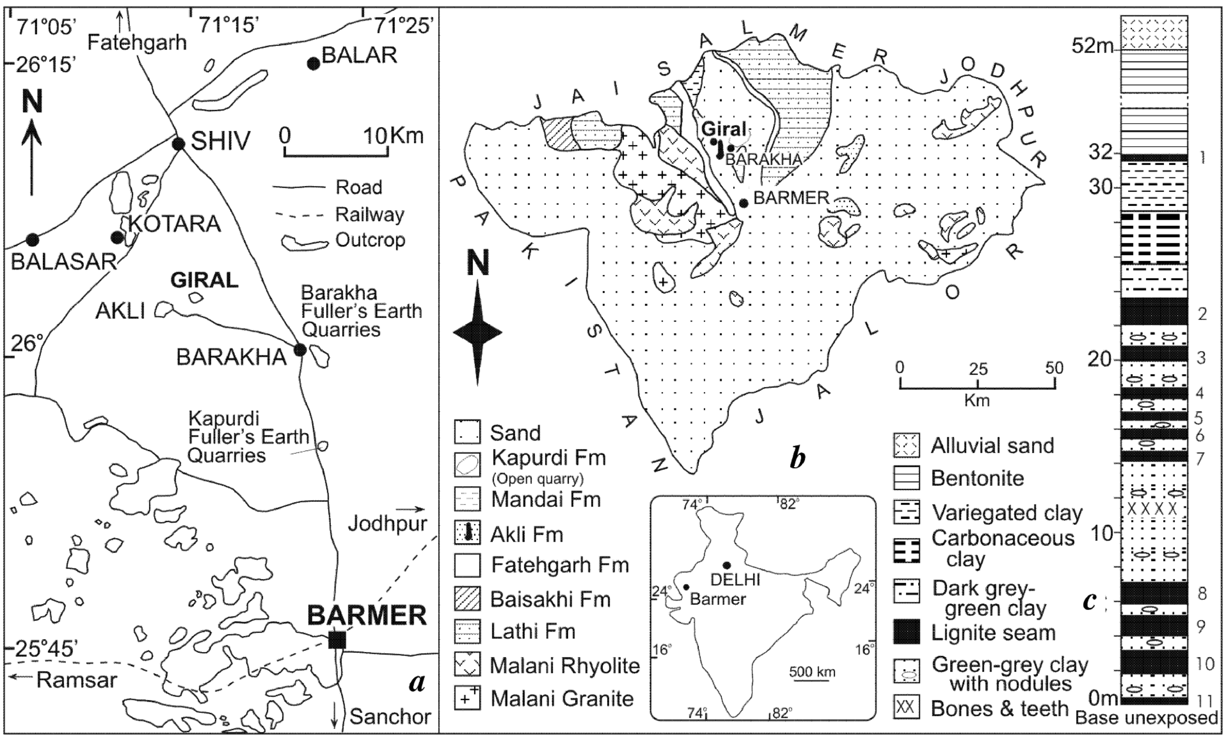

Figure 1. Geological and location map of the area around Giral, and measured log of vertebrate fossil-yielding section of subsurface beds of the Akli Formation, Giral Lignite Mine, Barmer District, Rajasthan.

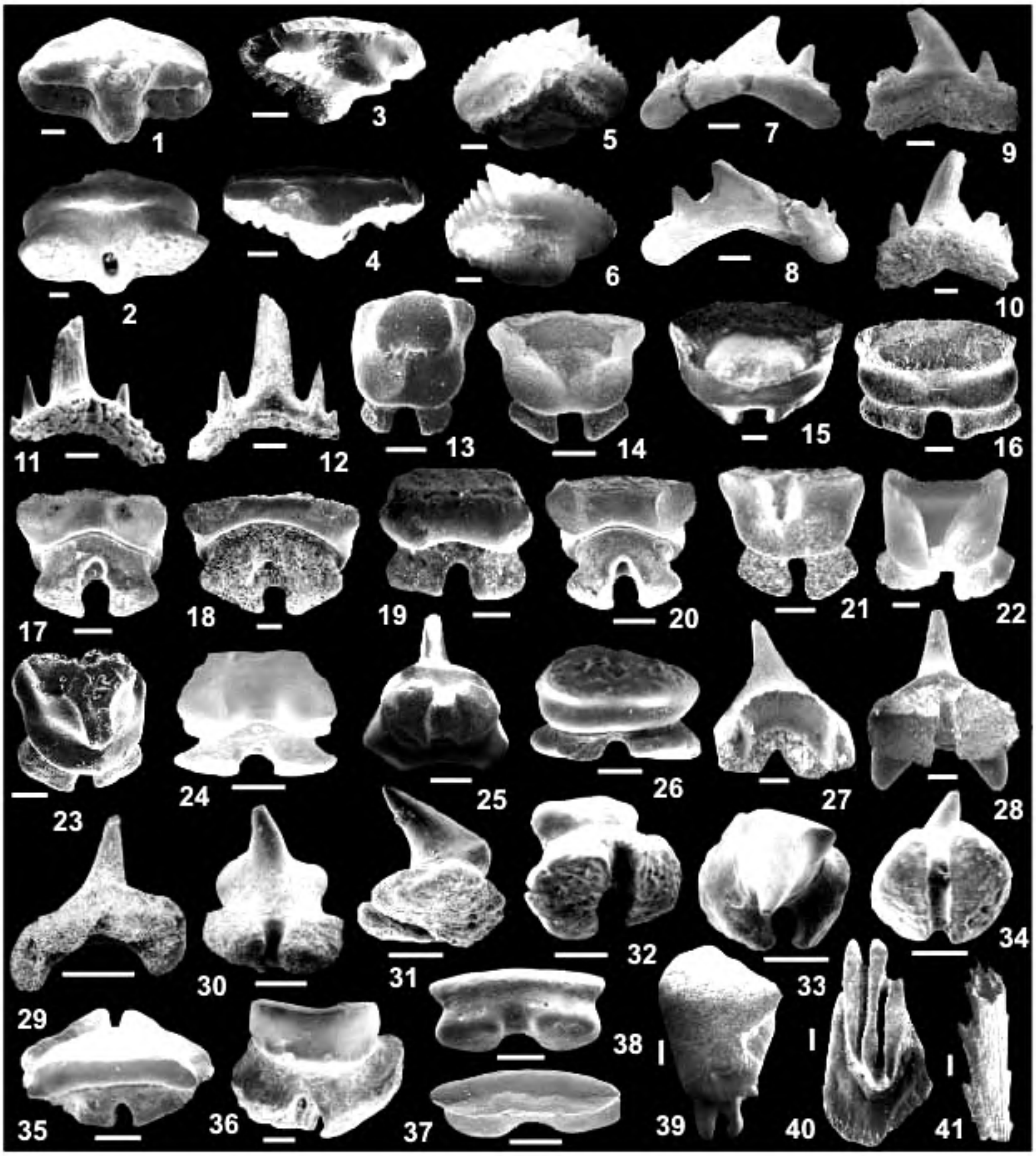

Figure 2. ***1–4***. *Squatina* sp., ***1–2***: GV/R/GU 5001, ***3–4***: 5002, isolated teeth in occlusal (1), basal (2), lingual (3) and labial (4) views; ***5–6***. *Ginglymostoma* sp., 5004, isolated tooth in lingual (5) and labial (6) views; ***7–12***. *Jaekelotodus* sp., ***7–8***: 5006, ***9–10***: 5007, ***11–12***: 5008, isolated teeth in lingual (7, 10, 11) and labial (8, 9, 12) views; ***13–25***. *Dasyatis* sp. 1, ***13***: 5212, ***14***: 5210, ***15***: 5215, ***16***: 5401, ***17***: 5210, ***18***: 5215, ***19***: 5404, ***20***: 5211, ***21***: 5217, ***22***: 5218, ***23***: 5214, ***24***: 5220, ***25***: 5219, isolated teeth of females (13–20) and males (21–25) in lingual (13–16, 21–23), labial (17–20, 24) and basal (25) views; ***26***. *Dasyatis* sp. 2, 5403, isolated tooth in lingual view; ***27–29***. *Gymnura* sp., ***27–28***: 5411, ***29***: 5412, isolated teeth in labial (27) and lingual (28, 29) views; ***30–38***. *Subathunura* cf. *S. casieri*, ***30***: 5428, ***31***: 5420, ***32***: 5424, ***33***: 5427, ***34***: 5427, ***35***: 5445, ***36***: 5446, ***37***: 5449, ***38***: 5450, isolated teeth of males (30–34) and females (35–38) in lingual (30, 33, 36, 38), lateral (31), labial (32), basal (34) and occlusal (35, 37) views; ***39–41***. *Myliobatis* sp., ***39–40***: 5459, lateral tooth in lingual (39) and basal (40) views; ***41***: 5464, spine shaft in lateral view. Scale bar equals 0.25 mm for figs ***1–4*** and ***9–41*** and 0.5 mm for ***5–8***.

tal cusplets and thin and sharp mesial cusplets; lingual side convex, labial flattened; apron broad not reaching base; lingual protuberance high; root with triangular basal face. Teeth are similar to those of *G. serra* from the Lutetian of Nigeria[11]. *Ginglymostoma* has been known from Cretaceous to Miocene of Europe, North America and Africa; presently it thrives in tropical Atlantic and Indo-Pacific Sea[10].

Jaekelotodus sp. (Figure 2; ***7–12***): Teeth high and wide with recurved main cusp and a pair of strong cusplets well separated from one another; lingual face convex, smooth; labial face flat, overhangs the root; lower part of crown has fine vertical marks; mesial cutting edge longer, smooth and convex, distal edge concave; root bilobed with a weak lingual protuberance, concave basal margin and nearly flat basal face. Teeth compare well with those of *J. trigonalis* from Lutetian of Uzbekistan[9].

Dasyatis sp. 1: Teeth of females (Figure 2; ***13–20***) unique in having an elliptical to quadrangular crested depression in upper part of lingual crown face and a deep central notch in lower part of labial visor; labial crown face pitted or smooth; lingual crown face with a median ridge flanked by depressions; teeth from median rows have more elongated depression and narrower lingual visor (Figure 2; ***15–18***). Teeth of males (Figure 2; ***21–25***) have a cusp with marginal crests merging into lateral angles; labial crown face nearly flat and smooth or irregularly pitted; labial crown edge with a central depression; lingual crown face with a faint median ridge. *Dasyatis* sp. 1 teeth differ from all known species of *Dasyatis* in possessing a prominent crested depression on lingual crown face and probably represent a new species. Its systematic designation will be taken up elsewhere.

Dasyatis sp. 2 (Figure 2; ***26***): Tooth non cuspidate, irregularly ornamented like those of *Dasyatis* sp. 1; lingual crown face too short, lacks any depression and or median ridge; occlusal surface elliptical, convex; labial crown edge without a central depression.

Gymnura sp. (Figure 2; ***27–29***): Teeth triangular; crown rather high and smooth with a lingually directed cusp having marginal crests meeting at lateral edges; transverse crest semicircular, prominent, joins lateral angles, which are acute and labially directed forming margino-labial protuberances; labial contour of crown very concave in occlusal view; lingual face of crown broad with lateral depressions and centrally notched lower margin; root bilobed with a deep and wide groove. *G. delpiti* from the Thanetian of Morocco[12] has similar teeth but with less prominent transverse crest.

Subathunura cf. *S. casieri* Kumar and Loyal 1987: Teeth of males (Figure 2; ***30–34***) cuspidate with smooth crown; lingual face lacks lateral depressions; root lingually expanded and bilobed. *S. casieri* from the Eocene Subathu Formation of the sub-Himalaya[13–15] has nearly identical teeth, but with more bulky root lobes. Teeth of females (Figure 2; ***35–38***) wider than long; crown smooth labio-lingually compressed and crest like; lingual face slightly concave, labial face convex; transverse crest high, joins lateral edges; root lingually expanded, bilobed with deep wide groove. Teeth are comparable to females of *S. casieri* from the Subathu Formation[13], but differ in having a high transverse crest instead of a crested transverse furrow, and may represent a new species.

Myliobatis sp. (Figure 2; ***39–41***): Lateral teeth labio-lingually elongated; crown-thickness uneven; crown and root separated by a deep groove; occlusal surface triangular, flat and rugged with fine pits; labial edge of crown wrinkled; lingual visor short; lateral edge rounded on one side, angular on other; root bi- or trilobed with flat base and deep grooves. Akli teeth are closely similar to those of *Myliobatis* sp. 2 from the Early Eocene Cambay Shale of Gujarat[16]. Lateral teeth of *Myliobatis* sp. 3 from the Palaeocene Fatehgarh Formation of Barmer differ in having a regularly pitted occlusal surface[4].

Myliobatidae gen. et sp. indet. (Figure 3; ***1–2***): Lateral tooth with uniformly thick hexagonal crown and a bilobed root, which does not show any appreciable expansion on lingual or other sides; labial crown edge more expanded than lingual and wrinkled; occlusal surface flat and smooth; lingual visor in the form of a prominent ridge. Tooth differs from most myliobatid teeth in having an unexpanded root.

Elasmobranchii indet. (Figure 3; ***3–4***): Numerous placoid scales in the collection are included here as a precise identification is not possible.

Lepisosteus sp. (Figure 3; ***5–10***): Scales typically gar like with distinct pegs and sockets. Teeth conical, without lateral edges, slightly recurved; apical part with smooth enameloid; basal part longer, vertically striated (Figure 3; ***7–8***). Some teeth with longer, compressed apical part having lateral edges (Figure 3; ***9–10***) look very similar to those of *Apateodus*, which has been widely reported from the Infra- and Intertrappean beds of peninsular India[17–19] and from the Fatehgarh Formation of Rajasthan[4]. These are here tentatively referred to *Lepisosteus* because similar teeth have been found closely associated with fossil remains of lepisosteids[20]. However, it is quite likely that *Apateodus* is also present in the Akli fauna. Gar teeth and scales are common in the Late Cretaceous–Eocene beds of peninsular India as well as the sub-Himalaya[17–24]. They also occur in the Fatehgarh Formation that underlies the Akli Formation[4].

Pycnodus sp. (Figure 3; ***11–12***): Teeth oval to rounded with a smooth central depression bounded by a rim (crenulated in a few teeth); base hollowed. In India, *Pycnodus* is widely known from the Infra- and Intertrappean beds of peninsular India[17–21] and from Kakara and Subathu formations (Palaeocene–Eocene), of the sub-Himalaya[13,15].

Teleostei indet.: Type ‘A’ (Figure 3; ***13***) – teeth hemispherical, smooth; top narrow with a tiny central depression bounded by a rim; base hollowed. Type ‘B’ (Figure 3; ***14–15***) – teeth rounded to elliptical or globular; occlusal surface has a large rim enclosing a smaller inner rim with a tiny central depression; closely but regularly spaced radial lines originate from outer rim and extend down; base not hollowed. Type ‘B’ teeth are more common and somewhat similar to teeth of *Gyrodus* (Pycnodontidae) from the English Chalk[25].

Osteoglossidae gen. et sp. indet. (Figure 3; ***16–18***): Squamules characterized by linear ornamentation on outer surface (Figure 3; ***16***, ***17***). Teeth conical, slightly curved or straight; apical part acute with transparent enameloid; basal part longer, smooth (Figure 3; ***18–20***). Teeth and squamules are similar to those known from the Palaeocene

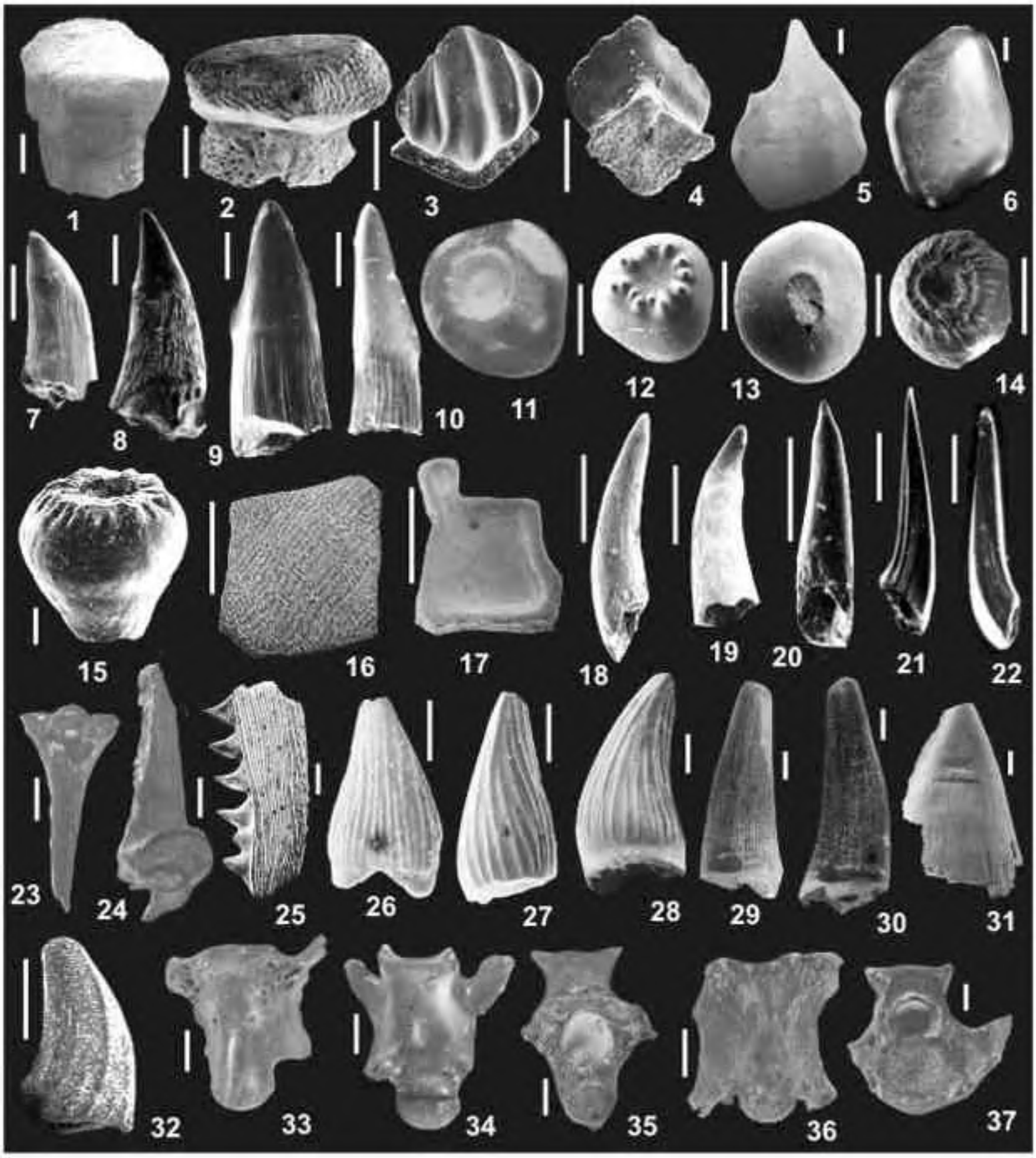

Figure 3. *1–2*. Myliobatidae gen. et sp. indet., GV/R/GU 5408 lateral tooth in lateral (*1*) and lingual (*2*) views; ***3–4***. Elasmobranchii indet., ***3***: 5055, ***4***: 5054, placoid scales in outer (3) and basal (4) views; ***5–10***. *Lepisosteus* sp., ***5***: 5474, ***6***: 5473, ***7***: 5471, ***8***: 5470, ***9***: 5784, ***10***: 5783, ganoid scales (5–6) and isolated teeth (7–10) in outer (5–6) and lateral (7–10) views; ***11–12***. *Pycnodus* sp., ***11***: 5515, ***12***: 5510, isolated teeth in occlusal views; ***13–15***. Teleostei indet., ***13***: 5512, Type 'A' tooth in occlusal view; ***14***: 5523, ***15***: 5524, Type 'B' teeth in occlusal (14) and lateral (15) views; ***16–20***. Osteoglossidae gen. et sp. indet., ***16***: 5553, ***17***: 5551, ***18***: 5537, ***19***: 5535, ***20***: 5533, squamules (16–17) and isolated teeth (18–19) in outer (16), inner (17) and lateral (18–20) views; ***21–22***. *Enchodus* sp., ***21***: 5903, ***22***: 5902, isolated teeth in lateral views; ***23–25***. Siluriformes indet., ***23***: 6506, ***24***: 6502, proximal halves of dorsal (23) and pectoral fin-spines (24) in anterior (23) and outer lateral (24) views, ***25***: 6505, shaft of pectoral fin-spine in lateral view; ***26–28***. Crocodylia indet., ***26***: 6584, ***27***: 6585, ***28***: 6588, isolated teeth in lateral views; ***29–32***. Crocodylidae gen. et sp. indet., ***29–30***: 6595, ***31***: 6594, ***32***: 6593, Type 'A' (29–31) and Type 'B' (32) isolated teeth in lateral views; ***33–37***. Serpentes indet., ***33–35***: 6566, ***36–37***: 6565, trunk vertebrae in ventral (33, 36), dorsal (34), posterior (35) and anterior (37) views. Scale bar equals 0.5 mm for figs ***1–2***, ***5–22*** and ***25–32***, 0.25 mm for ***3–4***, and 2 mm for ***23–24*** and ***34–37***.

Fatehgarh Formation of Rajasthan and the Lower Eocene Cambay Shale of Gujarat[16]. Osteoglossids are widely known in India from the peninsular part as well as the northwest sub-Himalaya[4,16–23,26–27].

Enchodus sp. (Figure 3; ***21–22***): Teeth recurved, slightly compressed, long conical with lateral edges; lower part of inner surface striated, outer surface smooth. *Enchodus* sp. teeth are comparable to those of *E. elegans* from Creta-

Table 1. Geological age range, palaeoenvironment and palaeoclimate of the Akli fauna of lower vertebrates

Taxa	Cretaceous	Palaeocene	Eocene			Oligocene	Miocene			Pliocene	Pleistocene	Recent	Water salinity/depth				Climate		
			Lower	Middle	Upper		Lower	Middle	Upper				Freshwater	River Mouth	Estuarine	Shallow Marine	Tropical	Subtropical	Temperate
Squatina	—	—	—	—	—	—	—	—	—	—	—	—	–	–	–	X	X	X	X
Ginglymostoma	—	—	—	—	—	—	—	—	—	—	—	—	–	–	–	X	X	X	–
Jaekelotodus		—	—	—									–	–	–	X	X	X	X
Dasyatis	—	—	—	—	—	—	—	—	—	—	—	—	–	X	X	X	X	X	X
Gymnura		—	—	—	—	—	—	—	—	—	—	—	–	X	X	X	X	X	X
Subathunura		—	—										–	X	X	X	X	X	X
Myliobatis		—	—	—	—	—	—	—	—	—	—	—	–	–	X	X	X	X	X
Lepisosteus	—	—	—	—	—	—	—	—	—	—	—	—	X	X	X	–	X	X	X
Pycnodus	—	—	—	—	—								–	X	X	X	X	X	X
Osteoglossidae	—	—	—	—	—	—	—	—	—	—	—	—	X	X	–	–	X	X	X
Enchodus	—	—	—	—	—								–	–	X	X	X	X	X
Siluriformes		—	—	—	—	—	—	—	—	—	—	—	–	–	X	X	X	X	–
Crocodylia	—	—	—	—	—	—	—	—	—	—	—	—	X	X	X	X	X	X	X
Serpentes	—	—	—	—	—	—	—	—	—	—	—	—	X	X	X	X	X	X	X

ceous–Tertiary of Africa[28–29], but much smaller. Similar teeth are also known from the Lower Eocene of Gujarat[16].

Siluriformes indet. (Figure 3; ***23–25***): Pectoral fin-spines dorso-ventrally compressed with irregular longitudinal striations; longitudinal ridges with or without denticles; denticles along anterior border prominent; flanges of articular head large and flattened. Dorsal fin-spines have similar ornamentation but are more compressed than pectoral spines; both have resemblance with spines of the catfish *Arius*, which is known in India from the Subathu Formation[30] and from Kachchh[31–32]. The Subathu species *A. sahnii* and the Kachchh species *A. kutchensis* are much larger.

Crocodylia indet.: (Figure 3; ***26–28***) Teeth alligatorine-like, small, laterally compressed, inflated in lower part with prominent vertical striations and distinct carinae; some shorter teeth bilobate in lower part; basal cross-section elliptical. Similar teeth from the Deccan Intertrappean beds of Andhra Pradesh have been referred to Alligatorinae[33].

Crocodylidae indet.: Morphotype ‘A’ (Figure 3; ***29–31***) teeth are smooth and conical with distinct but non serrated carinae, whereas Morphotype ‘B’ (Figure 3; ***32***) teeth are recurved with coarse striations. Both types can be related to *Crocodylus*.

Serpentes indet., (Figure 3; ***33–37***): Numerous fragmentary trunk vertebrae look similar to those of boids known from the Ypresian lignite beds of Kachchh[34].

The Akli vertebrates comprise nine species of selachians, eight of teleosteans and four of reptilians many of which were previously known from India. However, occurrence of *Squatina, Ginglymostoma*, *Jaekelotodus* and *Gymnura* is significant as it establishes their first record from the Indian subcontinent. The Akli fauna is similar to that from the underlying Fatehgarh Formation but differs in having sharks (*Squatina*, *Ginglymostoma*, *Jaekelotodus*), gymnurids (*Gymnura* and *Subathunura*), a new unnamed species of *Dasyatis* (*Dasyatis* sp. 1), a siluriform fish (catfish), alligatorine-like crocodiles and snakes. Sharks, gymnurids, catfish and snakes are not known yet from the Fatehgarh Formation. The common taxa of the two assemblages are *Dasyatis*, *Myliobatis, Pycnodus*, *Lepisosteus*, *Enchodus* and Osteoglossidae indet. Of these, the last three taxa represented by one species each in both Fatehgarh and Akli faunas look specifically similar. *Dasyatis* is known by a single species in Fatehgarh and by at least two in Akli including a new one; *Myliobatis* sp. from Akli is not comparable to any of the three species from Fatehgarh; *Pycnodus* sp. from Akli looks similar to that from Fatehgarh, but some peculiar teeth here referred to Teleostei indet. are not comparable to any teeth documented so far from well known ichthyofaunas of India and elsewhere.

The Akli ichthyofauna differs from the Lower Eocene faunas known from Vastan[16] and Panandhro[31] lignite fields of Gujarat, in having fewer sharks, but this may well be an artefact because the former is based on a smaller sample. It has more elements common with Vastan than with Panandhro; the notable absentees in Akli are *Stephanodus* and *Eotrigonodon*, which are commonly known by pharyngeal and oral teeth respectively (some authors consider these teeth to be of pycnodontids[20]), but snakes are present in all three faunas. Similarly, the Lower Eocene fauna from the Kapurdi Formation is dominated by sharks and rays[8]; *Dasyatis*, *Myliobatis* and *Enchodus* are common to Akli and Kapurdi. The Late Palaeocene–Lower Eocene faunas from the Kakara and Subathu formations of the northwest sub-Himalaya resemble Akli fauna in having *Subathunura*, *Dasyatis*, and *Myliobatis* but differ in lacking lepisosteids, osteoglossids and all of the Akli sharks[13–15]. However the

Lutetian faunas of the sub-Himalaya do contain lepisosteid and osteoglossid remains[23,27]. Several Akli fish, viz. *Dasyatis, Lepisosteus, Enchodus* and osteoglossids, are common in the Infra- and Intertrappean beds[17–23,35].

Based on palynological data, Middle-Late Palaeocene[36], Late Palaeocene[37] and Palaeocene–Eocene[38,39] ages have been proposed for the Akli lignite. The presence of larger forams *Assilina daviesi* and *Nummulites burdigalensis* corroborates extension of Akli lignite into the Lower Eocene[40]. Akli vertebrate fauna is supportive of a Late Palaeocene–Lower Eocene age.

A low energy floodplain deposition in tropical–subtropical lagoons with marine incursions inferred for the Akli Formation based on sediment and palynological data[36–39] receives support from the fauna recorded here. Akli vertebrates are typically coastal marine type with some freshwater elements like lepisosteids, osteoglossids, crocodilians and snakes that are known in several similar coastal plain assemblages and could have been washed down from the adjacent terrestrial habitats. The composition and palaeoecology of the Akli vertebrate fauna indicates a fair potential for recovery of mammal remains from the Akli Formation as have recently been recovered from the Vastan lignite mine (Gujarat), which has equivalent beds with similar fauna of lower vertebrates[16].

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ACKNOWLEDGEMENTS. We thank the Director, Wadia Institute of Himalayan Geology, Dehradun for providing the SEM and other facilities for this work and to Prof. Ashok Sahni for encouragement. Field work was supported by a National Geographic Society grant to K. D. Rose and a DST, Government of India grant to R. S. Rana.

Received 7 May 2005; revised accepted 14 October 2005

Antibacterial proteins from non-mulberry silkworms against flacherie causing *Pseudomonas aeruginosa* AC-3

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The muga silkworm, *Antheraea assama* (Ww) which produces golden yellow silk is indigenous to NE India, due to outdoor rearing it is susceptible to bacterial, viral and fungal infections. Diseases which are associated with pathogenic bacteria comes under the general term 'flacherie', which refers to the flaccid condition exhibited by silkworm due to different ailments and is caused by *Pseudomonas aeruginosa* AC-3. This communication reports the induction of antibacterial proteins in haemolymph of silkworm by injecting live non-pathogenic strain of *Pseudomonas* DAS-01. Protein profile of control and induced pupa were compared. In induced pupa 3 protein/peptide bands were found in low molecular weight region (18–24 kDa). These proteins/peptides were gel eluted as well as purified by Sephadex G-75 and were desalted by Sephadex G-25, G-10. The fractions were lyophilized and tested for antibacterial activity by both *in vitro* and *in vivo* methods. The fraction containing low molecular weight proteins were found to be effective in inhibiting the growth of *Pseudomonas aeruginosa* AC-3.

Keywords: Antibacterial proteins, *Antheraea assama*, induced proteins, *Pseudomonas aeruginosa* AC-3.

THE Muga silkworm, *Antheraea assama* is restricted to Northeast India, particularly Assam. These silkworms are reared outdoors, and hence are susceptible to many kinds of infections, i.e. bacterial, viral, fungal, etc. Among these, bacterial infection, collectively called 'flacherie', accounts for major loss of silkworms (Figure 1). It was found that these worms are naturally resistant to some strains of bacteria. This implies that there are some proteins present in the worms that are bactericidal in nature. If we can succeed in isolating and purifying the proteins and getting their amino acid sequenced, then it is possible to synthesize such proteins for further studies.

The defensive arsenal of insects, like that of man contains both passive structural barriers against infection and a cascade of active responses to organisms that gain access to the haemocoel following injury to integument. The primary defence of insects against pathogens and endoparasite is the prevention of infection via structural barriers such as rigid cuticle and peritrophic membrane that protects the mid gut. Even after this if the bacteria persist in the system, then initial haemolymph response is mediated by circulating haemocytes by the process of phagocytosis. If this innate mechanism of wiping out the antigen fails, synthesis of several proteins occurs, including lysozymes and other bactericidal proteins. The synthesis of these haemolymph proteins requires de novo RNA synthesis and follows a lag of minimum 8 h.

Muga silkworm is selected as a model system for studying humoral immunity, because it is of great economic importance due to its unique golden yellow silk and is the rarest variety of silkworm found exclusively in Northeast India. Pupal stage of this silkworm is selected for the experiments; the main advantage is that in the pupal stage the metabolic rate of silkworms is low, and injection with bacteria either live or attenuated, allows selective activation of genes for antibacterial protein synthesis. Potent antibacterial activity which appears in the haemolymph is attributed to low molecular weight proteins/peptides. In muga silkworm, causal organism[1] for 'flacherie' is *Pseudomonas aeruginosa*

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