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Vertebrate fauna from the subsurface Cambay Shale (Lower Eocene), Vastan Lignite Mine, Gujarat, India

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A rich collection of vertebrate fossils comprising mainly fish and some mammals has recently been recovered from subsurface beds of the Cambay Shale (Lower Eocene) exposed in the Vastan Lignite Mine, Surat District, Gujarat. Here we record a diverse assemblage of elasmobranch and teleostean fish, including the selachians *Triakis*, *Eogaleus*, *Abdounia*, *Rhizoprionodon* and *Eutrichiurides*, which are new to the subcontinent. The Vastan ichthyofauna has general affinities with the Palaeocene–Eocene fish assemblages from northern Africa, Europe and Uzbekistan, but it is most closely similar to faunas known from Rajasthan and the northwest sub-Himalaya.

THE Cambay Basin situated on the western margin of the Indian shield embodies Palaeogene and younger sediments that have been known to yield varied but sparse faunal and floral remains[1–7]. Recent prospecting by the two of us (R.S.R. and H.S.) in the subsurface beds of the Early Eocene Cambay Shale exposed in an open cast lignite mine at Vastan in the southern part of the basin has revealed multiple fossiliferous horizons containing foraminifers, ostracodes, molluscs, mammals and fish. Mammals are being treated separately and here we document the fish remains representing 23 taxa mainly of sharks, batoids and tetraodontoids. This record has threefold significance: (i) it adds to the knowledge of the Lower Eocene vertebrate faunas of the subcontinent, which are inadequately known but important for palaeobiogeographic inferences in the context of India–Asia collision; (ii) it includes *Triakis*, *Eogaleus*, *Abdounia*, *Rhizoprionodon* and *Eutrichiurides* that are new to the subcontinent, and (iii) vertebrate fossils from the Cambay Basin were earlier known only by otoliths[7], whereas now we have well-preserved dentitions as well as some postcranials. Previous reports of Eocene elasmobranch and teleostean fish in India are from Gujarat[7–10], Rajasthan[11,12] and the northwest sub-Himalayan region[13–15].

In the Cambay Basin, the Palaeogene beds are exposed as thin strips along the Saurashtra coast and to the east of the Gulf of Cambay (Figure 1). The Vagadkhol/Olpad Formation deposited over the Deccan Traps comprises the oldest sediments (Palaeocene–Lower Eocene) in the basin. It is overlain by 75–1500 m thick Cambay Shale comprising greenish and whitish-grey and black clay/shales with lignite seams[16].

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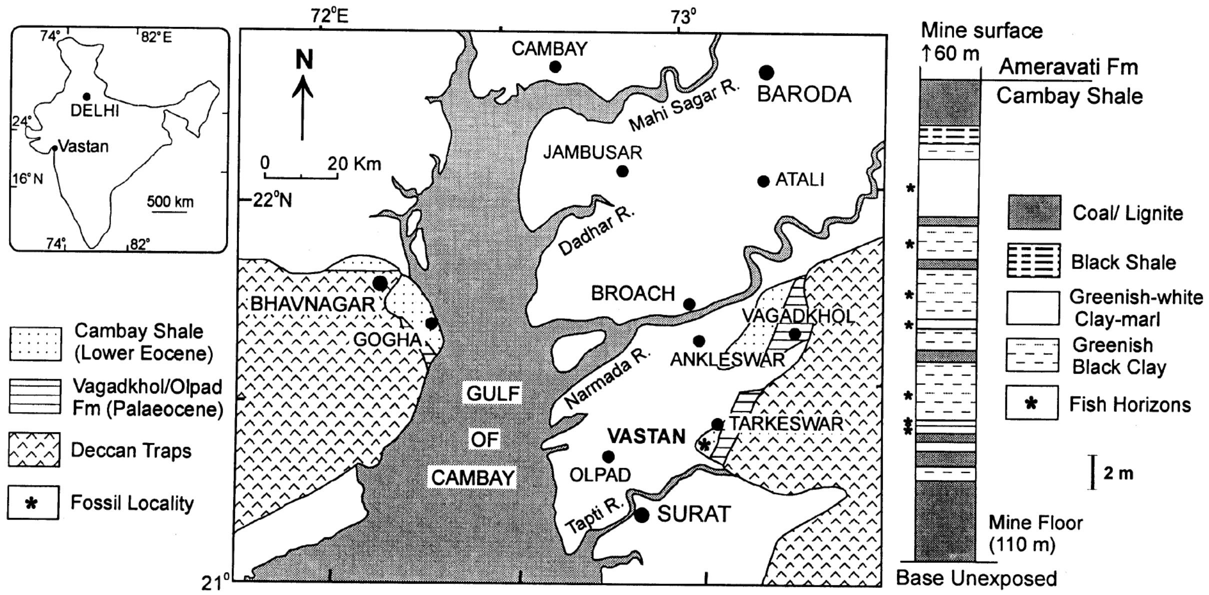

Figure 1. Geological and location map of the area around Vastan, and measured log of fossiliferous section, Vastan Lignite Mine, Surat District, Gujarat.

The Vastan lignite mine is situated 60 km NE of Surat and 29 km ENE of Kim town (lat 21°25′47″N, long 73°07′30″E). The Cambay Shale is 20–145 m thick here, but in the fossiliferous section only about 31.4 m thickness has been dug out so far (Figure 1). It is overlain by the Upper Eocene calcareous/bentonitic variegated clay followed by sub-recent and recent alluvium comprising brown sandy clay and black cotton soil. However, at places Upper Eocene nummulitic limestone and marl (Ameravati Formation) overlie the bentonitic clay followed by the alluvium.

The vertebrate fossils were noticed almost throughout the extent of the Cambay Shale exposed in the section (31.4 m), except in the two basal beds of greenish-grey clay and coal seam and in the top bentonitic clay bed. The whitish-grey marl is the richest horizon followed by greenish-grey clay and black clay. The fossils were recovered by disintegrating the clayey and marly matrix with kerosene/petrol and water followed by screen-washing.

The Vastan fish remains are rich, varied and well-preserved and comprise dental plates, isolated teeth, spines and dermal denticles. Twenty genera belonging to six elasmobranch (Triakidae, Carcharhinidae, Rhinobatidae, Dasyatidae, Myliobatidae and Rhinopteridae) and seven teleostean families (Osteoglossidae, Enchodontidae, Sphyraenidae, Phyllodontidae, Trichiuridae and Trigonodontidae, Diodontidae) are identified based on their dentitions. Several of these were earlier known from other parts of the country, hence only representative dentitions are illustrated here and their important features noted and compared with closely similar species. All specimens referred herein (EGV/GU/R, Eocene Gujarat Vertebrates/Garhwal University/Rana) are housed in the Department of Geology, HNB Garhwal University, Srinagar.

Galeorhinus sp. (Figure 2; 1–4): Mesial cutting edge straight and faintly crenulated in lower part; labial face of crown overhangs root along a bulge; root broad with distinct nutrient groove. Teeth resemble those of *G. gomphorhiza* and *G. minutissimus* from Morocco[17], but differ in fewer cusplets on distal heel. *Galeorhinus* sp. 1 from the Early Eocene Kapurdi Formation (Rajasthan) and *Galeorhinus* sp. from the Subathu Formation (northwest sub-Himalaya) possess entire mesial cutting edge in comparison to the finely incised one in Vastan species[12,13].

Triakis sp. (Figure 2; 5–8): Cusp small; cutting edges convex and entire, distal edge shorter; distal heel with two cusplets, labial face nearly flat; crown overhangs labial face of root along a bulge bearing fine folds; root expanded and slightly protruded with a deep nutrient groove and flat base. *T. wardi* from the Lower Eocene of England has similar teeth, but with longer and straight cusp and prominent folds at the crown base[18].

Abdounia sp. (Figure 2; 9–14): Small teeth with high cusp; labial face almost flat; mesial cutting edge nearly straight and entire; distal edge convex; each heel has a pair of low cusplets; crown foot overhangs weak; root base flat; nutrient groove strong. Teeth closely resemble those of *A. beaugei*, but are smaller with reduced cusplets[18,19]. *A. recticona* has three or more pairs of cusplets[18,19]. *A. lapierrei* has sharper and higher cusp and cusplets[19]. *Abdounia* sp. from Fayum has a single pair of cusplets[20].

Eogaleus sp. (Figure 2; 15–20): Posterior teeth with fairly high cusps; cutting edges convex and entire, distal edge short and separated from heel by a deep notch; distal heel high with fine cusplets in lateral teeth and 3–4 cusplets on posterior teeth; crown overhangs labial face of root; root slightly expanded with a shallow groove and flat base. Anterior

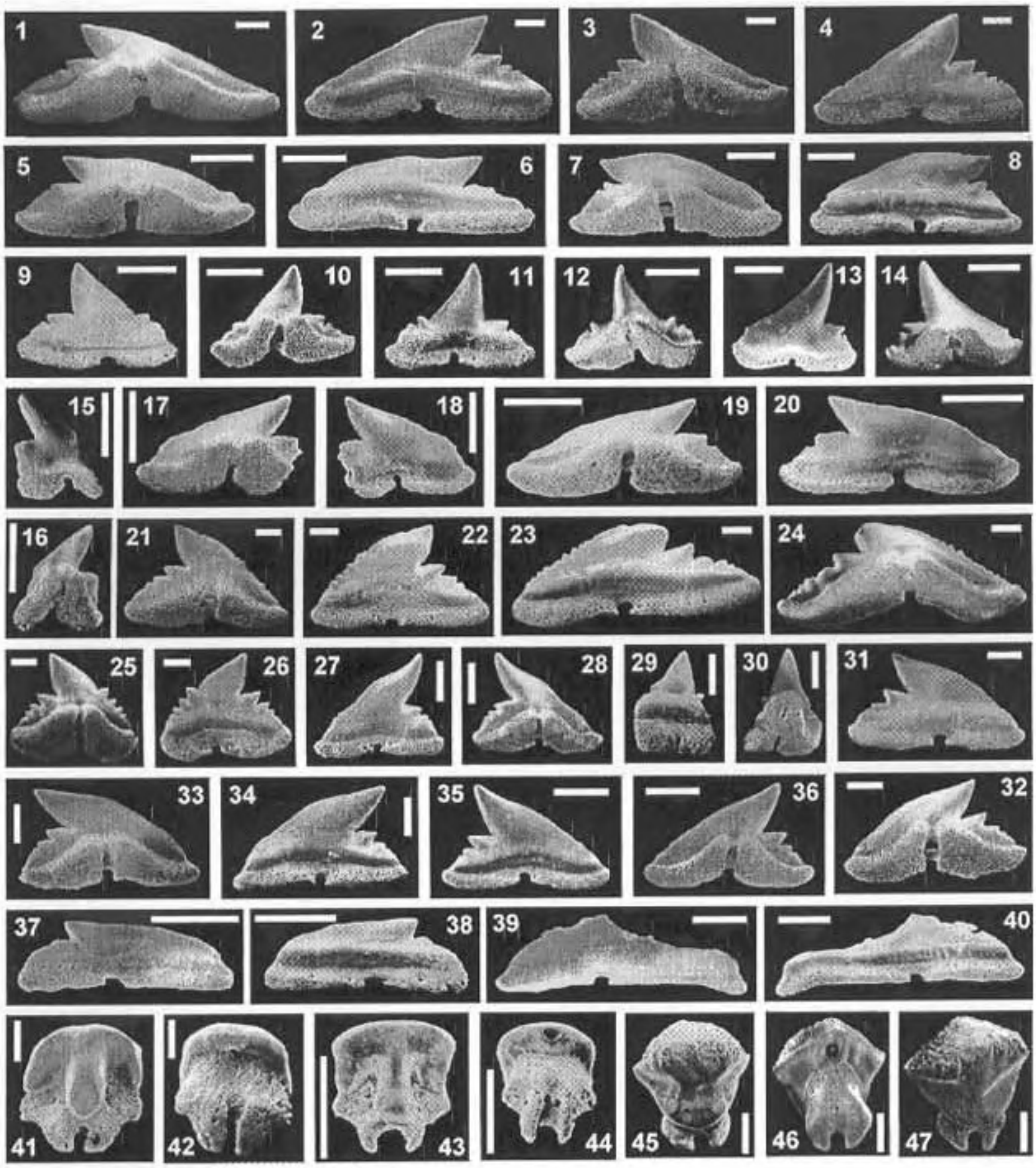

Figure 2. 1–4, *Galeorhinus* sp.: (1, 2) EGV/GU/R 101; (3, 4) 103 posterior teeth in lingual (1, 3) and labial (2, 4) views; 5–8, *Triakis* sp.: (5, 6) 251 (7, 8) 252 posterior teeth in lingual (5, 7) and labial (6, 8) views; 9–14, *Abdounia* sp.: (9, 10) 401, (11, 12) 402, (13, 14) 404 lateral teeth in labial (9, 11, 13) and lingual (10, 12, 14) views; 15–20, *Eogaleus* sp.: (15, 16) 302 anterior tooth in labial (15) and lingual (16) views, (17, 18) 301, (19, 20) 304 posterior teeth in lingual (17, 19) and labial (18–20) views; 21–26, *Galeocerdo latidense*: (21, 22) 152 anterior–lateral tooth in lingual (21) and labial (22) views, (23, 24) 153 posterior tooth in labial (23) and lingual (24) views, (25, 26) 151 anterior tooth in lingual (25) and labial (26) views; 27–36, *Physogaleus* sp.: (27, 28) 201 lateral tooth in labial (27) and lingual (28) views, (29, 30) 206, (31, 32) 205, (33, 34) 202, (35, 36) 203 posterior teeth in labial (29, 31, 34, 35) and lingual (30, 32, 33, 36) views; 37–40, *Rhizoprionodon* sp.: (37, 38) 351 antero-lateral tooth in lingual (37) and labial (38) views, (39, 40) 352 posterior tooth in lingual (39) and labial (40) views; 41–44, *Rhinobatos* sp.: (41, 42) 501, (43, 44) 503 lateral teeth in lingual (41, 43) and labial (42, 44) views; 45–47, *Dasyatis* sp. 1: (45, 46) 901, (47) 902, lateral teeth in lingual (45, 47) and labial (46) views. Scale bar equals 1 mm for 1–40, and 0.5 mm for 41–47.

teeth have more erect cusp with straight mesial cutting edge and slightly curved heel; distal cutting edge has a broad cusplet; root deep and protruded. *E. bolcensis* from the Lower Eocene of Italy has similar teeth, but with higher cusps[18].

Galeocerdo latidense Agassiz 1843 (Figure 2; 21–26): Teeth characterized by serrated cutting edges; serrations larger on mesial edge and smaller on distal edge. In India, *G. latidense* was earlier reported from the Kapurdi and Subathu formations[12,13]. It is common in the Eocene of Africa, Europe, North America and Uzbekistan[17–19].

Physogaleus sp. (Figure 2; 27–36): Anterior teeth resemble those of *Physogaleus* sp. from Uzbekistan[19]; posterior teeth similar to those of *Physogaleus* sp. from Rajasthan[12]. *P. secundus* from the Ypresian of Morocco has similar teeth but with shorter distal heel, more pointed cusp and strongly protruded root[17].

Rhizoprionodon sp. (Figure 2; 37–40): Teeth much wider than high with small cusp; base of crown extended; mesial cutting edge long, entire and arcuate; distal edge short; distal heel rounded without or with low cusplets; crown overhangs labial face of root; basal margin of root nearly straight and base flat. Teeth are comparable with those of *R. ganntourensis*, but in the latter species the cusp is more erect and the mesial cutting edge is concave[18]. *Rhizoprionodon* sp. from the Middle Eocene of Egypt has higher and erect cusp and the basal margin of its root is not as straight[20].

Rhinobatos sp. (Figure 2; 41–44): Crown high; occlusal surface smooth; three uvulae overhang the root; central uvula long, lateral uvulae shorter; root lingually displaced with subtriangular lobes and nearly flat bases. Some teeth (Figure 2; 43, 44) are much smaller with drop-shaped central uvula and may represent a juvenile or a smaller species. Teeth are comparable to those of *R. steurbauti* and *R. casieri*, but the former has an indistinct transverse ridge, smaller lateral uvulae, and broader root lobes[19] and the latter has a pointed and longer central uvula and more widely separated lateral uvulae[21]. *Rhinobatos* sp. from the Subathu Formation has more convex occlusal surface with a prominent ridge in the middle[13]. In Vastan species, the ridge is weaker and lingually placed and lateral uvulae are longer. Barring smaller size, teeth of *Rhinobatos* sp. have closest similarity with *Rhinobatos* sp. 1 from Rajasthan[12].

Dasyatis sp. 1 (Figure 2; 45–47; Figure 3; 1–6): Teeth of females have scalloped tetragonal occlusal surface; lingual visor with a strong median ridge and smooth but concave marginal faces; root with wide nutrient groove and flat base. Teeth of males have an occlusal surface with a peg-like projection and a lingual visor with a faint median ridge. *D. wochadunensis* from London Clay has closely similar but considerably higher teeth[22]. *D. vicaryi* from the Subathu Formation has coarsely pitted teeth, while *Dasyatis* sp.1 has scalloped teeth. *D. rafinesquei,* also from the Subathu Formation, has finely-pitted lower-crowned teeth with blunt lateral angles and a shallower visor[13]. *Dasyatis* sp. from the Kapurdi Formation has morphologically identical but up to 30% larger teeth[12].

Dasyatis sp. 2 (Figure 3; 7–12): Teeth of females differ from those of *Dasyatis* sp. 1 in that their crown is thinner and occlusal surface is flat and unornamented. Teeth of males differ from those of *Dasyatis* sp. 1 in that the projection of their transverse crest is shorter and occlusal surface has some depressions.

Heterotorpedo sp. (Figure 3; 13–17): Teeth cuspidate, labial edge of crown medially concave and laterally expanded; occlusal surface has some tubercles near labial margin and a long labio-lingual groove; transverse crest limited to basal part of cusp and upper part of lateral extension; lingual visor small; root lobes triangular with flat bases, nutrient groove deep. *H. fowleri* from the Lutetian of England has similar teeth, but their crowns are quadrate with indistinct ornamentation[23]. Vastan teeth are very similar to those described as *Heterotorpedo* sp. from Rajasthan[12].

Myliobatis sp. 1 (Figure 3; 18–20): Median tooth labio-lingually arched and laterally narrower and lower; occlusal surface flat; labial and lingual edges wrinkled; preserved part of root has 20 lobes. *Myliobatis* sp. teeth from the Middle Eocene of Kachchh are also labio-lingually arched but have hexagonal crowns[8], whereas those from the Lower Eocene Panandhro Lignite are straight with hexagonal crowns[10].

Myliobatis sp. 2 (Figure 3; 21–24): Lateral teeth labio-lingually elongated with triangular, flat and rough occlusal surface; labial edge of crown wrinkled; root displaced lingually out of crown margin, bilobed or trilobed, basal face flat. Teeth are much lower crowned and their roots are more lingually displaced to correspond with the median teeth of *Myliobatis* sp. 1 described here from Vastan. *Myliobatis* sp. from the Paleocene Cannonball Formation of USA has similar teeth, but their crowns are higher and rhomboid with irregular longitudinal ridges on labial and lingual faces[24].

Myliobatis sp. 3 (Figure 3; 25–29): Lateral teeth characterized by labial crown margin that extends well beyond labial face of root and by crown edges that are broad, rectangular, collar-shaped and more or less smooth (not wrinkled); occlusal surface sub-hexagonal, flat and rugged; labial visor broad and semicircular; root lingually directed with 3–4 unequal lobes. Teeth differ from those of *Myliobatis* sp. 1 and 2 in having greatly extended and more or less smooth labial crown margin and from *Myliobatis* sp. 1 in being lower crowned and having smooth crown margins.

?Rhinopteridae gen. et sp. indet. (Figure 3; 30–33): Teeth characterized by dasyatiform crown and three-lobed myliobatiform root; occlusal surface convex, tetragonal and scalloped; lingual visor lacks median ridge; outer root lobes broader and triangular; median lobe smaller and subtriangular. Some teeth have elliptical, finely scalloped occlusal surface. This assignment remains questionable because rhinopterid teeth generally have hexagonal outlines with flat or planar occlusal surface, whereas Vastan teeth have an elliptical and convex occlusal surface. It is possible that these teeth may be pathological dasyatid teeth and their small middle root lobe an aberration. A few similar teeth are also known from Rajasthan[12].

Osteoglossidae gen. et sp. indet. (Figure 3; 34): Apical part of teeth small, pointed and translucent; basal part long, cylindrical with smooth surface and blunt edges. Numer-

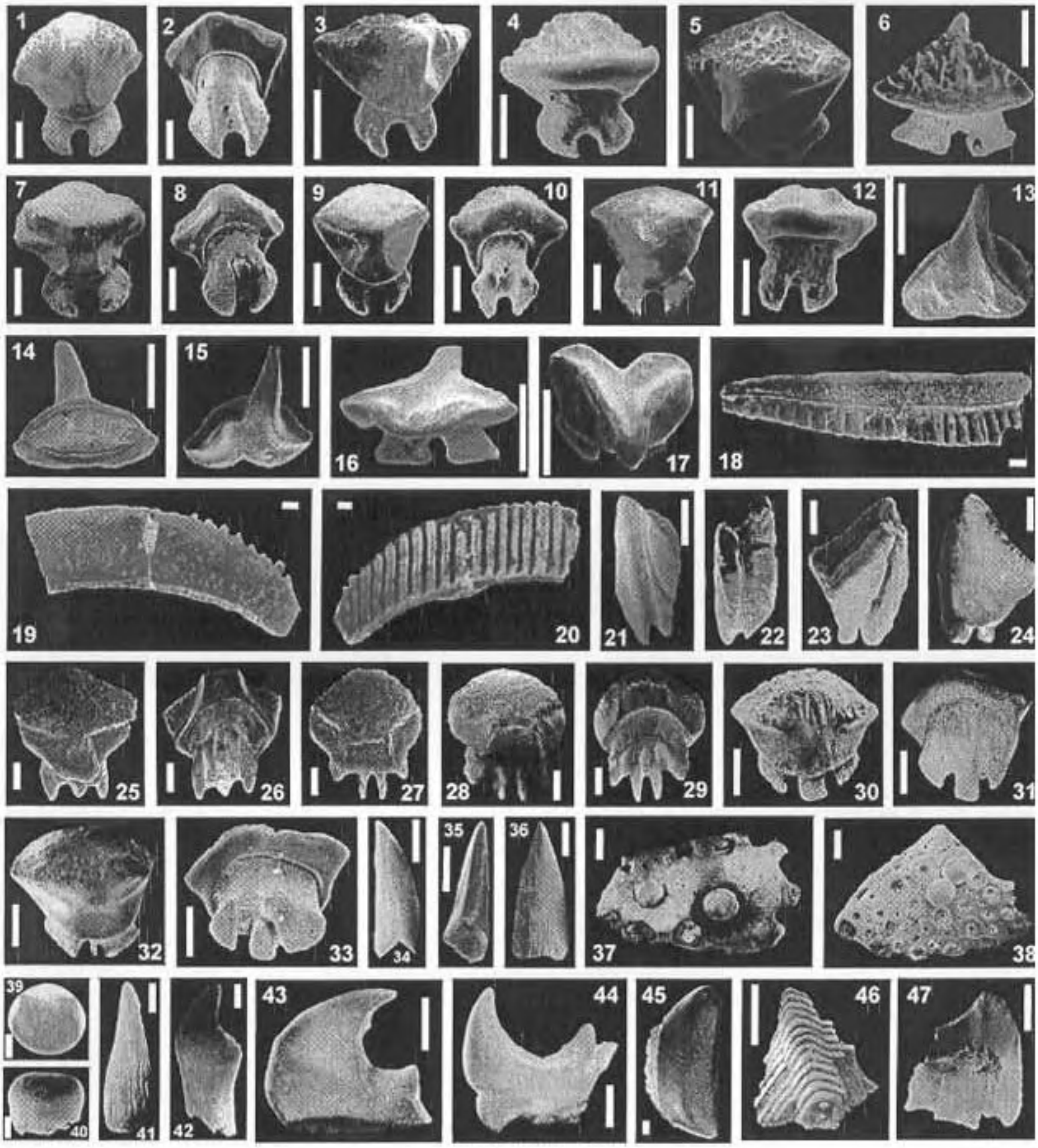

Figure 3. 1–6, *Dasyatis* sp. 1: (1, 2) EGV/GU/R 907 female tooth in lingual (1) and labial (2) views, (3, 4) 903, (5) 904, (6) 906 teeth of males in lingual (3, 5) and labial (4, 6) views; 7–12, *Dasyatis* sp. 2: (7, 8) 551, (9, 10) 552 teeth of females in lingual (7, 9) and labial (8, 10) views, (11) 553, (12) 554 teeth of males in lingual (11) and labial (12) views; 13–17, *Heterotorpedo* sp.: (13) 1504, (14) 1501, (15) 1505, (16) 1506, (17) 1507 teeth of males in occlusal (13, 15), basal (14), occlusal/labial (16) and occlusal/lingual (17) views; 18–20, *Myliobatis* sp. 1: 2551 median tooth in lingual (18), occlusal (19) and basal (20) views; 21–24, *Myliobatis* sp. 2: (21, 22) 2601, (23, 24), 2602 lateral teeth in basal (21–23), lateral (22) and occlusal (24) views; 25–29, *Myliobatis* sp. 3: (25, 26) 2501, (27–29) 2502 lateral teeth in lingual (25, 27, 28) and labial (26, 29) views; 30–33, ?Rhinopteridae gen. et sp. indet: (30, 31) 1401, (32, 33) 1402 lateral teeth in lingual (30, 32) and labial (31, 33) views; 34, Osteoglossidae gen. et sp. Indet., 2001 isolated tooth in lateral view; 35, *Enchodus* sp.: 2052 isolated tooth in lateral view; 36, *Sphyraena* sp.: 2101 isolated tooth in lateral view; 37–40, *Egertonia* sp.: (37) 1801, (38) 1802 dental plate in occlusal view, (39, 40) 1803 isolated tooth in occlusal (39) and lateral (40) views; 41, *Eutrichiurides* sp.: 1901 isolated tooth in lateral view; 42, *Stephanodus lybicus*: 1701 pharyngeal tooth in lateral view; 43–45, *Eotrigonodon indicus*: (43) 1751, (44) 1752 pharyngeal teeth in lateral view, (45) 1770 oral tooth in lateral view; 46, 47, *Diodon* sp.: (46) 1851, (47) 1852 dental plate fragments. Scale bar equals 0.5 mm for 1–17, 30–33 and 37–40, and 1 mm for 18–29, 34–36 and 41–47.

ous squamules of scales were also found in association with isolated teeth. Similar teeth and squamules have been recorded from the Infra and Intertrappean beds of Maharashtra, Andhra Pradesh, and Kachchh[25–27].

Enchodus sp. (Figure 3; 35): Teeth conical, hollow; cutting edges smooth but sharp; basal part has fine longitudinal striations; basal cavity elliptical. *Enchodus* is common in Eocene fish assemblages from India. *Enchodus* sp. from the Infra and Intertrappean beds of peninsular India has smaller teeth with coarser striations[28,29].

Sphyraena sp. (Figure 3; 36): Teeth labio-lingually compressed, pointed; apex small and smooth; surface ornamented by ridges and grooves; edges finely serrated; basal surface elliptical with a distinct pulp cavity. *S. fayumensis* from the Lutetian of northern Africa[17] and *Sphyraena* sp. from Kachchh[8] have similar teeth.

Egertonia sp. (Figure 3; 37–40): Teeth small and rounded; apex convex, smooth with translucent enameloid. Dentition is closely similar to that of *E. isodonta* from the Paleocene of USA[24] and from Middle Eocene Marh Formation of Rajasthan (India)[11]. *Egertonia* is also known from Ypresian beds of Belgium[30].

Eutrichiurides sp. (Figure 3; 41): Teeth conical; apex small chisel-like, about one-tenth of basal part; slight keel along the edges extend towards base; basal part laterally compressed with vertical ridges and grooves. *E. orpiensis* has similar teeth but with more pointed barbs[17,24]. *E. termieri* has slightly curved and slenderer teeth[17].

Stephanodus lybicus Dames 1883 (Figure 3; 42): Pharyngeal teeth compressed and flat with a large, hook-like principal cusp having a shelf-like structure near the base, a smaller secondary cusp and a fairly deep root.

Eotrigonodon indicus Lydekker 1886 (Figure 3; 43–45): Pharyngeal teeth differ from those of *S. lybicus* in having broader crown, more curved main cusp and a secondary cusp connected to it by a weak ridge. Oral teeth have laterally expanded, curved and translucent crown with convex outer and concave inner surface and smooth cutting edge. Pharyngeal teeth of *S. lybicus* and *E. indicus* are quite common in the Palaeocene–Eocene beds of India[11–15,28,29].

Diodon sp. (Figure 3; 46, 47): Dental plates consist of oblique stacks of over a dozen unequal-sized lamellae closely pressed together. A vertical line divides these lamellae into symmetrical halves. Previous reports of Eocene *Diodon* in India are from the Kapurdi (Rajasthan)[12] and Subathu formations (northwest sub-Himalaya)[13].

The Vastan ichthyofauna is represented by 23 species of selachians and teleosteans, many of which were previously recorded from India. However, occurrence of *Triakis, Eogaleus*, *Abdounia*, *Rhizoprionodon* and *Eutrichiurides* in the Cambay Shale is significant as it establishes their first record from the Indian subcontinent. The fauna has marked affinities with the assemblages known from the Early Eocene Kapurdi (Rajasthan)[12] and Subathu formations (NW Himalaya)[13] in India and from the Palaeocene–Eocene deposits of northern Africa[17,20], Europe[18] and Uzbekistan[19]. Out of 23 taxa reported here, at least 10 are common with those from Rajasthan, where thus far only around 10 taxa have been reported[12]. Similarity between the Vastan and Kapurdi faunas is striking, though at pre-

Table 1. Geological age range, palaeoenvironment and palaeoclimate of the Vastan ichthyofauna

Genus/species	Cretaceous	Palaeocene	Eocene			Oligocene	Miocene			Pliocene	Pleistocene	Recent	Water salinity/depth					Climate	
			Lower	Middle	Upper		Lower	Middle	Upper				Fresh	Brackish	Estuarine	Shallow marine	Deep marine	Tropical	Temperate
Galeorhinus	—	—	—	—	—	—	—	—	—	—	—	—	–	–	X	X	X	X	X
Triakis		—	—	—	—	—	—	—	—	—	—	—	–	–	X	X	–	X	X
Abdounia		—	—	—	—								–	–	X	X	–	X	X
Eogaleus			—										–	–	X	X	–	X	X
Galeocerdo latidens			—	—	—								–	–	X	X	–	X	X
Physogaleus			—	—	—	—	—	—	—				–	–	X	X	–	X	X
Rhizoprionodon			—	—	—	—	—	—	—	—	—	—	–	–	X	X	–	X	X
Rhinobatos	—	—	—	—	—	—	—	—	—	—	—	—	–	–	X	X	–	X	X
Dasyatis	—	—	—	—	—	—	—	—	—	—	—	—	X	X	X	X	–	X	X
Heterotorpedo		—	—	—	—								–	–	X	X	–	X	–
Myliobatis		—	—	—	—	—	—	—	—	—	—	—	–	–	X	X	–	X	X
Rhinopteridae		—	—	—	—	—	—	—	—	—	—	—	–	–	X	X	–	X	X
Osteoglossidae	—	—	—	—	—	—	—	—	—	—	—	—	X	–	–	–	–	X	X
Enchodus	—	—	—	—	—								–	–	X	X	X	X	X
Sphyraena			—	—	—	—	—	—	—	—	—	—	–	–	X	X	–	X	X
Egertonia		—	—	—									–	–	X	X	X	X	X
Eutrichurides		—	—										–	–	X	X	X	X	X
Stephanodus	—	—	—	—	—								–	–	X	X	–	X	–
Eotrigonodon	—	—	—	—	—								–	–	X	X	–	X	–
Diodon			—	—	—	—	—	—	—	—	—	—	–	–	X	X	X	X	–

sent the former looks much more diverse; but that may be because the study of Kapurdi assemblage is still in a preliminary stage. A high degree of similarity between the Kapurdi and Vastan fish faunas is indicative of similar palaeoecological conditions during their accumulation. This is understandable because both these areas are contiguous with coeval deposits. The Subathu ichthyofauna is equally diverse, but it has fewer taxa common with Vastan.

The Cambay Shale is generally considered as of Early Eocene age based on foraminiferal, ostracode and palynofloral assemblages[1–6]. This is corroborated by the presence of *Nummulites burdigalensis* in our fish-yielding samples (P. K. Saraswati, pers. commun.), as this species is restricted to Ypresian[31]. The Vastan ichthyofauna is mostly long ranging (Cretaceous–Recent), but a few taxa have shorter temporal ranges and support an Early Eocene age for the fossiliferous beds, as also indicated by foraminifers (Table 1). Age constraining Vastan fish taxa include *Eutrichiurides* (Palaeocene–Lower Eocene)[18,24]; *Heterotorpedo* (Palaeocene–Eocene)[18]; *Egertonia* (Late Palaeocene–Middle Eocene)[24]; *Abdounia* (Late Palaeocene–Eocene)[17–19]; *Eogaleus* (Early Eocene)[18] and *Galeocerdo latidens* (Eocene)[18].

Based on invertebrate fauna the depositional environment of the Cambay Shale is considered to have fluctuated from limnic to shallow inner neritic[2–4]. The Cambay vertebrates are dominated by shallow coastal and estuarine fish, but also include a few taxa that occur in shallow marine, brackish as well as freshwaters (e.g. *Dasyatis*), and some micro (bats) and small to medium-sized land-dwelling mammals. *Dasyatis* generally occurs in shallow coastal waters, but can also survive in coastal rivers. Extant osteoglossids thrive in freshwaters though some Eocene taxa (viz. *Brychaetus*) are known from the marine deposits. The Vastan ichthyofauna in general suggests confined shallow coastal water or lagoonal water of warm, tropical–temperate sea (Table 1). This is corroborated by the lithologic and biotic associations in the fossiliferous section, which are characteristic of a backshore lagoonal environment[32].

This and other recent reports of an admix of well-preserved marine and non-marine biotic remains in the lignite-associated beds of Gujarat[10] and Rajasthan[12,33] are important indicators of the potential for recovery of more complete land-mammal remains in the subcrops of the Cambay Shale and the coeval deposits in Vastan, Panandhro, Palana and nearby lignite fields. At present, these sites appear to be most promising for the earliest Tertiary mammals and are also prompting us to revisit coaly horizons of the sub-Himalayan Palaeogene in the quest of mammalian remains.

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Organic-walled microfossils from the Neoproterozoic black phosphatic stringers in the Gangolihat Dolomite, Lesser Himalaya, India

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A well-preserved microbiotic assemblage is recorded from the Jhiroli magnesite, eastern Kumaun Lesser Himalaya. The assemblage contains cyanobacterial filaments, coccoids and acritarchs identified mainly as *Siphonophycus robustum*, *S. typicum*, *S. capitaneum*, *Gunflintia minuta*, *Oscillatoriopsis obtusa*, *Chlorogloeaopsis contexta*, *Sphaerophycus parvum*, *Leiosphaeridia crassa*, *Trachyhystrichosphaera vidalii*, *Trachyhystrichosphaera* sp., *Micrhystridium pallidum* and *Cymatiosphaera minuta*. Presence of acanthomorphic acritarchs such as *Trachyhystrichosphaera*, *Cymatiosphaera* and *Micrhystridium* is important in assigning the age of the Gangolihat Dolomite. On the whole the microbiotic assemblage suggests Vendian or younger age for the Gangolihat Dolomite.

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IN recent years, our understanding of early complex life has enormously improved due to worldwide interest in microscopic fossils in Neoproterozoic–Cambrian rocks. A variety of relicts of early multicellular life is found trapped within Proterozoic sediments which were earlier seen as a province of cyanobacteria only. Proterozoic microfossils as compared to Palaeozoic microfossils, exhibit a comparatively low biotic diversity and low morphological complexity. This low morphological diversity resulted in fewer characters used for assigning taxa and their correlation worldwide. The Proterozoic carbonate rocks are being studied extensively for biostratigraphy, palaeoecology and palaeoenvironmental aspects, as well as for gathering information on biotic evolution throughout the world[1–3]. In the Lesser Himalayan succession of India, the Krol–Tal sequence[4–6], Deoban Formation[7,8], Vaishnodevi Limestone[9] and Gangolihat Dolomite[10] have proved to be significant as they have revealed well-preserved prokaryotic, eukaryotic and multicellular life forms. These formations have created immense interest among palaeobiologists for exploring the antiquity of multicellular life in the Proterozoic carbonates. The present communication reports a diverse microbiota in dark black phosphatic stringers within magnesite in the Jhiroli magnesite, ~45 km from Almora, in the eastern part of Kumaun Lesser Himalaya (Figure 1). It is the continuation of an earlier publication that first documented an early Vendian organic-walled microfossil and sponge-spicule from Gangolihat Dolomite[10]. Fossiliferous samples were collected from pit 1 of magnesite at Jhiroli (79°45′07.56″: 29°45′50.03″). In the Jhiroli magnesite section, Gangolihat Dolomite consists of limestone, cherty limestone, stromatolitic dolomite and phyllitic units. The magnesite horizon is conspicuous within the section (Figure 2). The individual magnesite bodies are elongate and dome-shaped and often stromatolitic.

At places, magnesite has completely replaced the stromatolites and the magnesitized stromatolites not only preserve the original stromatolitic structure but also the parts already phosphatized[11]. Within the cherty phosphatic bands microbiotic remains of cyanobacteria and phytoplanktons were found well preserved.

The vast argillo-calcareous succession exposed in the Inner Lesser Himalaya has been described as Calc Zone of Badolisera and Calc Zone of Pithoragarh[12]. The succession comprises in the ascending order the Rautgara–