Taxonomic and taphonomic appraisal of fish vertebrae from the early Eocene gypseous shales of Kachchh, Gujarat

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Vertebrae belonging to the teleost fishes from the Lower Eocene gypseous shales of the Naredi Formation (Nareda locality), Kachchh are described. All the vertebrae represent the trunk portion of the fish; they are short, amphicelous and imperforate. Only the centrum portion of the vertebrae is preserved with base of neural arch. The size of the vertebrae is variable, possibly representing different aged individuals who died in some unusual circumstances (trapped in shallow region of lagoon). The preservational features of the vertebrae suggest complete disarticulation due to the long post-mortem exposure. The vertebrae were initially sorted in the marine system (Voorhies Group I) and were deposited in oxidizing condition and low energy environment.

THE vertebrate fossil yield from the early Eocene horizons of Naredi is very little in comparison to that of middle Eocene (the Harudi Formation), which has produced numerous reptilian and mammalian fossils[1,2], especially earliest cetaceans[3,4] apart from fishes[5]. Lydekker[6] was the first to describe the fishes when he reported dental plate of ray fishes from the Eocene of Kachchh. The early Eocene fish record from Naredi, Kachchh is represented by fragmentary skull of siluroid cat-fish[7] and the teeth of *Scoliodon* sp.[2]. The present paper describes vertebrae of teleost fishes from the early Eocene.

The Tertiary beds of southwestern Kachchh essentially represent shallow marine deposits[2]. A detailed biostratigraphic zonation of Tertiary in Kachchh was done by Mohan and Soodan[8] and that of Naredi was done by Tandon *et al.*[9]. In Naredi, the base of the Tertiary succession is marked by the Deccan Traps. Above the traps, a 7 m thick horizon of ash-grey, yellowish to reddish-brown, friable gypseous shale of the Naredi Formation[10,11] is exposed. The gypseous shale horizon has intermittent lensoidal units of black pyriteferous shale (see legend to Figure 1). The fossil collection for the present work has been made from the upper part of this gypseous shale unit.

The age of the ossiferous gypsum shale may be inferred as the earliest part of early Eocene on the basis of Yepresian foraminifers, *Nummulites* (*Assilina*) *spinosa*, *N. globules*, *N. burdigalensis*, *Cibicides* spp., *Lockhartia* sp., shark teeth and ostracodes *Cythereis spinellosa* reported from the horizon just above the gypsum shale[11].

The material was catalogued in the Vertebrate Paleontology collection of the third author of this paper in the Department of Geology, Lucknow University (MPS/B-01/).

The vertebrae are mainly represented by the centrum. They are cylinder-shaped, slightly narrower in the middle and wider at the ends. The centra of the vertebrae are short and they are composed of concentric layers of bones, which form a concave cavity on both the ends. The dorsal and ventral arch bases fused with the centrum of the vertebrae are also preserved. In one specimen posteriorly directed ventral rib is preserved attached to the ventral arch base (Figure 2 *a*), representing a derived condition[12]. The base of the neural spines is distinguishable on the upper surface, but in none of the specimens is the neural arch preserved. On the lower surface, the hemal arch is not distinguishable.

The preservation of the bony element is poor and all the vertebrae are gypsiferrous. The maximum antero-posterior length of the vertebrae varies between 1.1 and 2.3 cm, and the maximum diameter varies between 0.9 and 2.5 cm. The average length and diameter of the vertebrae is 2.0 cm. The bones are altered by secondary gypsum but in two specimens the bony material is preserved (Figure 2 *b* and *c*).

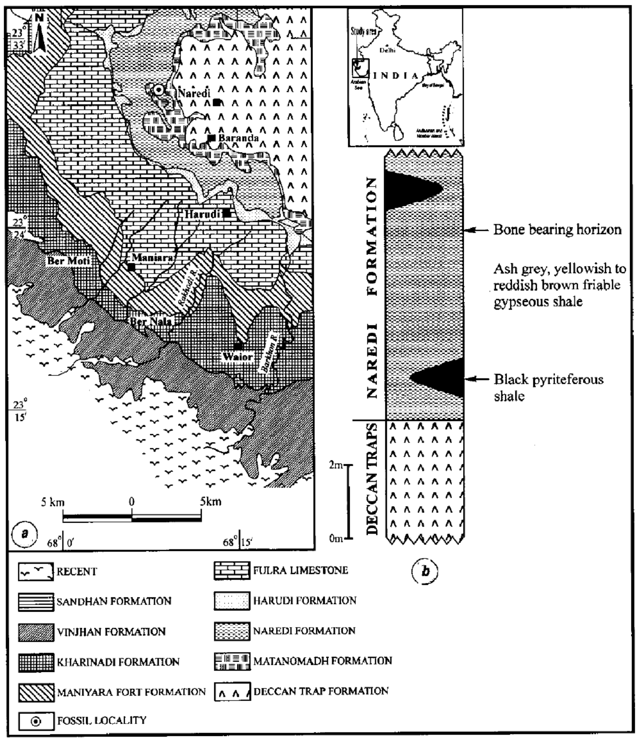

Figure 1. ***a***, Map of the Naredi area showing the fossil locality (after Biswas and Raju[10]); ***b***, Stratigraphic succession exposed at Naredi. Fossil vertebrae were recovered from the upper part of the Naredi Formation.

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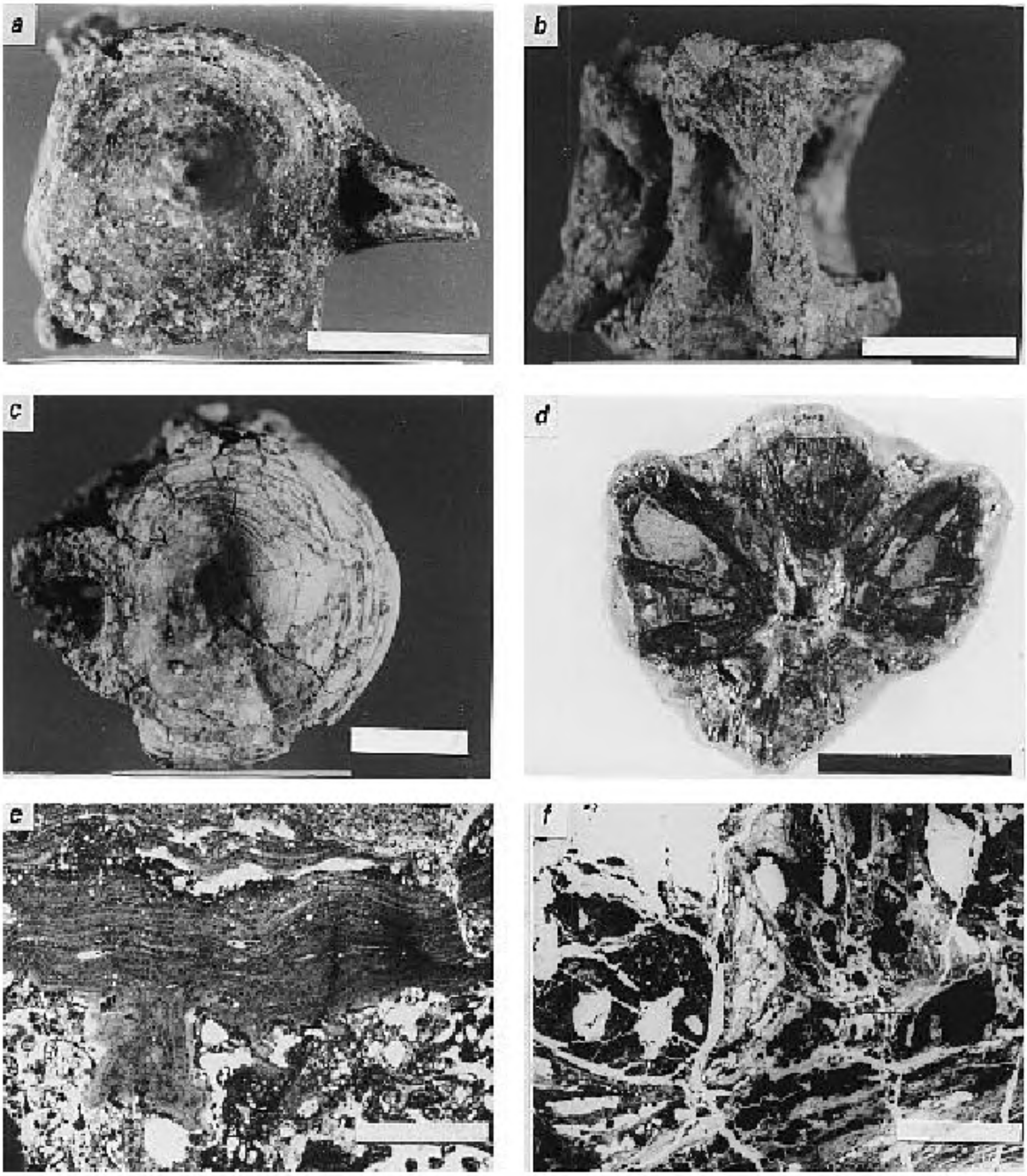

Figure 2. ***a***, MPS/B-01/02: Occlusal view of a trunk vertebra showing ventral rib attached to the ventral arch. Ventral rib is always posteriorly directed which helps in orienting the vertebra. Bony material of centrum portion of the vertebra is almost completely altered by secondary gypsum. Scale bar = 1 cm; ***b***, MPS/B-01/06: Lateral view of a trunk vertebra showing secondary alteration of bony material. Most of the bony material is lost because of alteration due to which arch bases cannot be distinguished. Scale bar = 1 cm; ***c***, MPS/B-01/07: Occlusal view of a trunk vertebra showing concentric layers in the centrum region. Gypseous alteration is not as intense as in previous specimens and therefore the arch bases can be distinguished (ventral arch base is visible on the left side of the centrum). Post-mortem cracks are visible in which gypsum has leached and has replaced the calcareous matter of bone. Scale bar = 1 cm; ***d***, MPS/B-01/05: Occlusal view of transversely sectioned and polished trunk vertebra. Floret-like arrangement of fibres forming triangular petal-like structure is characteristic of teleost fish vertebrae. Scale bar = 1 cm; ***e***, MPS/B-01/09: Thin section of a trunk vertebra (under plane-polarized light). Concentric ring structure of the centrum showing replacement of calcareous material by ferruginous clay (dark coloured). The light-coloured gypsum has occupied pore spaces and is replacing calcareous and ferruginous matter in the lower part; ***f***, MPS/B-01/09: Thin section a trunk vertebra (under plane-polarized light) showing irregular post-mortem cracks filled with secondary gypsum. At places, dark coloured ferruginous clay is also being replaced by gypsum.

In cross-section, the vertebrae show a radiating floret-like arrangement of fibres, which originate from the central part of the centrum and enclose the arch facets, thus forming a triangular petal-like structure (Figure 2 *d*).

The structure visible in the vertebrae is very much similar to that of sharks, but the whole region of the centrum is ossified and the arch bases are fused with the main centrum at the maturity; this condition is visible in actinopterygians, especially in the teleostei[13,14]. The vertebrae in question are different from those of Polypteridae and Lepistosteidae, which have vertebrae with distinctive shapes. The Ceratodontidae, Lepidosirenidae and Pycnodontidae lack ossified centra. The calcified centra of elasmobranches also show a radiating arrangement of fibres, but our specimens show radiating struts of dense bone, which is characteristic of teleostean centra[13]. Further, elasmobranches show spool-shaped form with hemispherical arch facets, but the specimens in question show prominent longitudinal ridges. The trunk vertebrae of Amiidae are wider than higher[14]. Thus, the fossil vertebrae represent teleostei indet. The number of vertebrae in living teleosts (*Perca*) varies between 40 and 45 (ref. 12). In all, they constitute approximately 65% of total body length. Our record represents vertebrae of various sizes, indicating towards the teleosts which were ranging in size between 150 and 250 cm. The smaller teleosts of early Eocene probably range in size between 120 and 150 cm and the larger ones range between 220 and 250 cm. The presence of such large fishes from the early Eocene of Naredi is noteworthy.

The specimen MPS/B-01/09 was cut for thin-section study. In thin-section, the porous bone structure of the vertebra is visible. The pore spaces of the bone are filled with either clay granules or gypsum crystals or at some places with both, where gypsum is replacing the clay from the centre. The gypsum penetrates the bone through the horizontal fissures and cracks present on the vertebra. The fissures and cracks are very frequent in all the vertebrae. The initial replacement of bony material by the calcareous and ferruginous clay is visible (Figure 2 *e*).

The preservational features and thin-section studies suggest that the teleost fishes were trapped in the shallow region of the lagoon and died. The isolated vertebrae suggest high degree of disarticulation, which took place when the fish carcasses were exposed for a long time to bacterial action while underwater[15–17]. During the exposure, several horizontal cracks and fissures could develop in the vertebrae as a result of post-mortem drying of the bones, and iron staining and impregnation took place in the oxidizing condition (Figure 2 *b*). The sorting effect has taken place for the initial accumulation of the vertebrae at the site of deposition. Such kind of accumulations fall under the 'Voorhies Group I' in which only ribs, vertebrae, sternum and sacrum are deposited[18,19]. These bones are most easily affected by the water transport and disperse very easily by water action even in very low energy environment[19,20]. The gypsum, which was formed under evaporitic conditions at the time of the deposition of clays, has replaced the bones during diagenesis.

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