

Fish otoliths from the subsurface Cambay Shale (Lower Eocene), Surat lignite field, Gujarat (India)

Here we report on a small assemblage of teleost fish otoliths (ear-bones) recovered from borehole clays obtained from the lignite field at Tarkeshwar, Surat district, Gujarat (Figure 1). Prior to this find, the only known occurrences of Tertiary otoliths in the Indian subcontinent were those from the Middle Eocene Harudi Formation of Kachchh^{1,2} and the Drazinda Shale (Khirthar Formation) of Pakistan³. The present find represents the oldest Cenozoic record of otoliths from India, adding an important component to the poorly known Lower Eocene vertebrate faunas. The Middle Eocene vertebrates from India, on the contrary, are fairly well-documented (especially from the Harudi Formation of Kachchh and the Subathu Formation of Himalaya).

The lignite field in the Surat–Broach area extends from the village Valia (Broach district) in the north to Tarkeshwar (Surat district) in the south. In the latter district, the lignite-bearing area falls within the latitudes 21°22'35"N and 21°26'35"N and the longitudes 73°04'00"E and 73°07'35"E. It is located 29 km ENE of Kim and about 60 km NW of Surat by road. The otolith-bearing samples of dark-grey clays were kindly provided to one of us (B.S.) by the Mineral Exploration Circle, Ahmedabad. These samples, recovered from the depths 182.65–183.55 m (Sample no. MLDS/1) and 206.25–209.30 m (Sample no. MLDS/5), occur both above and below the lignite levels (Figure 1 b). Stratigraphically, the otolith-bearing horizons form part of the Cambay Shale which occurs above the Deccan Traps and associated laterites/lithomarge (Vagadkhol Formation) and is, in turn, overlain by the Upper Eocene nummulitic limestones and marls (Amravati Formation). The Middle Eocene Ankleshwar Formation is notably absent in the area. Palynological investigations of lignites and associated clays indicate an Early Eocene age for the otolith-bearing levels (Samant, unpublished data).

The recovered otolith assemblage comprises approximately 30 sagittae, found together with a number of fragmentary fish remains (cranial elements, vertebrae, spines) as well as a single tooth of the ray *Raja*. Several of these otoliths are suffi-

ciently well-preserved to work out familial affinities. The dominant group, both numerically and taxonomically, is the family Ambassidae, represented by at least three species (Figure 2 a–l). Characteristic features of these otoliths include an elliptical or rounded outline; a characteristic predorsal angle on the dorsal rim followed anteriorly by an oblique truncation; wide ostium with a blunt rostrum and a narrower, slightly convex cauda; pronounced notch at the junction of ostial and caudal crista inferior; prominently developed dorsal area. Specific designation is not made here because of insufficient material, but it is important to note their resemblance to genus *Ambassidarum rhomboides* (Stinton 1978) from the Eocene of southern England⁴. Another important group represented in the collection is the apogonids (Figure 2 m), readily characterized by having a sulcus with large ostium showing a marked dorsal widening in its posterior part and a narrow cauda, more or less equal in length to ostium and bearing a collicular crest just above the crista inferior. Closely resembling otoliths have been described as genus *Apogonidartum kosdensis* from the Middle Eocene of Hungary⁵, but additional material is needed for assignment to that species. In addition to these families, a single large-

sized sagitta (Figure 2 n) bearing a large ostium opening widely on the ostial rim and a conspicuously curved crista superior, is tentatively referred to Pempheridae, a family of small-to moderate-sized (less than 20 cm) fish that live in shallow water, less than 100 m deep in tropical and subtropical areas of the Indo-Pacific realm. The only known otolith-based fossil record of this family is from the Upper Cretaceous of Mississippi and Maryland, USA⁶. Lastly, there are some otoliths with a circular outline (Figure 2 o) and with both outer and inner faces nearly flat and a cauda much longer than ostium; their affinities cannot be determined at present.

The family Ambassidae, recorded for the first time from the Indian Tertiary, is presently confined to coastal estuarine and freshwater environments of the Indo-Pacific region. Elsewhere, ambassids are known from a number of otolith-based fossil occurrences in analogous environments of the European Paleogene and Lower Miocene^{4,7}. Their dominance in the present association together with the associated skeletal remains of fish (including rays) suggests coastal, probably brackish water, conditions during the deposition of the Cambay Shale. Intermittent limnic environment is indicated by non-marine ostracods

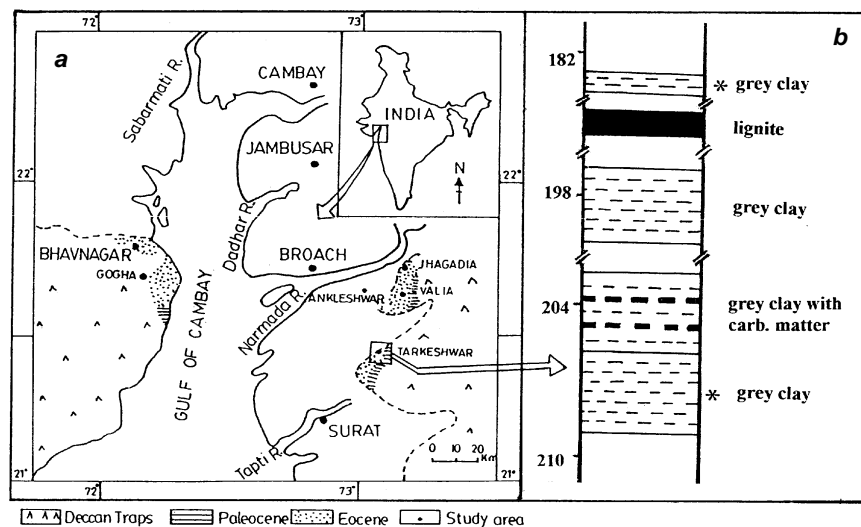


Figure 1. a, Map showing the location of the otolith-yielding samples; b, position of the otolith-bearing samples (*) in the borehole succession (depth in m).

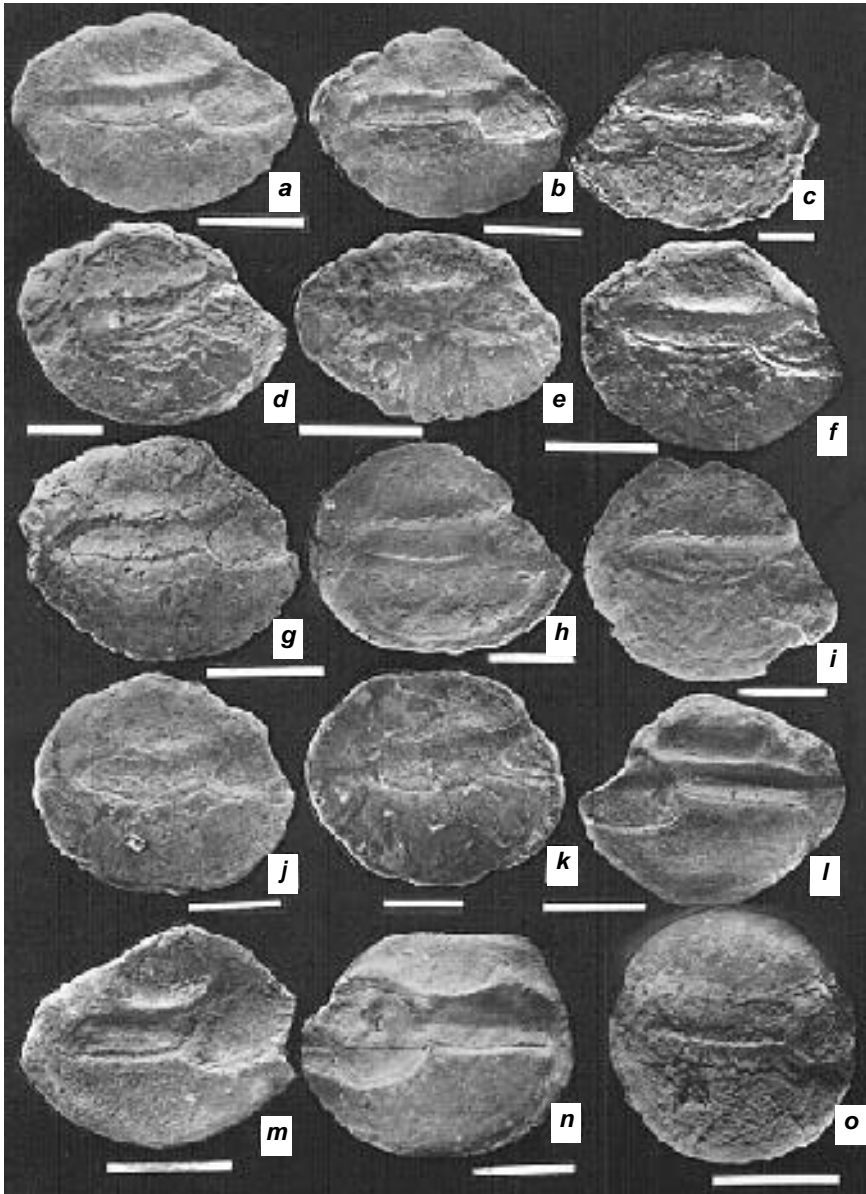


Figure 2. Otoliths from the Cambay Shale (Lower Eocene), Surat lignite field. *a-f*, genus *Ambassidarum* sp. 1 (RUSB 201–206; *a, b, d-f*, left otoliths; *c*, right otolith); *g-k*, genus *Ambassidarum* sp. 2 (RUSB 207–211; all left otoliths); *l*, genus *Ambassidarum* sp. 3 (RUSB 212; right otolith); *m*, genus *Apogonidarum* sp. (RUSB 213; left otolith); *n*, Pempheridae *indet.* (RUSB 214; right otolith); *o*, Percoidei *indet.* (RUSB 215; left otolith). Bar equals 0.5 mm for *a-c, g* and *o*; 0.2 mm for *d-f* and *h-k*; 1 mm for *l, m* and 2 mm for *n*.

encountered at several levels in the Cambay Shale⁸. Although precise biostratigraphic evaluation of this otolith fauna must await recovery of a larger sample, it should be noted that a slightly

younger (Middle Eocene) otolith assemblage from the Harudi Formation of Kachchh, deposited in inner neritic environments, is dominated by the family Apogonidae².

1. Sahni, A. and Saxena, R. K., *J. Palaeontol. Soc. India*, 1982, **27**, 64–67.
2. Nolf, D. and Bajpai, S., *Bull. Inst. R. Sci. Nat. Belg. Sci. Terre*, 1992, **62**, 175–221.
3. Nolf, D., *Tertiary Res.*, 1991, **12**, 121–126.
4. Nolf, D., in *Otolithi Piscium—Handbook of Paleichthyology* (ed. Schütze, H. P.), 10, Fischer, Stuttgart, 1985, pp. 1–145.
5. Nolf, D. and Reichenbacher, B., *Bull. Inst. R. Sci. Nat. Belg., Sci. Terre*, 1999, **69**, 187–196.
6. Nolf, D. and Stringer, G. L., in *Mesozoic Fishes – Systematics and Paleocology* (eds Arratia, G. and Viohl, G.), Verlag Dr Friedrich Pfeil, Germany, 1996, pp. 433–459.
7. Nolf, D., in *Recent Developments in Fish Otolith Research* (eds Secor, D. H., Dean, J. M. and Campana, S. E.), University of Carolina Press, 1995, pp. 513–544.
8. Bhandari, A., *Rev. Esp. Micropaleontol.*, 1998, **30**, 1–10.

ACKNOWLEDGEMENTS. We thank the Directorate of Geology and Mining, Government of Gujarat and to Mr V. N. Pathak, Mineral Exploration Circle, Ahmedabad for providing borehole samples that yielded the otoliths described in this paper, and also for the relevant geological information. S.B. thanks Dr Dirk Nolf (Belgium) and Prof. Ashok Sahni (Chandigarh) for their helpful comments and the DST, New Delhi for financial support. Financial assistance by CSIR, New Delhi to B.S. is thankfully acknowledged.

Received 12 February 2001; revised accepted 14 June 2001

BANDANA SAMANT[†]
SUNIL BAJPAI^{*#}

[†]Department of Geology,
Nagpur University,
Law College Campus,
Nagpur 400 001, India

^{*}Department of Earth Sciences,
University of Roorkee,
Roorkee 247 667, India

[#]For correspondence
e-mail: sunilfes@rurkiu.ernet.in