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Shark-Tooth-Bearing Coprolite from the Carlile Shale
(Upper Cretaceous), Ellis County, Kansas

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A coprolite containing a tooth of an extinct shell-crushing shark, Ptychododus sp., was collected from the Blue Hill Shale Member of the Upper Cretaceous Carlile Shale in Ellis County, Kansas. The Ptychododus tooth lacks enameloid, probably as a result of etching through digestion in some animal. This specimen suggests that isolated Ptychodontid teeth without enameloid which occur occasionally in other Upper Cretaceous deposits may be attributed to animal digestion.

INTRODUCTION

A tooth of an extinct shell-crushing Ptychodontid shark, (Chondrichthyes: Elasmobranchii) enclosed in a coprolite was recovered from the Blue Hill Shale Member (middle Middle Turonian) of the Upper Cretaceous Carlile Shale (for stratigraphy, see Hattin, 1962; Hattin, Siemers, and Stewart, 1987). It occurred in a bluish gray clayey bed in the E½, NE¼, sec. 21, T12S, R16W, Ellis County, Kansas. The specimen (Fig. 1) is deposited at Fort Hays State University, Sternberg Museum of Natural History (FHSN) in Hays, Kansas, and catalogued as FHSN VP-13325. Shark teeth contained in a coprolite are known in the fossil record (e.g., teeth of an Upper Pennsylvanian hybodontid in a coprolite, McAllister, 1988). Nevertheless, FHSN VP-13325 is noteworthy, because it is the first known Ptychododus tooth enclosed in a coprolite, and it shows surface features that possibly resulted from digestion by an animal.

DESCRIPTION

Coprolite. Fecal remains from fine-grained deposits of the Cretaceous Western Interior Sea can be classified into two categories: fecal pellets (generally up to 4 mm in maximum dimension) and coprolites (>4 mm: generally several centimeters in maximum dimension) (Savrda and Bottjer, 1993). Fecal pellets are thought to be produced by planktonic and benthic invertebrates; whereas, the origin of, at least, some coprolites are attributed to vertebrates, particularly where remains of macrovertebrates (e.g., fishes)
Figure 1. Tooth of *Ptychodus* sp. (white space in sketch) in coprolite (dotted area in sketch), FHSM VP-13325, from Blue Hill Shale Member of Carlile Shale, Ellis County, Kansas. Tooth, anterior to left: A, lateral view; B, basal view.

are enclosed (Savrda and Bottjer, 1993). FHSM VP-13325 can be categorized as coprolite based on size (described here), and the included ptychodontid tooth (described here) indicates that it could have been produced by a vertebrate. Coprolites produced by vertebrates refer specifically to fecal material preserved after expulsion from the hind gut (McAllister, 1988).

The coprolite (Fig. 1) is an ellipsoid phosphatic pebble similar to those occurring in some Upper Cretaceous marine deposits of Kansas (e.g., skeletal limestones in the Lincoln Limestone Member, Hattin, 1975). It measures about 21 mm along its longer axis and about 15 mm along its shorter axis. The coprolite is massive and brittle. It is buff white on the weathered external surface and light brown on the freshly broken surface.

*Ptychodonta* tooth. Ptychodonta teeth form a pavement dentition, presumably used for crushing shelled macroinvertebrates (Cappetta, 1987; Stewart, 1988). The only known ptychodontids in North America are species of the genus *Ptychodus* (Cappetta, 1987; Welton and Farish, 1993). Their teeth are characterized by a crown with a bluntly raised cusp surrounded by a marginal area, which is expanded over a massive weakly bilobate root (Welton and Farish, 1993). The species of *Ptychodus* generally are identified by (1) the height of the cusp (low to high), (2) the pattern and number of ridges on the cusp apex (radial or transverse ridges), and (3) the ornamentation of the marginal area (granular, concentric, or radiating ridges and bumps).

The overall shape of the ptychodontid tooth suggests that it belongs to
Ptychodus (Fig. 1). The tooth is developed fully, measuring approximately 13 mm in height, 13.5+ mm in anteroposterior length, and 14.5 mm in width. It has a highly raised cusp. However, the cusp is entirely smooth, and a spotted pattern from the internal osteodentine is exposed, because it lacks enameloid. The tooth is asymmetrical when viewed from the root direction, suggesting that it is not from the symphysial region. The right root lobe is placed anteriorly with respect to the left root lobe, so the tooth must be either from the right upper or left lower side.

The cusp height suggests that the tooth can be assigned either to *P. anonymus* Williston or *P. whipplei* Marcou (for dental characters, see Welton and Farish, 1993), both of which occur in the Blue Hill Shale of Kansas (Shimada, 1993). *Ptychodus anonymus* and *P. whipplei* are thought to be closely related (Meyer, 1974; Wolberg, 1985; Shimada, 1994). Therefore, the distinction between these two species may be difficult (Wolberg, 1985), particularly when a tooth lacks enameloid. Hence, the tooth is simply referred to *Ptychodus* sp.

**Discussion**

The origin of the smooth crown surface, lacking an enameloid layer, in FHSM VP-13325 is taphonomically intriguing. The tooth could have been subjected to abrasion on the seafloor and later ingested by an animal or fortuitously mixed with the animal feces prior to its fossilization. However, vertebrate teeth covered by enamel (and perhaps enameloid too) are considered too durable to suffer much abrasion (Argast and others, 1987). Enameloid abrasion prior to fossilization is unlikely, particularly because FHSM VP-13325 occurred in a low-energy deposit (suggested by very fine-grained sediments of the Blue Hill Shale), where all other ptychodontid teeth from the locality show no abrasion or erosion (suggested by complete ornamentation of the crown surface, at least, in all unweathered specimens). Furthermore, an accidental inclusion of an eroded tooth in the coprolite on the seafloor seems unlikely, because animal remains are sparse in the Blue Hill Shale.

The *Ptychodus* tooth is enclosed in a coprolite. Therefore, it is more likely that the surface features of the tooth resulted from etching through digestion in some animal. This interpretation is supported by the results from an experimental study of crocodilian digestive processes operating on vertebrate teeth (including isolated shark teeth) conducted by Fisher (1981). Fisher (1981) demonstrated that the crocodilian digestive processes decalcified vertebrate teeth resulting in a loss (= distraction) of their enamel or enameloid layer. Fisher (1981) did not experiment with articulated shark teeth but noted that mammalian teeth recovered from crocodilian feces were usually isolated. Shark teeth are attached to their jaws by connective tissues without tooth sockets (Peyer, 1968), and the tooth-jaw connection is considered to be loos-
er than that in mammals. Therefore, the isolated nature of FHSM VP-13325 is consistent with the view that the tooth was subjected to animal digestion.

Extant sharks occasionally swallow their own shed teeth (Stransberg, 1963; Uchida and others, 1996), so it is possible that the Ptychodus ingested its own tooth. However, the coprolite does not have any remains of the shark's expected diet (shelled invertebrates, Kauffmann, 1972; Cappetta, 1987; Stewart, 1988; Shimada, 1994) or spiral features resulting from the intestinal structure of chondrichthyans (for intestinal structures among fishes, see McAllister, 1987; for a recent study of spiral coprolites, see Coy, 1995). Assuming that the spiral structure is not lost during diagenesis, it seems that the Ptychodus specimen represents neither a self-ingested tooth nor tooth ingested by another shark.

Various macroinvertebrates (bivalves, gastropods, cephalopods, and crustaceans, Hattin, 1962), several sharks (e.g., Cretodus, Cretolamna, Scapanorhynchus, and Squaleicorax, Shimada, 1993), some bony fishes (pycnodontiform, Zeilinski, 1994; Bananogmius sp., Fielitz and Shimada, in preparation; Enchodus sp., Shimada, unpublished data), and a mosasaur (cf. Clidastes sp., Martin and Stewart, 1977) are known from the Blue Hill Shale of Kansas. However, the total constituents of the Blue Hill fauna remain poorly understood. Therefore, it is possible that the alleged Ptychodus tooth eater may be an animal that has not been recognized yet from the member.

FHSM VP-13325 is the only known specimen of a ptychodontid tooth enclosed in a coprolite. However, isolated Ptychodus teeth with a smooth crown surface, lacking an enameloid layer, occasionally occur in some other Upper Cretaceous deposits of Kansas. Examples include: FHSM VP-2178, P. decurrens? Agassiz from the Graneros Shale; one tooth in FHSM VP-12385, P. decurrens? from the Lincoln Limestone Member of the Greenhorn Limestone; and one tooth in FHSM VP-12873, Ptychodus sp. from the Fairport Chalk Member of the Carlile Shale. Such fossils may be subjected to extensive erosion and abrasion during their deposition. However, the discovery of FHSM VP-13325 suggests that the lack of enameloid in some (if not all) isolated ptychodontid teeth from various Cretaceous strata may be attributed to digestion by animals.

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