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Remains of a pycnodont fish (Actinopterygii: Pycnodontiformes) in a coprolite; An uppermost record of *Micropycnodon kansasensis* in the Smoky Hill Chalk, western Kansas

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Bone fragments, ganoid scales and the distinctive tooth crown of a pycnodont fish (FHSM VP-16583), were recovered from a coprolite (FHSM VP-16586) collected from the Smoky Hill Chalk Member (lower Santonian) of the Niobrara Chalk in northeastern Lane County, Kansas. Pycnodonts were small to medium-sized, deep-bodied bony fish with batteries of flattened, peg-like teeth on the vomer and prearticulars that are well adapted for feeding on hard-shelled prey. The tooth and a dermal bone fragment were identified as *Micropycnodon kansasensis* on the basis of comparison with the holotype and other specimens. Small inoceramid fragments inside the coprolite may represent gut contents of the pycnodont, or the larger, possibly durophagous, predator. The remains of pycnodonts are rare occurrences in the Smoky Hill Chalk and are generally limited to toothplates bearing their distinctive teeth. Previous specimens recovered from the Smoky Hill Chalk have also been restricted stratigraphically to the uppermost Coniacian. FHSM VP-16583 represents the first record of this species in the Santonian.

Keywords: Late Cretaceous, Santonian, Western Interior Sea, Niobrara Chalk, tooth

Introduction

In October, 2004, a small tan coprolite (FHSM VP-16586; Fig. 1) was surface collected from the lower Santonian Smoky Hill Chalk of northeastern Lane County. A black, 3.6 mm long pycnodont tooth crown was visible in lateral-occlusal view on the outer surface of the coprolite. Subsequent removal of the tooth crown and partial disaggregation of the coprolite revealed a fragment of a tooth bearing bone (possibly a nipping tooth or "incisor"), a dermal bone fragment bearing a double row of sharp spines, the bases of four broken fish teeth, a mixture of small fish scales and other bone fragments, and fragments of a small inoceramid clam. While most of the recovered material is too damaged by digestion to be useful, the tooth, tooth bearing bone fragment and dermal spines are sufficient to assign the remains to *Micropycnodon kansasensis*.

Abbreviations: FHSM – Fort Hays State University, Sternberg Museum of Natural History, Hays, Kansas; KUVP – University of Kansas Museum of Natural History, Lawrence, Kansas, and; YPM - Yale Peabody Museum, Yale University, New Haven, Connecticut.

Systematic Paleontology

Actinopterygii
Neopterygii Regan, 1923
Pycnodontiformes Berg, 1937
Pycnodontidae Agassiz, 1833

Micropycnodon
Hibbard and Graffham, 1945

Micropycnodon kansasensis
(Hibbard and Graffham, 1941)

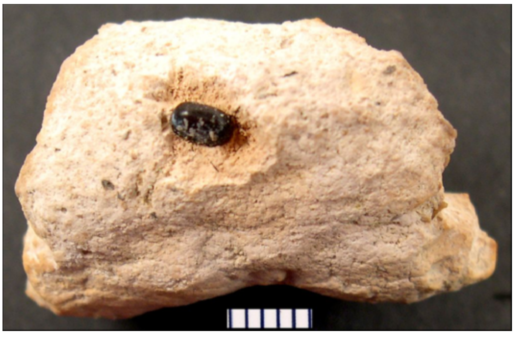

Figure 1. The FHSM VP-16583 pycnodont tooth crown in situ on the surface of the coprolite (FSHM VP-16586) prior to removal. (Scale = mm)

Figure 2. FHSM VP-16583 pycnodont tooth in occlusal, lateral and basal view. (Scale = mm)

Description

FHSM VP-16583: The tooth crown (Fig. 2) is lozenge shaped and is approximately 3.6 mm in length by 2.2 mm in maximum width by 1.4 mm in height. A single row of 8 low crenulations is visible along one side of the occlusal surface. The enamel is generally smooth and appears little affected by its passage through the gut of the predator. The basal side of the tooth is hollow. There is no evidence of a root or a dentine layer.

Another fragment from inside the coprolite appears to be dermal bone and exhibits a double row of curved sharp spines (Fig. 4A), possibly from the skull of the fish. These distinctive "conical granulations" were first described from the type specimen by Hibbard and Graffham (1941, p. 75). There were also several small, flat fragments that appear to be the remains of ganoid scales.

FHSM VP-16586: The coprolite containing the tooth crown, other bone and scale fragments, and small inoceramid clam fragments measured 31 mm long by 20 mm diameter. With the exception of the readily visible tooth crown, the surface of the coprolite (FHSM VP-16586) was slightly eroded and otherwise featureless. FHSM VP-16586 is not a "spiral coprolite" as described by Stewart (1990).

Locality /Stratigraphic Occurrence

The coprolite including the remains of FHSM VP-16583 was discovered as surface float approximately 1 m above Hattin's (1982) Marker Unit 6 in northeastern Lane County (Fig. 3), and is early Santonian in age. Exact locality information is on file at the Sternberg Museum of Natural History, Hays, Kansas. Eighteen other small coprolites, including a spiral coprolite, were surface collected in the immediate vicinity of FHSM VP-16583 within a 1-2 m stratigraphic interval.

Discussion

Relatively few pycnodontid specimens have been documented from the Cretaceous rocks in Kansas since the 1890s (Everhart, 2005). They range in age from the Lower Cretaceous (Albian) Kiowa Shale through the early Campanian of the Smoky Hill Chalk. Cragin (1894) described *Macromesodon abrasus* on the basis of isolated teeth collected from his "No. 3 of the Belvidere section" of the Kiowa Shale. Williston (1900a, 1900b) reported a fragment of the left lower jaw (prearticular) containing two rows of teeth of *Coelodus brownii* Cope 1895 and a fragment of the lower right jaw of *Coelodus stantoni* Williston from the Kiowa Shale of Kansas. Beamon (1999) reported pycnodontid teeth and a tooth plate from the Kiowa Shale (Albian) of McPherson County. Everhart et al. (2004) collected teeth of *Coelodus* sp. and *Hadrodus*

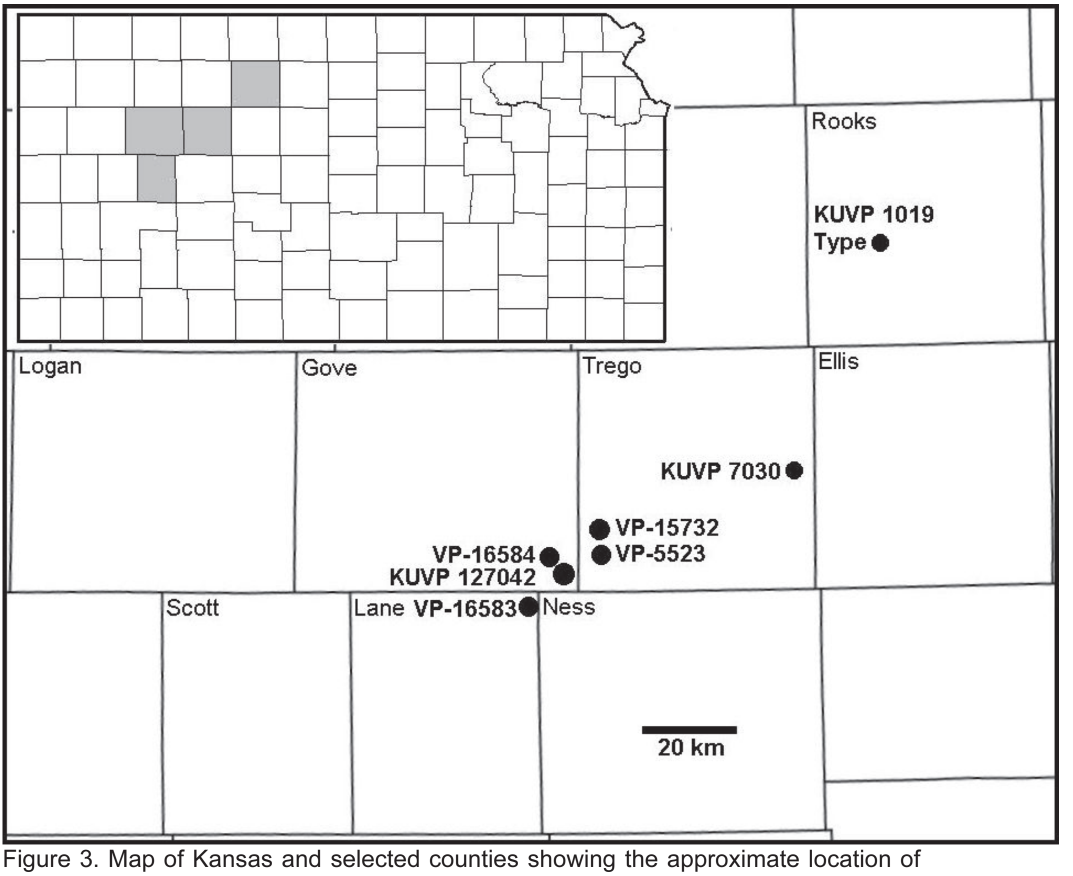

Figure 3. Map of Kansas and selected counties showing the approximate location of *Micropycnodon kansasensis* specimens discussed in this paper. Note that the specimens occur along a southwest to northeast trending line that approximates exposures of the Coniacian age rocks in the Niobrara Chalk (see Hattin, 1982).

sp. from the Upper Dakota Sandstone (Middle Cenomanian) of Russell County.

A previously unreported right prearticular tooth plate (FHSM VP-15548) was collected from the basal Lincoln Limestone Member of the Greenhorn Limestone of Russell County in 2003. A fragment of a large pycnodont vomer with 21 teeth (FHSM VP-16865) was surface collected in 2005 from a road cut in Republic County. The exact stratigraphic occurrence is uncertain, but it is probably also from the Lincoln Limestone Member of the Greenhorn Limestone. Hibbard (1939) described *Coelodus streckeri* from a vomer found in the Blue Hill Shale Member of the Carlile Shale (Middle Turonian) of Russell County, and Zielinski (1994; see also Shimada, 2006, figure 5B) noted the discovery of a pycnodont tooth plate (left prearticular; FHSM VP-6728) from the Blue Hill Shale Member in Ellis County. Everhart et al. (2003) reported teeth of *Hadrodus priscus* and Shimada (2006) figured a large *Hadrodus* sp. incisor (FHSM VP-14006. fig. 5A) from the Blue Hill Shale of Jewell and Smith counties, respectively.

As noted by Gregory (1950), the O.C. Marsh - Yale Scientific Expedition of 1872 collected the remains of a pycnodont-like fish (YPM 1950) from near the Smoky Hill River in

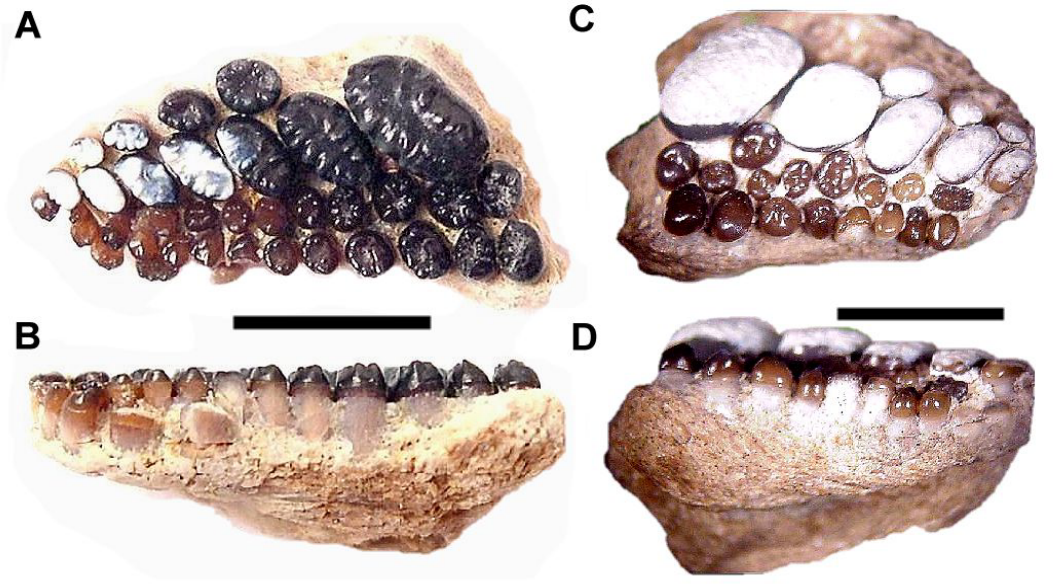

Figure 4. The right prearticular toothplate of FHSM VP-15732 in (A) occlusal and (B) medial view, and the left prearticular of FHSM VP-16584 in (C) occlusal and (D) medial view. Several teeth in both specimens have been whitened by weathering. Note exposed roots of teeth in B and D. (Scale bars equal 5 mm)

western Kansas. In Gregory's description of *Hadrodus marshii*, he noted that the specimen consisted of "fragments of the skull and dentition of a large pycnodont fish." Although *H. marshii* is still technically considered to be a pycnodontid, Poyato-Ariza and Wenz (2002) suggested that the remains were not from a pycnodontiform and that the genus *Hadrodu*s is in need of revision.

The type specimen of *Micropycnodon kansasensis* (KUVP 1019) was collected from the Niobrara Chalk of Rooks County and consists of a complete tooth-bearing vomer, anterior portions of the skull, including dermal bones, and associated anterior scales (Hibbard and Graffham, 1941). A prearticular (KUVP 75043) was also collected from Rooks County near the contact of the Smoky Hill Chalk and Fort Hays Limestone. KUVP 7030 (*M. kansasensis*) is the most complete specimen of a pycnodont ever collected in Kansas. It was collected by G. F. Sternberg from the Niobrara Chalk in Trego County between 1934 and 1936, and described by Dunkle and Hibbard (1946; see pls. VII and VIII). The exact stratigraphic occurrence of this specimen is uncertain (Fort Hays Limestone or Smoky Hill Chalk member?), but Stewart (1990) noted that it is Coniacian in age.

Stewart (1990) also indicated that the only specimens of *Micropycnodon kansasensis* that he was positive were from the Smoky Hill Chalk were collected in the biostratigraphic zone of *Protosphyraena perniciosa* (upper Coniacian), and that there was another, undescribed pycnodont from early to middle Santonian that was not *M. kansasensis*. More recently, Beeson and Shimada (2004; see also Shimada and Fielitz, 2006) reported the occurrence of pycnodont tooth crowns identified as *Palaeobalistum* sp. in vertebrate remains recovered from an unusual bonebed specimen (FHSM VP-644) collected from the middle Santonian Smoky Hill Chalk of western Gove County by G.F. Sternberg.

The right prearticular toothplate of a *Micropycnodon kansasensis* (FHSM VP-5523) was collected from upper Coniacian chalk of southwestern Trego County in 1977. Another, fairly complete pycnodont specimen (KUVP 127042) was collected in 1994 from southeastern Gove County. In 2006, I visited that locality and verified that the specimen had occurred between Hattin's (1982) marker units 4 and 5 (Upper Coniacian). Two other, previously unreported specimens (Fig. 4), a right prearticular tooth plate (FHSM VP-15732) and a left prearticular toothplate (FHSM VP-16584) were collected from the Smoky Hill Chalk below Hattin's (1982) Marker Unit (MU) 2 in southwestern Trego County and below MU 5 in southeastern Gove County, respectively. Until the discovery reported herein, FHSM VP-16583 and KUVP 127042 represented the highest known occurrences (Upper Coniacian) of *M. kansasensis* in the Smoky Hill Chalk, near the top of Stewart's (1990) biostratigraphic zone of *Protosphyraena perniciosa*.

Micropycnodon kansasensis

The FHSM VP-16583 tooth crown represents one of the five lozenge-shaped teeth in the central row of the vomer or one of the five similarly shaped crowns in each of the prearticulars of *Micropycnodon kansasensis*. There are a total of 32 teeth in the vomer of the type specimen (KUVP 1019) and 36-38 teeth in the prearticulars of KUVP 75043 and FHSM VP-15732. Although most fish teeth are acrodont (attached directly to the surface of the tooth-bearing bone), the crushing teeth of *M. kansasensis* exhibit a root-like structure (Fig. 4B and 4D) that penetrates the bone. Peyer (1968, pl. 44b) illustrated a pycnodont tooth crown in cross section from the Early Cretaceous of Texas that shows a distinct surface layer of enamel and an underlying layer of orthodentine. Pycnodont tooth crowns are normally collected without the root-like structure that connects them to the bone, but in some cases remnants of the structure are preserved (pers. obs.) in detached teeth. Although not previously described from a coprolite, a pycnodont was also identified as gut contents of a primitive, Late Cretaceous marine snake (Lee and Caldwell, 1998).

Although similar in shape, the length of the FHSM VP-16583 tooth crown (3.6 mm) is slightly less than the largest teeth in the prearticular tooth plates of KUVP 7030 and the vomer of the type specimen (KUVP 1019). The lozenge shaped teeth on both the prearticular and vomer differ considerably in size and increase in size from anterior to posterior. Based on tooth size alone, most of the specimens from the Upper Coniacian Smoky Hill Chalk appear to have come from similar sized individuals.

Dunkle and Hibbard (1946) noted that they were unable to provide an accurate estimate of the length of the KUVP 7030 specimen when alive because of differences in the directions that the head and body were crushed. The tail is missing, and unknown in *Micropycnodon kansasensis*, so any estimate of total length would be subject to some degree of error. The length of the actual specimen, however, is about 23 cm and it is reasonable to estimate, based on a number of complete specimens of other pycnodont species (see Poyato-Ariza and Wenz, 2002) that the standard length of KUVP 7030 would have been less than 30 cm. Likewise, the other nearly complete specimen (KUVP 127042) would have been somewhat smaller or about 25 cm in standard length. However, without knowing the position in the mouth of the tooth recovered from the coprolite, there is no way to accurately estimate the size of FHSM VP-16583. Based on the relatively small size of the other remains in the coprolite, however, it is most likely that the fish was somewhat smaller than the type specimen or KUVP 127042.

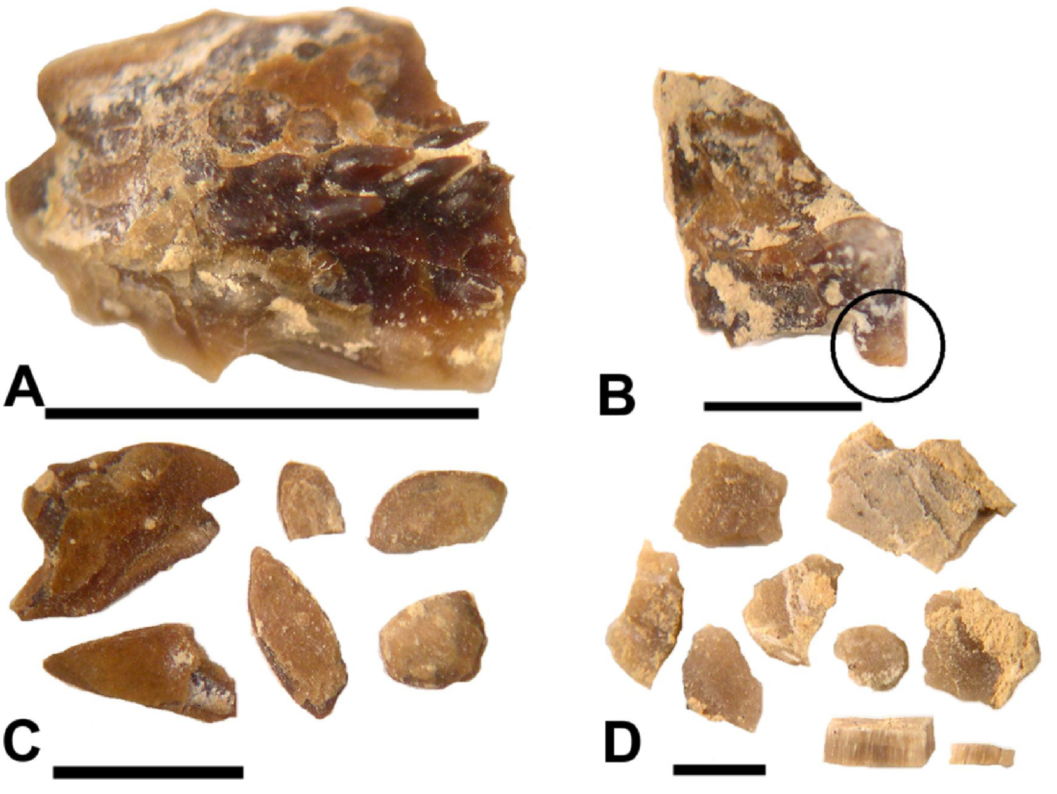

Figure 5. A. FHSM VP16583 dermal bone with 1 mm ganoin spines. (Scale = 5 mm); B. Probable left premaxilla with base of broken tooth circled at lower right (Scale = 1mm); C. Flat polygonal pieces of bone interpreted here as the remains of ganoid scales. (Scale = 2 mm) D. Fragments of inoceramid shell found inside the FHSM VP-16586 coprolite. (Scale = 1mm)

A small dermal bone fragment (Fig. 5A) bears two rows of sharp, reclined spines that are apparently composed of ganoin, an enamel-like substance that is secreted by the dermis of ganoid fishes and makes up the outer layer of their scales. Similar structures are visible on the type specimen (KUVP 1019), KUVP 7030 and KUVP 127042, and were described in more detail by Hibbard and Graffham (1941, p. 75) and Dunkle and Hibbard (1946, p. 172).

Another fragment appears to be a partial premaxilla and bears the broken base of a single tooth at its apex (Fig. 5B), and possibly the base of another tooth located posteriorly.

Premaxillae were not identified from the type specimen by Hibbard and Graffham (1941) or KUVP 7030 by Dunkle and Hibbard (1946), and thus that tooth-bearing element has not yet been described for *Micropycnodon kansasensis.* However, Poyato-Ariza and Wenz (2002) noted that pycnodonts have at least two teeth on the premaxilla.

The FHSM VP-16586 coprolite also contained a number of small, flat polygonal fragments (Fig. 5C) that are probably the remains of ganoid scales, but they are too damaged and fragile to be positively identified. In addition, various other small, unidentifiable bone fragments were recovered from the coprolite.

Coprolite

The first North American author to discuss and figure coprolites was DeKay (1830) who reported on specimens from the green sands of New Jersey. B.F. Mudge (1876, p. 217) was among the first to document the presence of coprolites in the Smoky Hill Chalk: "Coprolites of fish and Saurians are frequently found, containing the remains of the food of the animal. Small fish appear to be the most common food."

Williston (1898, p. 214) noted in his discussion of mosasaurs that "Coprolites which I have always had reason to believe were from these animals are in some places very abundant, weighing from an ounce or two up to a half a pound or more. They are ovoidal in shape with sphincter or intestinal impressions upon them, and contain very comminuted parts of fish bones, fish scales, etc."

Most coprolites collected in the Smoky Hill Chalk are composed of digested bone (calcium phosphate). Coprolites are relatively common at various stratigraphic levels in the chalk and about one out of ten exhibits visible bone fragments, the most common being fish vertebrae (pers. obs). The coprolites are normally more resistant to weathering than the surrounding chalk and are generally collected as float on the surface. Eighteen small coprolites, and one spiral coprolite (sensu Stewart, 1990) were picked up in the vicinity of FHSM VP-16586. Three of these had small bone fragments visible on their outer surface (pers. obs.).

Other than an early chemical analysis reported by Mudge (1876), relatively little work has been done on the contents of marine coprolites from the Kansas Cretaceous. Shimada (1997) reported the discovery of a *Ptychodus* tooth (FHSM VP-13325) inside a coprolite. The crown of the tooth is lacking most of its enameloid surface and was apparently partially digested while inside the gut of the predator.

Inoceramid

Several fragments of the shell of a small inoceramid clam (Fig. 5D) were also co-mingled with the pycnodont material inside the coprolite. It is possible that these fragments represent prey that the pycnodont was feeding upon before it was consumed by the larger predator. The shell fragments are 0.4 to 0.8 mm thick and are composed of a single, prismatic layer of calcite crystals. They represent the remains of a young inoceramid, or spat, probably less than a centimeter in diameter. Inoceramid spat of that size have not been reported as being preserved in the Smoky Hill Chalk although 0.5 cm spat of an abundant oyster species, *Pseudoperna congesta*, are frequently observed to be attached to larger inoceramid shells.

Conclusion

The fragmentary remains a pycnodont fish (FHSM VP-16583) in a coprolite establishes that *Micropycnodon kansasensis* was present in the early Santonian Western Interior Sea and provides an upper record of its occurrence. Inoceramid clam shell fragments commingled with the fish remains suggest that the pycnodont was feeding on inoceramid spat prior to being consumed by a larger predator, or that the fish was consumed by a durophagous predator. However, FHSM VP-16586 does not provide any useful information in regard to the identity of the animal which produced it. This specimen and associated materials add new information to our knowledge of the paleoecology of the Western Interior Sea during the Late Cretaceous.

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