BONNERICHTHYS GLADIUS (OSTEICHTHYES) FROM THE CRETACEOUS OF THE ATLANTIC COASTAL STATES

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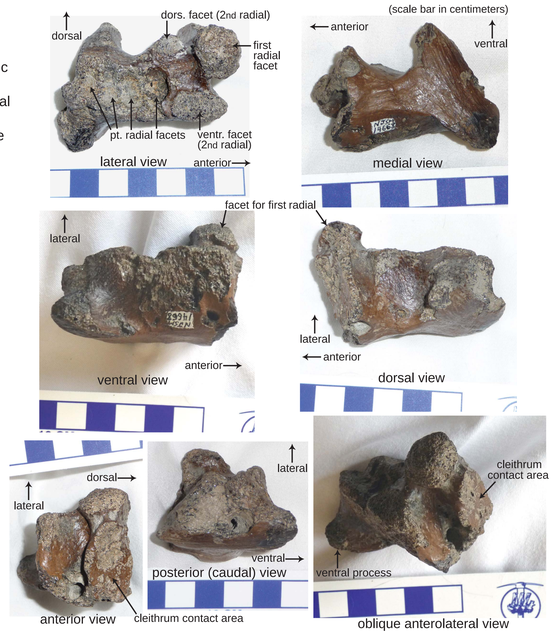
ABSTRACT: The large Late Cretaceous fish *Bonnerichthys gladius*, now interpreted to have been a plankton feeder, would presumably have thrived in an area with access to open oceanic environments, such as the Atlantic coast. Two specimens, previously cited but not described in detail, tend to confirm this suggestion. The more enigmatic of the two is a fragmentary scapulocoracoid from the Campanian of New Castle County, Delaware. It is anatomically consistent for a referral to *Bonnerichthys*, to the extent that the scapulocoracoid is known, in both articulations and proportions. However, it is of relatively small size compared to *Bonnerichthys* from the Western Interior Seaway.

The more diagnostic specimen is a highly characteristic fin spine fragment from the Maastrichtian of Monmouth County, New Jersey. It may be geologically later than any other specimen of *Bonnerichthys gladius* thus far reported. This suggests persistent survival of such a highly pelagic plankton feeder in proximity to the open ocean. Presumably the species survived until the mass extinction event at the end of the Cretaceous Period.

INTRODUCTION: The osteichthyan Family Pachycormidae, while dominated by large-toothed, piscivorous forms, included some taxa now recognized as planktovores. With the discovery of some excellent specimens, the species *Bonnerichthys gladius* Cope has become one of the better-known of these taxa (Friedman et al. 2010). Other specimens, which have been cited but remain undescribed (Parris et al. 2007), may provide further information of interest. The specimens described herein confirm the presence of pachycormids in the Late Cretaceous of eastern North America, but also provoke speculation as to their paleoecological role.

FIGURE 1
NJSM 15140
pectoral fin
(lateral view)

FIGURE 2. NJSM 14668. Right scapulocoracoid.



SPECIMENS: The fossils described here were collected by members of the Monmouth Amateur Paleontologists' Society: one of us (R. O. J.) and the late Richard Heintz. Both specimens have been referred to the Family Pachycormidae, but are subject to various interpretations of their precise affinities. Both specimens are in repository at the New Jersey State Museum (NJSM), in Trenton, New Jersey. Other museum abbreviations used herein are: FHSM (Sternberg Museum of Fort Hays State University, Hays, Kansas), KUVP (Vertebrate Fossil Collections of the University of Kansas at Lawrence), and MAPS (Monmouth Amateur Paleontologists' Society in West Long Branch, New Jersey).

NJSM 15140 is a fin fragment (Fig. 1) derived from the Wenonah Formation at the Big Brook Locality, Marlboro Township, Monmouth County, New Jersey (see map). Originally catalogued as MAPS 1036a, it is a curved piece 89 mm long and 38 mm wide. It exhibits the characteristic structure described for fins of *Bonnerichthys gladius* (Stewart 1988, Parris et al. 2007), with fin rays fitted behind a wedge-shaped, irregularly serrated ossification at the anterior edge of the fin. This basal fin fragment preserves the anterior edge ossification and approximately 14 ridges. Caudally there is a wide groove, occupied *in vivo* by the irregularly-ossified fin core. Estimation of the restored length of the entire fin is highly speculative, but would be considerably less than the 50cm or more observed or estimated for specimens of *Bonnerichthys gladius* (Parris et al. 2007, Friedman et al. 2010).

NJSM 14668 is a right scapulocoracoid (Fig. 2) from Marshalltown Formation spoil piles near Saint Georges Bridge, Chesapeake and Delaware Canal, New Castle County, Delaware. It agrees anatomically with pachycormid scapulocoracoids but is relatively small, measuring only 67mm in anteroposterior length despite being a major portion of the bone. By way of contrast, the scapulocoracoid of KUVP 60692 (Friedman et al 2010) is more than 200mm in its anteroposterior length.

Furthermore, NJSM differs in detail from scapulocoracoids of both *Bonnerichthys* and *Protosphyraena*, the two pachycormid genera known from the Late Cretaceous of North America. As is apparent in Figure 3, the preserved portions of the scapulocoracoids of KUVP 60692 and NJSM 14668 have similar morphologies. However, the facets for the posterior radials lie along a curved line in NJSM 14668 (which is not distorted) but are in a straight line in both *Bonnerichthys* and *Protosphyraena*. This difference affects angles between the anterior and posterior radial facets, as is evident from Table 1 and Figure 3.

TABLE 2A. Lithostratigraphic relationships of Wenonah & Marshalltown Formations.

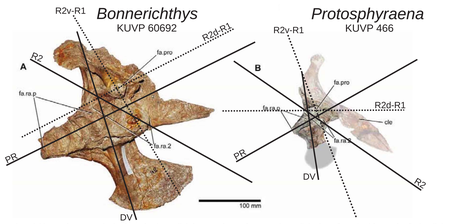
NEW JERSEY AND DELAWARE	NORTH CAROLINA	ALABAMA - MISSISSIPPI	ARKANSAS AND EAST TEXAS	TEXAS (AUSTIN AREA)	SOUTH DAKOTA (BLACK HILLS)	SOUTH DAKOTA (MISSOURI R.)
WENONAH FORMATION	BLACK CREEK GROUP	DEMOPOLIS CHALK (BLUFFPORT MARL MEMBER)	MARLBROOK MARL	CORSICANA FORMATION	PIERRE SHALE (LOWER UNNAMED SHALE MEMBER)	PIERRE SHALE (VIRGIN CREEK FORMATION)
			OZAN FORMATION			PIERRE SHALE (VERENDRYE FORMATION)
MARSHALLTOWN FORMATION		DEMOPOLIS CHALK (UPPER MASSIVE UNIT)	ANNONA CHALK	BERGSTROM FORMATION		

TABLE 2B. Bio- and chronostratigraphic relationships of these formations.

LITHO-STRATIGRAPHY	BIOSTRATIGRAPHY					CHRONO-STRATIGRAPHY
	EXOGYRA ZONES	PLANKTONIC FORAMINIFERA	*BOLIVINOIDES* ZONES	*BACULITES* ZONES	OTHER AMMONITES	
WENONAH FORMATION	*EXOGYRA*	*RUGOTRUNCANA SUBCIRCUMNOIDIFER*	*BOLIVINOIDES MILARIS*	*BACULITES REESIDEI*	*NOSTOCERAS STANTONI*	EARLY MAASTRICHTIAN
MARSHALLTOWN FORMATION	*PONDEROSA*	*GLOBOTRUNCANA CALCARATA*	*BOLIVINOIDES DECORATUS*	*BACULITES CUNEATUS*	*MANAMBOLITES RICENSIS*	LATE CAMPANIAN

After Cepek et al. 1968; Copeland 1972; Crandel 1958; Eaton, 1987; Gallagher et al. 1986; Gill & Cobban 1965; Lilligraven & McKenna 1986; Mancini 1984; Mancini et al. 1984; Pessagno 1967; Petters, 1976; Schoch et al. 1990; Shannon, 1974; Young 1986.

FIGURE 3. Biometric axes for the scapulocoracoid.



cle - cleithrum; fa.pro - articular facet for 1st radial; fa.ra.p - facets for posterior radials; fa.ra.2 - paired facets for 2nd radial. Anterior is to the right for all three scapulocoracoids. KUVP specimens after Friedman et al. 2010 (supporting online material)

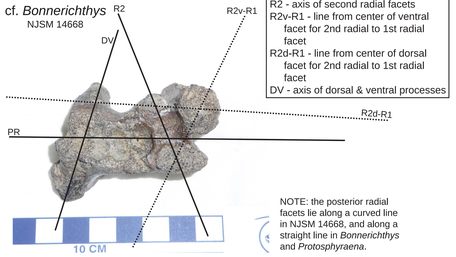


TABLE 1. Scapulocoracoid biometrics. Axes are identified above.

angle measured	angle measurement (in degrees)			
	Bonnerichthys KUVP 60692	*Protosphyraena* KUVP 466	*Protosphyraena* EPC 1995-12	cf. *Bonnerichthys* NJSM 14668
PR - R2	55	64	69	68
R2d-R1 - R2v-R1	86.5	69.5		68
PR - R2v-R1	86	81.5		64.5
R2 - R2d-R1	56	34.5		64.5
R2 - R2v-R1	30.5	35		48
PR - DV	81	69		72.5

DISCUSSION: While the standard practice would be to refer both specimens to *Bonnerichthys gladius*, the only described species of the genus, there are reasons to reserve judgment about such a referral. While the fin clearly pertains to *Bonnerichthys*, the scapulocoracoid differs significantly from that of *Bonnerichthys*. However, it also differs from the scapulocoracoid of *Protosphyraena*, and cannot readily be assigned to the latter genus. At the same time, the absence of other elements referable to *Protosphyraena* (teeth, rostra) despite their common occurrence in western faunas makes it seem unlikely that the scapulocoracoid could belong to this genus. Its size is consistent with that of the fin fragment.

All of the Late Cretaceous pachycormid fins from the Gulf and Atlantic coasts which we have examined have the distinctive anatomy characteristic of *Bonnerichthys*. All other fin fragments from outside the Seaway known to us (numerous fin fragments are known from the Ozan Formation in Texas) are similar in size to the fin described herein. We speculate that there was a distinctively small, coastal species of pachycormid living along the Gulf and Atlantic coasts during the latest Cretaceous (Table 2); that this species was planktivorous (given the absence of *Protosphyraena* teeth in these deposits); and that it is more closely related to *Bonnerichthys* than to *Protosphyraena* (Figure 4).

Differences in scapulocoracoid biometrics may reflect differences in the orientation or mobility of the fin relative to the body. If our attributions of the two NJSM specimens are correct, and if they belong to a single taxon of relatively small size (as we suspect), then this taxon may represent a fish that moved in a much different manner from that of *Bonnerichthys gladius*.

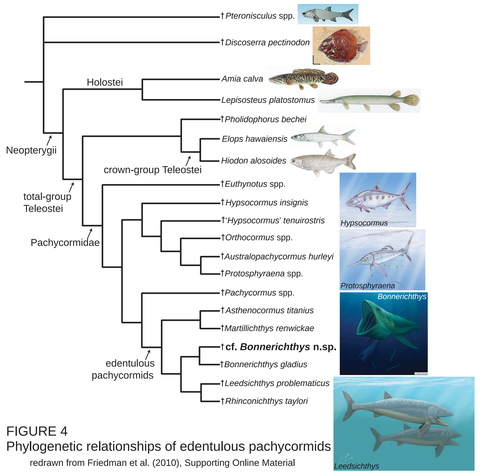


FIGURE 4
Phylogenetic relationships of edentulous pachycormids
redrawn from Friedman et al. (2010), Supporting Online Material

ACKNOWLEDGEMENTS: The authors are grateful for the contributions of Rich Heintz, Don Baird, J. D. Stewart, and Mike Everhart. The authors are grateful for the continuing support of the Friends of the New Jersey State Museum. Poster printing costs were underwritten by the Department of Animal Biology, School of Veterinary Medicine, University of Pennsylvania.

BIBLIOGRAPHY

Cepek, P., W. W. Hay, B. A. Masters and T. R. Worsley. 1968. Calcareous plankton in samples from field trip stops. Guidebook for the Sixth Annual Field Trip, Alabama Geological Society:33-41.
Copeland, C. W. 1972. Upper Cretaceous Series in Central Alabama. Guidebook for Field Trips, Southeastern Section of Geological Society of America, 21st annual meeting, Pages 2-1 to 2-24.
Crandel, D. R. 1958. Geology of the Pierre area, South Dakota. U.S. Geological Survey Professional Paper 307:1-83.
Eaton, J. G. 1987. Campanian-Maastrichtian Boundary in the western interior of North America. Newsletters on Stratigraphy 18:31-39.
Friedman, M., K. Shimada, L. D. Martin, M. J. Everhart, J. Liston, A. Maltese, and M. Triebold. 2010. 100-Million-Year Dynasty of Giant Planktivorous Bony Fishes in the Mesozoic Seas. Science 327:990-993 and supporting online material.
Gallagher, W. B., D. C. Parris, and E. E. Spamer. 1986. Paleontology, biostratigraphy, and depositional environments of the Cretaceous-Tertiary transition in the New Jersey coastal plain. Mosasaur 3:1-35.
Gill, J. R. and Cobban, W. A. 1966. The Red Bird section of the Upper Cretaceous Pierre Shale in Wyoming. U.S. Geological Survey Professional Paper 393-A:1-73.
Lillegraven, J. A. and McKenna, M. C. 1986. Fossil mammals from the "Mesaverde" Formation (Late Cretaceous, Judithian) of the Bighorn and Wind River Basins, Wyoming, with definitions of late Cretaceous North American Land-Mammal "Ages". American Museum Novitates 2840:1-68.
Mancini, E. A. 1984. Upper Cretaceous Planktonic foraminiferal biostratigraphy of western Alabama and eastern Mississippi. Geological Society of America, Abstracts with Programs 16:583.
Mancini, E. A., Smith, C. C. and Russell, E. E. 1984. Upper Cretaceous biostratigraphy of western Alabama and eastern Mississippi. Geological Society of America, Abstracts with Programs. 16:178.
Parris, D. C., B. S. Grandstaff, and W. B. Gallagher. 2007. Fossil fish from the Pierre Shale (Late Cretaceous): Clarifying the biostratigraphic record. Geological Society of America Special Paper 427:99-109.
Pessagno, E. A., Jr. 1967. Upper Cretaceous planktonic foraminifera from the western Gulf Coastal Plain. Palaeontographica Americana 5:245-445.
Petters, S. W. 1976. Upper Cretaceous subsurface stratigraphy of Atlantic coastal plain of New Jersey. Bulletin of the American Association of Petroleum Geologists 60:87-106.
Schoch, R. M., Craven, J. F., and Eldredge, M. P. 1990. Recent work on the stratigraphy and paleobiota of the Upper Cretaceous (Campanian and Maastrictian) Black Creek Group of the Carolinas. Geological Society of America, Abstracts with Programs 22:A43.
Shannon, S. W. 1974. Extension of the known range of the Plesiosauria in the Alabama Cretaceous. Southeastern Geology 15:193-199. (Reprint Series 30 of Geological Survey of Alabama).
Stewart, J. D. 1988. Stratigraphic distribution of Late Cretaceous *Protosphyraena* in Kansas and Alabama: Articles in honor of Myrl V. Walker. Fort Hays Studies, New Series, Science Series 3 (10): 80-94.
Young, K. 1986. Cretaceous marine inundations of the San Marcos platform, Texas. Cretaceous Research 7:117-140.