

CHONDRICHTHYAN AND OSTEICHTHYAN PALEOFAUNAS FROM THE CRETACEOUS (LATE MAASTRICHTIAN) FOX HILLS FORMATION OF NORTH DAKOTA, USA: PALEOECOLOGY, PALEO GEOGRAPHY, AND EXTINCTION

JOHN W. HOGANSON

State Paleontologist Emeritus, North Dakota Geological Survey, 600 E. Boulevard Ave, Bismarck, ND 58505
jhoganso@nd.gov

and

J. MARK ERICKSON

Chapin Professor Emeritus, Geology Department, St. Lawrence University, Canton, NY 13617
meri@stlawu.edu

and

F. D. HOLLAND, JR.

Professor Emeritus, Harold Hamm School of Geology and Geological Engineering, University of North Dakota, Grand Forks, ND 58201

ABSTRACT

As part of a study of the Vertebrata found in the Late Cretaceous (Early Maastrichtian to Middle Late Maastrichtian) Fox Hills Formation, 48 sites in western and central North Dakota were collected to interpret the chondrichthyan and osteichthyan paleofaunas. Based mostly on teeth, 19 shark species, 16 skate and ray species, and one ratfish species were recognized. Of those, three taxa are new, including *Cretalamna feldmanni* n. sp., “*Myliobatis*” *foxbillsensis* n. sp., and *Dasyatis northdakotaensis* n. sp. New chondrichthyan species occurrences for the Fox Hills Formation include: *Squalus ballingsloevensis*, *Plicatoscyllium derameei*, *Cretorectolobus olsoni*, *Carcharias* cf. *C. tenuiplicatus*, *Cretalamna feldmanni* n. sp., *Paranomotodon toddi*, *Squalicorax pristodontus*, *Palaeogaleus navarroensis*, *Archaeotriakis rochelleae*, *Paraorthacodus andersoni*, *Synechodus turneri*, *Walteraja exigua*, *Dasyatis northdakotaensis* n. sp., *Rhombodus levis*, “*Myliobatis*” *foxbillsensis* n. sp., and morphotypes of placoid scales and dermal denticles.

Twenty species of bony fishes were identified from teeth and other skeletal parts, two were vertebral morphospecies, two were based on scales, and four were recognized from otoliths. New osteichthyan occurrences in the Fox Hills Formation include: a lepisosteid, *Melvius* sp., *Cyclurus fragosus*, *Protosphyraena* sp., *Belonostomus longirostris*, *Xiphactinus vetus*, *Paratarpon?* sp., *Pollerspoeckia siegsdorfensis*, cf. *Bathylagus* sp., *Enchodus* cf. *E. ferox*, and “*Apogonidarum*” *maastrichtiensis*.

The Fox Hills Formation is Early Maastrichtian in Bowman County, southwestern North Dakota. The Bowman County sites yielded the oldest fossils of this study. Sites in the Fox Hills type area in north-central South Dakota and south-central North Dakota are Middle Late Maastrichtian based on the presence of *Hoploscaphites nicolletii* and *Hoploscaphites nebrascensis* Ammonite Zones and the *Wodehousia spinata* Pollen Zone. Age relationships of these fossil sites suggest temporal range extensions for several of the Fox Hills fish taxa.

Fox Hills fishes were derived from deep and shallow marine, brackish, and freshwater habitats. Five groupings were identified based on qualitative assessment of these habitat preferences. These groupings are: “offshore marine,” “nearshore marine,” “brackish water/estuarine–strong tidal influence,” “brackish water/estuarine–weak tidal influence,” and “riverine/lagoonal–strong freshwater influence.” Tooth morphology and comparison to modern analogs indicate presence of the following feeding types: omnivore, general invertebrate, molluscivore, pelagic piscivore, benthic piscivore, and scavenger. Species representing all feeding types occur in each of the five habitat groupings. Feeding competition was thus partitioned by habitat preference. When coupled with paleogeographic distribution information, the Fox Hills fish fauna indicates that some taxa represent a recurring assemblage of species that have a “large-river delta” habitat preference, as found today on major deltas of most continents.

Paleogeographic conditions in the Western Interior Seaway (WIS) were dominated by the physiographic conditions of the Hell Creek Delta and Dakota Isthmus complex, which is composed of lagoons, estuaries, and barrier island shorelines. The Fox Hills fish paleofauna includes taxa restricted to the WIS and those that also occurred in the Texas Gulf Coast, Mississippi Embayment, Atlantic Coastal Plain, Greenland, and Sweden. Pelagic, deep marine lamniform species were cosmopolitan and ranged to Europe

and North Africa. The Fox Hills fish fauna is most similar to the fish faunas of the Maastrichtian Kemp Formation, Texas, Severn Formation, Maryland, and Navesink and New Egypt formations, New Jersey.

The Fox Hills paleofauna documents fish extinction at the close of the Cretaceous. None of the 36 chondrichthyan species and none of the 20 osteichthyan species recovered from the Fox Hills Formation are found in the Paleocene worldwide. 58% of Fox Hills chondrichthyan and 77% of osteichthyan genera, and 20% of chondrichthyan and 33% of osteichthyan families, did not survive after the Cretaceous. Support for this interpretation is provided by comparison of the Fox Hills paleofauna to the Paleocene Cannonball Formation paleofauna in North Dakota. None of the 13 Cannonball chondrichthyan species, nor any of the four Cannonball osteichthyan species, occur in the Fox Hills Formation. Thirteen chondrichthyan genera (*Squatina*, *Squalus*, *Ginglymostoma*, *Carcharias*, *Odontaspis*, *Cretalamna*, *Palaegaleus*, *Galeorhinus*, *Paraothacodus*, *Synechodus*, *Myliobatis*, *Dasyatis*, and *Ischyodus*) range across the K-Pg boundary.

INTRODUCTION

Sedimentological and paleontological signatures of the last fluctuations of the Western Interior Seaway (WIS) in the northern midcontinent during the Late Cretaceous are documented by the Fox Hills Formation, and the Breien Member and Cantapeta Tongue of the Hell Creek Formation. The Fox Hills Formation is widespread with outcrops in North Dakota, South Dakota, Montana, Wyoming, and Colorado (Text-fig. 1). Originally described as "Formation No. 5" of the Cretaceous sequence (Meek and Hayden, 1856), the historical type area lies in the Missouri River Valley and its tributaries in north-central South Dakota (Waage, 1968). Exposures of the marine Breien Member and Cantapeta Tongue of the Hell Creek Formation are restricted to the Missouri River Valley in south-central North Dakota (Hoganson and Murphy, 2002). The Fox Hills Formation and marine tongues of the Hell Creek Formation consist of poorly consolidated mudstone, siltstone, and sandstone. These represent shoreline facies of the waning Pierre-Fox Hills Sea at the end of the Late Cretaceous in the North American Midcontinent (Waage, 1968; Gill and Cobban, 1973; Erickson, 1978, 1999; Murphy et al., 2002; Hoganson and Murphy, 2002).

Fox Hills strata intercalate vertically and laterally with the complexly interbedded delta-platform facies of the Hell Creek Formation in south-central North Dakota (Text-figs. 2–4; Feldmann, 1972a; Erickson, 1992; Peppe and Erickson, 2002; Murphy et al., 2002; Hoganson and Murphy, 2002). At that time, progradation of the Hell Creek Delta and sea level fluctuations created the Dakota Isthmus across the narrow Western Interior Seaway in what is now North Dakota and South Dakota. The dynamics of this depositional system resulted in the marine tongues, including the Breien Member and Cantapeta Tongue, in the Hell Creek Formation (Hoganson and Murphy, 2002; Murphy et al., 2002) and estuarine and lagoonal facies in the underlying and lateral coastal deposits of the Fox Hills Formation (Feldmann and Palubniak, 1975; Klett and Erickson, 1976; Bouchard et al., 2002). The resulting mosaic of delta platform and marginal marine facies, and their included fossils, have been of interest and a challenge to stratigraphers and paleontologists

(Erickson, 1992; Johnson et al., 2002; Murphy et al., 2002; Hartman et al., 2014).

Numerous faunal and floral studies have been completed to help define the complex interaction of marine, marginal marine, and terrestrial communities in the Hell Creek Delta platform and Fox Hills marine setting. Fox Hills Formation marine and brackish water invertebrate faunas have been thoroughly studied beginning over 150 years ago with the exploration of Meek and Hayden (1856, 1861), that culminated in the work of Meek (1876). Several works have modernized knowledge of major invertebrate groups, including Foraminifera (Mello, 1969), Bivalvia (Feldmann, 1967, 1972a; Speden, 1970; Feldmann and Palubniak, 1975; Erickson, 1978), Gastropoda (Erickson, 1974), and Cephalopoda (Waage, 1968; Feldmann, 1972a; Landman and Waage 1993; Landman et al., 2013). Other studies that help to define the Fox Hills invertebrate fauna have included treatment of echinoids (Holland and Feldmann, 1967; Rendall et al., 2010), crabs (Feldmann et al., 1976; Tucker et al., 1987; Crawford et al., 2006), Bryozoa (Cuffey et al., 1981), and trace fossils (Daly, 1991). The megafloora of the Fox Hills Formation was identified by Peppe and Erickson (2002) and Peppe et al. (2007). Erickson et al. (2010) reported on the palynomorphs from the Linton Member of the formation.

Leonard (1912) provided the earliest report of vertebrate fossils from the Fox Hills Formation in North Dakota when he mentioned the discovery of a large fish tooth and a *Mosasaurus* tooth (identified by C. W. Gilmore) from an exposure of the formation along the Cannonball River in Sioux County. In their investigation of the paleoecology of Fox Hills oyster assemblages from Emmons County, North Dakota, Feldmann and Palubniak (1975) illustrated otoliths, a chimaeroid tritor, and crocodile remains. The amphibian, reptilian, and avian fauna of the Fox Hills Formation in North Dakota was defined by Hoganson and Erickson (2004) and Hoganson et al. (1994, 1996, 2007). Fish fossils recovered from the Fox Hills Formation in South Dakota were reported by Waage (1968), Bouchard (1990), Cicimurri (1998), Cicimurri et al. (1999), and Becker et al. (2004, 2009). Hoganson et al. (2015) described chimaeroid remains from the Fox Hills Formation in Colorado.