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XIPHOSURID FOSSILS FROM THE PENNSYLVANIAN BEEMAN FORMATION, OTERO COUNTY, NEW MEXICO

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ABSTRACT—We document body fossils of the xiphosurid (horseshoe crab) *Euproops danae* Meek and Worthen from lacustrine black shale of the Missourian interval of the Beeman Formation near Alamogordo, New Mexico. These xiphosaurids, associated with conchostracans, bivalves, microconchids, fish scales and a paleoflora, are from a likely freshwater lake deposit. This is the first report of *E. danae* from the western USA and the first documentation of xiphosurid body fossils in the Pennsylvanian of New Mexico.

INTRODUCTION

Xiphosurids (Order Xiphosura), the true horseshoe crabs, are chelicerate arthropods with a fossil record that goes back to the Late Ordovician (Ashgillian, ~445 Ma) of central Canada (Rudkin et al., 2008). They are generally considered to be a sister group to eurypterids and arachnids within the Euchelicerata clade, although other alternatives have also been proposed (Dunlop, 2010). Their body and trace fossils are particularly well known from Carboniferous and Permian strata in North America and Europe (e.g., Filipiak and Krawczyński, 1996; Babcock and Merriam, 2000).

In New Mexico, the only late Paleozoic record of xiphosurids is of their trace fossils, notably their well-known walking traces (trackways) assigned to the ichnogenus *Kouphichnium* (e.g., Minter and Braddy, 2009). We document xiphosurid body fossils discovered in Pennsylvanian strata in the Sacramento Mountains of Otero County, New Mexico (Fig. 1). These specimens are the first occurrence of Pennsylvanian xiphosurid body fossils known from New Mexico.

PROVENANCE

The xiphosurid fossils documented here were collected at NMMNH (New Mexico Museum of Natural History, Albuquerque) locality 9109 in the Pennsylvanian Beeman Formation in La Luz Canyon, northeast of Alamogordo (Fig. 1). These fossils came from an approximately 2-m-thick interval of black shale at the base of a 10 m-thick, coarsening upward lake-fill deposit. The deposit also yields conchostracans, bivalves, microconchids, fish scales and a paleoflora. The floral elements are the most abundant fossils in the deposit. The flora is dominated by plants typical of seasonally dry climatic conditions, including common cordaitalean foliage with a wide variety of less common elements including *Sphenopteridium*, *Charliea*, *Taeniopteris* and walchian conifers; the flora also includes uncommon taxa typical of wet substrates--*Pecopteris* tree ferns, the pteridosperms *Alethopteris* sp., *Neuropteris* sp., and cf. *Macroneuropteris scheuchzeri*, and the calamitalean foliage *Annularia* cf. *spinulosa* and a small form similar to *A. asteris*, which probably lived only along the margins of the water body. The stratigraphic section that includes this deposit is in the middle part of the Beeman Formation and thus is of Missourian age (Pray, 1961; Raatz and Simo, 1998).

DESCRIPTION AND IDENTIFICATION

Two xiphosurid body fossils were collected at NMMNH locality 9109 and are described here. NMMNH P-67802 is a part/counterpart of an opisthosoma (thoracetron) in dorsal aspect (Fig. 2A-B). The opisthosoma is broad and rounded in appearance, with a width of ~16 mm. It consists of an axial column, pleural lobes and a marginal rim. The axial column is ~4 mm wide with a preserved length of 8 mm. It has a prominent posterior lobe containing a large tubercle at its center. The tubercle has at its anterior border a short, anteriorly directed spine. The lobe has sharply angled lateral borders that give it a sub-triangular appearance. The telson is not preserved. The axial column is missing the anterior first and second rings. There is a median axial node on the third ring. The third through fifth rings also contain paired lateral bosses. The pleural lobes are divided into segments by transverse ribs, some of which extend onto the marginal rim and appear as spines. The opisthosomal rim is ~2 mm wide and shows a scalloped border particularly at its posterior.

The second specimen, NMMNH P-67801, is also a part/counterpart of an opisthosoma (thoracetron) in dorsal aspect (Fig. 2C). It is comparable in morphology to P-67802, but not as well preserved. It too has a width of ~16 mm. There is a small (~2 mm) molluscan shell preserved midway on the right border of the axial column.

These specimens, although incomplete, show diagnostic features that justify assignment to *Euproops danae* Meek and Worthen, 1865, including a median tubercle on the third ring of the axial column, a spined tubercle on the posterior lobe of the axial column and pleural ridges that end in marginal spines (e.g., Størmer, 1955; Ambrose and Romano, 1972; Anderson, 1994; Anderson and Selden, 1997; Babcock and Merriam, 2000). We note, however, that the genus *Euproops* is currently under review, with the possibility being that supposed separate species may represent various ontogenetic stages within a single species (Haug et al., 2012).

DISCUSSION

Euproops danae is a xiphosurid previously documented from Illinois (Fisher, 1977, 1979), Indiana (Raymond, 1944), Kansas (Babcock and Merriam, 2000), Ohio (Murphy, 1970), Pennsylvania (Raymond, 1944), Nova Scotia (Copeland, 1957), Great Britain (Ambrose and Romano, 1972; Anderson 1994), Germany (Brauckmann, 1982) and some other European locations (France, Czech Republic, Ukraine: J. Schneider, written commun., 2014). Its New Mexico record documented here thus appears to be the first occurrence of *E. danae* in the western USA.

The paleoecology of the site that yielded the xiphosurid fossils, in a broad sense, is best indicated by the combination of the sedimentary environment and the fossil flora. The shale and siltstone layers from which the animal and plant fossils are derived comprise a 10-meter thick coarsening upward sequence. At the base, a dark, organic-rich shale rests directly on medium-grained, ripple laminated sandstone. The upper parts of the basal sandstone contain foliage of the coniferophyte *Cordaites*, and there are thin layers enriched in fine-grained sediment that are also mudcracked. The dark shale is clay rich and contains a well preserved flora dominated by cordaitalean foliage, with a moderately diverse assemblage of subsidiary taxa, possibly washed into the deposits, the most common of which mirror *Cordaites* in being typical of seasonally dry environments: *Walchia*, *Sphenopteridium*, *Charliea* and *Taeniopteris*. This flora includes a small mixture of more typically wetland plants, such as the pteridosperms *Neuropteris*, *Macroneuropteris*, and *Alethopteris*, calamitalean foliage, and the tree fern foliage, *Pecopteris*. The flora changes little upward, becoming increasingly fragmentary and allochthonous in character as the sediment becomes both coarser and less organic rich. The deposit terminates in a thin, 3-cm-thick coaly layer that is overlain by 25 cm of ripple-bedded sandstone.

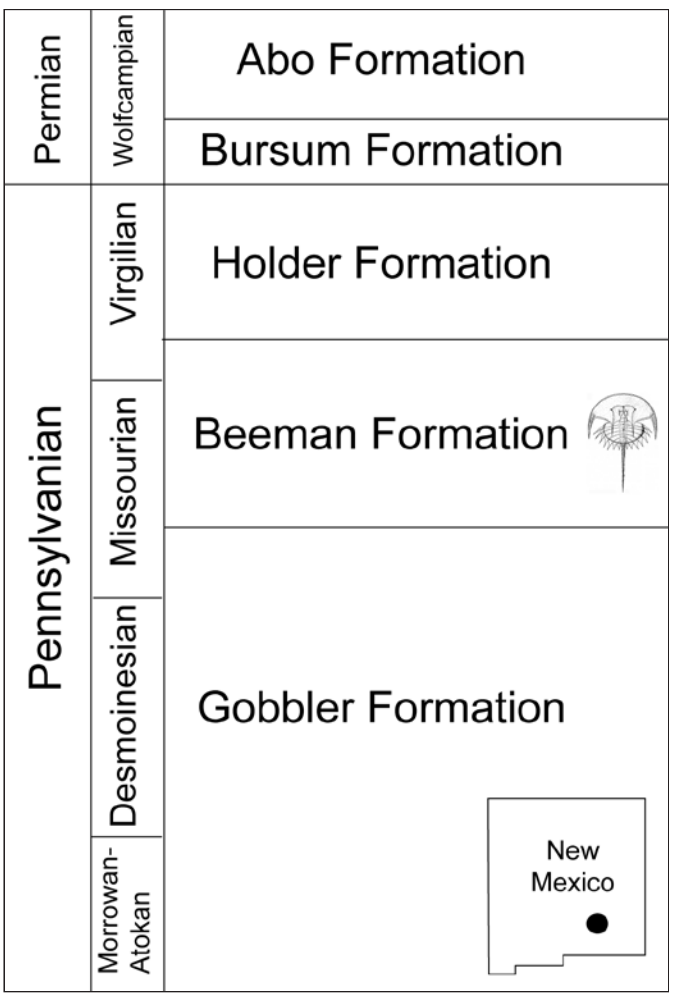

FIGURE 1. Late Paleozoic stratigraphy in the Sacramento Mountains (after Raatz and Simo, 1998) showing stratigraphic position of xiphosurid specimens (drawing of *Euproops*, after Anderson, 1994) in Beeman Formation.

The thinly laminated shale (green to black in color) also contains a low-diversity fauna composed of bivalves, microconchids (spirorbids), and conchostracans, in addition to the xiphosurids. This fauna is not diagnostic of a particular salinity level, although it suggests that conditions were certainly not marine, though the presence of xiphosurids suggests a connection to a marine environment. These animals would be consistent with slight salinity to freshwater. Conchostracans, in particular, are consistent with conditions of intermittent dryness in the surrounding landscape.

There is insufficient lateral exposure to characterize the geometry of this deposit, but the general features – a basal shallow-water, ripple laminated sandstone with evidence of subaerial exposure, suggests a channel with intermittent periods of low water. This channel was abandoned and flooded and may have become a lake, indicated by the organic shales at the base. Its proximity to marine strata (above and below) and the presence of xiphosurids suggests this was a coastal lake. Subsequent filling ensued and a swampy habitat developed at this site near as the former channel filled.

The mixture of plants typical of seasonally dry environments with those typical of wet substrates is characteristic of many Pennsylvanian floras described from the western parts of the US, then equatorial Pangea (see review in DiMichele, 2014). Dark, organic-rich shales containing floras and faunas similar to the one described here have been reported elsewhere from the Missourian of central New Mexico (e.g., Lerner et al., 2009), where they also appear to represent small lakes, set in a background of climatic seasonality. This strongly differentiates the western regions of Pangea from the more central portions of the supercontinent (Tabor and Poulsen, 2008), where the wetter portions of glacial-interglacial cycles were marked by the formation of coal beds.

Euproops danae is a characteristic Carboniferous coal swamp form that is usually associated with freshwater habitats (e.g., Babcock and Merriam, 2000). The first published descriptions of *E. danae* were from the well known Pennsylvanian (Desmoinesian) Mazon Creek deposits of Illinois (Meek and

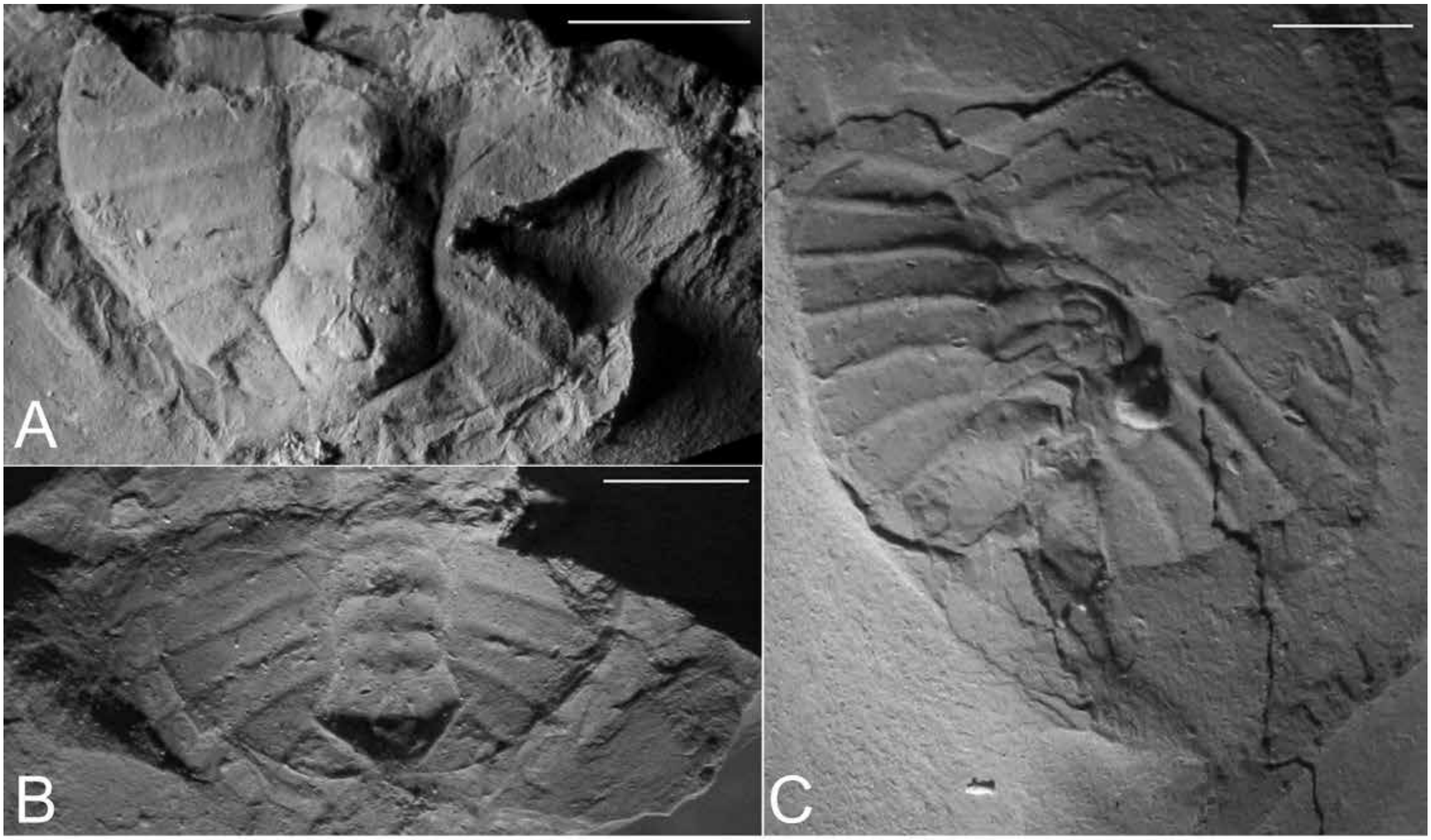

FIGURE 2. Specimens of *Euproops danae* from the Beeman Formation near Alamogordo, New Mexico. A-B, NMMNH P-67802, part and counterpart. C, NMMNH P-67801, part. Scale bars = 5 mm.

Worthen, 1865; Meek, 1867a, b) where they are preserved in siderite concretions. It's occurrence in Mazon Creek deposits is restricted to the freshwater Braidwood fauna, although it is sometimes found as fragmentary inclusions within coprolites of the marine Essex fauna (Mikulic, 1998). Preservational bias for *Euproops danae* being restricted to the Braidwood fauna can be excluded due to preservation being similar in both the Braidwood and Essex assemblages (Gray, 1988). Fisher (1979) suggested that *Euproops danae* was capable of subaerial excursions, although this was largely countered by Anderson (1994).

Xiphosurids in general have an overall poor body fossil record, which is due in part to their having a non-mineralized exoskeleton. There is also a poor representation in the fossil record of the depositional environments in which most fossil xiphosurids occur (Babcock et al., 2000). The New Mexico *Euproops* specimens appear somewhat unusual in regard to their mode of preservation as bedding plane compressions. *Euproops* is more typically seen preserved within concretions. The New Mexico specimens share comparable thoracetron widths, indicating that both individuals were of the same ontogenetic stage. Their fragmentary condition, however, makes it difficult to determine whether they were juveniles or adults, though they are likely adults based on the size data in Copeland (1957). It is possible that the New Mexico specimens are incomplete molts rather than having originated from dead individuals. Continued collecting within the Beeman Formation will hopefully provide more complete specimens.

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Anthropogenic "clast" in stream sediment in Sawmill Canyon east of Mayhill. *Photo courtesy of Ben Hallett.*