BROMALITES FROM THE MISSISSIPPIAN BEAR GULCH LAGERSTÄTTE OF CENTRAL MONTANA, USA

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Abstract—The Bear Gulch Lagerstätte (Mississippian: Chesterian) of central Montana is characterized by its extensive ichthyofauna. The vertebrate ichnofauna includes six morphotypes/ichnotaxa of bromalites: (1) morphotype A coprolites are large and ovoid to pear shaped; (2) morphotype B coprolites are elongate and triangular in shape; (3) morphotype C coprolites are elongate and rounded; (4) morphotype D coprolites are small, ovoid and composed of dense groundmass; (5) spiral coprolites; and (6) *Ostracobromus snowyensis* ichnogen. et ichnosp. nov, is ovoid and characterized by inclusions of multiple valves of ostracods set in a groundmass and is possibly a regurgitalite. The Bear Gulch assemblage provides a baseline for further work on Mississippian vertebrate bromalites.

INTRODUCTION

Sedimentary rocks of the Rocky Mountains yield one of the world's most extensive fossil records of Carboniferous marine and terrestrial life (Nelson and Lucas, 2011). The Bear Gulch Lagerstätte in the Big Snowy Mountains of Montana has been extensively studied (e.g., Horner and Lund, 1985; Lund et al., 1993, 2012; Schram and Horner, 1978; Schram, 1979; Grogan and Lund, 2002). Recent stratigraphic studies place this Lagerstätte in the Bear Gulch Limestone Member of the Tyler Formation (Porter et al., 2005; Nelson and Lucas, 2011) whereas most paleontological literature continues to refer this fauna to the Heath Formation (e.g., Lund et al., 2012). The Bear Gulch is Chesterian in age based on evidence from conodonts (Scott, 1973), palynomorphs (Cox, 1986), and diverse vertebrate and invertebrate faunas (Grogan and Lund, 2002). The fossils from the Bear Gulch Limestone include palynomorphs, algae, conulariids, sponges, brachiopods, bivalves, nautiloids, worms, arthropods, echinoderms and more enigmatic forms (e.g., *Sphenothallus*, *Typhloessus*). The most distinctive element of the Lagerstätte is the fossil ichthyofauna, which comprises more than 120 described taxa including an exceptionally diverse assemblage of chondrichthyans as well as a petromyzontiform, an acanthodian, many actinopterygians and several sarcopterygians (Horner and Lund, 1985; Lund et al., 1993; Grogan and Lund, 2002).

Zidek (1980) described spiral coprolites from Bear Gulch found in association with *Acanthodes lundi*. The purpose of this paper is to describe additional vertebrate bromalites from the Bear Gulch Limestone. Many bromalites occur in the Bear Gulch Limestone but in general they have previously not been collected or they have been discarded (B. Hawes, personal commun., 1995). Bill Hawes and Paula Ott collected and retained a small number of specimens (11), which are described here. The ichnofossil assemblage contains five morphotypes, one of which is distinct enough to be named as a new ichnogenus and ichnospecies. These specimens are considered to represent bromalites because they are discrete rounded bodies composed of phosphatic groundmass and fragmented fish material. The bromalites cannot be related to the Lagerstätte facies recognized by Grogan and Lund (2002). All specimens are preserved flattened on surfaces of split laminae of shale and are in the collection of the New Mexico Museum of Natural History and Science (NMMNH).

BROMALITES

Morphotype A

Morphotype A are large and ovoid to pear shaped with dimensions of up to 400 mm by 250 mm. NMMNH P-54188 is pear shaped and 49.7 mm long and 31 mm wide (Fig. 1A). One end is rounded and thicker, with a sharp margin, whereas the other end is more acute in shape, thinner and shows evidence of decay. Presumably one end was exposed above the sediment surface for a longer period than the other and subjected to deterioration. This bromalite contains a large amount of fish material in a phosphatic groundmass. There is a slight indication of a spiral structure. NMMNH P-63718 is similarly pear shaped with a length of 51 mm and a width of 34 mm, with an inferred maximum thickness above the sediment interface of 3 mm (Fig. 1D). The bromalite contains many fish scales, and there is scattered debris around the margin that indicates some decay prior to fossilization.

The third specimen (NMMNH P-54189) is 400 mm long and 250 mm wide and is largely covered by a thin lamina of shale except for an area of 80 mm by 28 mm (Fig. 1C). A halo of small fragments, including fish scales, indicates that the bromalite decayed on the sediment surface. NMMNH P-54191 preserves half a bromalite on the margin of a piece of matrix with maximum dimensions of 48 and 27 mm (Fig. 1B). The specimen seems to be weathered and contains abundant fish debris in a phosphatic groundmass.

This morphotype is considered to represent a coprolite because of the presence of abundant fish debris preserved within a phosphatic groundmass in a discrete rounded body. Given the diversity of the ichthyofauna in the Lagerstätte it is not possible to match the coprolite with a producer.

Morphotype B

The bromalites of morphotype B are elongate and triangular in shape. NMMNH P-54135 is elongate and tapering and contains a large number of scales, some of which are imbricated. The coprolite is 31.5 mm long and 22.1 mm at its widest point and 4-5 mm thick (Fig. 1E). This morphotype is also considered to represent a coprolite on the basis of abundant fish debris preserved within a phosphatic groundmass in a discrete rounded body. It is not clear which fish produced this coprolite.

Morphotype C

Morphotype C bromalites are elongate and rounded. NMMNH P-54133 is 36 mm long and a maximum width of 12 mm (Fig. 1F). It is elongate and ovoid in cross section with a thin, right angular extension that is 21 mm long. An area of the other end of the bromalite has fallen out, leaving a partial mold. The bromalite contains abundant phosphatic groundmass and little bone material. NMMNH P-54137 is an elongate and irregularly-shaped bromalite lacking its margins, which were damaged during collection (Fig. 1G). The abundance of phosphatic ground-

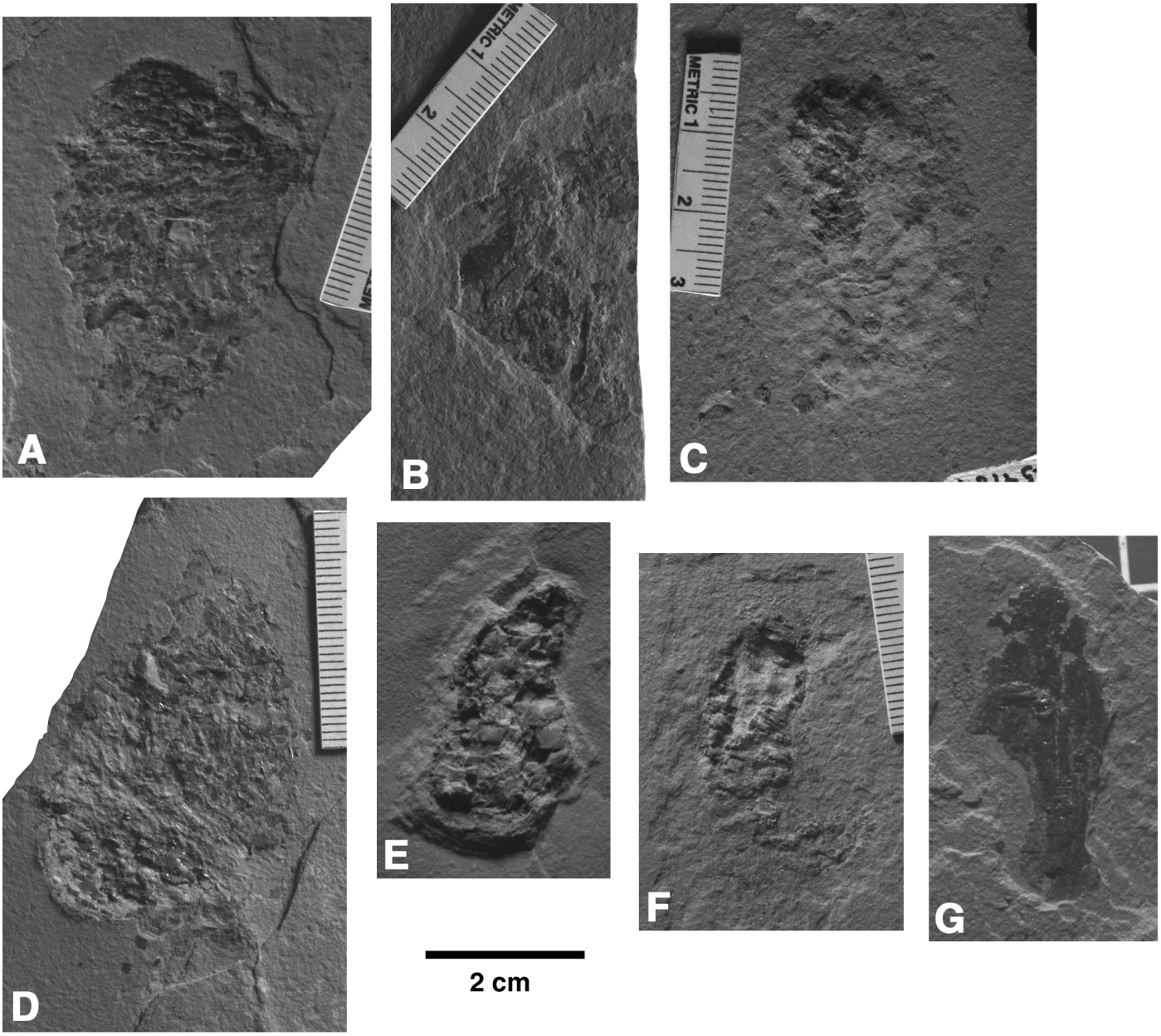

FIGURE 1. **A-D**, Morphotype A large ovoid coprolites, **A**, NMMNH P-54188l; **B**, NMMNH P-54191; **C**, NMMNH P-54189; and **D**, NMMNH P-63718. **E**, Morphotype B triangular coprolite, NMMNH P-54135. **F-G**, Morphotype C elongate narrow coprolites, **F**, NMMNH P-54133 and **G**, NMMNH P-54137.

mass and the relative paucity of bone material indicates that morphotype C represents a coprolite. Many members of the diverse Bear Gulch ichthyofauna could have produced this coprolite.

Morphotype D

Morphotype D bromalites are small, ovoid and composed of a dense phosphatic groundmass. NMMNH P-54192 has a length of 14 mm, a maximum width of 10 mm and a thickness of 2-3 mm (Fig. 2A). There is evidence of some decay around the margins. NMMNH P-54136 (Fig. 2B) is ovoid with a thin, sinuous extension at one end. The main body of the bromalite is 13 mm long and 8 mm wide, with the extension being 8 mm long. NMMNH P-54138 is weathered and may pertain to this morphotype. It is 12 mm long and 9 mm wide and contains more fish debris than the other specimens of this morphotype (Fig. 2C). The presence of abundant phosphatic groundmass in a rounded mass indicates that morphotype D represents a coprolite but its producer is not clear.

Ostracobromus, ichnogen. nov.

Type species: *Ostracobromus snowyensis* Hunt et al., 2012.

Included species: Known only from the type species.

Etymology: From the Greek *ostrako* (shell) for the presence of ostracode valves and the Greek *bromos* (food).

Distribution: Mississippian of Montana.

Diagnosis: Bromalite that differs from other ichnogenera in being ovoid in lateral view and thin in cross section and characterized by inclusions of multiple valves of ostracods set in a groundmass.

Discussion: The presence of ostracod valves in a phosphatic groundmass indicates that this ichnotaxon represents a bromalite (Hunt, 1992). There is some evidence that *Ostracobromus* is a regurgitalite rather than a coprolite: (1) abundance of ostracod valves which would be difficult to digest; and (2) some valves are still articulated, suggesting a relatively short period within the digestive tract. It is probable that the producer of *Ostracobromus* was a vertebrate given its relatively large

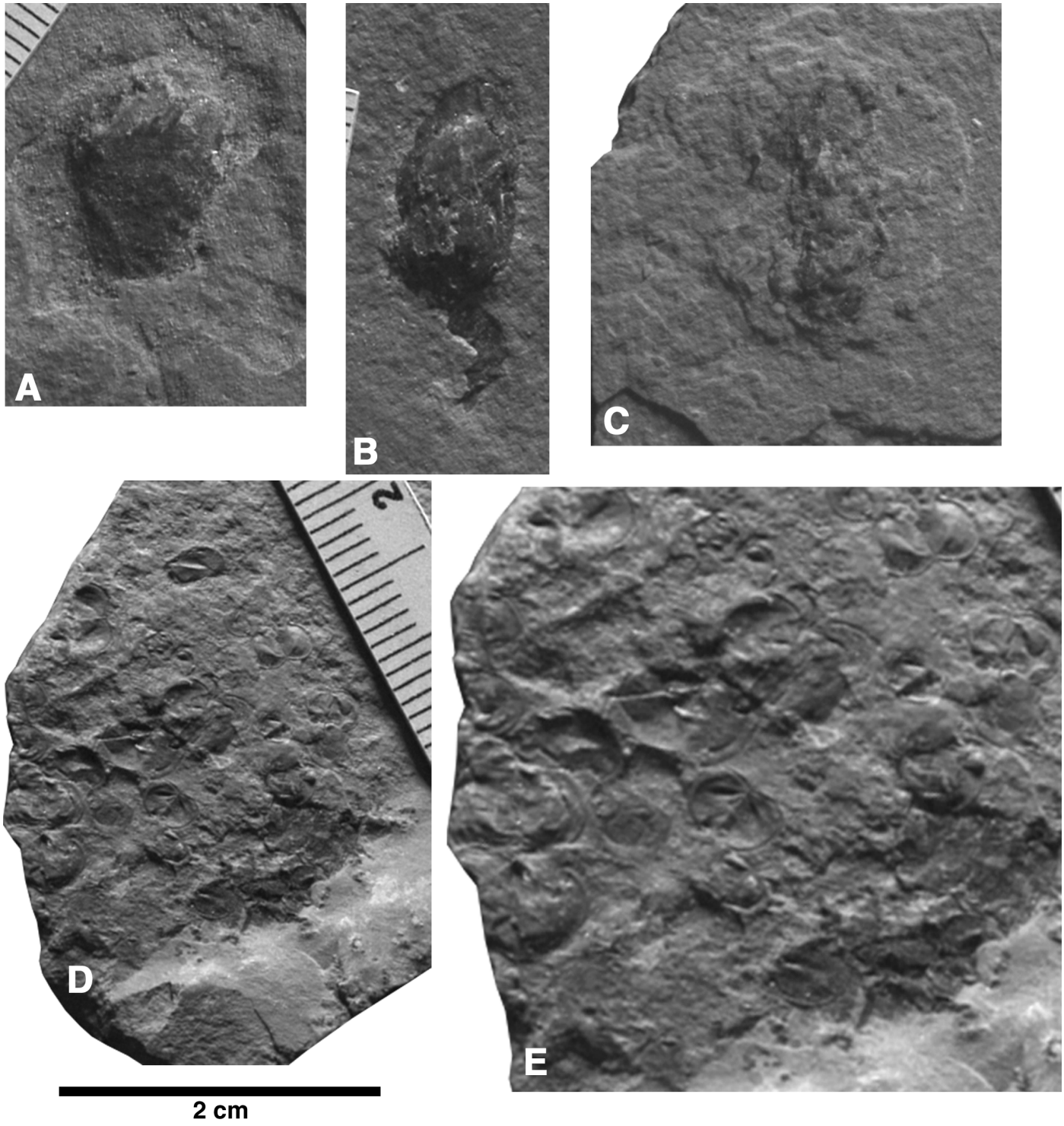

FIGURE 2. **A-C**, Morphotype D small ovoid coprolites, **A**, NMMNH P-54192; **B**, NMMNH P-54136; and **C**, NMMNH P-54138. **D-E**, *Ostracobromus snowyensis* ichnogen. et ichnosp. nov., NMMNH P-54134, holotype, in **D**, overview and **E**, close up.

size. The ichthyofauna of the Bear Gulch Lagerstätte is extremely diverse, so the number of potential producers is large and could range from one of the numerous chondrichthyans to a duraphagous palaeoniscoid.

***Ostracobromus snowyensis*, ichnosp. nov.**

Holotype: NMMNH P-54134 (Fig. 2D-E).
Etymology: For the type area of the Big Snowy Mountains.
Type locality: Big Snowy Mountains, Montana.
Type horizon: Bear Gulch Limestone Member of the Tyler Formation (Mississippian: Chesterian).
Distribution: As for genus.
Referred specimens: None.
Diagnosis: As for genus.
Description: NMMNH P-54134 (Fig. 2D-E) preserves a partial coprolite on the edge of a piece of shale. The coprolite is of very low relief and preserved on a bedding plane and has maximum dimensions of

25 mm and 26 mm. It has rounded margins and is probably ovoid in shape. Single and connected ostracod valves, many complete, are abundant and preserved in different orientations (internal or external sides up) in a phosphatic groundmass (Fig. 2E).

Discussion: Sohn and Chatterjee (1979) reported ostracods from a Late Triassic vertebrate coprolite from India, but the Bear Gulch record is the first occurrence from the Paleozoic. Sohn and Chatterjee (1979) did not discuss the morphology of the coprolite that yielded the ostracods.

CONCLUSIONS

Several bromalite ichnofaunas have been described from the Pennsylvanian of the United States (e. g., Zangerl and Richardson, 1963; McAllister, 1988; Hunt, 1992; Lerner et al., 2009; Hunt et al., 2012a-c), the majority from Lagerstätten. The Bear Gulch bromalite assemblage is one of the few to be described from the Mississippian. The sample size from Bear Gulch is relatively small but it provides a baseline for further work on Mississippian vertebrate bromalites.

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