

A NEW MARINE COPROFAUNA FROM THE BEEMAN FORMATION (LATE PENNSYLVANIAN: LATE MISSOURIAN), SACRAMENTO MOUNTAINS, NEW MEXICO, USA

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Abstract—There are two important coprolites localities of Late Pennsylvanian age in central New Mexico-- the lagoonal Lagerstätten of the Kinney Brick quarry and the Tinajas locality. A new Late Pennsylvanian coprolite locality is from the Beeman Formation in the southeastern part of the state (Sacramento Mountains). The coprolites from the Beeman Formation weather out of the outcrop as three-dimensional specimens, whereas the bromalites from Kinney and Tinajas are flattened and recovered by splitting shale. The Beeman Formation is middle to upper Missourian in age based on fusulinids. The coprolite locality (NMMNH locality 3276) occurs in a road cut on the north side of NM Highway 82 where the Beeman is represented by a basinal marine facies. The Beeman coprofauna differs from Kinney and Tinajas in: (1) representing a basinal marine facies rather than lagoonal; (2) the majority of Beeman coprolites are spiral in form, representing chondrichthyans or sarcopterygians, whereas the Kinney and Tinajas assemblages are more diverse; (3) Beeman coprolites are preserved three-dimensionally and are relatively undeformed and readily separable from the matrix, whereas those from Kinney and Tinajas are compressed and occur in finely-laminated shale; and (4) there is currently no fish fauna known from the Beeman Formation, whereas Kinney, and to a lesser extent Tinajas, have yielded diverse ichthyofaunas. The Beeman coprolites may provide a baseline for comparison of basinal coprofaunas with those of lagoonal environments both in taphonomy and taxonomy and may indicate distinct differences in the ichthyofaunas that produced them. New coprolite ichnotaxa from the Beeman locality named here are *Kalocoprurus oteroensis* and *Bibliocoprurus beemanensis*, both new ichnogenera and new ichnospecies.

INTRODUCTION

New Mexico preserves an important record of Late Pennsylvanian coprolites from lagoonal Lagerstätten (Kinney Brick quarry, Tinajas locality) in the central portion of the state (Hunt, 1992; Lerner et al., 2009; Hunt et al., 2012a-b). A third, significant locality for vertebrate coprolites occurs in the Missourian Beeman Formation in the southeastern portion of the state (NMMNH locality 3276). This locality is in the Sacramento Mountains and yields a large number of coprolites from an open marine facies (Lucas et al., 2011). The coprolites from the Beeman Formation weather out of the outcrop as three-dimensional specimens, whereas the bromalites from Kinney and Tinajas are flattened and recovered by splitting shale. The purpose of this paper is to give a preliminary description of the new Beeman coprolite assemblage.

GEOLOGIC SETTING

Pray (1961) named the Beeman Formation for exposures in the Sacramento Mountains of southeastern New Mexico. The unit is up to 152 m thick and comprises principally argillaceous limestone and calcareous shale with minor sandstone and other limestone. The Beeman is middle to upper Missourian in age based on fusulinids (Pray, 1961). The coprolite locality (NMMNH locality 3276) occurs in a road cut on the north side of NM Highway 82 in the northern Sacramento Mountains. Here, the Beeman is represented by a basinal facies characterized by brown-gray to dark gray, very argillaceous or silty limestone interbedded with brown, gray and green calcareous shale (Pray, 1961; Raatz and Simo, 1998).

SYSTEMATIC ICINOLOGY

Liassocoprurus hawkinsi Hunt et al., 2007

Referred specimens: NMMNH P-42547 (Fig. 1A-D).

Description: Heteropolar macrospiral coprolite.

Discussion: NMMNH P-42547 is 52.9 mm long with an ovoid cross section with maximum widths of 23.9 mm and 19 mm. It is heteropolar and macrospiral and thus is assignable to *Liassocoprurus hawkinsi* (Hunt et al., 2007, fig. 5A-E).

Liassocoprurus ichnosp.

Referred specimens: NMMNH P-63501 (tip), NMMNH P-63502 (tip).

Description: Partial large coprolites that appear to represent the anterior end of spiraled coprolites with an ovoid cross section.

Discussion: NMMNH P-63501 has a maximum length of 32 mm and a maximum width of 23.4 mm, whereas NMMNH P-63502 has comparable dimensions of 26.2 mm and 17.9 mm, respectively. Based on overall morphology and size these two fragments probably represent *Liassocoprurus*.

Heteropolacoprurus texaniensis Hunt et al., 1998

Referred specimens: NMMNH P-63504, NMMNH P-63506, NMMNH P-63508, NMMNH P-63510, NMMNH P-63511, NMMNH P-63514 (Fig. 1I-K), NMMNH P-63524 (Fig. 1II-LL).

Description: Several specimens represent a heteropolar, microspiral coprolite that tapers anteriorly and whose widest point is at the termination of the tightly coiled segment (posterior spire of Hunt and Lucas, 2012) with a rounded cross section.

Discussion: The best preserved specimen is NMMNH P-63514 (Fig. 1I-K), which is an incomplete, elongate microspiral coprolite comparable to the holotype and referred specimens of *Heteropolacoprurus texaniensis* (Hunt et al., 1998, fig. 2C-L). This specimen is 20.1 mm long and 6.3 mm in diameter. NMMNH P-63524 is a broken segment of a coprolite representing the tightly coiled posterior anterior end of a co-

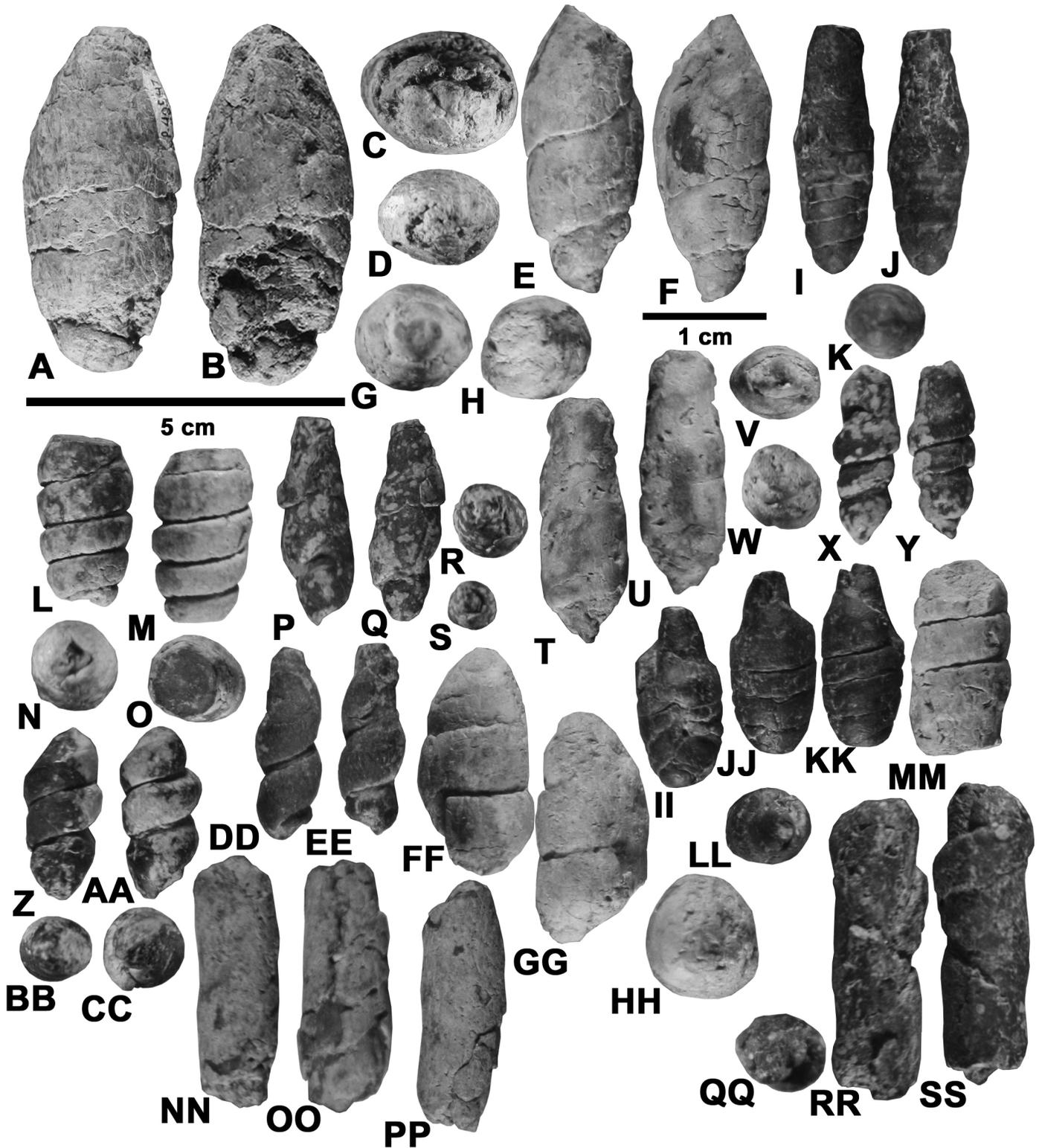


FIGURE 1. Selected coprolites from the Late Pennsylvanian (Missourian) Beeman Formation, Otero County, New Mexico. A-D, *Liassocoprus hawkinsi*, NMMNH P-42547, coprolite in A-B, axial and C-D, polar views. E-H, *Hyronocoprus* ichnosp., NMMNH P-63521, coprolite in E-F, axial and G-H, polar views. I-K, *Heteropolacoprus texaniensis*, NMMNH P-63514, coprolite in I-J, axial and K, polar views. L-O, *Hyronocoprus amphipola*, NMMNH P-63520, coprolite in L-M, axial and N-O, polar views. P-S, *Kalocoprus oteroensis*, NMMNH P-63511, coprolite in P-Q, axial and R-S, polar views. T-W, *Heteropolacoprus* ichnosp., NMMNH P-63517, coprolite in T-U, axial and V-W, polar views. X-CC, *Kalocoprus oteroensis*. X-Y, NMMNH P-63527, coprolite in axial views. Z-CC, NMMNH P-63523, coprolite in Z-AA, axial and BB-CC, polar views. DD-EE, *Kalocoprus oteroensis*, NMMNH P-63513, coprolite (holotype) in axial views. FF-HH, *Hyronocoprus amphipola*, NMMNH P-63519, coprolite in FF-GG, axial and HH, polar views. II-LL, *Heteropolacoprus texaniensis*, NMMNH P-63524, coprolite in II-KK, axial and LL, polar views. MM, *Hyronocoprus amphipola*, NMMNH P-63518, coprolite in axial view. NN-SS, *Bibliocoprus beemanensis*. NN-PP, NMMNH P-63515, coprolite in axial views. QQ-SS, NMMNH P-63503, coprolite (holotype) in QQ, polar and RR-SS, axial views.

proliterate that is 14.5 mm long and 6.9 mm in diameter (Fig. 1II-LL). The largest, well-preserved specimen (NMMNH P-63504) is 25.1 mm long and 9.9 mm wide. Smaller fragments suggest the occurrence of larger specimens.

Heteropolacoprus ichnosp.

Referred specimen: NMMNH P-63517 (Fig. 1T-W), NMMNH P-63522.

Description and discussion: Two specimens represent heteropolar, microspiral coprolites that are similar to *Heteropolacoprus*. NMMNH P-63517 (Fig. 1T-W) is a coprolite with a small short segment of tight coils and a similarity to *Kalocoprus* described below, but it differs in an acute posterior tip. NMMNH P-63522 is a fragment of a coprolite that also shows similarities to both *Heteropolacoprus* and *Kalocoprus*.

Hyronocoprus amphipola Hunt et al., 2005

Referred specimens: NMMNH P-63505, NMMNH P-63518 (Fig. 1MM), NMMNH P-63519 (Fig. 1FF-HH), NMMNH P-63520 (Fig. 1L-O).

Description: Amphipolar coprolite with rounded cross section and ends.

Discussion: Several specimens represent an amphipolar coprolite with four or more closely-spaced coils and are clearly assignable to *Hyronocoprus amphipola* (Hunt et al., 2005, fig. 3). The largest specimen is NMMNH P-63519 (Fig. 1FF-HH), which is 18.2 mm long and 9.3 mm in diameter and almost complete. NMMNH P-63518 (Fig. 1MM) is less complete but preserves four spirals. This specimen is 15.5 mm long with a diameter of 7.8 mm. Another well-preserved but incomplete coprolite is NMMNH P-63520 (Fig. 1L-O), which is 13.3 mm long and 7 mm in diameter. The largest specimen is NMMNH P-63505, which is 18.7 mm long and 10 mm in diameter.

Hyronocoprus ichnosp.

Referred specimen: NMMNH P-63521 (Fig. 1E-H).

Description and discussion: NMMNH P-63521 is an amphipolar coprolite that differs from typical specimens of *Hyronocoprus* in that the coils are of a less even width in lateral view and both ends are tapering.

Kalocoprus ichnogen. nov.

Type ichnospecies: *Kalocoprus oteroensis* Hunt et al., 2012.

Included ichnospecies: Known only from the type ichnospecies.

Etymology: From the Greek *kalos* (rope), in allusion to the look of an uncoiled rope, and *kopros* (dung).

Distribution: Late Pennsylvanian of New Mexico.

Diagnosis: Dominantly amphipolar coprolite (the spirals do not extend all the way to the posterior end) that differs from *Hyronocoprus* in that there are a small number of coils (about three) along the length of the coprolite and that the spirals are separated from each other by deep sulci so that a large percentage of the circumference is visible in lateral view and, as such, the entire spiral coprolite has the appearance of being slightly “unwound” (it is a loose spiral).

Discussion: It could be hypothesized that *Kalocoprus* is actually a degraded and uncoiled variant of *Hyronocoprus*, but we dismiss this idea because *Hyronocoprus*: (1) has more (>4) spirals in lateral view that are proportionally shorter than in *Kalocoprus*; (2) lacks a tapering termination; and (3) the spirals are more rounded in cross section. A partial specimen illustrated from the Lower Permian of north-central New Mexico is similar to *Kalocoprus* (Hunt et al., 2005, fig. 2R-S).

Kalocoprus oteroensis ichnosp. nov.

Holotype: NMMNH P-63513, coprolite (Fig. 1DD-EE).

Etymology: For Otero County, New Mexico, which yielded the holotype.

Type locality: Road cut on the north side of NM Highway 82 in the northern Sacramento Mountains (NMMNH locality 3276).

Type horizon: Beeman Formation (middle to upper Missourian).

Distribution: As for ichnogenus.

Referred specimens: NMMNH locality 3276: NMMNH P-63511 (Fig. 1P-S), NMMNH P-63512, NMMNH P-63516, NMMNH P-63523 (Fig. 1Z-AA), NMMNH P-63525, NMMNH P-63527 (Fig. 1X-Y), NMMNH P-63529, NMMNH P-63530.

Diagnosis: As for ichnogenus.

Description: NMMNH P-63513 (Fig. 1DD-EE) is 15.8 mm long and 5.5 mm in maximum diameter. In lateral view the coprolite consists of two principal spirals that are rounded, so the lateral margins are not parallel sided. The posterior termination is tightly coiled. The coprolite tapers anteriorly.

Discussion: The largest referred specimen (NMMNH P-63516) is 18.8 mm long and 7.1 mm in diameter. Other specimens are shorter and narrower (NMMNH P-63511 – 16.4 mm by 5.6 mm, NMMNH P-63523 – 14.1 mm by 6.4 mm, NMMNH P-63527 – 14.1 mm by 5.4 mm, NMMNH P-63512 – 14.7 mm by 6.1 mm, NMMNH P-63530 – 11.3 mm by 5.1 mm, NMMNH P-63525 – 14.1 mm by 6.3 mm, NMMNH P-63529 – 10.1 mm by 5.5 mm). The posterior tapering is well seen in NMMNH P-63527 (Fig. 1X-Y) and NMMNH P-63511 (Fig. 1P-S).

The spiral morphology of *Kalocoprus* indicates that it was produced by a less-derived fish such as a chondrichthyan or a sarcopterygian. The relative abundance of *Kalocoprus* would suggest it is the product of a chondrichthyan.

Bibliocoprus ichnogen. nov.

Type ichnospecies: *Bibliocoprus beemanensis* Hunt et al., 2012.

Included ichnospecies: Known only from the type ichnospecies.

Etymology: From the Greek *biblios* (scroll), in allusion to the appearance of a rolled manuscript, and *kopros* (dung).

Distribution: Late Pennsylvanian of New Mexico.

Diagnosis: Scroll coprolite (sensu Hunt and Lucas, 2012) that differs from microspiral heteropolar coprolites (e.g., *Heteropolacoprus*, *Malericoprus*, *Saurocoprus*, *Crassocoprus*, *Speiracoprus*, *Strabelocoprus*) in being parallel-sided and cylindrical in lateral view, and in having coils in lateral view that constitute less than 20% of the length and which are relatively thin so that the coprolite has the general form of a rolled-up scroll of parchment.

Discussion: *Bibliocoprus* is one of the most common coprolites at the Beeman locality, with 12 specimens. Based on the spiral morphology it is likely that *Bibliocoprus* was produced by a chondrichthyan origin or a sarcopterygian. The abundance of specimens again would suggest a chondrichthyan.

Bibliocoprus beemanensis ichnosp. nov.

Holotype: NMMNH P-63503, coprolite (Fig. 1QQ-SS).

Etymology: For the Beeman Formation, which yielded the holotype.

Type locality: Road cut on the north side of NM Highway 82 in the northern Sacramento Mountains (NMMNH locality 3276).

Type horizon: Beeman Formation (middle to upper Missourian).

Distribution: As for ichnogenus.

Referred specimens: NMMNH locality 3276: NMMNH P-63515 (Fig. 1NN-PP), NMMNH P-63526, NMMNH P-63531.

Diagnosis: As for ichnogenus.

Description: NMMNH P-63503 (Fig. 1QQ-SS) is a 23.9 mm long section of a coprolite missing its posterior termination. In lateral view the spiraling is only visible at the anterior end, and the coprolite is parallel-sided. The coprolite is circular in cross section with a diameter of 9.3 mm.

Discussion: The referred specimens are all slightly smaller than

the holotype: NMMNH P-63515 is 20 mm long and 7.7 mm wide, NMMNH P-63526 is 15.8 mm long and 7.2 mm wide, and NMMNH P-63531 is 19.7 mm long and 7.8 mm wide. P-63526 tapers slightly and is rounded relative to the other specimens.

Unassigned morphotype

Referred specimens: NMMNH P-63507, NMMNH P-63509, NMMNH P-63528, NMMNH P-63532, NMMNH P-63533, NMMNH P-63534.

Discussion: There are about 70 poorly preserved coprolites that are currently not assigned to an ichnotaxon. All of the better preserved of these coprolites have a spiral structure but it is possible that some of the others do not have this morphology.

LATE PENNSYLVANIAN COPROLITE LOCALITIES IN NEW MEXICO

The Beeman coprofauna provides an interesting contrast with the other Late Pennsylvanian assemblages in New Mexico, which are from the Kinney Brick Quarry and the Tinajas Lagerstätten (Hunt, 1992; Lerner et al., 2009; Hunt et al., 2012a-b):

1. The Beeman Formation represents a basinal marine facies, whereas the Kinney Brick Quarry formed in a lagoonal setting and the

Tinajas Lagerstätten in a coastal lake with intermittent marine connection.

2. The vast majority of Beeman coprolites are spiral in form, and thus represent chondrichthyans or sarcopterygians, whereas the Kinney and Tinajas assemblages are more diverse.

3. The Beeman coprolites are preserved three-dimensionally and are relatively undeformed and readily separable from the matrix. In contrast, the Kinney coprolites are compressed and occur in finely-laminated shale, and the Tinajas specimens represent an intermediate condition with more three-dimensionality, although they also occur in laminated shale. In this regard, Beeman coprolites are more similar to specimens from Early Permian redbeds in New Mexico (e.g., Hunt et al., 2005).

4. There is currently no fish fauna known from bones or teeth in the Beeman Formation, whereas Kinney, and to a lesser extent Tinajas, have yielded diverse ichthyofaunas (Zidek, 1992; Lerner et al., 2009).

The Beeman coprolites may provide a baseline for comparison of basinal marine fish-derived coprofaunas with those of lagoonal environments, both in taphonomy and taxonomy, and may indicate distinct differences in the ichthyofaunas that produced them.

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