NEW FOSSILS FROM TERMINAL NEOPROTEROZOIC STRATA OF SOUTHERN NYE COUNTY, NEVADA

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ABSTRACT

In the Death Valley region of the Mojave Desert, the Neoproterozoic-Cambrian boundary lies in the lower member of the Wood Canyon Formation (lmWCF). Below the boundary, the lower few meters of the lmWCF contain an assemblage of Ediacaran fossils, including the saclike genus *Ernietta*, the frondlike *Swartpuntia*, and the tubular fossils *Archaeichnium*, *Cloudina*, *Corumbella*, and *Onuphionella*. Associated trace fossils include bed-parallel burrows such as *Planolites* and *Helminthoidichnites*. We briefly describe four new fossils from this assemblage: a conical fossil referred to *Ladatheca*; a possible *Ernietta* specimen preserved in an unusual way, without the sand infillings that are typical for this genus; and the trace fossils *Palaeophycus* and cf. *Monomorphichnus*. Based on these occurrences and on previously described material, it appears that the lmWCF assemblage is atypical of most Ediacaran assemblages in that it has a relatively high diversity of mineralized tubular fossils and a possible arthropod trace fossil.

INTRODUCTION

Neoproterozoic-Cambrian boundary strata have been extensively studied in the Great Basin of the western United States. In the Death Valley region of the southwestern Mojave Desert, the Neoproterozoic-Cambrian boundary lies within the lower member of the Wood Canyon Formation (lmWCF; see Corsetti and Hagadorn, 2000). The lowest few meters of the lmWCF and the upper members of the underlying Stirling Quartzite have yielded an assemblage of Ediacara-type fossils, most of which have come from exposures in the Montgomery Mountains of southern Nye County, Nevada (Fig. 1). Two soft-bodied forms, the saclike fossil *Ernietta* and the flattened stalked frond *Swartpuntia*, have been found in the lmWCF of the Montgomery Mountains, along with the tubular fossils *Archaeichnium*, *Cloudina*, *Corumbella*, *Onuphionella*, and a smooth tubular form that could be a separate taxon but may alternatively be a preservational variant of *Cloudina* (Horodyski, 1991; Hagadorn and Waggoner, 2000). *Cloudina*-like tubes occur in the lmWCF at a number of additional localities in the nearby Spring Mountains, Nopah Range, Resting Springs Range, and Funeral Mountains. Discoidal "medusoid" structures, referred to the genus *Nimbia*, exist lower in the section, in the topmost E member of the

Figure 1. Locality map. Inset map shows state of Nevada, with Nye County indicated in black.

Stirling Quartzite of the Montgomery Mountains (Hagadorn and Waggoner, 2000). Poorly preserved fossils, including conical tubes and probable cloudiniids, have been reported from the D member of the Stirling Quartzite in the Funeral Range and the Salt Spring Hills, although these have not been formally described (Langille, 1974; Hagadorn and Fedo, 2000). Farther north, in the White-Inyo Mountains and neighboring ranges, tubular fossils occur in the lower and middle members of the Deep Springs Formation and the underlying Reed Dolomite, of terminal Neoproterozoic age (Taylor, 1966; Signor et al., 1983, 1987; Hagadorn and Corsetti, 2001). Several genera of tubular fossils have been identified, but most, if not all, are likely to be synonymous with *Cloudina* (Grant, 1990). A similar assemblage of tubular fossils is known from coeval rocks in Sonora, Mexico (Stewart et al., 1984; McMenamin, 1985; McMenamin et al., 1994).

Ediacaran fossils are rare in the Death Valley region, but our ongoing fieldwork since 1996 has yielded some fossils that have not been previously described. We present preliminary descriptions of four new fossils from the lowest few meters of the Wood Canyon Formation. Three of these are from the same locality in the Montgomery Mountains from which we have described *Archaeichnium, Corumbella, Onuphionella* and *Swartpuntia* (Fig. 2). A long conical fossil from this locality is referable to the genus *Ladatheca*; this genus has not previously been reported from the Neoproterozoic. A bag-like fossil may be an unusually preserved *Ernietta*. Large forked burrows, possibly *Palaeophycus*, represent the basal occurrence of this ichnogenus in the Death Valley and Mojave successions. Finally, a *Monomorphichnus*-like trace fossil is described from the basal submember of the lmWCF of the nearby Spring Mountains. This is currently the earliest trace fossil in the Mojave Desert section that could potentially be attributed to an arthropod. At this writing, these specimens are unique, and presenting complete taxonomic descriptions would be premature. The following preliminary descriptions are intended to stimulate discovery of additional fossils in the region, by providing search images for geologists working in this area.

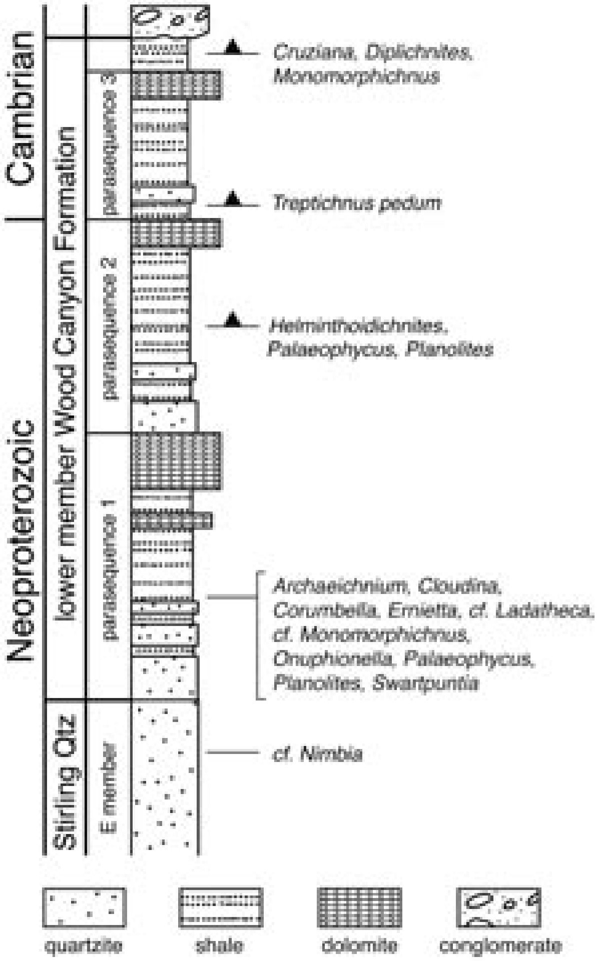


Figure 2. Generalized stratigraphic section through the lower member of the Wood Canyon Formation (modified from Corsetti and Hagadorn, 2000). Straight lines indicate isolated fossil occurrences in the section; wedges indicate first known occurrences of taxa also present at higher stratigraphic levels.

Significance

Although it contains a relatively depauperate assemblage of organisms, the Ediacaran biota of southwestern North America is important in our larger-scale understanding of terminal Neoproterozoic evolution. Many of these fossils also provide important biogeographic links between disparate Neoproterozoic section fragments. For example, a number of the Mojave fossils have counterparts in the Kuibis and Schwartzrand Groups of Namibia. The upper Schwartzrand Group in particular shares the distinctive fossil *Swartpuntia* with the lowest Wood Canyon Formation; in both regions *Swartpuntia* occurs directly below the base of the Cambrian (Narbonne et al. 1997). The agglutinated conical fossil *Archaeichnium* and the saclike *Ernietta* are uniquely shared by both regions, and *Cloudina* is also common to both regions. The Ediacaran biota of southwestern North America clusters with those of Namibia in biogeographic analyses, which is consistent with a number of recent global paleotectonic reconstructions (Waggoner, 1999a). Both the Namibia and the southwestern North America assemblages are also among the youngest Ediacaran biotas, extending to within a few meters of the basal Cambrian (Grotzinger et al., 1995). *Cloudina*, which is common to these two assemblages, appears close to the base of the Cambrian at other localities where its age can be constrained (e.g. Brasier et al., 2000). This implies that the Ediacaran fossil taxa from the Mojave Desert may be useful stratigraphic indicators. For example, the tubular fossil *Corumbella* has only been reported from the Mojave Desert and from South America (Hahn et al., 1982; Hagadorn and Waggoner, 2000). This is one of the few fossils that may potentially serve as a biogeographic and stratigraphic tiepoint between South America and the rest of the world in the late Neoproterozoic.

Another significant feature of the Mojave Desert biota is that it consists of a mixture of "typical" Ediacaran and "typical" Cambrian fossils. For example, the micaceous agglutinated tubular fossil *Onuphionella*, previously known from the Cambrian of the Great Basin (Signor and McMenamin 1988), is a rare member of the Ediacaran assemblage in the lmWCF (Hagadorn and Waggoner, 2000). On the other hand, there are several occurrences of "medusoids", fronds, and cloudiniid-like fossils in unequivocally Cambrian rocks in the Great Basin (Salak and Lescinsky, 1999; Hagadorn et al. 2000). The hypothesis that is emerging from these studies is that there was not a complete and sudden replacement of Ediacara-type biotas by Cambrian-type biotas. Rather, organisms typical of both biotas coexisted through the terminal Neoproterozoic and Lower Cambrian. The fossils that we describe here support this hypothesis: three of these fossils have ranges that are known to extend into the Lower Cambrian. Thus they raise the possibility that the lowest Wood Canyon Formation assemblage represents a faunal transition between "Ediacara-type" and "Cambrian-type" assemblages. Despite the scarcity of fossils in this region, the Mojave Desert assemblage may provide a unique window into the very earliest stages of the Cambrian radiation.

SYSTEMATIC PALEONTOLOGY

All fossils have been curated in the Los Angeles County Museum of Natural History (LACMNH), Department of Invertebrate Paleontology (LACMIP).

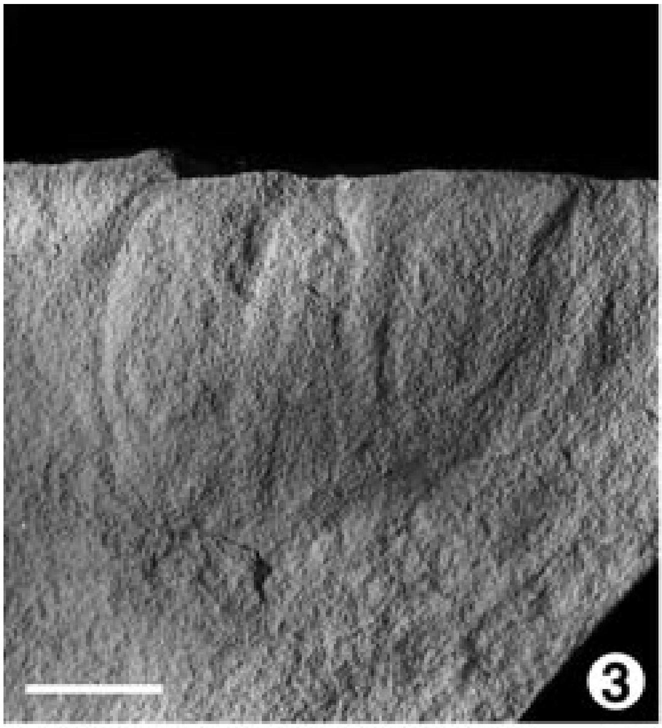
Incertae Sedis
Genus ?*Ernietta* Pflug, 1966
Figures 3, 8

Material.— One specimen (LACMIP hypotype 8067).

Locality and stratigraphy.— LACMNH locality 17130. SW 1/4 NW 1/4 SW 1/4 sec. 11, T18S, R52E, Mt. Schader 7.5" quadrangle. Dipslope and associated talus exposed in a wash, located 3.4 km (2.1 mi) SW of ghost town of Johnnie, Montgomery Mountains, southern Nye County, Nevada. Lower member of the Wood Canyon Formation, a meter below the lowest local occurrence of *Treptichnus pedum*. LACMNH 17130 has also yielded the frondlike fossil *Swartpuntia*, the tubular forms *Archaeichnium*, *Corumbella*, and *Onuphionella*, and most of the described specimens of *Cloudina* and smooth-walled tubes (Hagadorn and Waggoner, 2000).

Description.— Fossil preserved in positive relief (whether on top or bottom of bedding plane is not known), resembling a low mound in cross-section. Fossil represents portion of approximately oval sac-like body, crossed by several subparallel folds or creases; the creases do not appear to be radiating from a central point, but possibly from a midline that would have lain on the missing portion of the fossil, roughly parallel to the broken edge of the slab. Concentric wrinkles are visible along the margin, presumably induced by compaction.

Discussion.— It is possible that this specimen is a load cast or other inorganic surficial marking. However, it does not particularly resemble other bedding-plane markings from this site. It is also isolated on the bedding plane, and is currently known from only one specimen; in this interval load casts are usually clustered on bed surfaces. Examination of the broken edge of the specimen shows no signs of concretionary structure, and disturbed bedding, typical of loading or sediment/gas evulsion structures, is absent. The best-supported hypothesis is that this specimen is a biogenic structure.



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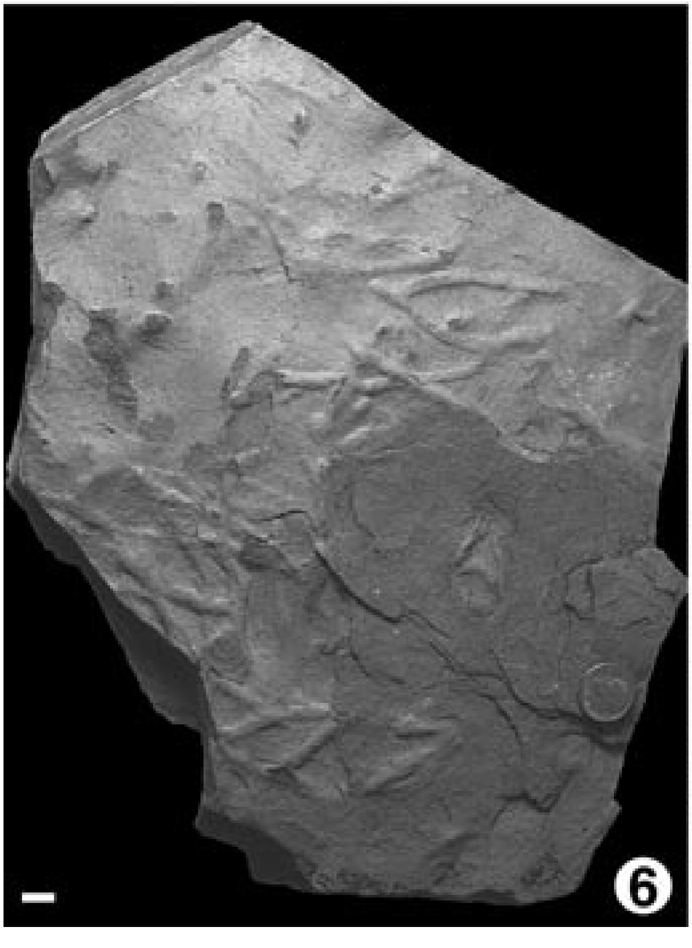

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Figure 3. Saclike fossil cf. *Ernietta*. LACMIP hypotype 8067. Scale bar = 1 cm.

Figure 4. Conical fossil cf. *Ladatheca*. LACMIP hypotype 8068. Arrow indicates narrow terminus; much of the apical half of the conch has exfoliated. Scale bar = 1 cm.

Figure 5. *Cloudina* sp.; impression in negative relief. LACMIP hypotype 12795. Included for comparison with cf. *Ladatheca*. Scale bar = 1 cm.

Figure 6. Trace fossil cf. *Palaeophycus*. LACMIP hypotype 8069. Scale bar = 1 cm.

Figure 7. Trace fossil cf. *Monomorphichnus*. LACMIP hypotype 8070. Arrows indicate near-parallel wedge-shaped marks. Scale bar = 1 cm.

The concentric marginal wrinkles are consistent with this fossil representing a partially collapsed hollow body. The fossil could be a "medusoid" similar to *Protodipleurosoma* from south Australia and the White Sea. *Protodipleurosoma* has a somewhat similar pattern of internal folds or creases, which was interpreted by Fedonkin (1985) as the sail of a chondrophorine hydrozoan. However, the fossil lacks the fine creases and defined outer rim zone of *Protodipleurosoma*. The discoidal *Beltanelliformis* is a sac-shaped fossil that could, if collapsed, resemble this specimen; however, *Beltanelliformis* is usually much smaller. Furthermore, enough of the outline is preserved to show that the complete organism was not precisely circular. Another possibility is that this fossil is a portion of a frondlike fossil such as *Swartpuntia*, already described from this locality (Hagadorn and Waggoner, 2000); however, *Swartpuntia* has much finer striations and would be preserved in lower relief.

We suspect that this specimen is in fact an *Ernietta* preserved in an unusual way. Typically, *Ernietta* is preserved as a three-dimensional sandstone infilling of the sac-like body, both in Namibia and in the Mojave Desert (Horodyski, 1991; Jenkins, 1992, fig. 7). We suggest that this fossil is a poorly preserved *Ernietta*, preserved as a compressed fossil in shale with no sand infilling. A bag-shaped body with multiple striations is diagnostic for *Ernietta*, and we infer that the striations arise from a central midline, which is also typical of *Ernietta*. Examination of the broken edge of the fossil does not show any coarser sediments filling the fossil. However, a collapsed *Ernietta*, perhaps partially infilled with fine sediment, might produce a fossil structure similar to the one figured here.

We cannot be sure what this sample represents without more specimens. Despite the fragmentary nature of this fossil, we have figured it here in hopes that more specimens will be recognized and collected by geologists working in this region.

?HYOLITHA
?ORTHOTHECIDA
Genus cf. *Ladatheca* Sysoiev, 1968
Figure 4

Material. One specimen (LACMIP hypotype 8068)

Locality and stratigraphy. LACMNH locality 17130.

Description.— Straight, narrow conical tube with faint transverse annulations. Narrow end pointed and apparently closed. Aperture at right angles to long axis; no ligula or other apertural structures visible; no longitudinal or spiral sculpture visible; no curvature. Fossil stained orange, in contrast to greenish matrix, representing iron-rich diagenetic remnant of original wall. Length 56 mm; maximum diameter 4 mm; L/D = 14.

Diagnosis.— The simplest explanation for this

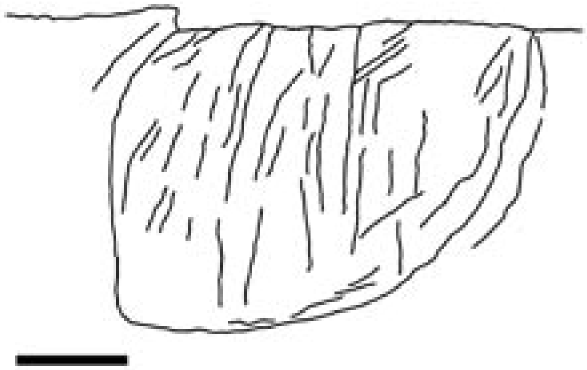

Figure 8. Line drawing of cf. *Ernietta* (LACMIP 8067). Note concentric wrinkling near margin, along with subparallel striae radiating from inferred midline. Scale bar = 1 cm.

fossil would be that it is a *Cloudina* or *Cloudina*-like form, possibly one which is plunging into the bed surface. The fossil does appear to have a weakly annulated surface sculpture, which might be seen on an abraded specimen of *Cloudina*. The mode of preservation, with the wall replaced by a thin iron-rich stain, is very much like that of *Cloudina* at this locality. However, all cloudiniids of comparable length from the Montgomery Mountains have a consistent gentle curvature (Fig. 5; also see Hagadorn and Waggoner, 2000, Figs. 3.7, 3.8), whereas this fossil is almost perfectly straight. Furthermore, a portion of the upper surface of the tube towards the narrow end is exfoliated, revealing the lower surface running parallel to the bedding plane. Careful examination shows that a pointed apex that appears to be rounded and closed is preserved on the bedding plane surface. In short, the fossil is conical, with a closed apex, and lies parallel to the bed surface, not oblique to it. Long *Cloudina* tubes may taper somewhat, but less evenly than this fossil, and none of the *Cloudina* specimens that we have examined show a closed apex.

The lack of bends and buckling in this fossil, and its relatively high relief, suggests that the original wall was firm and at least strongly sclerotized, if not mineralized. These factors, plus the conical shape, suggests that the fossil is not a sabelliditid, which typically are preserved as carbonized compressions of cylindrical tubes. The fossil also lacks the agglutinated micaceous wall of *Onuphionella* and the agglutinated cross-striated structure and flexible walls of *Archaeichnium*, which are also known from the lower Wood Canyon Formation and elsewhere (Glaessner, 1978; Hagadorn and Waggoner, 2000). The wall has been replaced by a reddish-colored mineral film, enriched in iron, potassium, titanium, and oxygen compared to the surrounding matrix (Fig. 9). This is similar to the mode of preservation of *Cloudina* from this locality.

The closest matches to LACMIP 8068 are a number of elongated conical fossils from the lower Cambrian (for overviews see Missarzhevskij, 1969, 1989). LACMIP 8068 is not longitudinally ridged or obviously triradially symmetrical, suggesting that it is not likely to be an anabaritid. Some Cambrian specimens assigned to the genus *Hyolithellus* somewhat resemble the fossil described here, being weakly transversely ornamented and expanding slightly; *Hyolithellus* may reach 20 mm in length, which is shorter than the fossil described here, but still relatively large for a Lower Cambrian shelly fossil. However, *Hyolithellus* has openings at both ends, whereas this fossil is closed off at the narrow end (cf. Missarzhevskij, 1969, pl. 7; 1989, pl. 24). *Hyolithellus* also tends to curve, as do other Cambrian conical genera such as *Byronia*, *Cambrorhytium, Cambrotubulus*, *Coleoloides*, *Torellella*, and *Tubulella* (Howell, 1962; Conway Morris and Robison, 1988; Brasier, 1989; Missarzhevskij, 1969, 1989; Dzik, 1994).

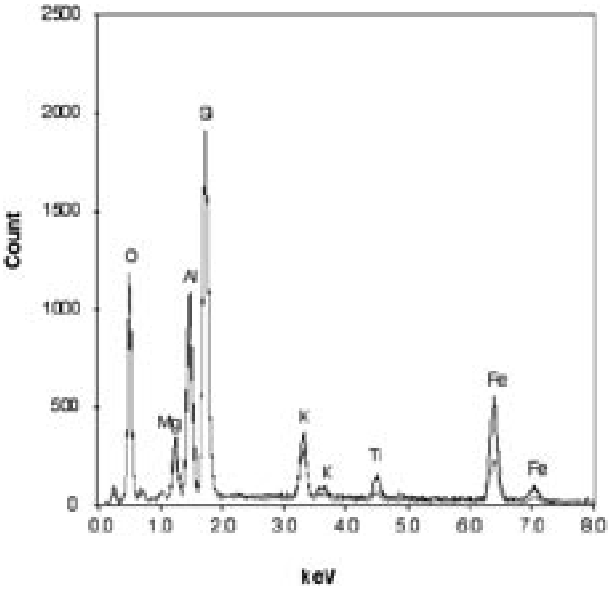

Figure 9. EDS spectrum of a 1 mm^2 area of the wall of cf. *Ladatheca* (LACMIP 8068), shown in black, with spectrum of a 1 mm^2 sample of surrounding matrix superimposed in gray. Both spectra are scaled identically. Note higher O, K, Ti and Fe peaks in *Ladatheca* wall.

The best match is provided by some simple Lower Cambrian conical fossils that have usually been described as orthothecid hyoliths, in particular those fossils in and related to the genus *Ladatheca*. Whether these fossils are true hyoliths or not is questionable; Landing (1993) referred *Ladatheca* to the Annelida, and also noted that a number of other genera of orthothecid-like shells should probably be synonymized with *Ladatheca*. *Ladatheca*_ specimens from Siberia reach 40-50 mm (Missarzhevskij, 1989), whereas Newfoundland specimens may exceed 150 mm (Landing, 1993). The conch of *Ladatheca* is extremely narrow (the ratio of length to maximum diameter is about 10 to 12), smooth to lightly annulated, and nearly perfectly straight; cross sections range from round to rounded triangular or oval. *Ladatheca* bears a simple cap-shaped operculum (Landing, 1993; Dzik, 1994); we have not found similar opercula, but predict that they will be found at this locality.

LACMIP 8068 is very similar to *Ladatheca*, but the rarity of specimens and lack of original shell material makes it difficult to confirm this identification, as do the current taxonomic controversies surrounding simple conical fossils. We are reluctant to section this specimen, which is unique for this region, but characterization of the cross-sectional shape, and ideally the operculum, will be necessary for a firm identification; obviously, more specimens are needed. *Ladatheca* and similar narrow conical fossils are known from very early in the Cambrian, extending into the Manykaian / Nemakit-Daldynian of Siberia and Central Asia (Missarzhevskij, 1989) and into the Nemakit-Daldyn-equivalent Placentian Series of Avalonia (Landing, 1993). McMenamin (1985, fig. 4.3) described fossils resembling orthothecid hyoliths from a *Cloudina* shell bed in the La Ciénega Formation of Sonora, Mexico, which is probably of comparable age to the lowest Wood Canyon Formation. However, the specimen in question is in fact a cloudiniid (McMenamin et al., 1994, p. 220). If our identification of this fossil is confirmed, it would extend the range of *Ladatheca*-like forms into the latest Neoproterozoic. However, regardless of whether or not this fossil should be considered congeneric with *Ladatheca*, and regardless of whether or not it is an annelid, a hyolith, or something else, it does represent a new type of late Neoproterozoic fossil.

Ichnogenus cf. *Palaeophycus* Hall, 1847
Cf. *Palaeophycus tubularis* Hall, 1847
Figure 6

Material.— One specimen (LACMIP hypotype 8069).

Locality and stratigraphy.— LACMNH locality 17130.

Description.— Lined trace fossil, nearly bed-parallel, showing several forking or branching shapes. Faint striae, running parallel to direction of movement, visible on some traces. Fossils preserved in positive relief, presumably hyporelief (Fig. 6) and in negative relief on the opposite side of the slab (not figured). Width of traces 4-5 mm; length of typical segments 40-60 mm.

Discussion.— This trace fossil could conceivably represent an ichnospecies in the ichnogenus *Treptichnus*, which is characterized by a quasi-branching morphology (Jensen, 1997). Most of the intersections between burrows in this specimen occur at their terminal ends, implying that the tracemaker may have originated or terminated burrowing activities in the same area; thus these burrows may represent a behavioral variant of treptichnid burrowing activity. Most *Treptichnus* ichnospecies are Cambrian or later, and in particular, *T. pedum* is by definition restricted to the Phanerozoic (Brasier et al., 1994; Jensen, 1997; but see Gehling et al., 2001). However, treptichnid ichnofossils other than *T. pedum* occur in Neoproterozoic strata of Namibia, together with soft-bodied Ediacaran fossils (Jensen et al., 2000). The mere presence of *Treptichnus*-like traces does not imply a Cambrian age for these strata.

However, the traces described here are not especially likely to be *Treptichnus*. Despite the forking morphology, they do not form connected chains of short branches, as is typical for *Treptichnus* in general and as is seen in *T. pedum* from the lower Wood Canyon Formation (Hagadorn and Waggoner, 2000). Many of these branchings probably represent the overlap of successive burrowing activities. The relatively large size, parallel striae, and occasional forking or branching morphology suggests that this trace fossil is best classified as *Palaeophycus*, which may show similar striations and branches (e.g. Pemberton and Frey, 1982, pl. 2 fig. 1, pl. 3 fig. 2). The absence of external structure and relatively thin lining suggests placement in *P. tubularis*. However, *Palaeophycus* and *Planolites* can be difficult to distinguish (Pemberton and Frey, 1982; Jensen, 1997). *Palaeophycus* is supposed to show a wall-lining and passive fill, while *Planolites* is defined as having a fill differing from the host matrix. In practice the difference is not always clear. Our identification remains tentative, pending the discovery of more specimens.

Palaeophycus has already been reported from the second parasequence of the lower member of the Wood Canyon Formation of the Death valley region (Corsetti and Hagadorn, 2000). If confirmed, the occurrence reported here extends the known range of *Palaeophycus* downwards, and confirms that its maker coexisted with Ediacaran organisms.

Trace Fossils
Genus cf. *Monomorphichnus* Crimes, 1970
Figure 7

Material. One specimen (LACMIP hypotype 8070). Previously figured in Waggoner (1999b, fig. 4g).

Locality and stratigraphy. LACMNH locality 17131. SW 1/4 sec. 34, T18S, R54E, Horse Springs 7.5" quadrangle. Talus slopes immediately NE of Santa Cruz Spring, Spring Mountains, just W of the approximate and unsurveyed border between Nye and Clark Counties, Nevada. Lowest Wood Canyon Formation. This locality has otherwise yielded only short trace fossils cf. Planolites and poorly preserved tubular fossils (?Cloudina).

Description.— Fossil preserved in positive relief, presumably hyporelief; bedding plane highly micaceous. Four strongly marked, narrow, wedge-shaped striae, roughly evenly spaced, each at about a 45° angle to the long axis of the fossil. Each stria terminates at one end in sharp tip; other end indistinct. Striae 4 mm long, spaced 5-8 mm apart.

Discussion.— It is possible that these are tool marks or scour marks. However, the arcuate- to quasi-teardrop shape of each mark, alignment of these marks into a well-defined linear set, and the relatively regular spacing between them, together with the near absence of tool or flute marks on bed soles in this part of the lmWCF, are more consistent with a trace fossil interpretation. The marks most closely resemble *Monomorphichnus*, an ichnogenus made by unidirectional scratching of multiple appendages, presumably arthropod legs. In particular, *Monomorphichnus* ichnospecies B of Jensen (1997) is similar to this specimen in having relatively wide, wedge-shaped striae. However, the specimen lacks the multiple ridges in each stria characteristic of *Monomorphichnus* isp. B. Jensen (1997, fig. 43) has also illustrated probable *Cruziana* undertracks that resemble *Monomorphichnus*.

Without more material, we cannot be certain of this fossil's affinity. Nonetheless, it suggests the presence of an arthropod or arthropod-like organism in the terminal Neoproterozoic paleocommunity. *Monomorphichnus*, together with an array of delicate arthropod scratch marks such as *Diplichnites* and *Cruziana,* is known from higher in the lmWCF (Waggoner, 1999b, fig. 4f; Corsetti and Hagadorn, 2000); if confirmed, the fossil described here would extend the range of this ichnogenus into the terminal Neoproterozoic of this region. It would also provide evidence for bilaterian animals with appendages just before the Cambrian.

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REFERENCES CITED

Brasier, M. D., 1989, Towards a biostratigraphy of the earliest skeletal biotas, *in* Cowie, J. W. and Brasier, M. D., eds. The Precambrian-Cambrian boundary: Oxford, Clarendon Press, p.117-165.

Brasier, M., Cowie, J., and Taylor, M., 1994, Decision on the Precambrian-Cambrian boundary stratotype: Episodes, v. 17, p. 95-100.

Brasier, M. D., McCarron, G., Tucker, M., Leather, J., Allen, P., and Shields, G., 2000, New U-Pb zircon dates for the Neoproterozoic Ghubrah glaciation and for the top of the Huqf Supergroup, Oman: Geology, v. 28, p. 175-178.

Conway Morris, S., and Robison, R. A., 1988, More soft-bodied animals and algae from the Middle Cambrian of Utah and British Columbia: University of Kansas Paleontological Contributions, no. 122, p. 1-48.

Corsetti, F. A., and Hagadorn, J. W., 2000, The Precambrian-Cambrian transition: Death Valley, USA: Geology, v. 28, p. 299-302.

Crimes, T. P., 1970, Trilobite tracks and other trace fossils from the Upper Cambrian of North Wales: Geological Journal, v. 7, p. 47-68.

Dzik, J., 1994, Evolution of 'small shelly fossils' assemblages: Acta Palaeontologica Polonica, v. 39, p. 247-313.

Fedonkin, M. A., 1985, Sistematicheskoe opisanie vendskikh metazoa [Systematic description of Vendian metazoa], *in* Sokolov, B. S., and Iwanowski, A. B., eds. Vendskaja Sistema. Tom 1: Istoriko-geologicheskoe i paleontologicheskoe obosnovanie [The Vendian System. Volume 1: Historico-geological and paleontological foundation]: Moscow, Nauka, p. 70-106.

Gehling, J. G., Jensen, S., Droser, M. L., Myrow, P. M, and Narbonne, G. M., 2001, Burrowing below the basal Cambrian GSSP, Fortune Head, Newfoundland: Geological Magazine, v. 138, p. 213-218.

Glaessner, M. F., 1978, Re-examination of *Archaeichnium*, a fossil from the Nama Group: Annals of the South African Museum, v. 74, no. 13, p. 335-342.

Grant, S. W. F., 1990, Shell structure and distribution of *Cloudina*, a potential index fossil for the terminal Proterozoic: American Journal of Science, v. 290-A, p. 261-294.

Grotzinger, J. P., Bowring, S. A., Saylor, B. Z., and Kaufman, A. K., 1995, Biostratigraphic and geochronologic constraints on early animal evolution: Science, v. 270, p. 598-604.

Hagadorn, J. W., and Corsetti, F. A., 2001, Terminal Neoproterozoic-Lower Cambrian transition I: White-Inyo Mountains, CA: Geological Society of America, Abstracts with Programs, v. 33, p. 72.

Hagadorn, J. W., and Fedo, C. M., 2000, Terminal Neoproterozoic cloudiniids from southwestern North America: Geological Society of America Abstracts with Programs, v. 32, p. 300.

Hagadorn, J. W., Fedo, C. M., and Waggoner, B. M., 2000, Ediacara-type biotas from the Cambrian of the southwestern United States: Journal of Paleontology, v. 74, p. 731-740.

Hagadorn, J. W., and Waggoner, B. M., 2000, Ediacaran fossils from the southwestern United States: Journal of Paleontology, v. 74, p. 349-359.

Hahn, G., Hahn, R., Leonardos, O. H., Pflug, H. D., and Walde, D. H. G., 1982, Körperlich erhaltene Scyphozoen-Reste aus dem Jungpräkambrium Brasiliens: Geologica et Palaeontologica, v. 16, p. 1-18.

Hall, J., 1847, Paleontology of New York, v. 1: Albany, State of New York, 338 p.

Horodyski, R. J., 1991, Late Proterozoic megafossils from southern Nevada: Geological Society of America Abstracts with Programs, v. 26, no. 5, p. 163.

Howell, B. F., 1962, Worms, *in* Moore, R. C., ed., Treatise on Invertebrate Paleontology, Part W; Miscellanea: Boulder, Colorado and Lawrence, Kansas, Geological Society of America and University of Kansas Press, p. W144-W177.

Jenkins, R. J. F., 1992., Functional and ecological aspects of Ediacaran assemblages, *in* Lipps, J. H. and Signor, P. W., eds., Origin and early evolution of the Metazoa: New York, Plenum, p. 131-176.

Jensen, S., 1997, Trace fossils from the Lower Cambrian Mickwitzia sandstone, south-central Sweden: Fossils & Strata, v. 42, p. 1-110.

Jensen, S., Saylor, B. Z., Gehling, J. G., and Germs, G. J. B., 2000, Complex trace fossils from the terminal Proterozoic of Namibia: Geology, v. 28, p. 143-146.

Landing, E., 1993, In situ earliest Cambrian tube worms and the oldest metazoan-constructed biostrome (Placentian Series, southeastern Newfoundland): Journal of Paleontology, v. 67, p. 333-342.

Langille, G. B., 1974, Problematic calcareous fossils from the Stirling Quartzite, Funeral Mountains, Inyo County, California: Geological Society of America Abstracts with Programs, v. 6, no. 3, p. 204-205.

McMenamin, M. A. S., 1985, Basal Cambrian small shelly fossils from the La Ciénega Formation, northwestern Sonora, Mexico: Journal of Paleontology, v. 59, p. 1414-1425.

McMenamin, M. A. S., Pittenger, S. L.,

Carson, M. R., and Larrabee, E. M., 1994, Upper Precambrian-Cambrian faunal sequence, Sonora, Mexico, and Lower Cambrian fossils from New Jersey, United States, *in* Landing, E., ed., Studies in stratigraphy and paleontology in honor of Donald W. Fisher: New York State Museum Bulletin, v. 481, p. 213-227.

Missarzhevskij, V. V., 1969 [transl. 1981], description of hyolithids, gastropods, hyolithelminths, camenides and forms of an obscure taxonomic position, *in* Raaben, M. E., ed., The Tommotian stage and the Cambrian lower boundary problem: New Delhi, Amerind Publishing, p. 127-205

Missarzhevskij, V. V., 1989, Drevnejsjie skeletnye okamenelosti i stratigrafija pogranichnykh tolshch dokembrija i kembrija [The oldest skeletal fossils and the stratigraphy of the Precambrian-Cambrian boundary layers]: Trudy Geologicheskogo Instituta, v. 443. Moscow, Nauka, p. 1-237.

Narbonne, G., Saylor, B. Z., and Grotzinger, J. P., 1997, The youngest Ediacaran fossils from southern Africa: Journal of Paleontology, v. 71, p. 953-967.

Pemberton, S. G., and Frey, R. W., 1982, Trace fossil nomenclature and the *Planolites-Palaeophycus* dilemma: Journal of Paleontology, v. 56, p. 843-881.

Pflug, H.-D., 1966, Neue Fossilreste aus den Nama-Schichten in Südwest-Afrika: Paläontologische Zeitschrift, v. 40, p. 14-25.

Salak, M., and Lescinsky H. L., 1999, *Spygoria zappania* new genus and species, a *Cloudina* -like biohermal metazoan from the Lower Cambrian of central Nevada: Journal of Paleontology, v. 73, p. 571-576.

Signor, P. A., Gevirtzman, D. A., and Mount, J. F., 1983, Two new pre-trilobite faunas from western North America: Nature, v. 303, p. 415-418.

Signor, P. A., and McMenamin, M. A. S., 1988, The Early Cambrian worm tube *Onuphionella* from California and Nevada: Journal of Paleontology, v. 62, p. 233-240.

Signor, P. A., Mount, J. F., and Onken, B. R., 1987, A pre-trilobite shelly fauna from the White-Inyo region of eastern California and western Nevada: Journal of Paleontology, v. 61, p. 425-438.

Stewart, J. H., McMenamin, M. A. S., and Morales-Ramirez, J. M., 1984, Upper Proterozoic and Cambrian rocks in the Caborca region, Sonora, Mexico—physical stratigraphy, biostratigraphy, paleocurrent studies, and regional relations: United States Geological Survey Professional Paper, no. 1309, p. 1-36.

Sysoiev, V. A., 1968, Stratigrafija i khiolity drevnejshchikh sloev Nizhnego Kembrija: Moscow, Nauka.

Taylor, M. E., 1966, Precambrian mollusc-like fossils from Inyo County, California: Science, v. 153, p. 198-201.

Waggoner, B. M., 1999a, Biogeographic analyses of the Ediacara biota: a conflict with paleotectonic reconstructions: Paleobiology, v. 25, p. 440-458.

Waggoner, B. M., 1999b, Los comienzos de la historia evolutiva de los artrópodos; ¿qué nos pueden contar los fósiles? [The earliest evolutionary history of arthropods: what do the fossils tell us?] *in* Melic, A., de Haro, J. J., Mendez, M. and Ribera, I., eds., Evolución y filogenia de Arthropoda: Boletín de la Sociedad Entomológica Aragonesa, v. 26, p. 115-131.