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MENISCATE BURROWS FROM MIOCENE LACUSTRINE-FLUVIAL DEPOSITS, DILIGENCIA FORMATION, OROCOPIA MOUNTAINS, SOUTHERN CALIFORNIA

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ABSTRACT—About 20 specimens of ?*Muensteria* ichnosp. burrows were found at one locality in the lower Miocene Diligencia Formation of southern California. The burrows are cylindrical, unlined and internally meniscate. They are up to 20 cm in length and 2 cm in diameter and are mostly horizontal. Some have vertical to oblique passageways where they pass from one bedding plane to another. Burrow morphology most closely resembles *Muensteria* von Sternberg, 1833. This heterogeneous ichnogenus is in need of taxonomic revision and most likely is synonymous with various other stuffed burrows (i.e., *Taenidium, Laminites, Scoyenia,* etc.). The meniscate structures indicate that infaunal deposit-feeders, possibly aquatic oligochaetes, backfilled their burrows in deposits where a braided river entered a lake.

INTRODUCTION

THIS paper describes and illustrates internally meniscate burrows from the nonmarine lower Miocene Diligencia Formation in the Canyon Spring area of the southeastern Orocopia Mountains, Riverside County, southern California (Figure 1).

The Diligencia Formation accumulated during the early Miocene in an intermontane basin flanked by alluvial fans. The alluvial fan/braided river deposits are laterally transitional into fluvial-deltaic and lake-shoreline deposits. Basin subsidence occurred intermittently with syntectonic outpourings of basalt and/or ash (Crowell, 1975; Spittler and Arthur, 1982; Squires and Advocate, 1982). In the Canyon Spring area, the Diligencia Formation consists of an 800 m-thick section of interbedded nonmarine sedimentary and volcanic rocks. The various facies in this area have been described and mapped by Squires and Advocate (1982).

The burrows were found at a single locality: California State University, Northridge locality 549, located 807 m (2,650 ft) north and 616 m (2,020 ft) east of the southwest corner of section 20, T7S, R13E, Canyon Spring SW Quadrangle, 7.5-minute series, 1963. The burrows are in beds exposed in the floor of the canyon where Holocene stream bed erosion has polished the rocks.

The locality is where Diligencia lake-shoreline and fluvial-deltaic deposits interfinger, about 620 m above the base of the formation. This locality plots in the upper part of Unit C on the stratigraphic column shown in Squires and Advocate (1982, fig. 2). The lake-shoreline deposits in the vicinity of this locality consist of laterally continuous beds of well sorted, fine-grained, purple to maroon sandstone with ripple marks, low-angle cross laminae, and horizontal laminae. Beds are up to 4 m thick. Spring-tufa deposits, ostracodes, and land-mammal remains are present locally (Yamashiro and Squires, 1983). The fluvial-deltaic deposits in this vicinity consist of conglomerate channel-fill deposits up to 2 m thick. The channel-fill deposits are composed of well stratified, clast-supported, small- to medium-pebble conglomerate that grades upward into fine-grained sandstone of the lake-shoreline deposits. The channels incise the lake-shoreline deposits.

Locality 549 is at the top of one of these channel-fill sequences, where lake-shoreline sedimentation apparently dominated. Most of the burrows are in the strongly laminated middle portion of a 50 cm-thick, very fine-grained sandstone bed and in the less laminated, fine- to coarse-grained sandstone of the upper portion of the bed. In places this bed, which can be traced laterally for about 30 m, has scour channels and some low-angle cross laminae. Some of the burrows in the upper portion of the bed are partly filled with conglomeratic sandstone that resembles the lithology of the overlying fluvial-deltaic deposit. This overlying fluvial-deltaic deposit

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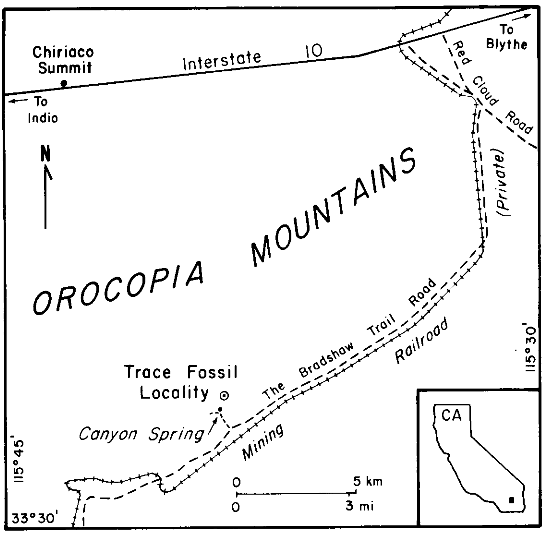

FIGURE *1*—Locality map for trace fossil site in the Diligencia Formation.

is 60 cm thick and grades upward into another very fine-grained sandstone bed (1 m thick) that is bioturbated. These burrows are very poorly preserved.

SYSTEMATIC ICHNOLOGY

Ichnogenus MUENSTERIA
von Sternberg, 1833
?MUENSTERIA ichnospecies
Figure 2A–F

Description.—The predominantly horizontal burrows are moderately large, cylindrical, and have a transverse meniscate packing pattern (Figure 2A–E). Burrows are visible only in cross-section. Natural entrances and termini were not seen. Maximum observed length is 19.5 cm, and maximum observed diameter is 2 cm. Burrows are subcircular to circular in transverse section, endostratal, moderately closely spaced, and locally crosscutting. They are straight to curved and many have abrupt, prominent bends. Walls are unlined and parallel. In some cases, one end may be hemispherical or bulbous. Vertical to oblique passageways (usually no more than 4 cm in length) are present where burrows pass from one bedding plane to another (Figure 2B, C, E).

Internal packing consists of alternating meniscate laminae of light- and dark-colored material. Laminae are 1 to 2.5 mm in width. The packing pattern is concentric in transverse section. The light-colored fill is the same as the very fine-grained host material. The dark-colored fill locally is more poorly sorted, with very fine to coarse grains. Laminae are parallel to one another except where a burrow changes direction. In such cases, the laminae truncate one another. Vertical to oblique passageways between burrows usually consist of light-colored, structureless coarse-grained sandstone (Figure 2B, C). Also, locally there are structureless areas up to 2 cm long between meniscate areas in some of the horizontal burrows.

One isolated vertical burrow (Figure 2F) was found, and it is from the upper portion of the 50 cm-thick bed. The burrow is 13 cm in length and 2 cm in diameter with a concave-upward meniscate packing pattern. The internal packing in this burrow is similar to

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FIGURE *2*—Meniscate burrows (?*Muensteria*) in the nonmarine lower Miocene Diligencia Formation, Canyon Spring area, Orocopia Mountains, California. California State University, Northridge locality 549. Burrows are all from the same 50 cm-thick bed. *A*, *B*, and *D* are bedding-plane surfaces. Coin is 2.4 cm in diameter. *A*, bulbous left margin probably due to burrow passing vertically from the bedding plane to another; tapered right margin due to burrow passing at a low angle from the bedding plane to another, upper portion of bed, ×0.8. *B*, University of California, Los Angeles, Department of Earth and Space Sciences (UCLA) hypotype 59345; meniscate laminae at bend in burrow are up to 2.5 mm wide; burrow fill is structureless in area where burrow passes from the bedding plane to another, middle portion of bed, ×1. *C*, oblique view of same burrow shown in B, showing the high-angle passageway from one bedding plane to another, ×1. *D*, discontinuous and tapered appearances of the two burrows are due to undulating nature of burrows along the bedding plane, middle portion of bed, ×0.5. *E*, cross-section perpendicular to bedding, showing complex passageway of burrow from one bedding plane to another, middle portion of bed, ×0.5. *F*, cross-section perpendicular to bedding showing a vertical burrow with very coarse sand fill in upper part of burrow, upper portion of bed, ×0.3.

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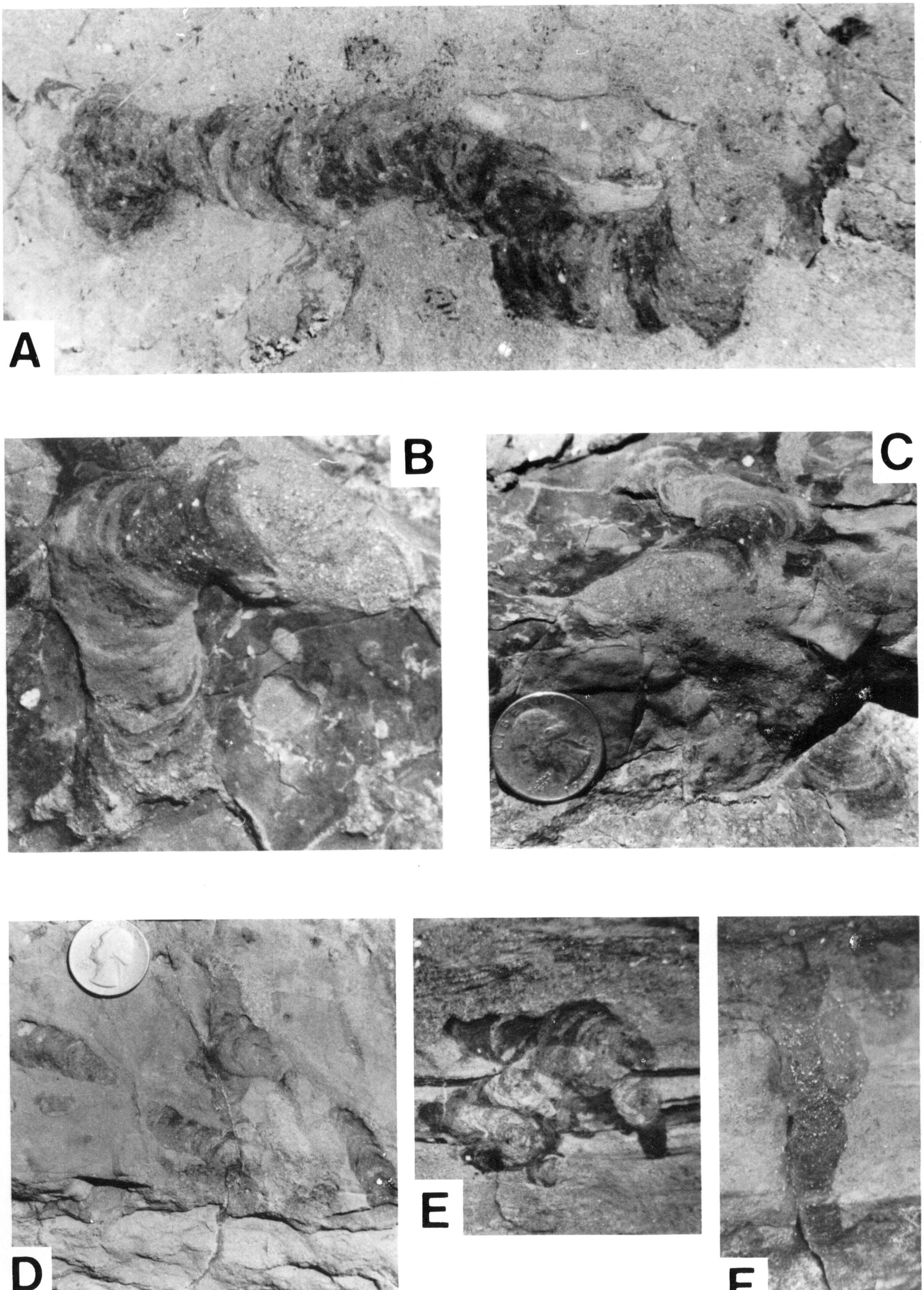
A
B
C
D
E
F

that in the horizontal burrows, but overall it is more dark colored and has more obvious grain sorting. This burrow may be a long passageway from one bedding plane to another.

Material.—About 25 specimens were found. Collection of specimens was difficult owing to the well indurated nature of the stratum. In addition, the resistant bed forms a small cliff on the canyon floor, and Holocene runoff has removed all the talus. Only a single specimen was collected.

Discussion.—Most of the burrows have a tapered appearance. This tapering is a result of the burrow leaving the plane of section.

The Diligencia burrows belong to a general category of "stuffed burrows" mentioned by Häntzschel (1975). Such cylindrical, unlined burrows exhibit transverse laminated structure. Various ichnogeneric names are applied to these burrows, and *Taenidium* Heer, 1877 is one of the most commonly used. *Taenidium* typically consists of an umbellated, rootlike system of burrows radiating downward and is unlike the Diligencia burrows. *Muensteria* von Sternberg, 1833, another name applied to various stuffed burrows, more closely resembles the Diligencia burrows. According to R. G. Bromley (1983, oral commun.), *Muensteria* is synonymous with most cylindrical, unlined burrows with meniscate fill (i.e., *Taenidium, Laminites, Beaconites, Scoyenia,* etc.). *Muensteria* is the oldest name and has priority, but *Muensteria* technically is not a valid name as it has no type species. Bromley and S. G. Pemberton presently are working to emend the taxonomy of *Muensteria* and other related "stuffed burrows," all of which may be species differentiates of just a single ichnogenus. We agree with Bromley's taxonomic opinion and refer the Diligencia material to ?*Muensteria* ichnosp.

Interpretation.—The meniscate burrows of the Diligencia Formation were produced in a transitional environment where a river entered a lake. There were periods of high discharge of coarse sands and gravels (fluvial-deltaic deposits), followed by low discharge of such sediments in which well sorted sands (shoreline deposits) accumulated. During times of low discharge, biogenic activity became common. Very shallow-water conditions existed, and there may have been temporary periods of exposure.

The burrowing organisms were selective as to where they concentrated their activities, as evidenced by their abundance in the middle and upper portions of the bed. Most of the activity was along bedding planes, with oblique to vertical passageways (rarely greater than 4 cm in length) where horizontal burrows passed from one layer to another.

The presence of menisci indicates that the burrows were actively filled. According to Toots (1967) and Frey, Howard and Pryor (1978), actively filled burrows exhibit distinctive internal structures such as laminae, as opposed to passively filled burrows which rarely show internal structures.

The mode of origin of the burrows is uncertain. They probably were formed by a selective deposit-feeder. Menisci are interpreted to be the result of sediment sorting by the burrower. Stanley and Fagerstrom (1974) have suggested three ways in which sediment sorting like this may have occurred: 1) all material was ingested and sorted in the gut of the burrower; 2) the sediment was sorted as it was excavated and transported around the body of the burrower as it made its way through the substrate; or 3) there was a combination of the above two processes.

The identity of the deposit-feeder that made the burrows is unknown. Possible candidates are aquatic oligochaetes. According to Pennak (1953, p. 279–281), these organism are especially common in shallow portions of lakes. They ingest sediment and sometimes burrow several centimeters below the water-substrate interface. It is unlikely that the meniscate packing of the burrows resulted from insect or spider activity. No adult insects and spiders or their instars are known to be true deposit-feeders (Ratcliffe and Fagerstrom, 1980; Bown, 1982).

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REFERENCES

Bown, T. M. 1982. Ichnofossils and rhizoliths of the nearshore fluvial Jebel Qatrani Formation

(Oligocene), Fayum Province, Egypt. Palaeogeography, Palaeoclimatology, Palaeoecology, 40:255–309.

CROWELL, J. C. 1975. Geologic sketch of the Orocopia Mountains, southeastern California, p. 99–110. *In* J. C. Crowell (ed.), San Andreas Fault in Southern California. California Division of Mines and Geology, Special Report 118.

FREY, R. W., J. D. HOWARD and W. A. PRYOR. 1978. *Ophiomorpha*: its morphologic, taxonomic, and environmental significance. Palaeogeography, Palaeoclimatology, Palaeoecology, 23:199–229.

HÄNTZSCHEL, W. 1975. Trace Fossils and Problematica. *In* C. Teichert (ed.), Treatise on Invertebrate Paleontology, Pt. W, Miscellanea, Supplement 1, Second Edition. Geological Society of America and University of Kansas Press, Lawrence, 269 p.

HEER, OSWALD. 1876–1877. Flora Fossilis Helvetiae. Die vorweltliche Flora der Schweiz. J. Würster and Company, Zürich, 182 p.

PENNAK, R. W. 1953. Fresh-water Invertebrates of the United States. The Ronald Press Company, New York, 769 p.

RATCLIFFE, B. C. and J. A. FAGERSTROM. 1980. Invertebrate lebensspuren of Holocene floodplains: their morophology, origin and paleoecological significance. Journal of Paleontology, 54: 614–630.

SPITTLER, T. E. and M. A. ARTHUR. 1982. The lower Miocene Diligencia Formation of the Orocopia Mtns., southern California: stratigraphy, petrology, sedimentology and structure, p. 83–99. *In* R. V. Ingersoll and M. O. Woodburne (eds.), Cenozoic Nonmarine Deposits of California and Arizona. Pacific Section, Society of Economic Paleontologists and Mineralogists.

SQUIRES, R. L. and D. M. ADVOCATE. 1982. Sedimentary facies of the nonmarine lower Miocene Diligencia Formation, Canyon Spring area, Orocopia Mountains, southern California, p. 101–106. *In* R. V. Ingersoll and M. O. Woodburne (eds.), Cenozoic Nonmarine Deposits of California and Arizona. Pacific Section, Society of Economic Paleontologists and Mineralogists.

STANLEY, K. O. and J. A. FAGERSTROM. 1974. Miocene invertebrate trace fossils from a braided river environment, western Nebraska, U.S.A. Palaeogeography, Palaeoclimatology, Palaeoecology, 15:63–82.

STERNBERG, K. M. G. VON. 1820–1838. Versuch einer geognostisch-botanischen Darstellung der Flora de Vorwelt: v. 1–8. Fr. Fleischer, Leipzig, Prague, 364 p.

TOOTS, H. 1967. Invertebrate burrows in the nonmarine Miocene of Wyoming. Contributions to Geology, University of Wyoming, 6:93–96.

YAMASHIRO, D. A. and R. L. SQUIRES. 1983. Miocene spring-tufa deposits, Diligencia Formation, southeastern Orocopia Mountains, California. Geological Society of America, Abstracts with Programs, 15:304.