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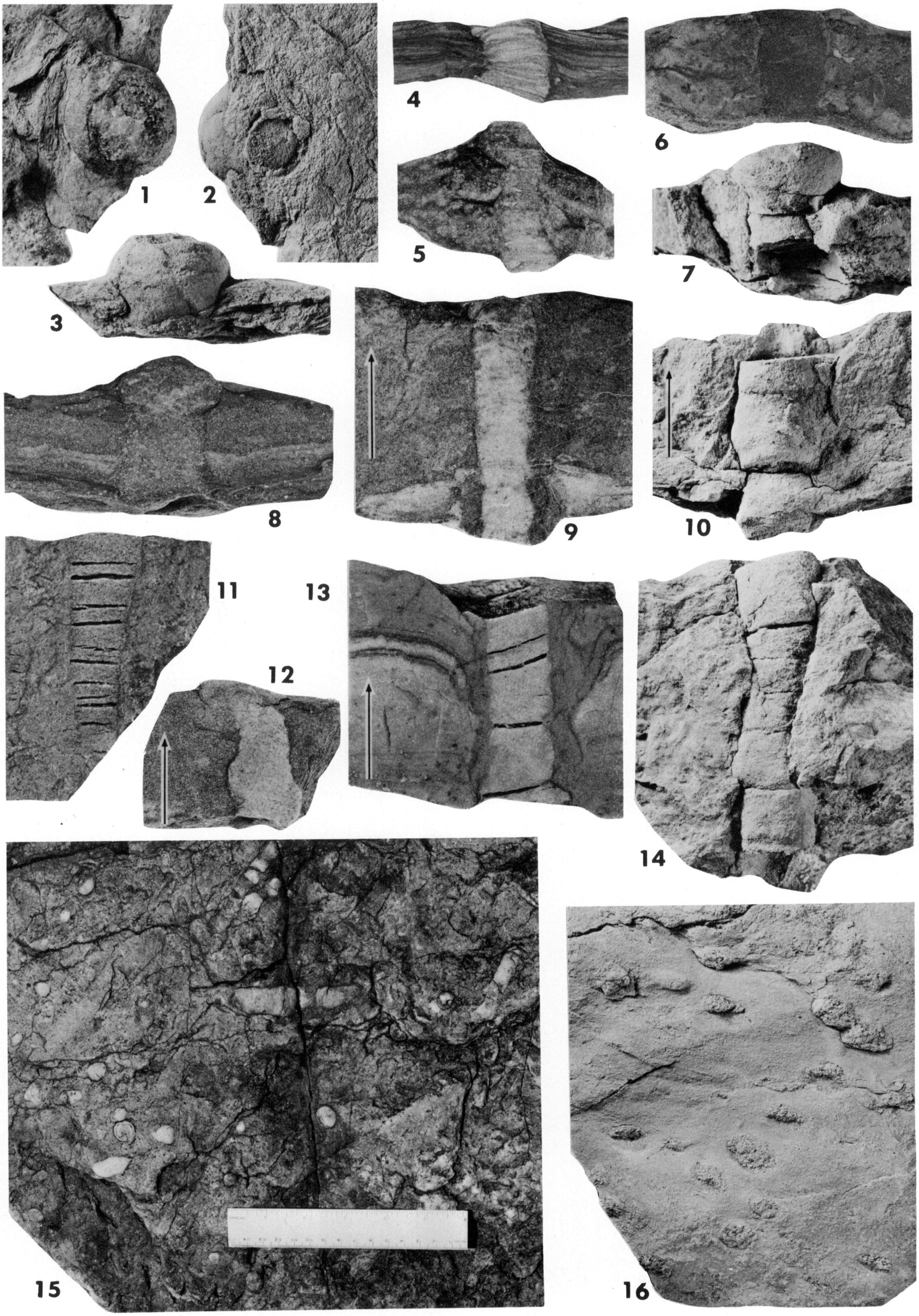
Reprinted from JOURNAL OF PALEONTOLOGY
Vol. 49, No. 3, May 1975
pp. 508–521
Made in United States of America



JOURNAL OF PALEONTOLOGY, V. 49, NO. 3, P. 508–521, 3 PLS., 2 TEXT-FIGS., MAY 1975

PLANOLITES AND *SKOLITHOS* FROM THE UPPER PRECAMBRIAN–LOWER CAMBRIAN, WHITE-INYO MOUNTAINS, CALIFORNIA

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ABSTRACT—Eight species of the trace fossil *Planolites* Nicholson, 1873, unbranched horizontal burrows, and two species of *Skolithos* Haldeman, 1840, unbranched vertical burrows, occur in the Upper Precambrian and Lower Cambrian rocks of the White-Inyo Mountains, California. Two species, *P. reticulatus* and *S. bulbus*, are new.

The genus *Planolites* and its relation to *Palaeophycus* Hall, 1847, is reviewed. The presence of true branching is suggested as the criterion for distinguishing *Palaeophycus* from *Planolites*. All the named species of *Planolites* and *Palaeophycus* are listed.

INTRODUCTION

Planolites burrows are the most abundant trace fossils in the Upper Precambrian-Lower Cambrian rocks in the White-Inyo Mountains, California (Text-fig. 1; Nelson, 1962). *Planolites* occurs throughout the section, from the upper Wyman Formation to the Saline Valley Formation (Text-fig. 2); it is rare in the Wyman Formation, and rare in carbonate rocks of the other formational units. *Planolites* occurs with almost all the other trace fossils found in the White-Inyo Mountains, many of which are characteristic of shallow water (Seilacher, 1967b). The associated trace fossils include *Skolithos*, *Bergaueria* (Alpert, 1973), *Rusophycus*, *Cruziana*, *Diplichnites*, *Monomorphichnus*, *Monocraterion*, *Laevicyclus*, *Archaeonassa*, *Scolicia*, *Arthrophycus*, *Teichichnus*, *Zoophycos*, *Plagiogmus*?, *Asteriacites*?, *Astropolithon*?, *Palaeophycus*?, and a new genus of smooth, flat trails. The relation to the Cambrian-Precambrian boundary problem, the

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EXPLANATION OF PLATE 1

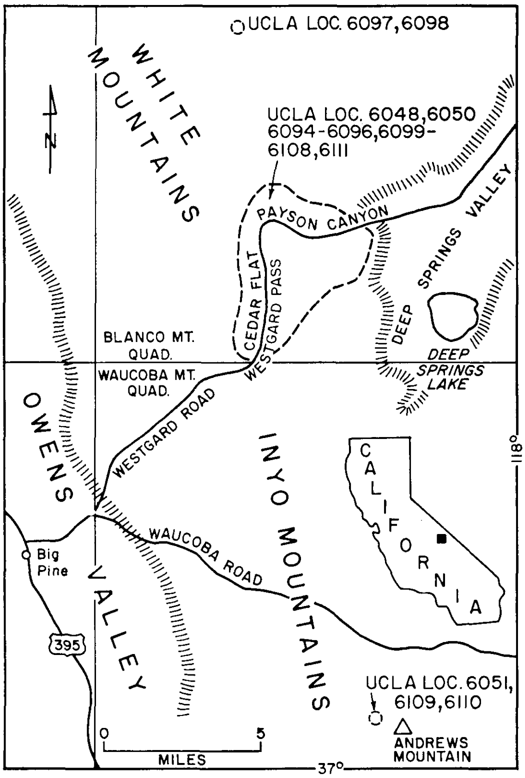
FIGS. *1–3*—*Skolithos bulbus* n. sp., holotype, UCLA 49022. *1*, presumed top view (uncoated). *2*, bottom view. *3*, side view. Quartzite, Poleta Formation, UCLA Loc. 6106. ×1.

4—*Skolithos*-like burrow, Montenegro Member, Campito Formation. UCLA 49034. Burrow filling layered, not a characteristic of *Skolithos*. UCLA Loc. 6111. ×1.

5–14—*Skolithos bulbus* n. sp., vertical sections and side views, natural size. Arrows indicate stratigraphic up, if known. All specimens (except 6 and 10) are from the quartzite of the Poleta Formation. *5*, hypotype, UCLA 49023, UCLA Loc. 6105. *6*, burrow with slight bulbous expansion within bed. Hypotype, UCLA 49024. Quartzite, Upper Member of the Deep Spring Formation, UCLA Loc. 6110. *7*, paratype, UCLA 49025; burrow segment with prominent bulbous expansion (incomplete). UCLA Loc. 6096. *8*, hypotype, UCLA 49026, UCLA Loc. 6107. *9*, burrow with abandoned or filled in bulbous expansion (at bottom). Orientation determined from specimen of *Monocraterion* present on same slab. Hypotype, UCLA 49027, UCLA Loc. 6096. *10*, Hypotype, UCLA 49028, siltstone, Harkless Formation, UCLA Loc. 6108. *11*, burrow with prominent horizontal tension cracks, seen on vertical fracture surface (uncoated). Hypotype, UCLA 49029, UCLA Loc. 6106. *12*, burrow with irregular expansion within bed, and another at top. Hypotype, UCLA 49030, UCLA Loc. 6096. *13*, burrow and disturbed bedding; burrow lined with darker sediment from above. Hypotype, UCLA 49031, UCLA Loc. 6094. *14*, paratype, UCLA 49032; burrow segment without prominent expansions. UCLA Loc. 6096.

15—Upper bedding surface (exposed in stream bed) in the quartzite unit of the Upper Member of the Poleta Formation, with abundant *Skolithos bulbus* (circular) and *Planolites beverleyensis* (oblong). Six-inch scale. UCLA Loc. 6050. ×0.25.

16—*Skolithos linearis* Haldeman, presumed upper bedding surface. Burrows elongated by deformation of rock. Hypotype, UCLA 49033. Quartzite, Harkless Formation, UCLA Loc. 6109. ×0.75.



TEXT-FIG. 1—Index map, showing situation of fossil localities.

stratigraphy, and the systematics of the remaining trace fossils of the White-Inyo Mountains, will be presented in a future work.

Skolithos is abundant in the quartzite unit of the Upper Member of the Poleta Formation; it is less common in the Harkless Formation, and is rare in the Deep Spring and Campito Formations. *Skolithos* is indicative of shallow water environments. *Planolites* occurs in rocks of various facies, and is thus of less paleoecological value.

SYSTEMATIC PALEONTOLOGY

Genus SKOLITHOS Haldeman, 1840

Vertical, cylindrical, unbranched burrows, 1 to 15 mm wide. See Alpert (1974) for complete description and synonymy.

SKOLITHOS LINEARIS Haldeman, 1840
Plate 1, fig. 16

See Alpert (1974) for complete synonymy.

Description.—Vertical burrows, cylindrical to subcylindrical, rarely inclined or curved. Diameter 4 to 6 mm. Burrows isolated or in clusters, not densely crowded. Burrow walls distinct or indistinct.

Stratigraphic distribution.—Skolithos linearis is rare in the White-Inyo Mountains. Specimens occur in siltstone of the upper Andrews Mountain Member of the Campito Formation, and in shales, siltstones, and quartzites of the lower and middle Harkless Formation. The distortion of *S. linearis* burrows in quartzite of the Harkless Formation near the Papoose Flat Pluton, Inyo Mountains, was noted by Sylvester and Christie (1968, p. 573, Pl. 2).

Hypotype.—UCLA 49033.

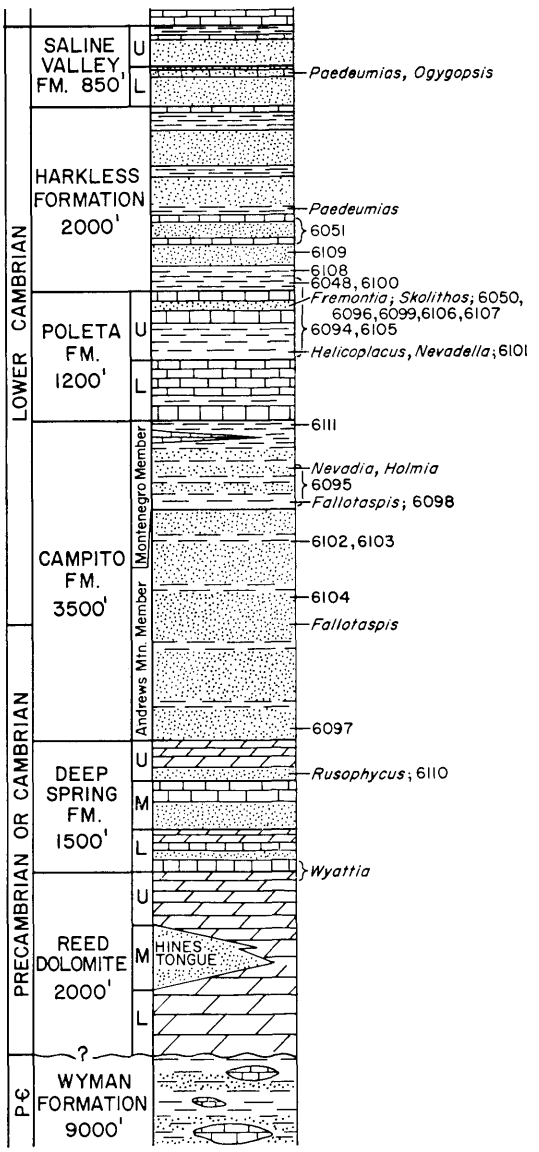
SKOLITHOS BULBUS n. sp.
Plate 1, figs. 1–3, 5–15

Description.—Burrows cylindrical to subcylindrical, vertical to inclined (rarely up to 45 degrees), straight, curved, or undulated. Diameter 4 to 15 mm, 7 to 11 mm most common. Burrow wall distinct, smooth. Burrows characterized by widely spaced spherical to subspherical expansions and slight bulges along the length. Diameter of bulbous expansions up to twice the diameter of the cylindrical portions of the burrow; maximum observed expanded diameter is 22 mm.

Remarks.—The bulbous expansions (or bulbs) are not present on all burrow segments of *S. bulbus*. Complete specimens have not been observed, as the burrows pass through one or more bedding surfaces. The longest segment observed is 26 cm long and without prominent bulges. The bulbous expansions commonly occur at upper and lower bedding surfaces, but also occur within the beds.

The burrows are slightly more resistant to weathering than the surrounding matrix, and commonly weather out of the rock. Horizontal tension cracks or fractures (not primary features) occur in many specimens (Pl. 1, figs. 5, 7, 10, 11, 13, 14), and indicate that the burrow fill possesses different mechanical properties than the matrix, in which such cracks are rare.

The density of *S. bulbus* burrows was determined for quartzite beds of the Poleta Formation, where the burrows are most abundant and occur with *Planolites beverleyensis* (Pl. 1, fig. 15). The number of *S. bulbus* burrows varies from 18 to 33 (mean of 23), and the number of segments of *P. beverleyensis* burrows from 0 to 12 (mean of 4), per square foot of bedding surface, on most beds (35 square feet measured). One horizon possesses 49 *S. bulbus* and 16 *P. beverleyensis* on a square foot exposure at UCLA Locality 6107.



TEXT-FIG. 2—Stratigraphic column of Upper Precambrian and Lower Cambrian formations, White-Inyo Mountains, California. Body- and trace-fossil reference horizons are shown at right, with stratigraphic positions of fossil localities. The Precambrian-Cambrian boundary can be drawn 1) below oldest trilobite (*Fallotaspis*), 2) below oldest trilobite trace fossil (*Rusophycus*), 3) below oldest shelled fossil (*Wyattia*), or 4) at possible local unconformity between the Wyman Formation and the Reed Dolomite. (Stratigraphy after Nelson in Nelson and Durham, 1966, Text-fig. 1.)

Interpretation.—The bulbous expansions may possibly have been turn-around areas to enable the organism to change its orientation in the burrow. Other possibilities are that the bulbs were brood or storage areas. One burrow (Pl. 1, fig. 9) appears to have an abandoned bulb; the cylindrical burrow continues through a prominent bulbous expansion without a significant change in diameter. The outer layer of the bulb is a darker color than the burrow filling. This may be due to organic material, used with sediment by the organism to fill the expansion, or to the use of darker sediment from above to form a burrow lining (Pl. 1, fig. 13).

Comparison.—*S. bulbus* is distinct from the five other species of *Skolithos* (Alpert, 1974). *S. verticalis* (Hall) and *S. linearis* Haldeman are smaller and have constant width. *S. magnus* Howell has indistinct burrow walls and constant width. *S. ingens* Howell displays slight bulges at irregular intervals; the bulges increase the burrow diameter by 1.5 mm. *S. annulatus* (Howell) has narrow ring-like expansions or annulations, 2 to 12 mm apart. The bulbous expansions of *S. bulbus* are more prominent and spherical than the slight expansions of *S. ingens* and *S. annulatus.*

The distinguishing characters of *S. bulbus* are, 1) the comparatively large average burrow diameter (7 to 11 mm); 2) the distinct, smooth walls; and 3) the prominent bulbous expansions.

Type specimens.—Holotype: UCLA 49022 (Pl. 1, figs. 1–3). Paratypes: UCLA 49025 (Pl. 1, fig. 7); UCLA 49032 (Pl. 1, fig. 14). The above specimens are from the quartzite unit of the Upper Member of the Poleta Formation, from the Westgard Pass area. Hypotypes: UCLA 49023, 49024, 49026-49031.

Stratigraphic distribution.—*S. bulbus* is abundant in the quartzite unit of the Upper Member of the Poleta Formation, especially in a 1.5 to 3 meter thick interval about 28 meters above the base of the quartzite unit, where the burrows form a resistant *Skolithos* marker bed (Pl. 1, fig. 15). Isolated specimens of *S. bulbus* are uncommon in siltstones of the lower Harkless Formation; questionable specimens occur in quartzites of the middle Harkless Formation. Rare specimens occur in siltstones of the Montenegro Member of the Campito Formation and in quartzite of the Upper Member of the Deep Spring Formation (Pl. 1, fig. 6).

Early Cambrian specimens of *Skolithos* have been reported from the basal Zabriskie Quartzite of the Nopah and Resting Springs Ranges, California (Hazzard, 1937, p. 310), and from the upper Wood Canyon Formation (= Daylight Formation, Cornwall and Kleinhampl, 1964, p. J2) in the Daylight Pass area of Death Valley. Examination of specimens from the Nopah Range (collected by C. A. Nelson) and from the Daylight Pass area (collected by R. H. Miller) indicates they are assignable to *S. bulbus.*

Genus PLANOLITES Nicholson, 1873

Palaeophycus Hall, 1847 (*partim*), p. 7; OSGOOD, 1970 (*partim*), p. 373–376.
Chondrites sp. Salter, 1856, p. 246; SALTER, 1866, p. 243, text-fig. 1; SALTER, 1881, p. 336, text-fig. 1.
?*Scolites* Salter, 1857, p. 204 (*partim*); SALTER, 1866, p. 292, Pl. 12, fig. 2; SALTER, 1881, p. 483, Pl. 12, fig. 2; HÄNTZSCHEL, 1965, p. 83.
Scolecites Salter, 1873, p. 2, 10 (= *Chondrites* sp. Salter); HÄNTZSCHEL, 1965, p. 82.
Planolites Nicholson, 1873, p. 289; NICHOLSON & HINDE, 1875, p. 138–139; NICHOLSON, 1875, p. 41–42; NICHOLSON, 1879, p. 319–320; NICHOLSON, 1885, p. 122–123; NICHOLSON & LYDEKKER, 1889, p. 482–484; MILLER, 1889, p. 520; HOWELL, 1943, p. 17–18; HÄNTZSCHEL, 1962, p. W210; GEKKER & USHAKOV, 1962, p. 72; HÄNTZSCHEL, 1965, p. 72; GREGORY, 1969, p. 6; FREY, 1970, p. 16; HEINBERG, 1970, p. 230–231; OSGOOD, 1970 (*partim*), p. 375–377; CHAMBERLAIN, 1971, p. 226; YOUNG, 1972, p. 14; FREY & CHOWNS, 1972, p. 32–33; CHAMBERLAIN & CLARK, 1973, p. 679.
Planulites Dawson, 1892, p. 29 (misspelling).
Planotites J. F. James, 1894, p. 135 (misspelling).
Planilites Dawson, 1897, text-fig. 11 (p. 53; misspelling).
?*Montfortia* Lebesconte, 1887 (*non* Recluz, 1843), p. 782.
"smooth tubes" Howard, 1966, p. 43, text-fig. 8.

Type species.—Planolites vulgaris Nicholson & Hinde, 1875 = *Palaeophycus beverleyensis* Billings, 1862.

Description.—Unbranched horizontal burrows, without backfilled or other internal structure. Circular, elliptical, or lenticular in transverse section; diameter or width from 0.5 to 23 mm. Diameter does not vary significantly along length of burrow. Burrow walls distinct, smooth, may be striated or annulated. Sediment filling burrow may differ from the host rock.

Burrows may be horizontally and vertically sinuous and may thus transect bedding surfaces; they may also be inclined or vertical for short distances. Burrows are isolated to densely crowded, and may cover the entire bedding surface. Burrows tend to overlap or parallel one another rather than intersect, which results in apparent, but not true, branching.

Remarks.—Planolites is believed to have been formed by a worm-like organism eating its way through the sediment, with the burrow fill representing the material that passed through the organism's alimentary canal. *Planolites* thus belongs in the Fodinichnia group of Seilacher's (1964) ethological classification of trace fossils.

Planolites is similar to *Palaeophycus* Hall, 1847, and the distinction between the two genera is unclear (Frey and Chowns, 1972, p. 32). Osgood (1970, p. 375, 376) addressed the problem, and suggested that the lithology of the burrow filling compared to that of the host rock could be used to distinguish the genera—similar lithology for *Palaeophycus,* distinct difference for *Planolites.* However, this is not always the case among specimens of horizontal burrows studied by the writer. A more useful criterion for differentiation is the presence or absence of true branching. Branched burrows are *Palaeophycus,* unbranched, *Planolites.*

Palaeophycus generally has irregular walls and exhibits collapse features, whereas *Planolites* generally has smooth walls without collapse features (Frey and Chowns, 1972, p. 32). A complete study of *Palaeophycus* and its relation to other branched burrows, such as *Chondrites,* has not been undertaken.

Scolites and *Scolecites* of Salter (1857 and 1873) are questionable genera with no named species. Both have been confused with *Skolithos,* but specimens illustrated as *Scolites* and *Scolecites* appear to be *Planolites.*

Mesozoic specimens of *Planolites* (Frey, 1970, for example) are oriented more randomly throughout the rock than Early Paleozoic specimens, which generally are horizontal.

The species of *Planolites* present in the White-Inyo Mountains are treated in order of increasing width of the burrows. The burrows are preserved on upper (epichnial) and lower (hypichnial) bedding surfaces, and less commonly within the beds. Where the burrows have been broken or weathered away, corresponding grooves, representing external molds of the burrows, are left on the bedding surface.

PLANOLITES BALLANDUS Webby, 1970
Plate 2, fig. 11

Planolites ballandus Webby, 1970, p. 95, text-figs. 14A-C.

Description.—Horizontal burrows, uncommonly inclined to vertical. Diameter 0.5 to 2 mm. Burrows straight to sinuous, commonly discontinuous in two-dimensional aspect. Vertical segments may be represented as small mounds on the bedding surface.

Remarks.—This species grades into the larger form, *Planolites montanus,* and is distinguished from it by its smaller size and sinuous burrow course.

A vertical burrow found in the Campito Formation, Pl. 2, fig. 2) closely resembles a burrow illustrated by Webby (1970, text-fig. 14B) as a section through a vertical segment of *P. ballandus.* My specimen is four times larger than Webby's, and has no bedding surface expression; it is doubtful whether either of these burrows are attributable to *P. ballandus.*

Stratigraphic distribution.—Specimens of *P. ballandus* occur in shales and siltstones of the lower Harkless Formation. Specimens less certainly assigned to *P. ballandus* occur in shales of the upper Andrews Mountain Member and upper Montenegro Member of the Campito Formation.

Hypotype.—UCLA 49008.

PLANOLITES SERPENS (Webby, 1970)
Plate 2, figs. 1, 4, 8

Cochlichnus serpens Webby, 1970, p. 97–98, text-figs. 16A-F.

Description.—Horizontal burrows, 0.75 to 2 mm in diameter. Burrows gently curved to sinuous.

Remarks.—The distinction between *P. serpens* and *P. ballandus* is not sharp. The burrow wall of *P. serpens* generally is smoother and more regular than the wall of *P. ballandus.* The burrows of *P. serpens* are rarely inclined and commonly are preserved as limonite casts. Some specimens of *P. serpens* from the Campito Formation contain limonite.

Stratigraphic distribution.—*P. serpens* is present in *Fallotaspis*-bearing green shale of the lowermost Montenegro Member of the Campito Formation, and in shales of the lower Harkless Formation.

Hypotypes.—UCLA 49005-49007.

PLANOLITES MONTANUS Richter, 1937
Plate 2, figs. 3, 6

Planolites montanus Richter, 1937, p. 151, text-figs. 1–5; JESSEN, 1950, p. 32, 35; HÄNTZSCHEL, 1962, text-fig. 129.7a, b; SEILACHER, 1963, p. 84, text-fig. 1; ?BANDEL, 1967, p. 9, Pl. 5, fig. 4, text-fig. 2.6.

Description.—Horizontal, cylindrical burrows, 1 to 5 mm in diameter. Burrows repeatedly transect individual bedding surfaces, or occur within beds; segments visible on bedding surfaces are about 5 to 25 mm in length.

Remarks.—Burrows of varied diameters, from 1 to 5 mm, generally occur together (Pl. 2, fig. 3). *P. montanus* commonly occurs with larger species of *Planolites* (Pl. 3, figs. 2, 7).

Stratigraphic distribution.—*P. montanus* is the most common trace fossil in the White-Inyo Mountains and occurs throughout the section. Questionable specimens are present in the upper Wyman Formation. Good specimens occur in the siltstones and quartzites of the Hines Tongue of the Reed Dolomite; in quartzites and siltstones of the Middle and Upper Members of the Deep Spring Formation; in shales and quartzitic siltstones and sandstones throughout the Campito Formation; in shale of the Lower Member of the Poleta Formation; in shales, siltstones and quartzites of the Upper Member of the Poleta Formation and lower to middle Harkless Formation; and in quartzitic siltstones of the Upper Member of the Saline Valley Formation.

Hypotypes.—UCLA 49010, 49011.

PLANOLITES RETICULATUS n. sp.
Plate 2, figs. 5, 7, 9

?*Palaeophycus*, type-C Osgood, 1970 (*partim*), p. 377–378, Pl. 83, figs. 1, 4.

Description.—Horizontal, cylindrical to flattened burrows, straight to curved, 1 to 5 mm wide, forming a network on the bedding surface. Burrows overlap, or run alongside others for short distances, creating apparent branching.

Type specimens.—Holotype: UCLA 49014 (Pl. 2, fig. 9), from the lower Harkless Formation. Paratypes: UCLA 49012 (Pl. 2, fig. 5), from the basal Upper Member of the Poleta Formation, and UCLA 49013 (Pl. 2, fig. 7), from the upper Andrews Mountain Member of the Campito Formation. The above specimens are from localities in the Westgard Pass area, and were in locally derived float.

Stratigraphic distribution.—As above; the Poleta and Harkless occurrences are in siltstones, and the Campito specimen is in a shaly parting between siltstone beds.

PLANOLITES BEVERLEYENSIS (Billings, 1862)
Plate 1, fig. 15; Plate 3, figs. 1, 7, 8

"annelide markings" Dawson, 1859, p. 73–74, text-fig. 6.

?*Palaeophycus congregatus* Billings, 1861a, p. 3; BILLINGS, 1861b, p. 944.

?*Planolites congregatus* Walcott, 1890a, p. 34–35; WALCOTT, 1890b, p. 602, Pl. 61, fig. 1.

Palaeophycus beverleyensis Billings, 1862, p. 97, text-fig. 86.

Palaeophycus beverlyensis Dawson, 1892, text-fig. 8 (misspelling); LESLEY, 1889, p. 586, text-fig. (misspelling).

?*Palaeophycus funiculus* Billings, 1862, p. 98.

?*Palaeophycus beauharnoisensis* Billings, 1862, p. 98.

?*Scolites* Salter, 1866, p. 292, Pl. 12, fig. 2; SALTER, 1881, p. 483, Pl. 12, fig. 2.

"casts of trails of worms" Dawson, 1868, p. 256, text-fig. 79.

Planolites vulgaris Nicholson, 1873, p. 290 (*nomen nudum*); NICHOLSON & HINDE, 1875, p. 139;

NICHOLSON, 1875, p. 42, text-fig. 18; NICHOLSON, 1879, p. 320, text-fig. 191; NICHOLSON, 1885, text-fig. 63; NICHOLSON & LYDEKKER, 1889, p. 483, text-fig. 348.
non Palaeophycus vulgaris Borrello, 1966, p. 19–20, Pl. 23, fig. 2, Pl. 24, figs. 1–4.
?*Planolites corrugatus* Walcott, 1899, p. 236, Pl. 24, fig. 8; WALCOTT, 1914, Pl. 21, fig. 8; RAYMOND, 1922, p. 113; SEILACHER, 1956, p. 165, text-fig. 1, no. 18; OSGOOD, 1970, Pl. 77, fig. 2.
Planolites sp. Bandel, 1967, p. 9, Pl. 5, fig. 6, text-fig. 2.4.

Description.—Horizontal, cylindrical to flattened burrows, inclined in places; surface smooth. Burrows straight to curved, 3 to 19 mm in diameter, 3 to 12 mm most common. Diameter may vary slightly along length of burrow. Burrows may cover entire bedding surface, overlapping each other.

Remarks.—Nicholson and Hinde (1875) state that *Planolites vulgaris* corresponds to some of the species of *Palaeophycus,* but do not name these; it is identical to *P. beverleyensis* of Billings, 1862.

The burrows of *P. beverleyensis* are generally larger than those of *P. montanus,* and transect individual bedding surfaces less commonly; thus the visible segments are generally several inches in length, as opposed to an inch or less for *P. montanus.*

Burrows larger (8 to 14 mm or more in diameter) than the normal *P. beverleyensis* or *P. vulgaris* (3 to 8 mm) are included here in *P. beverleyensis.* These larger burrows are commonly inclined or vertical for short distances, where they can be confused with *Skolithos bulbus.*

Burrows of *P. beverleyensis* exhibit the primitive behavioral method of foraging, termed scribbling (Seilacher, 1967a), a random circling and crossing of previous burrows. In addition to scribbling, specimens of *P. beverleyensis* from the White-Inyo Mountains exhibit irregular loose meandering and looping (Pl. 3, fig. 7).

Stratigraphic distribution.—*P. beverleyensis* occurs in the quartzites of the Hines Tongue of the Reed Dolomite; in shales and quartzitic siltstones and sandstones of the Campito Formation; in limestones of the Lower Member of the Poleta Formation; and in shales, siltstones, and quartzites of the Upper Member of the Poleta and lower to middle Harkless Formations.

Hypotypes.—UCLA 49015–49017.

PLANOLITES STRIATUS (Hall, 1852)
Plate 3, figs. 3, 4

Palaeophycus? striatus Hall, 1852 (*partim*), p. 22, Pl. 10, fig. 1a.
Palaeophycus? striatum Osgood, 1970, p. 374, Pl. 76, figs. 6, 7.

Description.—Horizontal, straight, cylindrical burrows; may transect bedding surfaces. Diameter 10 to 15 mm. Entire surface of burrow displays numerous faint longitudinal striations or ridges, which are parallel and continuous.

Remarks.—Similar to the larger forms of *P. beverleyensis,* but with striations; burrows commonly isolated. Presumably the striations were produced by the organism's bristles or setae, which scratched the burrow wall as the animal moved.

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EXPLANATION OF PLATE 2

FIGS. *1, 4, 8*—*Planolites serpens* (Webby). *1,* hypotype, UCLA 49005. Montenegro Member, Campito Formation, UCLA Loc. 6098. ×2. *4,* hypotype, UCLA 49006. Harkless Formation, UCLA Loc. 6100. ×0.75. *8,* two specimens, one visible in longitudinal section; uncoated. Hypotype, UCLA 49007. Same locality as *1.* ×1.

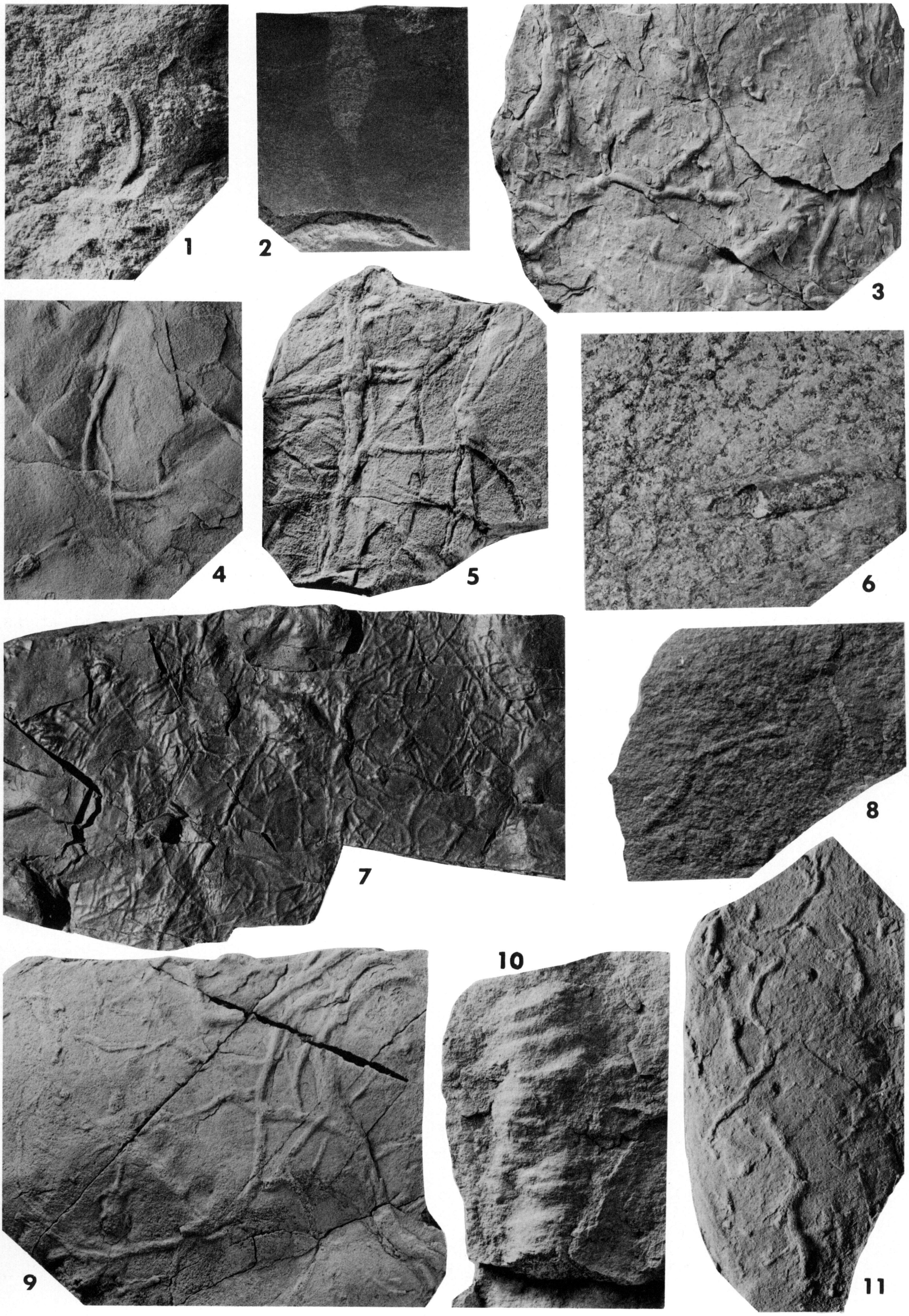
2—Vertical burrow, Andrews Mountain Member, Campito Formation. UCLA 49009, UCLA Loc. 6102. ×1.5.

3, 6—*Planolites montanus* Richter. *3,* numerous specimens on upper bedding surface. Hypotype, UCLA 49010. Quartzite, Harkless Formation, UCLA Loc. 6051. ×0.6. *6,* large specimen (uncoated) in shale containing abundant disarticulated plates (light specks) of the echinoderm *Helicoplacus,* and trilobite fragments (not visible). Hypotype, UCLA 49011. Upper Member, Poleta Formation, UCLA Loc. 6101. ×1.

5, 7, 9—*Planolites reticulatus* n. sp. *5,* paratype, UCLA 49012. Siltstone, Upper Member, Poleta Formation, UCLA Loc. 6101. ×0.75. *7,* paratype, UCLA 49013, probable lower bedding surface, uncoated. Upper Andrews Mountain Member, Campito Formation, UCLA Loc. 6104. Collected by J. E. Morhardt. ×0.5. *9,* holotype, UCLA 49014. Harkless Formation, UCLA Loc. 6094. ×0.75.

10—*Planolites annularius* Walcott ? Specimen on lower bedding surface. Hypotype, UCLA 49020. Montenegro Member, Campito Formation, UCLA Loc. 6095. ×1.

11—*Planolites ballandus* Webby. Hypotype, UCLA 49008. Harkless Formation, UCLA Loc. 6048. ×1.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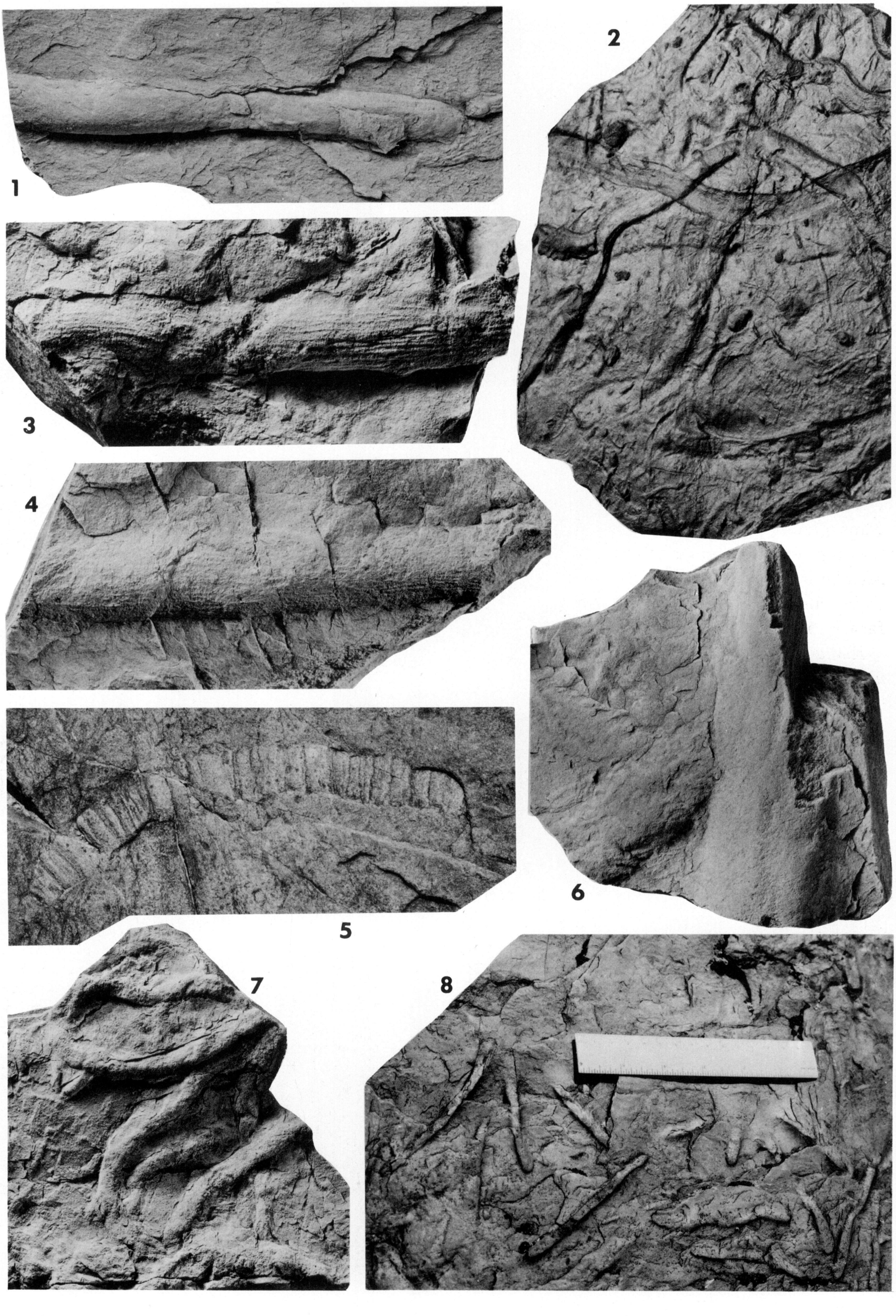
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Stratigraphic distribution.—*P. striatus* is common in the quartzites of the Upper Member of the Poleta Formation; one specimen was found in siltstone at the base of the Upper Member of the Poleta Formation. A questionable specimen was collected from quartzite of the middle Harkless Formation.

Hypotypes.—UCLA 49018, 49019.

PLANOLITES ANNULARIUS Walcott, 1890 ?
Plate 2, fig. 10; Plate 3, fig. 5

Planolites annularius Walcott, 1890a, p. 34; WALCOTT, 1890b, p. 602, Pl. 60, fig. 5; J. F. JAMES, 1891a, p. 36, text-fig. 7; OSGOOD, 1970, Pl. 77, fig. 3.
Planolites? sp. Webby, 1970, p. 96–97, text-fig. 15.

Description and stratigraphic distribution.—Horizontal burrows with tranverse annulations. Two specimens were found: one (Pl. 2, fig. 10; UCLA 49020), from shale of the lower Montenegro Member of the Campito Formation, is 15 mm wide and lenticular in transverse section; the other (Pl. 3, fig. 5), at the top of the quartzite unit of the Upper Member of the Poleta Formation, is 20 mm wide, curved, and dips below the bedding surface in places.

Remarks.—The larger specimen of *P. annularius* (Pl. 3, fig. 5) could be a backfilled burrow; the cross-sectional shape and internal structure is unknown, as the specimen could not be removed from the rock.

The above specimens are larger than the holotype, which is 4 mm wide.

PLANOLITES VIRGATUS (Hall, 1847)
Plates 3, figs. 2, 6

Palaeophycus virgatus Hall, 1847, p. 263, Pl. 70, fig. 1; GOEPPERT, 1851, p. 189; NICHOLSON, 1875, p. 38, text-fig. 13; *non* J. F. JAMES, 1885, p. 158; ?PACHECO, 1908, p. 85, Pl. 1, fig. 2.
Planolites virgatus Walcott, 1890b, p. 602–603, Pl. 61, fig. 5.
?*Palaeophycus* sp. Hall, 1852, p. 24, Pl. 8, fig. 3.
?*Chondrites* sp. Salter, 1856, p. 246; SALTER, 1866, p. 243, text-fig. 1, p. 292, Pl. 3, fig. 4; SALTER, 1881, p. 336, text-fig. 1, p. 483, Pl. 3, fig. 4.
Palaeophycus incipiens Billings, 1861a, p. 2; BILLINGS, 1861b, p. 943–944.
Planolites incipiens Walcott, 1890a, p. 35.
?*Scolecites* SALTER, 1873, p. 2, 10.
non Trichophycus venosum Miller, 1879, p. 112–113, Pl. 9, figs. 5, 5a; OSGOOD, 1970, p. 347–350, Pl. 60, fig. 7, Pl. 68, figs. 1, 3, 4–7, Pl. 70, fig. 4, text-figs. 16, 29w.
non Planolites virgatum (Hall) J. F. JAMES, 1891b, p. 47 (= *Trichophycus venosus*).
non Arthrophycus montalto Simpson in LESLEY, 1889, p. 40–41, text-fig.
?*Planolites montalto* (Simpson) HOWELL, 1943, p. 17–23, Pl. 8, figs. 1, 2.
Planolites superbus Walcott, 1899, p. 236–237, Pl. 24, fig. 9; WALCOTT, 1914, Pl. 21, fig. 9; RAYMOND, 1922, p. 114.
?*Palaeophycus arthrophycoides* Wilckens, 1947, p. 48, Pl. 9, fig. 3.
?"trace fossil" Wolfe, 1969, p. 274–276, Pl. 14–15.

Description.—Long, flat, horizontal burrows, 7 to 23 mm wide; elliptical to lenticular in transverse section. Length generally 15 to 50 cm. Surface smooth, may have a few faint longitudinal striations, grooves, or ridges, or a prominent median ridge (Nelson and Durham, 1966, Pl. 4, fig. 3). Burrows straight, curved or sinuous, and tend to overlap rather than intersect.

←

EXPLANATION OF PLATE 3

FIGS. *1, 7, 8*—*Planolites beverleyensis* (Billings). 1, hypotype, UCLA 49015. Harkless Formation, UCLA Loc. 6051. ×1. *7*, several specimens, two largest exhibit looping. Hypotype, UCLA 49016. The smaller burrows are *P. montanus.* Montenegro Member, Campito Formation, UCLA Loc. 6095. ×0.6. *8*, numerous specimens on upper bedding surface of quartzite in Harkless Formation (UCLA Loc. 6051), resembling *Diplocraterion* (bottoms of U-shaped burrows, seen on bottom of beds, only). Two burrow segments collected (UCLA 49017). Six-inch scale. ×0.25.

2, 6—*Planolites virgatus* (Hall). *2*, several overlapping specimens on probable lower bedding surface; one burrow preserved as a groove. Hypotype, UCLA 49160; collected by C. A. Nelson and J. N. Moore. *P. montanus, P. beverleyensis,* and other trace fossils are also present on the slab. Lower Andrews Mountain Member, Campito Formation, UCLA Loc. 6097. ×0.25. *6, P. virgatus* (left; hypotype, UCLA 49021), and cast of large trial (right, broken). Upper Andrews Mountain Member, Campito Formation, UCLA Loc. 6103. ×0.75.

3, 4—*Planolites striatus* (Hall). Quartzite, Upper Member of the Poleta Formation. *3*, burrow with distinct striations. Hypotype, UCLA 49018. UCLA Loc. 6094. ×1. *4*, burrow with fainter striations. Hypotype, UCLA 49019. UCLA Loc. 6096. ×1.

5—*Planolites annularius* Walcott ? Large specimen visible on upper bedding surface of quartzite beds in the Upper Member of the Poleta Formation (UCLA Loc. 6099). A two-inch segment of the same burrow is visible five inches from the left end along a straight line (not in figure). Specimen not collected. ×0.4.

Remarks.—Unflattened, cylindrical specimens of other species of *Planolites* occur with *P. virgatus*, suggesting that the flatness of the burrows is a primary feature and not due to compaction.

Structures resembling *P. virgatus*, but larger (29 to 60 mm wide), are found with *P. virgatus* (Pl. 3, fig. 6) in the upper Andrews Mountain Member of the Campito Formation. These occur as slightly curved ridges which do not transect bedding surfaces; they are probably hypichnial casts of large trails, and not *Planolites*. Similar forms have been found that are three-dimensional and oval in cross section; however, insufficient material is available at the present time to name a new species for these large forms of *Planolites*.

Stratigraphic distribution.—Questionable specimens occur in the upper Wyman Formation, in the Middle Member of the Deep Spring Formation, and in the lower Harkless Formation. *P. virgatus* is common in the Campito Formation, especially the Andrews Mountain Member, where it is generally found in thin shaly partings among the quartzitic siltstone and sandstone beds; the burrows are filled with siltstone or sandstone.

Hypotypes.—UCLA 49021, 49160.

DIAGNOSTIC CHARACTERS OF SPECIES OF *PLANOLITES* PRESENT IN WHITE-INYO MOUNTAINS

P. ballandus–up to 2 mm wide; straight to sinuous; commonly inclined.
P. serpens–up to 2 mm wide; curved to sinuous; rarely inclined.
P. montanus–1 to 5 mm wide; commonly inclined; short segments visible on bedding surface.
P. reticulatus–1 to 5 mm wide; burrows overlap, form network on bedding surface.
P. beverleyensis–3 to 19 mm wide; wall smooth; long, continuous segments visible on bedding surface.
P. striatus–10 to 15 mm wide; wall longitudinally striated.
P. annularius–burrows transversely annulated.
P. virgatus–7 to 23 mm wide; lenticular in transverse section; long.

OTHER SPECIES OF *PLANOLITES* AND *PALAEOPHYCUS*

The remaining species of *Planolites* (not found in the White-Inyo Mountains) are *P. ophthalmoides* Jessen, 1950, p. 34; *P. rugulosus* Reineck, 1955, p. 79; *P.? vermiculare* Müller, 1955, p. 657; and *P.? octichnus* Chamberlain, 1971, p. 227. Of these, only *P.? octichnus* truly represents the genus *Planolites*. Three species of *Planolites* are *nomena nuda*: *P. granosus* Nicholson, 1873; *P. articulatus* Nicholson, 1873 (*non Palaeophycus articulatus* Winchell, 1864, as Nicholson cites himself as author); and *P. arcticus* Ami, 1906.

J. F. James (1891b, p. 47) transferred many diverse trace fossils into the genus *Planolites*, at the beginning of his manual of paleontology of the Cincinnati area. Systematic treatment was to appear later in the Annelida section of the manual, which was never published. The new combinations James created (with the original genus following in parenthesis) are *P. diadematum* (Miller & Dyer) (*Blastophycus*); *P. ramulosus* (Miller), *P. succulens* (Hall), and *P. crassa* (Hall) (*Buthotrephis*); *P.? flabellum* (Miller & Dyer) (*Licrophycus*); *P. radiatus* (Orton), *P. rugosa* (Hall), *P. tubularis* (Hall), and *P. virgatum* (Hall) (*Palaeophycus*); and *P. asperum* (Miller) and *P. subangulatum* (Hall) (*Rusophycus*). The above species should not be placed in *Planolites*. The *Palaeophycus virgatum* mentioned by James is *Trichophycus venosus* Miller, 1879 (Osgood, 1970, p. 300, 347).

Eight species of *Palaeophycus* have been transferred, some questionably, to *Planolites* (see synonymies herein). Thirty-two remaining species of *Palaeophycus* and specific names associated with *Palaeophycus* are listed below in chronologic order, some dates being unknown. Those species with burrows that exhibit branching, or questionably branch, are noted by an asterisk (*); those species for which I have been unable to find an illustration or description are noted by a double asterisk (**).

P. tubularis Hall, 1847, p. 7; type species, subsequent designation by Miller, 1889, p. 130; (*).
P. irregularis Hall, 1847, p. 8, (*).
P. rugosus Hall, 1847, p. 63, (*).
P. simplex Hall, 1847, p. 63.
P. tortuosus Hall, 1852, p. 6, (*).
P. obscurus Billings, 1862, p. 98.
P. articulatus Winchell, 1864, p. 231, (*).
P. informis Winchell, 1864, p. 232, (*).
P. spinatus Geinitz, 1867, p. 16, (*).
P. hartungi Geinitz, 1867, p. 16, (*).
P. macrocystoides Geinitz, 1867, p. 17, (*).
P. acicula Eichwald (**), (see Bigsby, 1868, p. 1).
P. hocianus Geinitz (**), (see Schimper, 1869, p. 198).
P. insignis Geinitz (**), (see Schimper, 1869, p. 198).
P. kochi Ludwig, 1869 (= *Cochlichnus*; see Häntzschel, 1965, p. 23).
P. heberti (Saporta, 1872), (see Saporta and Marion, 1883, p. 97–98, text-fig. 23). Transferred back to (and type species of) original genus, *Siphonites* (see Häntzschel, 1962, p. W215; 1965, p. 85).
P. radiata Orton, 1873, (*), (see Osgood, 1970, p. 345).
P. devonicus Schimper, 1874, p. 2, Pl. 2, fig. 2, (*).

P. milleri Lesquereux, 1876, p. 136, (*).
P. gracilis Lesquereux, 1876, p. 137, (*).
P. divaricatus Lesquereux, 1876, p. 138, (*).
P. occidentali Whitfield, 1877 (**), (see Miller, 1889, p. 131).
P. plumosus Whitfield, 1878, p. 50 (*).
P. flexosus U. P. James, 1879 (inorganic ripple marks; present in White-Inyo Mountains).
P. limaciformis Lewis, 1880, p. 293.
P. ornatum Ulrich, 1880, *nomen nudum.*
P. sculptum Ulrich, 1880, *nomen nudum.*
P. marginatus Fritsch, 1908, p. 18.
P. fluctuans Ruedemann, 1925, p. 10, (*).
P.? dichotoma Wilson, 1948, p. 9, (*).
P. gracilis Borrello, 1966, p. 18 (*non* Lesquereux, 1876), (*).
P. vulgaris Borrello, 1966, p. 19 (*non Planolites vulgaris* Nicholson and Hinde, 1875).

The species listed above have not been studied in detail by the writer who therefore does not necessarily believe that they are all referable to the genus *Palaeophycus.*

ACKNOWLEDGMENTS

I thank Professors C. A. Hall and C. A. Nelson of the Department of Geology, University of California, Los Angeles (UCLA), for reading the manuscript and offering helpful suggestions. The Text-figures were drafted by Julie Guenther.

I also thank Messrs. J. E. Morhardt and Lee Early of Bishop, California, for the discovery of several localities yielding diverse Early Cambrian trace fossils, and for the donation of many important trace fossil specimens to the paleontological collection of UCLA.

LOCALITIES OF FIGURED SPECIMENS

UCLA Locality numbers

For localities 6048, 6050, and 6051, see Alpert, 1973, p. 923. The following localities are in the Waucoba Mountain 15′ quadrangle (1951), Inyo County, California (Nelson, 1966a).

6109–1.2 miles west and 700 feet north of SW corner sec. 7, T. 10 S., R. 36 E.
6110–200 feet west and 1300 feet north of SW corner sec. 7, T. 10 S., R. 35 E.

The remaining localities are in the Blanco Mountain 15′ quadrangle (1951), Inyo County, California (Nelson, 1966b).

6094–Northwest slope of ridge, east of Cedar Flat; 250 feet east and 1000 to 2000 feet north of SW corner sec. 34, T. 7 S., R. 35 E.
6095–South of gravel quarry at end of Payson Canyon; 2000 to 2500 feet north (from south end) along border of sections 26 and 27, T. 7 S., R. 35 E.
6096–2000 feet east and 2000 feet north of SW corner sec. 26, T. 7 S., R. 35 E.
6097–800 feet south of Goat Spring; 1250 feet east and 250 feet south of NW corner sec. 19, T. 6 S., R. 35 E. (locality 3 of Nelson and Durham, 1966).
6098–1200 feet north and 250 feet west of SW corner sec. 18, T. 6 S., R. 35 E. (locality 2 of Nelson and Durham, 1966).
6099–2400 feet west and 2400 feet north of SE corner sec. 35, T. 7 S., R. 35 E.
6100–2500 feet west and 1500 feet north of SE corner sec. 35, T. 7 S., R. 35 E.
6101–2250 feet east and 1750 feet south of NW corner sec. 8, T. 8 S., R. 35 E.
6102–1750 feet west and 2550 feet north of SE corner sec. 29, T. 7 S., R. 35 E.
6103–2500 feet east and 1900 feet south of NW corner sec. 29, T. 7 S., R. 35 E.
6104–North of road near end of Payson Canyon; 1750 feet west and 1950 feet south of NE corner sec. 27, T. 7 S., R. 35 E.
6105–NW¼, sec. 25, T. 7 S., R. 35 E.
6106–700 feet west and 1900 feet south of NE corner sec. 34, T. 7 S., R. 35 E.
6107–Along stream bed, 400 feet east and 1700 feet north of SW corner sec. 35, T. 7 S., R. 35 E.
6108–500 feet west and 2250 feet north of SE corner sec. 34, T. 7 S., R. 35 E.
6111–2000 feet west and 1250 feet south of NE corner sec. 32, T. 7 S., R. 35 E.

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Manuscript received November 21, 1973
Revised Manuscript received March 28, 1974