a few trace fossils is sufficient to make possible deductions regarding the depositional environment of the sediment. RUDOLF RICHTER (1931) demonstrated that the occurrence of *Chondrites* in the Hunsrück Shale of Germany indicates that the original sediment did possess an infauna and was not an H_2S-rich sapropel as had been believed previously. In a genuine euxinic environment, lebensspuren would be entirely absent.

Trace fossils can also help to determine certain characteristics of the depositional environments of sediments, especially in the marine realm. By studying trace fossils, lithologies, and body fossils in paralic Upper Carboniferous cyclothems of western Germany, SEILACHER (1963, 1964c, p. 307) (Fig. 20) has been able to distinguish whether a sediment was deposited in freshwater, brackish water, or under marine conditions. Some conclusions as to the strength and direction of currents can be drawn from the study of trace fossils. A few examples are: 1) deviation and obliteration of trilobite running trails, especially by lateral currents across the trails, 2) current orientation of resting impressions parallel to the direction of flow (rheotactic orientation, mostly against current direction), 3) existence of different kinds and varying abundances of lebensspuren in areas with strong, as contrasted with weak currents, and 4) orientation against the current (presumably tidal currents) of some dwelling structures in the Jurassic of England (FARROW, 1966).

TRACE FOSSILS

The definition of the concept "trace fossil" in the Introduction indicates the kind of fossils discussed in this section. As the result of the very numerous trace fossil investigations undertaken since the first edition of this chapter (HÄNTZSCHEL, 1962), the number of ichnogenera has increased considerably. Unfortunately, many forms lacking definite characters have been given names when only simple morphological descriptions were needed. In some cases, descriptions as well as illustrations were insufficient. Some of the original "generic" diagnoses were changed by some authors, mostly expanded, so that forms that diverged considerably from the early definitions were listed under the old names. Also, many transitional forms between well-defined and well-known ichnogenera have been recognized. This was to be expected and it demonstrates the difficulties of identification and nomenclature of trace fossils. It is not easy to find a compromise between a narrow and a broad definition of trace fossil generic concept. Frequently also, authors have changed their ideas about the definition of an ichnogenus, thus creating synonyms.

I have tried to list all ichnogenera published before the end of 1971. Since good, clear illustrations are very important in the description of trace fossils, the illustrations have been improved and their number has been increased as far as possible. In many recent ichnological publications, ichnocoenoses have been classified according to the well-known "ecological" system of SEILACHER discussed above. However, in this volume, for reasons given in the first edition, the arrangement of ichnogenera in alphabetical sequence of names has been preserved. Descriptions of especially widespread and important ichnogenera are given in greater detail, and following them, expanded statements concerning former and present interpretations. Complete references to old and new literature about ichnogenera are found in the reference list.

In a review of the *Treatise* Part W of

1962, SEILACHER (1964b) stated that in the section on trace fossils, about half of the names could have been placed in synonymy. This proportion seems too great to me. As already indicated in the Introduction, the placing of trace fossil names as synonyms depends very much on subjective judgment. In the future, careful research on individual ichnogenera based on abundant and well-preserved material on a worldwide basis is required, and so are fundamental monographs of entire rich ichnocoenoses, such as, for example, the extensive investigations of trace fossils of the Cincinnatian of Ohio by OSGOOD (1970). Such large, regional works are not only necessary for paleoichnology; they also contribute to understanding of the paleoecology and paleogeography of sedimentary basins and of animal-sediment interrelationships generally. This is true for Recent as well as fossil ichnocoenoses.

Acanthichnus HITCHCOCK, 1858, p. 150 [**A. cursorius*; SD LULL, 1953, p. 40] [Includes 9 widely different "species" (HITCHCOCK, 1865, p. 13-15); see also *Pterichnus* HITCHCOCK, 1865, p. 14]. Linear tracks consisting of 2 parallel rows of short straight strokelike impressions mostly slightly turned outward; tracks very different in width, position, and length of impressions of feet. [?Made by insects.] *Trias.*, USA(Mass.).

Acanthorhaphe KSIĄŻKIEWICZ, 1970, p. 301 [**A. incerta*; OD] [=*Acanthoraphe* KSIĄŻKIEWICZ, 1961, p. 883, 888; published as "n.f." without species name]. Thin sole trails, 1 mm. in width; winding in somewhat irregular curves of small "amplitude"; with short lateral thornlike branches, usually on convex side of curves, sometimes on both sides. [See also *Unarites* MACSOTAY, 1967, p. W120, and *Protopaleodictyon* KSIĄŻKIEWICZ, 1970, p. W97.] *L.Cret.(low.Neocom.,Berrias.); Tert.(low.Eoc.)*, Eu.(Pol.).——FIG. 21,*1a*. *A.* sp., L.Cret., Pol.; ×0.6(Książkiewicz, 1961).——FIG. 21,*1b-e*. **A. incerta*, L.Cret.(Berrias.), Pol.; ×0.5 (Książkiewicz, M., 1970, p. 302, in: *Trace Fossils* edited by T. P. Crimes & J. C. Harper, Geol. Jour. Spec. Issue 3, Seel House Press, Liverpool).

Aglaspidichnus RADWAŃSKI & RONIEWICZ, 1967, p. 545 [**A. sanctacrucensis*; M]. Hypichnial trace (15.5 cm. long by 12.0 cm. wide, max.) composed of sinuous, longitudinal axial ridge with ovally triangular posterior ending and 8 laterally opposed, posteriorly bent ridges projecting from axial ridge. [Interpreted as cast of resting place of aglaspid arthropod (very probably of family Beckwithiidae RAASCH, 1939); impression of pygidial shield preserved; no trace of prosoma visible; only one specimen known.] *U.Cam.*, Eu.(C.Pol.).——FIG. 21,*2*. **A. santacrucensis; 2a,b*, ×0.5 (Explanation of *2a: a', a"* =two small hieroglyphs, *Rusophycus* sp., deforming ant. part; *b*=small synaeresis crack cutting first three ridges on right side) (Radwański & Roniewicz, 1967, mod.).

Agrichnium PFEIFFER, 1968, p. 671 [**Palaeophycus fimbriatus* LUDWIG, 1869, p. 111; OD]. Groups of small subparallel smooth furrows of unequal moderate length. [Probably grazing trails; see also *Schaderthalis* HUNDT, 1931 *(nom. nud.)*, p. W000, whose type species *S. bruhmii* has been ascribed to *Agrichnium* by PFEIFFER, 1968, p. 672.] *L.Carb.(Kulm)*, Eu.(Ger.,Thuringia).——FIG. 22,*1*. **A. fimbriatum* (LUDWIG); ×1.2 (Pfeiffer, 1968).

Algites SEWARD, 1894, p. 4, *emend.* STOPES, 1913, p. 254 [no type species to be designated]. Seldom used, comprehensive generic name given to replace all older generic names of "algae" which suggest relationship with living forms. [According to PIA (1927, p. 110), SEWARD's "species" belong to algae but other species interpreted as algae (JACOB, 1938; ?Jur., India) represent trace fossils *(Chondrites)*.]

Allocotichnus OSGOOD, 1970, p. 358 [**Asaphoidichnus dyeri* MILLER, 1880, p. 219; OD] [=*partim Asaphoidichnus* MILLER, 1880, p. 217 (type, *A. trifidus*); for discussion see OSGOOD, 1970, p. 359]. Wide, bifid, dimorphic track; each set consisting of maximum of 4, occasionally only 3 or 2 pairs of imprints; on one side arranged as 4 long subparallel raking imprints, on other side preserved as *en echelon* support imprints; only first 4 or 5 pairs of walking legs used; body of producer angled to right of direction of movement; detailed morphology varies. [Interpreted as crawling track of large arthropod with relatively small number of walking legs, probably made by multisegmented trilobites *(Isotelus?)*, but differing greatly from known trilobite tracks by uniqueness of motion.] *U.Ord.(low.Cincinnat.)*, USA(Ohio-Ky.).——FIG. 23,*1*. **A. dyeri* (MILLER), Eden beds, repichnia of *?Isotelus*, convex hyporelief; *1a,c* (Ky.), ×0.56, ×0.6; *1b,d*(Ohio), ×0.45, ×0.56; *1e* (Ohio), holotype, ×0.6 (Osgood, 1970).

Amphorichnus MYANNIL, 1966, p. 202 [**A. papillatus*; OD]. Fillings of cylindrical and amphora-like hollows; length (max.) 7 to 8 cm., diameter (max.) 3 to 4 cm.; at lower end distinct peak similar to mamilla; perpendicular to bedding plane. [Dwelling burrow or resting trail.] *Low. M.Ord.*, USSR(Est.).——FIG. 24, *3*. **A. papillatus*, Ord. Kalke, Baltic; ×0.75 (Myannil, 1966).

Annelidichnium KUHN, 1937, p. 368 [**A. triassicum*; M]. Tunnel fillings with irregular sculp-

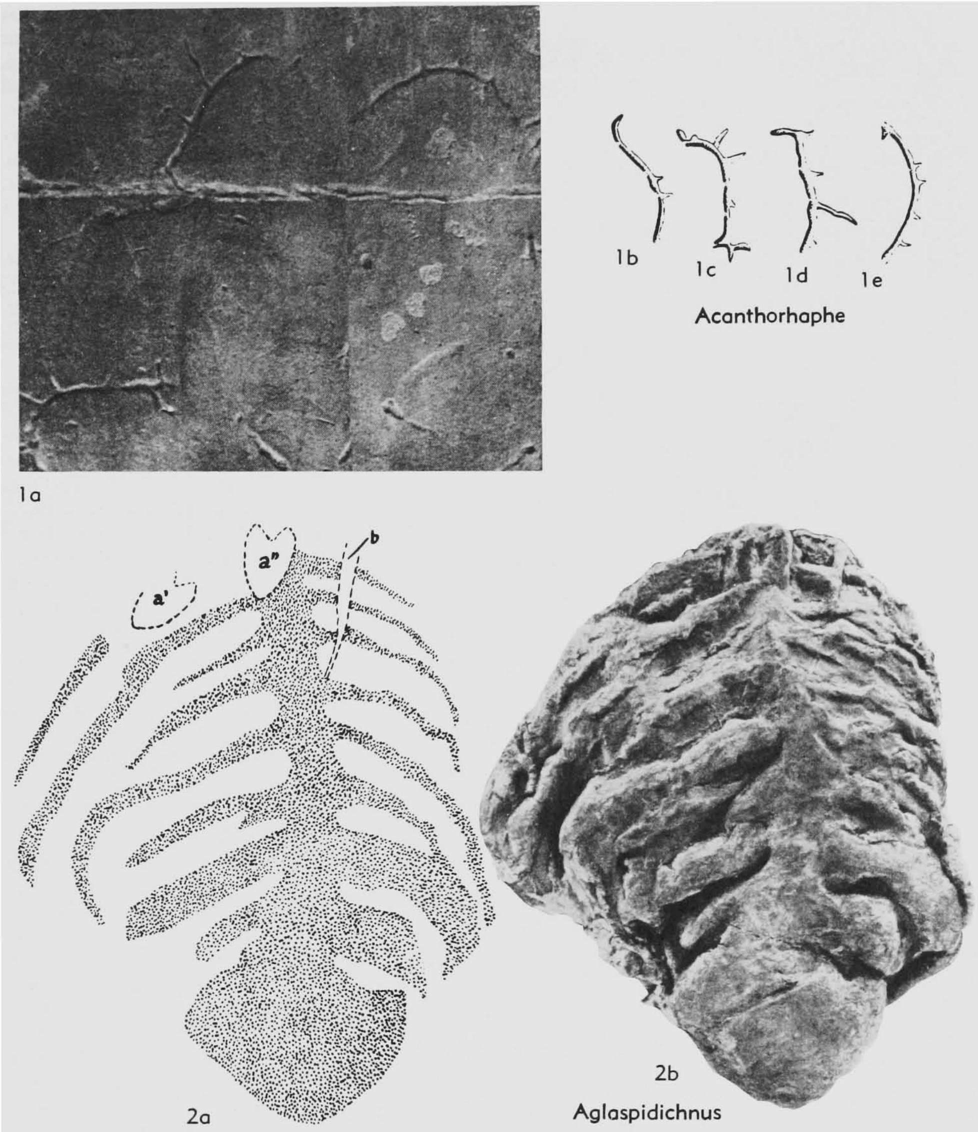

FIG. 21. Trace fossils (p. W36).

ture; ornamented with sharp or rounded longitudinal ridges or blunt tubercles. [Type or other specimens are lost.] *U. Trias.*, Eu.(S.Ger., Bavaria).

Archaeichnium GLAESSNER, 1963, p. 117 [**A. haughtoni*; M]. Fillings of cylindrical burrows with external longitudinal striation (10 to 12 striae), faint transverse sculpture inside; diameter (max.) about 5 mm., thickness of walls 1 mm. [Erroneously described as Archaeocyatha by HAUGHTON (in HAUGHTON & MARTIN, 1956; 1960), certainly a trace fossil.] *Uppermost Precam.(Nama Syst., Kuibis Quartzite)*, S.Afr.——FIG. 24,*4*. **A. haughtoni*; ×1.5 (Glaessner, 1963).

Archaeonassa FENTON & FENTON, 1937, p. 454 [**A. fossulata*; OD]. Crawling trail, 1 to 7 mm. wide, consisting of regularly convex furrow and 2 low narrow lateral ridges; furrow rarely smooth, mostly crossed by rounded wrinkles, which are convex in anterior direction. [Interpreted as gastropod trail, similar to those made by Recent snails on tidal flats (e.g., *Ilyanassa obsoleta* or small species of *Littorina*; trails probably belong-

FIG. 22. Trace fossils (p. W36).

ing to "group" *Scolicia* QUATREFAGES, 1849, p. 265.] *L.Cam.*, Can.(B.C.).

Ardelia CHAMBERLAIN & BAER, 1973, p. 88 [**A. socialia*; OD]. Cylindrical tunnels projecting radially from vertical and/or oblique shafts; may possess either smooth or nodose surfaces; straight or curving; radial bifurcations from central shaft may extend up to 10 cm. and can apparently occur at different levels; no internal lining of burrow system is apparent; diameter of total structure 10 to 20 cm.; depth in sediment 0.3 to 2 meters or more. [Interpreted to have been produced by a thalassinid decapod; judging from original description, it is possible that *Ardelia* is the same as *Ophiomorpha* (see p. W85) and *Thalassinoides* (see p. W115).] *U.Perm.(Wolfcamp.)*, N.Am.(USA,Utah). [Description supplied by CURT TEICHERT & W. G. HAKES.]

Arenicolites SALTER, 1857, p. 204 [**Arenicola carbonaria* BINNEY, 1852, p. 192; SD RICHTER, 1924, p. 137; second SD (rejecting RICHTER's designation) by BATHER, 1925, p. 198: *Arenicolites didymus* SALTER, 1857, p. 200 (=*Arenicola didyma* SALTER, 1856, p. 248)] [=*Arenicolithes* HILDEBRAND, 1924, p. 27 *(nom. null.)*]. Simple U-tubes without spreite, perpendicular to bedding plane; varying in size, tube diameter, distance of limbs, and depth of burrows; limbs rarely somewhat branched, some with funnel-shaped opening; walls commonly smooth, occasionally lined or sculptured; burrows may reach considerable depth. [Certainly made by worms or wormlike animals; in places widely distributed; TRUSHEIM (1934) described, from German Middle Triassic Muschelkalk, *Arenicolites franconicus* marker-bed, only 2 to 5 cm. thick, which has observed lateral extent of about 25 kilometers.] *Cam.-U.Cret.*, Eu.-USA-Greenl. [Probably worldwide.]——FIG. 24,*2a*. *A.* sp. SALTER; schematic (Trusheim, 1934).——FIG. 24, *2b*. *A. franconicus* TRUSHEIM, M.Trias., Ger.; schem. cross sec. of burrow, ×0.8 (Trusheim, 1934).

[Several species should not be placed in genus, e.g., *A. didyma* SALTER seems to be resting trace of the *Rusophycus* type; *A. spiralis* TORELL, 1868, is type species of *Spiroscolex* TORELL, 1870; *A. lunaeformis* KOLESCH, 1922, *A. zimmermanni* KOLESCH, 1922, *A. statheri* BATHER, 1925, and *A.? lymensis* BIGOT, 1941, are U-shaped burrows with spreite.]

Arthraria BILLINGS, 1872, p. 467 [**A. antiquata*; M]. Bars on bedding surfaces with spheroidal expansions at each end, similar to pair of dumbbells. [*Arthraria biclavata* MILLER, 1875 (p. 354), from the Cincinnatian of USA(Ohio) has been interpreted by K. E. CASTER (pers. commun.) and HÄNTZSCHEL (1962, p. W184), as U-shaped burrow with spreite, similar or possibly identical with *Corophioides* or *Diplocraterion*; OSGOOD, 1970, p. 323, placed this species in *Corophioides,* regarding it as base of U-tube with spreite "where the arms have been secondarily deepened below the base of the spreite"; type specimen of *A. antiquata* BILLINGS, 1872, from Silurian of Canada has been lost, thus this species is *incertae sedis*; as concerns *A. magna* RUEDEMANN, 1925 (U.Ord., USA), see OSGOOD, 1970, p. 325; *A. renzii* HUNDT, 1929 (Sil., Ger.) = *nom. nud.*] *?Cam., Ord.-Sil., ?Penn.*, N.Am.

Arthrophycus HALL, 1852, p. 4 [**A. harlani*; M (=*Fucoides harlani* CONRAD, 1838, p. 113)] [=*Harlania* GOEPPERT, 1852, p. 98 (no type species designated); *Rauffella palmipes* ULRICH, 1889, p. 235; *Arthrophicus* HERNANDEZ-PACHECO, 1908, p. 83 *(nom. null.)*; for synonymy see also BASSLER, 1915, p. 70]. Bundles of annulated curved burrows, simple or branched, subquadrate in cross section, mostly 1 to 2 cm. in diameter, up to 60 cm. long, commonly bilobate with median longitudinal depression; surface showing strong, very regularly spaced transverse ridges; internal chevron-shaped filling. [Feeding burrow; for history of the genus see JAMES (1893); at first regarded as plant (even as late as 1952 by BECKER & DONN), inorganic (tectonic origin advocated by SCHILLER, 1930); trails produced by arthropods or worms; first explanation as lebensspur given by NATHORST (1881a); according to SARLE (1906a), perhaps made by sedentary polychaetes; *Arthrophycus* sometimes considered junior synonym of *Phycodes* RICHTER, 1850 (e.g., by SEILACHER, 1955, p. 386); OSGOOD (1970, p. 342) agrees with author in differentiating the two genera; similar burrows from the Lower and Upper Cretaceous of USA (HOWARD, 1966; FREY

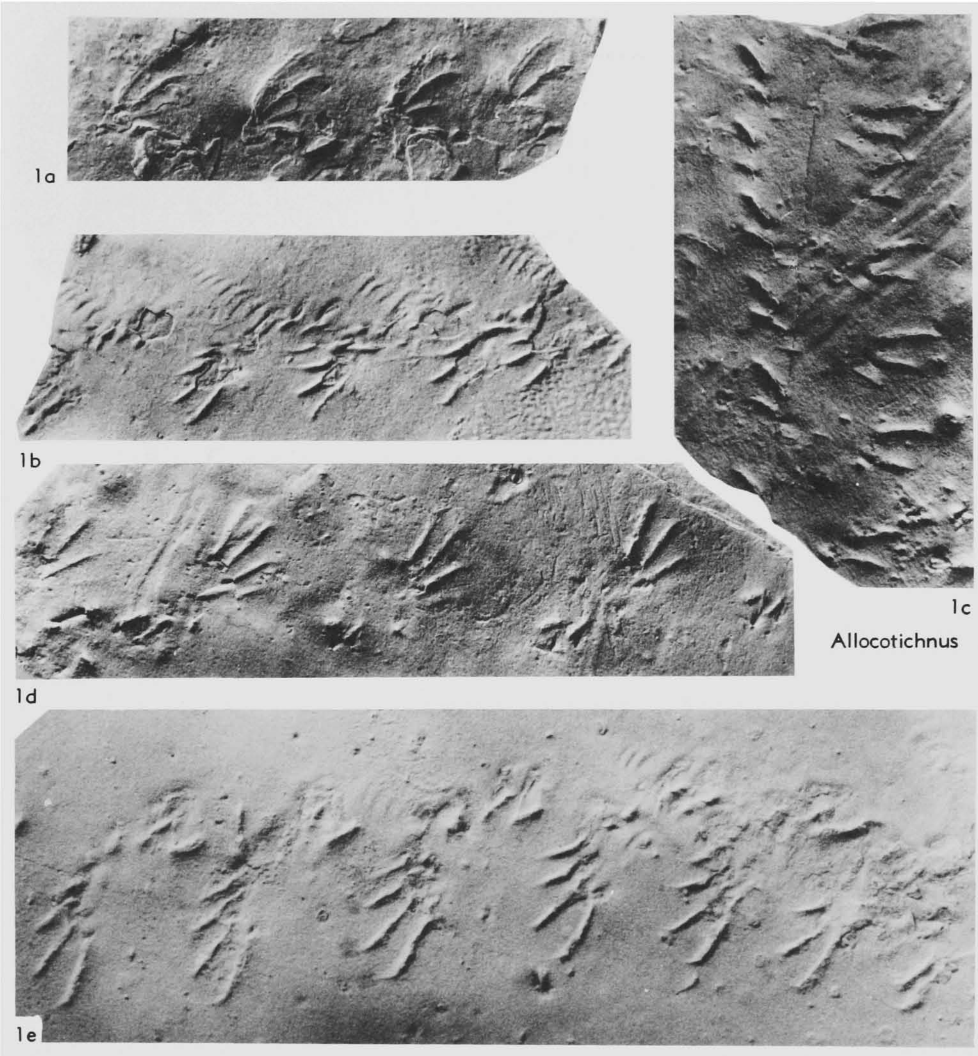

FIG. 23. Trace fossils (p. *W*36).

& HOWARD, 1970) and from European Cretaceous and Upper Tertiary deposits (Pol., Aus.) have been compared with *Arthrophycus,* but are not typical.] *Ord.-Sil.,* N.Am.-S.Am.-Eu.-N.Afr.-Asia M.——FIG. 25,*4*. *A. alleghaniensis* (HARLAN), L.Sil., N.Y., ×0.3 (Häntzschel, 1962).

Arthropodichnus CHIPLONKAR & BADWE, 1970, p. 3 [**A. indicus*; OD]. Track 1.8 to 2.0 cm. wide with 2 parallel rows of transverse slitlike opposing depressions separated by central axial region 0.25 to 0.3 cm. wide; distance between consecutive, marginal depressions 0.3 cm.; axial region has serially arranged slitlike depressions, apparently preserved in epirelief. [Probably produced by appendages of arthropod, perhaps a myriapod or chilopod.] *L.Cret.,* India.——FIG. 24,*1*. **A. indicus,* Nimar Ss., Amba Donger; ×0.7 (Chiplonkar & Badwe, 1970). [Description supplied by W. G. HAKES.]

Asaphoidichnus MILLER, 1880, p. 217 [**A. trifidus*; SD HÄNTZSCHEL, 1962, p. *W*184]. Large tracks, 6 to 15 cm. wide, consisting of 2 rows of mostly trifid imprints, about 2 cm. in length, individually varying in morphology; also combinations of unifid, bifid and trifid impressions observed; average per set, 9 imprints; tracks show both oblique and straight-ahead movement. [Produced by trilobites, most likely *Isotelus; A. dyeri* MILLER, 1880, removed by OSGOOD (1970, p. 359) from genus and placed as type species

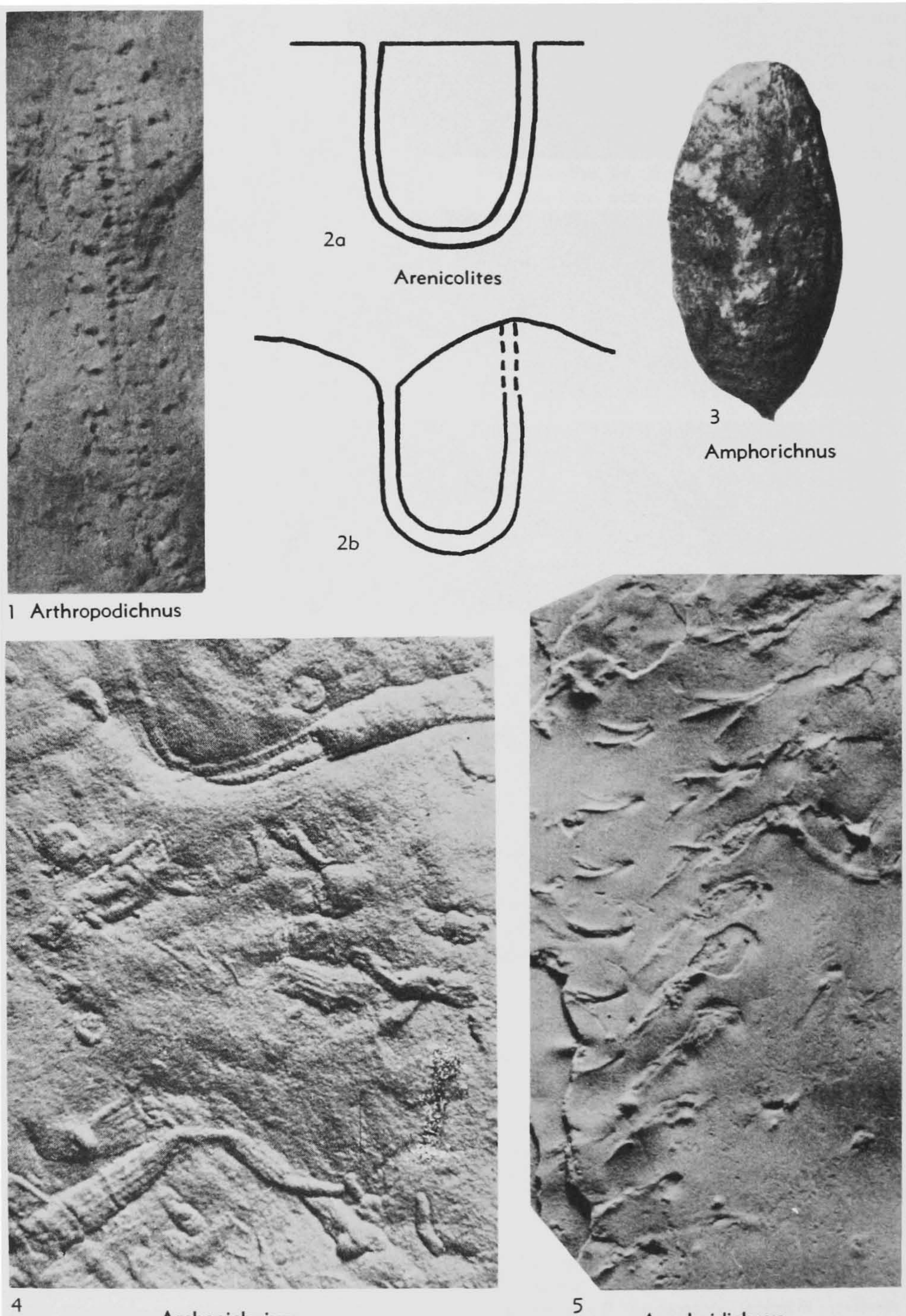

FIG. 24. Trace fossils (p. W36-37, 39).

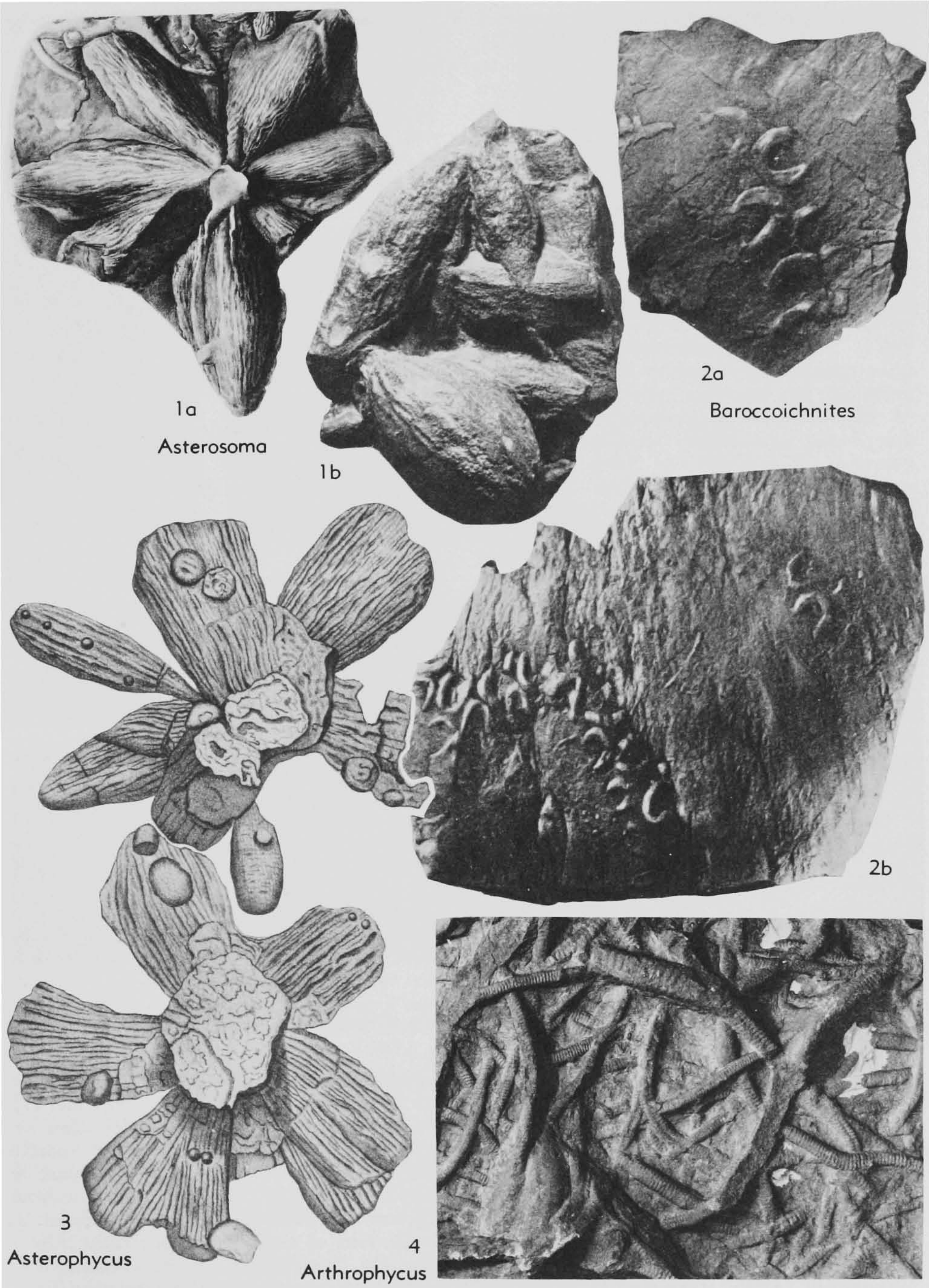

FIG. 25. Trace fossils (p. W38-39, 43, 45).

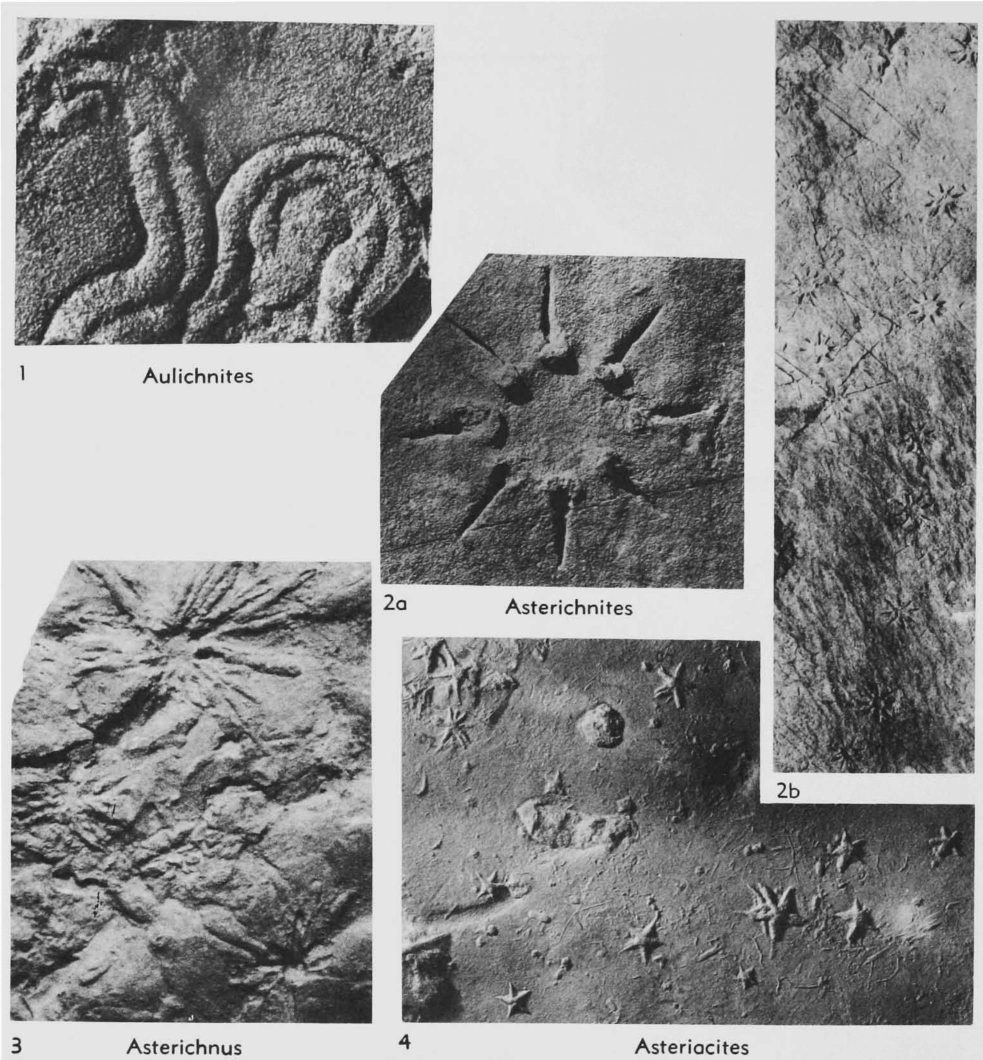

FIG. 26. Trace fossils (p. W42-43).

of *Allocotichnus* OSGOOD, 1970.] *U.Ord.(Cincinnat.)*, USA(Ohio).——FIG. 24,5. **A. trifidus*, loc. unknown; ×1 (Osgood, 1970).

Asteriacites VON SCHLOTHEIM, 1820, p. 324 [*non* VON SCHLOTHEIM, 1822, p. 71] [**A. lumbricalis*; SD SEILACHER, 1953, p. 93] [=*Heliophycus* MILLER & DYER, 1878b, p. 2 (type, *H. stelliforme*); *Spongaster* FRITSCH, 1908, p. 9 (*non* EHRENBERG, 1860) *(nom. nud.)*; *Asterocites* MIROSHNIKOV, 1959; *Ateriacites* CHAMBERLAIN, 1971, p. 212; *Asteriachites* CHAMBERLAIN, 1971a, p. 217); *(nom. null.)*]. Impressions in form of asteroids or ophiuroids, with transversely sculptured arms; their striae produced by activity of digging tube feet; often intersected by traces of neighboring animals ("horizontal repetition") or (as reaction to rapid sedimentation; see Fig. 17) "vertical repetition"; morphology dependent on preservation as convex hyporelief or concave epirelief. [Three different conical, subconical, or subcylindrical biogenic structures with pentameral symmetry on sides (ridges coarsely striated or double rows of nodes or rounded radial ridges) from the Pennsylvanian of USA (Okla.) were ascribed to *Asteriacites* by CHAMBERLAIN (1971a, p. 219), who named them "*A, lumbricalis* hiding forms A, B, C" and regarded them as true resting trace fossils; the proposal to expand the diagnosis of *Asteriacites* based on these forms is not accepted here. Regarded as body fossils of asteroids (ventral casts) ("stella lumbricalis") by KNORR & WALCH (1769) (="*Asterias lumbricalis*" GOLDFUSS, 1833); interpreted by SEILACHER (1953b) as resting traces of Asterozoa such as *A. lumbricalis* SCHLOTHEIM, produced by ophiuroids, and *A. quinquefolius* QUENSTEDT, produced by starfishes. The nomenclatorial status of *Asteriacites* is confused; the name *Asteriacites* VON SCHLOTHEIM, 1820, p. 324, has been interpreted by NEAVE *(Nomenclator Zoologicus)* as *lapsus pro Asteriatites* VON SCHLOTHEIM, 1813 (p. 68, 99, 108; used for at least two different fossils from Trias., Jur., and Cret. rocks). For nomenclatorial discussions see *Treatise,* Part C (1964, p. *C*796) and Part U (1966, p. *U*103); however, *Asteriacites* has been used so often in paleoichnological papers that it is the opinion here that *Asteriacites* VON SCHLOTHEIM, 1820, should be preserved for asterozoan resting trace fossils.] *Ord.-Tert.,* Eu.-USA.——FIG. 26,*4*. **A. lumbricalis,* L.Jur., Ger.; ×0.5 (Seilacher, 1953).

Asterichnites BROWN & VOKES, 1944, p. 658 [**A. octoradiatus*; OD]. Rows of stellate imprints, about 6 cm. in diameter, each consisting of unmarked central disc and 8 radiating grooves 13 to 18 mm. long; arranged in rows on bedding planes. [Probably produced by tentacles of dibranchiate cephalopod as the animal apparently bounced over the bottom of the sea on the tips of its tentacles while its body was in nearly perpendicular position.] *U.Cret.(Mowry Sh.),* USA(Mont.-Wyo.).——FIG. 26,*2*. **A. octoradiatus,* Mont.; *2a,* ×0.6; *2b,* ×0.1 (Brown & Vokes, 1944).

Asterichnus BANDEL, 1967, p. 2 [*non Asterichnus* NOWAK, 1961, p. 227, *nom. nud.; nec Asterichnus* KSIĄŻKIEWICZ, 1970, p. 310 (type, *A. nowaki*) (=*Subglockeria* KSIĄŻKIEWICZ, 1974, herein, p. *W*112)] [**A. lawrencensis*; OD]. Starlike traces, approximately circular in cross section; diameter 4 to 12 cm., 10 to 30 unbranched "rays" consisting of grooves or tubelike ridges, 5 to 8 mm. wide; center formed by an irregularly oval to round knob. [According to BANDEL (1967a, p. 3) subsurface traces made within sediment along bedding planes in same way as other known Recent and fossil starlike traces on the surface of the sediment; producer probably a relatively large organism of unknown systematic position.] *Penn.,* USA(Kans.-Okla.).——FIG. 26,*3*. **A. lawrencensis,* Rock Lake Sh., Kans.; ×0.55 (Bandel, 1967a).

Asterophycus LESQUEREUX, 1876, p. 139 [**A. coxii*; M]. Large starlike trace fossil similar to *Asterosoma* VON OTTO, 1854; diameter about 6 to 12 cm.; individual "rays" radiating from central tube, oblong or obovate, 1 to 2 cm. in diameter, cross section irregular, surface longitudinally wrinkled. [At first described by LESQUEREUX as plant; interpreted by DAWSON (1890, p. 603) as burrows of ?worms; no type or other specimen of occurrences in Indiana could be located.] *Miss.-Penn.,* USA (Kans.-Ind.-Ky.).——FIG. 25,*3*. **A. coxii,* Penn., Ky.; ×0.3 (Lesquereux, 1876).

Asterosoma VON OTTO, 1854, p. 15 [*non* GRUBE, 1867] [**A. radiciforme*; M]. Big stars diameter about 20 cm., with elevated center; about 3 to 9 rays, bulbous, tapering toward ends, longitudinally wrinkled, of different length, 2 of them mostly lying in same direction and commonly longer than other ones; rays sometimes do not radiate in all directions but form only acute-angled sector; longitudinally wrinkled. [Very probably burrows with radiating feeding trails; the Mesozoic forms suggested by ALTEVOGT (1968a) and HÄNTZSCHEL to have been made by decapod crustaceans. HÄNTZSCHEL agreed with GLAESSNER (1969, p. 375) that the following forms very probably have been incorrectly assigned to *Asterosoma:* FARROW's (1966) stellate structures (M. Jur., Eng.); three "forms" described as *Asterosoma by* FREY & HOWARD (1970) from the Upper Cretaceous of USA; and a starlike trace fossil from the Lower Tertiary (Paleoc.) of England (DURKIN, 1968). Similar starlike trace fossils were described from Paleozoic rocks partly as *Asterosoma* (Sil., Nor., SEILACHER & MEISCHNER, 1965, p. 616; Dev., Libya, SEILACHER, 1969a, p. 122) and partly as *Rosselia* DAHMER, 1937 (L.Cam., Pak., SEILACHER, 1955, p. 389; L.Dev., Ger., DAHMER, 1937, p. 532); for *Asterosoma? canyonensis* (BASSLER) (Precam., USA) see GLAESSNER (1969, p. 375). *Rosselia* has been regarded by SEILACHER (1969a, p. 122) as junior synonym, but as yet, no detailed discussion has been published.] *?Precam.,* USA(Ariz.); *Paleoz.,* Libya-Pak.; *?Paleoz.,* Eu.(Ger.-Nor.)-USA (Okla.); *?M.Jur.,* G.Brit.(Eng.); *?U.Jur.,* Eu. (France); *?L.Cret.,* Eu. (Ger.); *U.Cret.(Turon.),* Eu.(Ger.-Czech.), *?U.Cret.,* USA(Kans.-Utah). ——FIG. 25,*1a*. **A. radiciforme,* U.Cret.(Turon.), Ger.; ×0.3 (von Otto, 1854).——FIG. 25,*1b*. *Asterosoma* assemblage, *Cruziana* facies, Dev., Libya; ×0.67 (Seilacher, 1969a).

Aulichnites FENTON & FENTON, 1937, p. 1079 [**A. parkerensis*; OD]. Trail, 5 to 10 mm. wide, commonly strongly curved; consisting of 2 convex ridges, separated by rather deep median groove in epirelief. [Crawling and/or grazing trail, most probably made by gastropod.] *Sil.,* USA(Ga.); *?M.Dev.,* Eu.(Ger.); *Penn.,* USA (Texas-Kans.); *?Penn.,* USA(Ark.); *?Cret.,* USA (Utah); *?Tert.,* S.Am.(Venez.)——FIG. 26,*1*. **A. parkerensis,* Penn., Texas; ×1 (Howell in Häntzschel, 1962).

Balanoglossites HÄNTZSCHEL, 1962, p. *W*185 [**B. triadicus* MÄGDEFRAU, 1932, p. 153; OD] [=*Balanoglossites* MÄGDEFRAU, 1932, p. 153, *nom.*

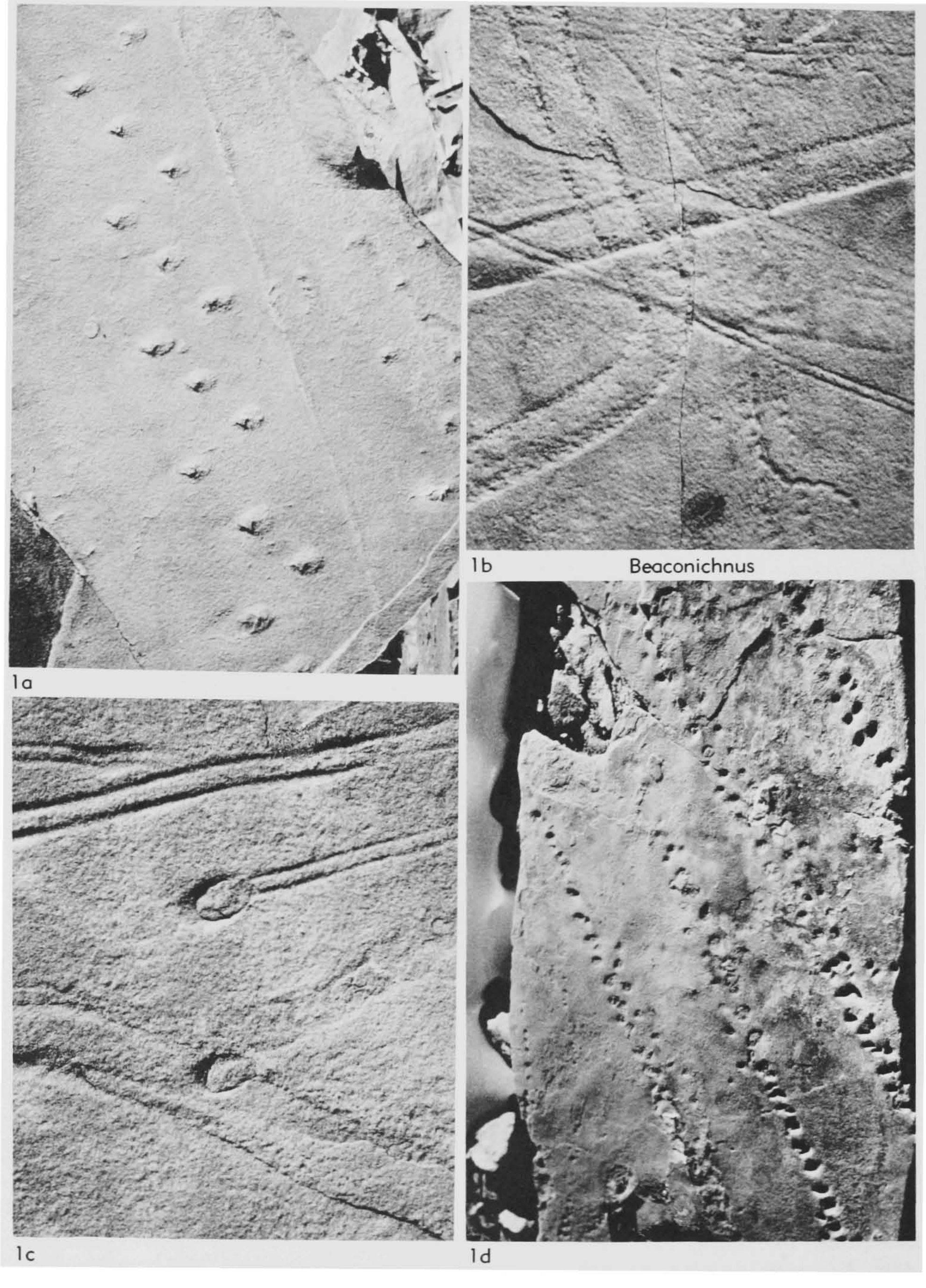

FIG. 27. Trace fossils (p. W45).

nud., established without designation of type species; *?Unculiferus* HUNDT, 1941, p. 58 (type, *U. transversus*), according to MÄGDEFRAU (1941, p. 526) identical to *Balanoglossites*]. Burrows, 1 to 3 cm. wide and up to 15 cm. deep, irregularly branched, with several openings that are sometimes funnel-shaped (e.g., *B. eurystomus* MÄGDEFRAU); walls of burrows may be sculptured by transverse ridges and delicate longitudinal striations. [Suggested by MÄGDEFRAU to have been made by polychaetes or enteropneusts; KAZMIERCZAK & PSZCZOLKOWSKI (1969, p. 305) compared *Balanoglossites* with very similar burrow systems from the Middle Triassic (low. Muschelkalk) of Poland, which they interpreted as made by enteropneusts.] *?Ord.*, Eu.(Ger.); *M.Trias. (Muschelkalk)*, Eu.(Ger.); *?M.Trias. (Muschelkalk)*, Eu.(Pol.).

Baroccoichnites VYALOV, 1971, p. 88 [**B. pamiricus*; OD]. Chain consisting of 2 rows of arched cylinders, each bent in different direction—open to outside, arranged in checkerboard pattern and in contact with each other along their convex lateral sides. *U.Trias.*, C.Asia(Pamir).——FIG. 25,2. **B. pamiricus; 2a,b*, ×0.67 (Vyalov, 1971). [Description supplied by CURT TEICHERT.]

Beaconichnus GEVERS, 1973, p. 1002 (*nom subst. pro Arthropodichnus* GEVERS in GEVERS *et al.*, 1971, p. 92 (*non* CHIPLONKAR & BADWE, 1970)) [**Arthropodichnus darwinum* GEVERS, 1971, p. 93; OD]. Ichnogenus comprising 3 different types: 1) 2 narrow parallel grooves, 9 to 18 mm. apart, absolutely linear or only slightly curving; length up to more than 1 m.; depth and width of grooves 1 to 4 mm.; very small closely spaced foot imprints may be preserved in wider trails (=**B. darwinum* (GEVERS)); 2) paired parallel rows of commonly very closely spaced footprints; rows 2 to 4 cm. apart, usually broadly curving; foot or claw imprints appearing as small circular pits or in larger trails commonly elongated, oblique to trend of tracks (=*B. gouldi* (GEVERS)); 3) large tracks, about 30 cm. wide, mostly straight, consisting of short parallel rows of foot imprints, up to 3 cm. wide, regularly arranged in sets of 3 or rarely 4, oblique (35°) to median line representing telson drag marking; distance between footprints averages 6 cm.; footprint pits show angular imprints of arrowhead shape indicating bipartite spines (=*B. antarcticum* (GEVERS)). [Epichnial crawling and walking trails; producers of *B. darwinum* probably shovelling and burrowing arthropods (?trilobites); *B. gouldi* possibly made by trilobites, the "species" is comparable to *Diplichnites* DAWSON, 1873 (see p. *W*61); origin of the large track *B. antarcticum* is doubtful (made by eurypterids?), somewhat resembles *Palmichnium* RUDOLF RICHTER, 1954 (L.Dev., Ger.), a smaller track tentatively interpreted as produced by eurypterids (see p. *W*91).] *?Dev.(up.Hatherton Ss.)*, Antarctic (Victoria Land).——FIG. 27,*1a*. *B. antarcticum* (GEVERS); single trails, ×0.17 (Gevers *et al.*, 1971).——FIG. 27, *1b*. *B. gouldi* (GEVERS); large tracks in center and at left, crossed by **B. darwinum* (GEVERS), also by narrow forms of *Beaconites antarcticus* VYALOV, ×0.11 (Gevers *et al.*, 1971).——FIG. 27,*1c*. **B. darwinum* (GEVERS); trails and burrows, ×0.3 (Gevers *et al.*, 1971).——FIG. 27,*1d*. *B. giganteum* GEVERS, low.Beacon sediments; irreg. pattern evident in each tread line (Dept. Geology coll., Univ. Witwatersrand).

Beaconites VYALOV, 1962, p. 728 [**B. antarcticus*; M] [=*?Laminites* GHENT & HENDERSON, 1966, p. 158 (type, *L. kaitiensis*); for description and discussion see p. *W*78]. Large horizontal segmented ("septate") burrows, many of them of giant size; 3 to 13 cm.(max.) wide, 8 to 10 cm. very common width; somewhat sinuous, large forms relatively straight; rather long (up to about 1 m.); commonly crowded; associated with rounded pits of similar cross section; marginal welts 5 to 30 mm. wide; curving "septal" ridges mostly remarkably equidistant; those of giant forms usually markedly crescentic, but size, shape, and spacing may vary considerably. [Originally doubted whether trace or body fossils were represented; interpreted by GEVERS *et al.* (1971, p. 83) as burrows made by unknown animals within the sediment; observed in highly bioturbated layers; for detailed discussion see GEVERS *et al.* (1971, p. 83-85)]. *Dev.*, Antarct.——FIG. 28,*1*. **B. antarcticus*, up.Hatherton Ss., Victoria Land; *ca.* ×0.24 (Gevers *et al.*, 1971).

Belorhaphe FUCHS, 1895, p. 395 [**Cylindrites zickzack* HEER, 1877, p. 159; OD] [=*Beloraphe multorum autorum (nom. null.); Helicolithus fabregae* AZPEITIA MOROS, 1933, p. 32 (see SEILACHER, 1959, p. 1068); *Belorapha* DIMIAN & DIMIAN, 1964, pl. 8 *(nom. null.)*]. Sharply zigzag-shaped locomotion trails, commonly with short protrusion at corners.[1] [Evidently postdepositional trail; MICHELAU (1955) placed *Sinusia* KRESTEW, 1928 (*nom. inval.:* preoccupied) and *Sinusites* DEMANET & VAN STRAELEN, 1938(U.Carb., Eu.) in *Belorhaphe*, but these two "genera" belong to regularly sinuous trail *Cochlichnus* HITCHCOCK, 1858, resembling sine curve.] [Found in flysch deposits.] *Cret.-L.Tert.*, Eu.——FIG. 29,*2*. *B.* sp. FUCHS, Aus.; ×0.6 (Fuchs, 1895).

Bergaueria PRANTL, 1946, p. 50 [**B. perata*; OD] [=*?Palaeactis* DOLLFUS, 1875 (type, *P. vetusta*); see WELLS & HILL (1956), p. *F*233; probably *nom. oblit.*]. Cylindrical or baglike protrusions with smooth walls, length and diameter subequal (2-4 cm.); lower end rounded, with shallow depression which is sometimes sur-

[1] For a discussion of the origin of these protrusions, see NOWAK (1970, fig. 3). [W. G. HAKES.]

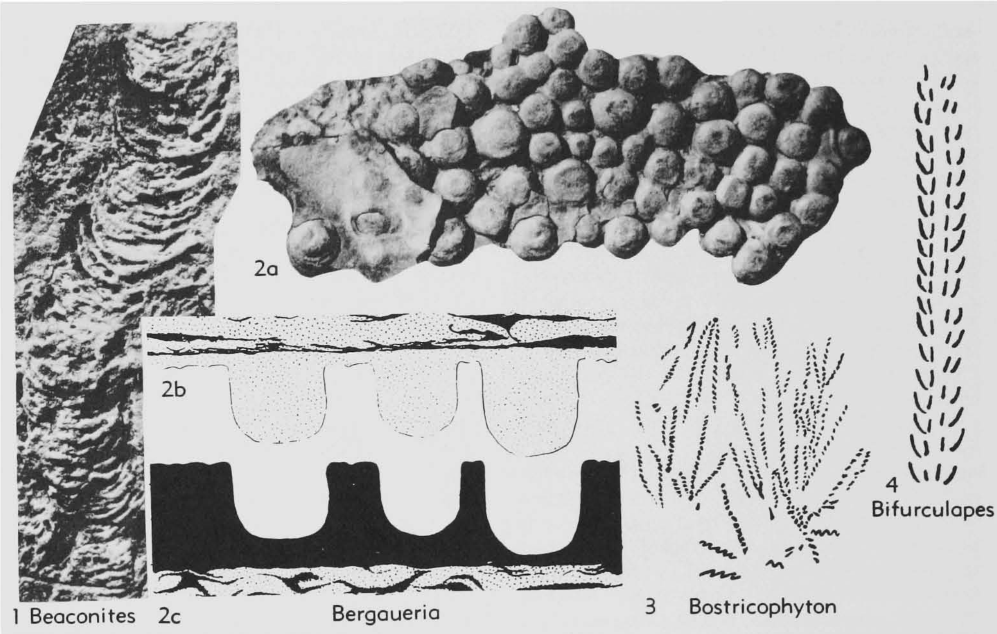

FIG. 28. Trace fossils (p. W45-46, 48).

rounded by 6 to 8 very short radially arranged tubercles; some specimens (L.Cam., Nev.) display biradially symmetrical impressions on ventral surface. [Probably resting burrows of suspension-feeding coelenterate, possibly of actinian anemones (ALPERT, 1973); comparisons have been made with *Edwardsia* or *Phyllactis conguilegia*; for detailed discussion of the origin see ARAI & MCGUGAN (1968, p. 206).] *Cam.-Ord.*, N.Am. (USA-Can.)-Eu.——FIG. 28,*2a*. *B.* sp., ventral surface of colony, L.Cam., Can.(Moraine Lake, Banff Area, Alta.); ×0.17 (Arai & McGugan, 1968).——FIG. 28,*2b,c*. **B. perata*, Ord., Czech.; *2b*, casts in overlying sandstone; *2c*, original burrow-cavities in underlying shale, ×0.3 (Prantl, 1946).

Bifasciculus VOLK, 1960, p. 152 [**B. radiatus*; M]. Starlike trace fossil, consisting of many (up to 40) tunnels 2 to 3 cm. long, radiating from central area and ending blindly, bent slightly upward and downward. [Feeding burrow.] *Ord. (Griffel-Schiefer)*, Eu.(Ger., Thuringia), *Ord. (Arenig.)*, Eng.-Ire.——FIG. 29,*4*. **B. radiatus*, Griffel-Schiefer, Ger.; ×1 (Volk, 1960).

Biformites LINCK, 1949, p. 44 [**B. insolitus*; OD]. Bimorphous form, consisting of narrow section, partly divided by longitudinal furrows, continuing into wider section with prominent transverse ribs; resembles shafted hand grenade; fillings visible at lower surface of layers. [According to SEILACHER (1955), dwelling burrow.] *?Penn.*, USA(Okla.); *U.Trias.(M.Keuper)*, Eu.(S.Ger.).——FIG. 29,*3*. **B. insolitus*, U.Trias.(M.Keuper), Ger.; *3a*, ×0.8; *3b*, ×1 (schem.) (Linck, 1949b).

Bifungites DESIO, 1940, p. 78[**B. fezzanensis* (=*?Buthotrephis impudica* HALL, 1852, p. 20); M]. Structures dumbbell-like or arrow-shaped, 1 to 5 cm. long; ends commonly hemispherical, diameter up to 1 cm.; on bedding planes respectively at erosional interfaces; preserved as positive hyporeliefs or positive epireliefs; similar to *Arthraria biclavata* MILLER (placed in *Corophioides* by OSGOOD, 1970, p. 323). [Interpreted by DESIO as fucoid or colonial animal; according to DUBOIS & LESSERTISSEUR (1965) filling of top of U-shaped burrow perhaps inhabited by small trilobite; regarded by SEILACHER (1955, fig. 5; 1969a, p. 112) as special kind of preservation of protrusive vertical U-tube representing feeding burrow; *Bifungites* predominant ichnogenus of ichnocoenoses in Upper Devonian of USA(Mont.) (RODRIGUEZ & GUTSCHICK, 1970, p. 418).] *L. Cam.*, Pak.; *?Ord.*, Eu.(Czech.); *?Sil.*, USA (N.Y.); *Dev.*, N.Afr.-USA(Mont.).——FIG. 29,*1*. **B. fezzanensis*, M.Dev.-U.Dev., N. Afr.; ×0.7 (Desio, 1940).

Bifurculapes HITCHCOCK, 1858, p. 152 [**B. laqueatus*; SD LULL, 1953, p. 42] [=*Bifurculipes, Biferculipes, Bifurcalipes* HITCHCOCK, 1865, p. 13, 14 *(nom. null.)*]. Four regular rows of tracks, commonly resembling small forks when united at base; may have 2 additional rows with pairs of opposing tracks; similar to *Permichnium* GUTHÖRL, 1934, and *Triavestigia niningeri* GIL-

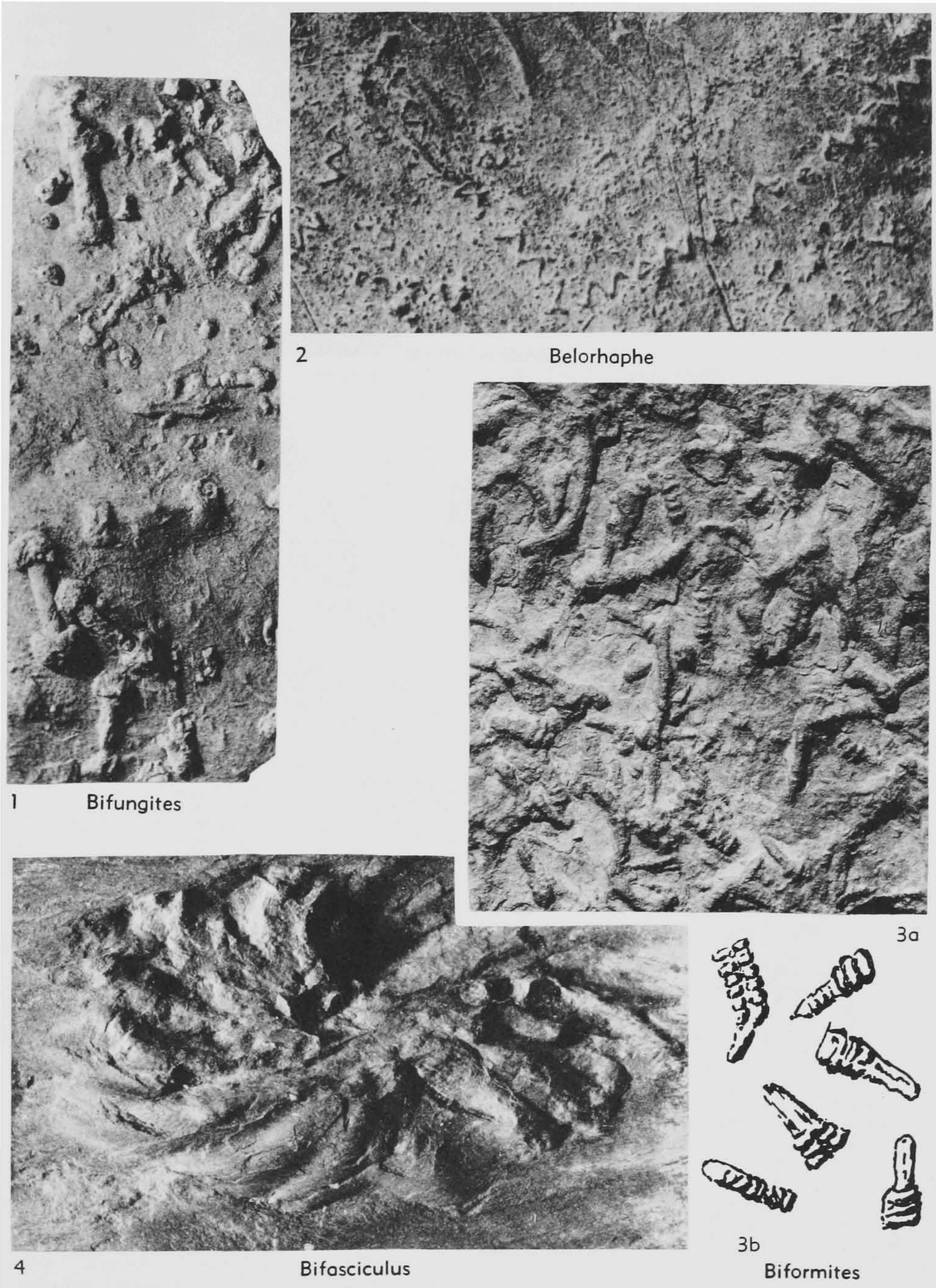

FIG. 29. Trace fossils (p. *W*45-46).

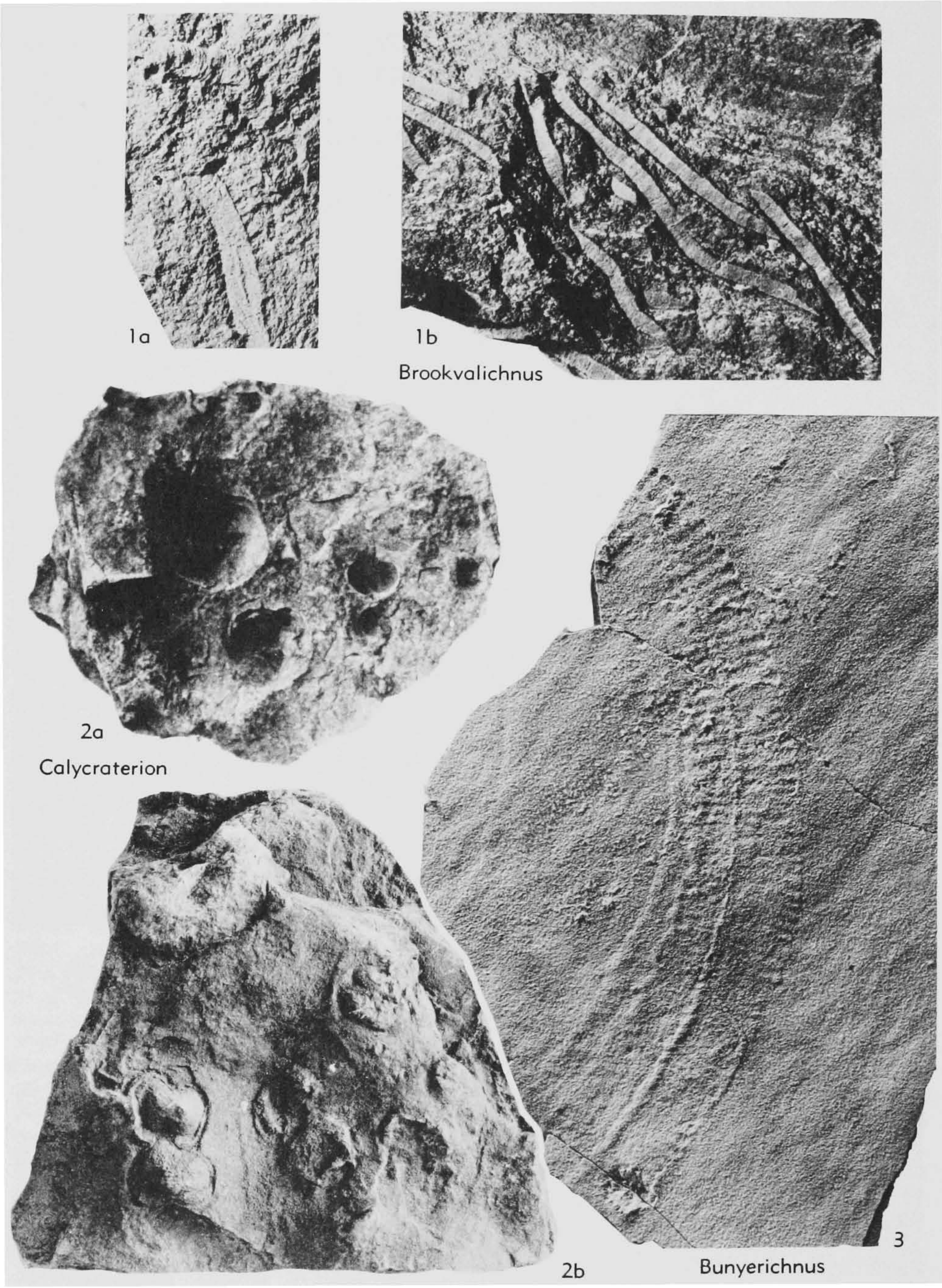

FIG. 30. Trace fossils (p. W49).

MORE, 1927. [Interpreted by HITCHCOCK (1858, 1865) and LULL (1915, 1953) as probably made by insects.] *Trias.*, USA(Mass.).——FIG. 28,*4*. **B. laqueatus*; ×0.7 (Lull, 1953).

Bostricophyton SQUINABOL, 1890, p. 181 [**B. pantanellii*; SD ANDREWS, 1955] [=*Bostrichophyton* ANDREWS, 1955 *(nom. null.)*]. Very thin threadlike burrows, spirally rolled, ?horizontal, ?branched. [Originally described as threadlike alga with spiral branchlets; according to FUCHS (1905, p. 366), identical to *Chondrites intricatus*; possibly related to *Helicolithus* AZPEITIA MOROS; not studied for many decades except for brief description of dubious "n. sp." from Precam.(U.Vindhyan) of India (VERMA & PRASAD, 1968).] [Found in flysch deposits.] *Precam.-Cam., India; Cret.-L.Tert.,* Eu.——FIG. 28,*3*. **B. puntanellii,* L. Tert., Italy; ×0.7 (Fuchs, 1895).

Brancichnus DOUGHTY, 1965, p. 148 [**B. dudleyi*; M]. Horizontal and branching cylindrical structures, maximal length 60 cm., main cylindrical portion ("stem") fairly straight; diminishing in diameter distally. [Burrow systems, according to DOUGHTY, more probably "remains of branching marine alga or some form of branching Porifera"; name rather superfluous; resembling or identical to *Saportia* SQUINABOL, 1891.] *L.Jur.,* Eu.(Eng.).

Brookvalichnus WEBBY, 1970, p. 528 [**B. obliquus*; OD]. Flat ribbonlike structures, sometimes in groups, straight to slightly curving, unbranched, normally inclined 10 to 15° to horizontal, up to 9 cm. long, uniform width 3.5 to 4.0 mm.; very thin ribbonlike part exhibits transverse annulations bordered on either side by a thicker structureless layer, consisting of dark shale; structures most likely originated by collapse of tubelike dwelling-burrows. [Perhaps made by freshwater (?) wormlike animal or insect larva.] *M.Trias.(up.Hawkesbury Ss.),* Australia (NewS. Wales, Sydney Basin).——FIG. 30,*1*. **B. obliquus,* shale lens in Hawkesbury Ss., NewS. Wales (Brookvale); *1a,* ×1.7; *1b,* ×0.83 (Webby, B. D., 1970a, p. 529, in: *Trace Fossils* edited by T. P. Crimes & J. C. Harper, Geol. Jour. Spec. Issue 3, Seel House Press Liverpool).

Buchholzbrunnichnus GERMS, 1973, p. 69 [**B. kröneri (recte kroeneri)*; OD]. *Precam.(Nama Syst., Kuibis F.),* SW.Afr.

Bunyerichnus GLAESSNER, 1969, p. 379 [**B. dalgarnoi*; OD]. Curved surface locomotion trail; somewhat variable width, changing throughout observed length from 2 to 3 cm.; submedian ridge about 2 mm. wide, distance from margins slightly variable; distinctly transverse rise-and-groove sculpture: grooves about 2 mm. long, separated by longer straight rises ending in pitlike depressions. [Produced by bilaterally symmetrical animal employing rhythmic muscular contractions, probably related to primitive mollusks without mineralized shells; only single specimens.] *U.Precam.(Brachina F.),* S.Australia (Flinders Ranges).——FIG. 30,*3*. **B. dalgarnoi*; holotype, ×0.67 (Glaessner, 1969).

Calycraterion KARASZEWSKI, 1971, p. 104 [**C. samsonowiczi*; M]. Regular calyx-shaped depressions; smaller ones similar to impression of lower part of very large hazelnut; inner walls smooth; "calyx" 15 to 40 mm. in diameter, 5 to 15 mm. in depth; 2 or 3 small circular depressions on the bottom representing outlets of filled burrows, 2 to 5 mm. in diameter. *L.Jur.(Hettang.),* Eu.(Pol.).——FIG. 30,*2*. **C. samsonowiczi,* Holy Cross Mts.; *2a,* preserved in concave epirelief; ×0.25 (Karaszewski, 1971a); *2b,* bottom of rock slab shown in *2a* with molds of calyces in convex hyporelief, ×0.25 (Karaszewski, n; I. G. 1285.11.2, Geol. Inst. Mus. Warsaw).

Capodistria VYALOV, 1964, p. 113 [**C. vettersi*; OD]. Starlike trace fossil; superfluous name for "genus" based on only one specimen observed in stone wall at Capodistria (Istria) and described by VETTERS (1910). [Found in flysch deposits.] *Tert.(Eoc.),* Eu.(Italy-Yugosl., Istria).

Caulerpites VON STERNBERG, 1833, p. 20 [**Fucoides Targionii* BRONGNIART, 1828, p. 56 (=*C. targionii* VON STERNBERG, 1833, p. 25); SD ANDREWS, 1955, p. 130] [=*Caulerpides* SCHIMPER, 1869, p. 160 *(nom. null.)*]. Very heterogeneous "genus" including plants (even conifers, according to SCHIMPER) as well as trails (e.g., *C. marginatus* LESQUEREUX, 1869, p. 314 = *Spreitenbau* similar to *"Taonurus"; C. annulatus* ETTINGHAUSEN, 1863, p. 462 = stuffed burrow similar to *Keckia* or *Muensteria*); other "species" also classified with Recent genus *Caulerpa* LAMOUROUX, 1809.

Chomatichnus DONALDSON & SIMPSON, 1962, p. 78 [**C. wegberensis*; OD]. Small circular conical mounds consisting of fecal castings, about 5 to 7 cm. high, connected with a vertical burrow; somewhat similar to piles of fecal castings produced by Recent polychaete *Arenicola*; according to SIMPSON (1970, p. 510), these castings probably produced by the *Zoophycos* animal. *L.Carb.(Dibunophyllum Z.),* G.Brit.(Eng.); *Cret.,* USA (N.Mex.).——FIG. 31,*6*. **C. wegberensis,* Carb., Eng. (Carnforth, Lancash.); *6a,* vert. sec., based on holotype, ×0.67; *6b,* ×0.4 (Donaldson & Simpson, 1962).

Chondrites VON STERNBERG, 1833, p. 25 [*non* M'COY, 1848] [**Fucoides lycopodioides* BRONGNIART, 1828, p. 72 (=*C. lycopodioides* VON STERNBERG, 1833, p. 20); SD ANDREWS, 1955, p. 127] [=*Caulerpites* VON STERNBERG, 1833, p. 20 *(partim); Sphaerococcites* VON STERNBERG, 1833, p. 28 *(partim); Buthotrephis* HALL, 1847, p. 8 *(partim); Phymatoderma* BRONGNIART, 1849, p. 59 *(partim); ?Trevisania* DE ZIGNO, 1856, p. 23; *Phycopsis* VON FISCHER-OOSTER, 1858, p. 64 ("subg."); *Bythotrephis* EICHWALD, 1860, p. 56 *(nom null.); Nulliporites* HEER, 1865, p. 140 (*non* KRUEGER, 1823, *nom. nud.*); *Chondrides* SCHIMPER, 1869, p. 168 *(nom. null.); Leptochondrides* SCHIMPER, 1869, p. 171 ("subg."); *?Theobaldia* HEER, 1877, p. 114 *(partim); ?Aulacophycus* HEER, 1877, p. 111 (type, *A. sulcatulus*); *Palaeochondrites* DE SAPORTA, 1882, p. 35; *Chondropogon* SQUINABOL, 1890, p. 180; *?Prochondrites* FRITSCH, 1908, p. 22; *?Labyrinthochorda* WEISSENBACH, 1931, p. 76; *?Isawaites* HATAI &

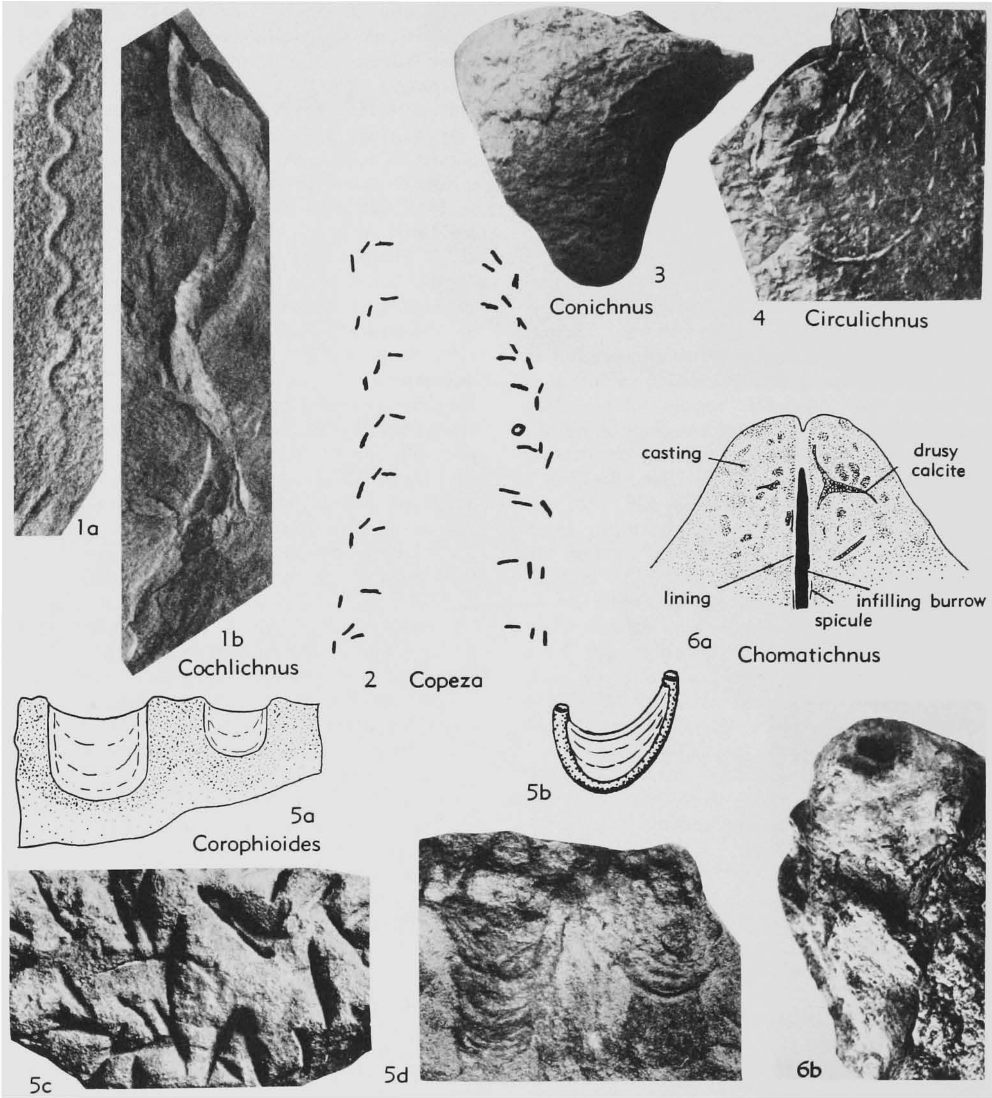

FIG. 31. Trace fossils (p. *W*49, 52-53).

NODA, 1971b, p. 5]. "Form genus" in widest possible sense; plantlike dendritic patterns of small cylindrical ramifying tunnel systems; individual tunnels neither crossing each other nor interpenetrating (perhaps only between tunnels of different systems); one or few main axes open to surface; branching tunnels trending downward across bedding and then (at least their distal portions) mostly lying parallel to bedding planes; may branch in regular or irregular patterns (highly variable); angle of branching may also be variable or constant, between 25 and 40°; branches may be arranged in pinnate or radial patterns or form compact groups; diameter of tunnels 0.5 to 5 mm., remaining constant within entire tunnel system; otherwise varying from large (e.g., *"Buthotrephis"*) to small (most *Chondrites*); some tunnels with transversely built-in ellipsoidal pills (their probable fecal origin doubted); preservation of fillings of tunnels controlled by stratinomic factors; trace fossil nature convincingly proved first by RICHTER (1927a, 1931), though earlier NATHORST (1881a) and FUCHS (1895) had rejected the former interpretation as algae; producer unknown, perhaps worms. SIMPSON (1957) suggested sipunculoid worms working from fixed center on the surface of sediment and producing tunnels by an ex-

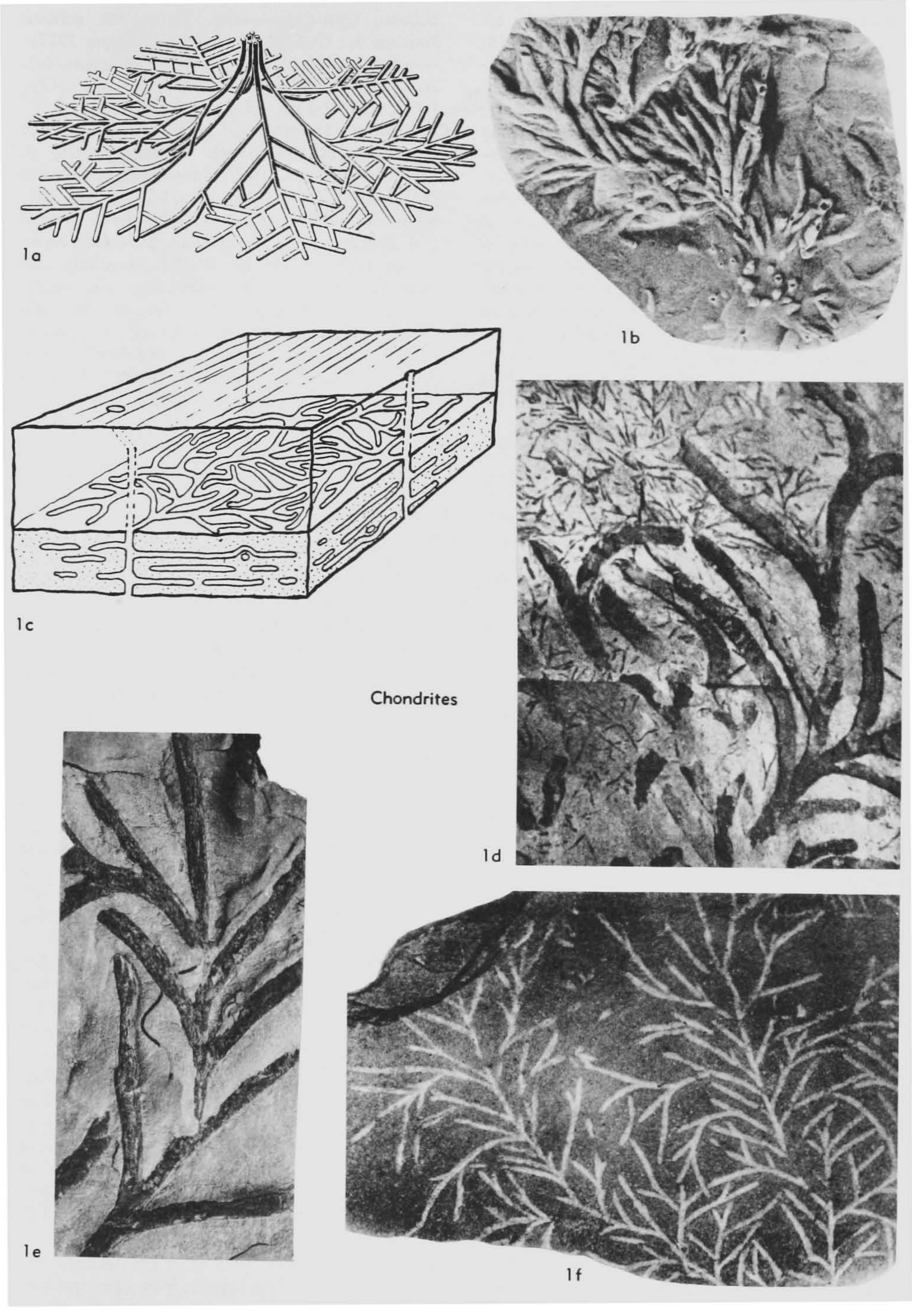

FIG. 32. Trace fossils (p. W49-50, 52).

tensible proboscis; branching pattern may be affected by phobotaxis (RICHTER, 1927a, p. 218; 1928, p. 226; 1931, p. 302); ethological interpretation is still discussed but *Chondrites* undoubtedly belongs to Fodinichnia and is to be regarded as feeding structures of sediment-eating animals (RICHTER, 1927; SEILACHER, 1955; OSGOOD, 1970) and not dwelling burrows of filter-feeding annelids (TAUBER, 1949); detailed studies of the ichnogenus would certainly lead to several additional "new ichnogenera"; some dozens of "ichnospecies" have been described but recognition of these within *Chondrites* very difficult (OSGOOD, 1970, p. 489); for historical account of many theories of the nature of *Chondrites,* detailed treatments, and literature, see especially SIMPSON (1957) and OSGOOD (1970, p. 328-331); for discussion and various reconstructions of tunnel systems of this form see RICHTER (1931, p. 301, fig. 2), TAUBER (1949, p. 149-150, fig. 1,2), and SIMPSON (1957, p. 484, fig. 2).] *?Cam., Ord.-Tert.,* cosmop.——FIG. 32,*1a,e,f. C.* sp., U.Cret.; *1a,* reconstr. of tunnel system (Simpson, 1957); *1e,* large form, Aus.; ×0.9 (Häntzschel, 1955); *1f,* small form, Maastricht., Spain; ×0.9 (Gómez de Llarena, 1946).——FIG. 32,*1b. Chondrites,* type C, U.Ord.(Cincinnat., Whitewater beds), USA(Ind.); ×1.2 (Osgood, 1970).——FIG. 32,*1c. C. bollensis* ZIETEN, Lias ε Ger.(Holzmaden); schem.(Richter, 1931).——FIG. 32,*1d. C. furcatus* VON STERNBERG, flysch deposits, ?Tert., Aus.; ×0.9 (Derichs, 1928).

Chondritoides BORRELLO, 1966, p. 15 [**C. insolitus*; OD]. Superfluous name for poorly figured straight burrows, 7 mm. in diameter, bifurcating at various angles up to 60°; somewhat resembling large "species" of *Chondrites* VON STERNBERG. *Ord.,* S.Am.(Arg.).

Circulichnis VYALOV, 1971, p. 91 [**C. montanus,* p. 91; OD]. Ring-shaped trace, almost circular (or oval), formed by some cylindrical object. *U.Trias.,* C.Asia(SW.Pamir).——FIG. 31,*4. *C. montanus*; ×0.67 (Vyalov, 1971). [Description supplied by CURT TEICHERT.]

Climactichnites LOGAN, 1860, p. 285 [**C. wilsoni*; M] [=*Climachtichnites* MILLER, 1877, p. 214 *(nom. null.); Climactichnides* CHAPMAN, 1878, p. 490 *(nom. null.)*]. Very large trails, width about 15 cm., maximum length 3 to 4 m., with prominent, slightly arched or V-shaped transverse ridges and very delicate, closely spaced arched rills; dishlike impressions, oval, distinctly bounded at beginning of trail. [Crawling trail of unknown producer; interpreted also as of plant origin (CHAPMAN, 1878); many groups of animals have been proposed as producers: burrowing crustaceans, eurypterids, large trilobites, worms, and mollusks; according to ABEL (1935, p. 242-249) most probably made by gastropods (likely marine nudibranchs); for history of genus see BURLING (1917, p. 390) and ABEL (1935, p. 242).] *U.Cam.,* USA-Can.——FIG. 33,*1a. *C. wilsoni,* Potsdam Ss., USA(N.Y.); ×0.02 (Walcott, 1912).——FIG. 33,*1b,c. C. youngi* (CHAMBERLAIN), St. Croix, USA(Wis.); *1b,* ×0.4 (Walcott, 1912); *1c,* ×0.5 (Walcott, 1912, in Malz, 1968).

Cochlichnus HITCHCOCK, 1858, p. 161 [**C. anguineus*; M] [=*Sinusia* KRESTEW, 1928, p. 574 (*non* CARADJA, 1916) *(nom. nud.); Sinusites* DEMANET & VAN STRAELEN, 1938, p. 107; MICHELAU (1956) incorrectly considered *Sinusia* and *Sinusites* to be synonymous with *Belorhaphe* FUCHS, 1895, p. 395 (p. *W*45)]. Regularly meandering smooth trails, resembling sine curve. [Found in flysch deposits.] *U.Precam.,* Australia (New S.Wales); *U.Precam. or L.Cam.,* Eu.(Nor.); *?L.Cam.-M.Cam.,* Eu.(Eng.); *Ord.(Arenig.),* Eu.(Eng.); *U.Carb.,* Eu.-USA; *Perm.,* Antarct.; *Trias.,* N.Am.(USA, Mass.); *L.Jur.,* Eu.(Ger.); *L.Jur. (Pliensbach.),* Greenl.; *L.Cret.,* Eu.(Ger.-Eng.-Pol.); *Tert.(Oligo.),* Eu.(Pol.).——FIG. 31, *1. C. kochi* (LUDWIG), Carb., Ger.; *1a,b,* ×0.67 (Michelau, 1956).

Conichnus MYANNIL, 1966, p. 201 [**C. conicus*; M]. Fillings of conical or conelike hollows; mostly very regular forms with circular cross section; lower end round, without distinct mammilliform peak, thus differing from *Amphorichnus* MYANNIL; length (max.) 12 cm., diameter (max.) 8 cm., perpendicular to bedding plane. [Dwelling burrow or resting trail.] *M.Ord.-U.Ord.,* USSR (Est.).——FIG. 31,*3. *C. conicus,* M.Ord. (?Kukruse F.), Est.; ×0.5 (Myannil, 1966).

Conispiron VYALOV, 1969, p. 106 [**Xenohelix babkovi* GEKKER in GEKKER, OSIPOVA, & BELSKAYA, 1962, p. 205; OD]. Dextrally or sinistrally coiled burrows having circular or elliptical cross sections; diameter of spiral possibly decreasing downward; vertical distance between the twist also decreases downward, the entire spiral having a conical outline. *Tert.(?mid. Oligo.),* USSR(Crimea). [Description supplied by CURT TEICHERT.]

Conopsoides HITCHCOCK, 1858, p. 152 [**C. larvalis*; M]. Tracks in 3 (?4) rows, divergent from median line; foot impression linear, blunt anteriorly; tracks straight or sharply curved. [?Made by insect.] *Trias.,* USA(Conn.-Mass.).

Copeza HITCHCOCK, 1858, p. 159 [**C. triremis*; M]. Three rows of impressions on either side of median line, with main track at right angles to that line; width of trackway 35 mm.; oblique impressions not outside of longitudinal ones as in *Lithographus,* but inside. [?Made by podites of insect.] *Trias.,* USA(Mass.).——FIG. 31,*2. *C. triremis*; ×0.7 (Lull, 1915).

Coprinisphaera SAUER, 1955, p. 9 [**C. ecuadoriensis*; M]. Spherical structures with one opening; about 6 cm. in diameter; walls about 1 cm. thick; mostly hollow or filled with consolidated mass similar to argillaceous excrement; found in loess-like tuffs *(cancagua).* [Probable breeding places

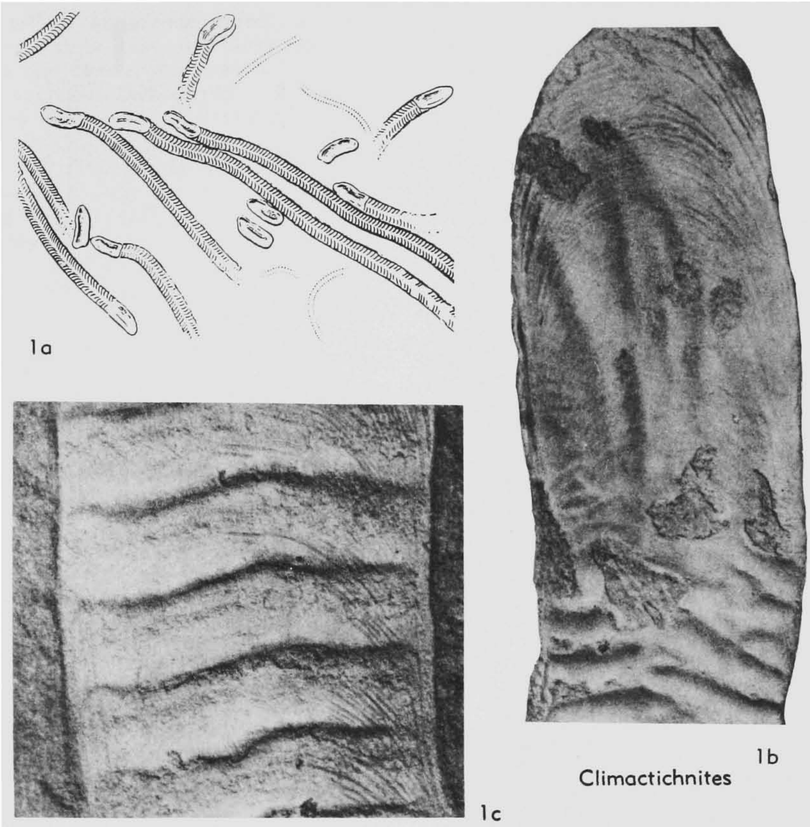

FIG. 33. Trace fossils (p. W52).

of scarabaeid beetles.] *Pleist.* (guide fossil of 3rd interglacial stage), S.Am.(Ecuad.-Colom.).

Corophioides SMITH, 1893, p. 292 [**C. polyupsilon*; M] [=*Arenicoloides* BLANCKENHORN, 1916, p. 39 (type, *A. luniformis*); *Arenicolithes* HILDEBRAND, 1924, p. 27 *(nom. null.)*; *Corophyoides* ÖPIK, 1956, p. 108 *(nom. null.)*; *Corophiodes* BORRELLO, 1966, p. 11 *(nom. null.)*]. U-shaped spreiten burrows similar to *Rhizocorallium*, but shorter and always perpendicular to bedding plane (Richter, 1926). Both limbs of each successive U-tube typically show lateral displacement from limbs of preceding U-tube (see KNOX, 1973, p. 135, for further discussion). [*Arenicoloides* comprises crescent-shaped grooves in bedding planes produced by erosion of burrows to their basal ends.] *Cam.-U.Cret.*, Eu.-Asia.——FIG. 31,*5a,c,d*. *C. luniformis* (BLANCKENHORN), L.Trias., Ger.; *5a*, side (somewhat schem.), ×0.67; *5c*, lower ends of U-shaped burrows with spreite, ×0.4; *5d*, side, ×0.4 (Abel, 1935).——FIG. 31,*5b*. *C.* sp. cf. *C. rosei* DAHMER, L.Cam., Pak.; ×0.4 (Seilacher, 1955).

Cosmorhaphe FUCHS, 1895, p. 395 (misprinted *Cosmoraphe*; correct spelling *Cosmorhaphe* twice on p. 447) [**Helminthopsis sinuosa* AZPEITIA MOROS, 1933, p. 45; SD HÄNTZSCHEL, herein]. "Free meanders" of simple, smooth ridges, of extraordinarily regular form, meanders commonly in 2 orders of size; windings not physically close to each other. [At first compared by FUCHS (1895) with spawn strings of gastropods; however, *Cosmorhaphe* is typical grazing trail. For discussion of the preservation (predepositional, formed along bedding planes, secondary casts of surface trails), see WEBBY (1969a, p. 84). *C. timida* PFEIFFER (*L.Carb.*, Ger.) is not typical *Cosmorhaphe*.] [Found in flysch deposits.] *?Ord.*, Eu.(Nor.); *U.Sil.*, Australia(New S. Wales); *?Dev.*, Eu.(Ger.)-USA(Mont.); *?U.Cret.*, Alaska; *U.Cret.-L.Tert.*, Eu.; *L.Tert.*, S.Am. (Venez.); *M.Tert.*, N.Z.——FIG. 34,*3*. *C.* sp., low.mid.Eoc., Pol.; ×0.6 (Książkiewicz, 1960).

Crossopodia M'COY, 1851, p. 395 [**C. scotica*; SD HÄNTZSCHEL, 1962, p. W189] [=*Crassopodia* TATE, 1859, p. 66 *(nom. null.)*; *Crossochorda* SCHIMPER, 1879, p. 52 (modified name for algal interpretation); *Chrossocorda*, *Chrossochorda*, *Chrossocarda* WILLIAMSON, 1887, p. 21, 22, 29

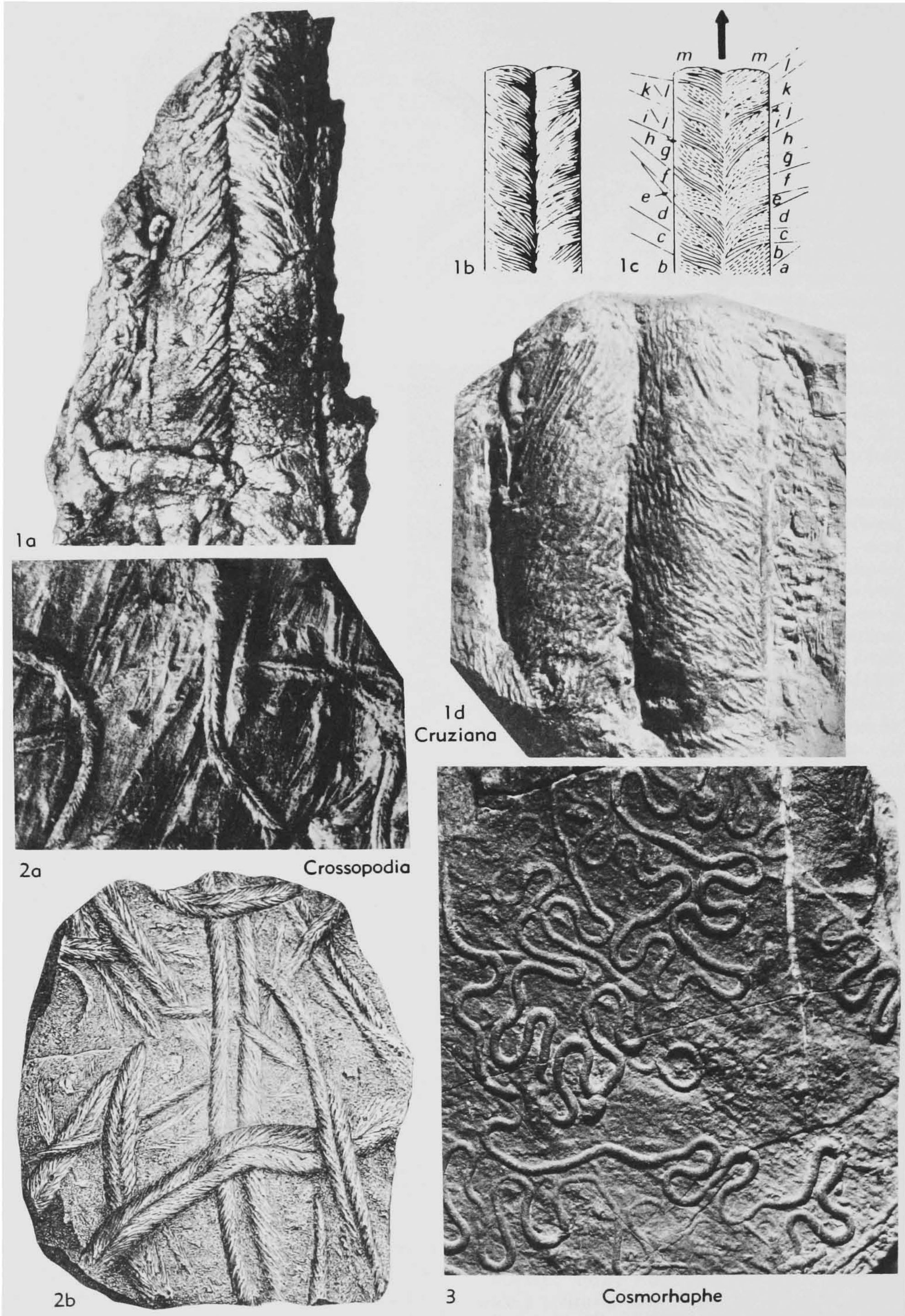

FIG. 34. Trace fossils (p. W53, 55).

(nom. null.)]. Meandering, curved, or straight trails, width about 1 cm., with broad dense fringe on each side (formerly regarded as "segments" of supposed worm), mostly with median furrow. [Crawling trail, at first interpreted as worm or alga; name *Crossopodia* should be restricted to the type of crawling trails as figured (e.g., by SCHIMPER or WILLIAMSON); *C. tuvaensis* MASLOV (1956, p. 87) (Sil., USSR) to be excluded from *Crossopodia* (markings?); concerning *C. henrici* (GEINITZ), see *Dictyodora* WEISS.] *Ord.-Carb.*, Eu.-USA(Kans.); *?Ord.-Carb.*, S.Am.(Arg.-Brazil), *?U.Cret.*, USA(Kans.-Okla.-Iowa).——FIG. 34,*2a*. *C. tuberculata* (WILLIAMSON), Carb., Eng.; ×0.3 (Williamson, 1887).——FIG. 34,*2b*. **C. scotia* (M'COY), Ord., France; ×0.5 (Schimper in Schimper & Schenk, 1879).

Cruziana D'ORBIGNY, 1842, p. 30 [**C. rugosa*; (first?) SD BASSLER, 1915, p. 292; later SD: *C. furcifera* D'ORBIGNY, 1842, p. 30, by SEILACHER, 1953, p. 107] [=*Bilobites* D'ORBIGNY, 1839, expl. pl. 1, fig. 1-3 (*non* DEKAY, 1824; *nec* RAFINESQUE, 1831; *nec* BRONN, 1848; *nec* QUENSTEDT, 1869), for discussion see SINCLAIR, 1951; *Crusiana* DAWSON, 1888, p. 30 *(nom. null.)*; *Bilobichnium* KREJCI-GRAF, 1932, p. 31 (no formal species name; proposed as *nom. nov.*)]. Elongate bandlike furrows covered by herringbone-shaped ridges, with or without 2 outer smooth or finely longitudinally striated zones outside V-markings occasionally with lateral grooves and/or wisp markings; variability in size and sculpture due to varied behavior of producer and preserved width of trail (0.5 cm. to about 8 cm.); length up to more than 1 m. (RADWAŃSKI & RONIEWICZ, 1972), commonly 10 to 20 cm.; V-angle quite variable, acute to blunt, along length of an individual trail. V-markings are scratch markings made by appendages of producer, certainly mostly by digging activity of endopodites of trilobites; V-markings grouped in sets of distinct parallel claw markings produced by multiple or serrate claws, thus consisting of 2 or more parallel or slightly diverging grooves. [Interpretation was very controversially discussed in many publications from 1881-87; some regarded *Cruziana* as plants or sponges (DELGADO, 1885; LEBESCONTE, 1883a,b; DE SAPORTA 1884), but NATHORST (1881a, 1886) argued for trace fossil nature; for a short account of this controversy see OSGOOD, 1970, p. 287. Occurrences in France were regarded as *"pas de boeuf"* or even as *"monument druidique"* (see DESLONGCHAMPS, 1856, p. 299; FAUVEL, 1868; MORIÈRE, 1879). These forms now are generally regarded as made by furrowing, burrowing, or shoveling trilobites or trilobite-like arthropods, in part perhaps of merostome origin, and have also been found in freshwater deposits, questionably attributed to notostracan branchiopods (BROMLEY & ASGAARD, 1972); originated by simple ploughing using all or only anterior appendages; lateral ridges may be made by dragging of genal spines; trails may also possess additional impressions of coxae, pleural spines, exopodites and/or carapace edges; produced at mud-sand interface or in muddy sediment by burrowing beneath a sand layer (BIRKENMAJER & BRUTON, 1971, p. 315). For undertrack trails see SEILACHER (1970, p. 448); V-shaped pattern points in opposite direction to that of animal's movement, V's gape forward; for many conclusions from studies of *Cruziana* on morphology of trilobite legs, trilobite motion and behavior, gradients in digging direction, and preservation, see SEILACHER (1962; 1970, fig. 1-6), CRIMES (1970b,c), BIRKENMAJER & BRUTON (1971, p. 314, 317).[1] Intermediate forms between *Cruziana*, *Rusophycus*, and *Diplichnites* have been observed; *Cruziana* and *Rusophycus* were often regarded as synonyms, but LESSERTISSEUR (1955, p. 45), SEILACHER (1955, p. 366), and particularly OSGOOD (1970, p. 303) recommended restricting *Rusophycus* to the short bilobate resting trails of trilobite origin, naming the longer bilobate forms *Cruziana*; however, SEILACHER (1970) did not follow that suggestion and placed all "resting tracks," "resting nests," and "resting burrows" in *Cruziana*. Owing to the difficulties in separating *Cruziana* and *Rusophycus*, it seems best "to base the names strictly on morphology" (OSGOOD, 1970); for discussion of stratigraphic significance of *Cruziana* see CRIMES (1968, 1969) and SEILACHER (1960, 1970); for detailed discussion of the genus see LEBESCONTE (1883a, p. 59-73), DE SAPORTA (1884, p. 58-89), DELGADO (1885, p. 27-68), DESIO (1940, p. 64-67); LESSERTISSEUR (1955, p. 44-47), SEILACHER (1955, p. 364-366) and other papers quoted above.] *U.Precam.-Dev.*, cosmop., *Trias.*, E.Greenl.——FIG. 34,*1a*. *C. semiplicata*, U.Cam., North Wales(Snowdonia); ×0.5 (Crimes, 1968).——FIG. 34,*1b,c*. *Cruziana*, Cam.; *1b*, diag. showing herringbone pattern consisting of sets of scratch marks thought to be produced by backward movement of trilobite appendages; *1c*, detail of the various sets (represented by letters *a-l*), schem. (arrow represents direction of movement of the animal) (Birkenmajer & Bruton, 1971).——FIG. 34, *1d*. *C. furcifera*, L.Ord., North Wales; ×0.37 (Crimes, 1968).

Ctenopholeus SEILACHER & HEMLEBEN, 1966, p. 47 [**C. kutscheri*; M]. Long horizontal tunnel-like burrow, straight or somewhat curved, with vertical shafts rising at equal intervals; burrow only rarely branched horizontally; fragments up to 60 cm. in length. [Feeding burrow.] *L.Dev. (Hunsrück Sh.)*, Eu.(Ger.).——FIG. 35,*1*. **C.*

[1] BERGSTRÖM (1973, p. 52-59) discussed the above mentioned papers and others in an excellent summary of the behavioral patterns of trilobites as they relate to the formation of different species of *Cruziana* and other related trace fossils. [W. G. HAKES.]

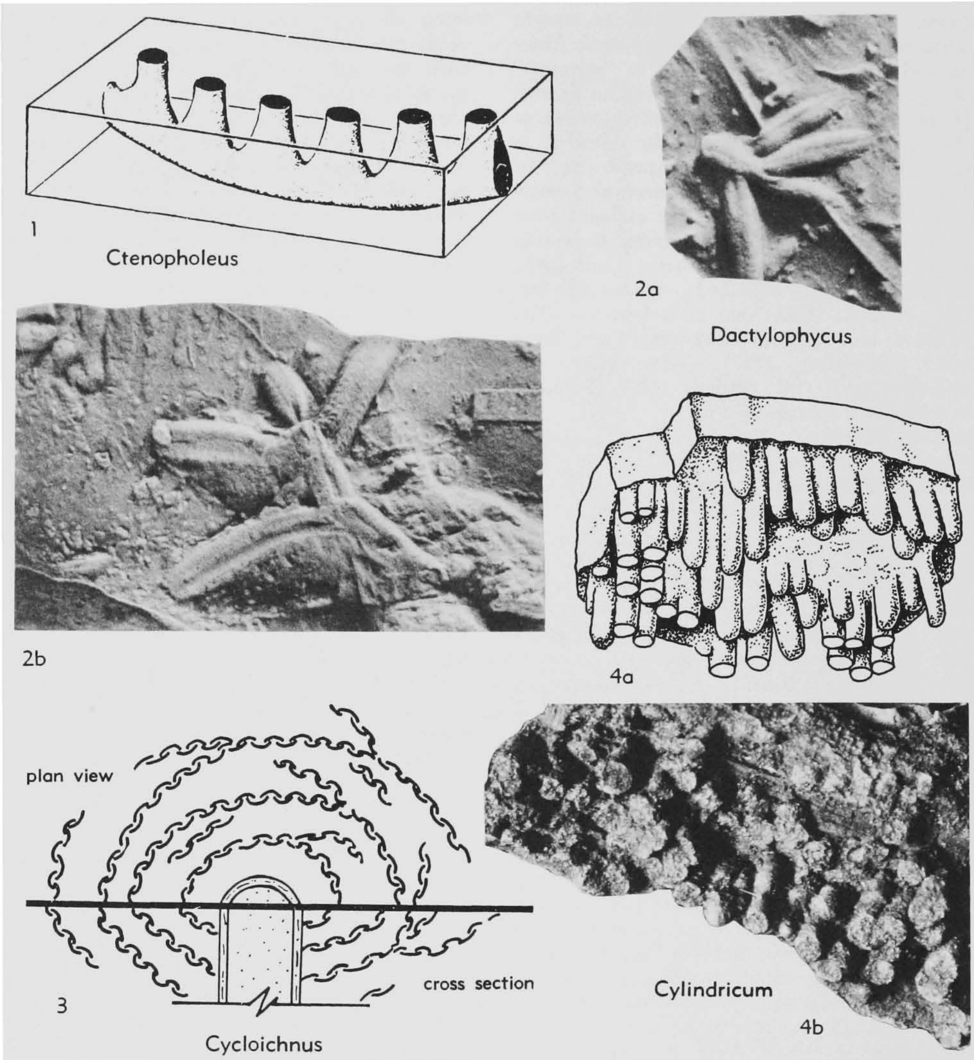

FIG. 35. Trace fossils (p. W55-58).

kutscheri; schem., ×1.3 (Seilacher & Hemleben, 1966).

Curvolithus FRITSCH, 1908, p. 13 [**C. multiplex*; SD HÄNTZSCHEL, 1962, p. W189]. Ribbonlike trails, more or less straight, flat; consisting of 3 parts: broad, usually smooth central stripe (about 0.5 to 2 cm. wide) and very narrow lateral ridges (1 to 2 mm. wide). [Endichnial crawling trails, also cutting bedding planes and passing over and under each other, probably produced by burrowing gastropods.[1] Two varied types of the genus described by HEINBERG (1970, p. 23); perhaps the grooved pipes described by KEIJ (1965, p. 226) (Mio., Borneo) should also be placed in *Curvolithus* as proposed by CHAMBERLAIN (1971a, p. 224). Identity of the Ordovician specimens with the Jurassic ones is not yet proved; *C. gregarius* FRITSCH, 1908, p. 13, differs distinctly from the type species.] *?Precam.*, Australia; *Ord.*, Eu.(Czech.); *Sil.*, USA(Ga.); *Penn.*, USA(Okla.); *L.Jur.-M.Jur.*, Eu.(Ger.)-Greenl.; *Cret.*, Eu.(Ger.); *Tert.(?Mio.)*, Borneo.——FIG. 36,*3a*. *C.* sp., M.Jur., Ger.; ×0.7 (Seilacher, 1955).——FIG. 36,*3b*. *Curvolithus* FRITSCH, Low. Lias (Hettang.), Ger. (Helmstedt); ×1.3 (Häntzschel & Reineck, 1968).

Cycloichnus GREGORY, 1969, p. 13 [**C. waitema-*

[1] See also HEINBERG (1973).

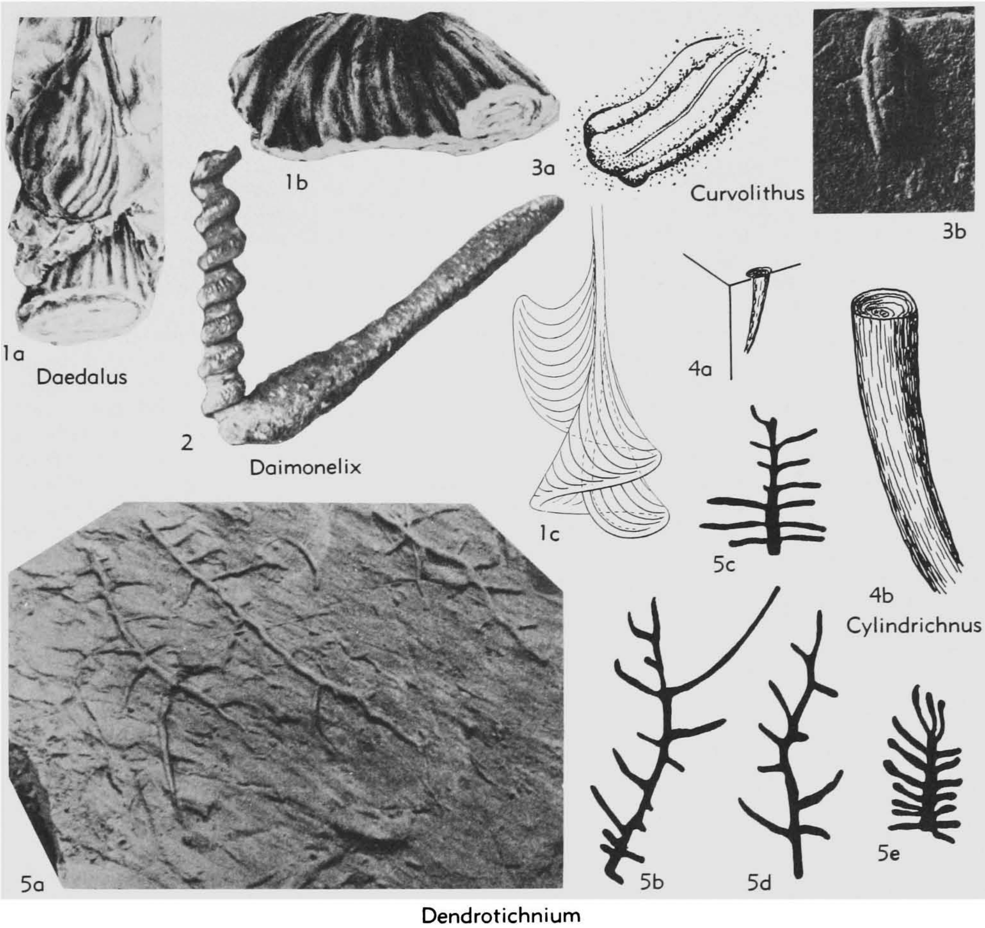

FIG. 36. Trace fossils (p. *W*56-57).

taensis; OD]. Simple central shaft, structureless, diameter about 1 cm., length 2 cm.; wall probably smooth, with several saucer-shaped galleries diverging from it, irregularly constricted to give small leaf-shaped impression, visible on bedding plane with concentric markings surrounding central shaft; galleries somewhat branching but not interconnected. [Tentatively interpreted by GREGORY to be result of proboscis-bearing animal systematically culling sediment about dwelling shaft. An inorganic origin (except central shaft) may be possible.] *Tert.(low.Mio.,Waitemata Gr.)*, N.Z.——FIG. 35,*3*. **C. waitemataensis*, Whanga Paroa Penin., Auckland, schem., ×1.1 (Gregory, 1969).

Cylindrichnus TOOTS in HOWARD, 1966, p. 45 [**C. concentricus*; M] [=*Anemonichnus* CHAMBERLAIN & CLARK, 1973; obj.] [*non Cylindrichnus* BANDEL, 1967a, =*Margaritichnus* BANDEL, 1973]. Subconical form, weakly curved, circular to oval in cross section with diameter of 10 to 20 mm., most commonly 12 to 15 mm.; central core 2 to 4 mm.; exterior wall composed of concentric layers; preserved in full relief; orientation from nearly horizontal to vertical. [Interpreted as permanent burrow (domichnia) of filter-feeding organism. Considered by FREY & HOWARD (1970) as a form of *Asterosoma*.] *L.Penn.*, USA(Utah); *U.Cret.*, USA(Utah-Wyo.-Kans.).——FIG. 36,*4*. **C. concentricus*, Utah; *4a,b*, diagram. (Howard, 1966). [Description supplied by W. G. HAKES.]

Cylindricum LINCK, 1949, p. 19 [**Tubifex antiquus* PLIENINGER, 1845, p. 159 (=*Cylindricum gregarium* LINCK, 1949b, p. 19; see LINCK, 1961, p. 9); OD]. Plugs (fillings of tubes) shaped like test tubes, rounded at lower end, not pointed, walls smooth; diameter up to 5 cm., up to several cm. long; preserved in groups in convex hyporelief oriented perpendicular to bedding plane. [Dwelling burrow.] *?Dev.*, Antarct.; *?L.*

Carb.(Kulm), Eu.(Ger.); *L.Trias.(Buntsandstein)*, Eu.(Ger.); *U.Trias.(Keuper)*, Eu.(Ger.); *?M.Jur.*, Eu.(Ger.).——FIG. 35,*4*. **C. antiquum* (PLIENINGER), U.Trias.(M.Keuper), Ger.; *4a*, U.Trias. (Schilfsandst.), diagram. (after Seilacher, 1955); *4b*, ×1 (Linck, 1949b).

Dactylophycus MILLER & DYER, 1878, p. 1 [**D. tridigitatum*; SD OSGOOD, 1970, p. 345]. Delicately annulated bilobate burrows, small, about 15 mm. long, 2 to 4 mm. in diameter; radiate or randomly branching, number of branches varying. [Originally regarded as plant; considered by JAMES (1884) to be fragments of burrows or of inorganic origin; according to OSGOOD (1970, p. 346), belongs to *Fodinichnia*, "excavation of *Sedimentfresser*"; as stated by JAMES (1885) and OSGOOD (1970) possibly identical with *Palaeophycus radiata* ORTON, particularly *Phycodes flabellum* (MILLER & DYER); type specimen of *D. tridigitatum* not located.] *U.Ord.(Cincinnat.)*, USA(Ohio).——FIG. 35,*2*. *D. quadripartitum* MILLER & DYER, Eden beds; *2a*, ×1; *2b*, ×1.3 (Osgood, 1970).

Daedalus ROUAULT, 1850, p. 736 [*non* REDTENBACHER, 1891] [**Vexillum desglandi* ROUAULT, 1850, p. 733; SD HÄNTZSCHEL, 1961, p. *W*191] [=*Vexillum* ROUAULT, 1850, p. 733 (*non* BOLTEN, 1798) *(nom. nud.)*; *Humilis* ROUAULT, 1850, p. 738 (no type species designated); *Vescillum* LEBESCONTE, 1892, p. 76 *(nom. null.)*]. Spreiten structures, J-shaped at beginning, later spirally twisted; spreiten surface may cut through itself, as in *Dictyodora* WEISS. [For synonymy of type species see ROUAULT in LEBESCONTE (1883a, p. 45-47).] *Ord.-Sil.*, Eu.-Asia(Iraq)-USA.——FIG. 36,*1*. **D. desglandi* (ROUAULT); *1a*, *1b*, Ord., France, ×0.25 (Lebesconte, 1892); *1c*, L.Sil., USA, diagram showing gradation from vertical to spiral (Sarle, 1906).

Daimonelix BARBOUR, 1892, p. 99 [**D. circumaxilis*; SD HÄNTZSCHEL, herein] [=*Daemonelix* BARBOUR, 1895, p. 517; *Helicodaemon* CLAYPOLE, 1895, p. 113 ("a more appropriate name") (all *nom. van.*); *Daemonhelix* AUCTT. (*non Daemonhelix krameri* VON AMMON, 1900, p. 63 (L. Tert., S.Ger.), see *Gyrolithes* DE SAPORTA); *non Daimonhelix Dusli* FRITSCH, 1908, p. 6 (Ord., Czech.)]. Large, vertical, open, spiral structure, regular in form, mostly coiled with strict uniformity; transverse rhizome-like piece at base. [Explained as freshwater sponges, or casts of rodent burrows; some forms also resembling concretions; interpretation of helical burrows as *Daimonelix* and other forms by TOOTS (1963); history of genus discussed by SCHULTZ (1942) and LUGN (1941). A somewhat comparable, though more tightly coiled, spiral structure was described by WHITEHOUSE (1934) from the Lower Cretaceous of Queensland.] *Tert.(Mio.)*, USA. ——FIG. 36,*2*. **D. circumaxilis*, USA(Neb.); side view, ×0.3 (Barbour, 1895).

Delesserites VON STERNBERG, 1833, p. 32 [**Fucoides Lamourouxii* BRONGNIART, 1823, p. 312 (=*D. lamourouxii* VON STERNBERG, 1833, p. 32); SD ANDREWS, 1955, p. 144] [=*Delessertites* BRONN, 1853, p. 110 (*non* RUEDEMANN, 1925, p. 8 = *Delesserella* RUEDEMANN, 1926, p. 156)]. Very heterogeneous "genus," including obvious trace fossils (e.g., *D. sinuosus*, *D. gracilis*, *D. foliosus* LUDWIG, 1869, from Devonian and Lower Carboniferous of Germany) and equally obvious plants (e.g., probably *D. lamourouxii*, and, according to PIA (1927), *D. salicifolia* RUEDEMANN, 1925, Ord., N.Y.); Cenozoic "species" are under name of Recent genus *Delesseria* LAMOUROUX.

Dendrotichnium HÄNTZSCHEL, herein [**D. llarenai* FARRÉS, 1967, p. 30; OD] [=*Dendrotichnium* GÓMEZ DE LLARENA, 1949, p. 123 (*nom. nud.*, without species designation); *Dendrothichnium* FARRÉS, 1963, p. 105 *(nom. null.)*; *Dendrotichnium* FARRÉS, 1967, p. 30 (*nom. nud.*, established without type species)]. Treelike trail, 7 to 30 cm. long; straight or somewhat curved "main stem," with several "side-branches" on both sides, their length quite variable, branching off perpendicularly in type species, but obliquely in *D. haentzscheli* FARRÉS. [Found in flysch deposits.] *U.Cret.*, Eu.(Spain).——FIG. 36,*5a*. *D. haentzscheli* and **D. llarenai*; ×0.2 (Farrés, 1967).——FIG. 36,*5b,d*. *D. haentzscheli* FARRÉS; *5b,d*, ×0.25 (Farrés, 1967).——FIG. 36,*5c,e*. **D. llarenai* FARRÉS; *5c,e*, ×0.25 (Farrés, 1967).

Desmograpton FUCHS, 1895, p. 394 [no type species named] [=*Pseudodesmograpton* MACSOTAY, 1967, p. 36 (type, *P. ichthyformis* MACSOTAY, 1967, p. 36)]. Trail, roughly in form of long and very narrow letter H, single patterns usually lined up in ribbons; form variable; similar to *Paleomeandron* PERUZZI but with long appendices. [Grazing trail. With reference to great similarity of *Pseudodesmograpton* to *Desmograpton* and varying pattern of latter, *Pseudodesmograpton* should not be considered separate genus.] [Found in flysch deposits.] *Cret.-L.Tert.*, Eu.-S. Am.(Venez.).——FIG. 37,*4*. *D.* sp., ?U.Cret., Italy; ×0.6 (Seilacher, in Häntzschel, 1962, coll. Florence Geol. Dept.).

Dictyodora WEISS, 1884, p. 17 [**Dictyophyton? liebeanum* GEINITZ, 1867, p. 288; M] [=?*Nemertites* MCLEAY, in MURCHISON, 1839, p. 701 (certainly *N. sudeticus* ROEMER, 1870, p. 33; for discussion, see WALTER, 1903, p. 76); *Myrianites gracilis* DELGADO, 1910, p. 28, and very probably several other "new species" of *Myrianites* MCLEAY, in MURCHISON, 1839, p. 700, in DELGADO, 1910]. Complicated three-dimensional spreiten structure, irregularly conical, vertical to bedding; apex of cone upward; very thin spreite *(=Dictyodora s.s.)* with exterior surface delicately striated, intensely "folded," may cut through itself, consisting of furrowlike lamellae crescent in cross section; irregular spiral or meandering "band"

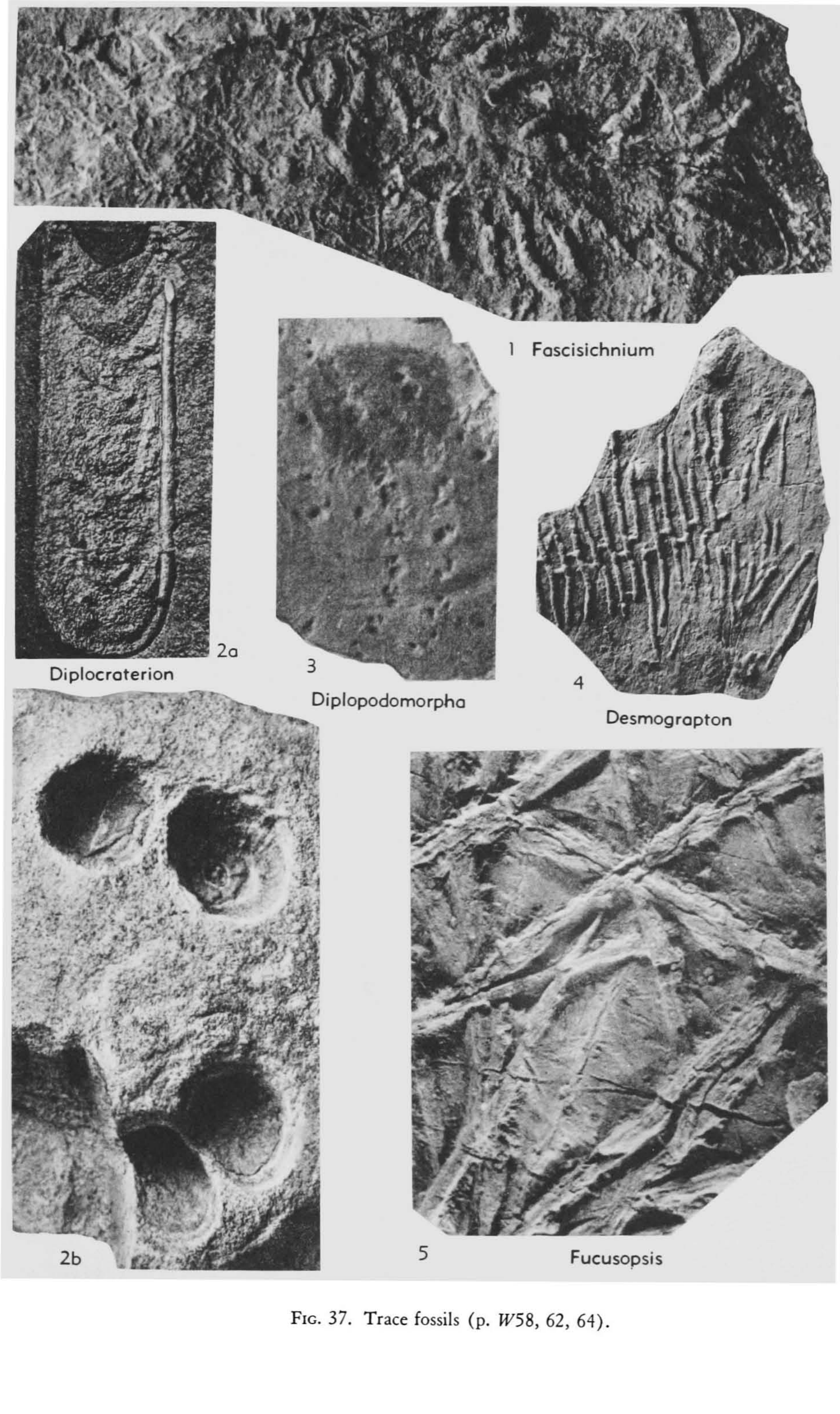

FIG. 37. Trace fossils (p. W58, 62, 64).

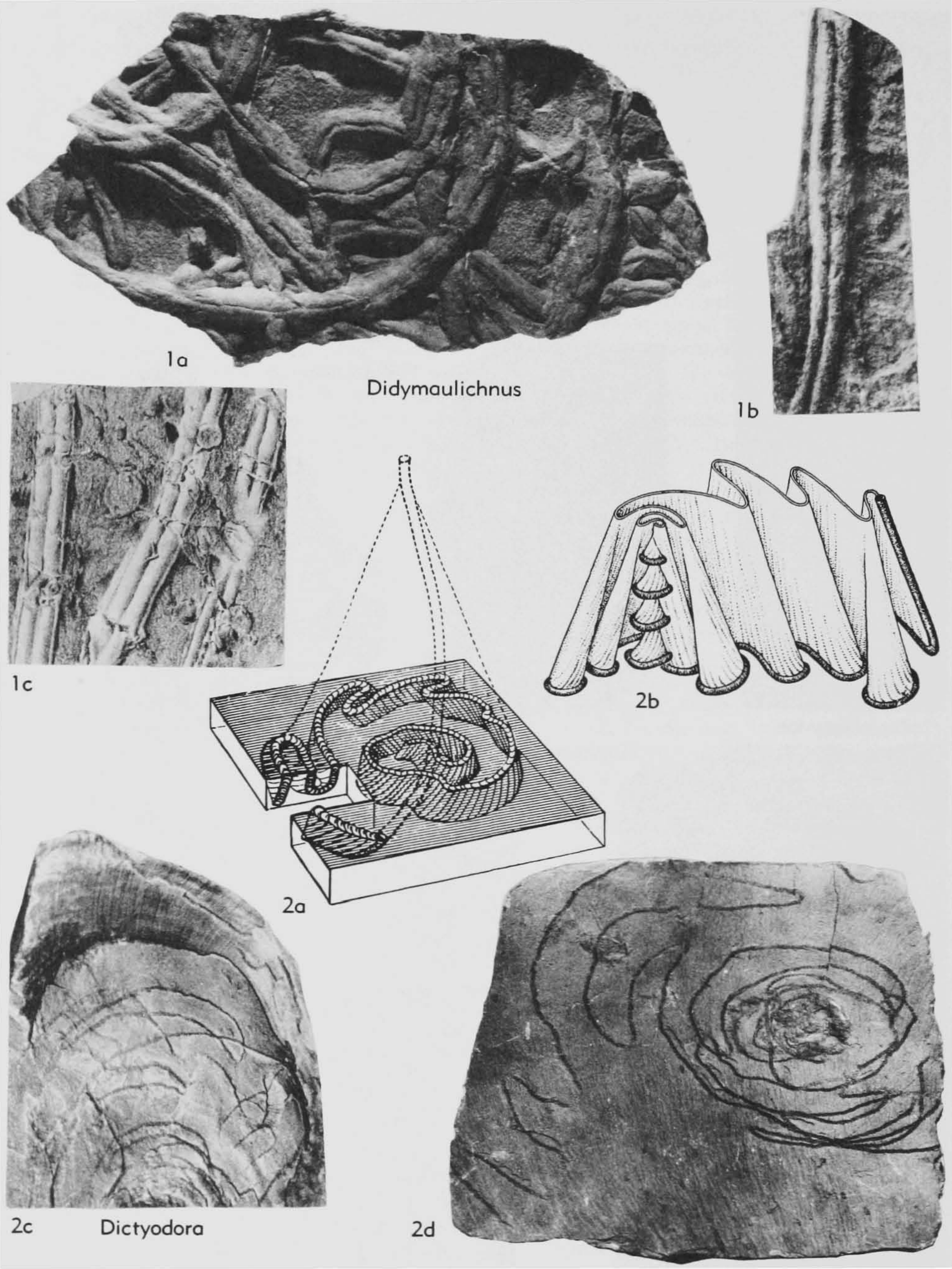

FIG. 38. Trace fossils (p. W58, 60-61).

(="*Palaeochorda marina*" GEINITZ) on cleavage planes parallel to bedding represents line of intersection of vertically spacious spreite; lower margin nonhorizontal, thick, tunnel-shaped, padlike (="*Crossopodia henrici*" GEINITZ); height of entire structure (in L. Carb. of Ger.) 3 to 18 cm. [Internal meandering foraging trail; producer unknown; SEILACHER (1967c, p. 78) explained the different forms of *Dictyodora* from Cambrian to Mississippian by anatomical changes (increasing length of the supposed siphons?) and behavioral evolution of producer; for various former interpretations and for discussion see WEISS (1884a), ZIMMERMANN (1889, 1891, 1892), ABEL (1935, p. 429), SEILACHER (1955, p. 379), PFEIFFER (1959), A. H. MÜLLER (1962, 1971b), SEILACHER (1967c, p. 78).] *L.Cam.*, Asia(Pak.); *Ord.*, Eu.(Ger.-Port.); *Sil.*, Eu.(Eng.)-USA(Ga.); *U.Dev.-L.Carb.*, Eu.(Ger.Aus.).——FIG. 38,*2a*. *D. simplex* SEILACHER, L.Cam., Pak., drawing of a model, ×0.5 (Seilacher, 1955).——FIG. 38,*2b*. *Dictyodora* trail, reconstr.: "The animal left the upper sediment, eating its way deeper along a corkscrew-like path and then meandering in a restricted manner" (Seilacher, 1967).——FIG. 38, *2c,d*. **D. liebeana* (GEINITZ), *2c*, L.Carb., Aus.; ×0.3 (Abel, 1935); *2d*, L.Carb.(Kulm facies), Wurzbach (Frankenwald); ×0.5 (Müller, 1962).

Didymaulichnus YOUNG, 1972, p. 10 [**Fraena Lyelli* ROUAULT, 1850, p. 732; OD] [=*?Fraena* ROUAULT, 1850, p. 729; *Rouaultia* DE TROMELIN, 1878, p. 501, obj. (*non Rouaultia* BELLARDI, 1878 (?1877), p. 233); *?Cruziana rouaulti* LEBESCONTE, 1883a, p. 67; *Rouaulita* HÄNTZSCHEL, 1962, p. *W*212 *(nom. null.)*]. Simple, smooth, gently curving bilobate trails (about 2 cm. wide) preserved in convex hyporelief; parallel to bedding; lobes separated by distinct furrow; may have 2 asymmetric "marginal bevels"; trails may overlap and truncate one another. [Origin speculative but possibly crawling trail of molluscan origin; similar to "molluscan trails" of GLAESSNER (1969, fig. 9B-9C); *Rouaultia rouaulti* considered by CRIMES (1970b, p. 56) probably to have been made by trilobites.] *U.Precam.*, N.Am.(Can.)-Australia-C.India; *?U.Precam.(U.Vindhyan)*, C. India; *L.Cam.(U.Arumbera F.)*, C.Australia; *U. Cam.(Ffestiniog Stage)*, Eu.(N.Wales); *L.Ord.*, Eu.(France); *Ord.*, Eu.(France-Port.-Spain); *?Sil.*, N.Afr.-AsiaM.(Jordan).——FIG. 38,*1a*. *D. miettensis* YOUNG, U.Precam.(Miette Gr.), Can.(B.C., Alta.); ×0.2 (Young, 1972).——FIG. 38,*1b*. **D. lyelli* (ROUAULT), Ord., Port.; ×0.7 (Delgado, 1885).——FIG. 38, *1c*. *D. rouaulti* (LEBESCONTE), L.Ord.(Arenig.), France; ×0.75 (Lebesconte, 1883a). [Description supplied by W. G. HAKES.]

Dimorphichnus SEILACHER, 1955, p. 346 [**D. obliquus*; M]. Asymmetrical trails with 2 different types of impressions; thin sigmoidal ones, produced by raking movement (*"Hark-Siegel"* of SEILACHER), and blunt ones, similar to impressions of toes ("support imprints," *"Stemm-Siegel"* of SEILACHER); both types arranged in series oblique to direction of movement. [Made by laterally grazing trilobites; for discussion of the paleoecologic significance see OSGOOD (1970, p. 353.] *Cam.*, Eu.(Swed.-Eng.-Pol.)-Asia(Pak.); *Ord.*, S.Am.(Arg.).——FIG. 38A,*1*. **D. obliquus*, Jutana Dol., Pak.; *1a*, ×0.16; *1b*, ×0.8; *1c*, ×0.4 (Seilacher, 1955).

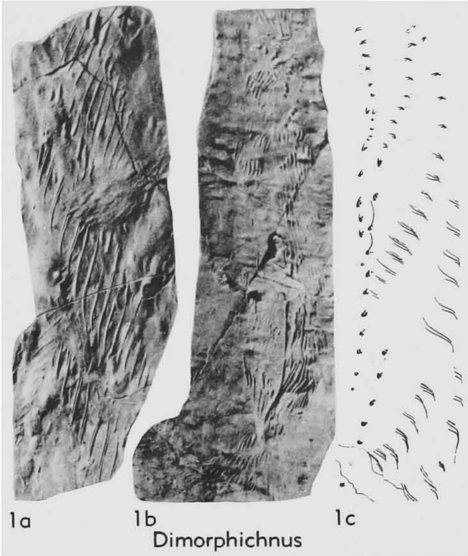

FIG. 38A. Trace fossils (p. *W*61).

Diplichnites DAWSON, 1873, p. 19 [**D. aenigma*; M] [=*Acripes* MATTHEW, 1910, p. 122 (type, *A. incertipes*; SD HÄNTZSCHEL, 1965, p. 6), for synonymy, see SEILACHER, 1955, p. 343]. Morphologically simple track, width about 1 to 2 cm., consisting of 2 parallel series of fine ridges (1-5 mm. long), individual ridges elongate obliquely to track axis, sometimes apparently occurring in pairs (illustrating two-clawed limbs of animal producing track), anterior ridge then more prominent. [Originally interpreted by DAWSON as traces of large worms or crustaceans or imprints of spines of fish; now considered locomotion tracks of trilobites, walking or striding in straightforward movement across the surface of the sediment; CRIMES (1970b, p. 57) observed transitional forms between *Diplichnites* and *Cruziana*; OSGOOD (1970, p. 352) is skeptical about the trilobite origin and the marine environment of DAWSON's type specimens of ichnogenus; a comparable track from the Devonian of Antarctica is *Beaconichnus gouldi* GEVERS, 1971 (see GEVERS *et al.*, 1971, p. 86, 93).] *L.Cam.*, Can.; *Cam.*, Eu.(Eng.-Swed.-Pol.)-USSR(Sib.)-Greenl.-Asia(Pak.)-Australia; *?Cam.*, Eu.(Nor.); *Ord.*, Eng.; ?Ord., Asia (Jordan); *?Dev.-Carb.*, N.Am.(Can.); *L.Perm.(Dwyka Gr.)*, S.Afr.——FIG. 39,*4a*. *D.* sp., L.Cam., Asia(Pak.); schem., ×1.3 (Seilacher, 1955).——FIG. 39,*4b*. *Diplichnites*, U.Cam., N.Wales; ×? (from Crimes, T. P., 1970, p. 120, in *Trace Fossils* edited by T. P. Crimes & J. C. Harper, Geol. Jour. Spec. Issue 3, Seel House Press, Liverpool).

Diplocraterion TORELL, 1870, p. 13 [**D. parallelum*; SD RICHTER, 1926, p. 213] [=*Polyupsilon* HOWELL, 1957, p. 151 (type, *"Tigillites" habichi* LISSON, 1904, p. 41); for discussion see GOLDRING, 1962, p. 238; *Diplocration* GOLDRING, 1964, p. 137 *(nom. null.)*]. U-shaped burrow with spreite; vertical to bedding plane; limbs of U parallel; both limbs of each successive U-tube confluent with limbs of preceding U-tube (see KNOX, 1973, p. 134); openings of tubes mostly funnel-shaped (but apparently often truncated by erosion); commonly protrusive, but also retrusive forms observed; bottom of burrow semicircular, rarely straight; horizontal cross section on bedding planes dumbbell-shaped; diameter of tubes 5 to 15 mm., distance between limbs 1 to 7 cm. (average, 2-3 cm.), depth of burrows 2 to 15 cm. (max. 35). [Dwelling burrow of suspension feeding animal, probably living in environment of high wave energy; several stages of erosion and sedimentation may be recognized from various levels of tube (e.g., *D. yoyo*; see GOLDRING, 1962, p. 235, and Fig. 16); intermediate forms between *Diplocraterion* and *Rhizocorallium* observed in the Carboniferous of Scotland (CHISHOLM, 1970b, p. 49).] *Cam.*, Eu.(Swed.-Nor.-Pol.-Spain)-N.Am. (USA-Newf.)-Australia; *Cam.*, Pleist. drift, Eu.(N.Ger.); Ord., Eu.(Nor.); *L.Paleoz.*, N.Afr.(Libya); *M.Dev.*, Eu.(Ger.); *Sil.*, USA(Ga.); *U.Dev.*, Eu.(Eng.); *Carb.*, Eu.(Scot.); *Jur.*, Eu.(Eng.-N.France-Pol.)-Greenl.; *Cret.*, N.Am.(USA,Colo.)-S.Am.(Peru); *?Cret.*, Eu.(Ger.).——FIG. 37,*2a*. **D. parallelum*, L. Cam.(Mickwitzia Ss.), Swed.: ×0.7 (Westergård, 1931).——FIG. 37,*2b*. *D. lyelli* TORELL, L.Cam., Swed.; funnel-shaped openings of U-shaped burrow to surface, concave epirelief, ×1.5 (Westergård, 1931).

Diplopodichnus BRADY, 1947, p. 469 [**D. biformis*; OD]. Long, continuous trail, consisting of 2 or 3 parallel grooves, each pair separated by narrow, low ridge; rarely with faint foot impression; somewhat similar to *Gordia* EMMONS [=*Unisulcus* HITCHCOCK]. [Made by arthropods; common in Coconino Sandstone.] *L.Perm.*, USA (Ariz.).

Diplopodomorpha CHIPLONKAR & BADWE, 1970, p. 4 [**D. cretaceca*; OD]. Trail 0.7 to 0.8 cm. wide with clusters of 3 or 4 tubercles separated by smooth axial region 0.35 to 0.4 cm. wide, consecutive clusters spaced 0.15 to 0.2 cm. apart, each cluster of tubercles composed of one large and 2 or 3 subequal smaller impressions. [Probably produced by diplopodous arthropod.] *U. Cret.*, India.——FIG. 37,*3*. **D. cretaceca*, Nimar Ss.; ×0.7 (Chiplonkar & Badwe, 1970). [Description supplied by W. G. HAKES.]

Echinospira GIROTTI, 1970, p. 60 [**E. pauciradiata*; OD]. Similar to *Zoophycos s.l.*; characterized by an "aculeate" edge; unbranched "radioli," 30 to 40 cm. in length; "pinnulae" on only one side of "radioli," disappearing at their end. [GIROTTI followed PLIČKA's description of these supposed imprints of sabellid prostomia, designating *Echinospira* as ichnofossil, although he was in agreement with PLIČKA's interpretation of *Zoophycos* and similar forms as "anatomical parts of polychaetes."] *U.Tert.(Mio.)*, Eu.(C.Italy).

Eugyrichnites AMI, 1905, p. 291 [**E. minutus*; M]. Minute tortuous trail, about 1 mm. wide; with fine annulations (25-30 closely set parallel lines in 1 cm.). [Said to resemble *Gyrichnites* WHITEAVES; never figured, no specimens located in Canadian collections.] *?Sil.*, Can.(N.B.).

Fascifodina OSGOOD, 1970, p. 340 [**F. floweri*; OD]. Vertically bundled shafts; mostly preserved as crescentic or horseshoe-shaped groups of short concave and vermiform markings (epireliefs) surrounding lower part of single shaft; upper portion of original burrow, particularly upper part of master shaft, very probably stripped away by erosion. [Morphology not yet fully understood; first described by FLOWER (1955), but left unnamed and interpreted as the vermicular markings produced by tentacles of orthoconic nautiloid *Orthonybyoceras* grasping sea bottom for feeding and clinging to substratum to resist motion of the water; interpreted by OSGOOD (1970) as feeding burrow.] *U.Ord.(mid.Cincinnat.)*, USA(Ohio).——FIG. 39,*3*. **F. floweri*; block diagram, ×0.19 (after Osgood, 1970).

Fascisichnium KSIĄŻKIEWICZ, 1968, p. 10 (Pol.), p. 16 (Eng.) [**F. extendum*; M]. Large central area surrounded by numerous arrowlike ribs arranged like bundle of scattered rods; ribs straight or curved, tapering to point, not diverging from center of inner field, but lying excentrically outside of it; whole trail 8 to 10 cm. long, up to 5 cm. wide. [Found in flysch deposits.] *L.Tert. (Paleoc.-low.Eoc.)*, Eu.(Pol.).——FIG. 37,*1*. **F. extendum*, Paleoc.-low.Eoc., Carpathians; ×0.8 (Książkiewicz, 1968).

Felixium DE LAUBENFELS, 1955, p. E36 [*pro Rhizocorallium* FELIX, 1913 (*non* ZENKER, 1836)] [**Rhizocorallium glaseli* FELIX, 1913; OD]. Elaborately sculptured, curved cylinder 5×20 cm. *Cret.*, Eu.(Ger.).

Fraena ROUAULT, 1850, p. 729 [**F. Sancti-Hilairei*; SD PÉNEAU, 1946, p. 77]. Rarely used name for simple trails, unilobate as well as particularly bilobate, some smooth, some striated longitudinally or transversely. [ROUAULT combined in "genus" seven "species" which were subsequently placed in *Cruziana*, *Rouaultia* (type species, *Fraena lyelli*), and *Rusophycus*; DE TROMELIN & LEBESCONTE (1876, p. 627), MATTHEW (1891, p. 158), PÉNEAU (1946, p. 77), and other authors recommended restricting name *Fraena* to simple smooth unilobate trails of type of first "species" described by ROUAULT, *F. sanctihilairei*; see also *Palaeotenia guilleri* CRIÉ, 1883.] *Ord.*, Eu.(France).

Fucoides BRONGNIART, 1823, p. 308 [**F. strictus*; SD JAMES, 1894, p. 69]. Formerly used as generic

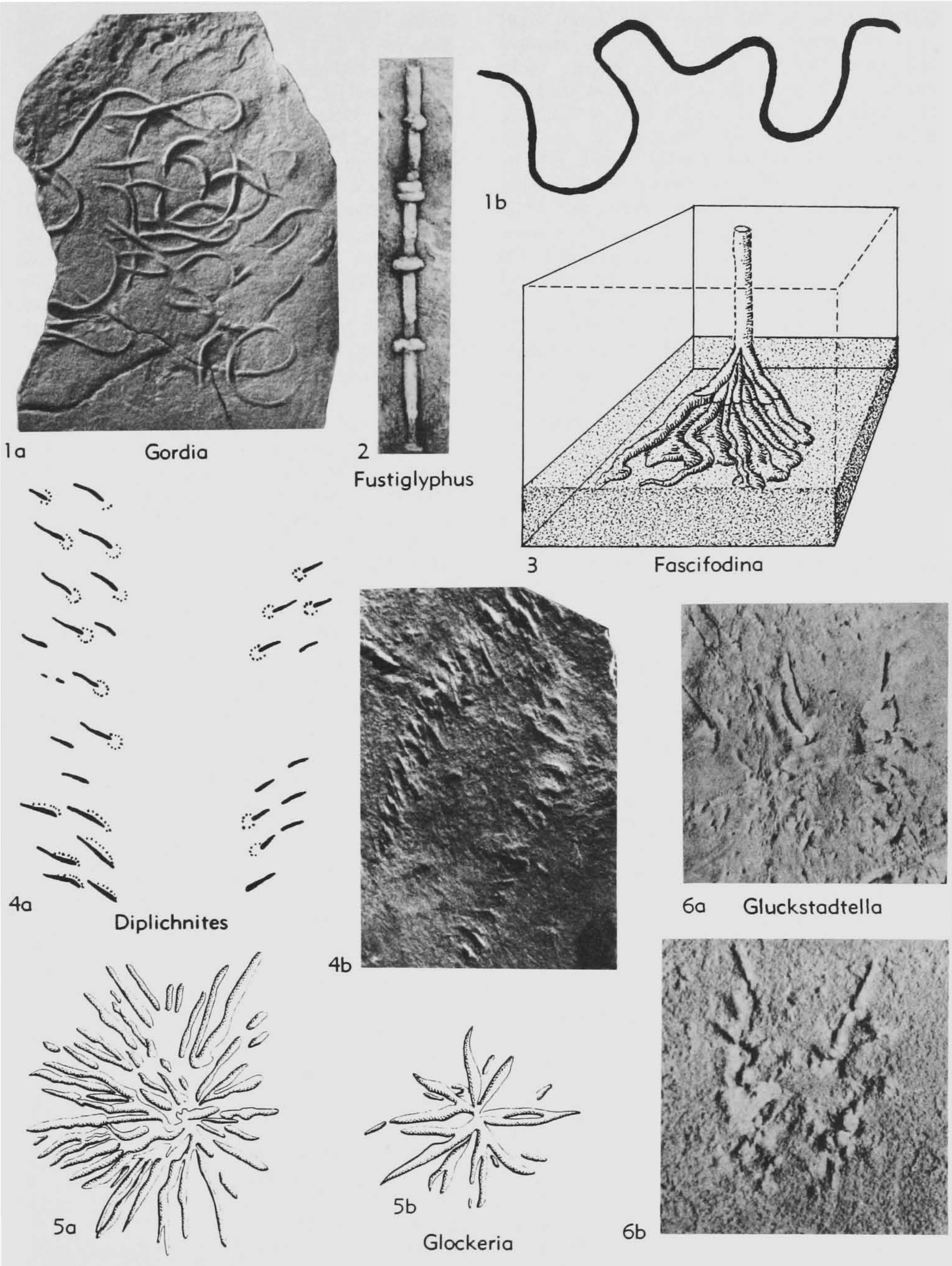

FIG. 39. Trace fossils (p. *W*61-62, 64).

name mostly for regularly branching, plantlike tunnel structures; at present only used informally ("fucoid"), due to too many widely differing "species" descriptions; BRONN's *"Index Palaeontologicus"* (1849) listed 59 "species," JAMES (1894), describing history of "genus," ascertained 85 "species"; by 1825 *Fucoides* had been divided into "subgenera" and by 1828 into *"sectiones."*

JAMES (1892a, p. 76) wrote "that before many years the genus *(Fucoides)* began to overflow and then, like an overloaded wagon, broke down. . . . Among the debris we find tracks of crustaceans, burrows of worms, trails of mollusks, marks made by trailing tentacles of medusae, markings made by the tide or waves, rills by running water, and holes formed by burrowing worms."; *Fucoides graphica* VANUXEM, 1842, common in the lower Upper Devonian of western New York, has been used for determining trends or directions of paleocurrents in that sequence (COLTON, 1967). [See also *Chondrites*.]

Fucusopsis PALIBIN in VASSOEVICH, 1932, p. 51 [**F. angulatus*; M] [=*Trichophycus sulcatum* MILLER & DYER, 1878, p. 4 (for synonymy see OSGOOD, 1970, p. 380); *Fucopsis* GROSSHEIM, 1946, p. 115 *(nom. null.)*; *?Gyrochorda fraeniformis* FARRÉS, 1963, p. 116]. Stretched tubiform burrows (2-10 mm. in diameter), long, straight, sometimes branching, crossing over and interpenetrating; with typical threadlike sculpture; regarded by SEILACHER (1959, p. 1070) as produced by burrowing activity; interpreted by OSGOOD (1970, p. 380) as "tension faulting" in sole of host rock; appearance depending on kind of preservation. [Originally regarded as marine alga or inorganic; now interpreted as burrows of infaunal origin.] [Found in flysch deposits.] *U.Ord.(Cincinnat.)*, USA(Ohio); *Cret.-L.Tert.*, Eu.(Switz.-Spain-Pol.-Italy-?Aus.-USSR); *?Tert.*, S.Am.(Venez.).——FIG. 37,5. **F. angulatus*, U. Cret.(Senon.), USSR; ×0.3 (Gekker, in Häntzschel, 1962).

Fustiglyphus VYALOV, 1971, p. 90 [**F. annulatus* (=*Rhabdoglyphus grossheimi* BOUČEK & ELIÁŠ, 1962, p. 146 *(partim)*, *non* VASSOEVICH, 1951, p. 61); M]. Straight strings or narrow cylinders of varying length encircled by ringlike "knots" or well-defined swellings at regular or varying intervals; rosary-like. [Difficult to interpret as trace fossil; according to OSGOOD, 1970, p. 369-371), a variety of repichnia or fodinichnia; believed by BOUČEK & ELIÁŠ (1962) to be made by amphipods or gastropods or even a holothuroid similar to *Leptosynapta*; for detailed discussion of *Fustiglyphus* see *Rhabdoglyphus* in OSGOOD (1970, p. 369-371) and (in Czech language) BOUČEK & ELIÁŠ (1962). See also *Rhabdoglyphus* BOUČEK & ELIÁŠ, p. *W*99, for a discussion of the nomenclatural history of *Fustiglyphus*.] *U.Ord.(Cincinnat.)*, USA(Ohio); *Tert.(Eoc.)*, Eu.(Pol.); *Tert. (Paleog., Magura Gr.)*, Eu.(Czech., Carpathians).——FIG. 39,2. **F. annulatus*, Magura Gr., Carpathians; ×0.56 (Bouček & Eliáš, 1962). [Description supplied by CURT TEICHERT and W. G. HAKES.]

Glockeria KSIĄŻKIEWICZ, 1968, p. 9 (Pol.), p. 15 (Eng.) [**G. glockeri*; OD]. Starlike trace fossil with numerous long rays, straight, pointed, commonly dichotomous and radiating from small central area; small ones between main ribs; diameter 6 to 13 cm.; feeding burrow. [Found in flysch deposits.] *L.Cret.*, Japan-Eu.(Pol.); *U. Cret.(Senon.)-L.Tert.(Paleoc.)*, Eu.(Pol.-Spain).——FIG. 39,5a. **G. glockeri*, L.Cret.(Berrias., Cieszyn Ls., Pol.(Goleszów); ×0.3 (Książkiewicz, M., 1970, p. 311, in: *Trace Fossils* edited by T. P. Crimes & J. C. Harper, Geol. Jour. Spec. Issue 3, Seel House Press, Liverpool).——FIG. 39,5b. *G. sparsicostata* KSIĄŻKIEWICZ, U.Cret.(Senon., Inoceramian Beds), Pol.(Zawoja); ×0.3 (from Książkiewicz, M., 1970, p. 311, in: *Trace Fossils* edited by T. P. Crimes & J. C. Harper, Geol. Jour. Spec. Issue 3, Seel House Press, Liverpool).

Gluckstadtella SAVAGE, 1971, p. 231 [**G. cooperi*; OD]. "Arthropod resting impression," 8 to 22 mm. long, 5 to 14 mm. wide; showing 6 pairs of appendage marks; anterior 2 pairs longest, remaining 4 pairs shorter and forming distinct group directed obliquely backwards. [Perhaps producer of trails described by SAVAGE (1971, p. 225) as *Diplichnites* sp.; from freshwater periglacial environment.] *L.Perm.(Dwyka Gr.)*, S. Afr.(N.Natal).——FIG. 39,6. **G. cooperi; 6a*, ×1.4; *6b*, ×1.7 (Savage, 1971).

Goniadichnites MATTHEW, 1891, p. 160 [**G. trichiformis*; M]. Small sinuous smooth trails, no larger than slender thread, commonly branching, apparently forking dichotomously; resembling trails of Recent *Goniada* as figured by NATHORST (1881a). *Cam.*, Can.

Gordia EMMONS, 1844, p. 24 [*non* MELICHAR, 1903] [**G. marina*; M] [=*Palaeochorda* M'COY in SEDGWICK, 1848, p. 224 (type, *P. minor* M'COY; SD HÄNTZSCHEL, herein) (*non P. marina* (EMMONS) *sensu* GEINITZ, 1867, p. 14; see *Dictyodora* WEISS, 1884); *Palaeochordia* EICHWALD, 1860, p. 53 *(nom. null.)*; *Herpystozeum* HITCHCOCK, 1848, p. 245 (type, *H. marshii*; SD LULL, 1953, p. 50); *Helminthoidichnites* FITCH, 1850, p. 868 (type, *H. tenuis*; SD HÄNTZSCHEL, 1965, p. 45); *Unisulcus* HITCHCOCK, 1858, p. 160 (*nom. nov. pro Herpystezoum* HITCHCOCK, 1848); *Gordiopsis* HEER, 1865, p. 439 (type, *G. valdensis*; M)]. Long, slender, smooth wormlike trails of uniform thickness throughout; mostly bent but not meandering; resembling hair-worm *Gordius*. *?Precam.*, Can.; *Paleoz.-Cenoz.*, Eu.-N. Am.——FIG. 39,1a,b. *G.* sp.; *1a*, M.Dev.(Eifel.), Ger.(Holzmülheim, Eifel), ×0.5 (Fischer & Paulus, 1969); *1b*, schem. drawing, ×0.5 (Häntzschel, 1962).

Granularia POMEL, 1849, p. 333 [**Algacites granulatus* VON SCHLOTHEIM, 1822, p. 45; "OD"] [*non Granularia* POLETAEVA, ?1936] [=*Alcyonidiopsis* MASSALONGO, 1856, p. 48 (no type species designated)]. Elongated fillings of burrows; long, diameter up to about 15 mm.; twig-shaped, with rather regular branching; walls originally lined with clay particles; burrows observed by SEILACHER (1962, p. 228) in flysch deposits of

Spain which are up to several meters thick. [BATHER (1911, p. 555) wrote erroneously that "*Granularia* was established by POMEL (1847) with *G. repanda* as genotype"; POMEL described six "species" and he founded *Granularia* on *Algacites granulatus,* the same species on which BRONGNIART (1849) founded his "genus" *Phymatoderma*; for discussion of somewhat confused synonymy and nomenclature see also ROTHPLETZ (1896, p. 889).] [Found in flysch deposits.] *Sil.,* Australia; *M.Jur.,* Eng.; *Cret.-L.Tert.,* Eu. ——FIG. 40,*3a*. *G.* sp. *cf. G. arcuata* SCHIMPER, L.Tert.Alberese, Italy; ×1.25 (Reis, 1909). ——FIG. 40,*3b*. *G. lumbricoides* (HEER), L.Tert. (Alberese), Italy; ×1.25 (Reis, 1909).

Gyrichnites WHITEAVES, 1883, p. 111 [**G. gaspensis*; M]. Trails of large size; undulating, slender, rounded furrows marked transversely by nearly straight, subparallel and subequidistant grooves. [?Annelid trail; name given as "provisional and local," apparently never used since 1883.] *?U. Cam.,* USA(N.Y.); *Dev.,* N.Am.(Can.).——FIG. 40,*4*. **G. gaspensis,* L.Dev., Can.; ×0.3 (Whiteaves, 1883).

Gyrochorte HEER, 1865, p. 142 [**G. comosa*; SD HÄNTZSCHEL, 1962, p. *W*196] [=*Gyrochorda* SCHIMPER in SCHIMPER & SCHENK, 1879, p. 51 *(nom. null.)*; *?Equihenia* MEUNIER, 1886, p. 567 (type, *E. rugosa*)]. Trace up to 5 (rarely 10) mm. wide; in epirelief preserved as plaited ridges with biserially arranged, obliquely aligned pads of sediment (*"Zopf-fährten"* of German literature); in hyporelief preserved as smooth biserial grooves separated by median ridge; course strongly winding and direction changing sharply; trace may intersect itself or other traces; ridges and their grooves may be separated by vertical distance of 1 cm.; usually preserved in clastic sediments. [Crawling trails, similar to amphipod trails (e.g., *Corophium*); doubtless made by tunnelling through sediment; producer unknown, ?worms or crustaceans; for model of this trail see SEILACHER (1955, p. 380, fig. 2b); for detailed discussion of mechanism of formation of this trail see HALLAM (1970, p. 192-195).[1] *G. bisulcata* GEINITZ, 1883-95 (Eoc., N.Ger.) does not belong to *Gyrochorte, s.s.,* but is similar to *Dreginozoum* VAN DER MARCK; *"Gyrochorte" carbonaria* SEILACHER, 1954 (U.Carb., Ger.) is no true *Gyrochorte*; for discussion see SEILACHER (1963, p. 83). MARTINSSON (1965, p. 219) has described the relationship of *Gyrochorte* to *Halopoa* TORELL.] *Sil.,* USA(Ga.), *?Carb., Jur.-Tert.,* Eu.-Greenl.; *?Carb., ?Jur.-Tert.,* USA-S.Am.-Antarct. ——FIG. 40,*1*. **G. comosa,* M.Jur., Switz.; ×1 (Heer, 1865).

[1] HALLAM's proposed mode of origin for *Gyrochorte* as a collapsed tunnel has been recently rejected by HEINBERG (1973), who described vertical spreite-like structures connecting the epichnial ridges with the hypichnial grooves and felt that *Gyrochorte* was produced by a polychaete-like worm moving obliquely through the sediment. [W. G. HAKES.]

Gyrolithes DE SAPORTA, 1884, p. 27 [**G. davreuxi*; SD HÄNTZSCHEL, 1962, p. *W*200] [="Gyrolithen" DEBEY, 1849, p. 10 (*partim*; not used as "genus"); *Siphodendron* DE SAPORTA, 1884, p. 38 (type, *S. girardoti*); *Syringodendron* FUCHS, 1895, p. 404 (?erroneously *pro Siphodendron*); *Daemonhelix krameri* VON AMMON, 1900, p. 63; *Xenohelix* MANSFIELD, 1927, p. 6 (type, *X. marylandica*)]. Dextrally or sinistrally coiled burrows up to several cm. in diameter, sometimes with rounded or elongate processes which may be branching near upper end; diameter of whorls mostly uniform; vertically oriented; up to several decimeters high. Thin mantle of burrows may be formed by network of small *Chondrites; "Xenohelix"* with *Ophiomorpha*-like ornament are also known from Tertiary of Germany (KILPPER, 1962) and Borneo (KEIJ, 1965). [Probably made by decapod crustaceans (with exception of the specimens from L. Cam., Nor.); for discussion see FUCHS, 1894b; UMBGROVE, 1925; HÄNTZSCHEL, 1934; KILPPER, 1962; TOOTS, 1963.] *?L.Cam.,* Eu.(Nor.); *Jur.-Tert.,* Eu.-USA-S.Am. (Venez.)-Borneo.——FIG. 41,*4a*. *G. marylandicus* (MANSFIELD), ?Mio., Md.; ×? (Mansfield, 1927). ——FIG. 41,*4b*. *G. saxonicus* (HÄNTZSCHEL), U. Cret.(Turon.), Ger.; ×0.4 (Häntzschel, 1934).

Gyrophyllites GLOCKER, 1841, p. 322 [**G. kwassizensis*; M] [=*Sargassites rehsteineri* FISCHER-OOSTER, 1858, p. 34; *?Discophorites* HEER, 1877, p. 145 (no type species designated)]. Vertical or oblique shaft from which 5 to 20 (average 10) club- or leaf-shaped feeding tunnels radiate at different levels in whorled or helical arrangement; rosettes up to several cm. in diameter, becoming larger upward; tunnels may show spreiten structure; shape of whole structure conical. [Definite trace fossil, producer unknown; for description of several "species" and interpretation as algae see LORENZ VON LIBURNAU (1900, p. 568); VONDERBANK (1970, p. 104) reconstructed complete sequence of rosettes of various sizes connected by the central shaft and ending in funnel-shaped aperture above highest rosette (Tert., Spitz.).] [Found in flysch deposits.] *Dev., Jur.-Tert.,* Eu.; *?Jur.-Tert.,* N.Z. ——FIG. 40,*2*. *G.* sp., U.Cret., Aus.; *2a,* ×1 (Fuchs, 1895); *2b,* schem. (Seilacher, 1957).

Haentzschelinia VYALOV, 1964, p. 113 [**Spongia ottoi* GEINITZ, 1849, p. 113; OD]. Starlike trail with elevated center, about 5 cm. in diameter; generally 6 to 10 radiating grooves, rather irregularly and often only unilaterally developed. [Originally described as sponge similar to *Peronidella furcata* (GOLDFUSS); obviously a feeding burrow made by crustaceans or worms.] *Trias.,* Asia(USSR, NE.Sib.); *U.Cret.(Cenoman.),* Eu. (Ger., Saxony).—FIG. 42,*3*. **H. ottoi* (GEINITZ), U. Cret., Ger.; *3a,* ×12.5; *3b,* ×0.33 (Häntzschel, 1930).

Halimedides LORENZ VON LIBURNAU, 1902, p. 710

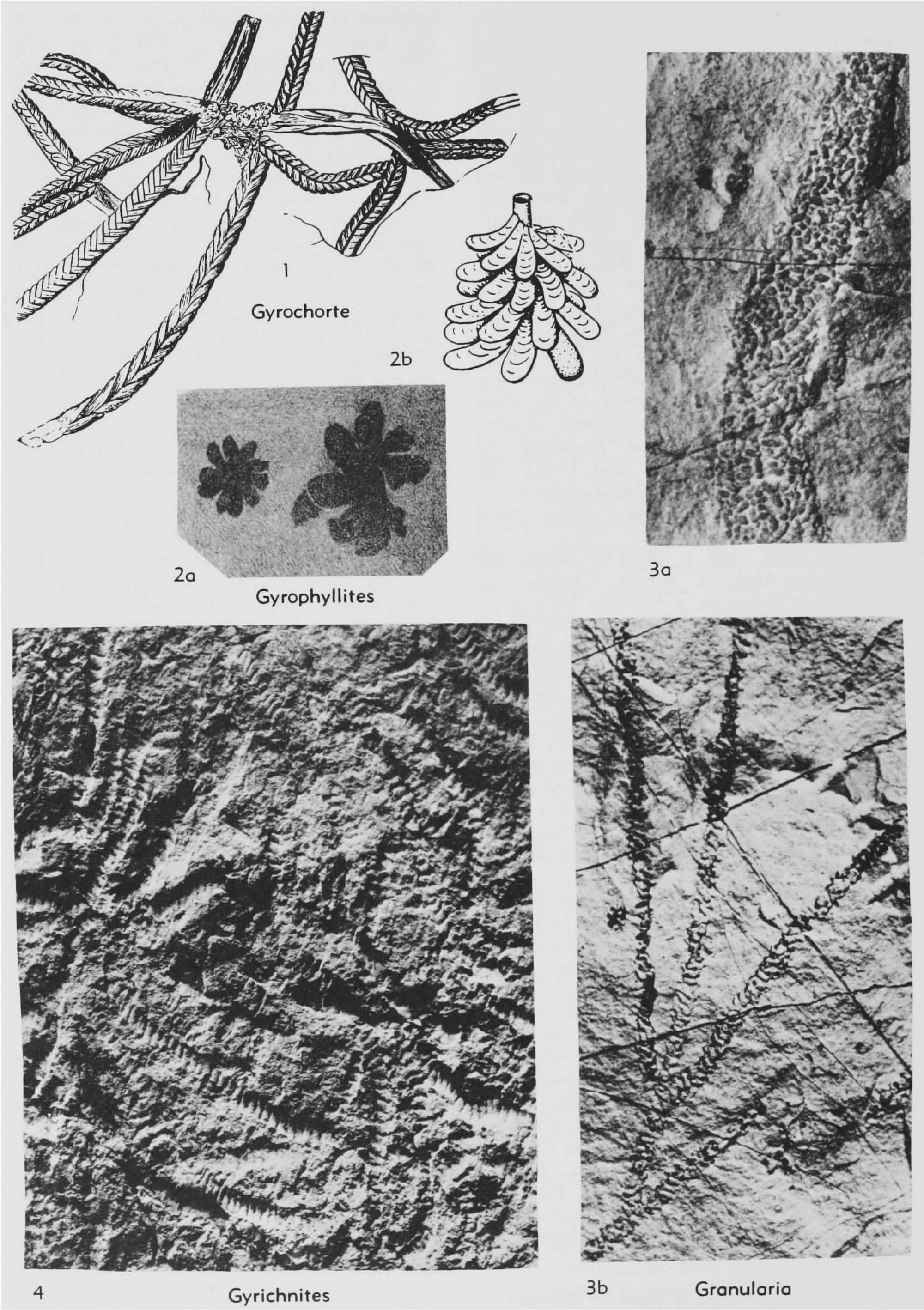

Fig. 40. Trace fossils (p. *W*64-65).

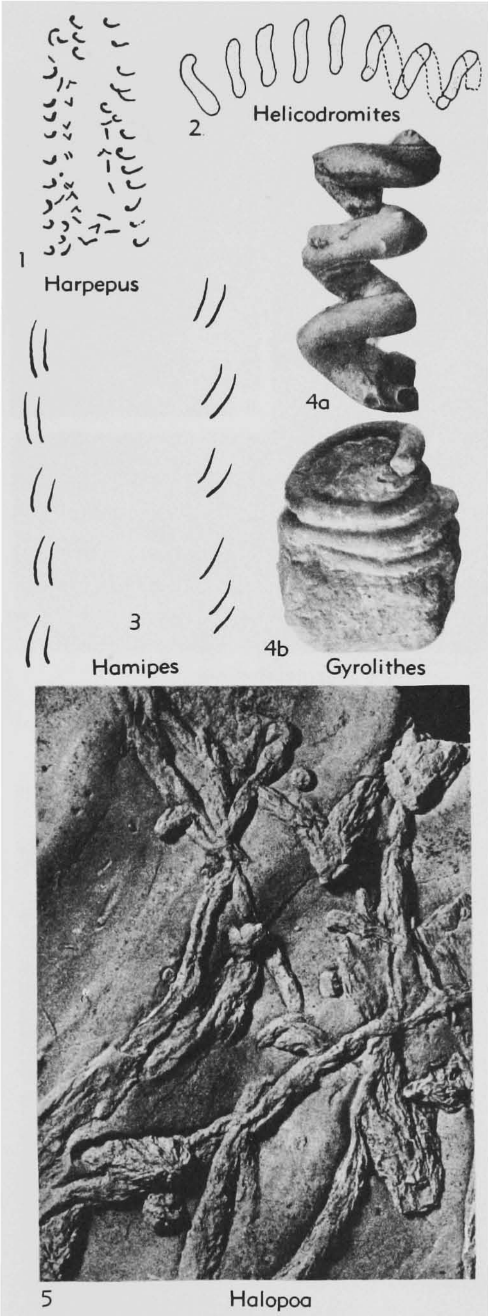

FIG. 41. Trace fossils (p. *W*65, 67).

[**Halimeda fuggeri* LORENZ VON LIBURNAU, 1897, p. 177; M]. Burrow with bilaterally ("pinnate') arranged, kidney-shaped extensions. [Morphologically very similar to Recent alga *Halimeda* LAMOUROUX; *Halimedides* proposed only for *Halimeda fuggeri; Halimeda saportae* FUCHS (1894c, p. 204) identical to problematical body fossil *Halysium* SWIDZINSKI, 1934.] [Found in flysch deposits.] *Cret.*, Eu.(Aus.).——FIG. 42,*1*. **H. fuggeri*; ×0.3 (Lorenz von Liburnau, 1897).

Halopoa TORELL, 1870, p. 7 [**H. imbricata*; SD HÄNTZSCHEL, herein (not ANDREWS, 1970, p. 99, which was a proposal rather than a valid designation)] [=*Scotolithus* LINNARSSON, 1871, p. 18 (type, *S. mirabilis*); for discussion see MARTINSSON, 1965, p. 219]. Long, slightly curved trails dug along surface; surface of trail with typical imbricate or lycopodiaceous structure; diameter of burrows about 0.5 to 1 cm. [Probable producers epipsammonts; for the first time since TORELL's description in 1870, figured and discussed by MARTINSSON (1965, p. 219), who grouped "the halopoans" with *Zopffährten* (=*Gyrochorte* HEER) although they show no typical plaitlike structures.] *Cam.*, Eu.(Swed.).——FIG. 41,*5*. **H. imbricata*; L.Cam., Lugnås, Västergötland; ×0.5 (Martinsson, 1965).

Hamipes HITCHCOCK, 1858, p. 150 [**H. didactylus*; M]. Two paired, regular, parallel rows of equidistant impressions of steps, curved inward, somewhat hook-shaped; width of trackway 40 mm; foot impressions nearly parallel, may be slightly divergent. [Arthropod trail.] *Trias.*, USA(Mass.).——FIG. 41,*3*. **H. didactylus*; ×0.7 (Hitchcock, 1858).

Haplotichnus MILLER, 1889, p. 578 [**H. indianensis*; OD]. Simple trail, straight or curved, sometimes bent sharply. [Supposed to be made by larva of ?palaeodictyopterid.] *U.Miss.(Kaskaskia Gr.)*, USA(Ind.)

Harpepus HITCHCOCK, 1865, p. 16 [**H. capillaris*; M]. One or 2 rows of tracks showing slightly curved feet impressions, somewhat sickle-like, one end raised, blunt. *Trias.*, USA(Mass.).——FIG. 41,*1*. **H. capillaris*; ×0.7 (Lull, 1953).

Helicodromites BERGER, 1957, p. 540 [**H. mobilis*; M]. Smooth screw-shaped burrows, horizontal; diameter of tunnels about 2 mm.; interval between spiral turns about 5 mm. [For discussion of similar Recent traces from marine and terrestrial sediments, see A. H. MÜLLER (1971a).] *Oligo.(Rupel.)*, Eu.(S.Ger.).——FIG. 41,*2*. **H. mobilis*; ×0.7 (Berger, 1957).

Helicolithus HÄNTZSCHEL, 1962, p. *W*200 [**H. Sampelayoi* AZPEITIA MOROS, 1933, p. 48; OD] [=*Helicolithus* AZPEITIA MOROS, 1933, p. 48, *nom. nud.*, established without designation of type species]. Small, meandering, screw-shaped burrows; diameter of tunnels 1 mm.; diameter of spiral up to about 3 mm.; somewhat similar to *Helicodromites* but much smaller; *Helicolithus fabregae* AZPEITIA MOROS resembling *Belorhaphe* FUCHS, but with sharp turns. [Grazing trails, first

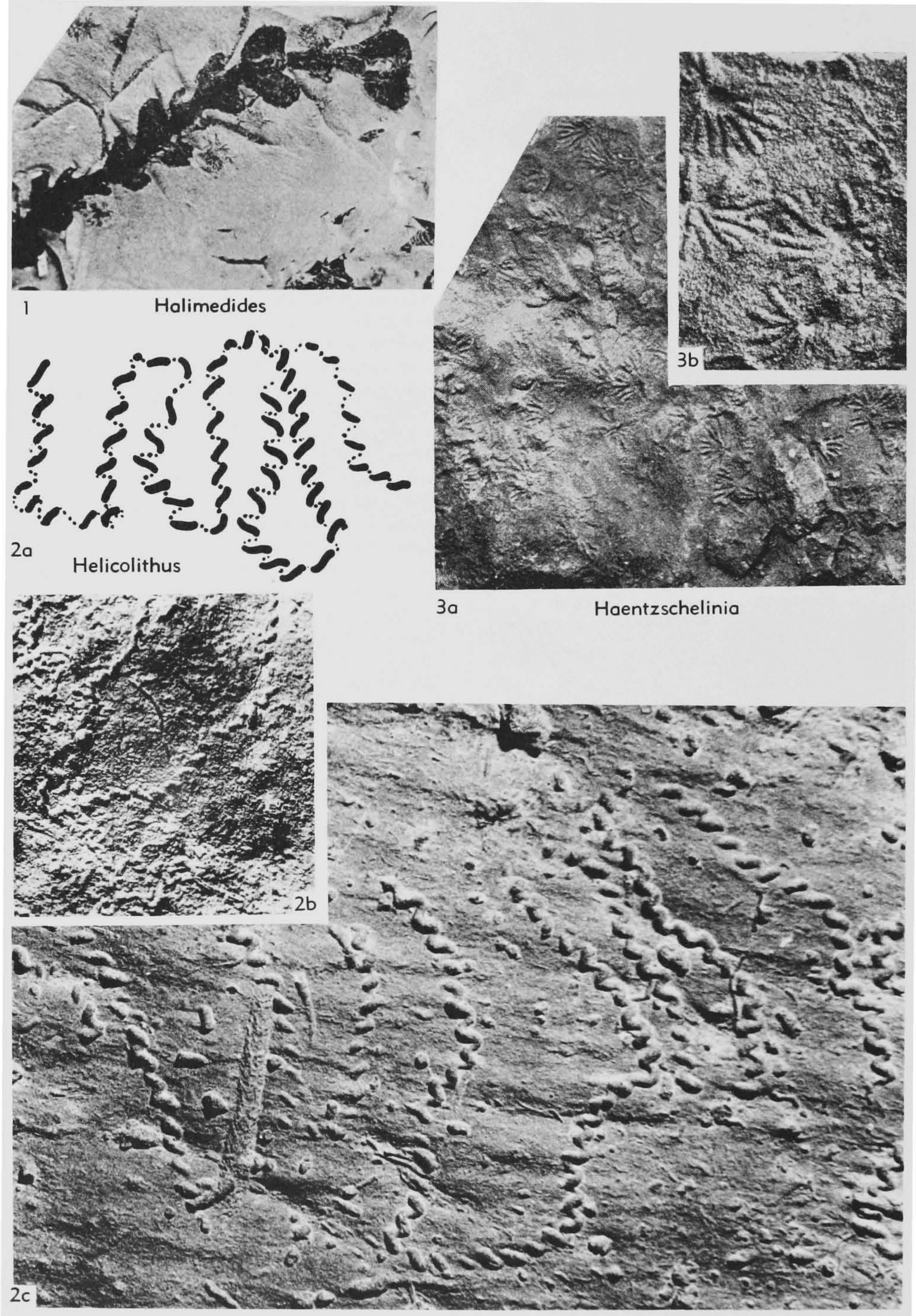

FIG. 42. Trace fossils (p. *W*65, 67, 70).

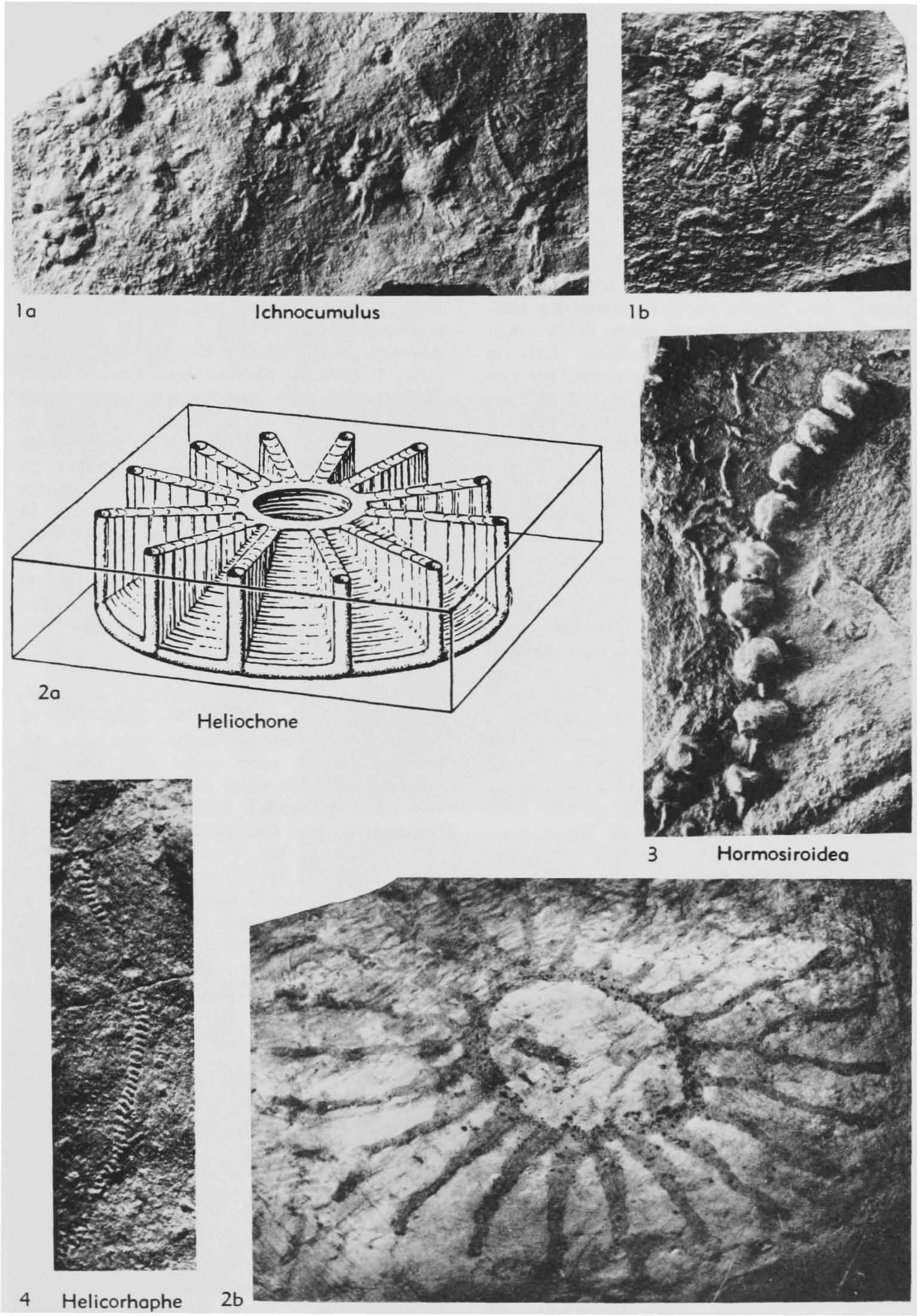

FIG. 43. Trace fossils (p. *W*70, 74).

interpreted as algae.] [Found in flysch deposits.] *?L.Cam.*, Eu.(Nor.); *Cret.-L.Tert.*, Eu.(Aus.-Pol.-Spain-Italy).——FIG. 42,*2*. **H. sampelayoi* AZPEITIA MOROS; *2a*, ?Cret., Italy; schem. drawing, ×1.5 (Seilacher, 1955); *2b*, U.Cret., Spain; ×1 (Azpeitia Moros, 1933); *2c*, U.Eoc. (Magura Ss.), Carpathians; ×1.3 (Książkiewicz, M., 1970, p. 297, in: *Trace fossils*, ed. by T. P. Crimes & J. C. Harper, Geol. Jour. Spec. Issue 3, Seel House Press, Liverpool).

Helicorhaphe KSIĄŻKIEWICZ, 1970, p. 286 [**H. tortilis*; OD] [=*Helicoraphe* KSIĄŻKIEWICZ, 1961, p. 885, 889; published as "n.f." without species name]. Very narrow sole trails resembling horizontal spring with narrow turns (15/1 cm.); differing from similar *Helicolithus* AZPEITIA MOROS, 1933, by nearly straight course, not meandering and more tightly twisted. [For discussion of similar Recent traces see A. H. MÜLLER (1971a).] [Found in flysch deposits.] *Tert. (low.Eoc.)*, Eu.(Pol.).——FIG. 43,*4*. *H.* sp., Pol.; ×1.5 (Książkiewicz, 1961).

Heliochone SEILACHER & HEMLEBEN, 1966, p. 46 [**H. hunsrueckiana*; M]. Large, somewhat complex system of burrows consisting of circular tunnel with numerous (max., 22) vertical shafts proceeding from it at equal intervals; shafts connect tunnel with surface of sediment; whole starlike system originated by congruent enlargement of ring-shaped tunnel in outward and downward direction; diameter of burrow up to 50 cm.; probably feeding burrow. *L.Dev. (Hunsrück shale)*, Eu.(Ger.).——FIG. 43,*2*. **H. hunsrueckiana; 2a*, schem. drawing; *2b*, ×0.4 (Seilacher & Hemleben, 1966).

Helminthoida SCHAFHÄUTL, 1851, p. 142 [**H. labyrinthica* HEER, 1865, p. 246; SD HÄNTZSCHEL, 1962, p. *W*200] [=*Elminthoida* SACCO, 1886, p. 940; *Helminthoidea* MAILLARD, 1887, p. 7 (and other authors); *Helminthoides* FUCHS, 1895, p. 385; *Helmintoidea* VINASSA DE REGNY, 1904, p. 318 (all *nom null.*)]. Meandering tunnel trails; meanders numerous, very regular, parallel and closely spaced, but may be irregular, not always parallel, and not closely spaced; about 1 to 3 mm. wide, max. width of meanders about 1 cm., and length 10 cm.; regular meanders (particularly *H. crassa*) are type of the "guided meanders" (RICHTER, 1924, p. 153); species of this "genus" exhibit much variability, thus KSIĄŻKIEWICZ (1970, p. 296) introduced two "groups" and some "formae" (e.g., *H. labyrinthica forma lata*). [Former interpretations: plants (algae), worms, feeding traces of gastropods, strings of spawn (RECH-FROLLO, 1962); now regarded as internal grazing trails of wormlike animals. For behavioral analysis, see RICHTER (1928) and SEILACHER (1967a,c); meanders are probably effected by stimuli (homostrophy, thigmotaxis, phobotaxis); SEILACHER (1967c, p. 76) described areas of disturbance created by churning of sediment along sides of tunnels.] [Found in flysch deposits.] *Cert.-Tert.*, Eu.-N.Am.(Alaska)-S.Am.(Chile-Venez.-Trinidad)-Asia (Japan)-?N.Z.——FIG. 44,*1a,b*. *H.* sp.; *1a*, schem. drawing; *1b*, Tert., Toscana, Italy; ×0.75 (Seilacher, 1967a,c).——FIG. 44,*1c*. **H. labyrinthica*, U. Cret., Aus.; ×1 (Häntzschel, 1955). [See also Fig. 55,*1b,c*.]

Helminthopsis HEER, 1877, p. 116 [*non* GROUVELLE, 1906] [**H. magna*; SD ULRICH, 1904, p. 144] [=*Elminthopsis* SACCO, 1886, p. 939; *Helmintopsis* VINASSA DE REGNY, 1904, p. 319 *(nom. null.)*; *Magarikune* MINATO & SUYAMA, 1949, p. 277 (type, *M. akkesiensis*); *?Serpentinichnus* MAYER, 1956, p. 8 (type, *S. bruchsaliense*); *Tosahelminthes* KATTO, 1960, p. 333 (type, *T. curvata*); *Helmenthiopsis* CHAMBERLAIN, 1971a, p. 216 *(nom. null.)*]. Simple meandering smooth trails, but not as strictly developed as *Helminthoida s.s.* (RICHTER, 1928); in part with marginal ridges. [*Helminthopsis involuta* DE STEFANI, 1895, and *H. ?concentrica* AZPEITIA MOROS, 1933, p. 46, are to be placed in *Spirorhaphe* FUCHS; *H. sinuosa* AZPEITIA MOROS, 1933, p. 45, in *Cosmorhaphe* FUCHS; *H. tenuis* KSIĄŻKIEWICZ, 1968, p. 7, should be ascribed to the "genus" *Gordia* EMMONS.] *Ord.-Tert.*, Eu.-Asia-N.Am.-Antarct.-S.Am.(Venez.).——FIG. 44,*2*. *H.* sp., U.Cret.; *2a*, Alaska, ×1 (Ulrich, 1904); *2b*, Aus., ×0.75 (Abel, 1935).

Hexapodichnus HITCHCOCK, 1858, p. 158 [**H. magnus*; SD LULL, 1953, p. 45]. Triple rows of tracks on either side of median line; inner impressions parallel, outer tracks also parallel or diverging outward; width 15 to 20 mm. [Probably made by insects.] *Trias.*, USA(Mass.).

Himanthalites VON FISCHER-OOSTER, 1858, p. 54 [**H. taeniatus*; M] [=*?Chondrites taeniatus* KURR, 1845, p. 16; *?Taeniophycus* SCHIMPER, 1869, p. 190 (type, *T. liasicus*)]. Probably only a large *Chondrites*; specimens from Switz. with fewer ramifications. *?Jur.*, Ger.; *Cret.-Tert.*, Eu. (Switz.-Italy), *Tert.(Mio.)*, N.Z.

Histioderma KINAHAN, 1858, p. 70 [**H. hibernicum*; M]. Curved tubes, upper extremities trumpet-shaped, lower turned up at right angle to bedding plane; upper portion of tubes marked by several ridges crossing each other at irregular intervals. [Dwelling burrow.] *Cam.*, Ire.——FIG. 45,*2*. **H. hibernica; 2a,b, ca.* ×0.7 (Hallissy, 1939).

Hormosiroidea SCHAFFER, 1928, p. 214 [**H. florentina*; OD]. Hemispherical or spherical bodies arranged on thin strings like pearls; diameter of hemispheres 0.5 to 1 cm., of string 1 to 2 mm.; surface of some specimens coarsely granulose. [SCHAFFER regarded *Hormosiroidea* (1928) as alga similar to Recent *Hormosira*, explaining the swellings as spore cases; interpreted by SEILACHER (1959, p. 1068) as a rosary-like trail of unknown origin. It is doubtful whether SCHAFFER

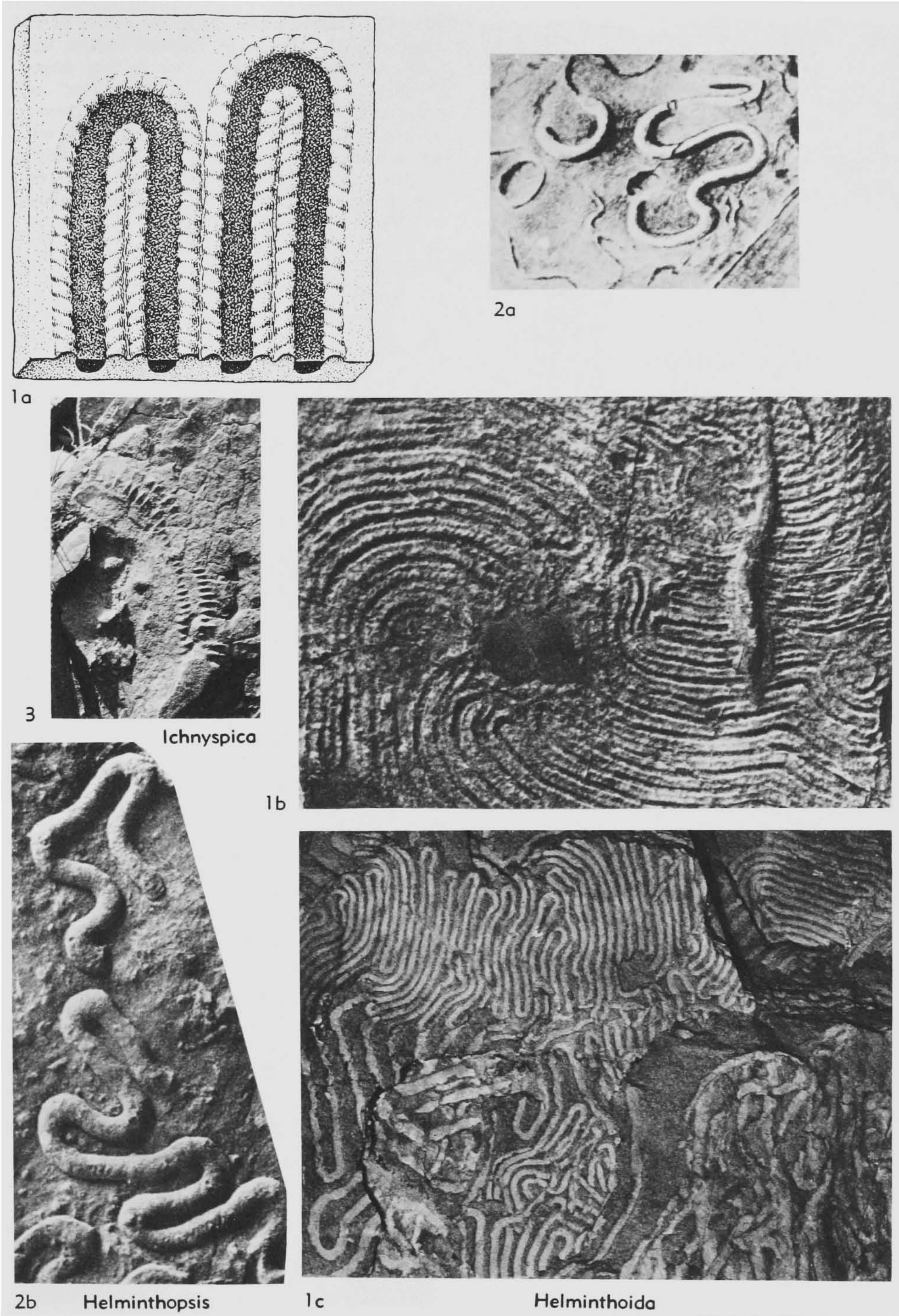

FIG. 44. Trace fossils (p. W70, 74).

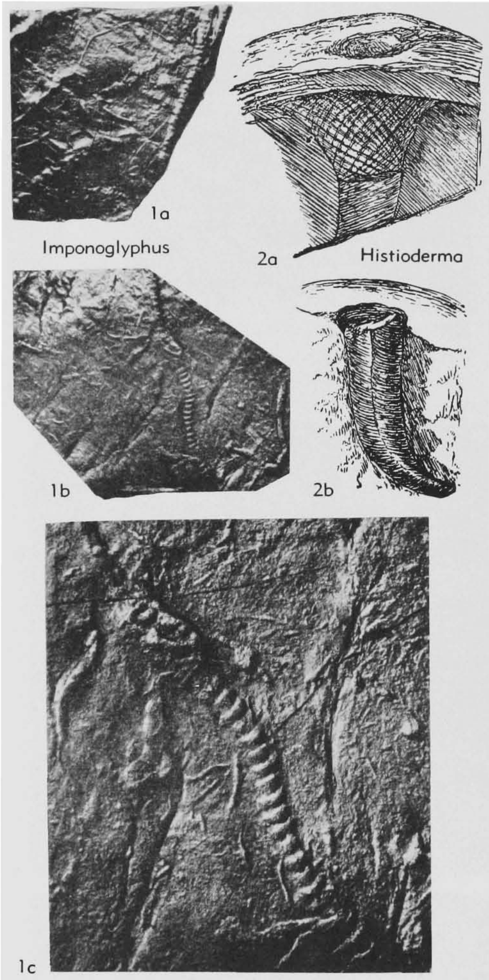

FIG. 45. Trace fossils (p. W70, 74).

(1928) regarded *Hormosira moniliformis* HEER, 1877, p. 161 (flysch, Switz.), as belonging to *Hormosiroidea*; for *Hormosira* see *Halysium* SWIDZINSKI (probably a body fossil). For discussion of possible synonymy of *Hormosiroidea* with *Fustiglyphus* BOUČEK & ELIÁŠ, see OSGOOD, 1970, p. 369, who placed *Hormosiroidea* in repichnia.[1]] [Found in flysch deposits.] *Cret.-L.Tert.,* Eu.(Aus.-Switz.-Spain-Italy).——FIG. 43, *3*. **H. florentina,* U.Cret., Italy; ×0.7 (Häntzschel, 1962, courtesy Naturhist. Mus. Wien).

Hydrancylus VON FISCHER-OOSTER, 1858, p. 39 [**Muensteria geniculata* VON STERNBERG, 1833, p. 32; OD] [=*Hydrancilus* NATHORST, 1881, p. 83 *(nom. null)*]. Groups of rounded leaflike impressions arranged irregularly or in lyre shape. [Feeding burrow, proposed as "subgenus" of *Muensteria* VON STERNBERG, originally interpreted as plant; first interpretation as trace fossil was by NATHORST, 1881a, p. 83.] [Found in flysch deposits.] *Cret.-L.Tert.,* Eu.——FIG. 46,*1*. *H. oosteri* VON FISCHER-OOSTER, ?U.Cret., Switz.; ×1.5 (von Fischer-Ooster, 1858).

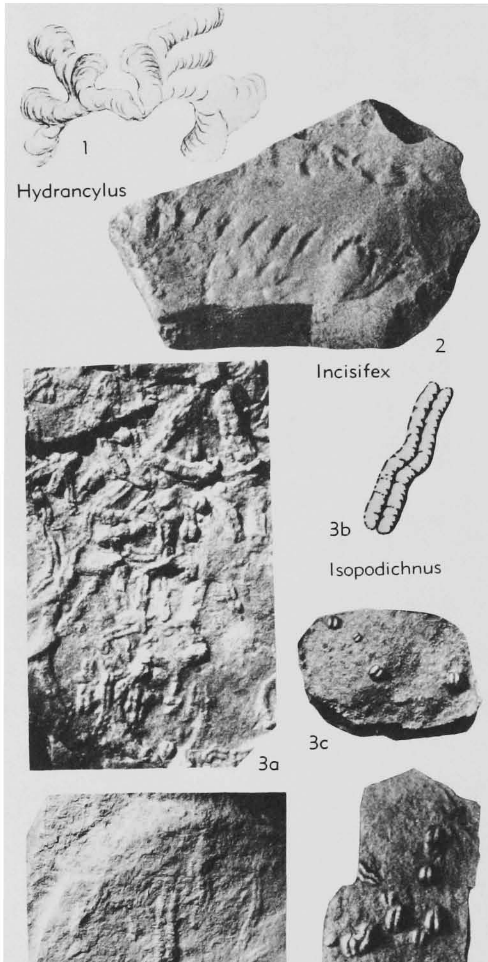

FIG. 46. Trace fossils (p. W72, 74-75).

[1] OSGOOD (1970) compared his specimens with those figured by BOUČEK & ELIÁŠ (1962); see both *Fustiglyphus* VYALOV, 1971, p. W64 and *Rhabdoglyphus* BOUČEK & ELIÁŠ, 1962, p. W99, for clarification. [W. G. HAKES.]

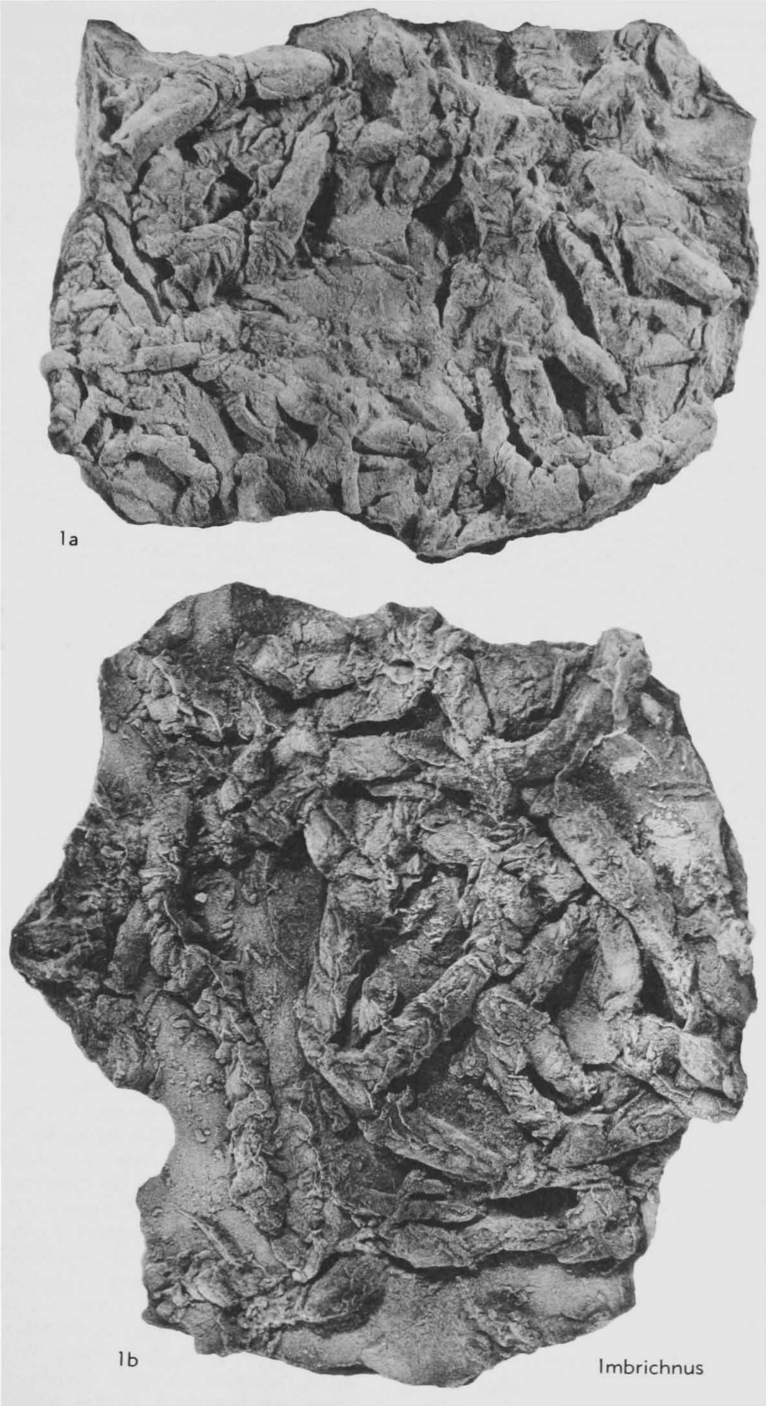

FIG. 46A. Trace fossils (p. *W*74).

Ichnites Hitchcock, 1837, p. 175 [=*Ichnites* Vinassa de Regny, 1904, p. 320]. Name introduced as general term for all footmarks (i.e., subgroups Tetrapodichnites, Sauroidichnites, Ornithichnites); sometimes also used as generic designation with species name for several tracks and trails of invertebrates and vertebrates (e.g., *Ichnites lithographicus* Oppel, 1862, a xiphosuran track from the Upper Jurassic Solnhofen Limestone from Bavaria, type species of *Kouphichnium* Nopcsa).

Ichnocumulus Seilacher, 1956, p. 154 [**I. radiatus*; OD]. Small pustule-shaped bodies possessing straight, radiate projections. [Resting traces made by unknown animals hiding temporarily in sediment.] *L.Jur.-M.Jur.*, Eu.(S.Ger.).——Fig. 43,*1*. **I. radiatus,* L.Lias(Angulaten-Schichten; *1a,* holotype, ×1; *1b,* another specimen with especially thin projections, ×1 (Seilacher, 1956b).

Ichnyspica Linck, 1949, p. 36 [**I. pectinata*; OD] [=*Ichnispica* Lessertisseur, 1955, p. 35 *(nom. null.)*]. Double track, each composed of numerous "teeth" as in a comb; teeth straight and ending in very sharp points; rows curved, parallel and equidistant. [Type of "ear-shaped" trails (e.g., *Ichnia spicea* Richter (1941, p. 229); according to Linck (1956, p. 50), *Ichnyspica* is sometimes difficult to distinguish from comblike drag marks of *Equisetites*.] *U.Trias.(M.Keuper),* Eu.(S.Ger.).——Fig. 44,*3*. **I. pectinata*; ×0.3 (Linck, 1949b).

Ichthyoidichnites Ami, 1903, p. 330 [**I. acadiensis*; M] [*?partim = Protichnites carbonarius* Dawson, 1873, p. 16]. Two rows of dashlike impressions with small ridges or monticules at posterior ends. [Believed to be made by fin or finlike appendages of acanthodians (Ami, 1903) or by arthropods (Abel, 1935, p. 79).] *L.Dev.(Knoydart F.),* N.Am.(Can., Nova Scotia).

Imbrichnus Hallam, 1970, p. 197 [**I. wattonensis*; M]. Sediment-filled, winding burrows 0.5 to 1.0 cm. in diameter, commonly parallel to bedding plane, only locally slightly ascending or descending, on lower surfaces of sandstones preserved as semirelief or full relief; characterized by superficial imbricate structure, formed by successive pads of sandy sediment, 1 to 3 mm. thick, inclined at approximately 60° to horizontal. [Produced by movement of an animal along or below sand-mud interface, perhaps by a small bivalve, imbrication formed by periodic extension of the foot, the smooth-walled core by the shell.] *M.Jur.(Bathon., Forest Marble F.),* Eu.(Eng., Dorset).——Fig. 46A,*1*. **I. wattonensis,* Forest Marble F., Watton Cliff, Dorset; *1a,* holotype, ×0.38; *1b,* ×0.34 (Hallam, A., 1970, p. 197, in: *Trace Fossils* ed. by T. P. Crimes & J. C. Harper, Geol. Jour. Spec. Issue 3, Seel House Press, Liverpool).

Imponoglyphus Vyalov, 1971, p. 89 [**I. torquendus,* p. 89; OD]. Single trace, curved to a greater or lesser degree, a cord with regularly spaced constrictions, being like truncated cones invaginated into one another. *U.Trias.,* C.Asia(SW. Pamir).——Fig. 45,*1*. **I. torquendus, 1a,b,* ×0.67; *1c,* enl. (Vyalov, 1971). [Description supplied by Curt Teichert.]

Incisifex Dahmer, 1937, p. 525 [**I. rhenanus*; M]. Two parallel rows of obliquely arranged notches, stemming from 3-membered extremities; between and outside rows smooth strips of sediment made by sliding ventral side of animal. [Produced by arthropods, perhaps *Homalonotus.*] *L.Dev.,* Eu.(Ger.-Belg.); *?Perm.,* S.Afr.——Fig. 46,*2*. **I. rhenanus,* L.Dev.(Seifener beds), Ger.; ×0.7 (Dahmer, 1937).

Irredictyon Vyalov, 1972, p. 79 [**I. chaos*; OD]. Similar to *Paleodictyon,* but meshwork of burrows more irregular. *Tert.(low.Paleoc.),* USSR (N. Daghestan). [Description supplied by Curt Teichert.]

Isopodichnus Bornemann, 1889, p. 25, explan. pl. III [*emend.* Schindewolf, 1928, p. 27 (*non* Brady, 1947, p. 470)] [**I. problematicus*; SD Schindewolf, 1928, p. 27 (=*Ichnium problematicum* Schindewolf, 1921, p. 21)] [=*?Bipezia* Matthew, 1910 (type, *B. bilobata*); for discussion see Glaessner, 1957, p. 107]. Dimorphous trace fossil consisting of small, straight, or curved double-ribbon trails, up to about 6 mm. wide, transversely striated by fine furrows; both "ribbons" separated by median ridge; trail may be intermittent; associated with "coffee-bean"-shaped impressions of corresponding size. [Combination of ribbonlike ploughing or raking trails (in German, *Weidespuren*) and coffee-beanlike resting trails, produced by arthropods, possibly by phyllopods or another group of entomostracans. Seilacher (1970, p. 456) considered *Isopodichnus* to be a facies indicator for the nonmarine environment; Linck (1942, p. 253) restricted its facies range to brackish water. Most similar trails in marine Paleozoic beds are probably made by trilobites, thus *Isopodichnus* has been regarded as a synonym of *Rusophycus* Hall or even *Cruziana* d'Orbigny; for detailed discussion of *Isopodichnus* see Linck (1942), Glaessner (1957), and Birkenmajer & Bruton (1971, p. 311, 317, 318); Osgood (1970, p. 303) restricted the name *Isopodichnus* to short *Rusophycus*-like imprints of non-trilobite origin.] *L.Cam.,* Asia(Pak.); *?Ord.,* S.Am.(Arg.); *U.Sil.(?Downton.),* Spitz.; *?L.Dev.,* Eu.(Ger.); *Carb.,* Australia, Can.(Nova Scotia-N.B.); *L.Perm.(Dwyka Ser.),* S.Afr.; *Trias.,* Eu.(Ger.)-USA. [The following "species" should be excluded from *Isopodichnus: I.* sp. Speck (1945, p. 411) (Mio., Switz.) (according to Seilacher, 1953b, p. 115, internal trails of creeping gastropods); *I. raeticus* Linck, 1942, p. 242 (U.Trias., S.Ger.);

I. sp. MÜLLER, 1955b, p. 483 (L.Trias., Ger.) and probably also *I. tritylotos* HUNGER, 1947, p. 419 (M.Trias., Ger.).]——FIG. 46,*3*. **I. problematicus,* L.Trias.(Buntsandstein), Ger.; *3a,* ×0.67 (Seilacher, 1960); *3b,* schem., ×0.3 (Seilacher, 1963); *3c-e,* ×0.5 (Schindewolf, 1928).

Ixalichnus CALLISON, 1970, p. 20 [**I. enodius*; OD]. Short track of subrectangular shape, formed by 2 rows of 15 to 18 impressions; 5 cm. in length, width decreasing more or less from rear to front. [Made by a vagile trilobite, usually swimming rather than crawling.] *U.Cam.(Deadwood F.),* N.Am.(USA, S.Dak.).——FIG. 47,*4*. **I. enodius,* W.S.Dak.; *4a,* trackway, ×1.1; *4b,* trackway of holotype, ×1.4 (Callison, 1970).

Keckia GLOCKER, 1841, p. 319 [**K. annulata*; M]. Fillings of cylindrical tunnels with transverse annulation, single "segments" bent; burrows straight or slightly curved, branched, 1 to 2 cm. wide, of varying length, lying in bedding plane; similar to *Taenidium* but much larger; fillings probably fecal material passed through gut of animal. [Originally described as plant, later interpreted as stuffed burrows of sediment-feeding animal (in German, *"Stopf-tunnel"*); for discussion of the interpretation, see HÄNTZSCHEL (1938) and particularly RICHTER in WILCKENS (1947, p. 44-45). Several "species" of *Muensteria* VON STERNBERG and *Caulerpites* VON STERNBERG have been placed by SCHIMPER (in SCHIMPER & SCHENK, 1879, p. 46) in *Keckia; K. andina* BORRELLO, 1966 (U.Jur., Arg.) and *K. haentzscheli* HUNDT, 1941 (L.Dev., Ger.) should probably not be assigned to *Keckia.*] *L.Cret.,* USA (Texas); *Cret.-Tert.,* Eu.(Ger.-Aus.-Czech.-Switz.-?USSR).——FIG. 47,*2*. **K. annulata,* U.Cret. (Cenoman.), Ger.; ×0.16 (Glocker, 1841).

Kingella SAVAGE, 1971, p. 299 [**K. natalensis*; OD]. Impression subellipsoidal in outline 40 mm. long, 15 mm. wide; curved marks at "anterior" end indicating pair of antennae (about 10 mm. long) and perhaps one pair of antennules; at least 4 pairs of impressions of appendages. [Only one specimen known, defined as resting impression by SAVAGE; undoubtedly impression of crustacean living in freshwater periglacial environment, possible producer of trails named *Umfolozia* SAVAGE. It is questionable whether such an impression is still to be included in lebensspuren though interpreted as a resting trace.] *L.Perm. (Dwyka Gr.);* S.Afr.(N.Natal).——FIG. 47,*1*. *K. natalensis,* U.Carb. or L.Perm.; ×1.3 (Savage, 1971).

Kouphichnium NOPCSA, 1923, p. 146 [**Ichnites lithographicus* OPPEL, 1862, p. 121; M] [=*Micrichnium* ABEL, 1926, p. 150 (type, *M. scotti*); *Micrichnus* ABEL, 1926, p. 35 *(nom. null.); Artiodactylus* ABEL, 1926, p. 52 (type, *A. sinclairi*); *Hypornithes* JAEKEL, 1929, p. 238 (type, *H. jurassica*); *Ornichnites* JAEKEL, 1929, p. 235 (type, *O. caudatus*); *Protornis* JAEKEL, 1929, p. 216 (*non* MEYER, 1844) *(nom. nud.); Paramphibius* WILLARD, 1935, p. 47 (no type species designated); *Limuludichnulus* LINCK, 1943, p. 10 (type, *L. nagoldensis*); *Limuludichnus* LINCK, 1949, p. 46 (type, *L. variabilis*); for discussion of all these synonyms see CASTER (1939, 1940, 1944), NIELSEN (1949), MALZ (1964)]. Heteropodous tracks of great variability; complete track consisting of 2 kinds of imprints, 1) 2 chevron-like series each of 4 oval or round holes or bifid V-shaped impressions or scratches, forwardly directed [made by anterior 4 pairs of feet], and 2) one pair of digitate or flabellar, toe-shaped or otherwise variable imprints [made by birdfoot-like "pushers" of 5th pair of feet, with their 4 or 5 leaflike movable blades]; track with or without median drag-mark; occasionally preserved in the Upper Jurassic, Solnhofen Limestone, leading to carcass of producer *(Mesolimulus)*. [These traces were originally misinterpreted as the work of fishlike amphibians, birds (even *Archaeopteryx!*), pterodactyls, or bipedal dinosaurs, or jumping mammals, later recognized as made by limulids, particularly by comparisons with tracks of Recent limulids (CASTER, 1938). Some tracks are traceable for distances of 10 m. or more. Rarely, burrowing activity is recorded by lunate casts corresponding to the limulid prosoma (e.g., *K. rossendalensis,* U.Carb., Eng.; see HARDY, 1970). Incomplete patterns of well-preserved limulid tracks were recently interpreted as "undertracks" (duplicate imprints on lower surfaces as opposed to "surface tracks") (GOLDRING & SEILACHER, 1971); composite types of these tracks apparently made by males and females during the mating season (BANDEL, 1967b, p. 7); for interpretation of 2 sinuous grooves with different amplitude produced by telsons of a pair of limulids in nuptial embrace (U.Carb., Eng.), see KING (1965).] *Dev.-Jur.,* Eu.-N.Am.-Greenl.——FIG. 47,*3a*. *K. didactylus* (WILLARD), U.Dev.(Chemung), USA(Pa.); ×1.4 (Caster, 1938).——FIG. 47,*3b*. *K. gracilis* (LINCK), U.Trias.(Schilfsandstein), Ger.; ×0.6 (Linck, 1949).——FIG. 47,*3c*. *Limulus polyphemus* and its tracks (schem. drawing) (Malz, 1964).

Kulindrichnus HALLAM, 1960, p. 64 [**K. langi*; M]. Stumpy, cylindrical or conical bodies with apex directed downward; oriented subvertically in bed; up to 13 cm. in length and 7.5 cm. in diameter; composed of shell aggregates, some aligned peripherally to margin; matrix may be phosphatic. [Interpreted as burrow (resting trail) produced by cerianthid sea anemone; somewhat similar "genera" are *Bergaueria* PRANTL, *Conichnus* MYANNIL, and *Amphorichnus* MYANNIL.] *L.Jur.,* Eu.(Eng.-Ger.).——FIG. 48,*2*. **K. langi,* Blue Lias., Eng.; *2a,* long sec. with phosphatic sheath; *2b,* long sec. without phosphatic sheath;

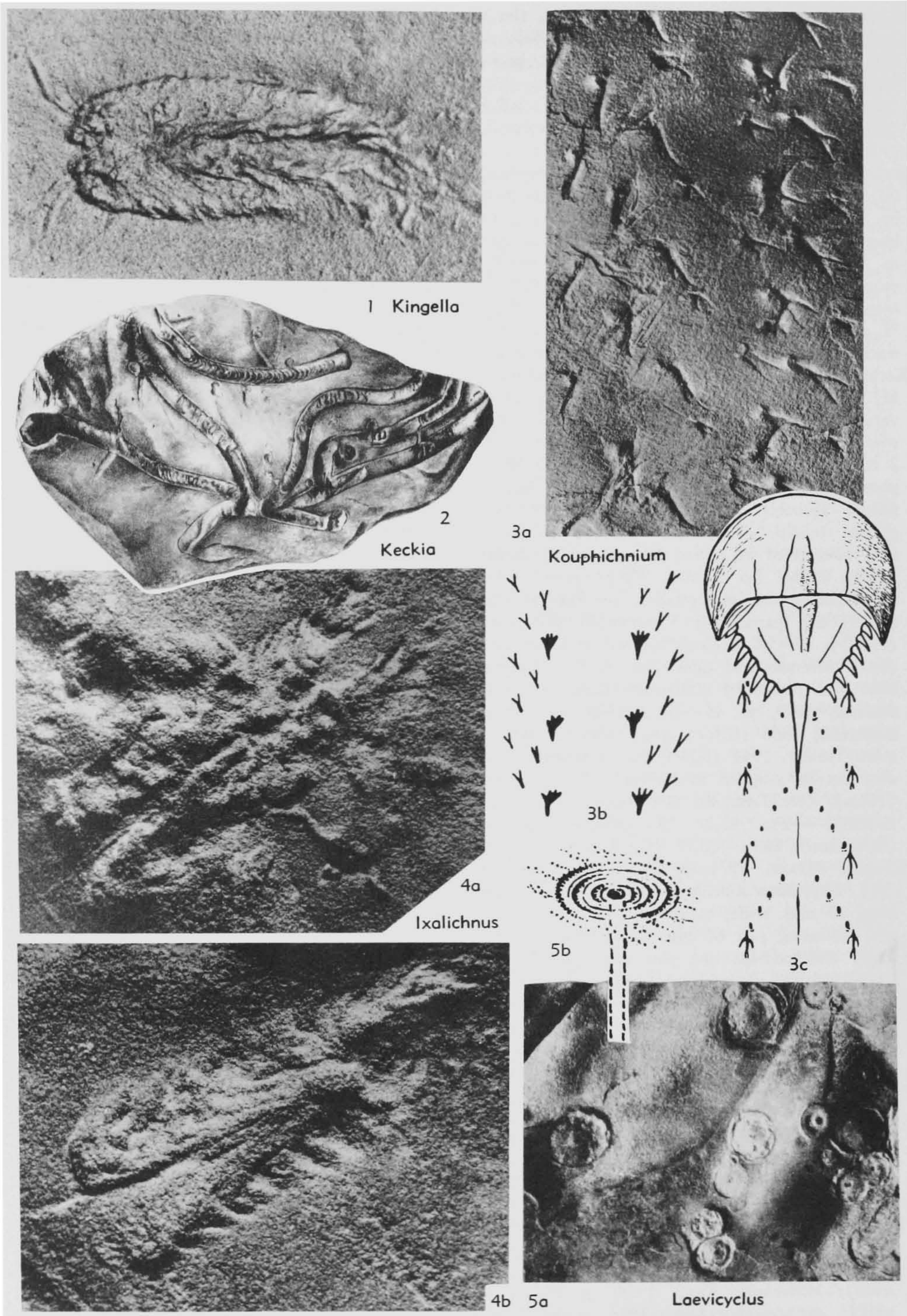

FIG. 47. Trace fossils (p. W75, 77-78).

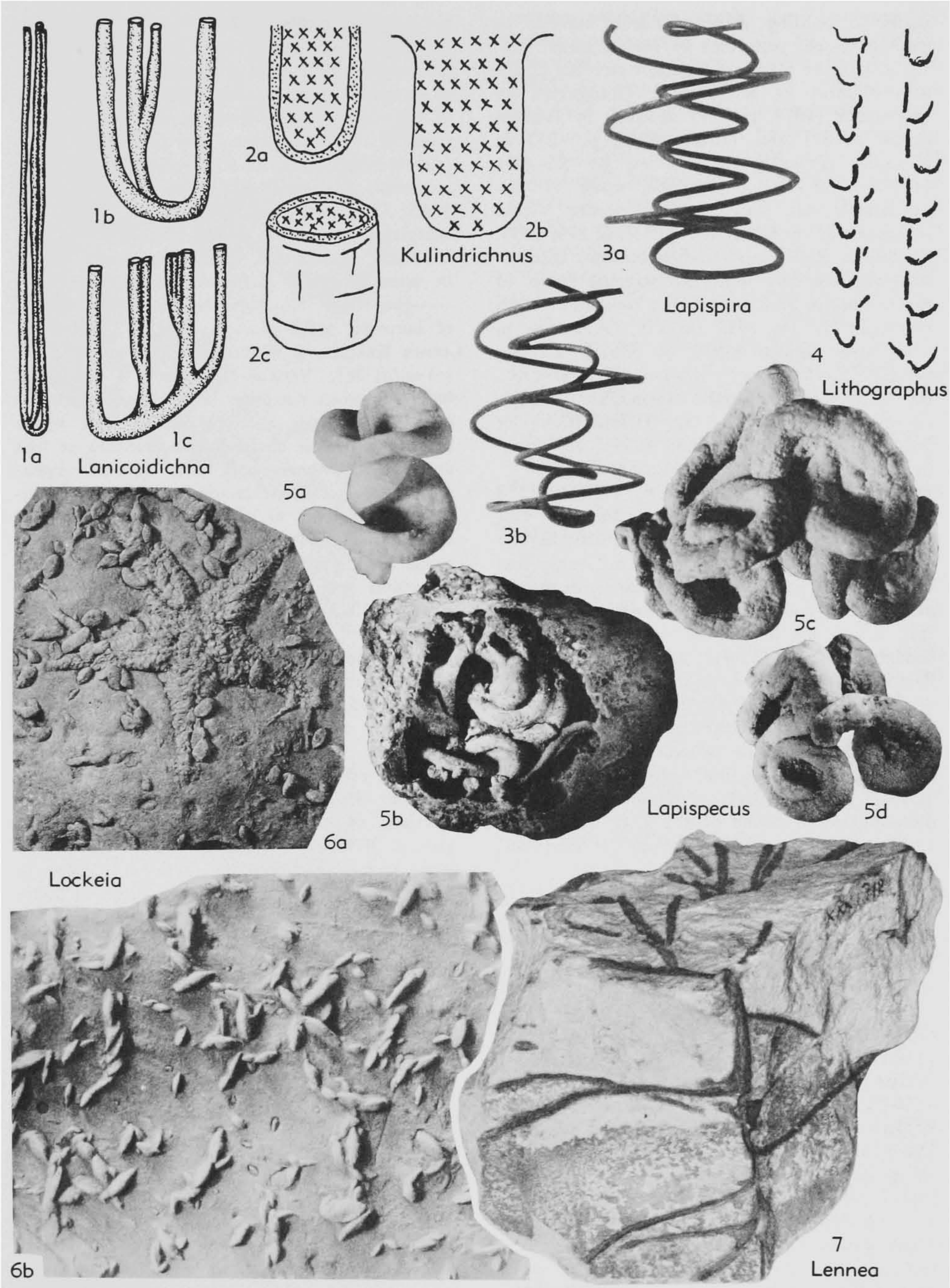

FIG. 48. Trace fossils (p. *W*75, 78-79).

2c, reconstr. burrow indicating calcite-filled cracks in phosphatic sheath, *ca.* ×0.3 (Hallam, 1960).

Laevicyclus QUENSTEDT, 1879, p. 577 [neither formal species name nor type species designated] [=*Cyclozoon* WURM, 1912, p. 127 *(partim)*]. Approximately cylindrical bodies standing at right angles to bedding plane; diameter variable in same specimen; perforated by central canal; visible on bedding planes as regular concentric circles with diameter of several cm. [Interpreted by QUENSTEDT (1879, p. 577) as coral, by PHILIPP (1904, p. 59) and WURM (1912, p. 128) as organism of unknown affinities, by SCHMIDT (1934, p. 18-27) as inorganic, made by gas-exhalations and water under pressure within sediment, and by SEILACHER (1953c, p. 270; 1955, p. 389) as trace fossil (feeding burrow) comparable with dwelling shaft and scraping circles of Recent annelid *Scolecolepis*. For comparison with *Palaeoscia* CASTER, 1942 (U.Ord., Ohio), see p. *W*147 and OSGOOD (1970, p. 396).] *L.Cam.*, Pak.; *?L.Carb.(Kulm)*, Eu.(Ger.); *Trias.-Cret.*, Eu. (Eng.-Ger.-Spain-Italy)-N.Am.USA (Kans.). ——FIG. 47,*5*. *L.* sp., *5a*, U.Trias.(Campiler beds), Italy; ×0.22 (Schmidt, 1934); *5b*, reconstr., L.Cam., Pak.; ×2.4 (Seilacher, 1955).

Laminites GHENT & HENDERSON, 1966, p. 158 [**L. kaitiensis*; OD]. Large, long burrows; subcircular to nearly circular in cross section; slightly meandering or running straight for some distance; filled with fine parallel laminations convex in distal direction; maximum width up to 7.5 cm., length up to 0.5 m.; usually parallel to bedding plane. [Similar to *Keckia* GLOCKER, *Planolites* NICHOLSON, or other *"Stopftunnel,"* but of much larger size; *Beaconites* VYALOV, 1962, possibly is senior synonym of *Laminites* (see p. *W*45). Interpreted as periodic filling by separate packets of feces backwardly extruded into burrow; probably produced by holothurians; for discussion see GREGORY (1969, p. 6) and CHAMBERLAIN (1971a, p. 226).] *Penn.*, ?N.Am.(USA, Okla.); *Tert.(Mio.)*, N.Z.

Lanicoidichna CHAMBERLAIN, 1971, p. 223 [**L. metulata*; M] [=*Lanicoidichnus* CHAMBERLAIN, 1971a, p. 216 *(nom. null.)*]. U-shaped burrows; vertical to bedding; 1 to 3 secondary galleries branching at base of U from main burrow and running parallel with it, yielding W-shaped structures; occasionally linked at bases by horizontal or oblique burrows; most additional burrows are smaller than primary gallery; individual burrows 2 to 7 mm. wide; interval of limbs of U- or W-shaped structure 2 to 3 cm.; length of entire system about 60 cm. or more. [Somewhat similar to occasional W-shaped tubes built by the Recent polychaete *Lanice* (SEILACHER, 1953a, p. 428, fig. 3).] *Penn.(Wapanucka Ls.)*, N.Am. (USA, Okla).——FIG. 48,*1*. *Lanicoidichna* structure; *1a*, total structure, *ca.* ×0.1; *1b,c*, lower part of "U" structure, approx. ×0.3 (Chamberlain, 1971a).

Lapispecus VOIGT, 1970, p. 373 [**L. cuniculus*; OD]. Long cylindrical burrows, 1 to 4 mm. in diam., winding similar to tubes of serpulid *Glomerula*; preserved only as casts in cavities which are result of partial leaching of pebbles, particularly small pebbles, in conglomerates. [Bladelike thin borders on concave or convex side of winding fillings of burrows not interpreted as spreite; borders are discontinuous along length of burrows; probably dwelling burrows of polychaetes.] *U.Cret.(Santon.)* [in pebbles of *U.Jur. (Kimmeridg.)* age], Eu.(Ger.).——FIG. 48,*5*. **L. cuniculus; 5a*, spindle-like spiral form, ×8; *5c*, ×4.5; *5b,d*, ×3 (Voigt, 1970).

Lapispira LANGE, 1932, p. 540 [**L. bispiralis*; M]. U-shaped tunnel with both legs spirally curved in same direction. *L.Jur.(low.Lias.)*, Eu.(Ger.). ——FIG. 48,*3*. **L. bispiralis; 3a,b*, wire models of burrows, ×0.2 (Lange, 1932).

Lennea KRÄUSEL & WEYLAND, 1932, p. 189 [**L. schmidti*; M]. Vertical shaft about 1 cm. wide, with numerous narrower lateral tunnels branching off irregularly at right angles along whole length of vertical shaft; lateral branches at first approximately horizontal, then directed downward; branching dichotomously. [Originally interpreted as roots of plants; later recognized as trace fossil (feeding burrow) (KRÄUSEL & WEYLAND, 1934, p. 100); for detailed description and discussion see PAULUS (1957) and FISCHER & PAULUS (1969).] *Dev.*, Eu.(Ger.).——FIG. 48,*7*. **L. schmidti*, M.Dev., Ger.; ×0.3 (Paulus, 1957).

Lenticraterion KARASZEWSKI, 1971, p. 886 [**L. bohdanowiczi*; M]. Lenticular depressions (7 to 12 mm. long and 4 to 8 mm. wide) in epirelief, maximum depth 5 mm.; individual depressions commonly display 2 funnel-shaped hollows, of the same or different depths, at each end of long axis but do not possess peripheral collars characteristic of *Calycraterion* KARASZEWSKI, 1971a (see p. *W*49); convex structures on bottom of same rock slab correspond with depressions in epirelief. [Interpreted by KARASZEWSKI (1971b, p. 889) to have been produced by an unknown animal moving upward in the sediment.] *L.Jur. (low.Pliensbach.)*, Eu.(Pol.). [Description supplied by W. G. HAKES.]

Lithographus HITCHCOCK, 1858, p. 156 [**L. hieroglyphicus*; SD LULL, 1953, p. 43]. Very similar or identical to *Copeza* HITCHCOCK but having oblique markings outside longitudinal ones. [?Insect trail.] *Trias.*, N.Am.(USA,Mass.). ——FIG. 48,*4*. **L. hieroglyphicus*; ×0.4 (Lull, 1953).

Lobichnus KEMPER, 1968, p. 72 [**L. variabilis*; M]. Very small or scooped hollows which form irregular main stem with unilateral pectinate branches comprised of very small leaf-shaped hollows also arranged unilaterally; systems are highly variable with many transitions between forms; limited to lobate configuration and thus resembling ammonite sutures; somewhat similar to *Lophoctenium*; endogenic and preserved exclusively in troughs of current ripple marks. [Interpreted as true grazing trails; KEMPER believed that *Lobichnus* was an indicator of shallow

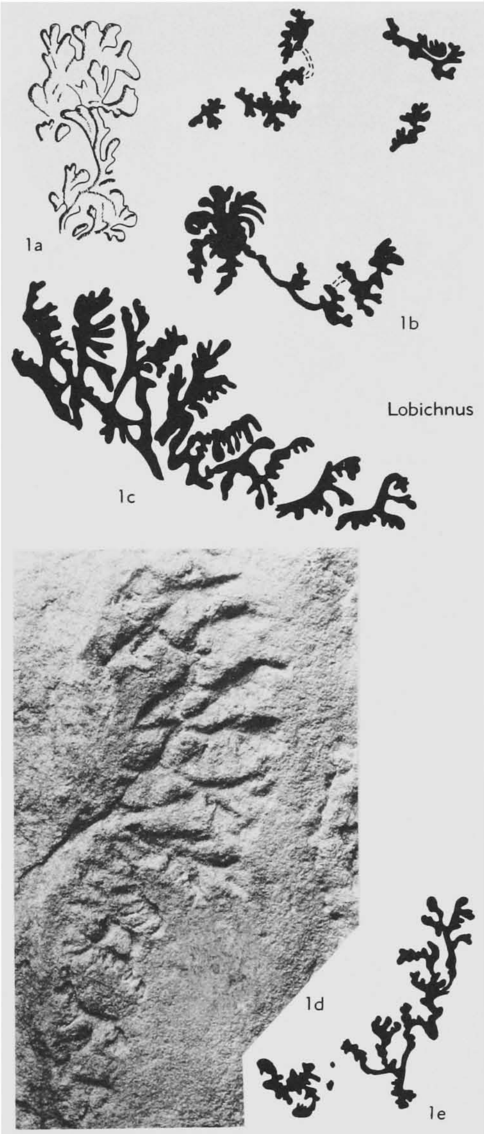

FIG. 49. Trace fossils (p. W78-79).

water in the Bentheimer Sandstein.] *L.Cret.(M. Valang., Bentheimer Sandstein)*, Eu.(Ger.).——FIG. 49, *1*. **L. variabilis; 1a,c,* holotype, schem.; *1b,e,* schematic examples of the wide range of forms, all approx. ×0.5; *1d*, ×1 (Kemper, 1968).

Lockeia U. P. JAMES, 1879, p. 17 [**L. siliquaria*; M] [=*Pelecypodichnus* SEILACHER, 1953b, p. 105 (type, *P. amygdaloides*); for discussion see OSGOOD, 1970, p. 308-312]. Small almond-shaped oblong bodies preserved in convex hyporelief; tapering to sharp and obtuse points at both ends; surface commonly smooth; mostly symmetrical; length varying from 2 to 12 mm. [Originally interpreted as algae; later regarded by J. F. JAMES (1885) as "ovarian capsules" of graptolites; now considered resting trails of small burrowing pelecypods, perhaps semi-sessile forms; for discussion on mode of formation and synonymy with *"Dawsonia"* NICHOLSON, 1873 (preoccupied by HARTT, in DAWSON, 1868), see OSGOOD, 1970, p. 208-212; regrettably, the most appropriate name *Pelecypodichnus* must be replaced by a very rarely used one published in an obscure journal!] *Ord.*, Eu. (Nor.-France)-USA (Ohio-Ky.)-Can., *?Ord.*, S.Am.(Arg.); *Penn.*, USA(Kans.-Okla.); *Trias.*, Eu.(Ger.-Swed.-Italy)-E.Greenl.; *Jur.*, Eu. (Eng.-France-Ger.-Swed.); *Cret.*, USA(Utah); *Tert.*, Eu.(Switz.)-Iraq.——FIG. 48,*6a*. *L. amygdaloides*, M.Jur.(Dogger β, Donzdorfer Ss.), Ger.; (shown with *Asteriacites quinquefolius* (QUENSTEDT), ×0.5 (Seilacher, 1953b).——FIG. 48,*6b*. **L. siliquaria*, Ord. (up. Trenton. or low. Cincinnat.), Ludlow, Ky.; ×0.7 (Osgood, 1970).

Lophoctenium RICHTER, 1850, p. 199 (without formal species name) [**L. comosum* RICHTER, 1851, p. 563; SM] [=*Buthotrephis radiata* LUDWIG, 1869, p. 114; *Criophycus* TOULA, 1906, p. 159 (type, *C. ramosus*)]. Bunches of closely spaced, inwardly bent "twigs" with comblike branches, joining to form main axis. [Formerly thought to have affinities with graptolites, sertularids, or algae; without doubt a feeding burrow; according to SEILACHER (1960, p. 49), *L. globulare* GÜMBEL (1879, p. 469) is identical to *"Schaderthalia"* HUNDT, 1953 (obscure nondescript "genus"); see also PFEIFFER, 1968, p. 671, who renounced establishment of a new name for this "species."] [Found in flysch deposits.] *Ord.-L.Carb.*, Eu.(Ger.-Port.)-N.Am.(USA,Okla.); *L.Tert.*, Eu.(Aus.-Switz.-Pol.).——FIG. 50,*1a*. **L. comosum*, M.Dev.(*Nereites* beds), Ger.; ×1.5 (Seilacher, 1954).——FIG. 50,*1b*. *L. ramosum* (TOULA), low. Eoc., Pol.; ×0.5 (from Książkiewicz, M., 1970, p. 284, in: *Trace Fossils* edited by T. P. Crimes & J. C. Harper, Geol. Jour. Spec. Issue 3, Seel House Press, Liverpool).

Macanopsis MACSOTAY, 1967, p. 32 [**M. pagueyi*; M]. Straight or somewhat bent burrows circular or oval in cross section, 1 to 3 cm. in diameter, not branched; burrows end with hemispherical hollow, 4 to 5 cm. in diameter; burrows perpendicular to bedding; usually slightly bent before enlarging to hemispherical hollow. *L.Tert. (Paleoc.-Eoc.)*, S.Am.(Venez.).——FIG. 51,*1*. **M. pagueyi; 1a,b,* holotype and paratype, ×0.3 (Macsotay, 1967).

Mammillichnis CHAMBERLAIN, 1971, p. 238 [**M. aggeris*; M] [=*Mammillichris* CHAMBERLAIN, 1971a, p. 238 *(nom. null.)*; *Mammillichnus* CHAMBERLAIN, 1971a, p. 217 *(nom. null.)*]. Subhemispherical teatlike protuberances 9 to 12 mm. wide, 7 mm. high, preserved in convex

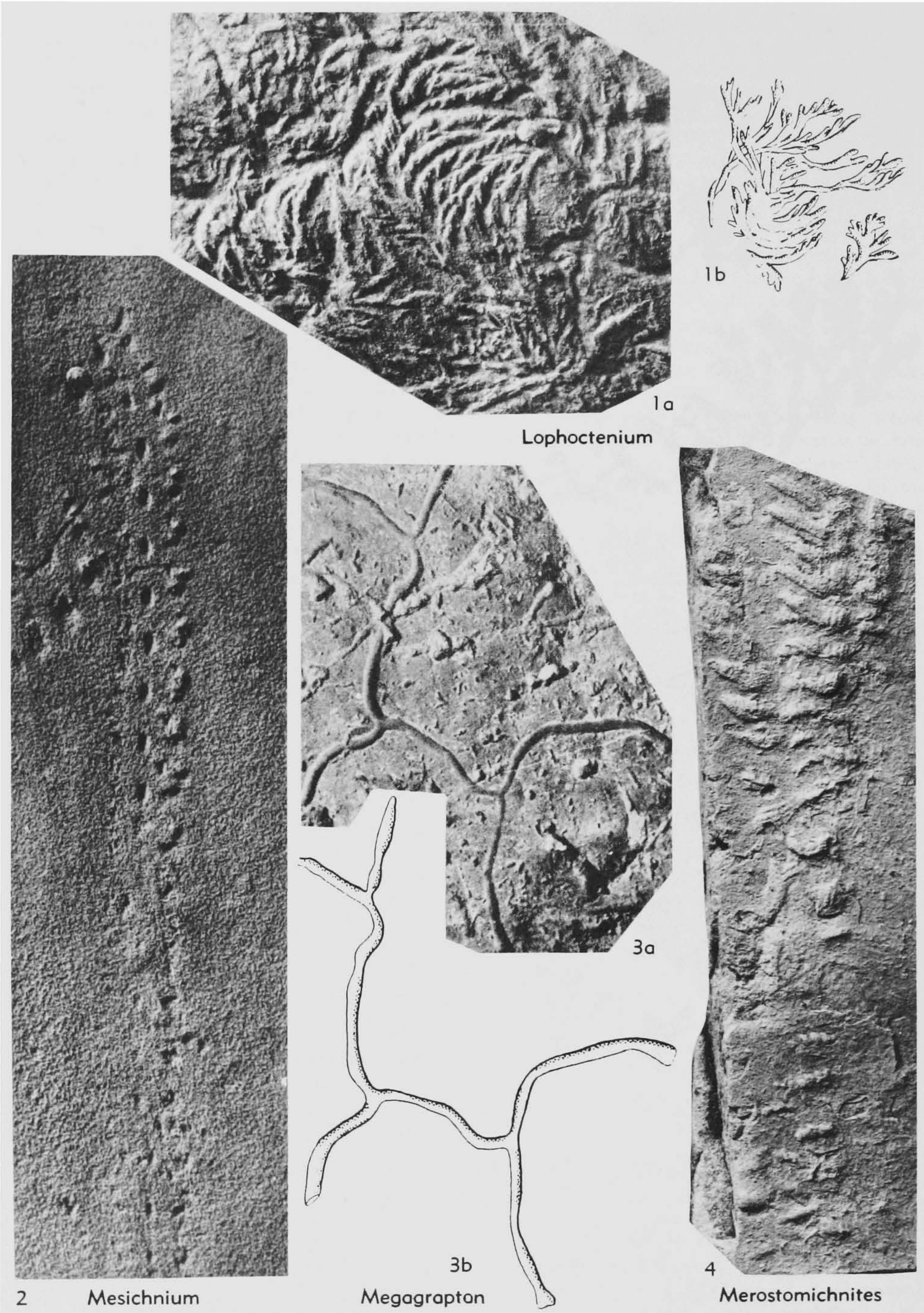

Fig. 50. Trace fossils (p. W79, 82).

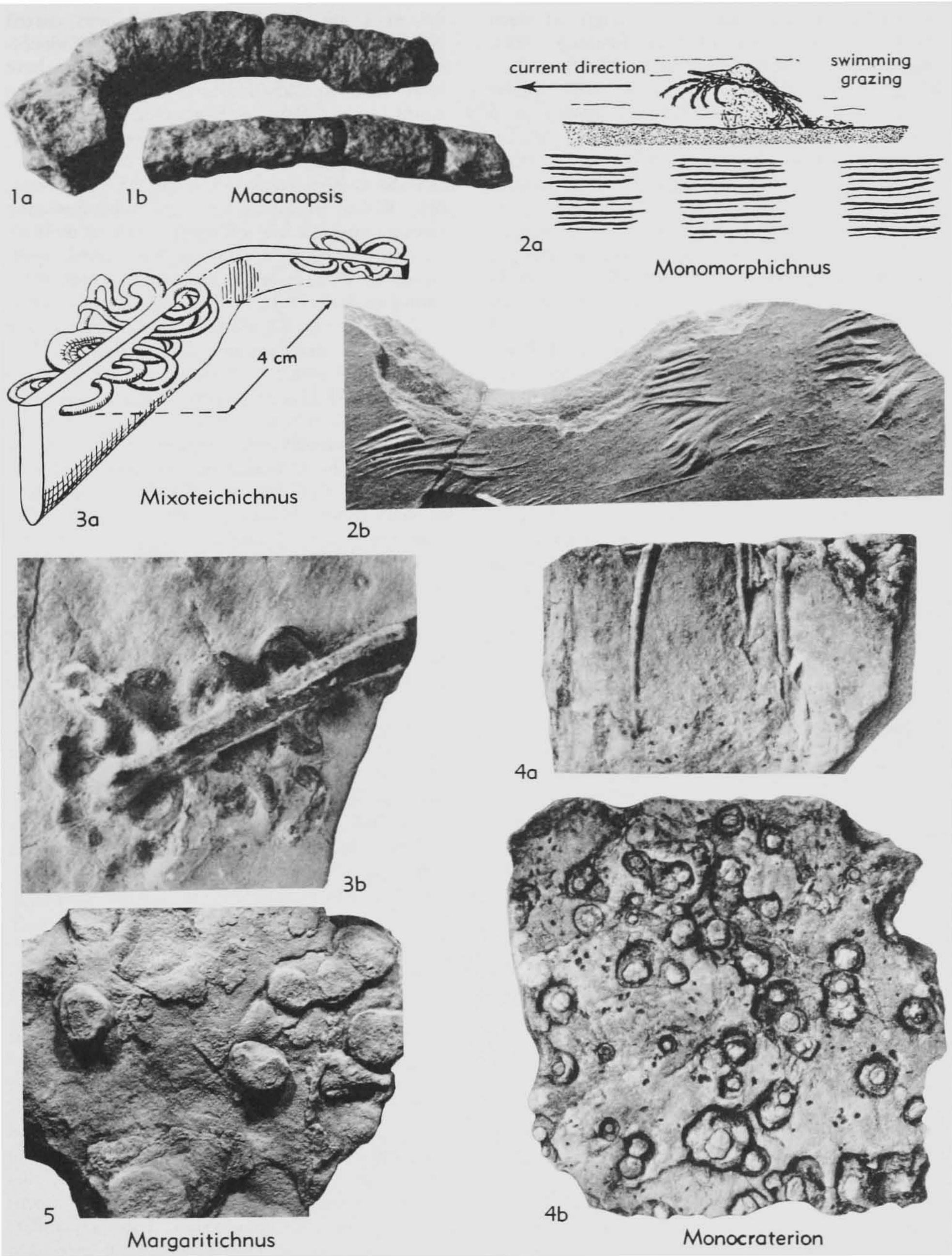

FIG. 51. Trace fossils (p. W79, 82, 84).

hyporelief, each mound consists of 3 to 5 mm. hemicircular apex and wide flange. [Origin unknown; the following three interpretations were discussed by CHAMBERLAIN (1971a): resting or hiding trace of an animal in the sediment; body fossil ("egg case" or juvenile deposited in sediment); excurrent end of burrow where animal worked sediment for food or formed fecal pellets;

impossible to make decision on origin of form from CHAMBERLAIN's (1971a) figures.] *Miss.(Jackfork Gr.)-Penn.(Atoka F.),* USA(Okla.).

Margaritichnus BANDEL, 1973, p. 1002 (*nom. subst. pro Cylindrichnus* BANDEL, 1967a, p. 6 (*non* TOOTS in HOWARD, 1966, p. 45)) [**Cylindrichnus reptilis* BANDEL, 1967a, p. 6; OD]. Vertically compressed ball structures 15 to 30 mm. in diameter; originally spherical; commonly arranged like string of pearls; rarely connected by ridges which show crescentic transverse grooves. ["Balls" interpreted as fecal pellets probably made by large wormlike sediment-eating animals (sipunculids?, priapulids?); "trail" possibly formed below the surface of the sediment.] *U.Penn.(Missouri.),* USA(Kans.); *Perm.,* W.Australia; *?Cret.,* USA.——FIG. 51,*5*. **M. reptilis* (BANDEL), U.Penn., Kans.; ×0.1 (Bandel, 1967a). [Also found in *U.Precam.,* S.Australia-USSR(Sib.Plat.).]

Megagrapton KSIĄŻKIEWICZ, 1968, p. 5, 14 [**M. irregulare*; OD] [=*Megagrapton* KSIĄŻKIEWICZ, 1961, p. 882, 888 *(nom. nud.)*]. Networks consisting of irregular polygons and rectangles which are never closed, formed by slightly curved or straight cylindrical strings, 1 to 5 mm. wide; rather regular intervals of branching at nearly right angles; possibly transitional to *Squamodictyon* VYALOV & GOLEV, 1960. [Evidently of postdepositional origin.] *L.Cret.,* Japan-Eu.(Pol.); *L.Tert.(low.Eoc.),* Eu.(Pol.).——FIG. 50,*3*. **M. irregulare; 3a,* L.Tert.(Eoc., flysch), Pol.; ×0.43 (Książkiewicz, 1961); *3b,* low.Eoc.(Beloveza Beds), Pol.; ×0.5 (Książkiewicz, M, 1970, p. 307, in: *Trace Fossils* edited by T. P. Crimes & J. C. Harper, Geol. Jour. Spec. Issue 3, Seel House Press, Liverpool).

Merostomichnites PACKARD, 1900, p. 67 [**M. beecheri*; SD HÄNTZSCHEL, 1962, p. *W*205] [=*Merostomchnites* OSGOOD, 1970, p. 355 *(nom. null.)*]. Two parallel rows of circular bow- or spindle-shaped feet impressions; transversely or slightly obliquely arranged, opposite to each other. [Paleozoic forms probably attributable to eurypterids, Triassic forms possibly to phyllopods; striding track *Merostomichnites* and burrowing trail *Isopodichnus* may have been produced by the same animal (SEILACHER, 1963, p. 88).] *Cam.-L.Trias.,* Eu.-Asia(AsiaM., Jordan)-N.Am.——FIG. 50,*4*. *M. strandi* STØRMER, Sil.-Dev.(Downton.), Nor.(Spitz.); ×1 (Størmer, 1934).

Mesichnium GILMORE, 1926, p. 34 [**M. benjamini*; M]. Two parallel lines of footprints with median row of suboval regularly spaced depressions; trackway about 20 mm. wide; stride (distance between depressions of median row) about 15 mm. long. [Crawling track; producer unknown.] *Perm.(Coconino Ss.),* N.Am.(USA, Ariz.).——FIG. 50,*2*. **M. benjamini,* Ariz.(Grand Canyon); *ca.* ×0.37 (Gilmore, 1926).

Mesonereis HATAI, 1968, p. 132 [**M. ragaensis*; M]. Name conditionally proposed. Burrow 0.5 to 1 cm. in diameter, lower part curved planispirally and upper part vertical. [Undoubtedly a trace fossil, considered by HATAI to have been made by "an undescribed kind of marine worm . . . . close in morphological feature to the living genus *Nereis*."] *L.Cret.(Miyakoan),* Japan(NE.Honshu). [Most likely invalid.]

Micatuba CHAMBERLAIN, 1971, p. 238 [**M. verso*; M]. Rather irregularly arranged tubes radiating from a center (central gallery?), singly or multiply bunched, straight or more or less curved, sand-coated or filled, about 20 mm. long, 1 mm. wide. *Penn.(up.Atoka F.),* N.Am.(USA,Okla.).——FIG. 52,*2*. **M. verso; 2a,* plain view; *2b,* cross section and oblique view, schem. (Chamberlain, 1971a).

Minichnium PFEIFFER, 1968, p. 683 [**M. wurzbachense*; M]. Large systems of rather long feeding burrows which diverge clusterlike from a starting point and trend slightly downward, exhibiting distinct bioturbate structures. [Poorly figured.] *L.Carb.(Kulm),* Eu.(Ger.,Thuringia).

Mixoteichichnus MÜLLER, 1966, p. 720 [**M. coniungus*; OD]. Straight or slightly curved, retrusively formed, wall-like back-fill *(Versatzbauten)* burrows similar to *Teichichnus* SEILACHER, with simply curved and semicircular burrows that originate from their upper parts; these smaller burrows partly resemble *Rhizocorallium* and are constructed parallel to bedding. [Trail belonging to Fodinichnia.] *Low.M.Trias.(low.Muschelkalk),* Eu.(Ger.).——FIG. 51,*3*. **M. coniungus,* low. Muschelkalk, Ger.; *3a,* schem., ×0.5; *3b,* ×0.3 (Müller, 1966).

Monocraterion TORELL, 1870, p. 13 [**M. tentaculatum*; M] [=*Lepocraterion* STEHMANN, 1934, p. 17; no "species" name; *Monocraterium* VOLK, 1967, p. 98 *(nom. null.)*]. "Trumpet pipes"; funnel structure penetrated by central straight or slightly curved plugged tube, perpendicular to bedding plane, never branched; diameter commonly 5 mm., up to 8 cm. (max., 16) long; funnel simple or multiple (latter discernible in transverse section as a series of concentric rings); diameter of funnels usually 1 to 4 cm., greatest depth about 2 cm.; tubes commonly abundant but never crowded like *Skolithos.* Funnel obviously constructed by upward migration of animal inhabiting tube is reflected by downward warping of surrounding bedding planes toward central tube. [Dwelling burrow; probably belonging to gregarious, suspension-feeding wormlike organisms. *Lepocraterion* STEHMEN differs from *Monocraterion* only by the occurrence of a carbonaceous wall which is not considered to be sufficient taxonomic reason to establish a "genus." BOUČEK (1938, p. 249) and HÄNTZSCHEL (1962, p. *W*218), with reservation, regarded *Monocraterion* as synonym of the commonly annulated tubes *"Tigillites"*; HALLAM & SWETT (1966, p. 103) properly retained *Monocraterion* as a valid name for vertical funnel-shaped burrows; for dis-

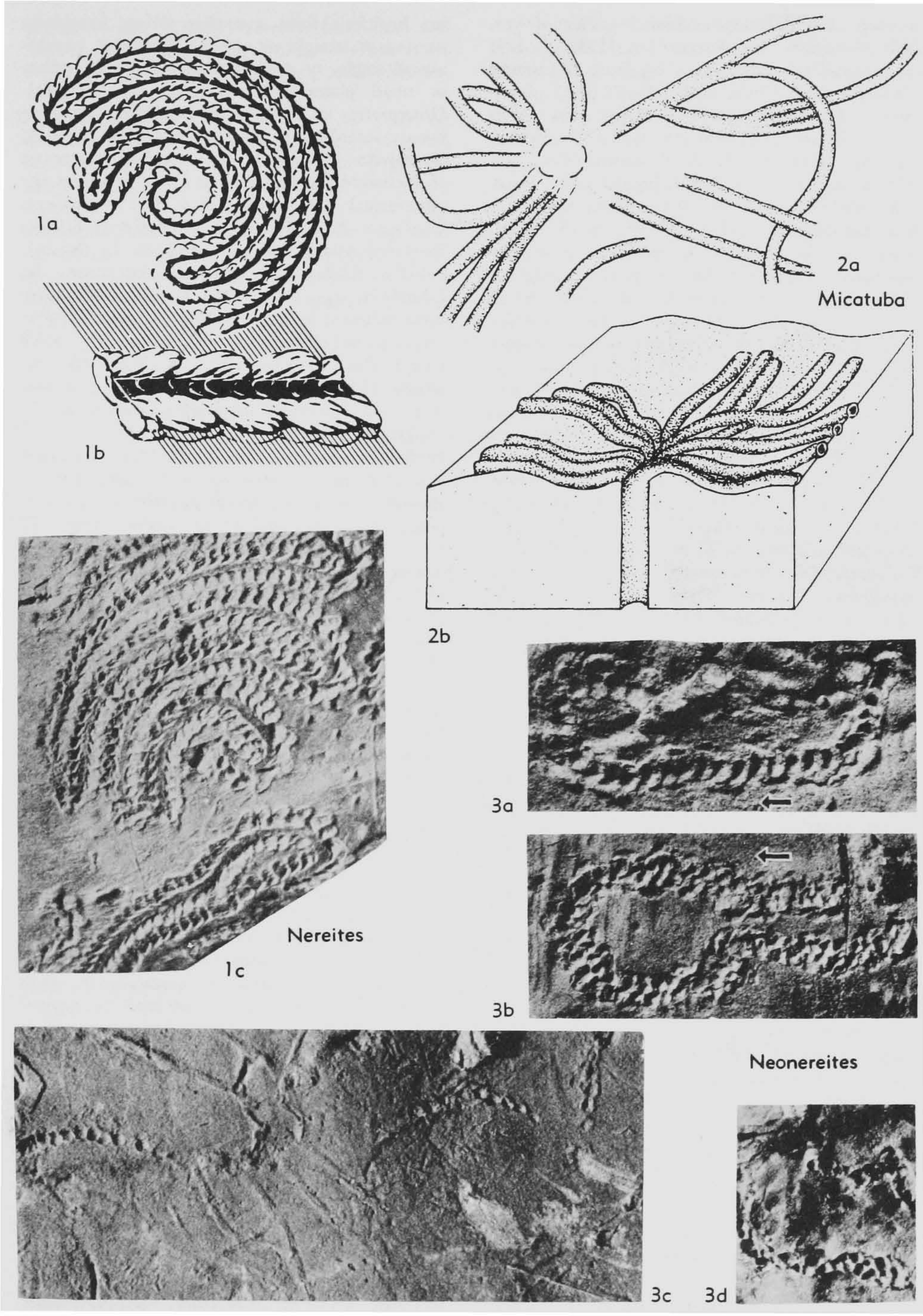

FIG. 52. Trace fossils (p. W82, 84-85).

cussion of relationship to *Skolithos, Histioderma,* and *Micrapium,* see WESTERGÅRD (1931, p. 12); also considered valid genus by FREY & CHOWNS (1972).] *Cam.* (Pleist. drift), Eu.(N.Ger.); *Cam.-Ord.,* Eu.(Swed.-Nor.-Eng.)-N.Am.-Asia (Jordan); *?U.Dev.,* Eu.(Eng.); *Carb.,* Eu.(Scot.); *?L.Trias.,* Eu.(Pol.); *L.Jur.,* Greenl.——FIG. 51,*4*. **M. tentaculatum*; L.Cam.(Lingulid ss.), Swed. (W.Gotl.); *4a,b,* ×0.5 (Westergård, 1931).

Monomorphichnus CRIMES, 1970, p. 57 [**M. bilinearis*; M]. Series of straight or slightly sigmoidal ridges associated in pairs; 1 ridge of each pair more prominent than the other; ridges 2 to 4 cm. long, sometimes repeated laterally; trail resembling *Dimorphichnus* SEILACHER, but without blunt markings and other markings to suggest sideways progression. [Produced by several clawed limbs of trilobites, perhaps members of the Olenidae; interpreted as swimming-grazing trail.] *U.Cam.(FfestiniogStage),* Eu.(Eng., N. Wales).——FIG. 51,*2a*. *M.* sp.; showing how trace is produced by swimming-grazing manner of trilobite locomotion (Crimes, 1970b).——FIG. 51, *2b*. **M. bilinearis*; ×0.4 (Crimes, 1970b).

Muensteria VON STERNBERG, 1833, p. 31 [*non* KROGERUS, 1931, *nec* DESLONGCHAMPS, 1835] [no type species designated]. Heterogeneous "genus," comprising bodily preserved fossils from the Jurassic Solnhofen limestone as well as trace fossils, particularly from European flysch deposits (e.g., *M. hoessii* HEER, 1877; *M. annulata* SCHAFHÄUTL, 1851; *M. involutissima* SACCO, 1888; *M. bicornis* HEER, 1877), these *"species"* are mostly stuffed burrows (German, *"Stopftunnel"*) with laminated structure ("segmentation") originated backfilling of the cylindrical burrows; *Muensteria* similar to *Taenidium* HEER but differs by being larger; it has been divided into "subgenera" by VON FISCHER-OOSTER, 1858 (*Eumuensteria, Keckia* GLOCKER, *Hydrancylus* VON FISCHER-OOSTER). *Jur.-Cret.,* Eu.(Ger.-Switz), N.Am.(Greenl.).

Myriapodites MATTHEW, 1903, p. 103 [published only as "*Myriapodites* sp."]. Two parallel rows of feet impressions, about 6 mm. apart, each row 2 mm. wide; linear prints closely set, arranged in double series of elongated scratches, mostly directed from outside to inside of row. [Tentatively interpreted as crawling track of myriapods.] *Carb.,* N.Am.(Can., Nova Scotia).

Neonereites SEILACHER, 1960, p. 48 [**N. biserialis*; OD] [=*Neonerites* CONYBEARE & CROOK, 1968, p. 276 *(nom. null.); Neoneretites* SEILACHER, 1969, p. 118 *(nom. null.)*; former German names: *Punkt-Fährte* PUTZER, 1938, p. 418; *Perlspur* WEISS, 1940, p. 344; *Perlketten-Fährte* KUHN, 1952, p. 224]. Bimorphous, shape depending on its hypichnial or exichnial preservation; as negative epireliefs consisting of irregularly curved chains of deep, smooth-walled dimples; chain restricted in length, some bordered laterally by flabby structures caused by burrowing; corresponding hypichnia form a median string, irregularly curving or straight or rarely meandering, consisting of single- or double-lined clay (fecal) pellets or small plates *(N. uniserialis, N. biserialis)*. [Interpreted to be internal burrow, postdepositional; according to SEILACHER (1962, p. 233), *Neonereites* is possibly the irregular counterpart of *Helminthoida labyrinthica* HEER in sandy environment.] *Ord.,* Asia (Iraq); *?L.Carb.(Kulm),* Eu.(Ger.); *L.Jur.-M.Jur.,* Eu.(Eng.-Ger.); *L.Cret.,* Eu.(Ger.)-Asia(Japan); *L.Tert.(Eoc),* Eu.(Spain).——FIG. 52,*3a,c*. *N. uniserialis* SEILACHER, *3a,* L.Jur.(Lias α_2), Ger.; ×0.9 (direction of movement indicated by arrow in *3a*) (Seilacher, 1960); *3c,* low.Lias(Hettang.), Ger.(Helmstedt); ×0.9 (Häntzschel, 1968).——FIG. 52,*3b,d*. **N. biserialis,* M.Jur.(Dogger β), Ger.; *3b,d,* ×0.6 (direction of movement indicated by arrow in *3b*) (Seilacher, 1960).

Neoskolithos KEGEL, 1966, p. 22 [**N. picosensis*; M]. Similar to *Skolithos* but tubes not so crowded, shorter and more irregular; 4 to 5 cm. long, 0.5 to 1 cm. in diameter. *L.Dev.(Pimenteira F.),* S.Am.(Brazil,Piauí).

Nereites MACLEAY, 1839, p. 700 [*non* EMMONS, 1846] [**N. cambrensis*; SD HÄNTZSCHEL, 1962, p. *W*205] [=*Myrianites* MACLEAY, 1839, p. 700 (type, *M. macleaii*); *Nereograpsus* GEINITZ, 1852, p. 27 (name for the supposed "graptolite genera" *Nereites, Myrianites, Nemertites,* and *Nemapodia*; name "corrected" by HALL, 1865, p. 43, to *Nereograptus*); for synonymy of the type species and *N. tenuissimus* see PFEIFFER, 1968, p. 669, 670)]. Meandering trails, consisting of narrow median furrow, flanked on both sides by regularly spaced leaf-shaped, ovate, or pinnate lobes; closely spaced; commonly finely striated; meanders may be densely spaced (type of *"Geführte Mäander"* of RICHTER, 1924, p. 153); width of trail 1 to 2 cm.; meanders variable in form in width, shape, and size of the lateral lobe-like projections. [Formerly regarded as plants, bodily preserved worms, or graptolites or their impressions; lateral lobes explained as impressions of the setae of a worm; now interpreted as internal meandering grazing trails; according to SEILACHER (in SEILACHER & MEISCHNER, 1965, p. 615), *Nereites* occurs on top surface of thin turbidites, thus most probably produced in deep water environment ("*Nereites* facies" of SEILACHER). Various producers have been suggested: worms (e.g., RICHTER, 1928, p. 241), gastropods (e.g., RAYMOND, 1931a, p. 191; ABEL, 1935, p. 237), or crustaceans (FRAIPONT, 1915, p. 449); many "species" described, particularly by DELGADO (1910, p. 11-24), but not all of them definitely belonging to *Nereites*; for "psychologic analysis" of these meandering trails, see RICHTER (1928, p. 240) and SEILACHER (1967a, p. 297)]. [Found in flysch deposits.] *Ord.-Carb.,* Eu.-USA-S.Am.-N.Afr.; *Cret.,* Eu.(Spain-Italy); *Tert.(Eoc.),* Japan.——FIG. 52,*1a,b*. *Nereites*, from Dev. and Carb.; schem. (Seilacher, 1967c).——FIG. 52,*1c*. *N. loomisi* EMMONS, M.Dev., Ger.; ×0.3 (Richter, 1928).

Octopodichnus GILMORE, 1927. p. 30 [**O. didactylus*; OD]. Tracks of apparently 8-footed animal; feet impressions arranged in 4 groups: alternating; 2 anterior impressions of each group didactyle, 2 posterior, unidactyle. [Various interpretations have been advanced: made by crustaceans (GILMORE, 1927), arachnids (ABEL, 1935, p. 265), large scorpionids (BRADY, 1947, p. 469), producer unknown (FAUL & ROBERTS, 1951, p. 272).] *L.Perm.(Coconino Ss.)*, N.Am.(USA, Ariz.); *?Jur.(?Navajo Ss.)*, N.Am.(USA,Colo.).——FIG. 53,*2*. **O. didactylus*, L.Perm.(Coconino Ss.), Ariz.; *2a*, ×0.8; *2b*, diagram of trackway, ×0.25 (Gilmore, 1927).

Oldhamia FORBES, 1849, p. 20 (publ. without formal species names; first description of species by KINAHAN, 1858, p. 69) [**O. antiqua* KINAHAN, 1858, p. 69; SD HÄNTZSCHEL, herein] [=*Murchisonites* GOEPPERT, 1860, p. 441 (type, *M. forbesi* GOEPPERT)]. Bunches of fine rills, radiating from joints of sympodial axis; representing a grazing pattern. [Numerous explanations of origin: as remains of algae, hydrozoans, bryozoans or of inorganic origin; first(?) interpretation as trace fossil by RUEDEMANN (1942) (radiating feeding trails supposedly made by worms); prevalent in Lower Cambrian turbidite successions; sometimes regarded as index fossil of Lower Cambrian; the Ordovician *"O." pedemontana* of Mendoza (RUSCONI, 1956) shown by FRITZ (1965) to be bryozoan (*Hallopora* sp.); *"O." keithi* RUEDEMANN (1942) (Ord., Gaspé) according to CHURKIN & BRABB (1965, p. D123), different in appearance and thus probably not belonging to *Oldhamia*.] *L.Cam.-M.Cam.*, Eu.-N.Am.——FIG. 53,*3a*. *O. radiata* FORBES, Cam., Ire.; ×1.3 (Sollas, 1900).——FIG. 53,*3b*. **O. antiqua*, Cam., Ire.; ×1.3 (Sollas, 1900).

Oniscoidichnus BRADY, 1949, p. 573 [**Isopodichnus filiciformis* BRADY, 1947, p. 470; M] [=*Isopodichnus* BRADY, 1947, p. 470, obj. (*non* BORNEMANN, 1889, p. 25)]. Track with low, sinuous median ridge and forward-pointing bractlike footprints on each side at intervals of about 1 mm.; width of entire track about 1 cm. [Resembles tracks of Recent isopod *Oniscus*.] *L.Perm.(Coconino Ss.)*, N.Am.(USA,Ariz.).——FIG. 53,*1a*. Trackway of *Oniscus* sp.; ×0.5 (Brady, 1947).——FIG. 53,*1b*. **O. filiciformis* (BRADY); ×0.5 (Brady, 1947).

Ophiomorpha LUNDGREN, 1891, p. 114 [*non* SZEPLIGET, 1905] [**O. nodosa*; M] [=*?Ophiomorpha* NILSSON in MANTELL, 1836, p. 25 *(nom. nud.)*; *Cylindrites spongioides* GOEPPERT, 1842 (?1841), p. 115 *(partim)*; *Spongites saxonicus* GEINITZ, 1842, p. 96 *(partim)*; *?Halymenites flexuosus* VON FISCHER-OOSTER, 1858, p. 55; *Cylindrites tuberosus* EICHWALD, 1865, p. 8; *Phymatoderma dienvalii* WATELET, 1866, p. 24; *Halymenites major* LESQUEREUX, 1873, p. 373; *?Broeckia bruxellensis* CARTER, 1877, p. 382 (*nom. oblit.* if identical with *Ophiomorpha*); *Astrophora* DEECKE, 1895, p. 167 (type, *A. baltica*); *Sabellastartites* DUDICH, 1962, p. 108 (type, *S. arenaceus*); for discussion see HÄNTZSCHEL, 1952, p. 144-149; for detailed list of synonyms of the type species see KENNEDY & MACDOUGALL, 1969, p. 460-461]. Three-dimensional burrow systems, vertical and horizontal; cylindrical tunnels (diam., 0.5-3 cm.) dichotomously branching, generally at acute angles; with local swellings close to or at points of branching; tunnels internally smooth, but outer surface of burrow lining characteristically mammillate due to presence of discoidal or ovoid pellets, which are several mm., rarely more, in diameter; tunnels may also be only partly lined by small pellets; longitudinal ridges occur on outer surface of some burrow fillings. Occasionally penetrating sediment for more than 1 m. in depth. [Doubtless to be ascribed to burrowing decapod crustaceans, particularly callianassids as proven by *Ophiomorpha*-like structures produced by Recent callianassids in modern sediments (WEIMER & HOYT, 1964); found associated in same rocks with *Callianassa* claws (Cret., Delaware) (PICKETT, *et al.*, 1971); swellings of the tunnels are "turn-arounds" of the animals; pellets cemented by the producer and put into the sides of the burrow; reticulate ridges on some burrows are scratches made by the inhabitant of the burrow, probably during initial burrowing; passing of warty exterior into smooth burrows observed (KENNEDY & SELLWOOD, 1970, p. 108). *O. borneensis* KEIJ, 1965, has been observed rarely to exhibit vertical, spiral burrows while in close association with horizontal ones, similar forms occur in sandy Tertiary sediments of West Germany (KILPPER, 1962, p. 57); *Ophiomorpha* occasionally seen to pass into *Thalassinoides* (AGER & WALLACE, 1970, p. 8) and rarely into wall-like structures similar to *Teichnichnus* (HESTER & PRYOR, 1972); cylindrical burrows with smooth walls (U.Cret., Saltholm Ls., Denm.) sometimes named *Ophiomorpha* in museum collections; generally regarded as indicator of marine environment, especially littoral, sublittoral, or upper neritic; for discussion of interpretation of occurrences in apparently brackish or freshwater environments see KENNEDY & MACDOUGALL (1969, p. 467); for a list of the very extensive literature on this trace fossil see KENNEDY & SELLWOOD (1970, p. 101) and MÜLLER (1969e, 1970b)]. *L.Jur.*, Greenl.; *M.Jur.-Pleist.*, cosmop.——FIG. 54,*1a*. *O. major* (LESQUEREUX), U.Cret., USA(N. Dak.); ×0.5 (Häntzschel, 1952).——FIG. 54,*1b*. **O. nodosa*, ?U.Cret. or L.Tert., S.Swed. (Scania); ×0.4 (Häntzschel, 1952). [CHAMBERLAIN & BAER (1973, p. 80) have recently extended the

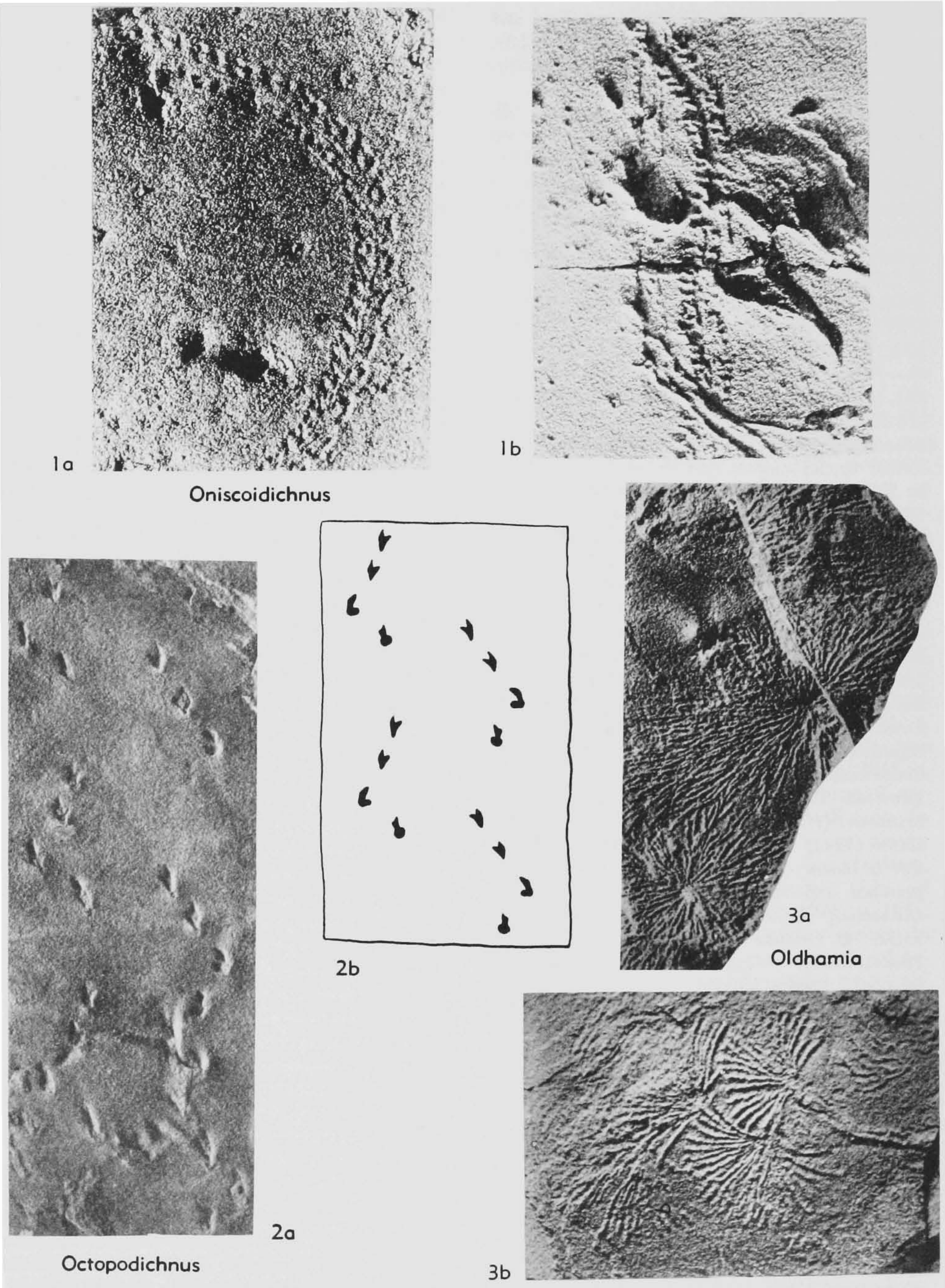

FIG. 53. Trace fossils (p. W85).

stratigraphic range of *Ophiomorpha*: *L.Perm. (Wolfcamp.),* N.Am.(USA,Utah); *low.U.Perm. (Zechstein),* Eu.——W. G. HAKES.]

Ormathichnus MILLER, 1880, p. 222 [**O. moniliformis*; M]. According to OSGOOD (1970, p. 372), "genus" comprising two different forms: 1) one

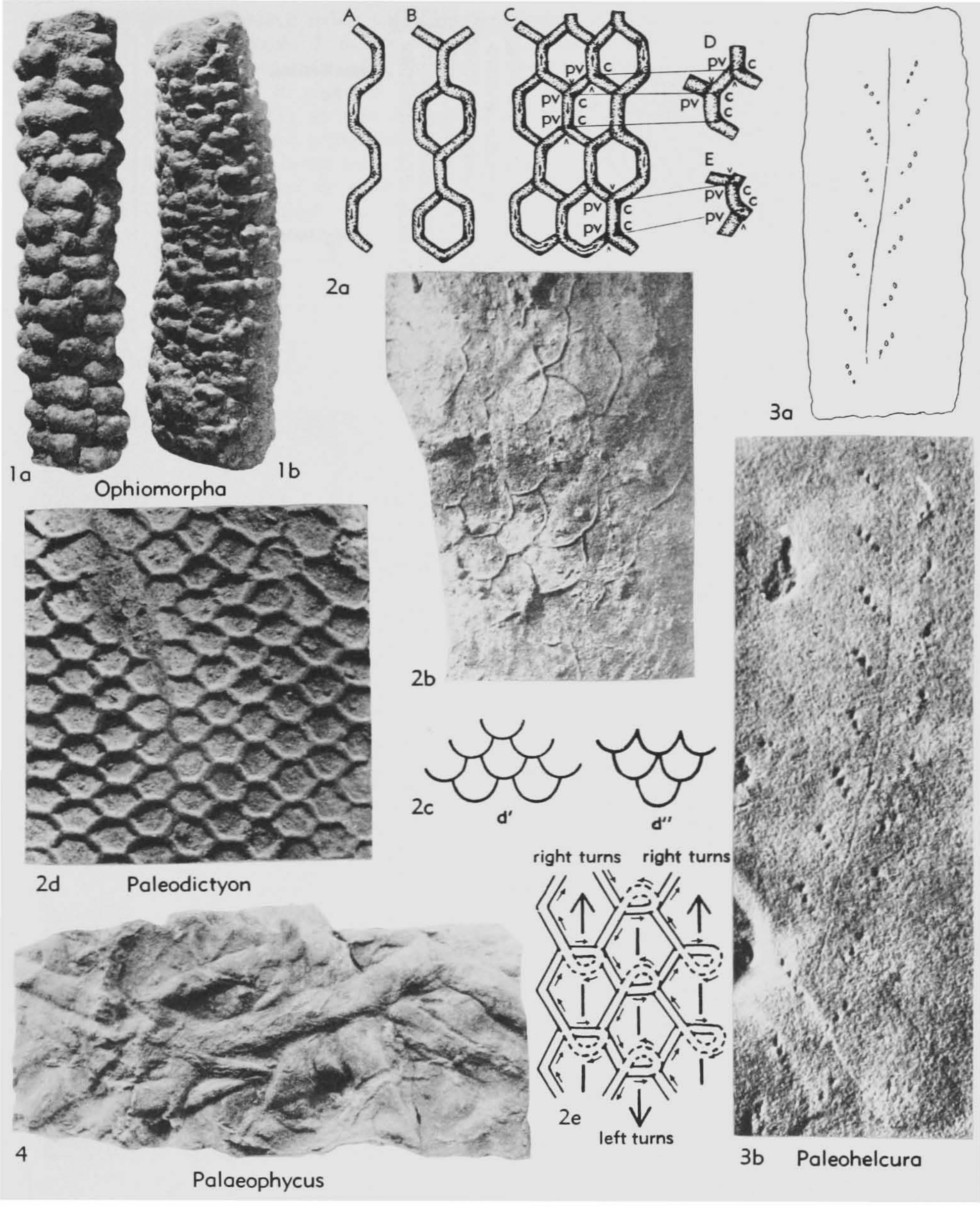

FIG. 54. Trace fossils (p. W85-86, 88-91).

syntype is a small trail, consisting of series of minute, disconnected *Rusophycus*-like bodies; 2) the other syntype was compared by MILLER with cast of column of *Heterocrinus*. [The first-mentioned specimen, according to OSGOOD (1970, p. 373) is trail of small arthropod (trilobite?), "a combination of *Cruziana* and *Rusophycus*"; the other syntype is certainly an inorganic tool mark (impression of a rolling crinoid stem) as supposed by JAMES (1886).] *U.Ord.(Cincinnat.)*, USA (Ohio).

Palaeohelminthoida RUCHHOLZ, 1967, p. 512 [**P. hercynia*; OD]. Very regular "guided meanders" like *Helminthoida* SCHAFHÄUTL, differing from it by very narrow, median, cordlike ridge and by close contact of meanders; trail about 4 mm.

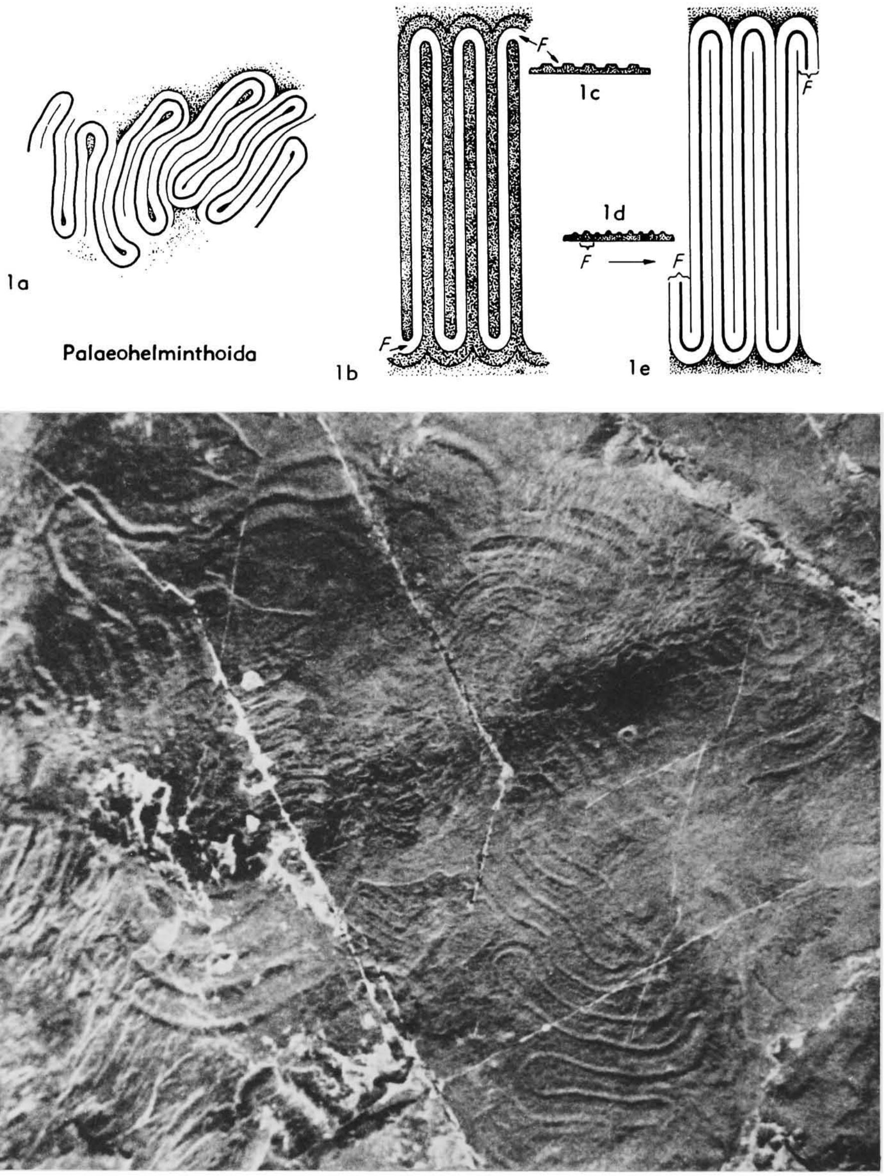

FIG. 55. Trace fossils (p. W87-88).

wide, length of meanders 3 to 6 cm.; rounded median ridge 1 mm. high, dividing trail into 2 smooth furrows. [Typical grazing trail.] *U.Dev., ?L.Carb.,* Eu.(Ger.,Hartz Mts.).——FIG. 55,*1a,f*. **P. hercynia,* U.Dev., S.Harz Mts., Ger.; *1a,* schem., ×0.7; *1f,* holotype, ×0.9 (Ruchholz, 1967).——FIG. 55,*1b-e*. Schematic comparison of *Helminthoida* (*1b,* plan view; *1c,* cross sec. view) and *Palaeohelminthoida* (*1d,* cross sec. view; *1e,* plan view) [*F,* trail] (Ruchholz, 1967).

Palaeophycus HALL, 1847, p. 7 [**P. tubularis*; SD BASSLER, 1915, p. 939] [=?*Aulacophycos* MASSALONGO, 1859, p. 92 (as generic name only proposed for *Palaeophycus simplex* HALL, 1847, p. 63); *Palaeospongia prisca* BORNEMANN, 1886, p. 21]. Ichnogenus showing wide range of morphology; cylindrical or subcylindrical burrows, usually sinuous, oriented more or less obliquely to bedding; commonly unbranched, though may be branched occasionally; surface of walls smooth or rarely with faint longitudinal striae; up to about 20 cm. or more in length; 3 to 15 mm. in diameter; commonly intersecting one another. [Originally considered to be stems of "fucoids," interpreted by JAMES (1885) as trace fossil; belongs to repichnia of infaunal origin; pathways of various groups of errant animals; neither parts of constructed tubes as suggested by several authors nor stuffed burrows of sediment ingestors; "no one has studied the genus in detail" (OSGOOD, 1970, p. 375); very many "species" established from different environments; impossible to list all "species" erroneously placed in *Palaeophycus,* e.g., *P. kochi* LUDWIG, 1869, p. 110 (="*Belorhaphe*" *kochi* MICHELAU, 1955) and *P. flexuosus* JAMES, 1879 (inorganic, according to OSGOOD, 1970, p. 393); genus often compared with *Planolites* NICHOLSON, 1873, but in *Palaeophycus* there is no distinct difference in lithology of the burrows and the host rock as in *Planolites*; for discussion see OSGOOD, 1970, p. 375; *Spongillopsis* GEINITZ, 1862, p. 132, established for *Palaeophycus* in lacustrine sediments (but *S. recurva* FLICHE, 1906, p. 34, belongs to *Rhizocorallium*, perhaps also *S. triadica* FLICHE, 1906, p. 33).] *Precam.-Rec.,* cosmop.——FIG. 54,*4*. **P. tubularis* HALL, 1847, Ord.(Beekmantown beds), USA(Amsterdam, New York); ×0.25 (Osgood, 1970).

Paleodictyon MENEGHINI in MURCHISON, 1850, p. 484 [**P. strozzii*; M] [=*Palaeodictyon, Palaeodictyum* AUCTT., *non* HEER, 1865, p. 245 (=jun. homonym of *Phycosiphon* VON FISCHER-OOSTER, 1858, p. 59)] [=*Reticulipora* STOPPANI, 1857, p. 407 (no type species designated); *Glenodictyum* VAN DER MARCK, 1863, p. 6 (type, *G. hexagonum*); *Cephalites maximus* EICHWALD, 1865, p. 82; *Paretodictyum* MAYER, 1878, p. 80 (no type species designated); *Palaeodyction* DE STEFANI, 1879, p. 446 *(nom. null.); Retiofucus* KEEPING, 1882, p. 488 (type, *R. extensus*); *Retiphycus* ULRICH, 1904, p. 139 (type, *R. hexagonale*); *Palaeopiscovum* BANYAI, 1939, p. 83 (no type species designated); the following "genera" may also be regarded as synonyms of *Paleodictyon* or as subgenera: *Priodictyon* VYALOV & GOLEV, 1960, p. 176 (established for small *Paleodictyon* on upper surfaces of beds; no formal species name); *Squamodictyon* VYALOV & GOLEV, 1960, p. 178 (type, *S. squamosum*) (established for *Paleodictyon* with meshes in outline resembling fish scales); *Largodictyon* VYALOV & GOLEV, 1965, p. 111 ("subg." of *Squamodictyon*); *"Pleurodictyon"* FUCHS, 1895, p. 394, considered to be named erroneously for *Paleodictyon* (used only in heading and in explanation of figure; no description of differences between *Paleodictyon* and *Pleurodictyon*)]. Honeycomblike network of ridges in hyporelief, consisting of remarkably regular hexagonal polygons; may be also 4- to 8-sided; reticulate pattern of considerably varying size (incomplete along margins) but diameter of meshes constant within individual net (from less than 1 mm. to about 50 mm.); walls of meshes 0.5 to 2 mm. wide and occasionally consisting of small circular or oval "pimples" closely arranged in rows which may cross one another regularly; networks may cover large areas up to about 1 sq. m.; polygons sometimes elongated due to current action. [One of the most famous Problematica, discussed for more than a century; interpreted as algae, sponges, corals, bryozoans, spawn of fishes or molluscs, and very often as inorganic in origin (infilled mud cracks, interference ripple marks, raindrop imprints); interpreted by FUCHS (1895) and ABEL (1935) as trace fossil; now thought to be grazing trails (SEILACHER, 1954, 1955); according to WOOD & SMITH (1959, p. 167), made by burrowing animals at interfaces of sandy and muddy sediment; manner of preservation in dispute, considered predepositional by SEILACHER (1962, p. 229) and WEBBY (1969a, p. 87) and postdepositional by SIMPSON (1967, p. 512) and KSIĄŻKIEWICZ (1970, p. 316) who believed that "evidence is conflicting" and "still open to argument"; preservation "pseudexogene" (SEILACHER, 1964, p. 292) = "preendogene" (WEBBY, 1969a, p. 91); for possible mode of origin discussed by WEBBY (1969a, p. 87) see Figure 54,*2e* (worms mining systematically in series through the sediment horizontally, regularly turning 120°, then overturning vertically in order to rejoin the tunnel at the last 120° section: this explanation assumes that producer is highly sensitive to thigmotaxis); for an explanation of polygons made by strictly planar feeding animal (simple meander pattern overlapping outside of each previous meander) see CHAMBERLAIN (1971a, p. 227); incomplete patterns and initial forms described as *Protopaleodictyon* KSIĄŻKIEWICZ (1970, p. 303) (see p. *W*97); more than 30 "species" have been named, many of them based on size of the meshes, their shape and thickness of walls; occurrences mainly in flysch deposits of all ages but also in facies intermediate between flysch and molasse and even (HÄNTZSCHEL, 1964) from epicontinental environment; representative for "*Nereites* facies." The following papers discuss *Paleodictyon,* its origin, synonymy and history; ANTONIAZZI (1966); NOWAK (1959); OSGOOD (1970, p. 384-386); SACCO (1939); SILVESTRI (1911); VYALOV & GOLEV (1960, 1964, 1966a); WANNER (1949); WEBBY (1969a).] *Ord.-Tert.,* Eu.-N. Am.-S. Am.-N. Afr.-Asia-Australia-N.Z.-Antarct. ——FIG. 54,*2a,b*. *P.* sp.; *2a, A-E,* development of structure, schem. [*c,* curve, v or ʌ, angle of convergence or divergence; *pv,* pseudoangle of truncation] (after Chamberlain, 1971a); *2b,* L. Cret. (Cieszyn limestones), Pol. (Coleszow), ×0.7 (Nowak, 1959).——FIG. 54,*2c*. *Paleodictyon* (="*Squamodictyon*" VYALOV & GOLEV),

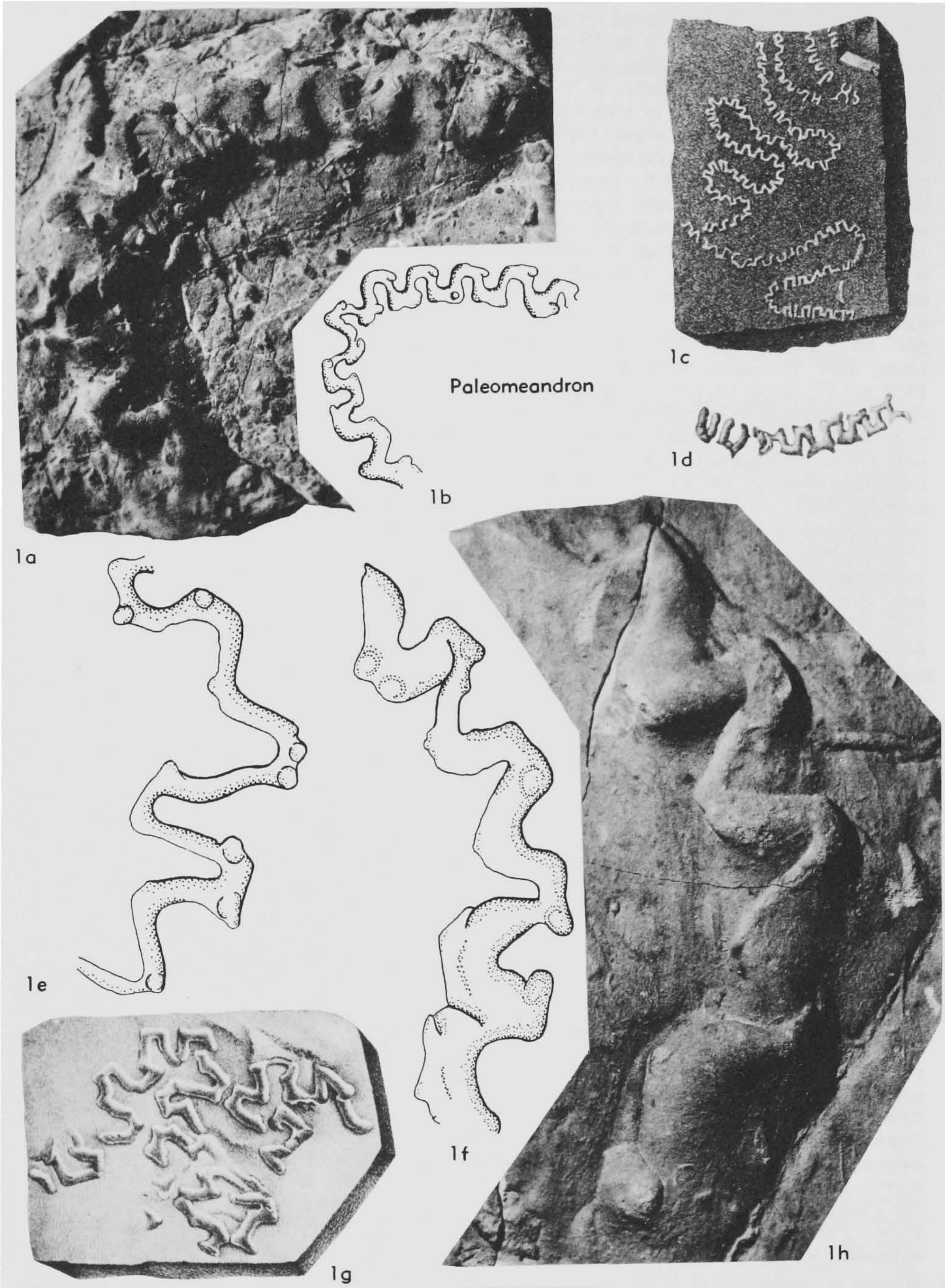

FIG. 56. Trace fossils (p. W91).

diagram. (Vyalov & Golev, 1960).——FIG. 54,2d. *P. regulare* SACCO, L.Tert.(flysch), Italy; ×0.4 (Seilacher in Häntzschel, 1962).——FIG. 54,2e. *P.* sp., interpretation of possible origin, schem. (Webby, 1969a).

Paleohelcura GILMORE, 1926, p. 31 [**P. tridactyla*;

M] [=*Palaeohelcura* BRADY, 1939, p. 32; 1961, p. 201 *(nom. null.)*]. Long continuous tracks, consisting of 2 parallel rows of foot imprints arranged in groups of 3; between them undulating drag mark occasionally present; groups of foot impressions arranged in straight line, inclined at 60° to 80° angle to median line; average width of track 25 mm.; stride varying from 14 to 22 mm. [Cluster of foot impressions made by apparently tridactyl pointed extremities, clusters alternating on both sides; probably made by small scorpionids as concluded by BRADY (1939, 1947, 1961) from his experiments with living scorpionid *Centruroides*.] *L.Perm.(Coconino Ss.)*, N.Am. (USA,Ariz.); *?L.Trias.*, Eu.(Ger.).——FIG. 54,*3*. **P. tridactyla*, Coconino Ss., Ariz.; *3a*, diagram of trackway; ×0.3; *3b*, ×0.3 (Gilmore, 1926).

Paleomeandron PERUZZI, 1881, p. 8 [**P. elegans*; SD HÄNTZSCHEL, herein] [=*Palaeomaeandron* FUCHS, 1895, p. 395 *(nom. null.)*]. Wide first order meanders consisting of small, mostly quadrangular, second order meanders with double-pointed corners; large meanders several cm. long, small meanders 1 to 5 mm. wide, rarely much larger (e.g., *P. robustum* KSIĄŻKIEWICZ, 1968). [Grazing trail.] [Found in flysch deposits.] *U. Cret.-L.Tert.*, Eu.(Aus.-Italy-Spain-Pol.)-S.Am. (Venez.).——FIG. 56,*1a,b,e*. *P. robustum* KSIĄŻKIEWICZ, low. and mid. Eoc. (Beloveza Beds), Pol.; *1a*, ×1 (Książkiewicz, 1968); *1b,e*, ×0.5 (Książkiewicz, M., 1970, p. 299, in: *Trace Fossils* edited by T. P. Crimes & J. C. Harper, Geol. Jour. Spec. Issue 3, Seel House Press, Liverpool). ——FIG. 56,*1c,d*. **P. elegans*, Eoc., Italy; *ca.* ×0.67 (Fuchs, 1895, after Peruzzi, 1881).——FIG. 56,*1f,h*. *P.* sp. *aff. P. robustum* KSIĄŻKIEWICZ, mid. Eoc. (Łącko Beds), Pol.; *1f,h*, ×0.5, ×0.7 (*1f*, Książkiewicz, M., 1970, p. 299, in: *Trace Fossils* edited by T. P. Crimes & J. C. Harper, Geol. Jour. Spec. Issue 3, Seel House Press, Liverpool; *1h*, Książkiewicz, 1968).——FIG. 56,*1g*. *P. rude*, Eoc., Italy; *ca.* ×2 (Peruzzi, 1881).

Palmichnium RICHTER, 1954, p. 267 [**P. palmatum*; OD]. Large, plantlike track, about 11 cm. wide; opposed symmetrical rows of [leg] impressions; median keel, divided at regular intervals; bordered by longitudinally directed club-shaped impressions distinctly set off toward interior, but indistinctly toward exterior. [Crawling track; made by arthropod, probably eurypterid; a similar track from Devonian of Antarctica is *Beaconichnus antarcticus* GEVERS, 1971 (see GEVERS *et al.*, 1971, p. 87, 93).] *L.Dev.*, Eu.(Ger.); *?L.Carb.(Kulm)*, Eu.(Ger.).——FIG. 57,*5*. **P. palmatum*, L.Dev., Ger.; *ca.* ×0.2 (Richter, 1954).

Parahaentzscheliana CHAMBERLAIN, 1971, p. 236 [**P. ardelia*; M] [=*Parathaentzscheliana* CHAMBERLAIN, 1971a, p. 236 *(nom. null.)*]. Numerous small tubes, about 15 to 20 mm. long, 1 to 2 mm. wide, radiating vertically and obliquely from common starting center within sediment upward to bedding plane, producing surface pattern (15 to 60 mm. in diameter) consisting of radially arranged openings which are mostly sediment-filled. *Penn.(AtokaF.)*, USA(Okla.).——FIG. 57, *4*. **P. ardelia*; schem. drawing, *4a*, plan pattern, ×0.9; *4b*, complete perforation of sediment, ×0.9 (Chamberlain, 1971a).

Paratisoa GAILLARD, 1972, p. 150 [**P. contorta*; OD]. Series of branching, straight to curved galleries (up to 40 mm. in diam.) with a small, characteristic axial tube (about 4 mm. in diam.); size of entire burrow system as much as 55 cm.; branchings can be either T- or Y-shaped; galleries may also possess distinct swellings and are commonly calcareous; axial tube commonly filled with ferruginous material. [Considered to have been produced by a marine burrowing annelid; similar to *Tisoa* (p. *W*117) but *Tisoa* does not branch and axial tube is U-shaped.] *Jur.(Oxford.)*, Eu.(France). [Description supplied by W. G. HAKES.]

Pennatulites DE STEFANI, 1885, p. 99 [*non* COCCHI, 1870, p. 116 *(nom. nud.)*] [**P. longespicata*; M] [=*Paleosceptron* DE STEFANI, 1885, p. 100 (type, *P. meneghinii*) (*non* COCCHI, 1870, p. 116, *nom. nud.*); *Virgularia presbytes* BAYER, 1955 (Tert. forms only)]. Thick cylindrical stalk (diameter about 4 cm.) followed by club- or ear-shaped part, with deep median furrow, consisting of biserially arranged overlapping rows of leaves; surface of ear-shaped part nodose, nodes arranged in parallel rows. [Regarded as alcyonarian by DE STEFANI (1885); certainly branching *Spreitenbau*; interpreted as feeding burrow by SEILACHER (1955, fig. 5). [Found in flysch deposits.] *Cret.-L.Tert.*, Eu. (Italy-Greece)-W.Indies (Trinidad). ——FIG. 57,*3a,b*. **P. longespicata*, U.Cret., Italy; *3a*, model, ×0.17 (Seilacher, 1955); *3b*, ×0.4 (de Stefani, 1885).

Permichnium GUTHÖRL, 1934, p. 174 [**P. völckeri*; OD]. Two parallel, equal, and equidistant rows of V-shaped foot impressions, open to exterior; indicative of equal walking feet with 2 claws each; somewhat similar to *Bifurculapes* HITCHCOCK, 1858. [Running track of insect (?blattoid).] *L.Perm.(Rotl.)*, Eu.(Ger.); *L.Trias.*, Eu.(Eng.).——FIG. 57,*1*. **P. voelckeri*, L.Perm. (Rotl.), Ger.; holotype, ×1.2 (Guthörl, 1934).

Petalichnus MILLER, 1880, p. 221 [**P. multipartitus*; M]. Simple or complex tracks of varied morphology, consisting of numerous transversely elongated unifid or bifid imprints, in complete series varying from 10 to 12; about 1 to 2 cm. wide. [Tracks indicating straight-ahead or slightly oblique movement of producer; tentatively regarded by MILLER (1880) to have been made by cephalopods (see TEICHERT, 1964b, p. *K*487); most probably tracks of moderately sized trilo-

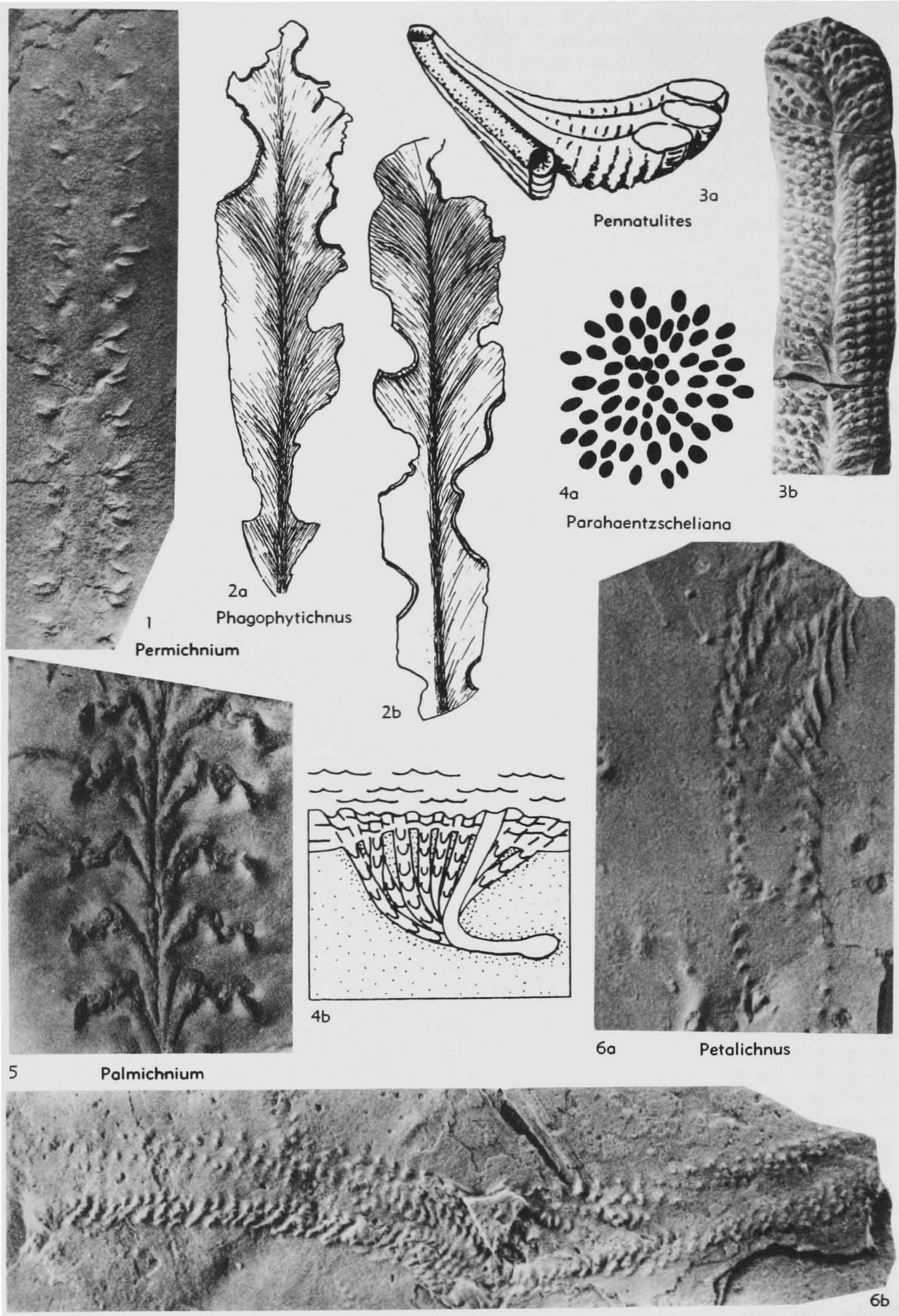

Fig. 57. Trace fossils (p. W91, 93).

bites, perhaps particularly by *Flexicalymene,* also by other trilobite genera, or even by other arthropods; OSGOOD (1970, p. 362) regarded the following as synonyms of type species: *Trachomatichnus permultus* MILLER, 1880, *T. cincinnatiensis* MILLER, 1880, and "*Merostomichnites* sp." (CASTER, 1938, p. 34).] *U.Ord.(Cincinnat.),* USA(Ohio).——FIG. 57,*6*. **P. multipartitus; 6a,* Eden beds, Ohio; ×0.9; *6b,* Southgate beds, Ohio (Hamilton Co.); *ca.* ×0.9 (Osgood, 1970).

Petaloglyphus VYALOV, GORBACH & DOBROVOLSKA, 1964, p. 94 [**P. krimensis*; OD]. Starlike trace fossil, insufficiently figured and described only in Ukrainian language. [Grazing trace with dwelling burrow.] *L.Cret.,* USSR(Crimea).

Phagophytichnus VAN AMERON, 1966, p. 182 [**P. ekowskii*; M]. Malformations of leaves of *Neuropteris praedentata* and *Glossopteris* sp., consisting of damaged margins nibbled by insects, leaving hemispherical or oval scallops, sometimes also broad concave or small uniform convex ones, rarely reaching midrib; ridge of scallops clearly marked and mostly thickened. *U.Carb.(Westphal. C),* Eu.(N.France), *U.Carb.(Stephan. B),* Eu. (N.Spain, Prov.Léon); *Permo-Carb.,* S.Afr.-Eu. (Spain).——FIG. 57,*2*. **P. ekowskii,* Perm.-Carb., Spain; *2a,b,* at a leaf of *Glossopteris,* ×0.7 (van Ameron, 1966).

Phoebichnus BROMLEY & ASGAARD, 1972, p. 29 [**P. trochoides*; OD]. Central shaft 6 to 8 cm. in diam., nearly vertical to bedding, with numerous, long, straight radial burrows oriented more or less parallel to bedding; radial burrows about 1.5 cm. in diam. including distinct, annulated wall lining about 5 mm. thick; mica flakes infilling of radial burrows oriented in discrete concavo-convex planes, concave toward central shaft; total length of shaft and tunnels unknown. [Central shaft interpreted as dominichnia, radial burrows as fodinichnia of same unknown animal; radial burrows actively filled.] *L.Jur.-M.Jur. (Bajoc.-Callov.),* Greenl.(Jameson Land).——FIG. 58,*1*. **P. trochoides,* low.Callov.; *1a,* schem. reconstr., ×0.15; *1b,* portion of holotype, ×0.25 (Bromley & Asgaard, 1972). [Description supplied by R. W. FREY.]

Pholeus FIEGE, 1944, p. 415 [**P. abomasoformis*; OD]. Large compactly cylindrical burrow with longitudinal axis parallel to bedding; anterior and posterior ends closed and rounded with 2 or more rounded tubes, oriented obliquely or vertically to bedding, leading to surface; walls lined with flakes. [Dwelling burrow, probably made by decapod crustaceans.] *M.Trias.(Muschelkalk);* Eu.(Ger.).——FIG. 59,*1*. **P. abomasoformis,* L. Muschelkalk, Ger.; ×0.4 (Fiege, 1944).

Phycodes RICHTER, 1850, p. 205 [*non* GUENEE, 1852; *nec* MILNE-EDWARDS, 1869] [**P. circinnatum* RICHTER, 1853, p. 20 (?=*Fucoides circinnatus* BRONGNIART, 1828); SM (see MÄGDEFRAU, 1934, p. 260)] [=*Licrophycus* BILLINGS,

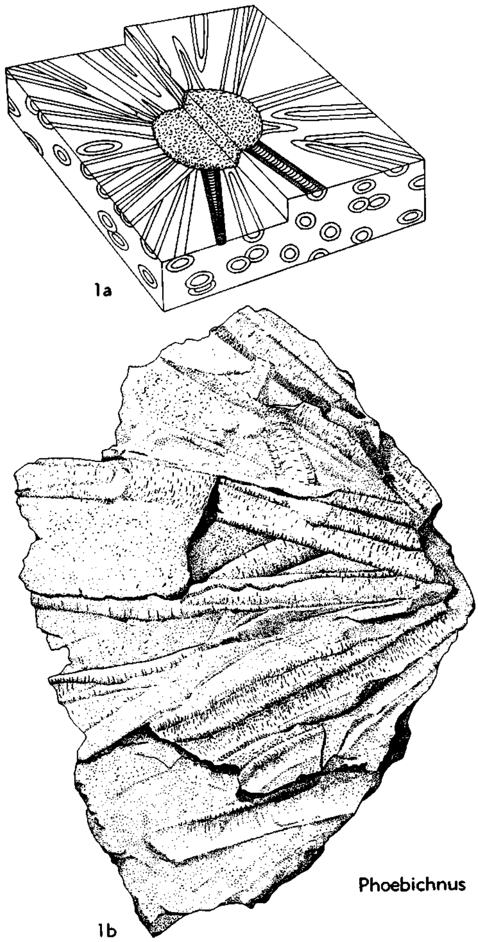

FIG. 58. Trace fossils (p. W93).

1862, p. 99 (type, *L. ottawaensis*); *Vexillum rouvillei* DE SAPORTA, 1884, p. 43; *Lycrophycus* TWENHOFEL, 1928, p. 83, 99 *(nom. null.)*; for discussion see MÄGDEFRAU (1934, p. 270) and OSGOOD (1970, p. 342)]. Bundled structures of flabellate or broomlike pattern, consisting of horizontal tunnels; proximal part of main tunnels unbranched, distal tunnels divide at acute angles into several free cylindrical tunnels showing delicate annulation beneath thin smooth "bark"; main branches may show structure similar to retrusive spreiten (absent in *P. flabellum* from Cincinnatian of USA); other "species" (e.g., *P. pedum* and *P. flabellum*) vary considerably in morphology from type species which is also variable (e.g., falcate or featherstitch-like pattern of feeding tunnels); about 15 cm. long in entirety; generally preserved as convex hyporeliefs in quartzites. [Originally interpreted as "fucoids"

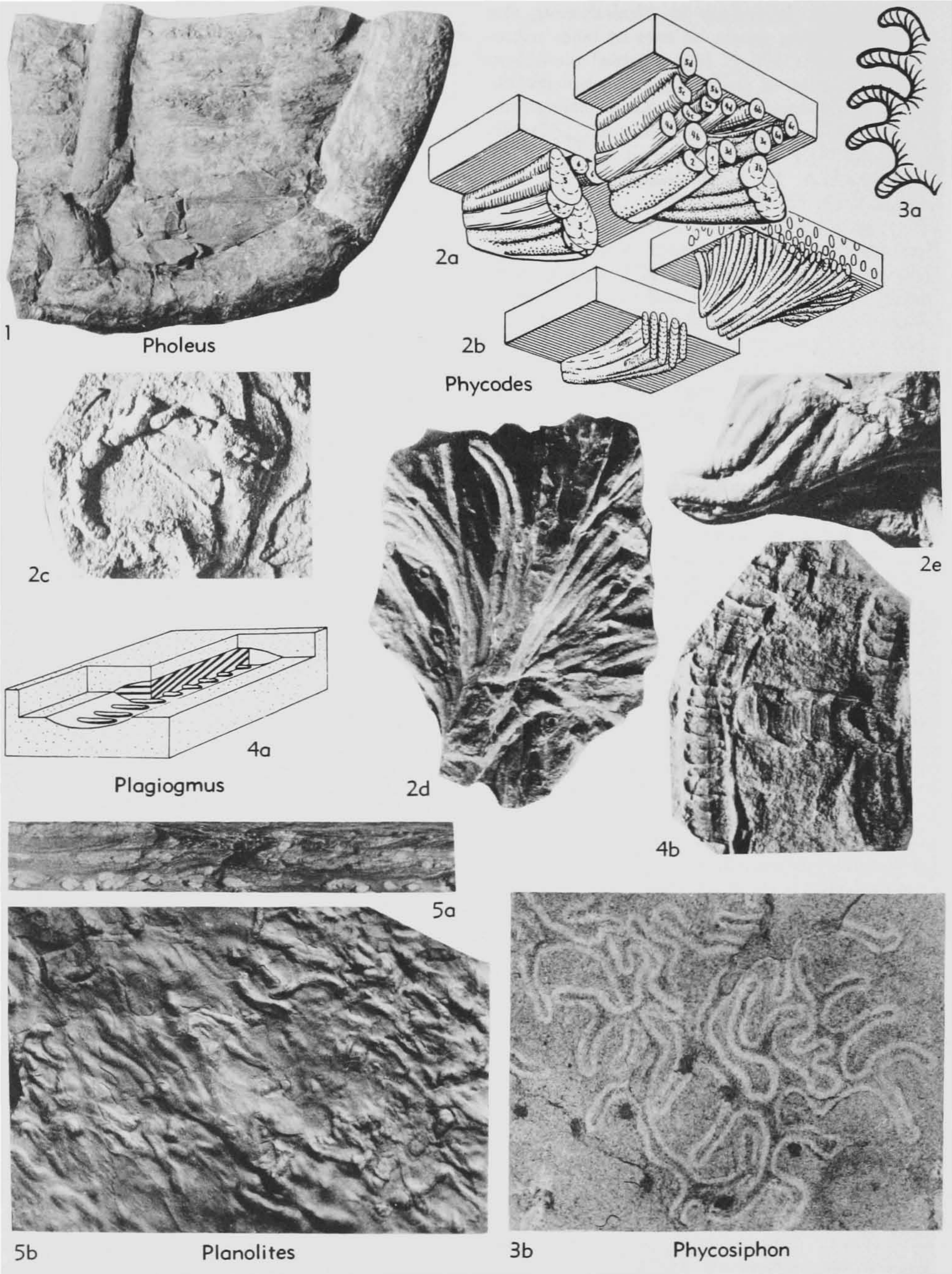

Fig. 59. Trace fossils (p. *W*93, 95-97).

or even as inorganic structures; certainly feeding structure of typical flabellate pattern; probably produced by sediment-feeding wormlike animal; relations of *Phycodes* to *Teichichnus* were discussed by Häntzschel & Reineck (1968, p. 26); *Arthrophycus* Hall, 1852, regarded by

SEILACHER (1955, p. 386) as junior synonym; *P. pedum* SEILACHER, according to OSGOOD (1970, p. 342), should be assigned to a separate genus; for detailed discussion see MÄGDEFRAU (1934), SEILACHER (1955, p. 383-388), and OSGOOD (1970, p. 341-343).] *?U.Precam.*, Australia; *Cam.*, Eu. (Eng.-Swed.-Nor.-Spain)-USA (Ariz.)-Asia (Pak.)-Australia; *Ord.*, Eu.(Eng.-France-Ger.)-N.Am.-S. Am.-Asia(Iraq)-N.Afr.(Libya); *L.Carb.*, Eu.(Scot.); *Jur.*, Eu.(Ger.-France-Swed.); *?Tert.(Mio.)*, N.Z. ——FIG. 59,*2a*. *P. cf. P. palmatum* (HALL), L. Cam., Pak.; model, ×0.7 (Seilacher, 1955).——FIG. 59,*2b,d*. **P. circinnatum; 2b*, L.Ord., Ger.; model, ×0.3 (Seilacher, 1955); *2d*, Ord.(Galena F.), USA(Minn.); ×0.7 (Mägdefrau, 1934).——FIG. 59,*2c*. *P. pedum* SEILACHER, Cam., Pak. (Salt Range); ×0.7 (Seilacher, 1955).——FIG. 59,*2e*. *P. palmatum* (HALL), Cam., Pak.(Salt Range); (arrow indicates direction of movement of producer), ×0.7 (Seilacher, 1955).

Phycosiphon VON FISCHER-OOSTER, 1858, p. 59 [**P. incertum*; M] [=*Palaeodictyon* HEER, 1865, p. 245 (type, *P. singulare*) (*non Paleodictyon* MENEGHINI in MURCHISON, 1850, often erroneously spelled *Palaeodictyon*); *Reticulum* DE STEFANI, 1879, p. 446 (type, *R. textum*) (*nom. nov. pro Palaeodictyon* HEER, 1865); *Eterodictyon* PERUZZI, 1881, p. 8 (type, *E. textum*); *Lophoctenium richteri* DELGADO, 1910, p. 51; *"Polydora?"* GÓMEZ DE LLARENA, 1946, p. 153]. Small U-shaped loops; frequently branched; in large numbers forming antler-shaped systems; similar to asymmetrical very small *Rhizocorallium*; parallel or oblique to bedding planes. [Feeding burrows; regarded by FISCHER & PAULUS (1969, p. 90) as true spreiten burrows, protrusively built; various forms (L.Carb., Kulm; Ger.) have been placed in *Phycosiphon* by PFEIFFER (1968, p. 676).] *Ord.-Carb.*, *Jur.-Tert.*, Eu.-USA(Okla.-Alaska). ——FIG. 59,*3*. **P. incertum; 3a*, U.Cret., Aus.; ×1 (Seilacher, 1955); *3b*, Eoc., Italy; ×2 (Seilacher in Häntzschel, 1962).

Phyllodocites GEINITZ, 1867, p. 1 [**Crossopodia thuringiaca* GEINITZ, 1864a, p. 3; SD HÄNTZSCHEL, 1962, p. *W*210]. Curved or meandering trails, similar to *Nereites*, up to several cm. wide; consisting of narrow median furrow (about 5 mm. wide); smooth or articulated, flanked on either side by oval lateral markings, mostly overlapping one another, somewhat irregularly but closely placed, resembling "foliaceous outgrowths." [Formerly regarded as parapodia of polychaetes, now interpreted as originating by turbation of sediment along sides of median string (the latter perhaps of fecal origin). Originally considered by GEINITZ (1867) to be impressions of the bodies of polychaetes related to *Phyllodoce*; interpreted by RAYMOND (1931a, p. 188) as feeding trails of branchiopods or phyllocarids; according to ABEL (1935, p. 241), made by gastropods. For discussion of *Phyllodocites* interpreted as endogene feeding burrows see also PFEIFFER, 1968, p. 686-687.] *Paleoz.*, Eu.-N.Am.

Phytopsis HALL, 1847, p. 38 [**P. tubulosum* HALL, 1847; SD HÄNTZSCHEL, 1966, p. 72]. Vertical inosculating tubes, straight or flexuous, nearly circular in section (5 to 10 mm. in diam.); variously branching, lined with dark material. [Originally described as probably a marine plant; according to RAYMOND (1931b, p. 195), probably burrows of polychaetes; another "species," *P. cellulosum* HALL, 1847, has been transferred to the tabulate corals as *Tetradium cellulosum* (HALL) (RAYMOND, 1931b, p. 197).] *Ord.*, USA (Ky.-Tenn.-N.Y.).

Pilichnia CHAMBERLAIN, 1971, p. 223 [**P. elliptica*; M] [=*Pilichna* CHAMBERLAIN, 1971a, p. 215, 224 (*nom. null.*)]. Large vertical or horizontal burrows, about 60 mm. wide; oval or elliptical in cross section. [Ill-defined form; name unnecessary.] *Penn.(WapanuckaLs.)*, USA(Okla.).

Plagiogmus ROEDEL, 1929, p. 51 [**P. arcuatus*; SD HÄNTZSCHEL, 1962, p. *W*210]. Smooth, flat, concave ribbon (1 to 2 cm. wide), straight or slightly curved; with pronounced single transverse ridges, mostly straight, usually not extending to sides, at regular or irregular intervals, also occasionally closely spaced, passing into obliquely textured band (backfill of trail) consisting of sandy laminae; rarely faint longitudinal furrows. [Formerly regarded as epichnial trail; according to GLAESSNER (1969, p. 387), endichnial burrow parallel to bedding; perhaps made by ancestral mollusk with foot and mantle feeding in sediment and backfilling its trail with rejected sediment; smooth surface of burrow cemented by mucus.] *?L.Cam.-?M.Cam.*, N.Am.(USA, Wyo.); *L. Cam.*, Eu.(Swed.-Nor.)-Greenl.-Australia; *L.Cam.* (Pleist. drift), Eu.(N.Ger.).——FIG. 59,*4*. **P. arcuatus*, Cam.(Pleist. drift), Ger.; *4a*, block diagram explaining endichnial burrow interpretation, filling shown by cross hatching (Glaessner, 1969); *4b*, ×0.4 (Roedel, 1929). [Also found in *U.Precam.*, USSR(Russ. Plat.).]

Plangtichnus MILLER, 1889, p. 580 [**P. erraticus*; OD]. Simple narrow trail, smooth, irregularly zigzagging in every direction. [Made by larva or pupa of palaeodictyopterous insect?] *L.Carb. (Kaskaskia Gr.)*, USA(Ind.).

Planolites NICHOLSON, 1873, p. 289 [**P. vulgaris* NICHOLSON & HINDE, 1875, p. 139 (=*P. vulgaris* NICHOLSON, 1873, p. 290, *nom. nud.*); SD HOWELL, 1943, p. 17] [=*?Scolecites* SALTER, 1873, p. 2, 10 (without formal species name)]. Cylindrical or subcylindrical infilled burrows (diam. up to 15 mm.), straight to gently curved, nonbranching; usually more or less horizontal or oblique to bedding planes, penetrating sediment in irregular course and direction, may cross one another. [Interpreted as infilled endichnial burrows (German, *"Stopftunnel"*); the name *Plano-*

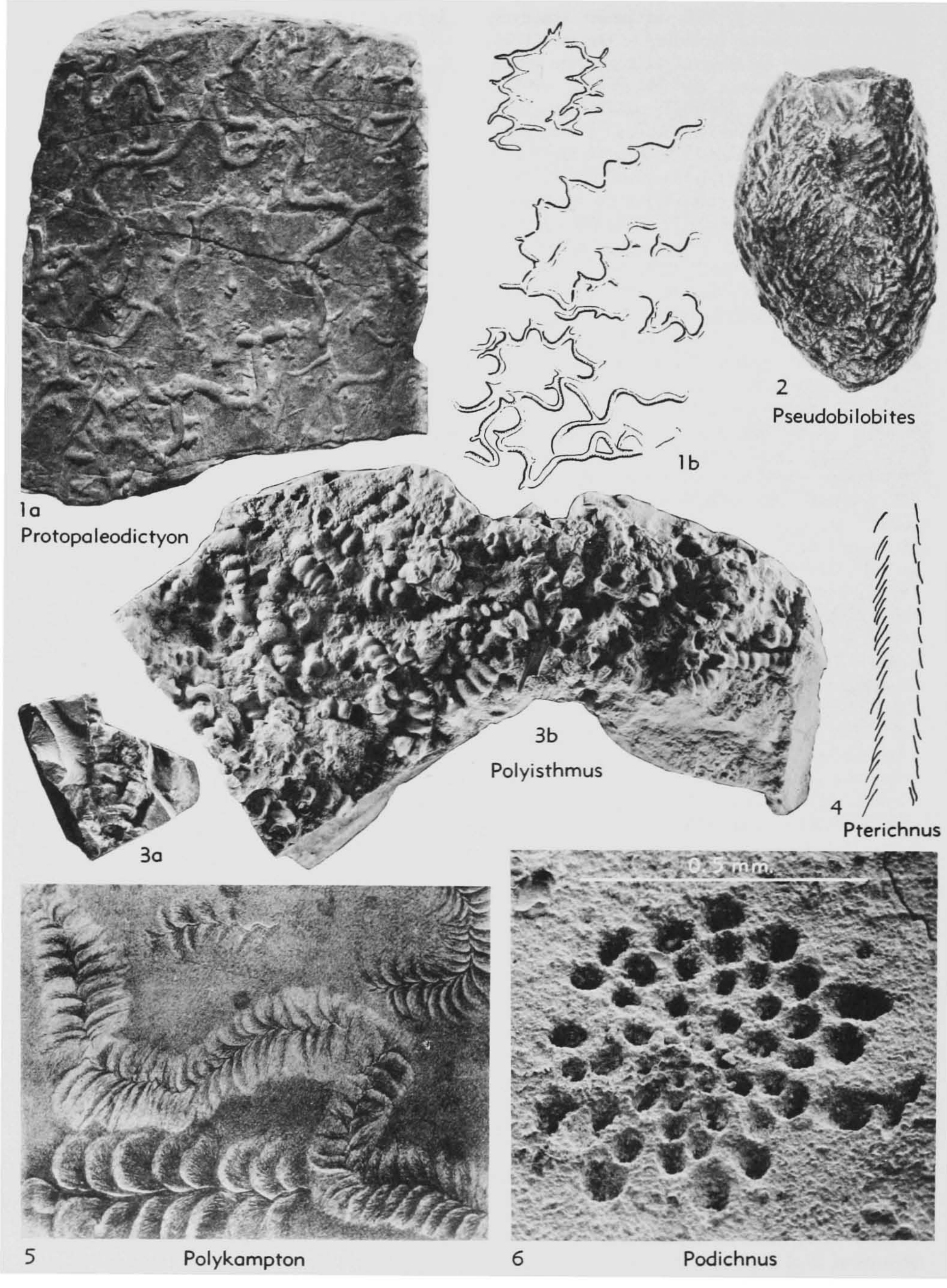

FIG. 60. Trace fossils, boring (p. *W*97, 99, 131).

lites explicitly established by NICHOLSON (1873, p. 288) for "burrows filled up with the sand or mud which worm has passed through its alimentary canal"; simple burrows showing transverse annulation ("packing structure," "backfilling") have been placed in *Planolites* by several authors (e.g., by CHISHOLM (1970, p. 24) for trace fossils from Carboniferous of Scotland). *Planolites* is often difficult to distinguish from morphologically similar *Palaeophycus* HALL; for discussion see OSGOOD (1970, p. 376) (fillings of *Palaeophycus* are generally regarded as apparently not having been passed through gut of animals); several "species" assigned to *Palaeophycus, Chondrites,* and even *Arthrophycus* more correctly referable to *Planolites; P. rugulosus* REINECK, 1955, type species of *Scoyenia* WHITE; *P. ophthalmoides* JESSEN, 1950, type species of *Opthalmidium* PFEIFFER, 1968 (superfluous name), for discussion of that "species" see SEILACHER (1963, p. 84), "guide fossil" for Upper Carboniferous *"Augenschiefer"* of Westphalia; Precambrian "species" described by WALCOTT (1899, 1914) were recently interpreted by CLOUD (1968, p. 55) as "algal?".] *Precam.-Rec.,* cosmop.——FIG. 59,*5*. *P. montanus,* U.Carb., Ger.; *5a,* transv. sec., ×0.7; *5b,* ×1 (Richter, 1937).

Polyisthmus BARTHEL, 1969, p. 128 [**P. enigma*; OD]. Fragmentary burrows, long-cylindrical to tapering; regularly widening and narrowing (3 to 9 mm. wide); intervals of constrictions sometimes variable; cross section circular to oval; wall smooth; greatest length of fragments observed about 3 cm.; whole burrow consists of 2 parallel pieces which converge V-shaped downward; mostly only washed-out fragments of whole broken burrows preserved. [Interpretation of construction of burrow difficult.] *U.Jur.(U.Tithon., U.Neuburg F.),* Eu.(Ger., Bavaria).——FIG. 60,*3*. **P. enigma; 3a,* holotype; *3b,* paratype, both ×0.7 (Barthel, 1969).

Polykampton OOSTER, 1869, p. 23 [**P. Alpinum*; M] [=*Polycampton* FUCHS, 1895, p. 433, *nom. null.*]. Central zigzag-shaped stalk, at angles of stalk featherlike bunches grow out at both sides with backwardly directed curvature; externally similar to *Sertularia.* [Interpreted originally as hydrozoan; explained by FUCHS (1895, p. 433) as spawn ribbons of gastropods (see also EHRENBERG, 1941, p. 303); according to SEILACHER (1959, p. 1070), feedng burrow with alternating fanlike feeding fields.] [Found in flysch deposits.] *Trias., Cret.-L.Tert.,* Eu.(Switz.-Aus.-Spain).——FIG. 60,*5*. **P. alpinum,* Trias., Switz.; *ca.* ×0.3 (Ooster, 1869).

Protichnites OWEN, 1852, p. 214 [**P. septemnotatus*; SD HÄNTZSCHEL, 1962, p. *W*210] [=*Protichnides* CHAPMAN, 1878, p. 490 *(nom. null.)*]. Two rows of bifid or trifid imprints and a commonly narrow, intermittent double drag trail in the middle; tracks irregularly and closely set; trackway in places connected with the resting trace *Rusophycus.* [Interpreted as tracks of limulids, crablike crustaceans or most probably trilobites moving straight forward (WALCOTT, 1912b, p. 275; 1918, p. 174), but also of gastropods; for discussion of the "genus" see BURLING (1917, p. 387) and OSGOOD (1970, p. 352); several "species," according to STØRMER (1934, p. 22), belong to *Merostomichnites*; see also ÖPIK (1959, p. 8).] *L.Cam.,* Asia(Pak.)-Can.; *U.Cam.,* N.Am.-Asia M.; *?Cam., ?Ord.,* W.Australia.——FIG. 61,*1b*. *P.* sp., L.Cam.(Jutana Dol.), Pak. (Salt Range); trail starting from *Rusophycus* impression, ×1.5 (Seilacher, 1955).——FIG. 61,*1a*. **P. septemnotatus,* U.Cam.(Potsdam Ss.), Can.(Que.); track, ×0.5 (Walcott, 1912b).——FIG. 61,*1c*. *P. logananus* MARSH, U.Cam., USA(N.Y.); track, ×0.1 (Walcott, 1912b).

Protopaleodictyon KSIĄŻKIEWICZ, 1970, p. 303 [**P. incompositum*; OD] [=*Protopalaeodictyon* KSIĄŻKIEWICZ, 1958, expl. pl. 2 *(nom. nud.); Protopalaeodictyum* NOWAK, 1959, p. 119, 125; *(nom. nud.); Protopalaeodictyon* KSIĄŻKIEWICZ, 1960, p. 737, 745 *(nom. nud.); ?Unarites* MACSOTAY, 1967, p. 38 (type, *U. suleki*); *?Spinorhaphe* PFEIFFER, 1968, p. 681 (type, *Palaeophycus spinatus* GEINITZ, 1867a, p. 16); *?Pseudopaleodictyon* PFEIFFER, 1968, p. 674 (type, *Palaeophycus hartungi* GEINITZ, 1867a, p. 16)]. Initial, irregular forms of *Paleodictyon,* quite variable, less regular, not strictly polygonal pattern; mostly meanders with ramifications on their apices; sometimes representing transitional forms from *Cosmorhaphe* or *Belorhaphe* to *Protopaleodictyon,* therefore is a combination of features of these ichnogenera. [Found in flysch deposits.] *?L.Carb.(Kulm),* Eu.(Ger.); *L.Cret.,* Japan; *Cret.-L.Tert.,* Eu.(Pol.-Aus.-Spain); *?Cret.-L.Tert.,* S. Am.(Venez.).——FIG. 60,*1a*. *P.* sp., low.Eoc. (Beloveza Beds), Pol. (Carpath.); ×0.7 (Książkiewicz, 1960).——FIG. 60,*1b*. **P. incompositum,* mid. Eoc. (Hieroglyphic beds), Pol.(Przykrzec); ×0.3 (Książkiewicz, M., 1970, p. 302, in: *Trace Fossils* edited by T. P. Crimes & J. C. Harper, Geol. Jour. Spec. Issue 3, Seel House Press, Liverpool).

Protovirgularia M'COY, 1850, p. 272 [**P. dichotoma* (=*?Cladograpsus nereitarum* RICHTER, 1853, p. 450; *Triplograpsus nereitarum* RICHTER, 1871, p. 251); M] [=*Provirgularia* GÜMBEL, 1879, p. 469 *(nom. null.)*]. Small keel-like trail, a few mm. wide, mostly straight or slightly curved, may branch dichotomously; consisting of an elevated median line and lateral wedge-shaped appendages, alternating on both sides. [Regarded by M'COY as octocoral because of its similarity to the Recent octocoral *Virgularia*; as late as 1952 considered an octocoral *incertae sedis* by ALLOITEAU (1952, p. 415); ascribed to graptolites by RICHTER (1853a, 1871); undoubtedly a trail as recognized by NATHORST (1881a, p. 85), belonging to "group" *Ichnia spicea* RUDOLF RICHTER (1941, p. 229); for detailed discussion see HÄNTZSCHEL, (1958, p. 84) and VOLK (1961); producing animal unknown.] *Ord.,* Eng.; *L.Dev.-M.Dev.,* Eu.(Ger.); *L.Carb.(Kulm),* Eu.(Ger.).——FIG. 61,*2*. *P. nereitarum* (RICHTER), M.Dev.

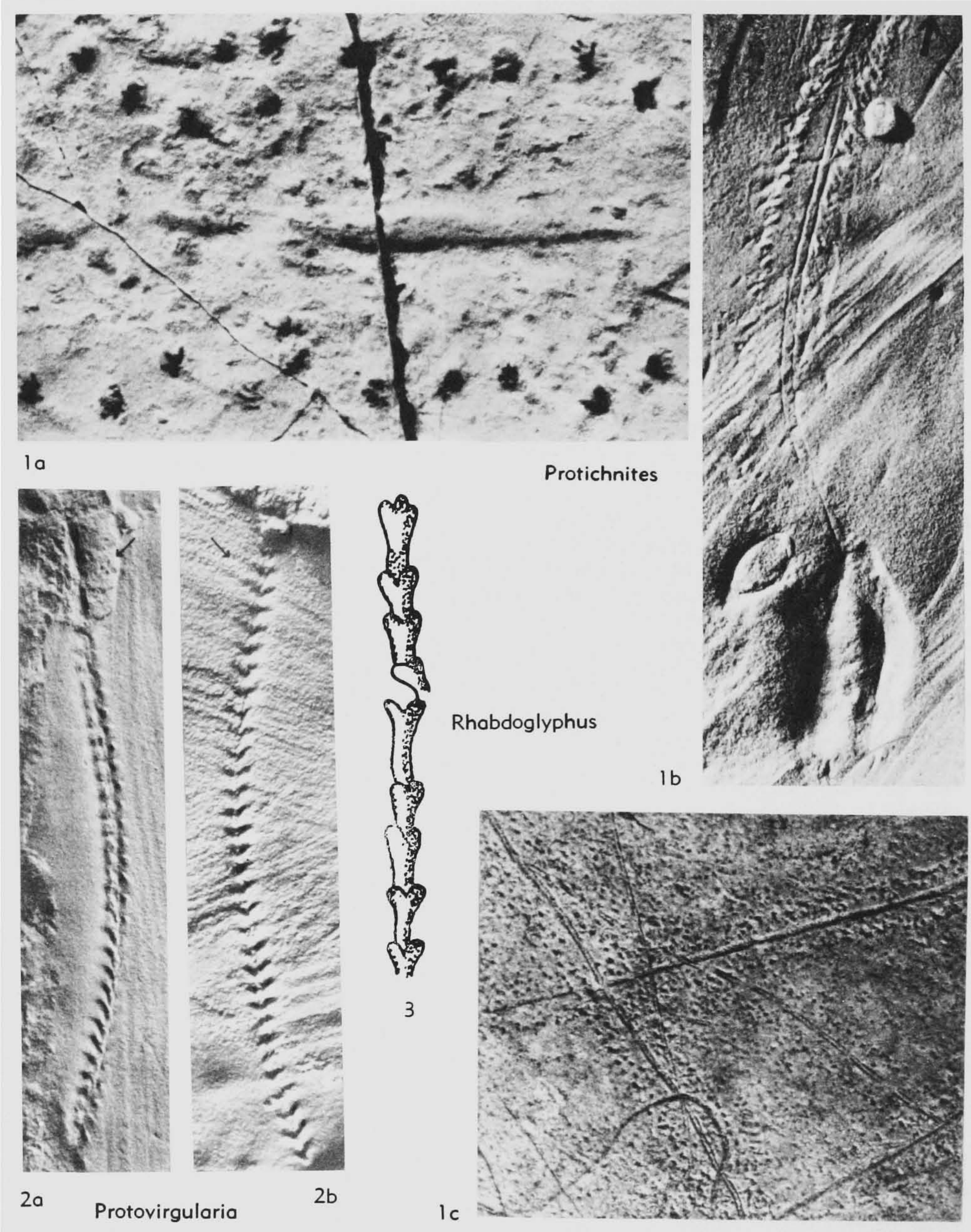

FIG. 61. Trace fossils (p W97-99).

("Nereiten-Schiefer"), Ger.(Thuringia); *2a,b*, ×2.25 (Volk, 1961).

Psammichnites TORELL, 1870, p. 9 [**Arenicolites gigas* TORELL, 1868, p. 34; SD FISCHER & PAULUS, 1969, p. 91] [=?*Cymaderma* DUNS, 1877, p. 352 (no formal species named)]. Large ribbonlike trails with narrow longitudinal median ridge; convex upper surface; mostly very flexuous, about 2 to 5 cm. wide; with very fine transverse ridges closely spaced. [Usually interpreted as trails made by burrowing gastropods; according to GLAESSNER (1969, p. 389) by mollusks without shells; belonging to the "group" *Scolicia* DE QUATREFAGES, 1849; interpreted by HÖGBOM (1926) as sandy excrements of worms or content of their intestines; regarded by HADDING (1929, p. 58) as worm trails.] *L.Cam.*, Eu.(Ire.-S.Swed.)-Can.; *L.Cam.*(Pleist.drift), Eu.(Ger.-Denm.); *?M.Dev.*, Eu.(Ger.); *?Penn.*, USA(Okla.).——FIG. 62,*2a,b*. *P.* sp., L.Cam.; *2a*, Swed., ×0.25; *2b*, loc. unknown, ×0.7 (Häntzschel, 1964b).——FIG. 62,*2c*. **P. gigas* (TORELL), L.Cam., S.Swed.; ×0.7 (Torell, 1868).

Pseudobilobites KENNEDY, 1967, p. 153 [**P. jefferiesi* KENNEDY, 1967, p. 154; OD] [=Pseudobilobite BARROIS, 1882, p. 175; *Pseudobilobites* BARROIS (in LESSERTISSEUR, 1955, p. 45 *(nom. nud.)*)]. Ovoid or rounded masses of shell fragments and sand-size microfossils cemented by calcite; 3 to 7 cm. long; upper surface mostly flat or slightly concave, smooth or somewhat granular; lower surface convex, covered by groups of short more or less parallel ridges inclined to long axis of structure. [Apparently surface trace made by crustaceans; for discussion see KENNEDY, 1967, p. 155.] [Author of this ichnogenus is neither BARROIS, 1882 (intended by him as a vernacular name) nor LESSERTISSEUR, 1955, p. 45, as attributed by KENNEDY (1967, p. 154); LESSERTISSEUR neither published a diagnosis nor designated a type species; conditions for the establishment of a valid generic name were fulfilled only by KENNEDY (1967).] *U.Cret.*, Eu.(Eng.-France).——FIG. 60,*2*. **P. jefferiesi*, mid.Cenoman.(Lower Chalk), S.Eng.(Buckinghamsh.); holotype, ×0.7 (Kennedy, 1967).

Pterichnus HITCHCOCK, 1865, p. 14 [**Acanthichnus tardigradus* HITCHCOCK, 1858, p. 151; OD]. Two rows of numerous [foot] imprints, turned outward from median line at angle of 15 to 20 degrees; width of track about 12 mm., foot imprints 3 mm. long. [?Myriapod track.] *Trias.*, USA(Mass.).——FIG. 60,*4*. **P. tardigradus* (HITCHCOCK); ×0.7 (Hitchcock, 1858).

Pteridichnites CLARKE & SWARTZ, 1913, p. 545 [**P. biseriatus*; M]. Two rows of small pits bordered by narrow elevated margin; about 4 mm. wide; median ridge crenulated; pits nearly equidimensional, alternating in position; somewhat similar to *Nereites*. [Interpreted as crawling trail of arthropod or annelid.] *U.Dev.*, USA (Md.).——FIG. 62,*3*. **P. biseriatus*, Jennings F.; ×1 (Clarke & Swartz, 1913).

Quebecichnus HOFMANN, 1972, p. 196 [**Q. lauzonensis*; OD]. Large, uniformly branching burrow systems along bedding planes; containing cylindroidal to ellipsoidal fecal pellets. Branches generally nearly rectilinear, fairly uniform in length (10-30 cm.) and width (1.5 cm.), developed by repeated equal, distally directed, lateral forking from opposite points along distal half of individual segments. Burrows show multiple laminations indicative of upward displacement of burrows during successive stages of occupation, similar to *Teichnichnus*. [Possible interpretation as being produced by one or several worms systematically traversing sediment.] *L. Ord.*, Can.——FIG. 62,*4*. **Q. lauzonensis*, Quebec Gr.; ×0.16 (Hofmann, 1972b). [Description supplied by W. G. HAKES.]

Radiichnus KARASZEWSKI, 1973, p. 159 [**R. staszic*; M]. Starlike trace fossil preserved in convex hyporelief; 6 to 7 cm. in diameter, maximum thickness (11 cm.) in central region (diam. 6-10 mm.) from which radiate approximately 30 ridges (1.5 mm. wide, 2-4 mm. in relief) grouped in "bundles"; ridges commonly bifurcate toward margins and occasionally reach margins. [Mold of a structure produced in sand by the movement of the antenna of a worm living buried in the sediment or the accumulation of undigested mud arranged by worm.] *Jur. (Bathon.)*, Eu.(Pol.). [Description supplied by W. G. HAKES.]

Radionereites GREGORY, 1969, p. 10 [**R. ballancei*; OD]. Featherlike structures of uniform size, arranged in radiating clusters consisting of sand-filled tubes; single burrows with narrow central rounded axis 2 to 4 mm. wide and about 10 cm. long; flanked bilaterally by closely set, opposed, leaf-shaped, lobate extensions, each up to 1 cm. long, arranged regularly at equal intervals and diverging at acute angles. [In first description by BARTRUM (1948, p. 489) "fucoid" or sponge affinities were suggested; later interpreted as feeding burrows by BALLANCE (1964, p. 492) and GREGORY (1969, p. 10).] *U.Tert.(low.Mio., Waitemata Gr.)*, N.Z.——FIG. 62,*1*. *R.* sp., Auckland; ×0.3 (Bartrum, 1948).

Radomorpha VYALOV, 1966, p. 72 [**R. ferganensis*; OD]. Straight, curved, or branching burrows, either single or forming complex patterns, characterized by longitudinal furrows. *Tert.(Oligo.)*, USSR(Ferghana). [Description supplied by CURT TEICHERT.]

Rauffella ULRICH, 1889, p. 235 [**R. filosa*; OD] [=*Raufela* SARDESON, 1896, p. 78; *nom. null.*] Only *R. palmipes* ULRICH a true trace fossil similar to *Arthrophycus* HALL; other species sponges or *incertae sedis* (see DE LAUBENFELS, 1955, p. *E*107). *U.Ord.*, USA.

Rhabdoglyphus VASSOEVICH, 1951, p. 61 [**R. grossheimi*; M]. Cylindrical tubes consisting of short, closely spaced, invaginated "calyces," some with short branches; preserved in convex hyporelief. [Trail of uncertain origin; considered post-depositional by KSIĄŻKIEWICZ (1970, p. 315-316). FUCHS (1895, p. 391) described "Rhabdoglyphen" from Austrian flysch deposits, several of his forms similar to paper bags packed one inside another.] *Cret.(Cenoman.)*, USSR(Azerbaidj.).——FIG. 61, *3*. *R. grossheimi*, U.Cret., Caucasus; ×1 (Vyalov, 1971).

[This trace fossil has a somewhat confused nomenclatural history. HÄNTZSCHEL (1965, p. 78) felt that an adequate

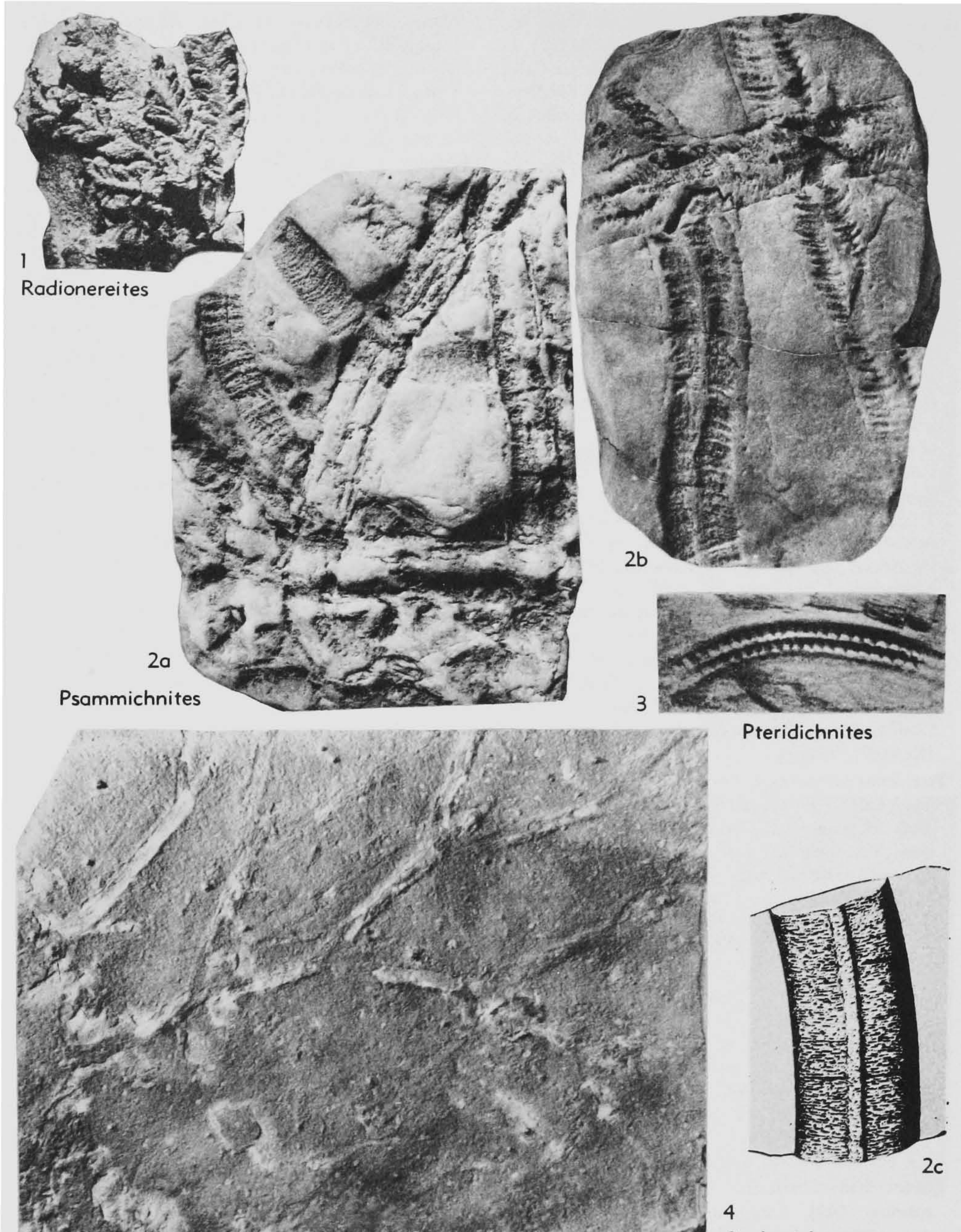

FIG. 62. Trace fossils (p. W98-99).

description of *Rhabdoglyphus* had not been provided by VASSOEVICH in either 1951 or 1953. He therefore claimed that the conditions of availability for the name had subsequently been met by BOUČEK & ELIÁŠ (1962, p. 146) nearly a decade later. However, after inspection of a rare copy of VASSOEVICH (1951), kindly lent to us by M. KSIĄŻKIEWICZ, it was found that an adequate description appears in the explanations of Plate V, figure 3 and Plate VI, figures 3 & 4, both on p. 219. BOUČEK & ELIÁŠ seem to have only expanded the description of *Rhabdoglyphus* VASSOEVICH and complicated matters by figuring specimens much different from the material described by

VASSOEVICH originally. This has been pointed out by KSIĄŻKIEWICZ (1970, p. 286-287). As a result, the figured specimens of BOUČEK & ELIÁŠ have been mistakenly considered *Rhabdoglyphus* by HÄNTZSCHEL (1965, p. 75; 1966, p. 15) and OSGOOD (1970, p. 369).

VYALOV (1971, p. 90) finally clarified matters by introducing the new name *Fustiglyphus* for the material figured by BOUČEK & ELIÁŠ and restricting the name *Rhabdoglyphus* to the material described by VASSOEVICH (see *Fustiglyphus*, p. W64).—CURT TEICHERT, W. G. HAKES.]

Rhizocorallium ZENKER, 1836, p. 219 [**R. jenense* (=*Spongia rhizocorallium* GEINITZ, 1846, p. 695); M] [=?*Lithochela* GÜMBEL, 1861, p. 411 (type, *L. problematica*); *Glossifungites* LOMNICKI, 1886, p. 99 (type, *G. saxicava*); ?*Myelophycus* ULRICH, 1904, p. 145 (type, *M. curvatum*); *Spongillopsis recurva* FLICHE, 1906, p. 34; ?*Spongillopsis triadica* FLICHE, 1906, p. 33; *Lissonites* DOUVILLÉ, 1908, p. 367 (provided for *Taonurus saportai* DEWALQUE, 1882, to be ascribed to *Rhizocorallium*); *Glossofungites* FRITEL, 1925, p. 35 *(nom. null.)*; *Cavernaecola* BENTZ, 1929, p. 1181 (type, *C. baertlingi*); *Upsiloides* BYRNE & BRANSON, 1941, p. 261 (type, *U. permiana*); *Rhizocorallum* SULLIVAN & ÖPIK, 1951, p. 13 *(nom. null.)*; *Rhyzocorallium* HARY, 1969, p. 120 *(nom. null.)*; for discussion of *Cavernaecola* see HAMM, 1929, p. 105, and KEMPER, 1968, p. 64-67)]. Simple U-tubes with spreite, generally protrusive, or somewhat oblique to bedding; "arms" more or less parallel, several cm. apart; very rarely branched, occasionally with lateral flaps; tubes relatively thick (1 cm. or more), commonly initially vertical for several cm. downward, then sharply bending at right angle; outer side of many tubes often marked by numerous striae interpreted as scratch markings indicative of crustaceans (see WEIGELT, 1929); pills of ellipsoidal excrements may be incorporated in walls or within tube; median line of U often curved; horizontal forms on bedding planes characteristically winding. [Tentatively interpreted originally as sponges or corals; now regarded as burrows of deposit-feeding animals, or perhaps as dwelling burrows of plankton-feeding animals (VEEVERS, 1962, p. 10: "protective nest") for discussion of mode of life of *Rhizocorallium* animal see SELLWOOD, 1970, p. 494; parallel orientation of *Rhizocorallium* tubes observed in Jurassic of England (AGER & WALLACE, 1970, p. 14); interpreted by FARROW (1966, p. 132, 146) as orientation in response to tidal currents, oblique or horizontal position possibly depending on water depth (see AGER & WALLACE, 1970, p. 15); horizontal tubes of 70 cm. and more long have been observed (Jur., Eng.; see FARROW, 1966, fig. 7-9); very large screwlike form (30 cm. in diam.) described by FIRTION as *R. uliarensis* (FIRTION, 1958; U.Jur., France); other specimens (M.Trias., Ger.) consist of one vertical limb surrounded spirally by the other (MÜLLER, 1956b, p. 405); sometimes also vertically retrusive forms have been assigned to *Rhizocorallium* (e.g., RIOUET, 1960, p. 8; SELLWOOD, 1970, p. 492); for transitions to *Teichichnus* see SELLWOOD, 1970, p. 494; reworked burrows rarely observed (SCHLOZ, 1968, p. 697; L.Jur., S.Ger.).] *Cam.-Tert.*, cosmop.——FIG. 63,*1*. *R.* sp.; *1a*, U.Cret., France, ×0.8 (Abel, 1935); *1b*, L.Cam., Pak., model, ×0.6 (Seilacher, 1955).

Rosselia DAHMER, 1937, p. 532 [**R. socialis*; M]. Cylindrical pencil-thick burrows, commonly oblique (30° or more) to bedding; lower end not observed; opening expanded and filled with concentric layers of matrix which as a rule are strongly weathered. [According to DAHMER (1937, p. 533), dwelling burrow; interpreted by SEILACHER (1955, p. 389) as feeding burrow, recently regarded by him (1969, p. 122) as a junior synonym of *Asterosoma* VON OTTO, 1854 (see Fig. 25,*1*).] *L.Cam.*, Asia(Pak.), *L.Dev.*, Eu.(Ger.); ?*Penn.*, USA(Okla.); ?*Jur.*, Eu.(Ger.); *U.Cret.*, N.Am.(USA, Utah).——FIG. 63,*2*. **R. socialis*, L.Dev.(low. Taunus Quartzite), Ger.; *2a*, opening, ×0.5; *2b*, upper end of dwelling burrow with opening, ×0.5 (Dahmer, 1937).

Rusophycus HALL, 1852, p. 23 [**Fucoides biloba* VANUXEM, 1842, p. 79; "OD"] [=*Rhyssophycus* EICHWALD, 1860, p. 54 *(nom. null.)*; *Rusichnites* DAWSON, 1864, p. 367 *(nom. van.)*; *Rysophycus* DE TROMELIN & LEBESCONTE, 1876, p. 627 *(nom. null.)*; *Rhysophycus* SCHIMPER, in SCHIMPER & SCHENK, 1879, p. 54 *(nom. null.)*; *Rhizophycus* BUREAU, 1900, p. 148 *(nom. van.)*]. Short bilobate bucklelike forms, resembling shape of coffee beans; lobes transversely wrinkled by anterolaterally directed coarse of fine striae; with deep median furrow; outline mostly elliptical; generally width equal to one-half to two-thirds length; bilobate pits deeply excavated or only shallowly dug; quite variable in size and shape (size of Cincinnatian specimens from 1-25 cm.); morphology variable and dependent on mechanics of burrow excavation, and therefore difficult to render an unobjectionable "diagnosis." ["The most famous of all the 'fucoids' " (OSGOOD, 1970, p. 301); originally interpreted as of plant origin; undoubtedly resting excavations made by trilobites digging in sediment to rest there temporarily, interpretation given by DAWSON (1864, p. 365, 366: "for shelter or repose" or "places of incubation"); other less probable interpretations: feeding structures or egg depositories; well-preserved specimens may show imprints of segments, pygidia, pleural spines, and other parts of the trilobite; in several cases (U.Ord., USA, Ohio) the producer of the burrow has been found preserved *in situ* (see *Rusophycus pudicum* HALL with *Flexicalymene meeki* (OSGOOD, 1970, pl. 57, fig. 6)). CRIMES (1970c, p. 114) has shown that several "forms" of *Rusophycus* have restricted time range (U.Cam. or L.Ord.) and thus are usable as guide fossils. Many "species" were

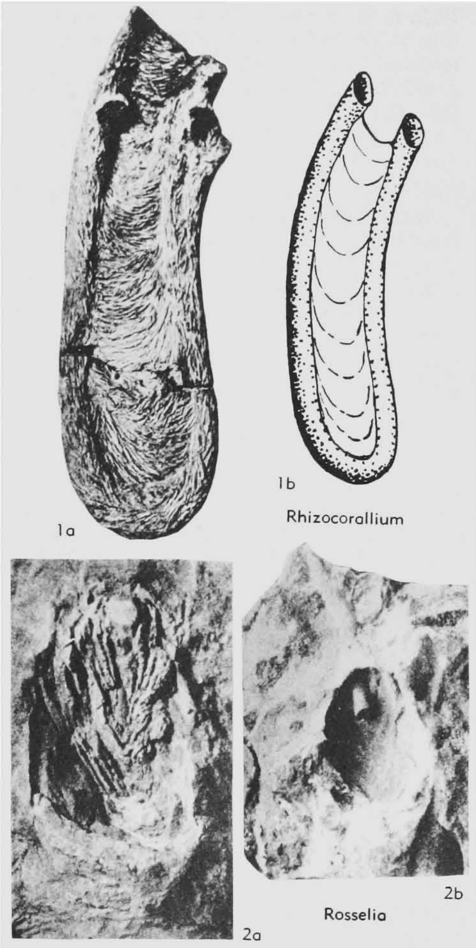

FIG. 63. Trace fossils (p. W101).

established only on small differences in shape; for discussion of nomenclatural status of *Rusophycus* see OSGOOD (1970, p. 303); with regard to intermediate specimens between *Rusophycus* and *Cruziana*, *Rusophycus* was often regarded as synonym of *Cruziana*, but LESSERTISSEUR (1955, p. 45), SEILACHER (1955, p. 366), and OSGOOD (1970, p. 303) recommended *Rusophycus* for the short bilobate resting trails of trilobite origin, and this is approved by the present author. However, SEILACHER (1970, p. 455) recently proposed combining all presumable "resting tracks," "resting nests," and "resting burrows" of trilobites in the one ichnogenus *Cruziana*; for detailed discussions see SEILACHER (1955, p. 358-364) and OSGOOD (1970, p. 301-305).] *U.Precam.-Dev.*, cosmop.——FIG. 63A,*1a*. **R. bilobatus* (VANUXEM), L. Cam., Pak.; ×0.5 (Seilacher, 1955).——FIG. 63A,*1b,c*. *R. didymus* (SALTER), L.Cam., Pak.; *1b*, ×0.5; *1c*, ×1 (Seilacher, 1955).——FIG. 63A,*1d-f*. *R. pudicum* HALL, 1852, U.Ord.(Corryville beds), Ohio (Cincinnati area); *1d*, convex hyporelief, ×1; *1e*, the originator of the trace, *Flexicalymene meeki, in situ*, ×0.9 (Osgood, 1970); *1f*, Mt. Hope beds, convex hyporelief associated with 6 specimens of *Lockeia siliquaria*, ×0.9 (Osgood, 1970).——FIG. 63A,*1g*. *R. carleyi* (J. F. JAMES), loc. unknown; convex hyporelief, ×0.6 (Osgood, 1970).

Sabellarifex RICHTER, 1921, p. 50 [**S. eifliensis*; M] [=*Sabellarites* RICHTER, 1920, p. 226 (*non Sabellarites* DAWSON, 1890, p. 605)]. Similar to *Skolithos*, but individual tubes less straight and not as crowded; never branched. [Regarded by RICHTER (1920, p. 226; 1921) as constructed tubes comparable to those of the Recent annelid *Sabellaria alveolata* LAMARCK; according to WESTERGÅRD (1931, p. 14-15), forms intermediate between *Sabellarifex* and *Skolithos* have been observed in Lower Cambrian of Sweden; "*Sabellarifex dufrenoyi* (ROUAULT)" (=*Tigillites dufrenoyi* ROUAULT) described from Lower Paleozoic of Jordan (HUCKRIEDE in BENDER, 1963, p. 253-254) differs from *Sabellarifex* by its distinct annulation; these forms should be named *Tigillites*.] *L.Cam.*, Eu.(Swed.)-?N.Am.; *L.Dev.*, Eu. (Ger.).——FIG. 64,*5*. **S. eifliensis*, L.Dev., Ger.; *5a*, ×0.65; *5b*, ×0.6 (Richter, 1921).

Sabellarites DAWSON, 1890, p. 605 [*non* RICHTER, 1920, p. 226] [**S. trentonensis* DAWSON, 1890, p. 608; SD HÄNTZSCHEL, 1962, p. W215]. Somewhat tortuous tubes, 1 to 3 mm. in diameter, about 3 cm. long; walls thick, composed of grains of sand and minute calcareous organic fragments cemented by organic substance; some in groups of 2 or more attached together. [Similar to Recent genus *Terebella*.] *U.Precam.*, Eu.(Eng.); *U.Ord.(Trenton.)*, Can.; *?M.Dev.*, Eu.(Ger.).

Saerichnites BILLINGS, 1866, p. 73 [**S. abruptus*; M]. Track consisting of 2 parallel rows of semicircular or subquadrate pits, about 15 mm. in diameter; alternating with each other uniformly; somewhat curved in outline on outer margin; anterior and posterior margin nearly straight. [Very tentatively interpreted by BILLINGS as made by mollusks, perhaps cephalopods (see TEICHERT, 1964b, p. K487); according to TWENHOFEL (1928, p. 100), also comparable to impressions of fucoids (giant kelp of the North Atlantic).] *Ord.*, Can. (Anticosti).——FIG. 64,*7*. **S. abruptus*, English Head F.; ×0.1 (Twenhofel, 1928).

Sagittichnus SEILACHER, 1953, p. 115 [**S. lincki*; M]. Trails suggestive of arrowheads with median keel; up to 5 mm. long. [Resting trail; producer unknown, belonging to epipsammonts; occurring in masses equally oriented rheotactically.] *U. Trias.(mid.Keuper, Schilfsandstein)*, Eu.(S.Ger.); *?Tert.(Oligo.)*, Eu.(Pol.).——FIG. 65,*5*. **S. lincki*; ×2 (Seilacher, 1953b).

Saportia SQUINABOL, 1891, p. XX [**Zonarides striatus* SQUINABOL, 1888, p. 554; M] [=*Saportaia*

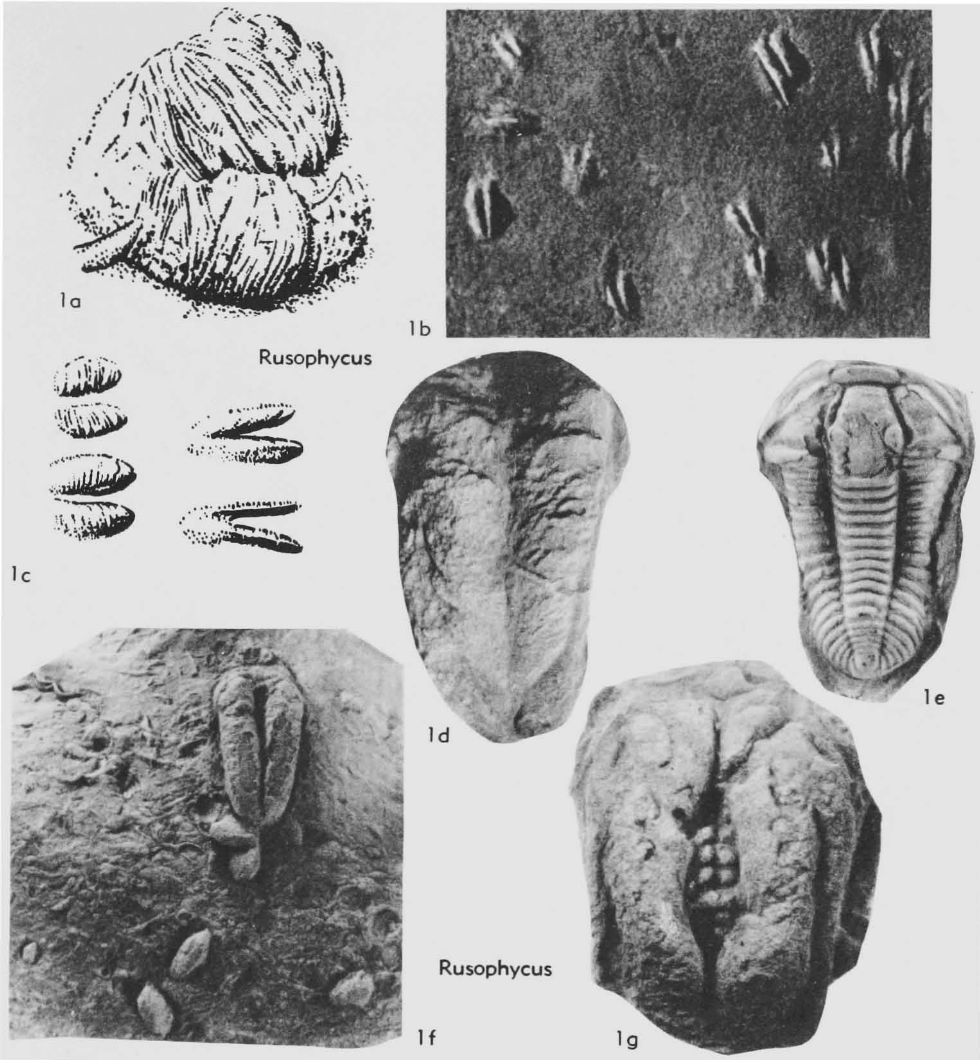

FIG. 63A. Trace fossils (p. W101-102).

WILCKENS, 1947, p. 47 *(nom. van.); Palaeosaportia* BORRELLO, 1966, p. 20 (type, *P. loedeli*)]. Long large cylindrical burrows, 1 to 2 cm. in diameter, commonly in dendriform arrangement, branching dichotomously; surface with rhombic pattern produced by delicate arched parallel striations in 2 systems. [Interpreted by RICHTER (in WILCKENS, 1947) as fillings of burrows made by animals and deposited posteriorly after passing through alimentary canal; in German, *"Stopftunnel mit Kotfüllung."*] [Found in flysch deposits.] *L.Tert.(Eoc.),* Eu.(N.Italy).——FIG. 64, 4. **S. striata* (SQUINABOL); ×0.3 (Squinabol, 1891).

[BORRELLO (1966, p. 20) observed that there are only small differences in shape between his *Palaeosaportia* from the Ordovician of South America(Arg.) and *Saportia* from the Tertiary of Italy. In my opinion, a new generic name is not required for such burrows which vary considerably in shape.]

Scalarituba WELLER, 1899, p. 12 [**S. missouriensis*; M]. Subcylindrical burrows, 2 to 10 mm. (max.) in diameter; sinuous; parallel, oblique or nearly vertical to bedding; marked by transverse "scalariform" ridges situated at average distances of 2 to 3 mm., which may be only poorly preserved or lacking in argillaceous rocks. [In "unbelievable abundance" in silty sequences (e.g., the Hannibal F. of Missouri), to be interpreted as internal trail; according to HENBEST (1960, p. B383) and CONKIN & CONKIN (1968, p. 5),

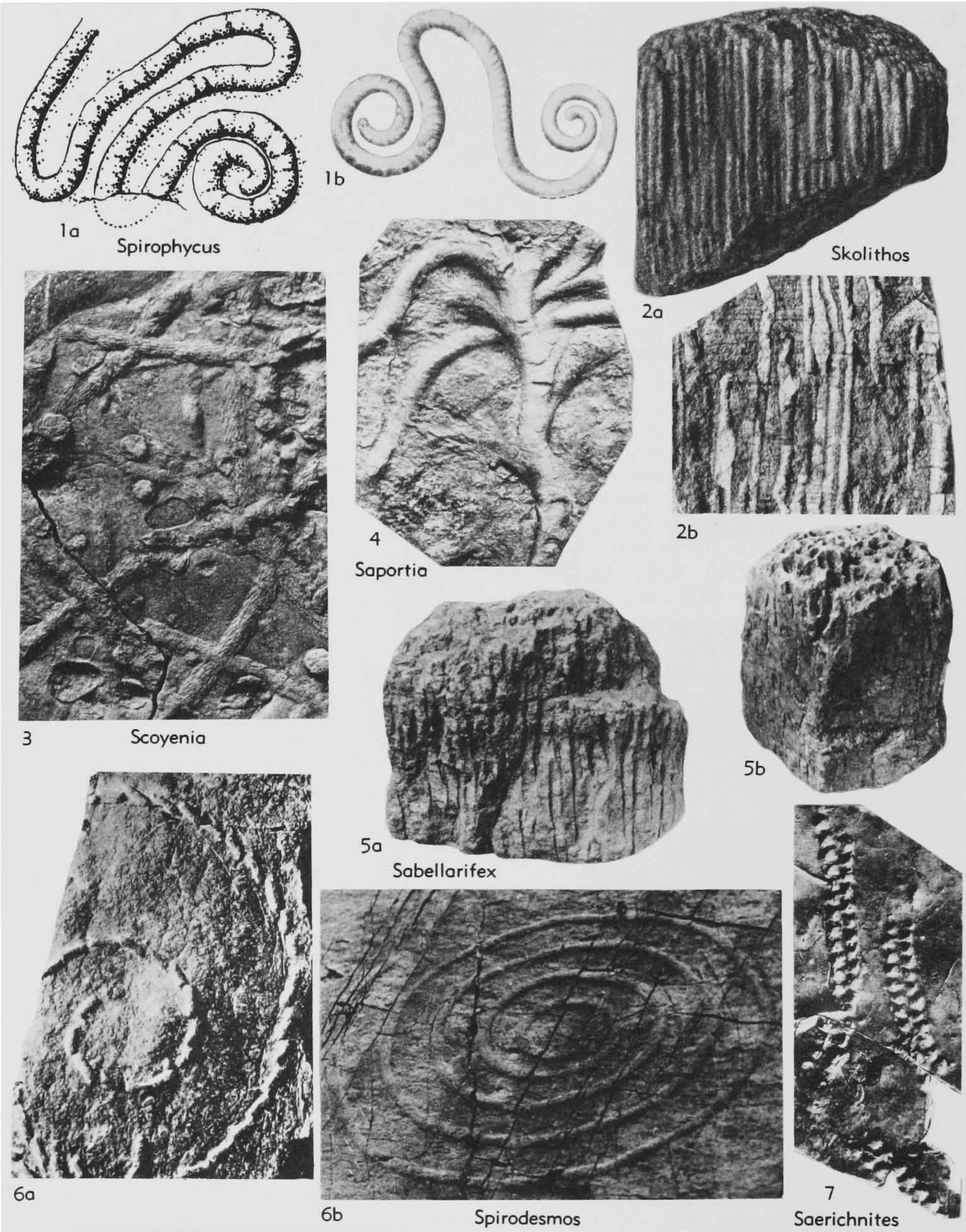

FIG. 64. Trace fossils (p. W102-103; 106-108).

made by sediment-eating worm or wormlike organism living in shallow marine, possibly estuarine, or even (CONKIN & CONKIN, 1968) tidal-flat environment; SEILACHER (1964c, p. 309) listed occurrences of this ichnogenus from all of his three trace fossil communities (*Cruziana, Zoophycos, Nereites* facies) related to depth, which would mean occurring from epicontinental to geosynclinal environments; SEILACHER & MEISCHNER (1965, p. 615) compared *Scalarituba* with *Nereites* and *Neonereites,* referring to the similar general structure.] *Ord.,* Eu.(Nor.)-USA

FIG. 65. Trace fossils (p. *W*102-104, 106, 108-109, 111).

(Ill.); *M.Dev.*, Eu.(Aus.)-USA; *Miss.-Penn.*, USA (Ala.-Ky.-Ind.-Mont.-N.Mexico-Ill.-Ohio-Mo.-Ark.-Okla.-Utah); *Perm.*, Mexico.——FIG. 65,*4*. **S. missouriensis,* L.Miss.(Kinderhook), USA(Mo.); ×0.8 (Häntzschel, 1962).

Scolicia DE QUATREFAGES, 1849, p. 265 [**S. prisca*; M] [The following ichnogenera belong to the "*Scolicia* group" but are not classifiable as true synonyms: *Nemertilites* SAVI & MENEGHINI, 1850, p. 421 (type, *N. strozzii*); *Nereiserpula* STOPPANI, 1857, p. 334 (no type species designated); *Psammichnites* TORELL, 1870, p. 9 (see p. W98); *Cymaderma* DUNS, 1877, p. 352 (no formal species named; ?jun. synonym of *Psammichnites*); ?*Phyllochorda* SCHIMPER in SCHIMPER & SCHENK, 1879, p. 50 (no type species designated); ?*Bolonia* MEUNIER, 1886, p. 567 (type, *B. lata*); *Scolithia* KINDELAN, 1919, p. 187 *(nom. null.)*; *Palaeobullia* GÖTZINGER & BECKER, 1932, p. 379 (no formal species named); *Subphyllochorda* GÖTZINGER & BECKER, 1932, p. 380 (no formal species named); *Olivellites* FENTON & FENTON, 1937b, p. 452 (type, *O. plummeri*); *Paleobulla* CLINE, 1960, p. 92]. Horizontal bilaterally symmetrical gastropod trails of great variability, long, bandlike; morphology depending on their origin as surface trails or internal trails; varied sculpture caused by different methods of burrowing, creeping, and removing sediment; up to about 4 cm. wide; two main types: 1) type species (*Scolicia s. str.* = "group" *Palaeobullia* GÖTZINGER & BECKER, 1932) representing a "true trail" as surface trail of negative epirelief, consisting of variably shaped median axis, ribbonlike or ridgelike, ribbed; lateral parts transversely striated (the striae slanting backward from the midline) or of "gill-like" structure, width larger than or equal to median axis; type species briefly described by DE QUATREFAGES represents this type; 2) internal trails as sole trails, varied full relief burrows ("group" *Subphyllochorda* GÖTZINGER & BECKER, 1932); bandlike, trifid, with varied longitudinal markings; on both sides of the median ribbon characteristic narrow carinate ridges common; both of these types occasionally traceable over great distances. [Originally interpreted by DE QUATREFAGES as long annelid about 2 m. long; now regarded as creeping or feeding trail (or both) of burrowing gastropods; of wide facies range (*Nereites* and *Cruziana* facies); large bedding planes of European flysch deposits furrowed by countless trails of *Palaeobullia* type; nomenclatural treatment of these variable trails difficult (e.g., KSIĄŻKIEWICZ, 1970, p. 289, used *Scolicia* only for the *Palaeobullia* type, and retained *Subphyllochorda* GÖTZINGER & BECKER); for detailed discussion of *Scolicia* see GÖTZINGER & BECKER (1932, p. 377-384; 1934, p. 82-84); AZPEITIA MOROS (1933, p. 9-17); ABEL (1935, p. 219-237); SEILACHER (1955, p. 373-376)]. *Cam.-Tert.*, cosmop.——FIG. 66,*1a-i*. *Palaeobullia*; schem. drawing of different forms (Götzinger & Becker, 1934).——FIG. 66,*2a-d*. *Subphyllochorda,* schem. drawing of different forms (Götzinger & Becker, 1934).——FIG. 66,*2e*. *Subphyllochorda* striata, low.Eoc.(Beloveza Beds), Pol. (Lipnica Wielka); ×0.4 (from Książkiewicz, M., 1970, p. 291, in: *Trace Fossils* edited by T. P. Crimes & J. C. Harper, Geol. Jour. Spec. Issue 3, Seel House Press, Liverpool).——FIG. 66,*3*. **Olivellites plummeri* FENTON & FENTON, Penn. (Cisco F.), Texas; ×0.48 (Fenton & Fenton, 1937b).——FIG. 66,*4*. **S. prisca, 4a,* low.Eoc. (Beloveza Beds), Pol.(Zubrzyca Gorna); ×0.4 (from Książkiewicz, M, 1970, p. 291, in: *Trace Fossils* edited by T. P. Crimes & J. C. Harper, Geol. Jour. Spec. Issue 3, Seel House Press, Liverpool); *4b,* Eoc.(flysch), Aus., Italy; ×0.4 (Seilacher, 1955).

Scoyenia WHITE, 1929, p. 115 [**S. gracilis*; M] [= *cf. Spongillopsis dyadica* GEINITZ, 1862 (*non* POTONIÉ, 1893, p. 18); *Planolites rugulosus* REINECK, 1955, p. 79; for discussion see REINECK, 1955, p. 81-82]. Slender burrows with ropelike sculpture; 2 to 10 mm. (max. 20) in diameter; in half or full relief or flattened; linear and commonly curved, not branched, often crossing each other; parallel or vertical or oblique to bedding; sometimes showing slight "peristaltic" thickenings; outside covered by fine clustered wrinkles densely arranged; inner structure as on stuffed burrows with backfilling, visible if preserved in full relief. [According to MÜLLER (1969c, p. 926, 927), probably made by same animal (polychaete worm?) or one similar to that making ichnogenus *Tambia* MÜLLER; *Scoyenia,* index trace fossil for "*Scoyenia* facies" (SEILACHER, 1967, p. 415), representing nonmarine sand and shales, commonly red beds.] *Perm.*, Eu.(France-Ger.)-USA(Ariz.).——FIG. 64,*3*. **S. gracilis,* Hermit Sh., Ariz.; *ca.* ×0.7 (White, 1929).

Siphonites DE SAPORTA, 1872, p. 110 [**S. heberti*; M]. Tubes, several cm. long and about 1 cm. in diameter, with sandy lining, mostly washed out and collapsed on bedding planes. [For detailed description and discussion see GARDET, LAUGIER, & LESSERTISSEUR (1957); regarded erroneously by some authors as synonym of *Palaeophycus* HALL.] *U.Trias.(Rhaet.),* Eu.(France). ——FIG. 65,*2*. **S. heberti*; ×0.35 (Laugier in Häntzschel, 1962).

Skolithos HALDEMANN, 1840, p. 3 [**Fucoides ?linearis* HALDEMANN, 1840, p. 3; M] [=*Scolithus* HALL, 1847, p. 2 (and all later authors dealing with this "genus" till HOWELL (1943, p. 6) who detected HALDEMANN's spelling *Skolithos*) (type, *S. linearis*); *Scolecolithus* F. ROEMER, 1848, p. 171 *(nom. van.)*; *Scolites* SALTER, 1857, p. 204 (no species name) *(nom. null.)*; ?*Haughtonia* KINAHAN, 1859, p. 119 (type, *H. poecila*)]. "Ordinary pipes"; straight tubes or pipes perpendicular to bedding and parallel to each other,

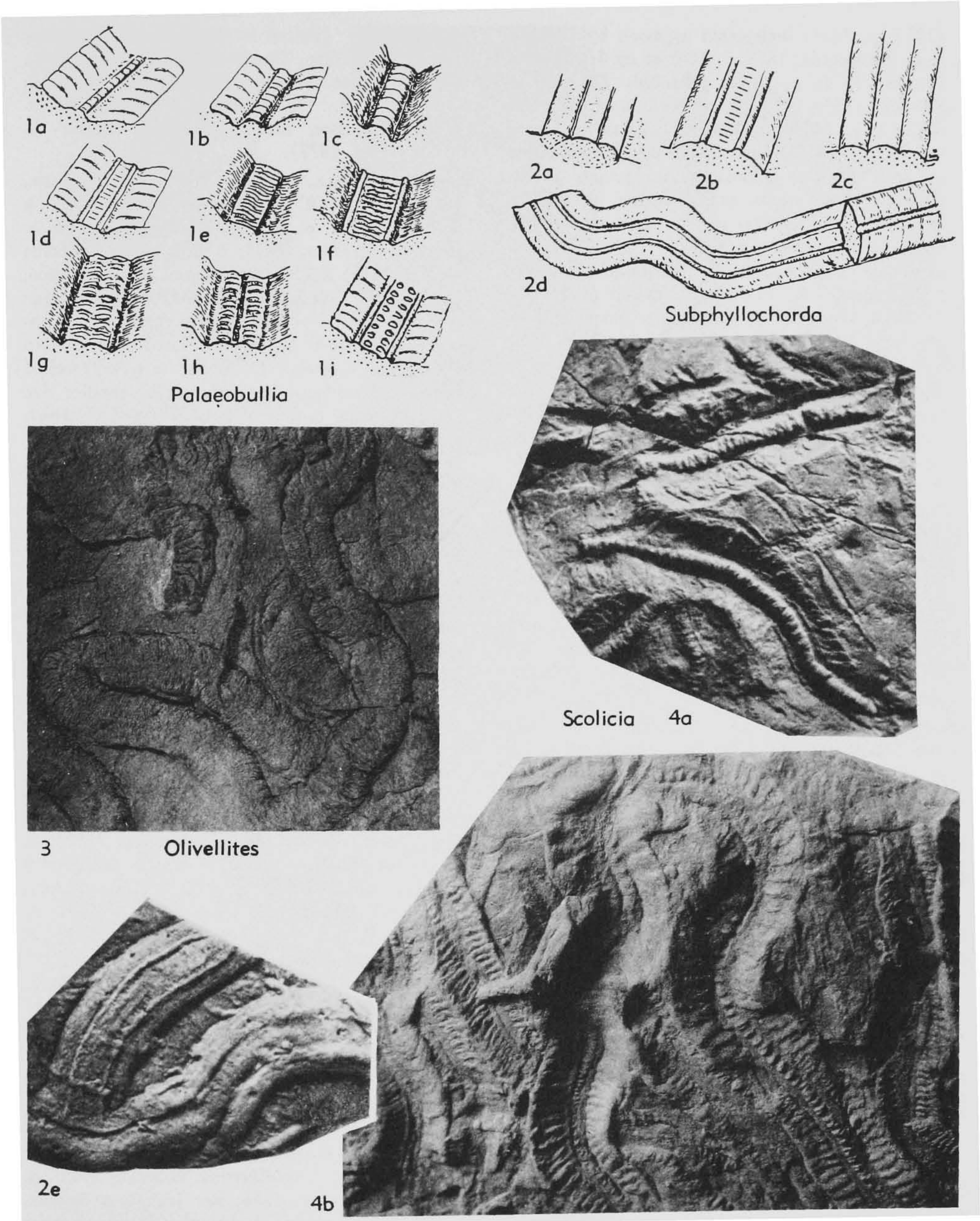

FIG. 66. Trace fossils (p. *W*106).

subcylindrical, unbranched; 1 to 15 mm. in diameter, constant for each tube; few cm. up to 30 cm. (max. 100) long; inner walls may be finely annulated; tubes commonly closely crowded (particularly the *Skolithos* in the Cambrian of Sweden), but also may show widely spaced gradations; frequent in arenaceous sediments; forming Cambrian "pipe rocks" of Scotland. [For a detailed discussion and treatment of ichnogenus see JAMES (1892b), RICHTER (1920, 1921), FENTON & FENTON (1934d), WESTERGÅRD (1931), HOWELL (1943); originally interpreted as marine plants *in situ,* but Scottish occurrences referred to "*Sabella* or other marine worm" by MCCULLOCH

(1814, p. 461); interpreted as made by annelids (e.g., NICHOLSON, 1873, p. 288) or by brachiopods (PERRY, 1872, p. 139), phoronids (FENTON & FENTON, 1934d, p. 348), or even as of inorganic origin (e.g., HÖGBOM, 1915). HALLAM & SWETT (1966, p. 104) rejected RICHTER's interpretation as "reefs" built by colonial worms, proposing that *Skolithos* tubes were made during periods of negligible sedimentation by the same animal that produces *Monocraterion* tubes by upward movement due to influx of sand. *Sabellarifex* RICHTER, 1921, regarded by FENTON & FENTON (1934d, p. 344) as synonym of *Skolithos*; other authors (PÉNEAU, 1946, p. 78; SEILACHER, 1969b, p. 118) considered *Tigillites* ROUAULT a synonym of *Skolithos*; this question not yet cleared up, particularly due to cursory descriptions of *Tigillites* and *Skolithos* itself, along with missing type species and figures in the first descriptions. Therefore, in agreement with OSGOOD (1970, p. 326): "at present the genus remains in a state of confusion . . . it is badly in need of a monographic study"; this concerns the "species" of *Skolithos* as well as its synonyms.] *U.Precam.*, N.Australia; *Cam.-Ord., Dev.*, cosmop.; *U.Penn.*, USA(Texas); *U.Carb.*, S.Afr.; *L.Cret.*, USA(Colo.); *L.Jur.*, Greenl.——FIG. 64,2. **S. linearis*, L.Cam.; *2a*, Swed. (Öland), ×0.6; *2b*, Swed., ×0.5 (Westergård, 1931).

Spirodesmos ANDRÉE, 1920, p. 85 [**S. interruptus*; M]. Large spiral-shaped form, diameter up to about 30 cm.; consisting of individual parts 2 to 3 cm. long and up to 10 mm. wide; in outer coils parts are displaced toward interior with respect to each other; *S. archimedeus* HUCKRIEDE (1952) differs from type species by uninterrupted spiral band; type species possibly part of large double spiral such as *Spirophycus*. [Interpreted by ANDRÉE (1920) and HUCKRIEDE (1952) as strings of spawn of gastropods; more likely trace fossil (see PFEIFFER, 1968, p. 674); HÜLSEMANN (1966, p. 455) discussed similarity of *Spirodesmos* to some large Recent trails in the form of coiled or spiral pattern observed on abyssal sea floor of the Pacific and other oceans (BOURNE & HEEZEN, 1965).] *L.Carb.(Kulm)*, Eu.(Ger.).——FIG. 64, *6a*. **S. interruptus*; ×0.17 (Andrée, 1920).——FIG. 64,*6b*. *S. archimedeus* HUCKRIEDE; ×0.2 (Huckriede, 1952).

Spirophycus HÄNTZSCHEL, 1962, p. *W*215 [**Muensteria bicornis* HEER, 1877, p. 165; SM HÄNTZSCHEL, 1962, p. *W*215 (=*Muensteria caprina* HEER, 1877, p. 163; *M. involutissima* SACCO, 1888, p. 168)] [=*Ceratophycos* SCHIMPER in SCHIMPER & SCHENK, 1879, *non* FISCHER DE WALDHEIM, 1824]. Cylindrical bulges, about 5 to 20 mm. thick, transversely folded or rugose; curved like horns or bent spirally at ends; similar to *Taphrhelminthopsis* SACCO, 1888. [Grazing trail, according to SEILACHER (1962, fig. 1), predepositional.] [Found in flysch deposits.] *Miss.-Penn.*, USA(Okla., Ouachita Mts.); *Cret.-L.Tert.*, Eu.(Aus.-Switz.-Spain-Italy-Pol.)-S.Am. (Venez.).——FIG. 64,*1*. **S. bicornis*; *1a*, Eoc., Aus., *ca.* ×0.4 (Seilacher, 1955); *1b*, Eoc., Switz., *ca.* ×0.3 (Heer, 1877).

Spirophyton HALL, 1863, p. 78 [**S. typum* HALL, 1863, p. 80; OD (SCHIMPER in SCHIMPER & SCHENK, 1879, p. 55, incorrectly designated *S. cauda-galli* (HALL, 1863, p. 79) as type species; see Art. 68(b) ICZN)] [=*Zoophycos* MASSALONGO, 1855, p. 48 (*partim*, see p. *W*120); list of true synonyms only possible after thorough monographic treatment of closely related cosmopolitan ichnogenus *Zoophycos*]. Similar to spirally coiled forms of *Zoophycos* but differing by smaller size and by circular outline of laminae (spreite) which are also composed of lamellae; laminae (=whorls) not tending to lobate forms, 1 to 4 mm. thick, sloping outward from axis, then flattening and bent upward to margin in dextrogyrate or sinistral spirals, curving ridges on laminae convex in the sense of the rotation; diameter of last whorl up to about 10 cm., central axis J-shaped. [For older and newer interpretations (plants, inorganic, feeding burrows) see *Zoophycos*; it is difficult to decide which forms described as *Spirophyton* belong to *Zoophycos* and vice versa (*S. cauda-galli* HALL, 1863, to be ascribed to *Zoophycos*); SIMPSON (1970) is correct in regarding *Spirophyton* as a separate ichnogenus, with the name *Spirophyton s. str.* maintained for forms such as *S. eifeliense* KAYSER, 1872 (Dev., Ger.); this "species" placed in the Recent polychaete genus *Spirographic* VIVIANI, 1805, by PLIČKA (1968, p. 843); for discussion of *Spirophyton* see ANTUN (1950) and SIMPSON (1970).] *?Sil.*, N.Afr.; *Dev.,Carb.*, Eu.-Afr.-N.Am.——FIG. 67,*1a-c*. *S. eifeliense* KAYSER; *1a*, schem. (Antun, 1950); *1b*, Dev. (Ems.), Luxembourg; tang. sec., ×0.7 (Antun, 1950); *1c*, L.Dev.(Eifel.), Ger.(Prüm); a sinistral specimen viewed from above, ×0.47 (Plička, 1968, after Kayser, 1872, pl. 28, fig. 1c).——FIG. 67,*1d*. *Zoophycos crassus* (HALL) [*"Spirophyton crassum"* HALL], U.Dev., USA; ×2.7 (Hall, 1863).

Spirorhaphe FUCHS, 1895, p. 395 [**Helminthopsis involuta* DE STEFANI, 1895, p. 16; SD HÄNTZSCHEL, herein] [=*Gilbertina* ULRICH, 1904, p. 140 (*non* MORLET, 1888; *nec* JORDAN & STARKS, 1895) (*nom. nud.*); *Helminthopsis? concentrica* AZPEITIA MOROS, 1933, p. 46 (see SEILACHER, 1959, p. 1068); *Spiroraphe* of many authors (*nom. null.*); "*Spirodictyon* ABEL" OSGOOD, 1970, p. 386 (*nom. null.*)]. Spirally coiled threads, 0.5-3 mm. thick, running from outside inward, with diameter of spiral 5 to about 30 cm., turning at center and looping backward between primary whorls; simple closely coiled spirals not reversing direction at the center have been assigned to

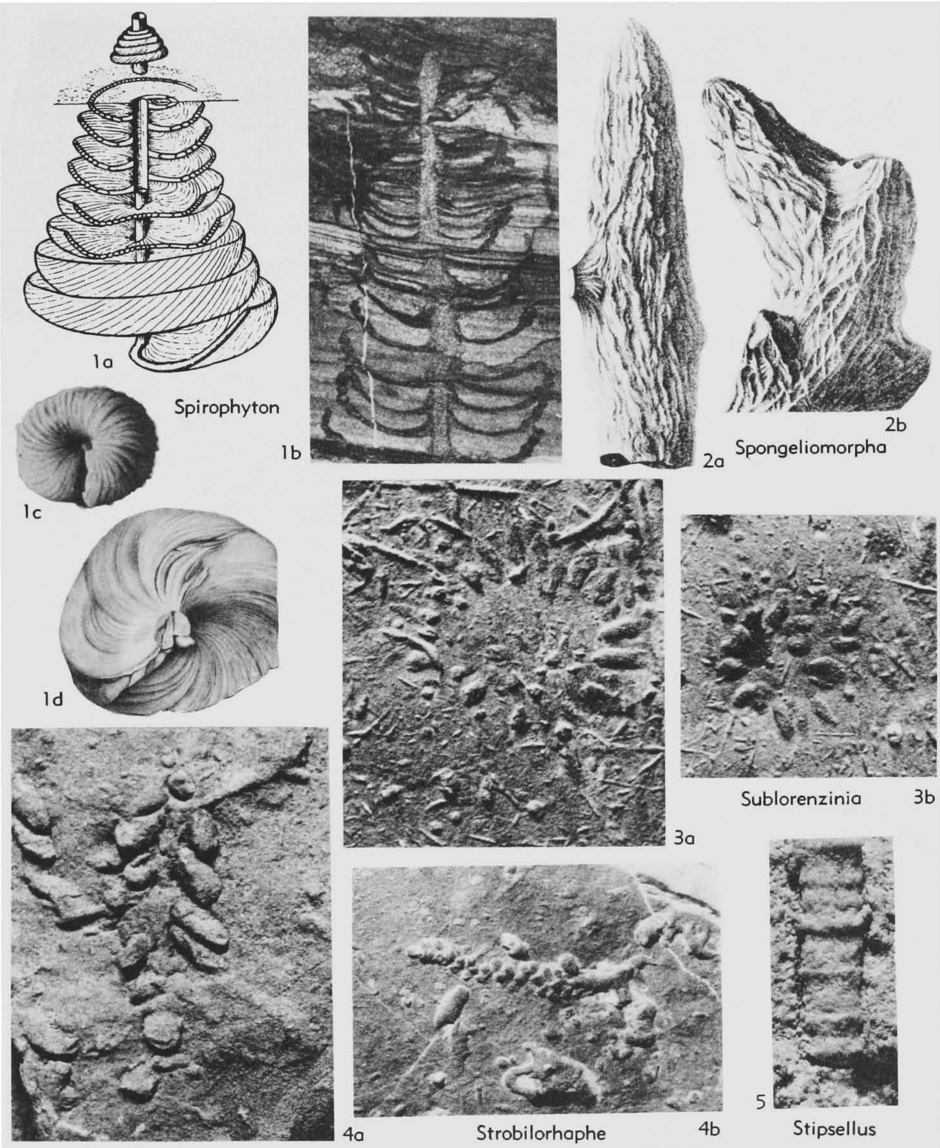

FIG. 67. Trace fossils (p. W108-109, 111-112).

Spirorhaphe (e.g., *S. minuta* KSIĄŻKIEWICZ, 1970, p. 305). [Grazing trail; for a new interpretation as a multifloored three-dimensional tunnel, see SEILACHER (1967c, p. 75-76).] [Found in flysch deposits.] *Cret.-L.Tert.*, Eu.(Aus.-Spain-Italy-Pol.-Greece)-N.Am. (Alaska)-?Asia (Japan).——FIG. 65,*1*. *S.* sp.; *1a,* Tert.(Greifensteiner Ss.), Aus.; *ca.* ×0.5 (Abel, 1935); *1b, ("Gilbertina"),* U. Cret.(Yakutat F.), Alaska; ×1 (Ulrich, 1904).

Spongeliomorpha DE SAPORTA, 1887, p. 298 [**S. iberica*; M] [=*Spongiliomorpha* DARDER, 1945, p. 405 *(nom. null.)*]. Thick, elongate burrows, cylindrical; suggestive of antlers; with ramifications and lateral tapering offshoots; surface with network of ?scratching traces crossing each other at acute angles. [Originally regarded as sponges (DE LAUBENFELS, 1955, p. E36); according to REIS (1922, p. 231), burrows similar to *Rhizocorallium*; "a rather unsatisfactory ichnogenus" (KENNEDY, 1970, p. 272); most probably arthropod dwelling burrows; for synonymy and discussion of the relations to *Thalassinoides* see

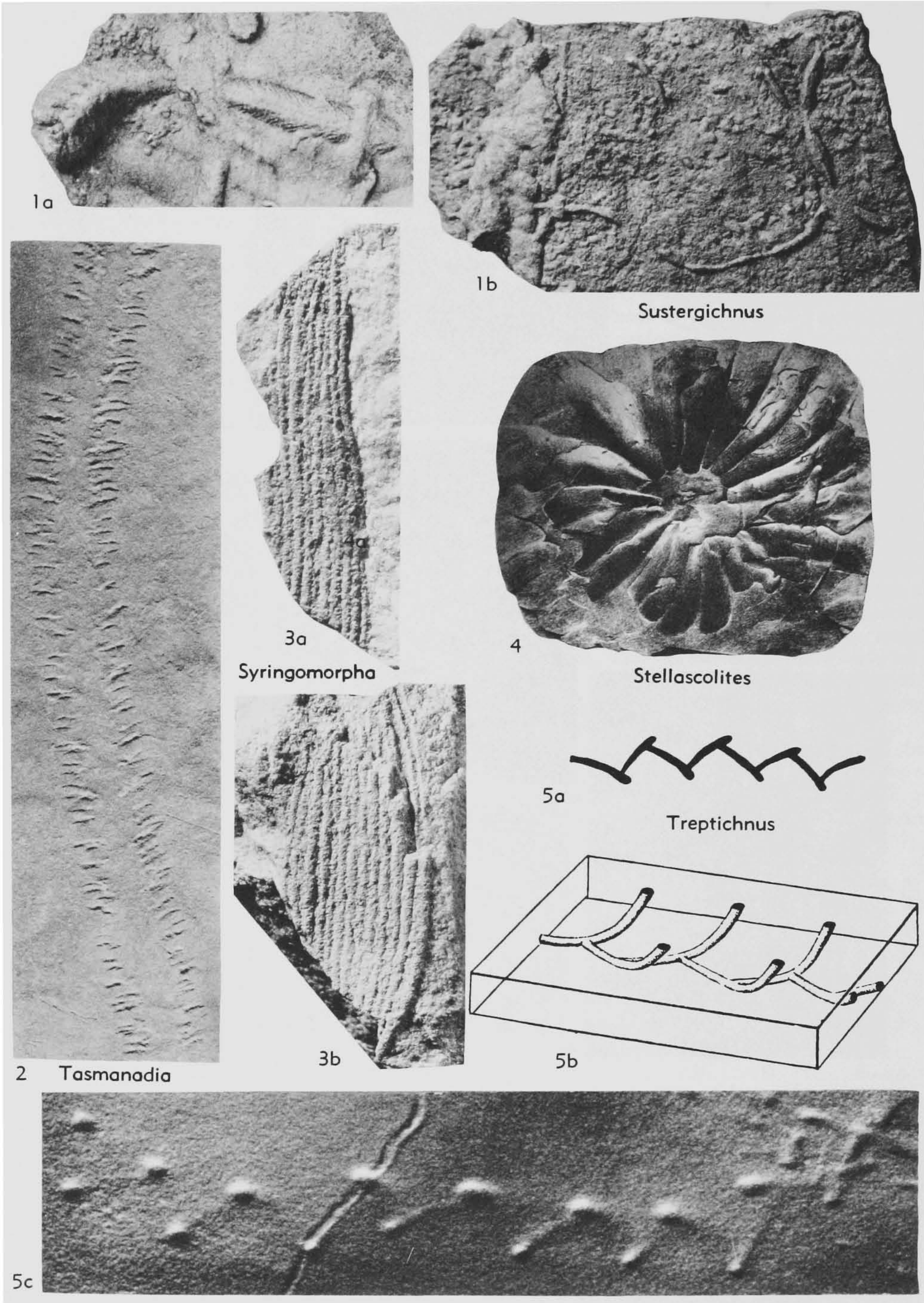

FIG. 68. Trace fossils (p. W111-112, 114, 117).

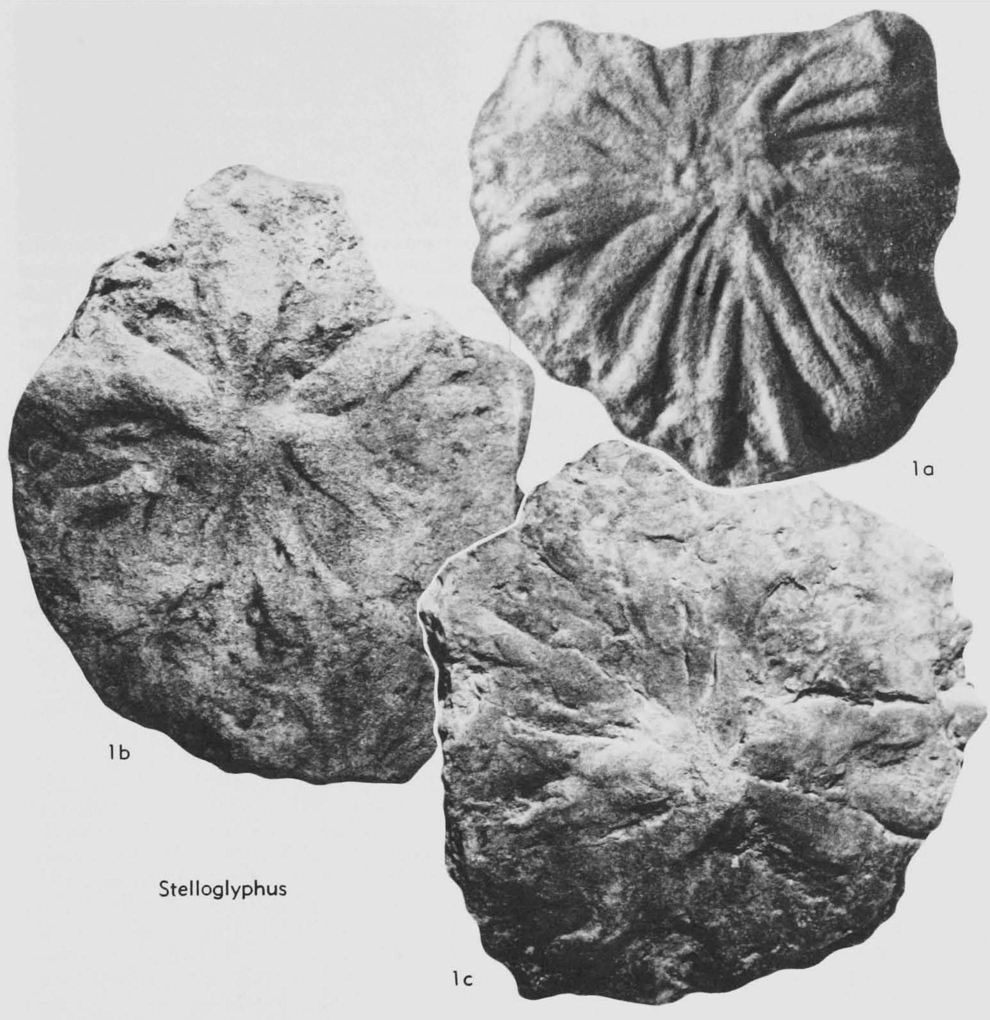

FIG. 69. Trace fossils (p. W111-112).

KENNEDY, 1967, p. 150-151.] *Trias.-Tert.*, Eu.; *?Trias.-Tert.*, *L.Cret.*, USA.——FIG. 67,2. **S. iberica*, ?Tert., Spain; *2a,b*, ×0.7 (de Saporta, 1887).

[FÜRSICH (1973, p. 728) considered *Ophiomorpha* and *Thalassinoides* to be subjective synonyms of *Spongeliomorpha*.—CURT TEICHERT.]

Steigerwaldichnium KUHN, 1937, p. 366 [**S. heimi*; M] [=*Steigerwaldichnites* KUHN, 1937, p. 368 *(nom. null.)*]. Straight, rarely curved, tunnel traces parallel to bedding with distinct longitudinal rows of tiny projections and impressions from doubtful parapodia. [Probably made by polychaetes; holotype lost, no other specimens preserved.] *U.Trias.*, Eu.(S.Ger., Bavaria).——FIG. 65,*3*. **S. heimi*, M. Keuper; *ca.* ×1.5 (Kuhn, 1937).

Stellascolites ETHERIDGE, 1876, p. 109 [**S. radiatus*; M]. Radiate or stellate disclike impression with 16 rays of nearly equal length radiating from central round space, becoming broader at their extremities which are not clearly defined; diameter 20 to 25 cm. [Name only very rarely used.] *L.Ord.*, Eu.(Eng.); *?Miss.*, N.Am.(USA, Mont.).——FIG. 68,*4*. **S. radiatus*, Ord., Eng.; ×0.17 (Etheridge, 1876).

Stelloglyphus VYALOV, 1964, p. 112 [**S. turkomanicus*; OD] [=*Stelleglyphus* VYALOV, 1968, expl. pl. 2 *(nom. null.)*]. Large rosette-like trace fossils, consisting of about 25 very closely spaced "rays," without central smooth field; diameter about 7 cm. *?Penn.*, N.Am.(USA,Okla.); *Perm.*, S.Afr.; *U.Cret. (Santon.-Turon.)*, USSR (Turkmenistan-Crimea).——FIG. 69,*1a*. **S. turkomanicus*, U.Cret.(Turon.), W.Kopet Dag, Turkmen.;

×1 (Vyalov, 1968).——FIG. 69,*1b,c*. *S. giganteus* VYALOV, U.Cret.(Turon.), Kopet Dag; ×0.25 (Vyalov, 1968).

Stipsellus HOWELL, 1957, p. 18 [**S. annulatus*; OD] [=*Stripsellus* HOWELL, 1957b (correct spelling only in the title of HOWELL's paper; B. F. HOWELL, pers. commun., 1957) *(nom. null.)*]. Perpendicular, cylindrical burrows, spaced about 2 cm. apart in sediment, diameter about 1 cm.; differing from *Skolithos* by distinct ringlike expanded belts regularly distributed throughout length of tube; perhaps identical with *Trachyderma serrata* SALTER, 1864. *Cam.(Tapeats Ss.)*, N.Am.(USA, Ariz.); *?Penn.*, USA(Md.)-?Arabia. ——FIG. 67,*5*. **S. annulatus*, Tapeats Ss., Ariz.; ×1 (Howell, 1957b).

Strobilorhaphe KSIĄŻKIEWICZ, 1968, p. 8 (Pol.) and 15 (Engl.), [**S. clavata*; OD]. Short narrow string, with 3 to 4 ranges of small pearl-like knobs about 7 mm. long, laterally protruding from string; entire trail cone-shaped, usually 3 to 4 cm. long, 1 to 1.5 cm. wide. [Found in flysch deposits.] *Tert.(low.Eoc.-mid.Eoc.)*, Eu. (Pol.).——FIG. 67,*4a*. **S. clavata*, low.Eoc. (Beloveza Beds), Pol.; ×1.1 (Książkiewicz, 1968).——FIG. 67,*4b*. *S. pusilla* KSIĄŻKIEWICZ, low. Eoc.(Beloveza Beds), Pol.; ×2.2 (Książkiewicz, 1968).

Subglockeria KSIĄŻKIEWICZ, 1974, *nom. subst.*, herein, *pro Asterichnus* KSIĄŻKIEWICZ, 1970, p. 310 (*non* BANDEL, 1967a) [**Asterichnus nowaki* KSIĄŻKIEWICZ, 1970, p. 310; OD] [=*Asterichnus* NOWAK, 1961, p. 227, *nom. nud.*]. Rosetted trace, up to 16 cm. in diameter, fairly structureless central area (4 to 6 cm. in diameter surrounded by an aureole of ribs, variable in length, which always point outward; central area may possess a central knob. *U.Jur.(Tithon.)-L.Cret. (Hauteriv.)*, Eu.(Pol.). [Description supplied by W. G. HAKES.]

Sublorenzinia KSIĄŻKIEWICZ, 1968, p. 10 (Pol.) and p. 15 (Engl.) [**S. plana*; OD]. Similar to *Lorenzinia* DA GABELLI; midfield large and flat, encircled by ring of 12 to 20 knobs; diameter 3 to 6 cm.; differing from *Lorenzinia* by irregular (not circular) form of ring and by different shape of knobs, which vary from round to elongate. [Found in flysch deposits.] *U.Cret.(Cenoman.-Turon.)*, Eu.(Pol., W.Carpathians).——FIG. 67,*3*. **S. plana*; *3a,b*, ×0.7 (Książkiewicz, 1968).

Sustergichnus CHAMBERLAIN, 1971, p. 231 [**S. lenadumbratus*; M]. Carinate burrows, irregularly sinuous, 1 to 10 mm. wide, 1 to 7 mm. high; numerous fine striae crossing exterior surface obliquely and converging near lower apex; this outer structure not always present; inner structure consisting of sand rod with smooth external surface, almond-shaped in cross section; preserved as hyporelief and full relief. [According to CHAMBERLAIN, made by animal pulling itself through the sediment following the sand/mud interface, disturbing it by feeding and pulling, then forming the smooth-walled tunnel when drawing its body forward; inner sand-packing perhaps fecal; fossil named "Arkansas Razorback" by petroleum geologists.] *Miss.-Penn.*, USA (Okla.).——FIG. 68,*1*. **S. lenadumbratus*, Ouachita Mts.; *1a*, Penn.(?Johns Valley Sh.), ×1; *1b*, L.Penn.(Atoka F.), ×1 (Chamberlain, 1971a).

Syringomorpha NATHORST, 1886, p. 47 [**Cordaites ?nilssoni* TORELL, 1868, p. 36; OD]. Cylindrical sticks several cm. long and 1 to 2 mm. wide lying close together; slightly arched; touching each other along whole length and forming complete slab; occurring in large numbers independent of bedding. [Interpretation difficult; according to RICHTER (1927b, p. 267), perhaps work of gregarious worms on flat substratum.] *L.Cam.*, Eu. (Swed.-Nor.-N.Ger., Pleist. drift).——FIG. 68,*3*. **S. nilssoni* (TORELL), L.Cam., drift boulder, Berlin; *3a,b*, ×1 (Richter, 1927b).

Taenidium HEER, 1877, p. 117 [**T. serpentinum* HEER, 1877, p. 117; SD HÄNTZSCHEL, 1962, p. W218] [The following ichnogenera are not strictly considered as synonyms of *Taenidium* but all are stuffed burrows (German, *Stopftunnel*) that exhibit transverse annulations (some names are invalid and others are less frequently used than *Taenidium*): *Muensteria* VON STERNBERG, 1833 *(partim)*; *?Eione* TATE, 1859 (*non* RAFINESQUE, 1814) *(nom. nud.)*; *Volubilites* LORENZ VON LIBURNAU, 1900; *Pseudocrinus* ANELLI, 1935 (*non* PEARCE, 1843, *nec* GEINITZ, 1846, *nom. nud.)*; *Notaculites* KOBAYASHI, 1945 (=*Notakulites* KOBAYASHI, 1945, *nom. null.*); *Scolecocoprus* BRADY, 1947 (=*Scolecoprus* HÄNTZSCHEL, 1965, *nom. null.*); *Tebagacolites* MATHIEU, 1949; *?Rhizocorallites* MÜLLER, 1955]. Cylindrical burrows with distinct stuffed structure, mostly branched, typical *Taenidium* (*T. fischeri* HEER, 1877) umbellated, rootlike system of burrows radiating downward; burrows with transverse segmentation reminiscent of *"Orthoceras"*; segmentation may also be observed on outside as annular constrictions; similar to *Keckia* GLOCKER and *(partim) Muensteria* VON STERNBERG (see p. W75, W84) but commonly smaller. [*Taenidium* was originally interpreted as alga (see LORENZ VON LIBURNAU, 1900, p. 528-567), but originates in feeding burrows by periodic filling of tunnel in backward direction; it occurs in wide range of environments. Stuffed burrows have been discussed by RICHTER in WILCKENS (1947, p. 44-45) and by TOOTS (1967).] *?Carb., Perm.-Tert.*, Eu.-N.Am.-(Japan)-?N.Z.-Antarctic.——FIG. 70,*1*. *T.* sp., U.Cret., Aus.; *1a*, ×0.7 (Papp, in Häntzschel, 1962); *1b*, ×0.27 (Seilacher, 1955).

Tambia MÜLLER, 1969, p. 924 [**T. spiralis* (=gen. inc. *spiralis* MÜLLER, 1956a, p. 149); OD]. Spirally coiled structures with circular outline; diameter 2 to 3 cm.; surface covered by

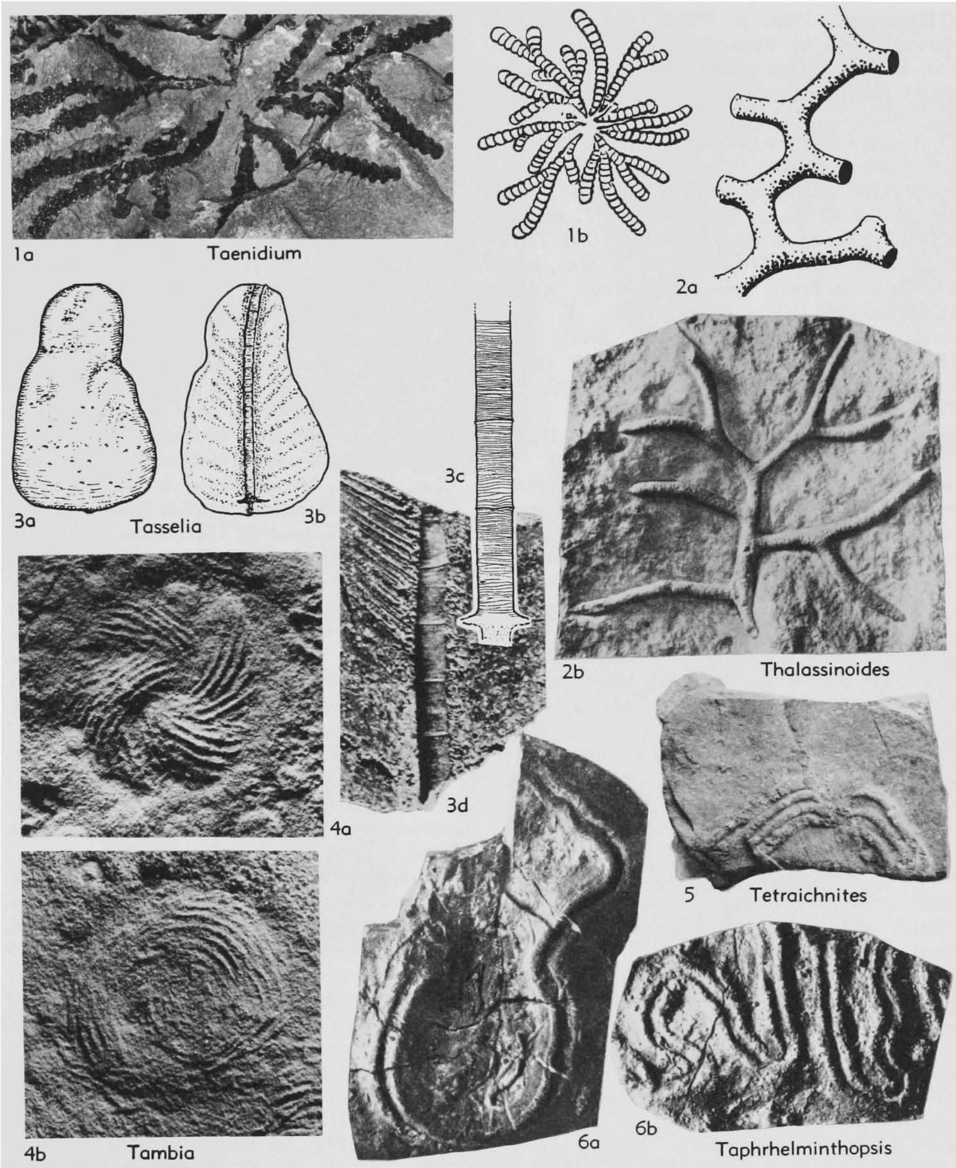

FIG. 70. Trace fossils (p. *W*112-115, 117).

streaks either running parallel to periphery of circular outline or arranged in subspiral fanlike manner; streaks sometimes transversely annulated. [Probably part of feeding burrow dipping into sediment at low angle.] *L.Perm.(up. Rotliegendes)*, Eu.(Ger., Thuringia).——FIG. 70,*4*. **T. spiralis*; *4a,b*, ×0.9, ×1.4 (Müller, 1969c).

Taphrhelminthopsis SACCO, 1888, p. 170 [**T. auricularis*; SD HÄNTZSCHEL, 1962, p. *W*218]. Bilobate trails, 1 to 3 cm. wide; mostly very long; morphology varying: more or less straight (*T. recta* SACCO), freely winding (*T. auricularis* SACCO), or even meandering with distinct rather large median furrow 3 to 10 mm. wide, flat; lateral ridges may be transversely striated; trails varying in size and relief. [Most probably gastropod grazing trail, description of *Taphrhelminthopsis* as having tightly coiled spirals and meanders

(HÄNTZSCHEL, 1962, p. *W*218) was based on drawing given by SEILACHER (1955, fig. 5, no. 76), which does not represent true *T. auricularis* as described and figured by SACCO, 1888, p. 172, pl. 2, fig. 3; see also KSIĄŻKIEWICZ (1970, p. 290); coiled spirals or meanders named *Taphrhelminthopsis* have been figured only by KSIĄŻKIEWICZ (1968, pl. 6, fig. 3) ("*T.* sp. ind.") and by MÜLLER (1962, p. 16, fig. 12) *("T. auricularis").*] [Found in flysch deposits.] *Cret.-Tert.*, Eu.——FIG. 70,*6a*. **T. auricularis* (SACCO), low. Eoc.(Beloveza Beds), Pol.(Lipnica Mala); ×0.08 (Książkiewicz, 1970).——FIG. 70,*6b*. *T. convoluta* (HEER), low.Eoc.(Beloveza Beds), Pol. (Sidzina); ×0.08 (Książkiewicz, 1970) (*6a,b*, from Książkiewicz, M., 1970, p. 293, 297, in: *Trace Fossils* edited by T. P. Crimes & J. C. Harper, Geol. Jour. Spec. Issue 3, Seel House Press, Liverpool).

Tasmanadia CHAPMAN, 1929, p. 5 [**T. twelvetreesi*; M]. Double row of very sharp transverse imprints, commonly single but some joined internally or rarely externally to form bifid impressions. [Originally interpreted by CHAPMAN (1929) as bodily preserved worm with its bristles preserved as sets of imprints. GLAESSNER (1957, p. 103) conclusively proved it to be arthropod track. The age of the Australian representatives of this ichnogenus, originally reported as Cambrian by CHAPMAN, is now known to be Late Carboniferous (GULLINE, 1967; GLAESSNER, 1973b).] *Precam.-Cam.*, India; *U.Carb.*, *?L.Perm.*, Australia(Tasm.).——FIG. 68,*2*. **T. twelvetreesi*, U.Carb., Tasmania; part of holotype, ×0.8 (Glaessner, 1957).

Tasselia DE HEINZELIN, 1965, p. 505 [**T. ordam* (=*T. ordamensis; nom. correct.*, herein); M]. Sideritic and phosphoritic concretions of cylindrical, pyriform or subspherical shape with an axial straight unbranched tube; concretions 3 to 30 cm. long, 2 to 15 cm. wide, primarily found with vertical orientation in fine marine sands and usually occurring in groups; tube 1 to mostly 3 mm. in diameter, with segmentation intervals of 2.5 to 6 mm., each segment exhibits very fine transverse annulation with striae at intervals of about 0.2 mm., tube ending in small flat chamber near bottom of concretion, but lower part of tube often continues more indistinctly downward several decimeters into underlying sediment. [Tubes tentatively interpreted as made by *Pogonophora.*] *L.Pleist.(Merxem.)*, Eu.(Belg.).——FIG. 70,*3*. **T. ordamensis; 3a,b*, concretion and long. sec., ×0.8; *3c*, fine transverse annulation in the tube, diagram. (all van Tassel, 1965); *3d*, holotype, ×1.4 (de Heinzelin, 1965).

Teichichnus SEILACHER, 1955, p. 378 [**T. rectus*; M]. *Spreiten-bauten* formed by series of long horizontal burrows stacked vertical to bedding, resembling stacked flat U-shaped roof gutters with pipe at top; wall-shaped laminar body straight or slightly sinuous; generally not branching; commonly retrusive built but can also be protrusive; up to about 50 cm. long (in M.Cam. of Öland up to 135 cm.), about 10 cm. or more in height. [Endogenic burrows, belonging to fodinichnia; producer unknown, but, due to the very long time range of this ichnogenus, certainly made by different groups of animals; comparable modern structures made by the Recent polychaete *Nereis diversicolor* (see SEILACHER, 1957, p. 203); MARTINSSON (1965, p. 216) explained Cambrian specimens as combinations of retrusive and protrusive digging activity; transitional forms to *Rhizocorallium* (L.Carb., Scotland) were described by CHISHOLM (1970b); as shown by SELLWOOD (1970, p. 494), a limb of a vertically retrusive *Rhizocorallium* may be mistaken for *Teichichnus*; tunnels of *Ophiomorpha* have been observed to grade into *Teichichnus*-like structures (Eoc., N.Am., Miss.) (Hester & Pryor, 1972, p. 686); the relationships of *Teichichnus* to *Phycodes* were discussed by HÄNTZSCHEL & REINECK (1968, p. 26).] *Cam.*, Eu.(Nor.-Swed.-Spain)-N.Am.(USA,Ariz.)-Asia(Pak.); *Ord.*, Eu.(Ger.-Eng.)-N.Am.(Can.)-Asia(Iraq); *U.Dev.*, Eu.(Eng); *L.Carb.*, Eu.(Scot.-USSR); *M.Trias.*, Eu.(Ger.); *Jur.*, Eu.(France-Ger.-Swed.)-Greenl.; *U. Cret.*, USA(Kans.-Utah); *Tert.*, Eu.(Eng.-Belg.).——FIG. 71,*4a,c*. **T. rectus*, L.Cam. (Kusak F.), Pak.(Salt Range); *4a*, model, ×0.4; *4c*, ×0.7 (Seilacher, 1955).——FIG. 71,*4b*. *T.* sp., Cam. (Tapeats Ss.), Ariz. (Grand Canyon); ×0.7 (Seilacher, 1956).——FIG. 71,*4d*. Large teichichnian burrow, M.Cam., Swed. (Äleklinta, Öland); ×0.3 (Martinsson, 1965).

Teratichnus MILLER, 1880, p. 221 [**T. confertus*; M] [=*Tetraichnus* FLOWER, 1955, p. 857 *(nom. null.)*]. Complex track, sickle-shaped; 17 mm. wide; consisting of numerous bifid imprints, 9 per set arranged in elliptical pattern; in part very confused, probably resulting from rotation of body of animal; 3 sharply defined median grooves visible between the 2 series, indicating medial posterior terminal spine or appendage. [Only type specimen is known; originally interpreted by MILLER (1880) as made by cephalopod (see TEICHERT, 1964b, p. *K*487); detailed interpretation as crawling track of an unknown small arthropod with bifid dactyls (?trilobite, aglaspid such as *Neostrabops* CASTER & MACKE, 1952?) given by OSGOOD (1970, p. 368-369).] *U.Ord. (Cincinnat.)*, USA(Ohio).

Tetraichnites DE STEFANI in DE STEFANI, *et al.*, 1895, p. 15 [**T. majorianus*; M]. Flexuous trail, 2 cm. wide; consisting of 4 parallel ridges, smooth, 3 mm. wide; 1 to 3 mm. wide furrows between ridges. [Regarded by DE STEFANI as probably made by crustaceans; placed by SEILACHER (1955, p. 374) in group *Scolicia* DE QUATREFAGES, interpreted as creeping trails of burrowing gastropods.] *L.Tert.*, Eu.(Medit., Isle

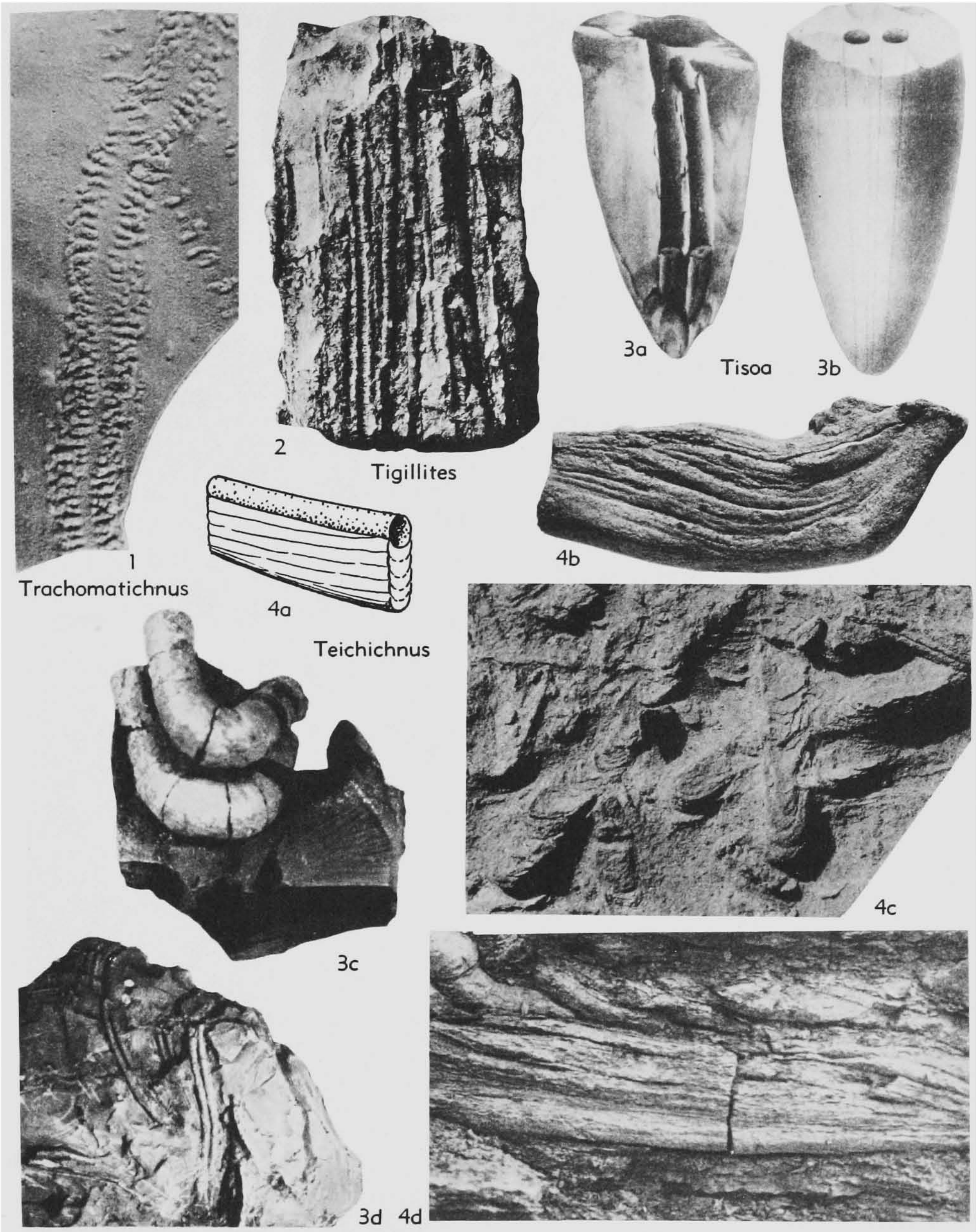

FIG. 71. Trace fossils (p. W114, 117).

of Kárpathos).——FIG. 70,*5*. **T. majorianus*; ×0.47 (de Stefani in de Stefani *et al.*, 1895).

Thalassinoides EHRENBERG, 1944, p. 358 (*emend.* KENNEDY, 1967, p. 132) [**T. callianassae*; OD] [For detailed synonymy of the "species" *T. saxonicus, cf. T. suevicus,* and *T. paradoxicus* see KENNEDY, 1967, and MÜLLER, 1970]. Cylindrical burrows forming 3-dimensional branching systems consisting of horizontal networks connected to surface by more or less vertical shafts; burrows

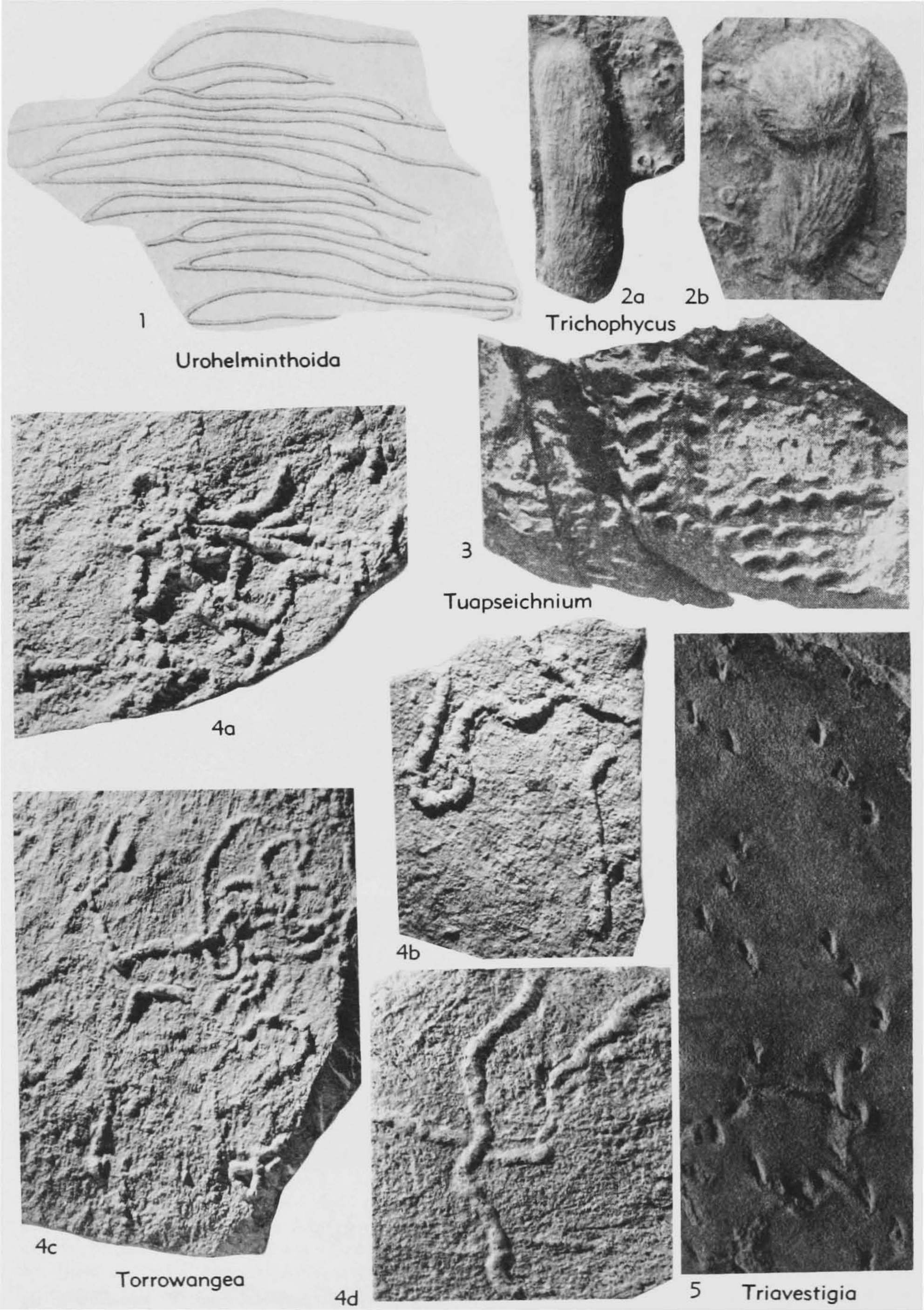

FIG. 72. Trace fossils (p. *W*117-118, 120).

1 to about 20 cm. (typically 10-15 mm.) in diameter; regularly branching, Y-shaped bifurcations; in horizontal systems forming polygons; typical swellings at points of branching or elsewhere; rare transitional forms with tuberculate structure of *Ophiomorpha* have been described (MÜLLER, 1970b). [Formerly interpreted as algae or horny sponges (Ceratospongidae); undoubtedly feeding and dwelling burrows of crustaceans; sometimes associated with actual remains of callianassids (EHRENBERG, 1938; MERTIN, 1941, GLAESSNER, 1947, MÜLLER, 1970b), described with *Glyphea* crustacean inside burrow (SELLWOOD, 1971); Recent lebensspuren comparable to *T. saxonicus* described from modern burrows of callianassids; producers most likely living in sublittoral environment; burrows and burrow systems in hardgrounds more irregular (lacking widenings, branching) than those in soft chalk; for discussion of filling mechanism of such crustacean burrows (fill channels on their crests) see SEILACHER, 1968, p. 200.] *Trias.-Tert.,* Eu.-Asia(Iraq)-Taiwan-USA (Kans.-Utah)-Australia (Vic.); *L.Jur.,* Greenl.-G.Brit.; *L.Cret.,* USA(N.Mex.-Texas); *U. Cret.(Cenoman.),* Eu.(Pol.).——FIG. 70,*2a*. *T.* sp., Mio.(marine molasse), Switz.; *ca.* ×0.07 (Seilacher, 1955).——FIG. 70,*2b*. *T. saxonicus* (GEINITZ), U.Cret.(up. Cenoman.), Ger.(Sax.); ×0.08 (Müller, 1970b).

Tigillites ROUAULT, 1850, p. 740 [**T. dufrenoyi*; SD HÄNTZSCHEL, 1962, p. *W*218] [=*Foralites* ROUAULT, 1850, p. 742 (type, *F. pomeli*; SD HÄNTZSCHEL, 1965, p. 36)]. Simple vertical burrows without special lining; smooth or regularly annulated; openings may be funnel-shaped; not crowded. [Dwelling burrow; e.g., *Tigillites habichi* LISSON (1904, p. 41) (Jur. or Cret.; S. Am., Peru) is U-shaped burrow with spreite and type species of *Polyupsilon* HOWELL, 1957, p. 151 (according to GOLDRING, 1962, p. 238, junior synonym of *Diplocraterion* TORELL); whether *Tigillites* is to be regarded as a synonym of *Skolithos* HALDEMAN, 1840, or *Monocraterion* TORELL, 1870, has been under discussion for more than a century—see SALTER (1864b, p. 289), BOUČEK (1938, p. 249), PÉNEAU (1946, p. 78), HALLAM & SWETT (1966, p. 103), SEILACHER (1969a, p. 118, 122); thorough studies of many specimens of these three ichnogenera are required before questions of synonymy will be resolved.] *Cam.-Jur.,* Eu. (G.Brit.)-N. Am.-?S. Am. (Arg.)-Antarct.-Arabia; *?L.Cret.,* Eu.(Ger.); *U.Cret.,* USA(Kans.); *?Tert.,* N.Z.——FIG. 71,*2*. *T.* sp., Ord., France (Normandy); ×0.7 (Haug, 1911).

Tisoa DE SERRES, 1840, p. 6 (*emend.* FREY & COWLES, 1969, p. 21) [**T. siphonalis*; M] [=*?Tissoa* REYNES, 1868, p. 65 *(nom. null.)*]. Vertical U-shaped cylindrical tubes with closely appressed limbs; individual tubes 2 to 3 mm. in diameter, lying 1 to 15 mm. apart, rarely branched; principally form axis of elongated conical concretions 1 m. or more long; basal part of "U" commonly not preserved; burrow walls usually lined, occasionally striated; transitional forms difficult to distinguish from *Arenicolites*. [Dwelling burrow; according to FREY & COWLES (1969, p. 20; 1972) probably made by a shrimp or amphipod-like arthropod rather than by worm; for history of various interpretations (e.g., siphons of pelecypod having extremely degenerate valves, worm burrow, or algal origin), see FREY & COWLES (1969, p. 20); for bibliography see GOTTIS (1954, p. 190).] *Jur.,* Eu.(France-Ger.)-Madagascar; *L. Cret.,* USSR; *Tert.,* N.Afr.(Tunisia)-USA(Wash.-Ore.).——FIG. 71, *3a,b*. **T. siphonalis,* L.Jur. (Lias), France; *3a,b, ca.* ×0.7 (de Serres, 1840).——FIG. 71,*3c,d*. *T.* sp., Eoc.(Numidian), Tunisia; *3c,* individual, *ca.* ×0.7; *3d,* colony, *ca.* ×0.7 (Gottis, 1954).

Torrowangea WEBBY, 1970, p. 99 [**T. rosei*; OD]. Trails, sinuous to meandering, 1 to 2 mm. wide; characterized by crudely transverse annulation produced by irregularly spaced constrictions, mainly at 1 to 4 mm. intervals; trails tending to form random meshwork. *U.Precam.(up.TorrowangeeGr.),* Australia(NewS.Wales).——FIG. 72, *4*. **T. rosei; 4a,b,d,* paratypes, ×1; *4c,* holotype, ×0.7 (Webby, 1970b).

Trachomatichnus MILLER, 1880, p. 219 [**T. numerosus*; SD MILLER, 1889, p. 454]. Trackway consisting of 2 rows of crowded, poorly defined polydactylous imprints, ?9 to 11 per set; width about 5 to 15 mm.; track straight ahead; no dimorphism in the 2 rows of imprints; morphology of trackway varying along its length resulting from different types of movement. [Tentatively interpreted by MILLER (1880) as made by cephalopod (see TEICHERT, 1964b, p. *K*487); for detailed discussion and interpretation as trilobite tracks, probably made by *Cryptolithus* GREEN, see OSGOOD (1970, p. 367-368); *T. permultum* MILLER and *T. cincinnatiensis* MILLER lacking sufficient features; according to OSGOOD (1970, p. 362), possibly tracks of *Flexicalymene* SHIRLEY and belonging to *Petalichnus multipartitus* MILLER.] *U.Ord.(Cincinnat.),* USA(Ohio).——FIG. 71,*1*. **T. numerosus,* Eden Gr.; convex hyporelief, movement from bottom to top, ×0.7 (Osgood, 1970).

Treptichnus MILLER, 1889, p. 581 [**T. bifurcus*; OD] [="Feather-stitch trail" WILSON, 1948, p. 57]. Straight or curved row of short individual burrows of equal length, arranged alternating to right and left, tending upward, resulting in a zigzag featherstitch pattern, comparable to sympodial ramification of plants. [Feeding burrow (SEILACHER & HEMLEBEN, 1966, p. 49).] *L.Cam.* E.Greenl.*(Bastion F.)*-Eu.(N.Nor.)*(Breivik F.); Cam.,* USA(Ariz.); *Ord.(Trenton.),* Can.; *L.Dev. (Hunsrück Sh.),* Eu.(Ger.); *L.Carb.,* USA(Ind.); *L.Jur.,* Eu.(Ger.); *L.Cret.(Valang., Bentheim Ss.),* Eu.(N.Ger.).——FIG. 68,*5*. "Feather-stitch trail" WILSON; *5a,* schem. drawing (Wilson, 1948); *5b,* schem. reconstr.; *5c,* L.Dev., Hunsrück Sh., Ger.; ×1.7 (*5b,c,* Seilacher & Hemleben, 1966).

Triavestigia GILMORE, 1927, p. 32 [**T. ninigeri*; M]. Trackway consisting of 3 rows of [foot] impressions between 2 of which faintly impressed "tail" drag; longer axes of foot markings slightly diagonal to direction of movement, alternating; feet ?unidactyl. [Origin of third row with most distinct imprints dubious; arthropod (?insect) trackway.] *L.Perm.(Coconino Ss.),* N.Am.(USA, Ariz.).——FIG. 72,*5*. **T. niningeri*; ×0.6 (Gilmore, 1927).

Trichichnus FREY, 1970, p. 20 [**T. linearis*; OD]. Threadlike, cylindrical burrows, 10 mm. to 35 mm. long; diameter less than 1 mm.; straight or very slightly curved; branched or unbranched; typically vertical but also inclined to bedding plane or horizontal; with distinct walls, commonly lined with diagenetic minerals such as pyrite or rarely calcite. [Possibly combined feeding-dwelling burrow of very small deposit-feeding animal.] *U.Cret.(Niobrara Chalk),* USA(Kans.).——FIG. 73,*1*. *T.* sp.; ×2.6 (from Frey, R. W., & Howard, J. D., 1970, p. 147, in: *Trace Fossils* edited by T. P. Crimes & J. C. Harper, Geol. Jour. Spec. Issue 3, Seel House Press, Liverpool).

Trichophycus MILLER, & DYER, 1878, p. 1 [**T. lanosus*; M]. Large cylindrical burrows showing slight constrictions, 15 to 25 cm. long, diameter 1 to 3 cm.; floor of burrow ornamented by fine striae radiating from midline; some forms (e.g., *T. venosus* MILLER, 1879) with a few vertically directed secondary branches; backfill structure of burrows similar to *Teichichnus* or *Pennatulites*; type species *T. lanosus* consists of sinuous trails ending (?anteriorly) in buttonlike depression from which radiate fine striae; the ichnogenus better typified by more common ichnospecies *T. venosus* (=*Cyathophycus siluriana* JAMES, 1891). [Interpreted by SEILACHER & CRIMES (1969, p. 148) as feeding burrows probably made by small trilobites (trinucleids?), striation of burrows (=scratches) indicate lateral movement of animals in burrows. For history and interpretation of trace fossil (originally described as alga, later as inorganic in origin), including a very detailed discussion of synonymy, see OSGOOD (1970, p. 346-350). Entire morphology of the two ichnospecies, however, still requires some study; particularly of *T. lanosus,* now regarded by OSGOOD (1970, p. 347) as perhaps "a behavioral variant of the same organism that produced *T. venosum*."] *Ord.,* Eu. (Ger.-Nor.)-N.Am. (Ohio-Newf.)-Asia (Iraq).——FIG. 72,*2a*. *T. venosus* MILLER, loc. unknown; ×0.4 (Osgood, 1970).——FIG. 72,*2b*. **T. lanosus,* U.Ord.(Eden Gr.), Ohio; ×0.2 (Osgood, 1970).

Trisulcus HITCHCOCK, 1865, p. 18 [**T. laqueatus*; M]. Sinuous trail, about 1 cm. wide; consisting

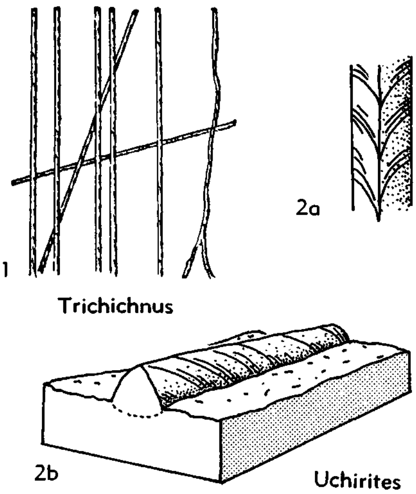

FIG. 73. Trace fossils (p. W118).

of 3 continuous grooves with intermediate ridges. [Originally interpreted by HITCHCOCK (1865) as made by annelids; according to LULL (1915, p. 69) perhaps mollusk trail.] *Trias.,* USA(Mass.).

Tuapseichnium VYALOV, 1971, p. 86 [**T. ramosum,* p. 86; OD]. Paired traces occurring as 2 rows of short cylinders that do not touch and give off long free branches. *U.Cret.,* Eu.(?Aus.)-USSR(Caucasus).——FIG. 72,*3*. **T. ramosum,* Caucasus; ×0.8 (Vyalov, 1971). [Description supplied by CURT TEICHERT.]

Tylichnus OSGOOD, 1970, p. 371 [**Rusophycus asper* MILLER & DYER, 1878a, p. 25; OD]. Weakly bilobate burrow, preserved in convex hyporelief subquadrate in cross section; showing an unusual pustulose ornamentation consisting of 3 to 9 parallel rows of transversely elongated nodes in form of zipper-like pattern; nodes may in addition be distributed randomly over surface. [Uncommon crawling trail.] *U.Ord.(Cincinnat.),* USA (Ohio).——FIG. 74,*2*. **T. asper* (MILLER & DYER), Eden Gr., Ohio(Cincinnati); *2a,* enl., diagram., ×5; *2b,* several superimposed trails, loc. unknown, ×1.8; *2c,* ×1 (Osgood, 1970).

Uchirites MACSOTAY, 1967, p. 37 [**U. triangularis*; M]. Elevated ribs of triangular cross section; with sharp edge projecting over the bedding plane; about 3 mm. high; both sides very finely striped; both ends gradually tapering. *L.Tert.(Paleoc.),* S.Am.(Venez.).——FIG. 73,*2*. **U. triangularis; 2a,b,* dorsal view, three-dimensional diag. (after Macsotay, 1967).

Umfolozia SAVAGE, 1971, p. 221 [**U. sinuosa*; OD]. Biserial trackway, 20 to 25 mm. wide, consisting of paddle-shaped impressions, indicating repetition every 4 pairs; cross-interval of first pair smaller than that of fourth pair; between

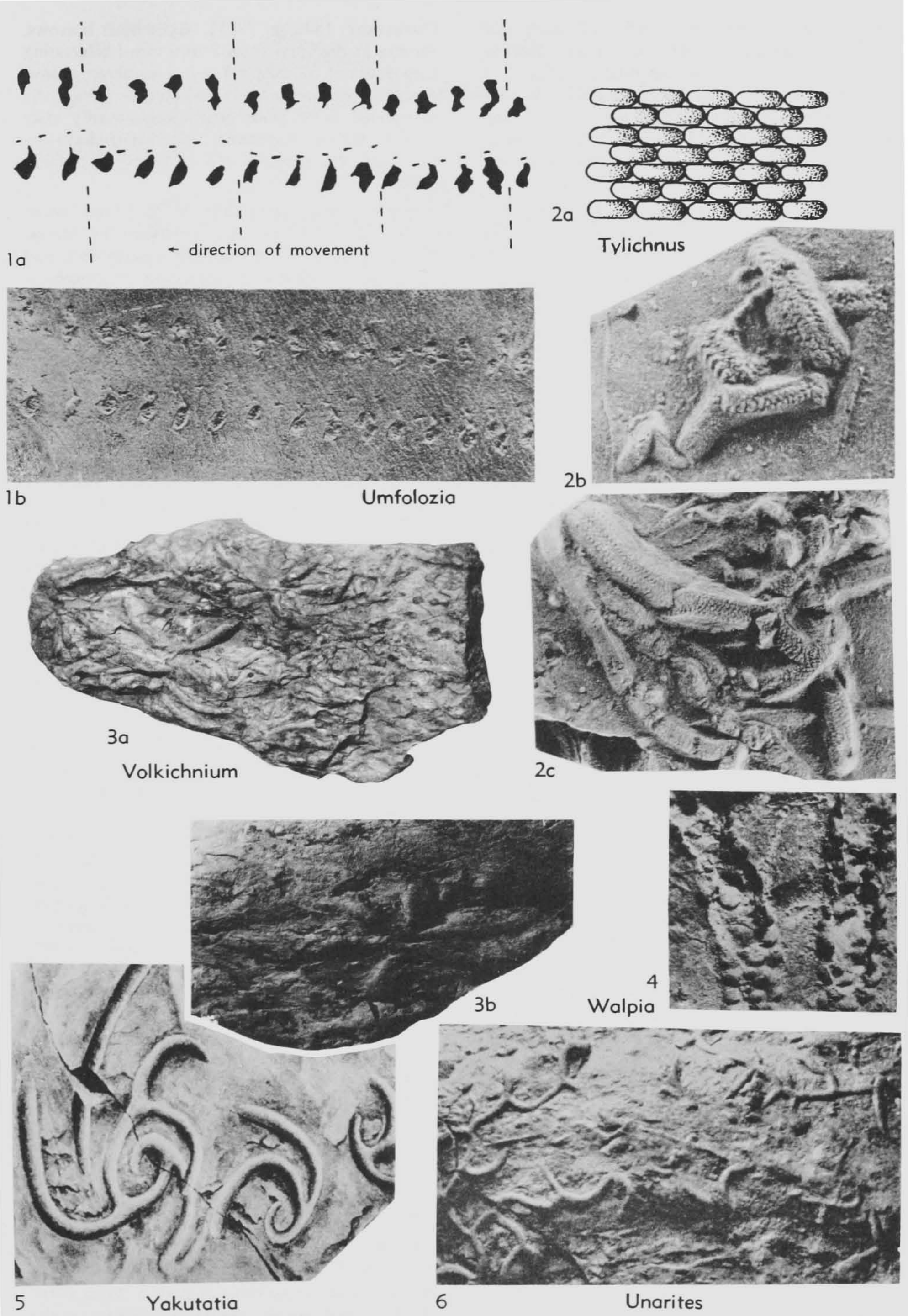

FIG. 74. Trace fossils (p. *W*118, 120).

the 2 rows of imprints a series of small oval marks [according to SAVAGE, telson marks], closer to one side than the other, arranged in regularly sinuous pattern with 6 marks to each curve. [Belonging to "*Diplichnites* group"; suggested to have been made by crustaceans, perhaps syncarids or peracarids, probably half swimming, half walking, living in freshwater periglacial environment.] *L.Perm.(Dwyka Gr.),* S.Afr. (N. Natal).——FIG. 74,*1*. **U. sinuosa; 1a,* tracing of trail, ×0.78; *1b,* holotype, ×0.8 (Savage, 1971).

Unarites MACSOTAY, 1967, p. 38 [**U. suleki*; M] [=*Cylindrites submontanus* AZPEITIA MOROS, 1933, p. 44; placed in *Palaeochorda* McCOY by KSIĄŻKIEWICZ (1970, p. 302)]. Very irregular winding and branching trail, may be straight or broadly curving; strings 1 to 3 mm. wide, circular in cross section; commonly with rather short thornlike ramifications. [Grazing trail similar to, perhaps even identical with, *Protopaleodictyon* KSIĄŻKIEWICZ, 1970, and *Acanthorhaphe* KSIĄŻKIEWICZ, 1970; GÓMEZ DE LLARENA (1946, p. 141) regarded *Cylindrites submontanus* AZPEITIA MOROS as an irregular net of *Paleodictyon.*] [Found in flysch deposits.] *L.Tert.(Paleoc.),* S. Am.(Venez.).——FIG. 74,*6*. **U. suleki*; ×0.6 (Macsotay, 1967).

Urohelminthoida SACCO, 1888, p. 183 [**Helminthoida appendiculata* HEER, 1877, p. 168; SD HÄNTZSCHEL, 1962, p. *W*219] [=*Hercorhaphe* FUCHS, 1895, p. 395 (no type species designated, no formal species name established)]. Threadlike reliefs forming meanders with tail-like appendage at each turn; forking strings 1 mm. to about 2 mm. thick. [Grazing trail.] [Found in flysch deposits.] *Cret.-L.Tert.,* Eu.(Aus.-Switz.-Italy-Spain-Pol.)-S.Am.(Venez.).——FIG. 72,*1*. **U. appendiculata* (HEER), Eoc., Switz.; ×0.3 (Heer, 1877).

Volkichnium PFEIFFER, 1965, p. 1266 [**V. volki*; M]. Starlike trace fossil, about 5 cm. in diameter; consisting of 6 to 8 tunnel-shaped "rays"; vertical shaft not observed. [Feeding burrow; very similar to *Bifasciculus* VOLK; ?made inside sediment]. *?L.Cam.,* Eu.(N.Nor.); *L.Ord.(Phycodes beds),* Eu.(Ger.); *?L.Carb.(Kulm),* Eu.(Ger.).——FIG. 74,*3*. **V. volki, Phycodes* beds, Thuringia; *3a,* holotype, ×0.8; *3b,* ×0.7 (Pfeiffer, 1965).

Walpia WHITE, 1929, p. 117 [**W. hermitensis*; M]. Tunnels lined with flattened, lenticular, smooth pellicles of rather leathery texture; irregularly crowded or imbricated; probably representing excrement packed against walls of burrows. [?Made by worms or crustaceans.] *Perm. (Hermit Sh.),* USA(Ariz.).——FIG. 74,*4*. **W. hermitensis*; ×0.9 (White, 1929).

Yakutatia HÄNTZSCHEL, 1962, p. *W*220 [**Gyrodendron emersoni* ULRICH, 1904, p. 140; M] [=*Gyrodendron* ULRICH, 1904, p. 140, obj.(*non* QUENSTEDT, 1880, p. 797)]. Cylindrical burrows, varying in thickness from 2 to 6 mm.; bifurcating 1 to 3 times, forming 1.7 volutions about acuminate inner extremity; outer end obtuse. [Originally interpreted as of plant origin, undoubtedly trace fossil.] *U.Cret.(YakutatF.),* N.Am.(Alaska).——FIG. 74,*5*. **Y. emersoni* (ULRICH); ×0.5 (Ulrich, 1904).

Zoophycos MASSALONGO, 1855, p. 48 [Type species questionable; "genus" first published by MASSALONGO, in 1851, p. 39 (without description), and founded on *Zonarites? caputmedusae* = *Zoophycos caputmedusae* MASSALONGO, 1855, p. 48; PLIČKA (1968, p. 840) regards *Fucoides circinnatus* BRONGNIART, 1828, p. 83, as type species; TAYLOR (1967, p. 4), "*Zoophycus laminatus* SIMPSON" *(nom. nud.)*; other authors, *Fucoides brianteus* VILLA, 1844, p. 22] [Due to lack of a thorough monographic treatment of the "genus," its confused nomenclature, and the many discussions of it still in flux, it is impossible to establish a list of valid synonyms; several of the following genera and species are certainly synonyms but some of them will probably be retained as separate ichnogenera if the "genus" is subsequently subdivided (see SIMPSON, 1970, p. 506): *?Umbellularia longimana* FISCHER DE WALDHEIM, 1811, p. 31; *Zoophycos* MASSALONGO, 1851, p. 39 *(nom. nud.)*; *Chondrites scoparius* THIOLLIÈRE, 1858, p. 718; *Taonurus* VON FISCHER-OOSTER, 1858, p. 41 *(partim) (type, Fucoides brianteus* VILLA, 1844, p. 22); *Spirophyton* HALL, 1863, p. 78 (*partim,* for discussion see SIMPSON, 1970, p. 506, and herein, p. *W*108); *Sagminaria* TRAUTSCHOLD, 1867, p. 46 (=*Umbellularia longimana* FISCHER DE WALDHEIM, 1811, p. 31); *Alectorurus* SCHIMPER, 1869, p. 203 (type, *Fucoides circinnatus* BRONGNIART, 1828, p. 83); *?Physophycus* SCHIMPER, 1869 *(partim)* (type, *Caulerpites marginatus* LESQUEREUX, 1869, p. 314); *Zoophycus* SCHIMPER, 1869, p. 210 (and several subsequent authors) *(nom. null.)*; *Cancellophycus* DE SAPORTA, 1872, p. 126 (type, *Chondrites scoparius* THIOLLIÈRE, 1858, p. 718); *?Glossophycus* DE SAPORTA & MARION, 1883, p. 103 (type, *G. camaillae*); *?Flabellophycus* SQUINABOL, 1890, p. 198 (type, *F. ligusticus* SQUINABOL); *Zoophicos* VASSOEVICH, 1953, p. 41 *(nom. null.)*; *Palaeospira* PLIČKA, 1965, p. 1 (type, *P. ensigera*); *Spirographis carpatica* PLIČKA, 1968, p. 843 (*Spirographis*= Recent genus!); *Palaeospirographis* PLIČKA, 1962, p. 359 (type, *P. hrabei*) (regarded by PLIČKA (1968, p. 840) as synonym of *Zoophycos*)]. Complex spreiten structures with numerous morphological variations; divided into 2 basic forms: 1) helicoidal, and 2) flat or planar. Shallowly-conical, spiral form, consisting of 3 main parts: spirally coiled spreite (=lamina, plate), major and minor lamellae contained within the lamina, and a cylindrical tunnel (marginal and axial);

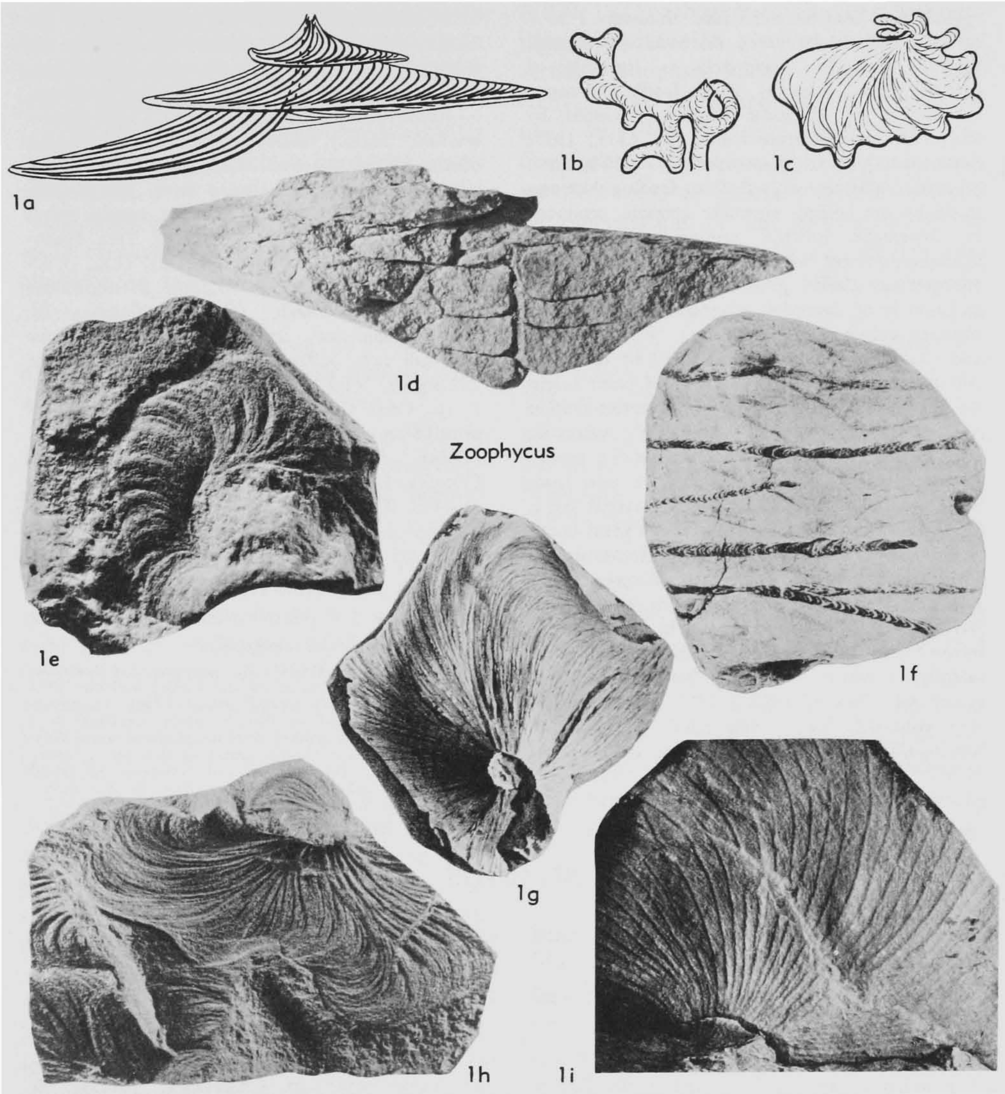

FIG. 75. Trace fossils (p. W120-122).

axis of spiral vertical to bedding; height small; single volutions conelike, sloping outward; diameter of successive whorls generally increasing downward; occasional inverse direction of coiling; basal diameter of structure (particularly in flysch deposits) up to 60 cm. or more (max., 1.45 m., Tert., N.Z.); whorls comprising lamina variable in outline: circular, arcuate, or lobate (broadly based or tonguelike); occasionally first volutions lobate and larger and deeper ones nearly circular in outline; laminae exhibit major and minor lamellae (ridges), appear lunate in cross section, and curve radially from axis of spiral; major lamellae branch at acute angle toward axis forming minor lamellae; cylindrical tunnel with axial and marginal part forms the axis of spreite, has same thickness as spreite, may continue for a part or for whole length of lamina and then may be open to sediment at both ends. Planar forms of *Zoophycos* similar to closed spiral spreite, may also be antler-like; thickness 1 to 7 mm. [One of the most discussed problematic fossils; originally interpreted as imprints of marine algae, later as body fossils (sponges, corals), as of inorganic origin (produced by eddy currents); as trace fossils (by ABEL, 1935; SEILACHER, 1954; LESSERTISSEUR, 1955, and others), tentatively regarded as feeding burrows made by soft-bodied wormlike animals, produced by systematic helicoid mining and foraging through sediment which shifted lobes of burrow (SEILACHER, 1967c, p. 80); other interpretation as imprints of discarded prostomial parts of sedimentary polychaetes (Sabellidae) (PLIČKA, 1962, and especially 1968, 1969) accepted by only few authors; for new interpretation as of plant origin see PLUMSTEAD (1967); "no single interpretation has yet found general acceptance" (TAYLOR, 1967, p. 11) and "much remains to be discovered" (SIMPSON, 1970, p. 505) as may be seen from many controversial discussions during recent years; for Recent "*Zoophycos* burrows" from great depth of the Pacific see SEILACHER, 1967b (cross section with lunate lamellae as in fossil *Zoophycos*, pl. 1, fig. E); complex spiral forms mostly in deep *Nereites* facies (SEILACHER, 1967b, p. 421), flat forms typical of *Zoophycos* facies, but also occasionally in neritic or even shallower marine environment (OSGOOD, 1970, p. 403); nomenclature very confused, the "cauda galli" (*Spirophyton cauda-galli* HALL, 1863) according to SIMPSON (1970, p. 506) undistinguishable from *Zoophycos*; BISCHOF (1968) proposed to restrict name to *Z. brianteus* (VILLA), for other proposals see TAYLOR (1967, p. 19); for the older history see BARSANTI (1902); (see also BISCHOF, 1968; SIMPSON, 1970; LEWIS, 1970).] *Ord.-Tert.*, cosmop. ——FIG. 75,*1a*. *Z. crassus* (HALL) [*"Spirophyton crassum"* HALL], U.Dev., USA; schem. drawing (Sarle, 1906b).——FIG. 75,*1b,c,f*. *Zoophycos; 1b*, schem. drawing, antler-shaped form, ×0.08 (Seilacher, 1959); *1c*, schem. drawing, regular spiral form, ×0.05 (Seilacher, 1959); *1f*, Tert. (probably Mungaroa Ls. = Kaiwhata Ls.), N.Z.; ×0.5 (Webby, 1969b).——FIG. 75,*1d,h*, *Z. circinnatus* (BRONGNIART), Czech. (Carpath. flysch); *1d*, Paleoc., long. sec., imprint of prostomial lobe with gill rays, ×0.3; *1h*, Eoc., spiral imprint of gill organs, ×0.25 (Plička, 1968).——FIG. 75,*1e*. *Z.* sp., Cret., Czech.(Carpath. flysch); planar imprint of an uncoiled spiral of the gill rays; ×0.27 (Plička, 1968).——FIG. 75,*1g*. *Z. brianteus* (VILLA), Eoc., Italy; ×0.4 (Massalongo, 1855). ——FIG. 75,*1i*. *"Zoophycos,"* prob. up. Mio.(up. Tongaporutan beds), N.Z.(Gower R.); dextral specimen, ×0.08 (Stevens, 1968) (from Plička, M., 1970, p. 367, in: *Trace Fossils* edited by T. P. Crimes & J. C. Harper, Geol. Jour. Spec. Issue 3, Seel House Press, Liverpool).

[BRADLEY (1973, p. 118-122) has proposed that *Zoophycos* could have been produced by the feeding activities of a sea pen or similarly related animal. Such an animal would be positioned so that its calyx remained in a relatively stationary position near the sediment water interface and its tubular rhachis protruded into the sediment, free to move. The volution and accompanying lateral movement of the rhachis would account for the characteristic spiral structure of *Zoophycos*.—W. G. HAKES.]

BORINGS

Borings in shells, bones or other hard parts of invertebrates or vertebrates, in sedimentary rocks or in wood, occupy a special position among trace fossils, which entitles them to a chapter of their own. Borings are known as far back as the early Paleozoic, and may be produced by plants or by animals. Those of plant origin are made by algae, fungi, or lichens. Within the animal kingdom, boring organisms are known from the following groups: Porifera, Bryozoa, Phoronidea, Sipunculidea, Polychaeta, Turbellaria, Brachiopoda, Gastropoda, Amphineura, Bivalvia, Cephalopoda, Arthropoda (Isopoda, Amphipoda, Insecta), Cirripedia, Echinoidea, and perhaps also Foraminiferida.

In the fast few years, Recent and, especially, fossil borings have attracted much interest among paleontologists. New and important publications are by BROMLEY (1970, with many bibliographical references), BOEKSCHOTEN (1966, 1967), and CAMERON (1969b). For additional papers, one may refer to CARRIKER, SMITH, & WILCE (1969). These papers were presented at the International Symposium *Penetration of calcium carbonate substrates by lower plants and invertebrates*, which was held in Dallas in 1968. However, as the title suggests this symposium was restricted to borings and their producers only in calcareous substrates. In this symposium, CARRIKER & SMITH (1969, p. 1012) introduced the following concepts:

Calcibiocavitology. The study dealing with the hollowing out of spaces in hard, calcareous substrata by organisms.