SVERIGES GEOLOGISKA UNDERSÖKNING

SER. C. Avhandlingar och uppsatser. N:o 372.

ÅRSBOK 25 (1931) N:o 5.

DIPLOCRATERION, MONOCRATERION AND SCOLITHUS

FROM THE LOWER CAMBRIAN OF SWEDEN

BY

A. H. WESTERGÅRD

WITH TEN PLATES

Pris 2 kr.

STOCKHOLM 1931
KUNGL. BOKTRYCKERIET. P. A. NORSTEDT & SÖNER
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1. Diplocraterion TORELL, 1870.

Original diagnosis: Two tubes, joined inferiorly, situate superiorly in excavated funnels.

Under the "generic" name of *Diplocraterion* Otto Torell described two forms of U-shaped burrows, *D. parallelum* and *D. lyelli,* from the Lower Cambrian sandstone at Lugnås in Västergötland. Unfortunately one essential characteristic was not mentioned, and the descriptions were not accompanied by figures: hence contradictory opinions as regards the structure of *Diplocraterion* are to be found in the literature. Older Swedish geologists (N. O. Holst, J. C. Moberg and others) identified with *Diplocraterion* burrows which are built after the scheme "U-in-U" and have what the Germans call a "Spreite", *i. e.* the burrow is formed like a pocket with a series of festoons or traces of a number of tubes connecting the limbs of the U and roughly parallel to its bottom curve. Dr. Hadding (1929, p. 44) also agrees with this opinion when he characterizes *Diplocraterion* as "U-shaped tubes with connecting arches between the two vertical limbs". Other authors, on the contrary, *e. g.* Professor Rud. Richter, who in two valuable papers (1924 and 1926) has thoroughly discussed U-shaped burrows from different geological formations in the light of similar burrows made by recent animals, has interpreted Torell's descriptions of *Diplocraterion* as applying to burrows forming a single U, without "U-in-U"-structure, which is easily explained by the fact that Torell does not mention anything that might indicate the pocket-form. This difference of structure of U-shaped burrows is shown by Richter to be of particular value for their interpretation, and therefore he has used it as principal basis of classification. He distinguishes between two groups of U-shaped burrows, viz. (1) *Rhizocorallidae,* with "U-in-U"-structure (type *Rhizocorallium* ZENKER) and (2) *Arenicolitidae,* forming a single U, without "Spreite", (type *Arenicolites* SALTER). Now, *Diplocraterion* is placed by Richter in the latter group, whereas, in the opinion of most Swedish geologists, it should be referred to the group of *Rhizocorallidae,* and, as is shown below, under the name of *Corophioides erraticus* Richter has described a form which probably is identical with *Diplocraterion parallelum.* Evidently only the bringing to light of Torell's type specimens would

give us necessary supplementary information as regards this question. While working at the map section "Lugnås", within which the type locality of *Diplocraterion* is situated, the present writer had occasion to pay attention to this question, and I have succeeded in finding three samples which in all probability are some of the specimens on which Torell founded his descriptions of *Diplocraterion.*

The samples belong to the Geological Survey of Sweden. For want of space they were packed away more than thirty years ago and were only recently unpacked. Sample No. 1 (Pl. I, Figs. 1—2) which was labelled "Diplocraterion parallelum Tor. Lugnås, Vestergötland. O. Torell" is a piece of typical Mickwitzia (Eophyton) sandstone with a brown-reddish colour due to weathering. Sample No. 2 (Pl. IV, Figs. 1 a—b) had two small labels attached, one of them with a figure and exactly similar to labels marking a series of samples of the older collections from Lugnås belonging to the Geological Survey, the other one marked — probably by the hand of A. G. Nathorst — "Doit être retourné" indicating that it was sent on loan with other specimens to a foreign scientist, probably during the period 1873—84, when Nathorst was engaged on the Geological Survey. Sample No. 3 (Pl. IV, Figs. 2 a—b) had a label attached marked "Diplocraterion lyelli Tor. Eophyton sandsten. Lugnås, Vestergötland. O. Torell" in G. C. v. Schmalensee's hand. Nos. 2 and 3 probably originate from one and the same stratum and consist of a yellowish-greyish sandstone which is less hard than the typical Mickwitzia sandstone; it agrees with layers embedded in the latter, but also with the bottom stratum of the Lingulid sandstone. The labels accordingly tell us that Torell has collected at least Nos. 1 and 3 of these samples, but nothing is said about the point of time when they were found. Of course they might have been collected after the publishing of Torell's paper on *Diplocraterion,* but there are reasons for the assumption that they were found before that time.[1]

Diplocraterion parallelum TORELL. Pl. I—III; X, Figs. 2—3.

For comparison of the specimens found again with Torell's diagnosis, the latter, translated into English, may be cited.

"Tubes linear, diam. 4 mm, erect, parallel, joined in a curved line below. Each funnel small, diam. 7—15 mm, irregular, with lacerated surface. Distance between the funnels 6—12 mm, between the tubes 22 mm. Funnels apparently lacerated by tentacles.

Locality: In the lowest layer of the sandstone at Lugnås. At different localities

[1] Torell published the paper in question in 1870, the last year he lived in Lund. From the beginning of 1871 till the end of 1897 he was Director of the Geological Survey at Stockholm. From the financial accounts of the Geological Survey we learn that Torell never visited Lugnås during the latter period, at least never on his journeys on official business, which unquestionably speaks in favour of the assumption that the specimens were collected before 1871.

In view of Torell's great interest in the oldest organic remains of our country it is easy to imagine that — instead of presenting his private collections from Lugnås to the Geological Museum of Lund — he preferred to bring them with him to Stockholm in order to have them at hand for further investigations.

in Scania specimens of this kind have been found which, though resembling *D. parallelum*, possibly should be referred to a new species."

Torell's diagnosis squares fairly well with the specimen in Pl. 1, Fig. 1. The tubes, which are not wholly cylindrical but vary somewhat in thickness, have a maximum diameter of exactly 4 mm, and also the distance between the tubes is that given by Torell, 22 mm. The openings of the tubes in Fig. 1 are imperfectly preserved but can hardly be said to be funnel-shaped, and accordingly in this point the diagnosis and the figured specimen disagree. However, in the same sample two more U-burrows are to be seen, one showing slightly widened openings and the other one (Pl. 1, Fig. 2) — which is in part concealed in the matrix — has the opening of one limb distinctly funnel-shaped with a diam. of 8 mm., and the other limb forming a double opening like an 8 which immediately beneath the surface forms an ovate funnel. The longer axis of the double opening is 12 mm. The funnels are irregular and their surface somewhat lacerated, as described by Torell. Consequently we may be justified in concluding that Fig. 1 and associated specimens — together with other specimens which have not been found again — in all probability are Torell's co-types of *D. parallelum.*

The specimens allow of a completion of Torell's diagnosis with an essential characteristic: the burrow has a distinct "U-in-U"-structure with traces of arches connecting the limbs. In Fig. 1, a particularly distinct imprint of such a curved tube is seen near the upper surface. There is a strongly marked petrographical difference between the tubes, including the plate between them, and the surrounding rock. The latter is a hard and rather pure sandstone, the tubes are built up of clay with quartz grains or a strongly argillaceous, rather loose sandstone; and so too is the plate, though in the latter the content of clay is less than in the tubes proper. The petrographical difference between the pocket and the matrix proves that the festooned area is due to a true "U-in-U"-structure and not to sagging, as shown by Dr. Bather in the case of *Arenicolites statheri* BATH. The surface of the tubes is smooth or slightly rough owing to quartz grains; no striation is visible. The funnel-form of the openings in one of the specimens seems to be a primary characteristic and not caused by weathering.

Burrows of very varying size but otherwise agreeing with the co-types of *D. parallelum* are common in the Mickwitzia sandstone at Lugnås, and, as shown below, they are widely distributed, regionally as well as vertically, in the Lower Cambrian of Sweden. Owing to the usually strongly marked petrographical difference between the burrows and the matrix the former are conspicuous especially on weathered surface. On weathered bedding surface they form very characteristic shallow slits which are often dumb-bell shaped and are sometimes limited by straight margins. They occur as a rule in great abundance, and strata crowded with them have characteristic rough bedding surfaces (see Pl. II, Fig. 1 a) with the slits lying irregularly in all directions of the compass. The plane of the burrow is always normal to the bedding-plane, and so too, as a rule, is the axis. Specimens with the axis

1† —312987. *S. G. U., Ser. C, N:o 372. A. H. Westergård.*

forming an acute angle with the bedding-plane are rarely seen. The pocket is usually plane, occasionally slightly curved in transverse section. Occasionally two specimens traverse each other at right or acute angles. The tubes are sub-cylindrical with alternating slightly wider and narrower portions and may even in one and the same specimen vary considerably in thickness (see Pl. I, Fig. 3). In smaller specimens, with the slit about 2 cm long, the tubes are about 0.2—0.4 cm in diameter, in larger specimens — slit 6—7 cm long — the tubes are 0.8—1.0, occasionally 1.5 cm in diam. The openings of the tubes are in unweathered specimens undoubtedly found to be funnel-shaped, but the enlargment seems in most cases to be due to weathering, and, as a rule, even the topmost part of the tube seems to be cylindrical. Usually the two vertical limbs are strictly parallel, and the bottom of the burrow is semicircular. Rare specimens which no doubt belong here have the tubes slightly converging downwards, and in other cases the lower part of the burrow is slightly widened (Pl. X, Fig. 2). Thus, a large specimen which was found associated with specimens of normal type and which was 24 cm deep was 7.5 cm long at the opening and 5 cm near the bottom. Occasionally the bottom of the burrow is transverse and straight, as in Pl. 1, Fig. 3, in the latter case probably caused by a lithological change of the sediments, the sand-layer being underlain by clay. The length of the slit varies. The burrows of one layer are generally of about equal slit length; 2.5—3.5 cm seems to be the most common. The smallest form found is 1.2 cm and the largest about 7.5 cm long. The breadth of the slit is equal to the diam. of the tubes at the ends of the latter, usually considerably narrower at the middle; especially in shallow, occasionally also in deep specimens, the slit is about equal in breadth throughout. Short burrows, c. 2 cm long, are rarely more than 10 cm deep, and in the deepest burrow found, 32 cm, the slit was 6.5 cm long.

The depth is independent of the length, and short as well as long burrows which are certainly complete are sometimes only 2—3 cm deep. The arrangement of the festoons and the varying depth of associated specimens equal in length indicate that the burrow has grown only in axial direction (distinction from *Corophioides*). It may be remarked, however, that in very few specimens traces of a very shallow U-tube slightly shorter than the slit are seen near the upper margin.

The openings of the burrows are confined to distinct bedding-surfaces.

As has already been mentioned, burrows of the type of *D. parallelum* are widely distributed in the Lower Cambrian of Sweden. Apart from Lugnås they are found in the Mickwitzia sandstone at the northern end of Billingen and at Kinnekulle. At the latter locality they appear already immediately above the basal conglomerate and continue into the Lingulid sandstone.

They are known of old from the Kalmarsund area. Holst (1893) distinguished two zones with *Diplocraterion* in this district, a lower one with a smaller form (slit-length 2 cm or usually more) and a higher one with a larger form (length 6—7 cm) in the uppermost part of the series at Mörby-

långa (compare p. 17). In reality these burrows have a far more widely vertical distribution in the Kalmarsund series, than has been known hitherto. Thus they occur abundantly in the lowest red or red-striped sandstone, in boulders on the Isle of Jungfrun, where these boulders are rather frequent though they have been overlooked, and in solid rock on Runnö, both in Kalmarsund; and they have been found, though very rarely, also in a greenish-gray clayey sandstone resembling the "kråksten" and in a thin-bedded, strongly glauconitic sandstone of the *Discinella (Mobergella) holsti* zone. It is true that the specimens from the lower horizons of the Kalmarsund series are, on the average, of smaller size than those from the top of the series; but it should be remarked that burrows with the slit at least 5 cm long are by no means rare, *e. g.* on Runnö, and, on the contrary, specimens 3 cm in length are met with in the topmost zone at Mörbylånga.

In Scania burrows of *D. parallelum* are known from the districts of Simrishamn and Hardeberga, at Torekov and Rekarekroken (W. of Ängelholm). At the latter two localities they appear already a few meters above the basal conglomerate; in the former districts these and other burrows and trails characterize a fairly thick zone between the *Schmidtiellus torelli* zone and the totally barren quartzitic sandstone forming the lower part of the Hardeberga sandstone (see p. 21). The burrows found in this province as in other areas are of very varying size, usually 3—4 cm in length. The smallest form found, 1.2—1.5 cm long, occurs S of Simrishamn in layers alternating with beds crowded with burrows 6—7 cm in length. Thus it is obvious that different-sized burrows of this kind cannot be used as index fossils for correlation of beds of different areas, as Holst seems to have thought possible.

As the tubes of a burrow do not seem to increase in thickness when the latter increases in depth and as the depth is independent of the slit-length, the smaller and the larger burrows possibly have been made by animals of different species. Assuming that the burrows have served as habitat for a relatively short time, the different size may be due to different age of the individuals, which in that case may belong to one species. Against the latter view it can be argued that the burrows of one and the same layer are usually, or at least very often, approximately equal in slit-length. Be this as it may, as I am not able to point out a safe distinction except the difference in size, and as, moreover, a totally continuous series from the smallest to the largest specimens is found in adjacent layers, I think it appropriate to unite all the forms in question under the name of *D. parallelum,* and, if a further discrimination is wanted, add the slit-length of the specimen.

Probably also the form in Pl. II, Fig. 3 should be included in this species. The weathered tubes look as if they were chambered, owing to their having been filled alternately with sand and clay. Only the specimens figured have been found in a boulder of greyish white sandstone from Brantevik, Scania, and are associated with specimens of the normal type of *D. parallelum.*

Another related form is characterized by being bulb-shaped, almost twice as long in the lower as in the upper part of the burrow. Only two specimens have been found, on the eastern shore of Runnö, Kalmarsund, and in a boulder at Kristianopel, Blekinge. The latter is 8 cm deep, 1.7 cm in diam. in its upper and 2.9 in its lower part. It seems to be identical with an Esthonian form which was recently described by Dr. Öpik (1929) under the name of *Corophioides helmerseni.* It may be noticed, however, that the form in Pl. X, Fig. 2, is to some extent intermediate between the latter and *D. parallelum,* even if it is closer to the latter.

Under the name of *Corophioides erraticus* Richter (1926) described a specimen from an erratic boulder of greyish quartzite found at Fürstenwalde a. d. Spree, Prussia, and said to originate from the Lower Cambrian of the Kalmarsund area or from Scania; and later Öpik (1929) recognized the same form in the topmost zone of the Lower Cambrian of Esthonia. Professor Richter has had the kindness to send me a cast of his specimen, which so far as I can see is identical with *D. parallelum,* and judging from Öpik's descriptions and figures also the Esthonian form can be identified with the Swedish one. — A form from Rekarekroken, W. of Ängelholm, which was identified by Dr. Troedsson (1930) as *Corophioides,* certainly belongs to the group of *D. parallelum.*

The above description and the figures attached accordingly prove that *Diplocraterion* belongs to the *Rhizocorallidae* Richter, *i. e.* U-shaped burrows with "U-in-U"-structure. Of recent animals making burrows of this type we only know the Polychaet worm *Polydora,* which usually bores into hard substances (limestone, sandstone, shells, wood, etc.) and, as established by Richter, occasionally also into non-consolidated sediments. The structure of the burrows and their ecological aspects indicate that *D. parallelum* was the habitation of a fairly sedentary, gregarious and plankton-feeding, marine creature, probably an Annelid, which lived in sandflats with shallow and tranquil water.

Structures closely comparable with *Diplocraterion* are known from formations of different ages and countries from the Cambrian upwards. The following may be mentioned here, and further references will be found in Richter (1924, 1926) and Kraus (1930): *Rhizocorallium devonicum* Kraus, 1930 (possibly identical with *Arenicoloides balticus* Andrée, 1926) from the Old red sandstone of the Baltic area; *Arenicoloides luniformis* Blanckenhorn, 1916, from the Bunther sandstone of Germany (the generic name was by the author himself in 1924 changed to *Corophioides*); *Rhizocorallium jenense* Zenker, 1836, from the Germanic Muschelkalk. From the Rhaetic-Liassic sandstone of Scania Hadding (1929) has mentioned a similar burrow, which, however, has not yet been described.

As regards the nomenclature a real confusion as yet prevails which at least in part is due to many of the forms in question being still unsatisfactorily known. Recently Professor Kraus (1930) proposed that all forms

of U-shaped burrows of "U-in-U"-structure should be brought together under one "generic" name, viz. *Rhizocorallium* ZENKER, 1836, which is clearly defined and is probably the oldest of those which may be considered. Certainly it is wise not to make a too close discrimination as regards these burrows, the true systematic position of whose inhabitants we shall never know, as recent burrows of the same appearance in some cases are made by quite different animals. However, so far as I can see, there are fairly essential differences between *Diplocraterion* and *Rhizocorallium* s. s. The latter is oblique or parallel to the bedding-plane, the median line is curved and the connecting arches between the limbs of the U regular and parallel, whereas *Diplocraterion* is normal to the bedding-plane, the median line straight and the connecting arches as a rule irregular. Therefore I think it justified to retain *Diplocraterion* for a group of Rhizocorallid burrows showing these distinctions.[1]

Before the "U-in-U"-structure of *D. parallelum* was established some students referred it to *Corophioides* J. SMITH, 1893, as mentioned above. However, I am not sure that the latter "generic" name should be regarded as a mere synonym for *Diplocraterion.* Judging from the original description and figure of the genotype, *C. polyupsilon* J. SMITH from a Carboniferous sandstone of Ayrshire, *Corophioides* seems to have a markedly different structure from *Diplocraterion:* the former consists of a series of U-tubes not only of different depth but also of different diameter, in the latter all U-tubes of one specimen are equal in diameter. *Corophioides* grows accordingly in two directions, *Diplocraterion* (and *Rhizocorallium*) only in axial direction. Therefore objections may be made to including *Corophioides* s. s. in *Diplocraterion.*

Burrows of the *Arenicolithidae,* forming a simple tube of U-shape without a pocket between the limbs, from the Cambrian of Sweden are unknown to me. According to Hadding (1929), however, such forms also occur in our Lower Cambrian, but they are said to be rare.

Diplocraterion lyelli TORELL. Pl. IV.

Torell's diagnosis, translated into English, runs as follows:

"Tubes linear, erect, breadth 3 mm, not parallel but slightly converging downwards, conjunct by a short, transverse, somewhat curved line. Each funnel (diam. 16—28 mm, height 30 mm) narrow, often longitudinally striated (by tentacles?), with the margin proper formed like a somewhat immersed exterior ring. Distance between the funnels 5—0 mm, between the tubes superiorly 25—20 mm, inferiorly 15—9 mm. Not quite half the funnels filled with clay.

Locality: Lugnås, Västergötland."

[1] An imperfectly known U-shaped burrow with dumb-bell like slit from the Upper Cambrian of Newfoundland was described by Billings in 1872 under the name of *Arthraria antiquata* (Canad. Naturalist, New Ser., Vol. 6, p. 467). Even if this form will prove to be a *Rhizocorallid,* which does not seem to be probable, the name *Arthraria* cannot be substituted for *Diplocraterion* as the latter name is the older one. (Compare also Matthew, Trans. Roy. Soc. Canada, Sec. Ser., Vol. 5, Sec. 4 (1899), p. 71).

With the specimens of Pl. IV, Figs. 1 and 2, Torell's diagnosis can be said to agree almost completely, and, even if some small disagreements exist, it can hardly be doubted that the figured specimens are some of Torell's co-types of *D. lyelli.* The diam. of the tubes seems to be rather 2—2.5 than 3 mm, as claimed by Torell, but it should be noticed that the tubes in their present state of preservation scarcely allow of a minute determination of the thickness. As regards the dimensions of the funnels and the distance between the latter the diagnosis and the specimens agree. In a few funnels a faint longitudinal striation is indicated. So great a distance between the tubes superiorly as 20—25 mm is not found in any of the present specimens, however, unless these figures refer to the distance between the centra of the funnels at the surface, when the agreement is complete. The distance between the tubes near the bottom of the figured specimens is 7 or 8 mm and consequently somewhat less than that stated by Torell. The bottom of the burrows is indistinct and possibly not preserved. Therefore a transverse tube connecting the vertical tubes is not directly visible. However, the U-form is clearly indicated by the funnels being always arranged two by two, and by the character of the plate between the tubes. The lower part of the funnels and the tubes are filled with a clayey mud with scattered quartz grains. The upper part of the funnel which is now empty (owing to weathering) is pot-shaped with curved bottom. In some specimens the sub-cylindrical tube is seen to continue through the filling of the funnel. The plate between the tubes, at least in the lower part of the burrow,[1] consists of clayey sandstone and differs markedly from the matrix, which is a rather pure quartz sandstone. The vertical sections present do not show traces of transverse tubes connecting the vertical tubes. However, the existence of a true "U-in-U"-structure even in this form is proved by the above-mentioned petrographical character of the plate between the tubes. The tubes and funnels are surrounded by a thin rust-coloured zone.

The principal difference between *D. parallelum* and *D. lyelli* is shown by the openings of the tubes: in the latter the tubes end in large funnels, in the former the funnels are small and shallow, and usually they seem to be absent, the tubes being sub-cylindrical up to the surface. Because of this difference the two forms possibly will be given different "generic" names in the future, and in this case the form *parallelum* has to keep the name given it by Torell, since Richter in 1926 has chosen the latter as the genotype of *Diplocraterion,* though the verbal sense of *Diplocraterion* applies far better to *lyelli* than to *parallelum.*

A separated limb of *D. lyelli* resembles *Monocraterion tentaculatum* to the extent that it is hardly possible to distinguish it from the latter.

D. lyelli seems to be rare. It has been sought in vain at Lugnås, nor has it been observed at any other locality. The rock indicates that it originates

[1] The upper part of the vertical sections exposes a surface which does not coincide with the plane of the tubes.

from a thick bed in the Mickwitzia sandstone or possibly from the basal layer of the Lingulid sandstone.

The creature, presumably and annelid, which used *D. lyelli* as habitation seems to have claimed about the same ecological conditions as did *D. parallelum,* but the former appears to have been less gregarious than the latter.

2. Monocraterion TORELL, 1870.

Monocraterion tentaculatum TORELL (?). Pls. V—VI.

This species is the genotype and the only species of *Monocraterion* described from Sweden. The following is the original diagnosis, translated into English.

"Erect, linear, superiorly somewhat widened, breadth 3—6 mm, length of the fragment 60 mm; situated in funnels (breadth 30—40 mm, height 22—30 mm). Tentacles c. 20 (in one specimen 21, in two specimens traces are found), long, extending above the margin of the funnel. Maximum length of tentacles 34 mm.

Locality: In a sandstone boulder of the Cambrian formation at Lugnås, Västergötland.

When the worm reaches the upper part of the funnel, it seems to thrive in a sheltering tube, as is the case of recent worms of the division *Tubicola*."

The diagnosis, which is difficult to interpret in some respects, is not illustrated by any figure, and hitherto I have not succeeded in finding Torell's type specimens. Therefore it has not yet been possible to recognize this species with full certainty. However, a form from the lower part of the Lingulid sandstone at Lugnås is described below which possibly may be identified as *M. tentaculatum;* at any rate it seems to be a *Monocraterion* even though no "tentacles" are preserved.

A sub-cylindrical tube, perpendicular to the bedding-plane, usually straight, sometimes slightly curved, ends superiorly in a funnel. Tube generally 3—4 mm in diam., often slightly increasing in width upwards; fragments 6—8 cm in length frequent, longest specimen found 16 cm. Funnel in transverse section circular or fairly irregular, in vertical section wide or narrow, straight-sided, cup- or trumpet-shaped; varying in width and depth, often 10—15 mm, rarely 20 mm in diameter; greatest depth observed 22 mm (in one specimen 20 mm in diam.). The tube continues often through the funnel, and occasionally it is seen to end in a second funnel at a higher level.

Nothing resembling the bodies interpreted by Torell as tentacles has been observed in the material collected by me. The nature of these bodies is enigmatic. Nathorst (1881, p. 50) was inclined to regard them as "cemented thread-like excrements, analogous to those of *Arenicola,* of whose species *A. marina* has a similar funnel-shaped burrow". Without having seen them any attempt to give a satisfactory explanation must be vain, and it cannot even be ascertained that there exists any actual connection between the "tentacles" and the funnel. The funnel is in Torell's specimens larger

than in the specimens found by me, but specific value can hardly be attached to this difference. As Torell's diagnosis otherwise squares very well with the form described above, the latter may be tentatively identified as *M. tentaculatum.*

As the rock in the tubes and funnels generally is not distinguished from the surrounding rock, and as the former at least in most cases have the greyish white colour of the latter, they are often invisible on fresh surface and appear conspicuously only after weathering. As shown by the figures, the tubes can occur abundantly but are never so closely packed as often is the case in *Scolithus.* The funnels are sometimes confined to certain bedding-surfaces, sometimes placed at irregular levels in the rock, and in the latter case a bedding surface cuts the specimens at varying distances from the end and exposes sections of tubes as well as of funnels at varying height.

Monocraterion resembles *Scolithus,* with which it indeed has been identified. It is evident that incomplete specimens of the former, with the funnel not preserved, cannot be distinguished from the latter. However, as the opening seems to be constantly funnel-shaped in this form, and is likewise constantly cylindrical in the *Scolithus,* which occurs *e.g.* in the lowest zone of the sandstone series of Kalmarsund, it seems appropriate to let the former keep the name of *Monocraterion* and confine *Scolithus* to forms with the opening not widened. If this view be accepted, at least some of the forms from the Lower Cambrian pipe-rocks of Scotland (Peach, 1907) which have been included in *Scolithus* should be referred to *Monocraterion.*[1]

Cone-formed bodies resembling the funnel of *Monocraterion* are known from the Lower Cambrian of different areas of Scandinavia. Presumably these bodies are of varying nature, and probably some of them in reality might be identified as *Monocraterion.* Thus, a form from Lugnås, described by Torell under the name of *Micrapium,* is said to show occasionally a cylindrical tube which penetrates the cone, as is the case in *Monocraterion.* It seems hardly possible to distinguish *Micrapium* cones of the latter appearance from specimens of *Monocraterion* of which only the funnel is visible owing to the difficulty in tracing the tube on unweathered surface. Some specimens of a form from Torneträsk which were by Moberg (1908) compared with *Monocraterion* and which — thanks to the courtesy of Professor Grönwall — I have had the opportunity of examining, are too poorly preserved to allow of a safe identification. Holst (1893) has mentioned cone-formed bodies from sandstone boulders found on the islet of Hästholmen, N. of Skägganäs, Kalmarsund, and probably originating from Zone

[1] The body described by Kinahan in 1858 under the name of *Histioderma hibernicum* from the Cambrian of Ireland (Journ. Geol. Soc. Dublin, Vol. 8, p. 70) is, according to Zittel, distinguished from *Scolithus* by having trumpet-shaped orifice and curved tube, *i.e.* characteristics which at least to some extent square with *Monocraterion.* The original description and figures show a relatively thick and short tube, which widens upwards fairly continuously and has the lower end turned up. Thus *Monocraterion* must be kept distinct from *Histioderma.*

No. 6 of the scheme on p. 17, which he compared with similar bodies from the Nexö sandstone on Bornholm. The former are somewhat elliptical in transverse section, 4—5 cm wide and at least 6 cm deep. In one of the specimens the cone continues downwards into a tube, 0.8 cm thick, and in two other specimens the cone seems to be penetrated by two or three tubes. Probably these cones belong to a form of *Monocraterion.* According to Deecke (1906), the cones from the Nexö sandstone are of inorganic origin and were formed in the same manner as certain cone-shaped bodies which he observed in sand on the southern shore of the Baltic. This may be right, but possibly a new examination of better preserved specimens might give a different result.

Torell and Nathorst regarded *Monocraterion* as formed by an annelid, a view which seems to be well founded. Some authors explain tubes of this kind as being built mechanically, by ascending air or gas bubbles, and according to A. G. Högbom tubes in sand formed in the latter manner often end upwards in cups or funnels just as in the case of *Monocraterion.* However, the fact that the tube of the latter, as a rule, continues through the funnel and occasionally ends in a second funnel at a higher level speaks against the latter explanation. It may also be remarked that Seth Rosén (1922) mentions *Scolithus* tubes from the Lower Cambrian of Östergötland which penetrate thin seams of clay shale embedded in the sandstone and consequently can hardly be formed by rising air bubbles. Rosén identified these tubes as *Scolithus,* which may be right, though the horizon at which they occur seems to indicate that they more probably belong to *Monocraterion.*

Thus, an organic origin of *Monocraterion* is by far the more probable one. As the tubes are confined to pure quartz sandstones, are never branched and usually occur in assemblages, the annelid, or whatever it may have been, seems to have been plankton-feeding and gregarious. A sudden covering of sand has not killed the animal which kept its habitation, elongated the tube upwards and formed another funnel at the new surface, indicating that the animal was fairly sedentary.

Monocraterion is found in the Lingulid sandstone of Västergötland, at Lugnås, at the northern end of Billingen and Kinnekulle. From the latter locality it was first mentioned by A. G. Högbom (1924, p. 78), who identified these tubes as *Scolithus:* "Sie sind denjenigen des Kambriums von Kalmarsund ähnlich, jedoch durchgehend etwas gröber." At Kinnekulle the form occurs abundantly in certain beds in the lower part of the Lingulid sandstone, and in the upper part scattered specimens have been observed. One has good opportunities of studying it in weathered blocks, *e. g.* in the breakwater of Råbäck harbour and on the shore 1 km farther towards the north. A few tubes found in the Mickwitzia sandstone at Lugnås may possibly belong here. Whether the form from Östergötland also belongs here must be left undecided. As mentioned above a large form is known from the Kalmarsund area. It may be emphasized that

Monocraterion has not been observed in the zone of *Scolithus* of the Kalmarsund area and of Scania, and, so far as is yet known, the former is distinctive of a higher horizon of our Lower Cambrian than the latter.

3. Scolithus HALDEMAN, 1840.

Scolithus linearis HALDEMAN. Pls. VII—IX; X, Figs 1 a—c.

Much has been written on the peculiar bodies known under the name of *Scolithus* or pipe-rocks — sub-cylindrical, straight and long, closely packed or scattered tubes, which never branche or communicate, normal to the bedding-planes — and contradictory opinions of their origin have been put forward. This is partly due to the fact that objects of quite different nature have been brought together under one name. Here only the forms from the Lower Cambrian of Sweden will be considered. In the two last decades they have been dealt with rather thoroughly by Professor A. G. Högbom (1915) and Professor Rud. Richter (1920). Högbom arrived at the result that the *Scolithus* tubes have been formed by ascending air bubbles which were pressed up through the sand when the latter in dried condition was overflowed by the tide. This explanation was adopted at the time by most Swedish geologists. Richter showed that the above as well as all earlier attempts at explanation fail in some respect or other, and put forward a new interpretation: the tubes are built up vertically, from the bottom upwards, of sand-grains cemented by a slimy secretion by a plankton-feeding annelid which occupied the tube head-up. This view was supported by reference to a recent annelid, *Sabellaria alveolata* L., which builds similar sand-reefs of considerable stability, several meters in thickness and of wide extent, at places in the North Sea off the coast of Schleswig-Holstein. Certainly there is a striking resemblance between the latter reefs and the most common form of the Scolithus sandstone of Kalmarsund. There is in reality only one difference: in the *Sabellaria* reefs the tubes are slightly undulating, whereas the *Scolithus* tubes are usually almost mathematically straight — a characteristic which has induced some students to adopt the conception of their being of inorganic origin. However, in the Kalmarsund sandstone different forms of *Scolithus* occur. In forms with scattered tubes the latter are often slightly winding and sometimes straight; in case of closely crowding almost mathematically straight tubes predominate, and rarely a somewhat undulating specimen can be observed. However, at least in one case of extremely crowding (a narrow form, 1.5 mm thick, in an argillaceous and micaceous sandstone from Runnö)[1] all the tubes are slightly wavy about as in the organ-form of *Sabellaria*. As these different *Scolithus* forms are connected by intermediate forms and

[1] Though the tubes are distinct, I have not succeeded in obtaining a good photographic picture of this sample.

occur associated, they can hardly be distinguished genetically, and accordingly the almost mathematically straight form of the tubes does not seem to disprove the view of their organic origin. Certainly it cannot be doubted that tubes formed by ascending air or gas bubbles can be fossilized under favourable conditions, and therefore we have to expect bodies similar to certain forms of *Scolithus* having the latter — mechanical — origin; but, as Richter has emphasized, this hypothesis fails to explain the *Scolithus* form with extremely close-set and never communicating tubes, which is the most common form in the Kalmarsund region (Pls. VII and VIII). At any rate the explanation given by Richter is the most probable put forward hitherto. It may appear remarkable that nobody earlier has compared our *Scolithus* sandstone with the *Sabellaria* reefs. The reason is that the latter were practically unknown to geologists until Richter in 1920 made us acquainted with them.

Richter left unanswered the question whether the forms with closely crowded and, as a rule, almost mathematically straight tubes and those with scattered and usually slightly undulating tubes should be regarded as distinct or identical. Pending the results of further investigations, he tentatively distinguished them. Thus he proposed that only the former should be included in *Scolithus,* and the latter were given the new "generic" name of *Sabellarifex* (substituted for the originally proposed *Sabellarites* which term was found to be preoccupied). It seems hardly possible to retain this discrimination for the forms of the Kalmarsund sandstone, since a series of intermediate forms occur, as stated above. Figs 2—4 of Pl. VIII show the varying frequency of the tubes in the quartzite of Furön, and more distinctly the same thing is shown by a weathered boulder from Mörbylånga, reproduced in Figs 1 a—c of Pl. X. The latter is composed of three indistinctly separated strata: in the uppermost — whether in reality uppermost or lowest may be left undecided — the tubes are abundant; in the middle one sparse; and in the lowest one fairly numerous. In the latter two or more tubes sometimes show a tendency to cluster (for mutual support), as can often be observed in specimens with scattered tubes. Solitary tubes possibly continue through all the three strata, at all events many of them project from the outer strata into the middle one. In part of the boulder not visible in the figure some tubes are slightly but distinctly undulating. Evidently it cannot be doubted in this case that all tubes are of the same origin (built by animals of the same species).

The *Scolithus* tubes of the Kalmarsund sandstone vary in thickness between 1 and 7 mm, but in one and the same stratum all tubes are of approximately equal diameter. The most common forms and — apart from the above-mentioned narrow form from Runnö — the only ones I have seen in solid rock (on Furön and Runnö, at several localities in the neighbourhood SW and S of Mönsterås and at Brömsebro) have a thickness of 3—4 or 4—5 mm, and as a rule the tubes are closely crowded.

In boulders also forms with narrower as well as thicker tubes have been observed. The most narrow form found is 1—1.5 mm, and the thickest one 6—7 mm. Possibly the different-sized tubes are built by animals of different species. But even in this case a fairly continuous series is present, making a discrimination with respect to the thickness subjective. Thus I think it wise to bring together under one name all the forms in question, without consideration to differences of frequency, form and thickness of the tubes. Of old they were identified as *Scolithus linearis*. Whether this may be justified or not, we may submit to the decision of the American geologists.

If the tubes and the matrix are differently coloured — as often is the case in the red-striped sandstone — the former appear distinctly, but usually no difference of colour and only a very obscure petrographical difference exist. Hence the tubes are, as a rule, almost indiscernible on fresh surface and appear conspicuously only after weathering. This is a serious obstacle to the study of these bodies. Thus the original terminations of the tubes can rarely be proved. In specimens with scattered tubes I have been able to establish that the upper as well as the lower end is blunt or truncate and never widened; and this seems also to suit the forms with crowded tubes. At all events I have never seen in the Scolithus zone of the Kalmarsund sandstone a specimen with funnel-shaped opening, a characteristic distinctive of an otherwise similar form of the Lingulid sandstone described above under the name of *Monocraterion*. This difference seems to indicate different creatures and may indicate the reason for giving the forms different "generic" names.

S. linearis in the above-mentioned sense is known from the Kalmarsund area and from Torekov, Rekarekroken (W of Ängelholm), Röstånga and Hardeberga, all in Scania.[1] At all Scanian localities forms with crowded and with scattered tubes, about 4 mm thick, have been found. It occurs at a horizon older than the *Schmidtiellus torelli* zone of Scania and the *Discinella (Mobergella) holsti* zone of Kalmarsund.

Of a *Scolithus* mentioned by Svenonius[2] from Skeldavare, parish of Kvikkjokk, Lappland, no specimen is available, and therefore it cannot be decided whether it possibly belongs here or not.

The age of the Kalmarsund sandstone in the light of the above-mentioned burrows and trails.

The sandstone series which forms the solid rock within a strip of varying breadth on the east coast of Småland shows, according to Holst (1893), the following sequence (in descending order).

[1] *Scolithus* has as yet not been reported from the Simrishamn district. In beds alternating with *Diplocraterion*-bearing strata which crop out on the shore between Simrishamn and Baskemölla *Scolithus*-like tubes have been observed. The specimens present are too poorly preserved to be safely identified.

[2] Geol. Fören. Förhandl., Vol. 18, p. 344. Stockholm, 1896.

6. White sandstone with granular texture, also including shaly and calcareous sandstone beds.

5. Sandstone with *Diplocraterion*. Whether this unit underlies or superimposes the following is left undecided. (As is shown below, at least the bulk of the former underlies the latter.)

4. Greenish grey argillaceous and micaceous sandstone, often crowded with winding trails (»kråksten»).

3. White and reddish sandstone with *Scolithus linearis*.

2. Red-striped sandstone, thinning out towards the south.

1. Conglomerate, resting on the Archaean.

The beds are horizontal or dip slightly towards the east. Owing to the predominant thickness of the overlying soils, which leave the solid rock accessible only at a few places, the above scheme has been constructed almost exclusively by aid of the occurrence of the boulders and consequently it can give only the main features of the sequence. True fossils have not been found in this part of the series; those are known only from younger beds, the *Discinella (Mobergella) holsti* zone, which is assumed to crop out on the bottom of Kalmarsund. However, as the lower beds are in part rich in burrows and trails and no evidence of a break is indicated, the whole sandstone series intercalated between the Archaean and the *Paradoxides ölandicus* shale were by all older geologists regarded as Lower Cambrian until Dr. Asklund (1927) expressed the supposition that the lower beds of this series constitute the remnants of a distinct pre-Cambrian formation. In the latter he included also the "kråksten", and the Diplocraterion sandstone was regarded as the bottom zone of the Lower Cambrian.

The following seem to be the principal reasons on which Asklund founds his conception of the existence of two distinct formations.

1. The lower beds of the series have a lithological character which is distinct from that of the certain Lower Cambrian sandstone in this and other areas of Sweden, and they have no direct parallels in the Lower Cambrian sandstone series beneath Gotland and at Humlenäs, NW of Oskarshamn.

2. *Scolithus linearis* is said to be of inorganic origin (formed by air bubbles) and consequently to be of no stratigraphic value; it is said only to indicate marine sediments deposited under the influence of the tide. (Other trails and burrows of which at least those of the »kråksten» were earlier known are passed by in silence.)

3. In a conglomerate or rather a sedimentary breccia on Runnö Rödskär — porous and loosely cemented and thereby sharply distinguished from the very hard basal conglomerate known from boulders on Runnö not far away — Asklund has found pebbles of a red sandstone which is said to be identical with a rock occurring on Runnö. From this it is concluded that the conglomerate and the conglomeratic breccia represent quite different horizons, the latter indicating a break and corresponding to the Cambrian bottom conglomerate. One more proof of the existence of this break Asklund derives from the fact that Holst was not able to fix the succession of the »kråksten» and the lower Diplocraterion zone: the supposed pre-Cambrian formation has been eroded to varying depth and consequently the Cambrian may be expected to cover different beds of the former at different localities.

No one of these evidences proves, but taken together may be said, he thinks, to indicate a pre-Cambrian age of the deposits in question.

In a paper on a deep boring through Cambrian strata at Borgholm the present writer in 1929 ligthly touched upon the age of the Kalmarsund sandstone. The "kråksten" was established to be of Lower Cambrian age since a bed with *Discinella holsti* was found embedded in the "kråksten" of the boring core, and as thin layers of this rock, according to Asklund himself, are found to alternate with beds of red Scolithus sandstone on the eastern shore of Runnö also the latter must be included in the Cambrian. Against Asklund's interpretation of the pebbles of red sandstone in the above-mentioned conglomeratic breccia on Runnö Rödskär it was emphasized that a conglomerate formed during the transgression over a flat area sometimes contains pebbles of the same rock which superimposes the conglomerate, and as an example the Cambrian basal conglomerate in Västergötland was mentioned. Hence the evidences quoted by Asklund were regarded as insufficient to support the conception of the existence of two distinct formations.

In the recently issued third edition of Ramsay's textbook of geology Asklund, without presenting any new and conclusive reasons, holds to his opinion on this question, apparently with some hesitation, however. Thus the lower part of the Kalmarsund sandstone is regarded as p o s s i b l y belonging to a pre-Cambrian and post-Jotnian formation, in which now also the lower beds of the sandstone series in the districts of Hardeberga and Simrishamn are included and which is tentatively correlated with the Sparagmite formation of South Norway. Another collaborator in the same textbook, Dr. Troedsson, takes a step further when regarding the beds in question as possibly of Jotnian age.

When in the course of last summer I got an opportunity of studying the Kalmarsund sandstone in the field, I was concerned for procuring of evidences which might give, if possible, a definitive answer to the present question. The observations made tell decidedly in favour of the older opinion, that only one formation is present.

The localities affording the best opportunities of studying the older beds of the series are the little island of Furön, off Oskarshamn, and the somewhat larger island of Runnö, off Påskallavik. Furön is built up exclusively of beds of reddish, grey and greenish grey quartzite with *Scolithus*. The latter is rarely discernible on fresh surface but wherever weathered bedding-surfaces are to be seen — and these occur almost continuously along the north and west coasts — they show the rock crowded with *Scolithus* (see Pl. VIII Fig. 2—4) giving an impression of reefs.

The solid rock of Runnö has been closely studied by Asklund, who has also published a sketch-map of the island. The following four beds (in descending order), the cropping out of which forms strips running approximately from N to S, have been distinguished.

4. Red *Scolithus* sandstone with seams of green clayey sandstone.
3. Alternating red and white quartzitic sandstone, with *Scolithus* in its eastern part.
2. White hard quartzitic sandstone.
1. Coarse white quartzitic sandstone.

The total thickness of the whole series may be estimated at about 15 m, or possibly somewhat more.

In parts of Beds Nos. 3 and 4 an abundance of burrows and trails occur. Of these *Diplocraterion parallelum* is by far the most common, and it may be especially emphasized that the forms of the latter found here agree completely *e. g.* with those from the Mickwitzia sandstone of Västergötland. Clean-washed beds crowded with *Diplocraterion* are exposed *e. g.* on the north-eastern point, at places on the east coast and along the road between Oxlenäs and the village on the west shore. However, these burrows are tacitly ignored by Asklund, though they are very conspicuous and are said by himself to characterize the oldest Cambrian zone of this area.

The occurrence of *Diplocraterion* beds on Runnö shows that the lower *Diplocraterion* zone — at least the bulk of it — is situated beneath and not above the "kråksten" in the scheme given by Holst. The zone does not seem to be sharply distinguished from the subjacent Scolithus sandstone, as strata with *Scolithus* are embedded in layers crowded with *Diplocraterion.* Moreover, *Diplocraterion* has a wider vertical distribution in the Kalmarsund series than has been hitherto known (see p. 7). In reality *Diplocraterion parallelum* persists through the whole sandstone series of Kalmarsund, and links together the lower and upper beds to one formation.

According to Asklund, the *Scolithus* of the Kalmarsund sandstone is formed by ascending air bubbles, and consequently it is said to have no stratigraphic value. As has been shown above (p. 15), this view is by no means established, and in all probability it is wrong. It can scarcely be doubted that the form in question is of organic origin, and all evidences known indicate that it is confined in Sweden to the (almost) oldest part of the Lower Cambrian.

The lower sandstone beds in Kalmarsund differ from (the bulk of) Lower Cambrian strata of other areas in being quartzitic or sometimes developed as true quartzites and in part red-coloured. Especially owing to the colour it seems in some cases hardly possible to distinguish macroscopically the former from our Jotnian sandstones. However, already in the explanation of the map-sheet Vreta Kloster (1882) the occurrence of quartzitic beds in loose sandstone of undoubted Lower Cambrian age was mentioned, and researches in later years have shown that beds of quartzitic sandstone and real quartzite are widely distributed in the Lower Cambrian of Östergötland. — Red layers alternate repeatedly with greyish white ones in the northern part of Kalmarsund. Farthest to the north the former seem to predominate. Boulders of red and red-striped sandstone occur abundantly

on Jungfrun, and on Furön red layers have somewhat greater thickness than on Runnö, where also the basal stratum seems to be grey. Now, as red beds are totally absent farthest to the south, this probably is due to a decreasing in thickness of the red and an increasing of the intercalated and adjacent greyish white beds in the direction from the north to the south. Apart from differences in colour and hardness, no evidence indicates that the sequence is less complete in the south than in the north. The *Scolithus* of the white and comparatively loose sandstone which crops out at Brömsebro is identical with the form in the red quartzite on Furön, and the *Diplocraterion* occurring in greyish white sandstone boulders in the neighbourhood of Kristianopel is not distinct from that in the red quartzitic sandstone on Runnö and Jungfrun. Thus it is of no consequence for the present question that red and quartzitic beds are absent in the sequence under Gotland and at Humlenäs. A closer correlation of the zones of the Kalmarsund sandstone with the Lower Cambrian of the boring core from Visby cannot at present be carried out, as we still have only a very cursory account of the latter, from which we only learn that the Lower Cambrian is built up of "yellowish-grey sandstone, alternating with bluish-grey shale", which has a total thickness of 104.4 m, and which has yielded *Discinella (Mobergella) holsti* and an undetermined brachiopod, both of them occurring in about the middle of the series. However, it does not seem very probable that direct parallels to the zones of *Scolithus* and *Diplocraterion* are lacking in the sequence under Gotland; and it is evident that the fact that these zones have not as yet been recognized in the narrow core (21 mm in diam.) does not indicate their absence. — It may be mentioned, moreover, that also red sandstone occurs at Humlenäs, even if it differs from the red sandstone in Kalmarsund in being markedly looser and often spotted (not striped).

As regards Asklund's conclusions from the difference between the normal basal conglomerate and the conglomeratic breccia on Runnö Rödskär I content myself with referring to the statement in my paper of 1929. It may be added that the basal conglomerate at places is almost as porous and loosely cemented as the breccia. Thus boulders of the former occurring at Granshult, SW of Mönsterås, crumble into gravel when struck by the hammer.

The evidences quoted by Asklund are therefore quite insufficient to indicate the existence of a pre-Cambrian formation beneath the Cambrian of the Kalmarsund area. In my opinion the occurrence of *Diplocraterion* also in the lower beds of the series is enough to warrant the Lower Cambrian age of the latter, even though it should not be ignored that *D. parallelum* evidently has not the stratigraphic value of a regular index fossil. Burrows of similar type are known from different post-Cambrian formations in Sweden and other countries (see p. 8). However, beds yielding *D. parallelum* from other areas of Sweden and Esthonia are certainly of Lower Cambrian age. If nevertheless the stratigraphic value of *D. pa-*

rallelum and other trails found is altogether rejected also for the present question, and the conception of two distinct sandstone formations in the Kalmarsund area is maintained, we arrive at the result that identical forms of this peculiar burrow occur in different formations within a narrowly limited area, which presupposes similar ecological conditions during different periods in this district, a coincidence of circumstances which might be possible but is improbable. And, moreover, we should here have before us a pre-Cambrian — Lipalian, to use Walcott's term — in all probability marine formation with traces of a rich fauna, which undoubtedly would be sensational — if it were true.

As has been mentioned above, Asklund includes in the supposed pre-Cambrian formation also the lower beds of the sandstone series in the Simrishamn and Hardeberga districts in Scania. The following is the sequence in these districts (in descending order):

4. Grey or green, usually calcareous and glauconitic fossiliferous sandstone, zone of *Schmidtiellus torelli*.
3. White or grey, siliceous or calcareous, occasionally glauconitic and phosphoritic sandstone, including beds rich in burrows and trails, *Diplocraterion, Syringomorpha, Psammichnites*, etc.
2. White quartzitic non-fossiliferous sandstone.
1. Arkose with or without conglomerates, resting on the Archaean.

Evidently Beds Nos. 1 and 2 — which according to Hadding, have a total thickness of about 25 m in the Simrishamn district — are regarded by Asklund as possibly pre-Cambrian. As no reasons are adduced, we are obliged to suppose that the absence of traces of organic life, a not very marked lithological difference between these and overlying beds and, above all, their resemblance to the lower quartzitic beds in Kalmarsund — by Asklund wrongly regarded as barren — have led to this conception. Now, as the latter beds are shown to be Cambrian, no real reason remains for referring the Scanian deposits to a pre-Cambrian formation. The sandstone formations of Scania have recently been subjected to a scrutiny by Dr. Hadding (1929), who states that the white quartzitic barren sandstone grades without a break into the superimposed beds with burrows and trails, and no evidence known gives rise to any doubt regarding this statement.

We may sum up the results of the above investigation thus: A late pre-Cambrian formation, supposed by Dr. Asklund to underlie the Lower Cambrian sandstone series in the Kalmarsund area and in Scania, is absent in the former area, and no evidences for its existence in Scania have so far been presented.

Geological Survey of Sweden, October 1931.

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The papers of Richter, 1920, 1924 and 1926, cited above, list a wealth of papers on *Scolithus* and on U-shaped burrows.

Explanation of Plates.

PLATE I.

Diplocraterion parallelum TORELL.

All figures are in natural size.

Fig. 1. Vertical section of a very regular specimen. Only the right limb of the tube is preserved. The »U-in-U»-structure is distinct.

Lower Cambrian, Mickwitzia sandstone. Lugnås, Västergötland. Collected by O. Torell. This and Fig. 2 are probably two of Torell's co-types.

Fig. 2. Part of the bedding-surface of the same sample as seen in Fig. 1, showing the openings of another specimen. One of the openings is double and shaped like an 8; the other is somewhat widened, which in this case seems to be a primary characteristic (not caused by weathering). The slit is in this specimen indistinct.

Fig. 3. Lower part of one of the largest specimens found at Lugnås. The »U-in-U» structure is not visible in the figure, but it is indicated lithologically: the tubes, as well as the plate between them, consist of clayey sandstone, the surrounding rock is a fairly pure sandstone. The limits of the tubes are marked by fine ink-lines.

Lower Cambrian, Mickwitzia sandstone. Lugnås, Västergötland.

Fig. 4. Somewhat irregular specimen in a light-grey, fine-grained, quartzitic sandstone. Tubes preserved as imprints.

Lower Cambrian. Boulder found at Röhälla, parish of Glömminge, Isle of Öland.

PLATE II.

Diplocraterion parallelum TORELL.

Fig. 1a. Weathered bedding-surface of a sandstone layer crowded with burrows marked as straight slits, which sometimes have slightly widened ends.

Lower Cambrian. Brantevik, south of Simrishamn, Scania.

Fig. 1b. Section normal to the bedding-plane of the sample seen in Fig. 1a. Several burrows are visible, one of which is especially well preserved.

Fig. 2. Grey quartzitic sandstone, crowded with burrows, of which two are visible, the left one with the tubes somewhat converging downwards.

Lower Cambrian. N. Femmeryd, parish of Kristianopel, Blekinge.

Fig. 3. Weathered section normal to the bedding-plane of a sandstone layer crowded with burrows. The tubes look as if they were »chambered». Associated specimens (not visible in the figure) show the ordinary form.

Lower Cambrian. Brantevik, south of Simrishamn, Scania.

PLATE III.

Diplocraterion parallelum TORELL.

Vertical section of two large specimens. The festoons of the deeper one are irregular and show in part a slight curvation upwards. In the left-hand specimen part of the tube is preserved near the bottom.

Lower Cambrian, upper part. Mörbylånga, Öland. Block in the place of disintegration.

PLATE IV.

Diplocraterion lyelli TORELL.

Fig. 1a. Bedding-surface, showing the funnel-shaped openings of five specimens. The specimen marked x is the same as that, shown in Fig. 1b.

Fig. 1b. Section perpendicular to the bedding-plane, showing one specimen in vertical section.

Fig. 2a. Bedding-surface, showing the openings of two specimens; the lower one is the same as is seen in Fig. 2b.

Fig. 2b. Section normal to the bedding-plane, showing the lower part of a specimen, the upper part of which is concealed in the matrix. In this and in Fig. 1b the tubes and the plate between them consist of clay or clayey sandstone, the matrix of quartz sandstone.

Lower Cambrian, Mickwitzia sandstone (or the basal layer of the Lingulid sandstone). Lugnås, Västergötland. At least Fig. 2, probably also Fig. 1, was collected by O. Torell. In all probability they are Torell's co-types.

PLATE V.

Monocraterion tentaculatum TORELL (?).

Fig. 1a. Weathered bedding surface, showing funnels of different width and tubes in transverse section. Most of the funnels are penetrated by the tubes, which in some cases are considerably widened upwards. — Nat. size.

Fig. 1b. Weathered surface, normal to the bedding-plane, of the same sample, showing three tubes terminating in funnels at the upper bedding-surface.

Lower Cambrian, lower part of the Lingulid sandstone.

Block at Råbäck harbour, L. Vänern, Kinnekulle, Västergötland.

PLATE VI.

Monocraterion tentaculatum TORELL (?).

Fig. 1. Weathered bedding-surface, showing transverse sections of funnels and tubes. Some of the funnels are penetrated by the sub-cylindrical tubes. — Nat. size.

Lower Cambrian, Lingulid sandstone, lower part. Block at Råbäck harbour, L. Vänern, Kinnekulle, Västergötland.

Fig. 2a. Bedding-surface, showing four tubes and, at the lower margin, half of a funnel, all empty owing to weathering. — Nat. size.

Lower Cambrian, Lingulid sandstone, probably upper part.

Boulder near the stable of Råbäck, Kinnekulle, Västergötland.

Fig. 2b. The same sample as in Fig. 2a. Surface normal to the bedding-plane, showing the funnel continuing into a sub-cylindrical tube.

PLATE VII.

Scolithus linearis HALDEMAN.

Fig. 1a. Surface normal to the bedding-plane, showing a form with rather thick and very close-set tubes (forming a reef). Nat. size.

Fig. 1b. Surface, approximately parallel to the bedding-plane, of the same sample.

Lower Cambrian. Weathered boulder of grayish white sandstone. Mörbylånga, Isle of Öland.

PLATE VIII.

Scolithus linearis HALDEMAN.

Fig. 1. Weathered boulder of greyish white sandstone with closely crowded tubes of ordinary thickness. — Half of the nat. size.

Lower Cambrian. — N. Komstorp, parish of Kristianopel, Blekinge.

Boulders of this kind, occasionally attaining a thickness of 0.5 m and a length of more than 1 m, are fairly common at places on the west coast of Kalmarsund, especially in the neighbourhood of Kristianopel.

Figs. 2—4. Samples of quartzite with weathered bedding-surface, showing *Scolithus* forms with crowded and scattered tubes. — Nat. size.

Lower Cambrian. — Isle of Furön, off Oskarshamn, Småland.

PLATE IX.

Scolithus linearis HALDEMAN.

Fig. 1a—b. Thin-bedded, greenish grey, very fine-grained, clayey and micaceous sandstone, traversed by scattered, slightly irregular tubes, which are filled with comparatively coarse-grained white quartz sandstone. In a few tubes the ends are conspicuous, the lower as well as the upper blunt or truncate. — Nat. size.

Lower Cambrian. — Boulder from the bottom of Kalmarsund, off Kalmar.

Fig. 2. Weathered bedding-surface of white fine-grained sandstone crowded with narrow tubes. — Nat. size.

Lower Cambrian. — Boulder from Mörbylånga, Isle of Öland.

PLATE X.

Scolithus linearis HALDEMAN.

Figs. 1a—c. Weathered boulder of very fine-grained, somewhat quartzitic sandstone in which three zones can be distinguished: an upper one with extremely close-set tubes, a middle one with few tubes, and a lower one with the tubes common but not so abundant as in the uppermost zone. Fig. 1b shows the upper, Fig. 1c the lower bedding-surface. — Nat. size.

Lower Cambrian. — Mörbylånga, Isle of Öland.

Diplocraterion parallelum TORELL.

Fig. 2. Specimen somewhat widened at its bottom.

Fig. 3. Specimen narrowing slightly downwards.

Both specimens originate from a boulder crowded with burrows, most of which have the ordinary form of *D. parallelum*. — Nat. size.

Lower Cambrian. — Kristianopel, Blekinge.

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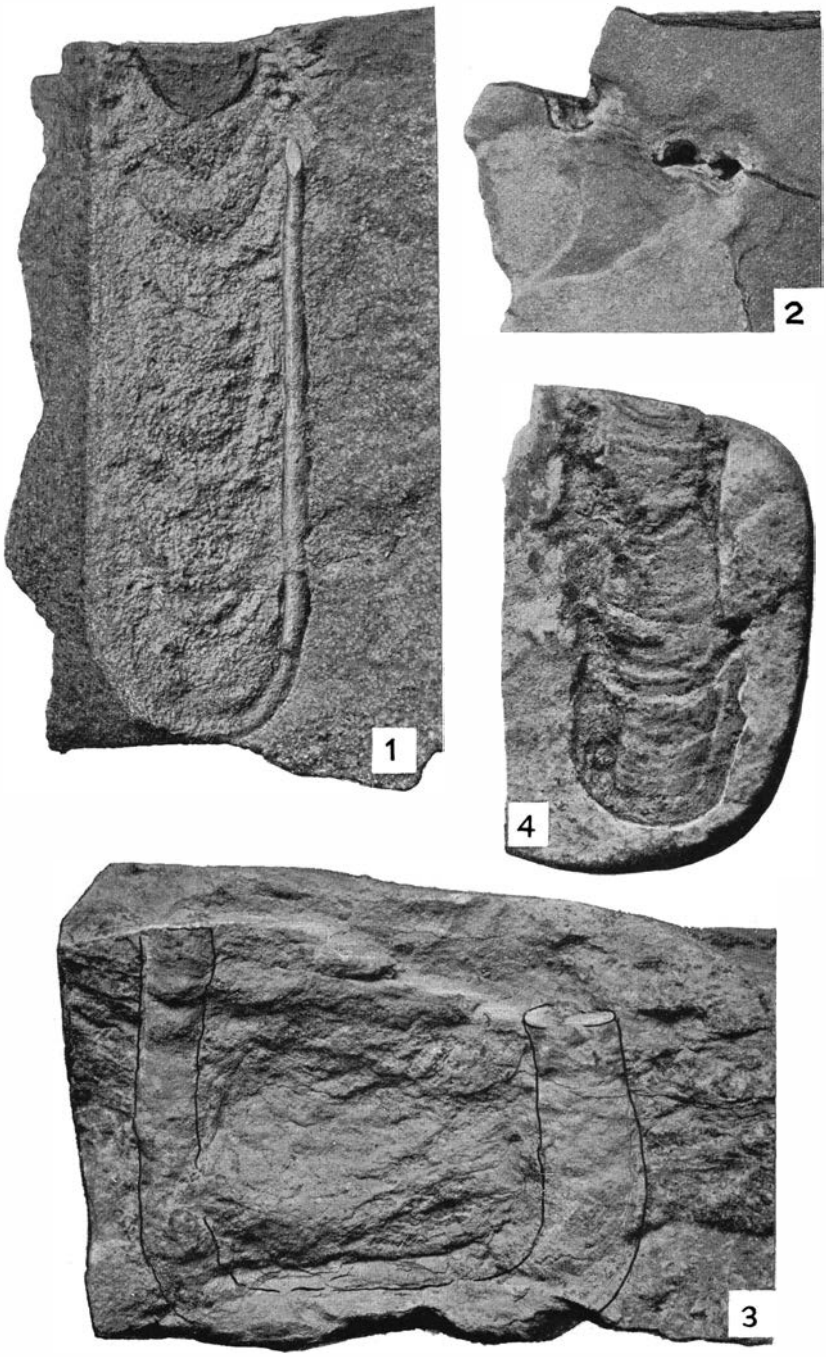

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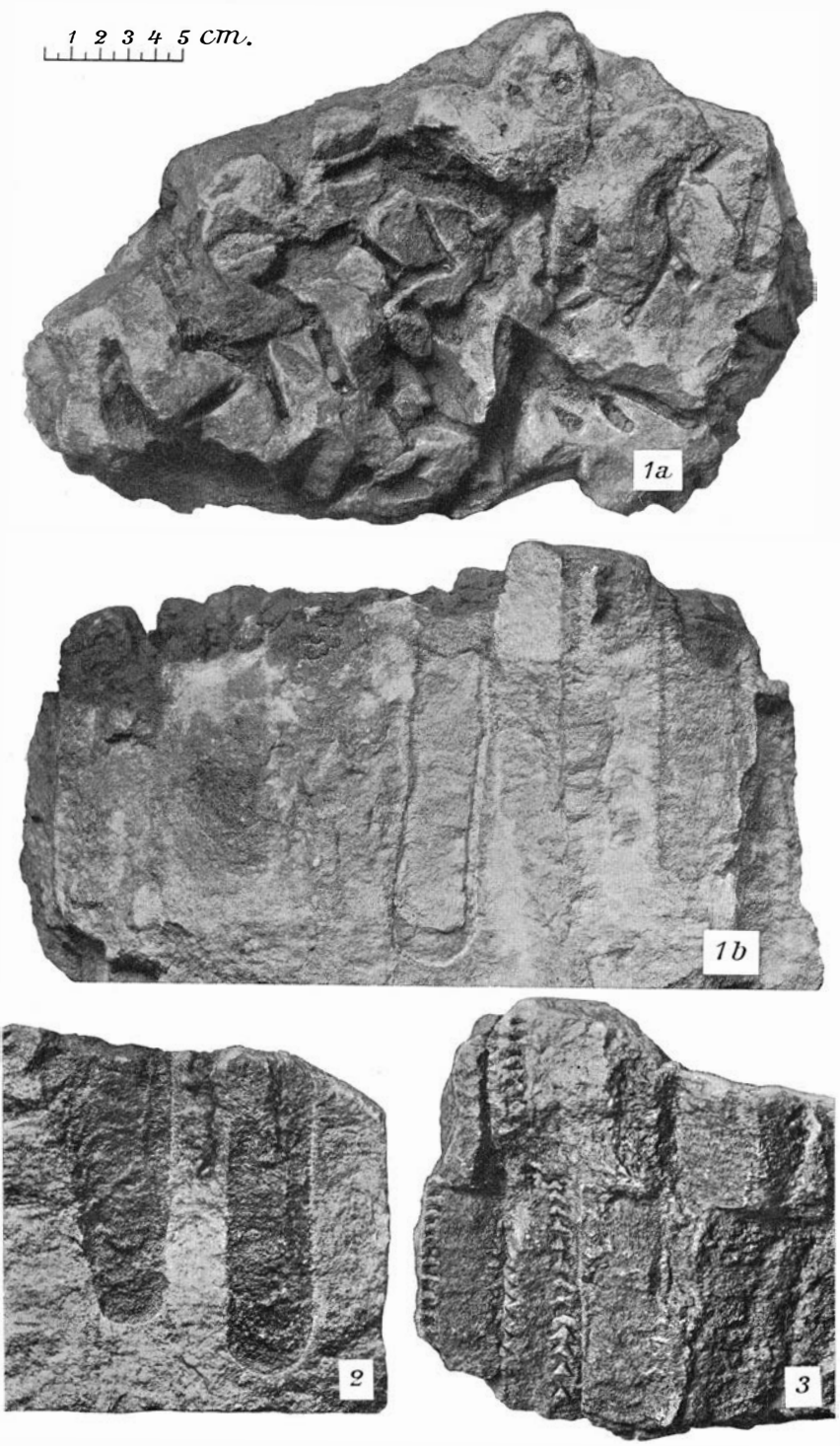

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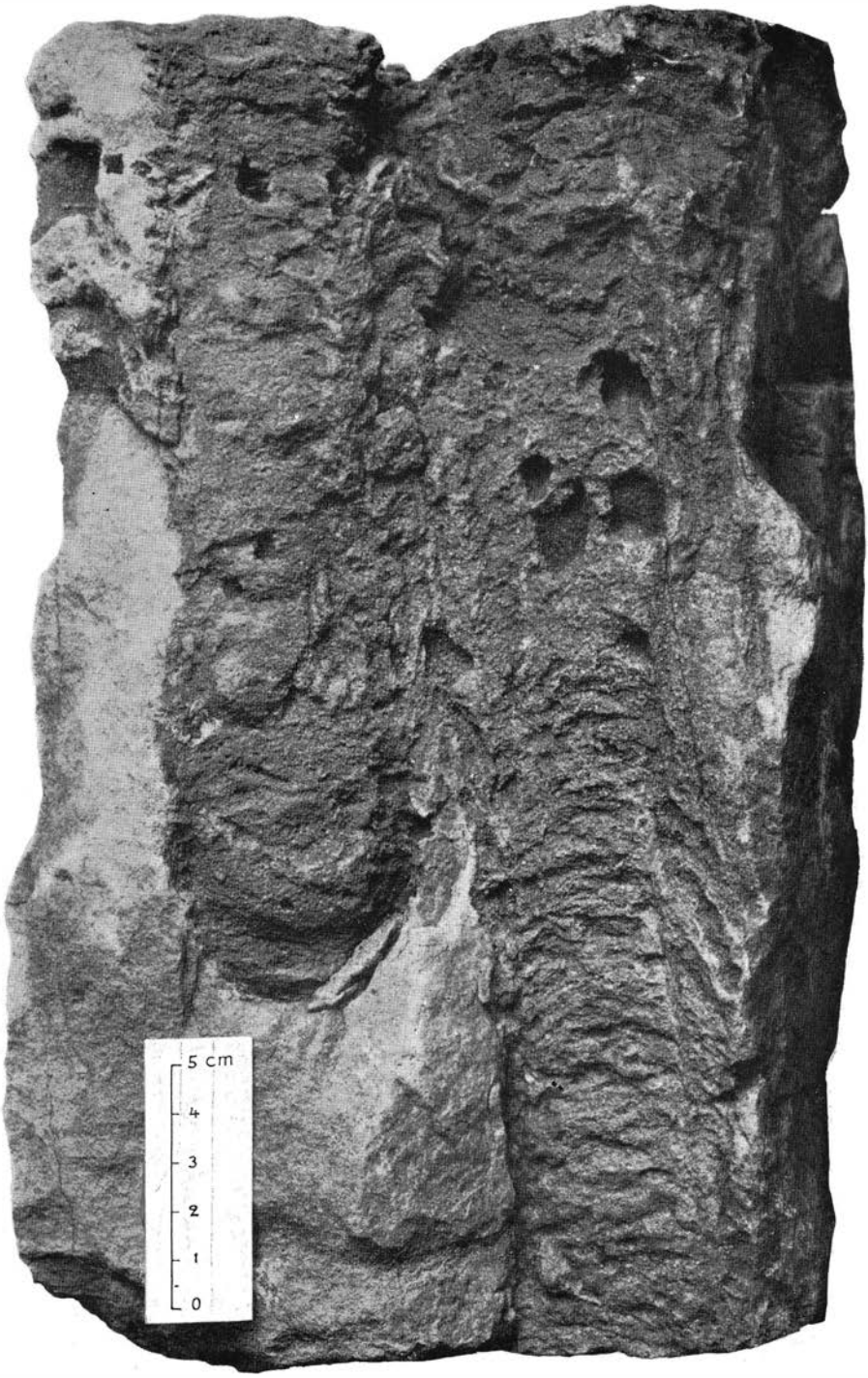

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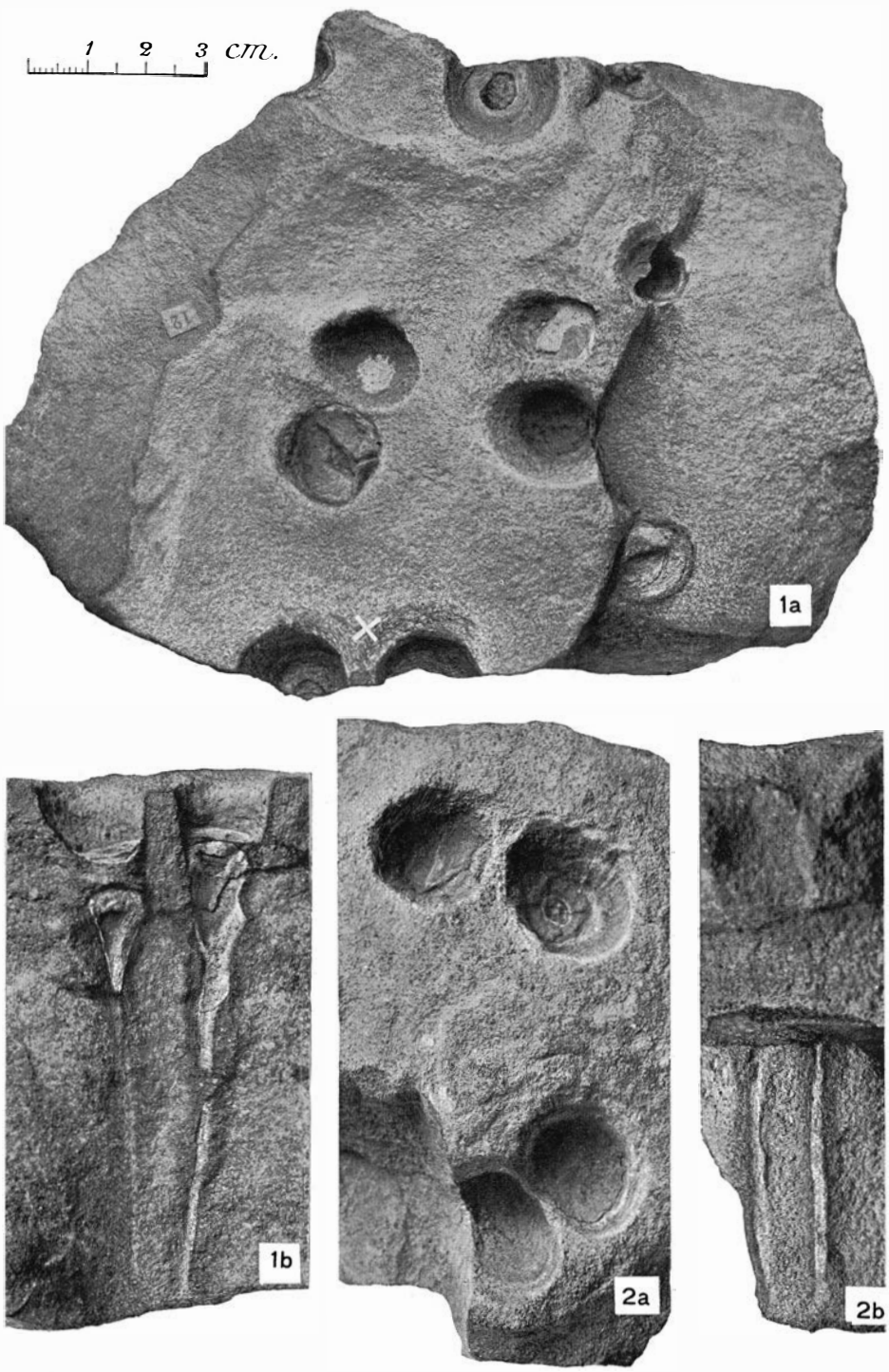

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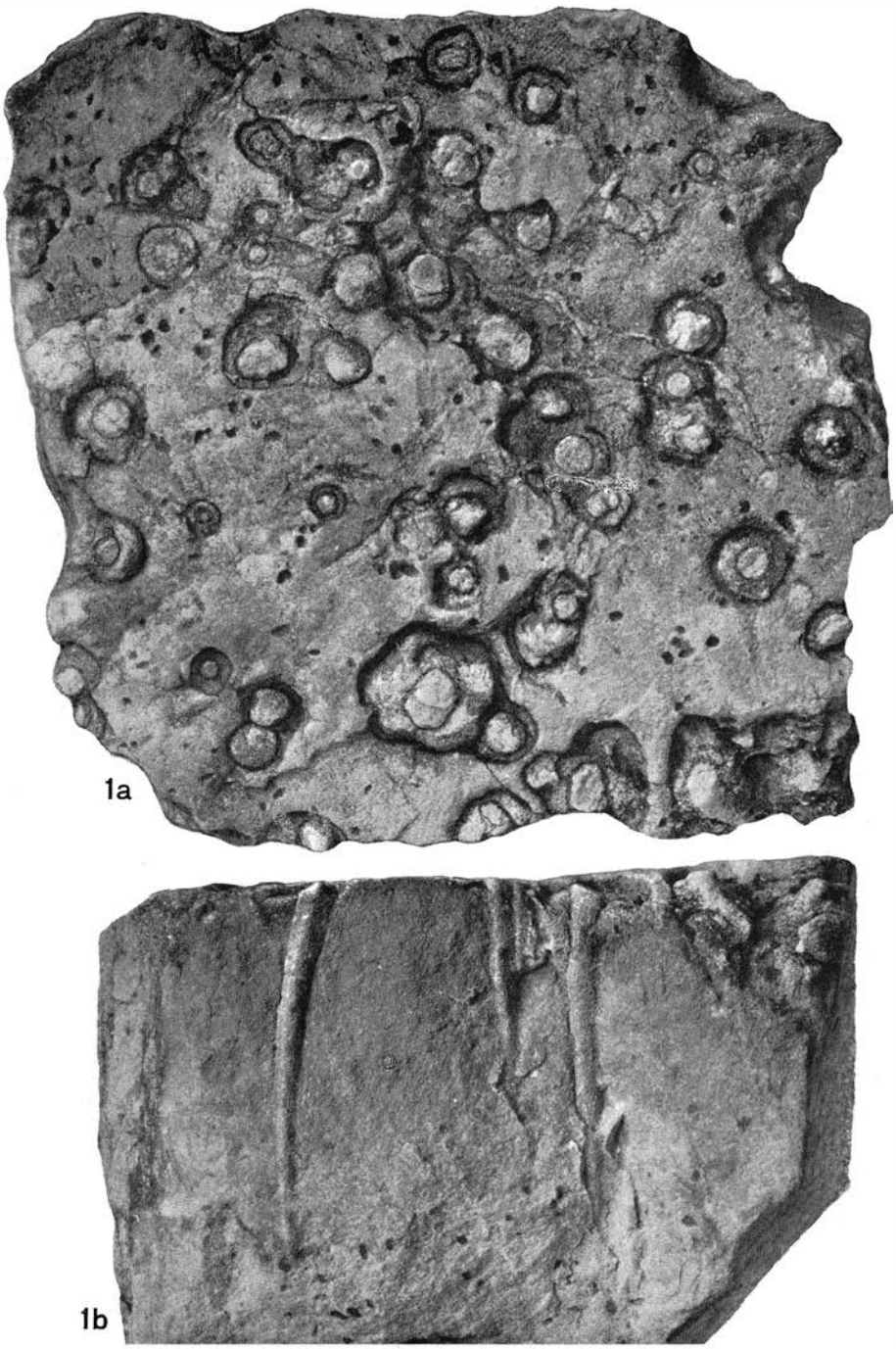

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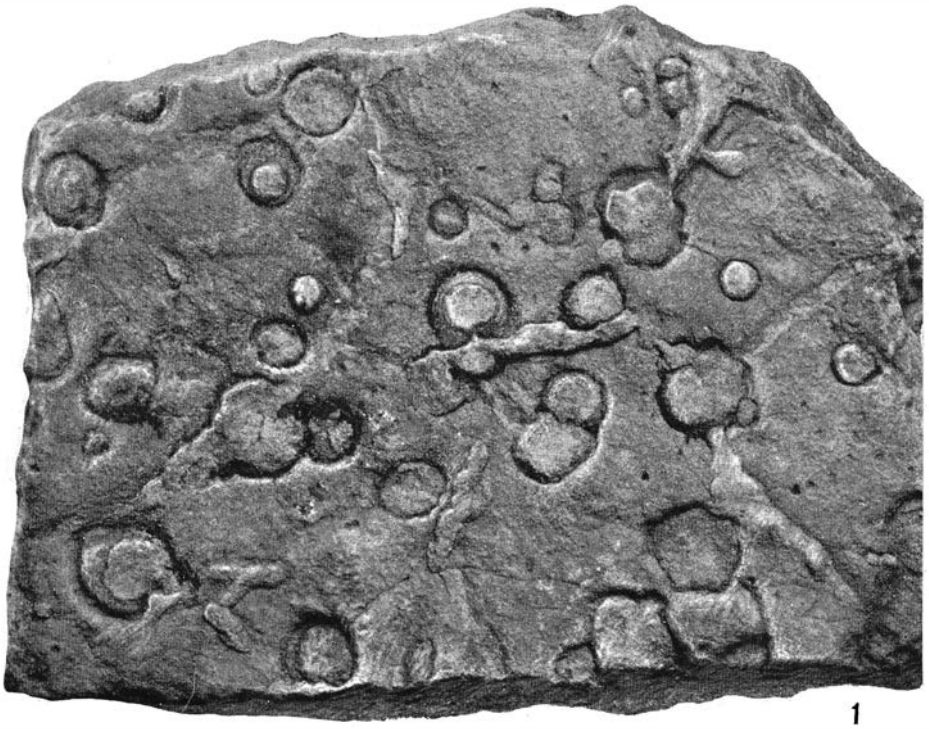

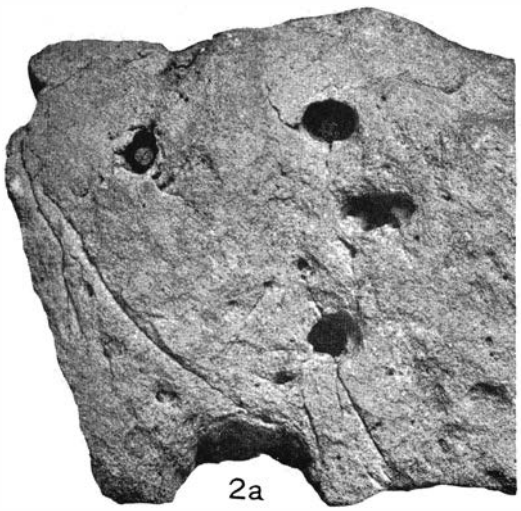

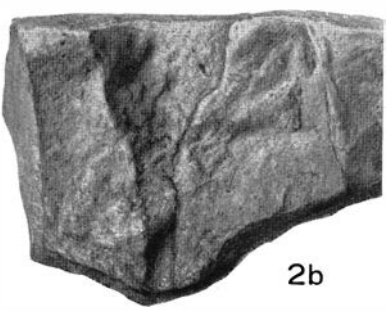

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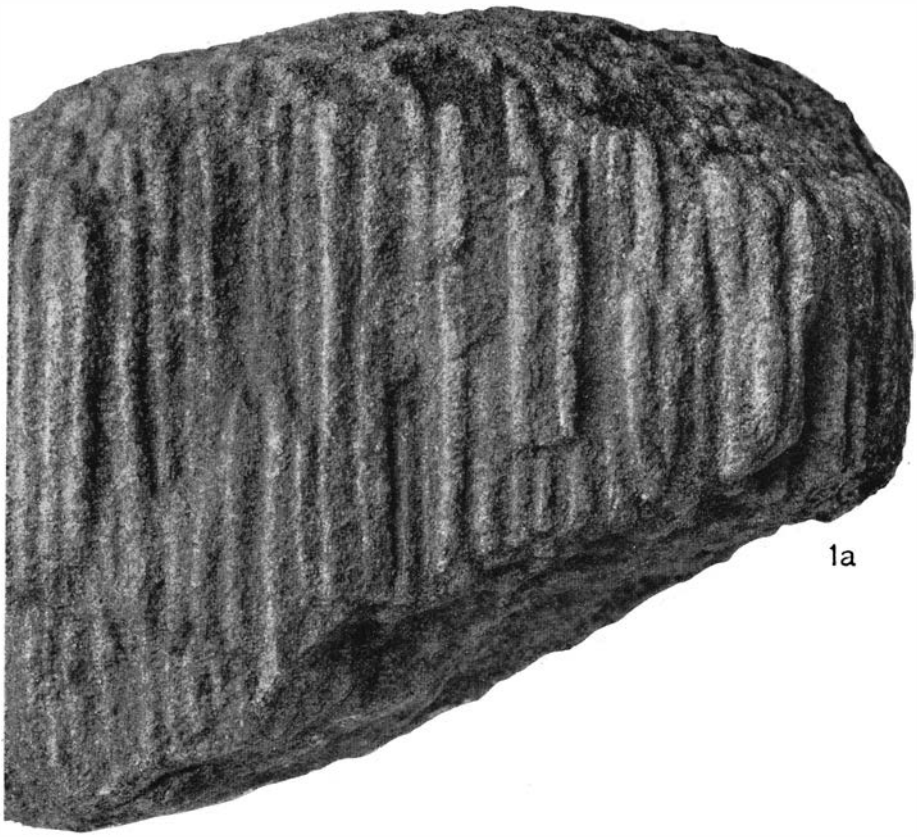

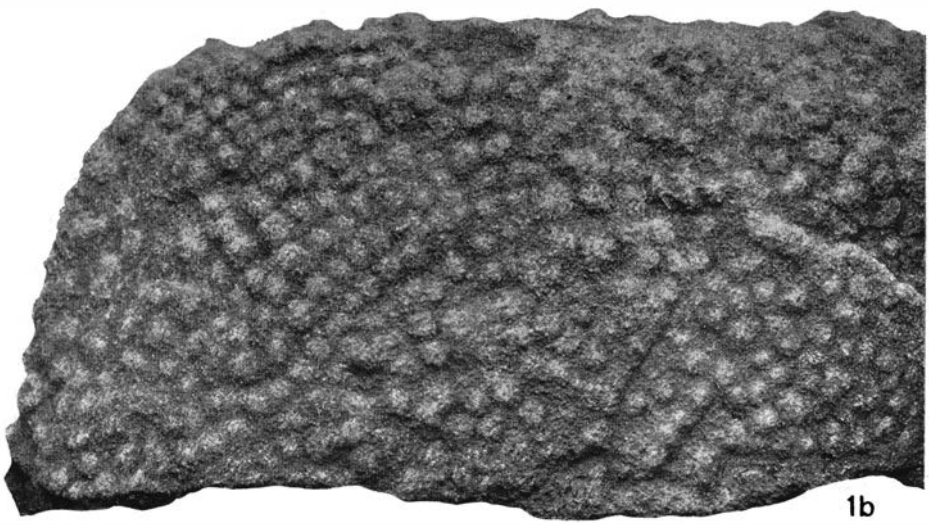

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Scolithus linearis HALDEMAN

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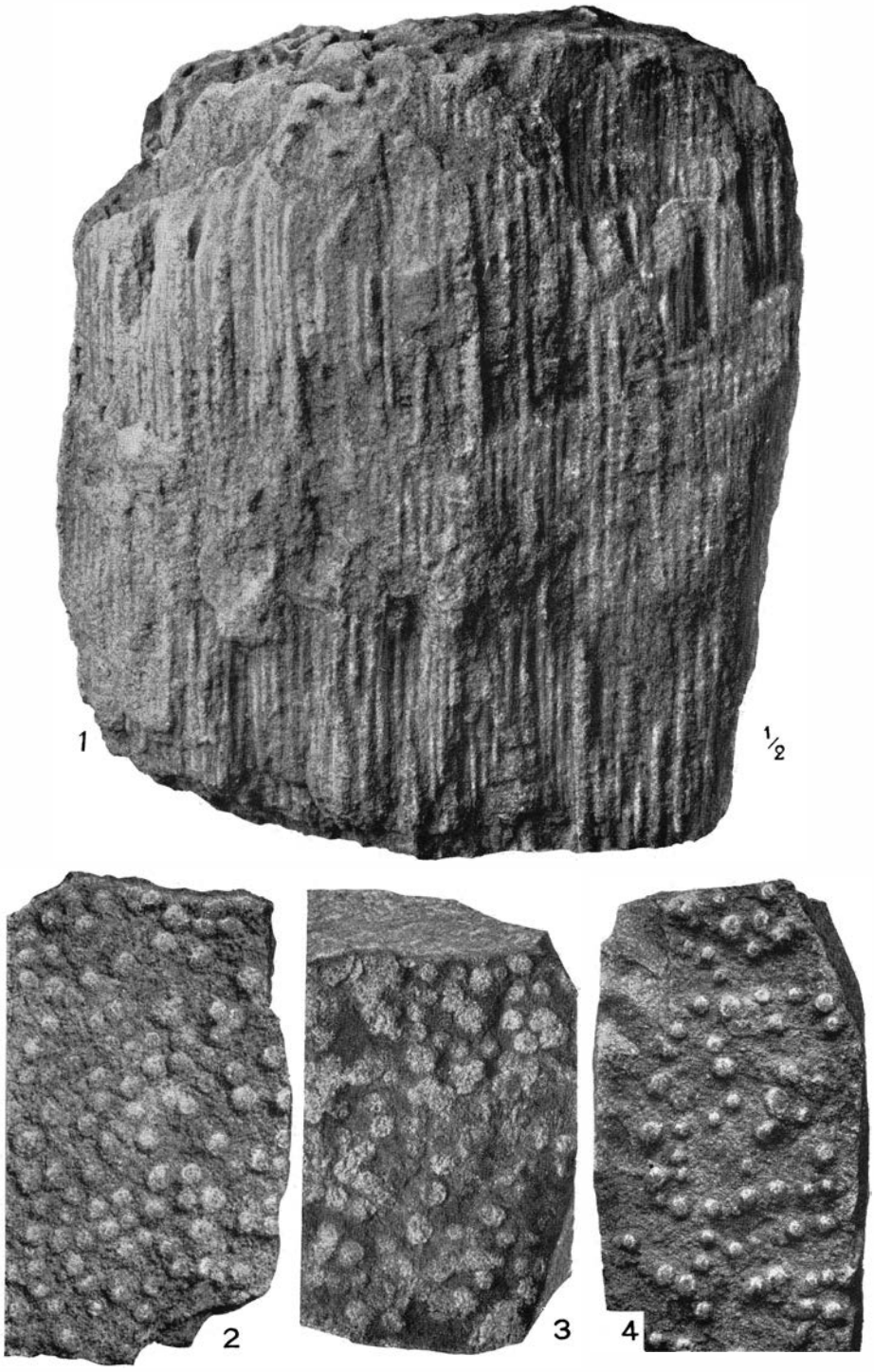

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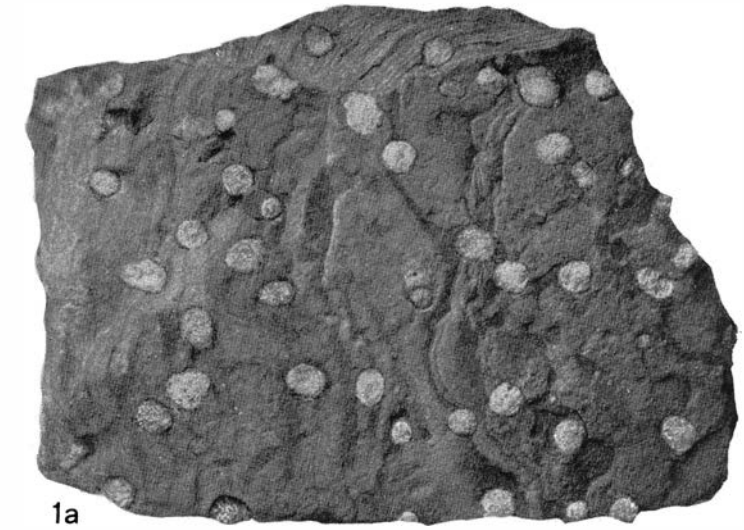

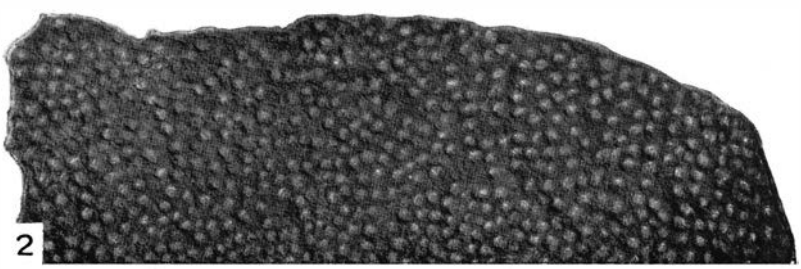

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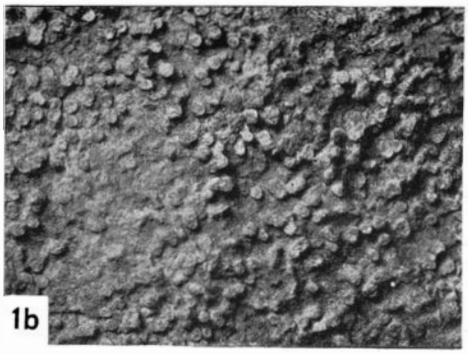

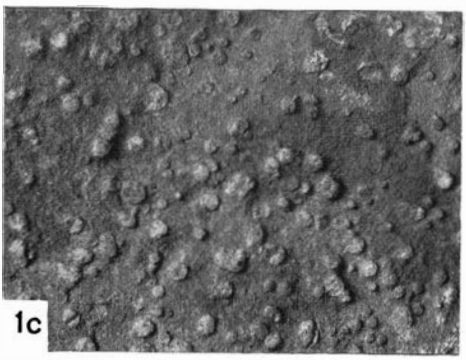

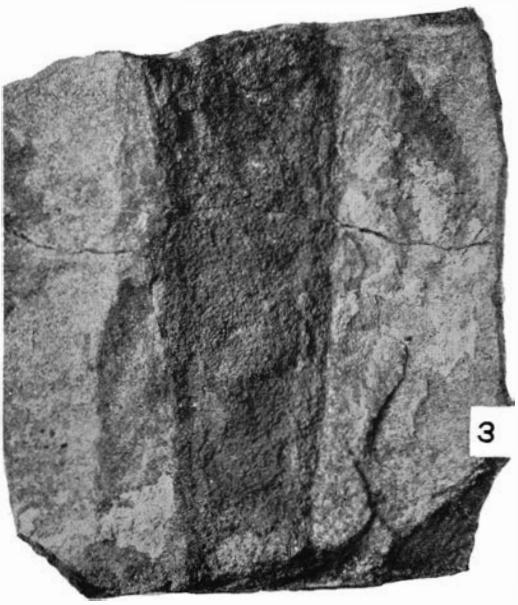

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Figs. 1 a—c *Scolithus linearis* HALDEMAN
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