GRØNLANDS GEOLOGISKE UNDERSØGELSE
RAPPORT NR. 49

The Geological Survey of Greenland
Report no. 49

Notes on Greenland trace fossils

I. Freshwater *Cruziana* from the Upper Triassic of Jameson Land, East Greenland

II. The burrows and microcoprolites of *Glyphea rosenkrantzi*, a Lower Jurassic palinuran crustacean from Jameson Land, East Greenland

III. A large radiating burrow-system in Jurassic micaceous sandstones of Jameson Land, East Greenland

by

R. G. Bromley and Ulla Asgaard

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Abstracts

Freshwater *Cruziana* from the Upper Triassic of Jameson Land, East Greenland.

An occurrence of well-preserved *Cruziana problematica* (Schindewolf) in Triassic red-beds in Jameson Land allows a more detailed morphological description of these trace fossils than has hitherto been possible. Rheotactic orientation of the traces indicates the direction of palaeocurrents in the area. *C. problematica* has previously been ascribed to branchiopod crustaceans, but the present material allows a narrowing of the field to Notostraca, and is supported by field observations of the living notostracan *Lepidurus arcticus* (Pallas).

The burrows and microcoprolites of *Glyphea rosenkrantzi,* a Lower Jurassic palinuran crustacean from Jameson Land, East Greenland.

In Toarcian sediments in Jameson Land, phosphatic concretions at certain horizons contain well-preserved *Glyphea rosenkrantzi.* These crustaceans are confined to the fill of *Thalassinoides* burrow systems and it is therefore probable that the burrows were constructed by *Glyphea.* It is possible that associated microcoprolites of rod-like shape, without internal canals, may also be ascribed to the *Glyphea.*

A large radiating burrow-system in Jurassic micaceous sandstones of Jameson Land, East Greenland.

Large trace fossils consisting of more or less straight burrows radiating from a vertical shaft are described from Jurassic sandstones of Jameson Land. The mica orientation of the sediment reveals the internal construction of the burrows and aids the interpretation of their mode of formation. The trace fossil has not been previously named and is designated *Phoebichnus trochoides* ichnogen. et ichnosp. nov.

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NOTES ON GREENLAND TRACE FOSSILS

Richard G. Bromley and Ulla Asgaard

Fieldwork in Greenland in recent years, particularly that in the Scoresby Sund area, East Greenland from 1968–71, has produced a great deal of information on trace fossils. While it is intended to publish this material systematically over the following years, much of the information is isolated and limited and not suited to extended publication. Other data, of a more topical nature, warrant a more rapid publication in preliminary form, rather than await eventual appearance in the embracive work. The present series of short papers, therefore, is designed to accommodate these two categories of material.

FRESHWATER *CRUZIANA* FROM THE UPPER TRIASSIC OF JAMESON LAND, EAST GREENLAND

While mapping the Jurassic and Triassic sediments on the west coast of Carlsberg Fjord, Jameson Land in 1971, the Upper Triassic red-beds (Fleming Fjord Formation) were found to contain well-preserved *Cruziana problematica* (Schindewolf) at many horizons (Perch-Nielsen *et al.*, 1972). These occurred in the lower two thirds of the Ørsted Dal Member, i.e. in the red-bed facies and not in the dolomitic facies which comprises the upper third of the member.

In this area, the Ørsted Dal Member consists chiefly of friable red-weathering mudstone lacking distinct primary lamination. At fairly regular intervals of about 1 or 2 m the mudstone is interrupted by finely bedded siltstones, red-weathering and breaking into slabs. These horizons, each some 20 cm thick, show small-scale flat and cross lamination and in most cases the upper surface is sharp with well-developed oscillation ripple-marks and polygonal mud-cracks. *Cruziana* is abundant within these siltstones, chiefly as convex hyporeliefs on one or more parting planes.

Morphology

The *Cruziana* occur chiefly in three forms, while transitional types and various combinations of the three forms are not uncommon. All of them occur as well-preserved convex hyporeliefs, but are also found as poorly preserved concave epireliefs.

Cubichnia

Bilobite, coffee-bean traces are the most abundant type (fig. 1), showing all grades between very low relief to highly sculptured "deep" forms. The sculpture takes the form of two sets of striae. Most of the trace is striated transversely to the midline or slightly obliquely. A second set of finer striae cut through the transverse striae at the posterior end of the trace. These striae are very oblique to nearly longitudinal (fig. 1A), but are replaced in some cases by a smooth area (fig. 1B).

Deep Repichnia

Extended, deeply cut *Cruziana* are not common but well-preserved examples show an almost transverse striation (fig. 2).

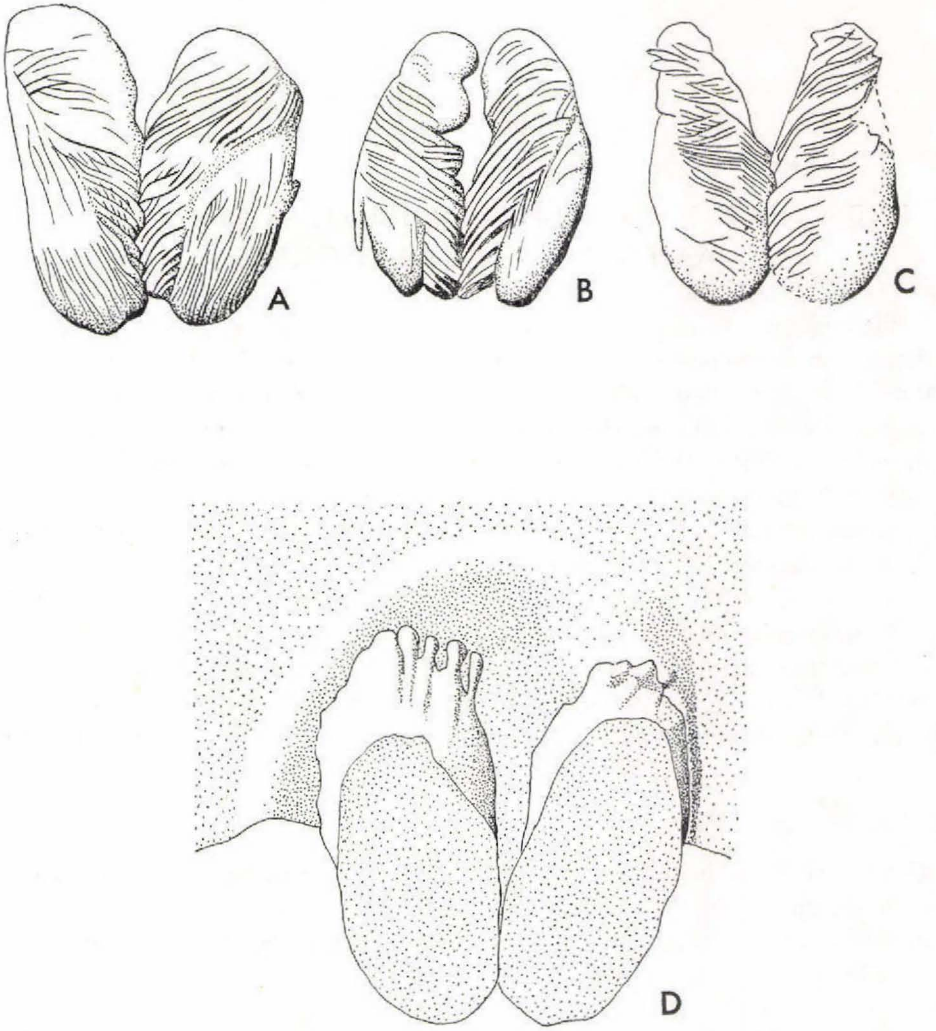

Fig. 1. *Cruziana* hyporeliefs. Four resting traces showing variety of form. × 5. A: with two sets of striae well developed. GGU 146261. B: the hinder set of striae partly obliterated and smooth. GGU 146269. C: hinder area quite smooth. GGU 146243. D: a large, damaged example with semi-circular impression round the anterior end. GGU 146231.

Shallow Repichnia

Shallow traces equivalent to the deep repichnia are abundant, occurring on sole surfaces as weak sculpture representing the tops only of the transversely striated pair of ridges in type 2. These extend in some cases up to 15 cm across bedding planes, but most are interrupted for short distances.

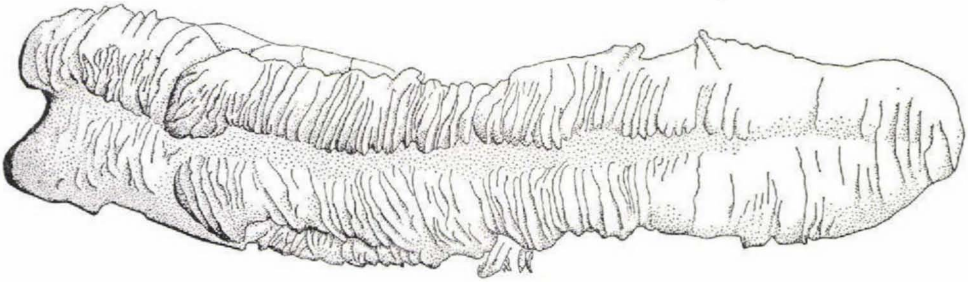

Fig. 2. *Cruziana* hyporelief. A deeply ploughed repichnion. × 3.6. GGU 146225.

Interpretation

Cruziana has been previously described from red-beds by several authors, particularly in Germany, mostly under the name *Isopodichnus,* and the trace has usually been ascribed to the activity of branchiopod crustaceans without a closer identification (e.g. Seilacher, 1953, 1960, 1963).

Several bedding planes in the Carlsberg Fjord succession are covered with numerous body fossils of conchostracan branchiopods. There would thus appear to be a case for ascribing the Greenland Triassic *Cruziana* to conchostracans. However, in extant forms, leg movement in conchostracans is longitudinal, i.e. from front to back, and the limbs hardly extend beyond the bivalved carapace which, as in an ostracod, cannot be opened flat (Cannon, 1933; Wesenberg-Lund, 1937). These forms could not, therefore, have been responsible for the bilobed traces, which have involved lateral leg movement towards the mid-line of the body. Furthermore, the body size of the fossil conchostracans is consistently too small for the associated *Cruziana.* On the contrary, the conchostracans are associated in several cases with the trace fossil *Lockeia* [=*Pelecypodichnus*], the size of which corresponds well with that of the body fossils. Extant conchostracans spend much time lying on one side on the sediment or dug head downwards into it in much the same way as burrowing pelecypods (Wesenberg-Lund, 1937). It is therefore highly probable that the *Lockeia* are the work of the conchostracans.

Seilacher (1960, fig. 1c) has figured a coffee-bean trace similar to the Triassic examples from Jameson Land as the work of an anostracan branchiopod. However, anostracans swim on their backs and do not burrow (Wesenberg-Lund, 1937). The only important and widespread group of branchiopod with burrowing habits and transverse leg-movements is the Notostraca.

In a Triassic succession comparable in lithology to that of Jameson Land, Trusheim (1938) described body fossils of the notostracan branchiopod *Triops cancriformis* (Schaeffer), but found no trace fossils which might have corresponded to them. In the present case no body fossils of notostracans have been found.

A single example in the Jameson Land material, however, provides some positive support for notostracan branchiopods as causative agents for the *Cruziana.* In this case, a distinct, semicircular impression has been left anterior to a large cubichnion which strongly suggests the form of the shield-like carapace of a notostracan (fig. 1D).

This interpretation is supported from another source. The numerous tarns and melt-water ponds in the same area are thickly populated today by the notostracan *Lepidurus arcticus* (Pallas). In ponds with sparse vegetation and silt or sand bottom these animals produce traces which provide an opportunity for comparison of closely similar fossil and Recent traces. (They do not resemble the exogene trails produced by *Triops* under artificial, very shallow water conditions and recorded by Trusheim, 1931.)

In this natural environment it was observed that *Lepidurus* spends much time swimming actively in the free water and ploughing through the superficial silt in search of food. The ploughing activity results in a crude double furrow in the surface of the bottom silt (fig. 3D). This exogene trace does not closely resemble any traces in the Triassic material. However, the hypothetical downward projection of the trace as an endogene structure at an interface close beneath the surface of the sediment (fig. 3E) would produce a trace closely comparable in dimensions and sinuous course to the shallow *Cruziana* in the Triassic material.

Deeply dug-down, stationary *Lepidurus* were commonly seen. On leaving this position some animals proceeded to plough deeply forward. Most individuals, however, swam suddenly upwards out of the sediment, producing a cloud of sediment in suspension and leaving behind them a shapeless exogene depression. This suggests that in the fossil, endogene cubichnia, the more or less transverse striae correspond to activity of the endopods as the animal dug itself down, while the deeper, more posterior set of finer striae correspond to the exopods producing the forward propulsion of the animal on its quitting the site. In those cases where the posterior area is smooth rather than striated, it was presumably excavated not so much by the exopods themselves as by the water current created by them (cf. Birkenmajer & Bruton, 1971).

Rheotaxis

Notostracans are stream-lined animals. It was observed in the living *Lepidurus* that even in slowly flowing water the animals can maintain their equilibrium only by facing upstream.

This strong orientational control is reflected in the Jameson Land Triassic trace fossils interpreted as the work of notostracans. In many of these Triassic trace fossil horizons, the *Cruziana* show a distinct preferred orientation. Seilacher (1953) has described a similar case from the German Triassic.

Some 2–3 cm above the orientated *Cruziana,* the top surface of each laminated

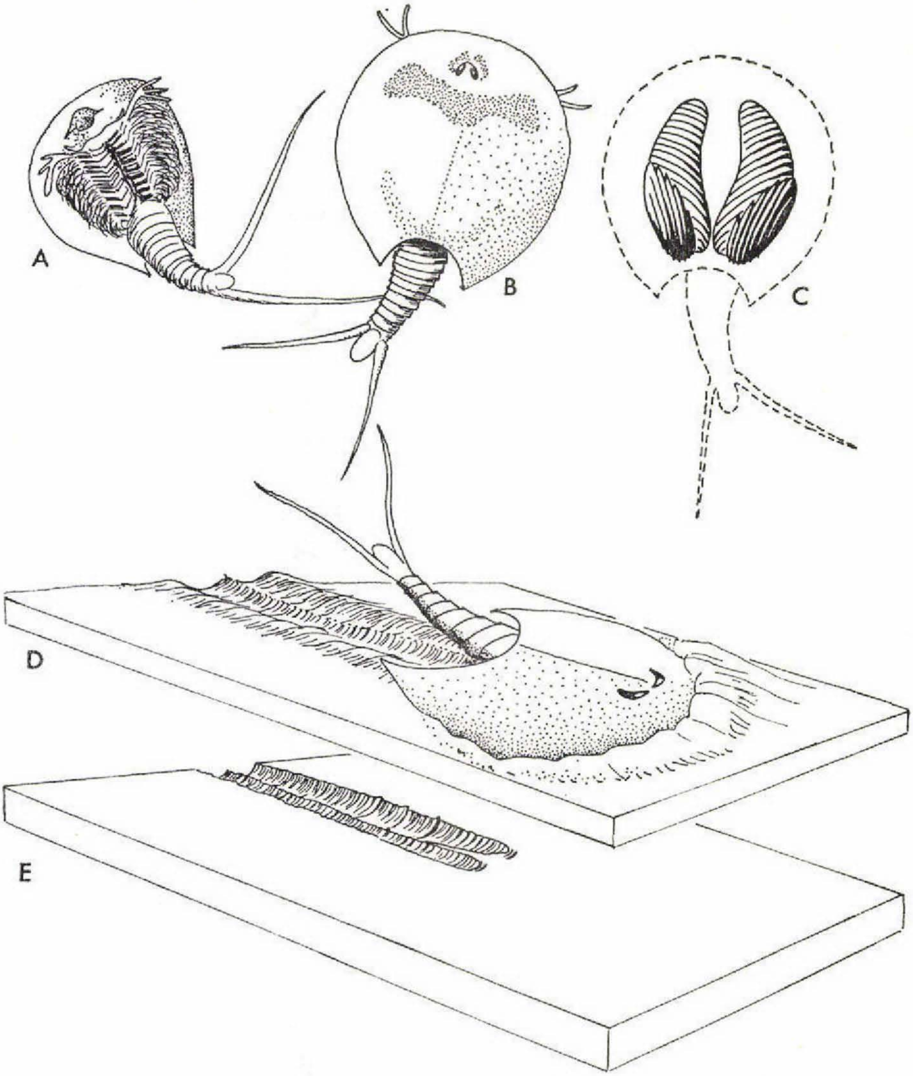

Fig. 3. *Lepidurus arcticus* and its traces. A: ventral and B: dorsal views of the animal. × 2. C: outline of the animal placed over stylized resting trace based on the Triassic material. D: *L. arcticus* ploughing through bottom sediment as it feeds and producing an exogene double furrow. E: hypothetical *Cruziana* produced at a slightly lower interface in the sediment.

siltstone takes the form of oscillation ripple-marks. These are easily measured, indicating a north–south oscillation (fig. 4). No information is gained from their external form as to the prevailing current direction, whether north or south. The *Cruziana,* occurring nevertheless at a slightly lower horizon, also face both ways. They show, however, a high preference for facing south, indicating a prevailing current from that direction.

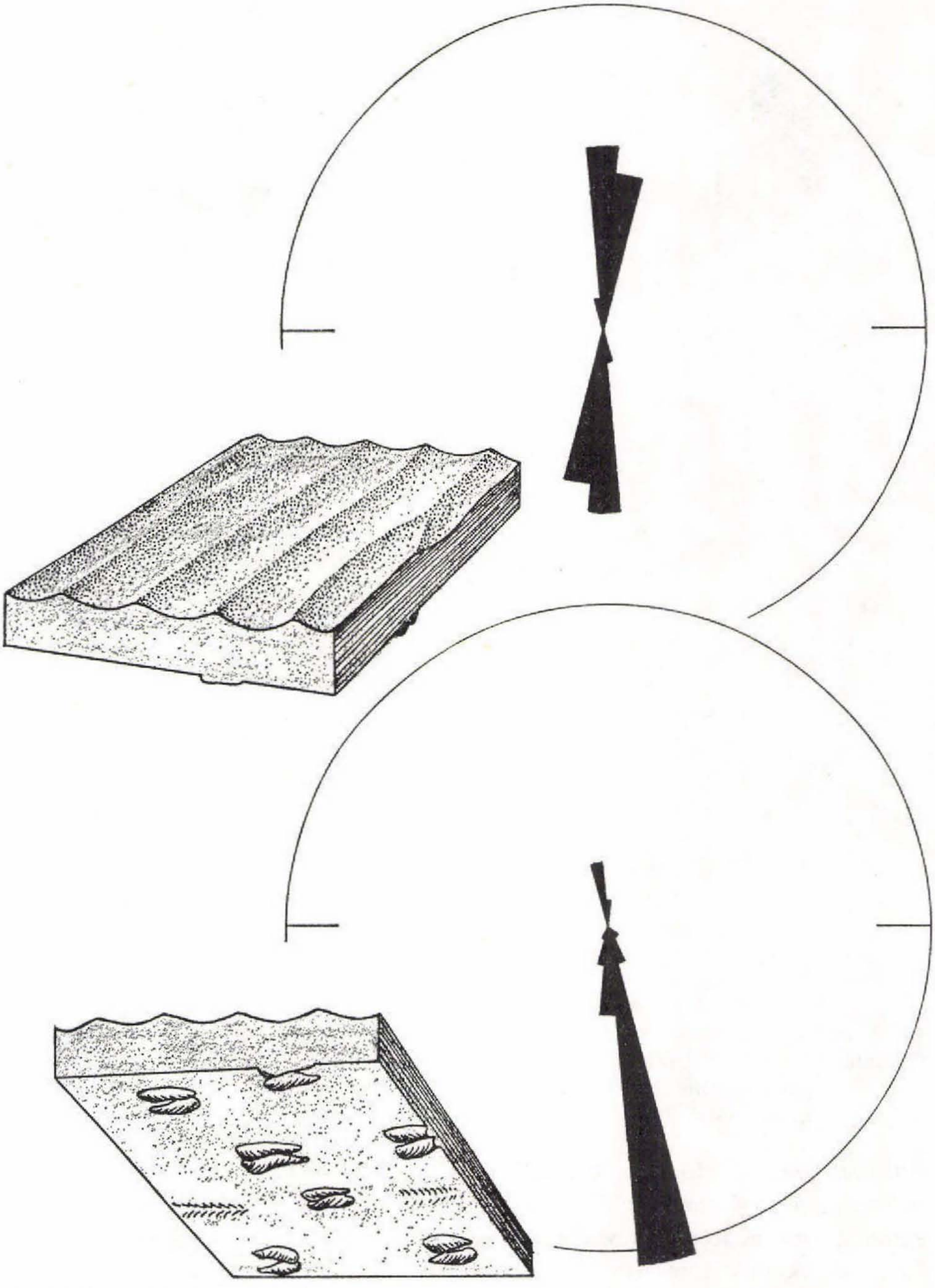

Fig. 4. Current-direction data from two sources on a slab of siltstone: oscillation ripple-marks and *Cruziana* hyporeliefs.

The *Cruziana* occur on bedding planes covered with orientated prod-marks which confirm the prevailing current from south.

The ichnocoenosis

The Triassic red-beds of Carlsberg Fjord contain a suite of several trace fossils. The *Cruziana* are characteristically associated with the walking trace *Merostomichnites triassicus* Linck, a form which has been ascribed by Linck (1943) not only to branchiopods but to the notostracans themselves. In the present material *Merostomichnites* occurs with a width of up to 1 cm, both as epireliefs and hyporeliefs, and may well be the work of the same animals that dug the *Cruziana*. A similar association in the German Triassic led Seilacher (1963) to the same conclusion.

Generally the trace assemblages are monotonous, comprising only two or three forms on any particular bedding plane. They include several stuffed burrows, some new, which it is intended to describe elsewhere. It is worth noting here, however, that *Planolites rugulosus* Reineck was also recorded in association with branchiopod *Cruziana* in the German Triassic red-beds by Seilacher (1963). In the Carlsberg Fjord area this ichnospecies likewise occurs with *Cruziana,* though also commonly without. In Jameson Land today, closely similar trails to *P. rugulosus* are being produced by insect larvae at the sediment surface or very closely beneath it in wet mud of drying puddles and streams.

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THE BURROWS AND MICROCOPROLITES OF *GLYPHEA ROSENKRANTZI*, A LOWER JURASSIC PALINURAN CRUSTACEAN FROM JAMESON LAND, EAST GREENLAND

The palinuran crustacean *Glyphea rosenkrantzi* Van Straelen, was shown by Rosenkrantz (1934) to be abundant in beds of Toarcian age in SE Jameson Land. Rosenkrantz's observations were confirmed in the 1970 field season when the shrimp was found to occur only in small, phosphatic concretions at certain restricted horizons within the Ostreaelv Member of the Neill Klinter Formation (Surlyk *et al.* in press).

Two types of phosphatic concretions were found to occur in these beds. About 50 % of them are irregularly shaped or roughly subspherical with uneven boundaries. These contain oysters, *Trigonia,* and other bivalves, ammonites and phragmocones of belemnites and bone fragments but no crustaceans. The other concretions are smaller, smoother, and of more regular shape, rounded as spheres, sausages or kidney-shapes, a few with a lobe as if showing a tendency to branch. In some 50 % of these (the rest are barren), well-preserved fragments of *Glyphea* occur, in many cases almost the complete skeleton (fig. 5). Owing to the clear distinction both in form and contents between the two types of concretion, it was considered that those containing crustaceans had developed within burrows while the others had formed in the surrounding sediment.

Burrow/concretion relationship

During the 1971 field season, this relationship was confirmed when a locality was found where extensive bedding planes and sections in these beds were exposed by river erosion. The site, at the mouth of Ostreaelv, west of Kap Stewart, was chosen as type locality of the Ostreaelv Member (Surlyk *et al.* in press). In this section the horizon with concretions was found to be highly bioturbated with small, sinuous fodinichnia, larger *Muensteria,* and dominated by well-preserved horizontal systems of *Thalassinoides.* Wherever the relationship could be detected, the mollusc-bearing concretions lay outside the *Thalassinoides* while the shrimp-bearing concretions lay within the fill of the burrows (fig. 6). It was also clear that all concretions are autochthonous, consisting of the same sediment as that in which they lie and showing no signs of exhumation.

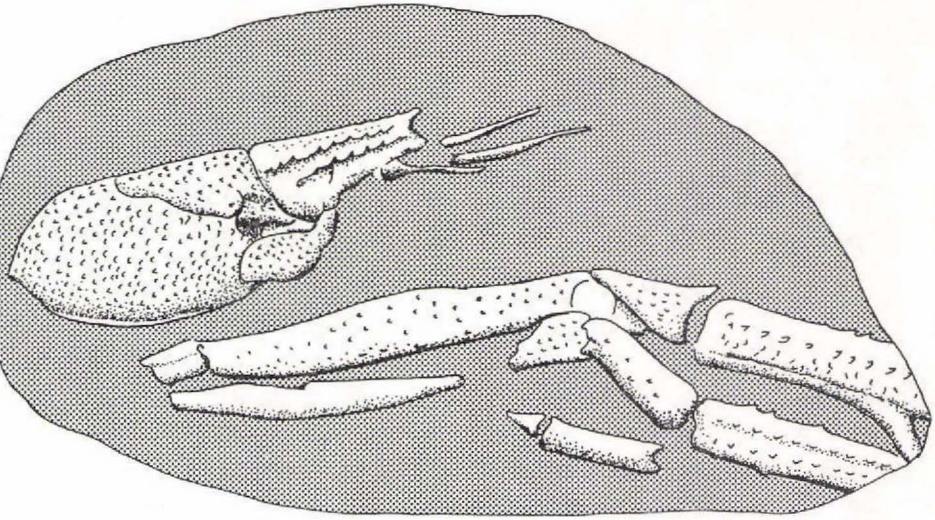

Fig. 5. A typical concretion from a burrow, split open and unprepared, containing the anterior half of *Glyphea*. × 1.4. GGU 137163.

The thalassinoid burrow

Although successive systems of burrows cross each other, it was possible in several places to observe fairly extensive areas of the thalassinoid system (figs. 7 & 8). The burrows exhibit normal *Thalassinoides* characteristics, with Y-branching and swollen turn-arounds at the point of branching. However, T-branches and long, straight, unbranched horizontal tunnels also occur. The burrows have a depressed oval cross-section, probably due to compaction, and their width is now 3–4 cm. The wall is represented by a thin dark line without any visible special structure. The fill is passive, in many cases with a strictly horizontal lamination.

Discussion

The concretions bearing *Glyphea rosenkrantzi* are confined to the thalassinoid fills and there can therefore be little doubt that the crustaceans inhabited the burrow systems. There is a previous record of a species of *Glyphea* (a single individual) having been found within a Jurassic *Thalassinoides* fill (Sellwood, 1971). It may therefore be reasonable to assume that *Glyphea* is itself the excavator of the thalassinoid system. The animal appears to be little adapted morphologically for this role, having a thorny ornament, a rigidly calcified exoskeleton and long walking legs. This can no longer be raised as an objection, however; Rice & Chapman (1971) have shown that extant species of *Nephrops* and *Goneplax* produce more

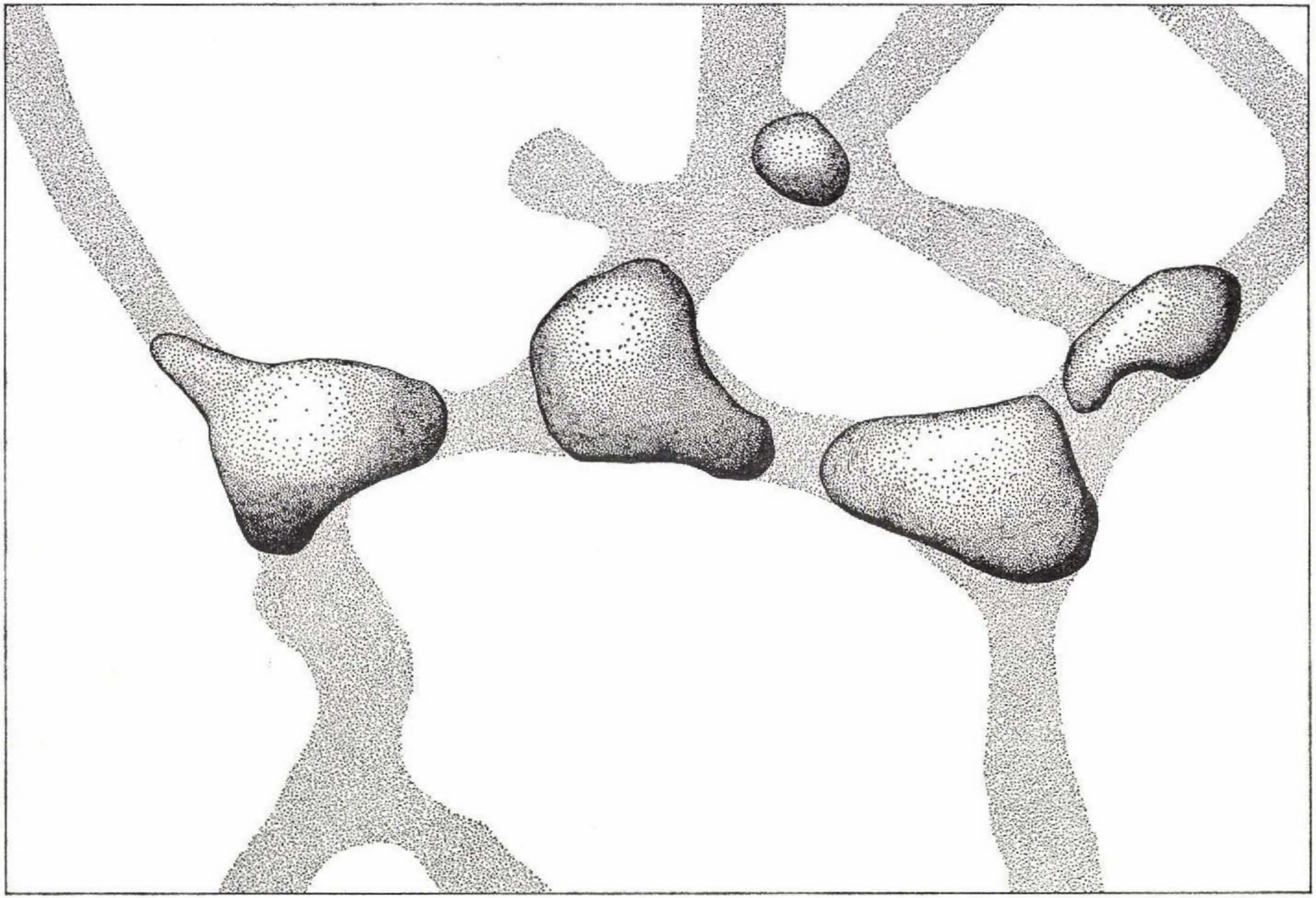

Fig. 6. Concretions *in situ* within *Thalassinoides*. From GGU photograph RB.C267.71.

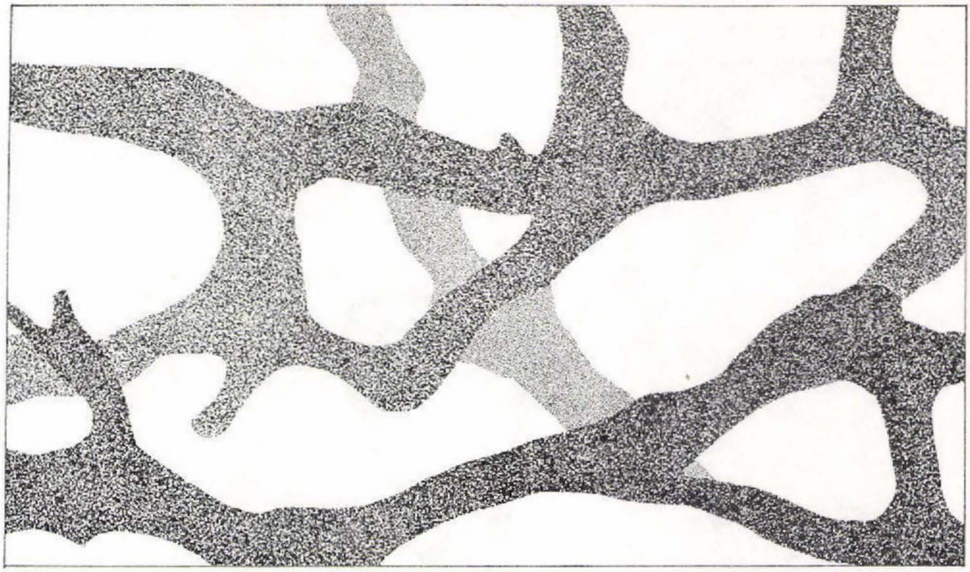

Fig. 7. A *Thalassinoides* system showing younger, re-excavated parts in darker tones. No concretions are present in this area. Burrows 3–4 cm in diameter. From GGU photograph RB. C268.71.

or less complex burrow systems and yet show no special morphological adaptation towards a burrowing mode of life.

In the case of the seemingly ill-adapted lobster *Nephrops*, it is noteworthy that the burrow diameter is relatively large in respect of the diameter of the animal (cephalothorax) (fig. 9A). In contrast, the highly adapted shrimp *Callianassa* fits its burrow very snugly (e.g. MacGinitie & MacGinitie, 1949, fig. 134; Weimer & Hoyt, 1964, pl. 123, fig. 6), the diameter of the tunnel hardly exceeding that of the animal's carapace (fig. 9B), and necessitating the construction of enlarged turn-arounds. Furthermore, while *Nephrops* quits its burrow nightly (Chapman & Rice, 1971), the extreme specialization of *Callianassa* has left it unsuited to outdoor life and records of healthy individuals leaving their burrows are few.

Although *Glyphea* would seem to be no better adapted than *Nephrops* to life within a burrow, the dimensions of *Glyphea* and of the burrow in which it is found are not so divergent (fig. 9C). Indeed, the size relationship is closer to that of *Callianassa,* as is the form of the burrow system, complete with turn-arounds.

Despite the completeness of many of the *Glyphea* skeletons, the presence also of fragments and half skeletons suggests that these are chiefly exuviae rather than the remains of dead individuals. Thus, although *Glyphea* seems to be well constructed for life beyond the confines of its burrow, the animals appear to have moulted within their tunnels, where they were protected from predators. Glaessner

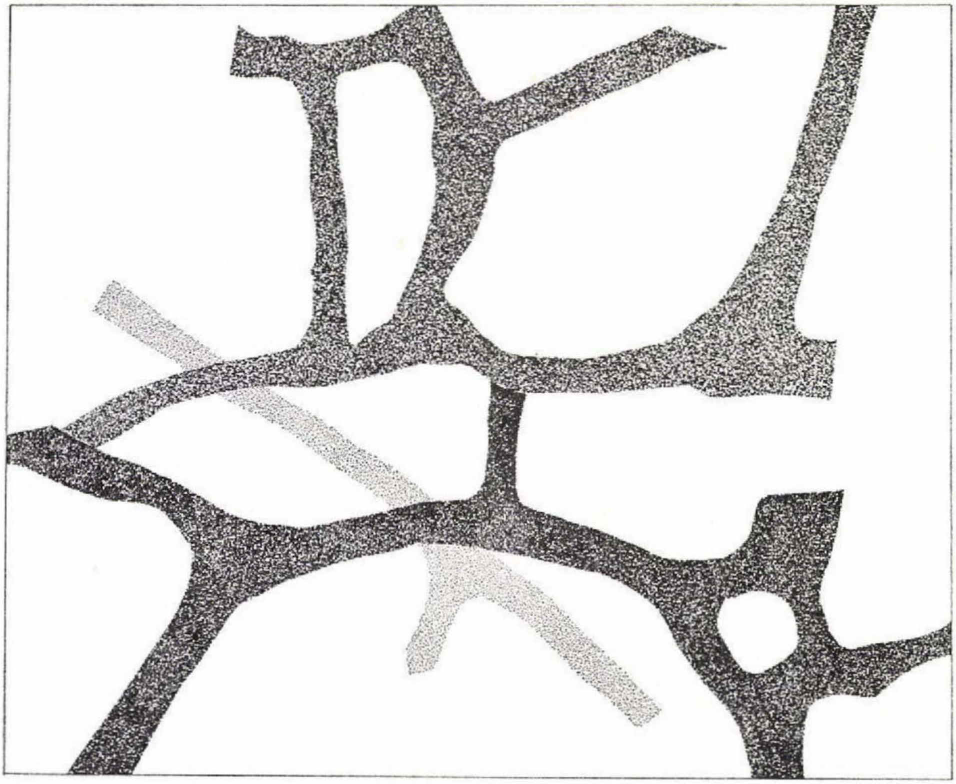

Fig. 8. As for fig. 7. From GGU photograph RB.C269.71.

(1969) records the burrowing shrimp *Thalassina* as occurring in early diagenetic concretions, probably Holocene, in mangrove sediments. Crustacea are commonly preserved within concretions and it would seem likely that preservation within burrow systems is not as uncommon as it has hitherto been considered.

Microcoprolites

The sediment comprising both mollusc-concretions and crustacean-concretions contains small coprolites. These are patchily distributed and occur both within the burrows and in the surrounding sediment. They are of two kinds. Small ovoid bodies about 0.5 mm long, generally known as 'SPORBO' (e.g. Emery, 1960), probably represent annelid excrement. These consist of a pale green core of glauconite with a waxy lustre, surrounded by concentric layers of glossy brown phosphate. The other kind consists of rod-shaped bodies, cylindrical but with variably rounded ends, about 0.4 mm in diameter. These are also composed of glauconite with a very thin envelope of phosphate. The surface is smooth to finely transversely wrinkled. Internally they show strong cleavage transverse to the axis of the rod,

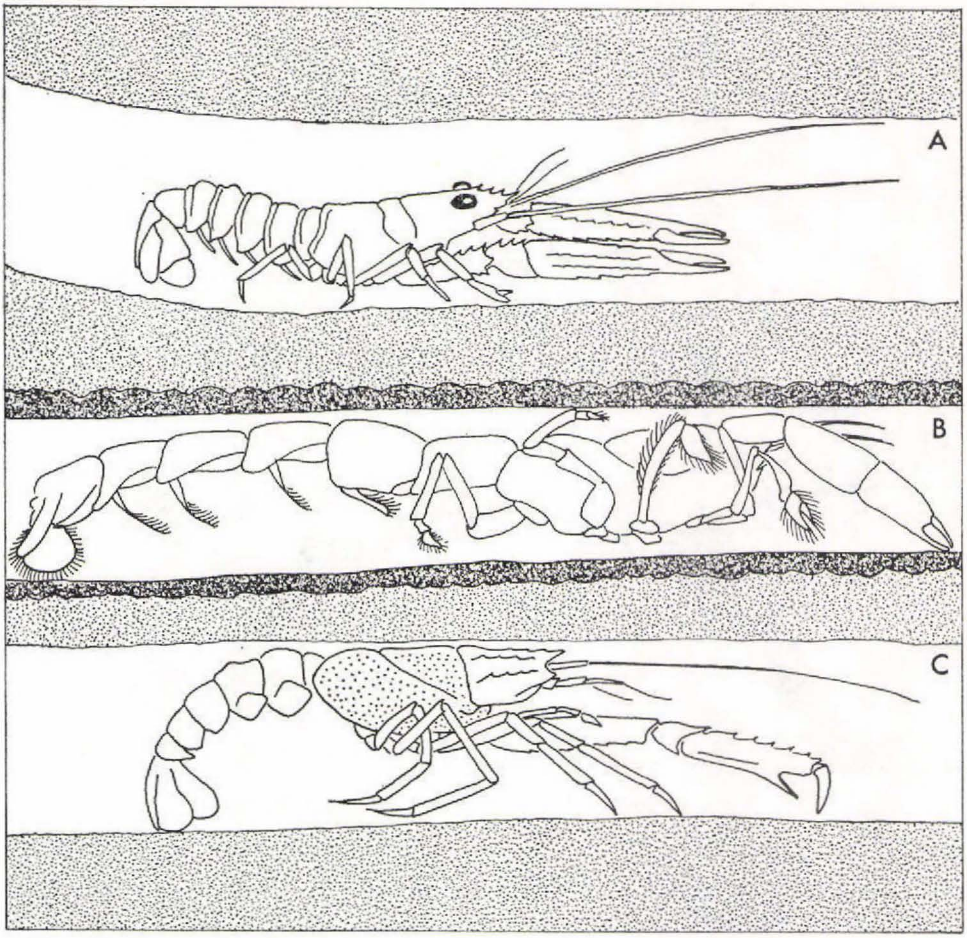

Fig. 9. Burrows of three crustaceans reduced to the same diameter in order to show the relative degree to which their occupants fill the lumen. A: *Nephrops norvegicus,* modified after Rice & Chapman (1971). B: A female *Callianassa major,* modified after Weimer & Hoyt (1964) and others, and showing the strengthened wall of the burrow. C: *Glyphea rosenkrantzi.*

suggesting compaction within the intestine, which has been exaggerated by diagenesis. The general form is that of a crustacean coprolite.

Despite examination of broken surfaces, polished surfaces and thin sections, no indication of internal longitudinal canals can be seen in these rod-coprolites. It is unlikely that such canals should be completely obliterated by glauconitization. Canaliculated microcoprolites composed of glauconite in Cretaceous chalk usually present well-preserved internal structure. It may be concluded, therefore, that these Jameson Land microcoprolites have never possessed canals.

As a general rule the coprolites of aquatic burrow-dwelling animals are compact and able to survive unbroken for some time in order that they may be removed efficiently from the burrow, while coprolites of non-burrowing animals decompose relatively rapidly (Schäfer, 1962). This is particularly the case among crustaceans; the literature testifies to the high fossilization potential of coprolites of burrowing crustaceans. In the present material, the preservation of this single, crustacean type of microcoprolite thus strongly suggests that it is the excrement of a burrowing form, and its association with *Glyphea rosenkrantzi* must be accepted as evidence that the coprolites are the excrement of the shrimp.

Confirmation of this association awaits the description of coprolites of extant palinurans. Hitherto internal canals have been described only in the coprolites of anomurans while those of brachyurans and astacideans lack canals (Moore, 1932). In the absence of direct evidence, Kennedy *et al.* (1969) suggested that their Bathonian canalicular microcoprolites were the excrement of palinurans, possibly that of *Mecochirus clypeatus* (Carter). However, the non-canalicular coprolites in the Jameson Land material are provisionally ascribed here to the palinuran *Glyphea rosenkrantzi* with which they are associated.

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A LARGE RADIATING BURROW-SYSTEM IN JURASSIC MICACEOUS SANDSTONES OF JAMESON LAND, EAST GREENLAND

During the mapping of Jameson Land in 1968–1971, a large burrow-system was encountered in sandstones at several stratigraphical levels. At first, long, straight, annulated burrows were met with in beds of Lower and Middle Jurassic age. In the 1971 field season, however, several field parties independently recognized these in different formations as belonging to a large radiating system. It also became clear that, while valuable locally even as an index fossil, the system is facies dependent and present only in micaceous sandstones.

Morphology and preservation

Examination of the burrow-system in different types of sediments, reveals various aspects of its internal construction and outer form which are never seen together in a single specimen. The trace fossil has chiefly been found in two types of sandstone each of which displays it in a characteristic mode of preservation.

Medium grained, richly micaceous sandstone

In the Ostreaelv Member (Toarcian) of the Neill Klinter Formation and the Pelion Member (U. Bajocian-Bathonian) and Fossilbjerget Member (Bathonian-Callovian) of the Vardekløft Formation (see Surlyk *et al.*, in press) the trace fossil is particularly common in medium grained sandstones with a high mica content. In this facies, the more or less complete systems are preserved as cleavage reliefs on bedding planes as a number of characteristically straight, horizontal burrows radiating from a central region, and resembling the spokes and hub of a wheel (figs 10 & 11). The central area is a cross-section of a vertical shaft.

The vertical shaft is 6–8 cm in diameter and is usually weathered out as a hole. In a few cases where the sediment in this central shaft is preserved it is seen to be bioturbated, the mica grains showing no preferred orientation. In one case the sediment contains a concentration of plant fragments and other fossils which are otherwise rare in that bed. However, at the somewhat irregular boundary of this central shaft the mica shows a strongly vertical orientation, tangential to the boundary and sloping slightly downwards and inwards (fig. 13).

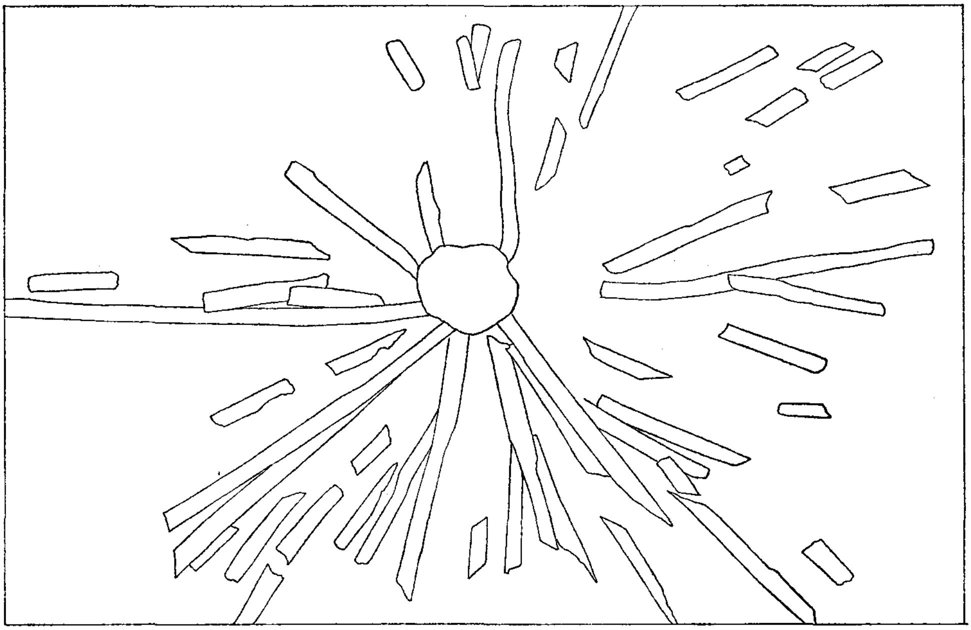

Fig. 10. A single system of *Phoebichnus trochoides* sectioned on a bedding plane, Ostreaelv Member. From GGU photograph RB.24.01.71.

From this shaft the radial burrows emerge abruptly. They show the same width of ca. 2 cm throughout their length and generally lie horizontal. Thus where bedding planes are flat they can be traced for some distance, the maximum length measured being 58 cm. Usually, however, the course of the radial burrows is interrupted where the surface of the specimen, or the burrow itself, departs from the bedding plane (figs 10 & 11).

In contrast to the fill of the shaft, the radial burrows show a complex internal structure as revealed by the orientation of mica flakes. The tunnels consist of two parts: a wall structure up to 0.5 cm thick and a fill up to 1 cm wide. In medium grained, micaceous sandstones these are usually sectioned together and the mica orientation becomes clear where these sections are weathered. The mica flakes stand more or less perpendicular to the burrow axis in both parts. In the fill they show a gentle doming as a meniscus structure, concave towards the central shaft. In the wall sections on either side the mica menisci bend in the opposite direction, convex towards the centre (fig. 12). The wall commonly has a slightly darker tint than the fill and surrounding sediment. The cross section of the radial burrows is somewhat depressed, possibly owing to later compaction of the sediment.

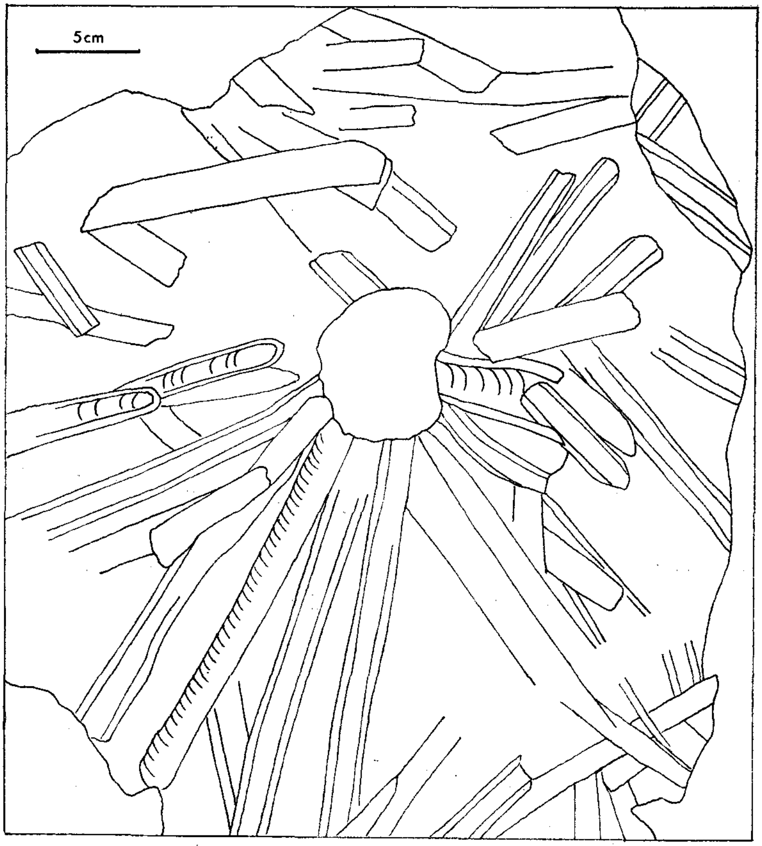

Fig. 11. *Phoebichnus trochoides* displayed on a bedding plane in a large concretion in the Fossilbjerget Member, from a horizon rich in this trace fossil. Most of the radial burrows derive from the central shaft in the middle of the picture. These intersect with at least two other sets of radials which connect with centres out of the bottom of the figure and beyond the top left corner. From GGU photograph TB.C 11.01.71.

Medium grained sandstone poor in mica

In the Gule Horn Member (between Pliensbachian and Toarcian members) of the Neill Klinter Formation, the same burrow-system is recognizable despite a completely different mode of preservation. It occurs in ripple-bedded sediments composed of rapidly alternating shales and quartz sandstones, and is preserved in demirelief both as hyporeliefs and epireliefs in the sandstones.

In the thicker sandstones in the Gule Horn Member, the long, straight tunnels of this trace fossil are preserved in full-relief, but the central shaft has not been seen. Usually, however, the bedding planes are not flat and the tunnels are preserved only for short lengths. The burrows are themselves slightly sinuous in the

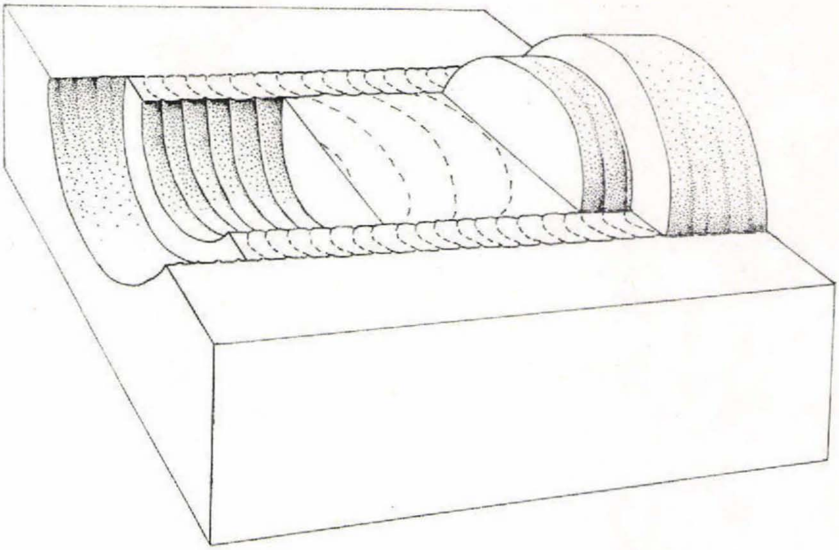

Fig. 12. Compound figure to illustrate the internal structure of a radial burrow. Mica orientation in the fill and wall is indicated by broken lines.

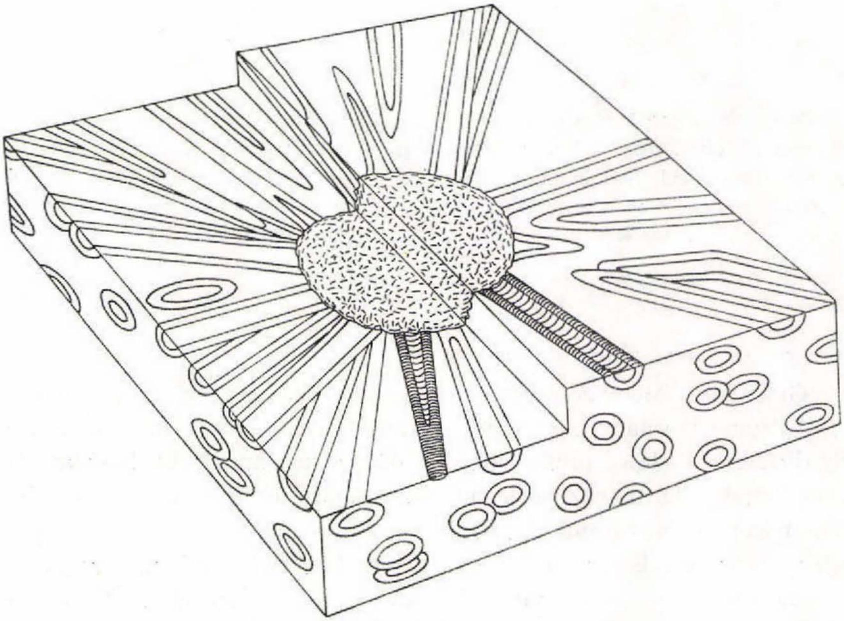

Fig. 13. Reconstruction of general form of *Phoebichnus trochoides*. Mica orientation is indicated in the central shaft and in two radials.

thinly bedded sandstones. Their cross-section shows various degrees of depression due to compaction of the sediment but examples in concretions are usually circular in section and probably represent the true original form.

In this facies the tunnels show a strong annulation. In most cases this is the sculpture on the inner face of the wall structure, but some cases show also a weaker annulation of the external surface of the walling material. Many specimens make it clear that this annulation is not a reflection of the structure of the fill but is due to the composition of the wall itself. The wall can be seen to be composed of a series of annular units with a curved front and back surface, convex to the hypothetical centre and corresponding to the mica structure seen in the more mica-rich sandstones.

Synthesis of morphology

Combining information from the two facies, a structural picture of the radial tunnels can be built up as in figs 12 & 13. There is enough overlap to show that the burrows in the two facies represent the same type of system. The central shaft has only been observed in the medium grained, micaceous sandstone where fairly complete systems are commonly observed. Without the accompanying radial burrows the central structure would not easily be recognizable.

Information is seriously lacking with regard to the vertical extension of the trace fossil. While numerous examples have been seen on bedding planes, these are only clearly visible on weathered surfaces. Attempts to excavate them in depth have failed. It has only been possible to demonstrate that the radiating burrows emerge from a central shaft over most of its visible extent, and are not restricted to certain bedding planes. The central shaft has not been traced to a depth of over 15 cm, however, though this is possibly only a small part of its original extent.

Similarly, the natural end of a radial branch has not been recognized, and the complete form and full length of these is therefore unknown.

Comparison with other trace fossils

The present form resembles in shape the star-shaped traces which occur in the deep sea floor and have been recorded photographically (e.g. Häntzschel, 1970) but the Recent traces are smaller. However, these are all exogene structures while the Jameson Land fossils are decidedly endogene. The mica-orientation in the radial burrows is similar to that shown by *Muensteria* in similar lithofacies (see Heinberg, 1970, "meniscus tunnels"), but the scale is larger, the course straighter and branching does not occur, while the presence of a central shaft distinguishes them completely. Thus the radiating fossil appears to be new (Häntzschel, pers. comm.) and, although incompletely known, deserves a name.

Fig. 14. One of the pieces comprising the holotype: MMH 12819 A (GGU 144193).

Phoebichnus n. ichnogen.

Type: *Phoebichnus trochoides* n. ichnosp.

Derivatio nominis: from Greek, *Phoibos:* the sun personified; and Greek, *Ikhnos:* trace.

Diagnosis: as for ichnospecies.

Phoebichnus trochoides n. ichnosp.

Holotype: MMH 12819 A, B and C (GGU 144193). Fig. 14. Three pieces of a system preserved in richly micaceous sandstone. Taken from a horizon 400 m above sea level, locally characterized by these burrows. Basal beds of *Cadoceras nordenskjoeldi* Zone, Lower Callovian, Fossilbjerget Member, Vardekløft Formation. Section east of top 490 m, south of Mikael Bjerg; 71°08'N, 23°15'W.

Derivatio nominis: From Greek, *Trokhos:* wheel.

Diagnosis: a central shaft of unknown depth and *c.* 6–8 cm diameter with numerous long, straight burrows radiating more or less horizontally from it. The radial burrows have a lumen *c.* 1 cm wide containing active fill, and a wall 5 mm thick composed of discrete annuli. An annulation is imparted by the wall to the surface of the fill and the surrounding sediment.

Occurrence: restricted to sandstones. Known from Liassic and Bajocian-Callovian of Jameson Land.

Interpretation

Mica orientation is a valuable tool in the interpretation of the behaviour patterns and organic activities which produce trace fossils, as has been shown by Heinberg (1970 and in press). In the present case it may be assumed that the organism which produced the trace lived within the central shaft. It was from this shaft that the radial tunnels were constructed and refilled by the activity of the animal. For the completion of this programme, a double journey was required within each radial burrow. During the outward journey, away from the central shaft, it is probable that the special wall structure of the burrow was produced, its mica orientation reflecting both compaction and the direction of movement (convex towards shaft fig. 12). There is no information to suggest whether the whole animal undertook this journey, or only a "proboscis", the rest of the body remaining in the shaft. Neither is it clear whence excess sediment, displaced by the animal, was transported. Moreover, the existing active fill of the burrow is highly indicative of the return journey of the animal or part of the animal, with its meniscus concave towards the shaft. The structure of the burrow thus indicates a bi-directional movement in the sediment, but reveals very little about the nature of the originating organism. It would not be reasonable at the present state of knowledge to attempt to identify the animal. The behaviour programme, however, may safely be attributed to the exploitation of the sediment for food, and the trace fossil may thus be designated a fodinichnion.

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