A "PIPE-ROCK" IN THE UPPER CARBONIFEROUS OF BEAR ISLAND

BY

OLAF HOLTEDAHL.

In a paper printed in "Norsk Geologisk Tidsskrift" some years ago[1] the writer puplished some notes on the Paleozoic formations, particularly the pre-Devonian strata, of Bear Island, based on observations made during the summer of 1918. In the present article I wish to draw the attention to an observation which concerns the youngest Paleozoic division of the island.

Mt. Misery, the highest and most dominating mountain of Bear Island, is as is well known to a large extent made up of the Upper Carboniferous "Spirifer-limestone" in horizontal beds. This division does not contain limestone only, as is evident from the description given by J. G. Andersson[2]: "In der Mitte des Spiriferenkalkes, zwischen zwei mächtigen Kalksteinbetten liegt eine Bank von Sandstein, mindestens 10 M. mächtig. Dieser Sandstein ist teils dickbankig und fossilienfrei, in welchem Falle er dem Ursandstein täuschend ähnlich ist, teils enthält er in anderen Schichten zahlreiche Fossilien, *Productus*-Formen und Bivalven". (1. c. p. 258).

During an ascent of the northwestern side of Mt. Misery in 1918 I passed this sandstone-zone and in the débris I observed pieces of sandstone with numerous parallel, cylindrical tubes standing vertical to the plane of bedding. I collected a number of specimens of the rock and on these specimens the following

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1 On the Paleozoic Series of Bear Island, especially on the Heclahook System. N. G. T., V, 1919, p. 121.

2 Ueber die Stratigraphie und Tektonik der Bären Insel. Bull. Geol. Inst. Upsala, IV, 1909.

observations are based. Photographs of two of the specimens are shown in figs. 1 2.

The sandstone is of a very massive character. One rock specimen represents a bed of about 2 dm. thickness, with no sign of stratification between the bedding planes. The sandstone is of a hard, rather quartzitic type; the average size of the fairly well rounded grains is 0,2 0,3 mm.

Fig. 1. Specimen of the "pipe-rock" from Bear Island. 3/5 nat. size.

On the surface of the weathered specimens we notice numerous parallel or nearly parallel cylindrical or sub-cylindrical holes with, in many cases, more or less of the mass that once filled them still preserved. The (original) diameter of the cylinders at some distance from the bedding-planes generally is between 5 and 10 mm., some holes being smaller, only 2 3 mm. In many cases the holes show a very marked widening towards what is considered the upper bedding-plane, where the diameter may be as much as 20 mm.

In fig. 1 a very regularly shaped sandstone cylinder is seen. The marked widening of the hole at the upper end of it might

be thought to be a secondary feature only; however, the rock around the upper end of the cylinder, occurring in places on the sides of the funnel-shaped hole, is of a different, less solid and quartzitic character than the rock around the hole. The surface widening seen in one of the holes shown in fig. 2 is at any rate no secondary feature, as also the diameter of the sandstone cylinder seen there, increases correspondingly (to 15 mm.).

I have studied some microscopical slides, but not been able to find any marked difference in the character of the rock in a sandstone cylinder, and in the normal "ground-mass" of the same specimen.

The cylinders do not all go through the whole thickness of the sandstone bed, many of them become quite indistinct towards what is considered the lower part of the layer. Where the rock is freshly broken the tubes are nearly always very faintly marked. On the (supposed) lower plane of bedding and in the adjacent portion of the rock very fragmentary casts of large shells are seen; in one case the cast no doubt represents a *Productus*.

We are here evidently dealing with a "pipe-rock", a *Scolithus* sandstone, which type of rock is especially known to occur in the Cambrian of various countries: Scotland, Sweden, North America a. o. As to the Scottish "pipes" I could especially refer to the description by B. N. Peach[1]; the Swedish ones have been treated fairly recently by A. G. Högbom[2] while for the American ones I can refer to the list of literature dealing with *Scolithus* given by R. S. Bassler[3]. F. A. Bather has published a note on a "pipe-rock" from Tasmania[4].

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[1] The Geological Structure of the North-West Highlands of Scotland. Mem. Geol. Surv. Great Britain, p. 372—375.

[2] Zur Deutung der Scolithus-Sandsteine und "Pipe Rocks". Bull. Geol. Inst. Upsala, XIII, 1916 (p. 45) Where older literature.

[3] Bibliographic Index of American and Silurian Fossils, U. S. Nat. Mus. Bull. 92, II, p. 1153.

[4] Salt-weathering and supposed Worm-borings in Australia. Geol. Mag. 6 ser., IV, 1917, p. 526. This „pipe-rock" — in which also tubes lying horizontally occur — is stated to persist in the said area to Silurian time.

As Högbom emphasizes there is a considerable difference between the *Scolithus*-type of the Kalmarsund district of Southern Sweden and those occurring in the Cambrian sandstone of N. W. Scotland. The Bear Island type, with rather thick pipes and (sometimes?) a widening of the cylindrical cavities at the supposed upper end, come decidedly nearest to Scottish types of *Scolithus*. The description by Peach shows, however, that in Scotland the size, and also the form of the "pipes", varies considerably in different zones. "Hence successive sub-zones of the "pipe-rock"

Fig. 2. Specimen of the "pipe-rock" from Bear Island. 3/5 nat. size.

have been mapped out by means of them". I might, for comparison, further cite the following lines: „Sub-zone III, is characterized by "trumpet pipes", the *Arenicolites* of Salter. In these the cylinders, when followed to the surface of the bed, are found to end at the bottom of cup-shaped depressions, which sometimes measure two inches across. Seen in section, the cylinder can be observed to stand up a little into the bottom of the cup, ." This feature may be of a similar nature as that seen at the regular cylinder of fig. 1, even if the hole in this case is not cup-shaped.

As to the American types the very regular *Scolithus linearis* HALDEMANN seems to be typical of the Cambrian, while others, with the cylinders less straight, are known from younger, Ordovician and Silurian, sandstones.

These cylindrical structures have in very old times been thought to represent plants, later on it was generally believed that they were brought about by burrowing animals. Peach, for instance, writes about the pipes: "These are attributable to burrowing annelides " (1. c. p. 372). More recently quite another explanation has been proposed, namely that the cylindrical holes have been originally formed through air passing upwards through sand (in a flat beach) after the beach had been covered by the sea-water (through tide or through waves).

W. Deecke[1] has discussed the mode of formation of sandstone-tubes, arranged vertically to the bedding, and describes how he has observed a small *Gammarus* making vertical burrows in sand. He says however (p. 726): "Die *Skolithen* der cambrischen Sandsteine sind eine analoge Erscheinung. Aber ich führe diese nicht auf organische Mitwirkung, sondern auf *Luftblasen* zurück. Damit harmoniert sowohl ihre grosse Zahl in verhältnismässig kleinem Stüke als auch ihre Parallelität und die Stellung senkrecht zur Schichtung".

Högbom has in the previously cited paper in some detail described observations on "Bildung scolithusähnlicher Luftlöcher bei Überflutung an sandigem Meeresufer". (1. c. p. 52). The diameter of the holes in the sand observed by Högbom on the Dutch coast was mostly about 2 mm., sometimes as much as 4 mm., the depth mostly a few centimetres, the greatest depth measured being 12 13 cm. The writer has observed the formation of similar holes in the sand of a flat beach (at Sæby, Jutland, Denmark) when the water of the breakers sunk into the sand. The diameter of the holes did not generally exceed 2 3 mm. As emphasized by K. Andrée[2] the formation of similar holes through "das Aufperlen der in dem trockenen Sande eingeschlossenen Luft, die durch das teilweise Einsickern des Wassers der Welle ausgetrieben wird" evidently is a process very characteristic of flat sand-beaches periodically washed by the sea-water.

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[1] Einige Beobachtungen am Sandstrande. Centralblatt für Min., Geol. u. Pal., 1906, p. 721.

[3] Geologie des Meeresbodens, II, 1920, p. 87.

Fairly recently Rud. Richter has published an interesting paper [1], where he describes a "pipe-rock" from the Lower Devonian Koblenz-quartzite of the Eifel-area and discusses the origin of it. He comes to the conclusion that the remarkable structure cannot be due either to burrowing animals, nor to air-bubbles rising in the sand, but that we must think of "eines planktonfressenden, in aufrechter Stellung kopfoben lebenden Wurmes, der aus Sand und Schleim unverzweigte und bis auf die Mündung geschlossene Köcher aufbaute und die annähernd senkrechten Köcher zu ausgedehnten Bündeln verkittete" (1. c. p. 220). As a recent parallel he mentions *Sabellaria alveolata* L. "Dieser Wurm kittet sich nicht nur wie mancher andere Röhrenbauer mit verhärtendem Schleim aus Sandkörnern geschlossene Röhrenköcher, sondern führt diese auch in ausgesprochen senkrechter Anordnung auf; nach jeder kleinen Abweichung im einzelnen wird die Lotstellung immer wieder aufgenommen. Und diese senkrechten Köcher, jeder von seiner Einwohnerin unabhängig gebaut, verkitten mit den zu Tausenden gesellig angeschmiegten Nachbarköchern der Länge nach zu festen Bauten, scheinbaren Stöcken, die noch in der Hand ganz an Korallen erinnern . Und wo Zwischenräume zwischen den Köchern bleiben wollen, wird auch der Sand, der sich da hineinlegt, "durch eine von den Tieren ausgeschiedene, ihn durchdringende Klebemasse" (Hempelmann & Wagler p. 284) verfestigt und so das Ganze zu einer einzigen, zusammenhängenden Masse". The *Sabellaria* tubes may form widely distributed "reefs", in places visible at low tide. Because of the similarity to these reefs the Devonian pipes from the Eifel are by Richter given the name *Sabellarites eifliensis*, the generic name later, because the term *Sabellarites* was preoccupied,. changed to *Sabellarifex* [2].

Now, concerning the "pipe-rock" from Bear Island, the material, consisting of only a few weathered specimens, does not afford any good opportunity of deciding on their mode of

[1] Ein devonischer "Pfeifenquarzit" verglichen mit der heutigen "Sandkoralle" (Sabellaria, Annelidae). Senckenbergiana, II, 1920, p. 215. Here is also found a list of papers dealing with the *Scolithus* problem. I am very much obliged to Prof. Kiær for drawing my attention to this paper.

[2] Senckenbergiana, III, 1921, p. 49.

origin (a study *in situ* would of course be of much interest), yet it seems to the writer that the structure cannot have been caused by air-bubbles.[1] One main point is the thickness of the cylinders, which is considerably greater than noticed by Högbom (and also by the writer) for air-made holes. It is difficult to see that air rising in sand should be able to make holes with so large a diameter as 7 10 mm. When experimentally producing air-bubble holes by pouring water over dry (rather coarse) sand, the diameter seems to be fairly constant, 2 4 mm. The description by Peach of the Scottish "pipe-rock" shows that the pipes there may reach very considerable dimensions. Sub-zone V "contains "pipes" measuring sometimes nearly an inch across" (1. c. p. 373).

When we take into consideration that we are dealing with a sandstone bed of marine character, that we never find a cylinder lying horizontally, and furthermore remember the upper widening of the pipes (cp. especially the Scottish types) we may further leave the plant-theory out of question.

We have then the two explanations left: 1. the cylinders have been formed by burrowing animals, or 2. through a worm of the *Sabellaria* type, building up sand-tubes, one near the other, forming a reef-like mass of vertical tubes. There is no doubt that, when we learn about the characters of the "sand-coral" and see the illustrations given by Richter of its reef (1. c. p. 222), a number of points in favour of explanation 2. at once become evident. Just the points which are difficult to explain through the first theory that the cylinders are all parallel (or nearly parallel), that they commonly occur very close to each other, yet never interfere are very nicely explained through the other one. Yet there seem to be difficulties. Richter mentions one, the widening of the pipes upwards, distinct also in the Eifel-quartzite. He emphasizes, however, that this widening may to a large extent be of secondary origin. Yet, especially when reading the description of the Scottish Scolithus-

[1] I must agree with Richter that the air-bubble explanation seems unsatisfactory also for the regular *Scolithus linearis* type with very crowded cylinders.

structures, one gets the impression that this widening into a slightly conical funnel- or a cup-shaped hole, is a very characteristic feature of many pipe-rocks. Just this widening at the upper end is characteristic of tubes formed in accordance with explanation 1, through burrowing organisms.

The surface of the *Sabellaria* reef is stated by Richter to be "im ganzen gleichmässig hoch", yet "durch höhergewachsene Einzelbündel vielkuppig gewellt" (p. 221). This irregular surface is what should be expected in such a case. Is, however, not the bedding of the pipe-rocks regular? This is a point that must be carefully studied *in situ*.

One should expect, when taking the *Sabellaria* as example, that the sand-tubes made by the animal, should be distinctly seen, distinguishable from the sand that filled the interspaces; however, Richter emphasizes that "die Trennung von Sandwandung und Zwischensediment ist nach der Schleimverfestigung des letzteren schon beim frischen Bau nicht scharf ". Also this, like the character of the lamination seen in some pipe-rocks, is a main point that should be particularly studied.

The difficulty which meets one by assuming burrowing animals (like annelids) to have made the Scolithus-pipes is of course especially marked when we are dealing with types with very regular and very crowded cylinders. For types like that from Bear Island the burrowing-theory seems in several ways to be a rather natural one. That animals (like annelids, crustaceans a. o.) are able to make very regular, to some extent also very vertical and rather crowded canals in the sand is a fact; that they by lining the hole with mucus may make it very resistant and distinct in the later rock, and that similar burrows commonly may have a funnel-shaped upper end, are of course, further points of main importance. In any case, however, the correctness of the idea, emphasized by Richter, that the holes must have been a sort of "Dauerwohnung" and not a "Wandertunnel", seems to be evident.

The specimen figured by Richter (p. 225, fig. 4), with all pipes except one strongly curved, is very interesting, and no doubt point towards the conclusion that we are dealing with tubes originally existing above the massive bottom layer. However,

also the pipe especially marked in the said picture, is somewhat curved and if we assume that this pipe originally had a slight bend in the other direction, its value as a proof against a later deformation in the sand mass would be lost.

I may here mention that, when looking through a paper by J. Rekstad dealing with an exposure of Quaternary deposits in S. E. Norway[1], I found the following remark: "I sandlagene over myrniveauet fandtes talrige vertikalt stillede, rustfarvede sandrør. Alle var de udelte, uden forgreninger. De bestaar av sand, sammenkittet av jernoxydhydrat. Da rørene altid optraadte uden forgreninger, var jeg straks paa det rene med, at de ikke kunde skrive sig fra planterødder. Professor Sars undersøkte med vanlig velvillie disse rør, og han erklærede, at der ingen tvivl kunde være om, at de skrev sig fra *annelider*. Mest sandsynlig fandt han det efter deres udseende, at de stammede fra fjæremakken *Arenicola marina*" (l. c. p. 6). I have asked Mr. Rekstad about the dimensions of these sand-cylinders and his statement is that the length was about 20 cm., the diameter about 5 mm., thus very much like in more slender types of *Scolithus*.

The cylinders or holes in the Bear Island specimens are in places so widely apart as 5 cm.; only massive quartzite being seen between them. As in cases also a slight curving of the holes are seen, the type cannot be referred to what Richter terms *Scolithus* s. str. I think, however, that it will be difficult to separate such a type with "streng geradlinigen, gleichlaufenden und dicht aneinandergedrängten Röhren" (1. c. p. 227) from types with less regular and less crowded tubes. It is evident that the characters, as for instance in the Scottish "pipe-rock", varies very considerably. I might in this connection also refer to a paper by J. F. James[2] where the American Cambro-Silurian *Scolithus*-types are treated. It seems to the writer that the old name *Scolithus* should be used for all types of "pipe-rock" with vertical or nearly vertical, unbranched sand-tubes occurring in great numbers in sandstone. The name *S. linearis* may then be attributed to Richters type *Scolithus* s. str., as e. g. found

[1] Et profil fra de løse masser ved Fredrikshald. Norsk Geol. Tidsskrift, I, 5, 1907, p. 6.

[2] The Genus Scolithus. Bull. Geol. Soc America, 3, 1892, p. 32.

in the Cambrian of eastern North America (from where *S. linearis* was first described) and Southern Sweden.

The occurrence of a sandstone (of rather coarse grain) in the "Spirifer-limestone" of Bear Island is in itself a point indicating shallowness for that part of the Arctic "Productus sea", the find of a *Scolithus*-structure still more emphasizes such a conclusion. I might refer to the statement made by Andrée (l. c. p. 90)[1] when discussing the two ways in which he thinks a Scolithus-structure can be formed, viz. through air-bubbles in sand or through the activity of organisms: "Beide Entstehungsarten vertikal stehender Röhren sind im übrigen an Litorallokalitäten gebunden, und die Scolithus-Frage ist vom paläogeographischen Standpunkt aus nur einer eindeutigen Lösung fähig. Das zeigt auch das Zusammenvorkommen dieser fossilen Dinge mit anderen Litoralerscheinungen, wie schon A. G. NATHORST früher beschrieben und HÖGBOM neuerdings abermals ausgeführt hat".

Now, the occurrence of worm-burrows in general is certainly not restricted to the shore region, yet the larger types, like that of *Arenicola*, are probably characteristic of very shallow water. (The investigation of features like the burrows is, as is natural, very little advanced for deeper regions of the sea). The *Sabellaria* reefs described by Richter occur in shallow water (in part laid dry at very low tide). Similar reefs must in any case grow in a fairly calm sea if they shall not get more or less broken.

Like so many other features of the Arctic Upper Carboniferous the Scolithus-sandstone of Bear Island points towards the existence of widespread flats of very expressed shallowness. This shallowness in connection with the huge extension of the Upper Carboniferous Arctic sea is in itself a feature of great interest; it has further a bearing on conclusions on the climatic conditions as emphasized by the writer in a recent paper[2]. "This shallowness means that the temperature of the water where the animals lived, was directly and most intimately

[1] In the chapter on "Strandablagerungen".

[2] On the Rock Formations of Novaya Zemlya. Rep. Scient Res. Norw. Exp. to N. Z. 1921, no. 22. Kristiania 1924.

influenced by the temperature of the air" (l. c. p. 164). If there did exist well marked climatic zones, like maintained e. g. by Köppen and Wegener [1], we should expect to find these zones expressed in the character of, for instance, the brachiopod faunas, when passing from the Ural Mountains across Spitsbergen and northern Greenland to Alaska. What we find is, however, a remarkable homogeneous character across this vast area [2].

1 Die Klimate der geologischen Vorzeit, Berlin 1924, map of Carboniferous period p. 22.

2 I might in this connection also point to Tschernyschew's summary on Upper Carboniferous and Permo-Carboniferous marine faunas (Obercarb. Brachiopoden. Mém. Com. Géol., XVI, 1902, p. 740) where the extreme similarity of faunas from areas scattered around the earth is especially emphasized.

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