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Per Theodor Cleve: a short résumé and his radiolarian results from the Swedish Expedition to Spitsbergen in 1898

KJELL R. BJØRKLUND[1*], TAKUYA ITAKI[2] & JANE K. DOLVEN[3]
[1]Natural History Museum, Department of Geology, University of Oslo, PO Box 1172 Blindern, N-0318 Oslo, Norway
[2]Geological Survey of Japan, AIST, Marine Geology Research Group/Institute of Geology and Geoinformation, Tsukuba Central 7, 1-1-1 Higashi, Tsukuba, Ibaraki 305-8567, Japan
[3]Department of Geosciences, University of Oslo, PO Box 1047 Blindern, N-0316 Oslo, Norway
*Corresponding author (e-mail: k.r.bjorklund@nhm.uio.no)

ABSTRACT – Cleve's material from the Swedish Expedition to Spitsbergen in 1898 has been re-examined and lectotypes and some paralectotypes have been established for three spumellarian species, eight nassellarian species, and three phaeodarian species. In addition, important species in the Cleve collection, including three spumellarian species, 10 nassellarian species and three phaeodarian species have been illustrated and commented on. Some of Cleve's identifications were erroneous, and we have carefully discussed these in our re-evaluation of Cleve's species concepts. J. Micropalaeontol. **33**(1): 59–93, January 2014.

KEYWORDS: *radiolaria, taxonomy, Cleve's 1898 collection, type species, Norwegian Sea*

INTRODUCTION

Per Theodor Cleve was born on 10 February 1840 in Stockholm and died in Uppsala on 18 June 1905. After his death, H. Euler (1906) published a biography in the yearbook of the Swedish Academy, from where most of the information in this introductory section has been taken. Cleve was a hardworking man and, from his school days, showed special interest in the natural sciences. He showed quite unusual reading habits as a student at Stockholm's Gymnasium, as his focus on natural science topics influenced his concentration on other topics. This was not at all appreciated by his teachers. Cleve, on the other hand, worked hard during the last year at school and compensated for earlier neglected topics. He graduated from school in 1858 and started his studies at Uppsala University in the autumn of the same year. It was obvious that his main research would be in the natural sciences, as during his school days he had undertaken many excursions and field trips and had gained a good knowledge of the Swedish flora and fauna. Cleve continued to work hard and became a 'fil. kandidat' in 1862. His teachers were the botanist J. Areschoug and the chemist Fredric Svanberg, the latter being very helpful and offering access to his rich library. The same year, 1862, Cleve also defended his doctoral dissertation on 'Mineral-analytical investigations'. In 1863, he made his choice between geology and chemistry when he accepted a post as 'docent' in organic chemistry at Uppsala University. He judged that organic chemistry was a field where he had better opportunities, but by no means did he set aside his interest in geology. In 1868, he received a scholarship to travel to the West Indies and, in 1871, he published probably his best known geological paper 'On the geology of the north-eastern West Indian Islands'. The large collection of material that was brought home was not studied in detail by Cleve, but the collection – hundreds of rock samples – was studied by A. G. Högbom. Among the numerous collections that Cleve brought to Uppsala University, it is worth mentioning the rich collection of fossils from the West Indies.

Cleve as a chemist

It would be too lengthy to mention all the different subjects that Cleve published, but there are 77 listed chemistry papers. When Cleve returned from his trans-Atlantic travel in 1869, he was appointed as an 'adjunct' at the Technical Institute in Stockholm and, two years later, at the age of 31, he became a member of the Swedish Academy of Sciences. He spent five years in Stockholm and was extremely productive in his authorship. He not only published science for professionals but showed an interest also in communicating with ordinary people through popular articles, e.g. on coal (1872*a*) and corals (1873*a*). That he was also interested in teaching is shown by his two textbooks, one on 'inorganic chemistry' (1872*b*) and one on 'organic chemistry' (1874*a*). His professional output, in addition to his teaching skill and his textbooks, made him the successful candidate for the chair vacated by Prof. Svanberg at Uppsala University, a position that he began in 1874, and occupied for more than 30 years, until his death. Cleve had already started a new field of science during his stay in Stockholm; the chemistry of soils. The study of Mendeleev's system was of great interest for general chemistry, but also more specifically for his studies of soils, and Cleve became a man who spent a lot of time in the laboratory and conducted many experiments with great enthusiasm. His studies concluded with major monographs on five elements: yttrium and erbium (1873, together with O.M. Höglund), thorium (1874*b*), lanthanum (1874*c*) and didymium (1874*d*). Cleve's eminence within chemistry is also shown in his first estimation of the atomic weight of the element scandium, and the discovery and characterization in 1879 of two new elements – holmium and thulium. He furthermore concluded that scandium had to be identical to the element that Mendeleev had predicted and characterized as ekaboron. Cleve was an authority on the chemistry of rare earths and during his last years he was very satisfied to be able to give valuable advice to industry. Cleve's contribution to chemistry was acknowledged by the Royal Society of London in 1894 when he was awarded the prestigious Davy Medal.

Cleve as a biologist and oceanographer

Cleve was interested in biology from his early days as a student and, in his later years, he again returned to his plankton studies. As a student he had especially focused on freshwater diatoms (*Vaucheria*, Desmidiaceae and Zygnemaceae) and had published a monograph on the Swedish Zygnemaceae forms in 1868. In 1894*a* and 1895 he published the descriptive articles *Synopsis of the Naviculoid diatoms I* and *II*, respectively. For his contribution to one of his dearest fields of science, the diatoms, he was honoured by the Royal Microscopical Society, a distinction that Cleve highly appreciated. Cleve applied his general knowledge of siliceous algae to two other branches of science, geology and hydrography. Of great practical value was Cleve's postglacial classification based on fossil diatoms, especially in Baltic Sea deposits where the changes between freshwater and marine diatom associations were of great importance for understanding the evolution of this basin. The first report from Cleve on modern marine diatoms was prepared from surface water material off Java and the second report on material collected by the Swedish expedition to Greenland, both published in 1873 (*b* and *c*, respectively). The German biologist Victor Hensen introduced in 1887 the term 'plankton' for the small organisms that fish feed upon. Cleve (1894*b*) used this term for the first time in his paper *Planktonundersökningar: Cilicoflagellaer och diatomacéer*. From this point on Cleve produced several papers on plankton organisms, in the beginning only on diatoms, but later (Cleve, 1903) he reported on 25 different groups of plankton (dinoflagellates, silicoflagellates, ciliates, radiolarians, foraminifers, cladoceras, ostracods, to mention only some). Cleve worked mostly in the coastal waters of Sweden, in the North Sea and Skagerrak, but also on plankton from the entire Atlantic Ocean, in the arctic waters off Svalbard, as well as on material from the Red Sea, the Indian Ocean, Malaysia and off South Africa. Cleve produced two important papers where he described and illustrated new radiolarian species. The first one is based upon his research between Spitsbergen and Greenland (Cleve, 1899), and the second paper is on the North Atlantic (Cleve, 1900*a*).

Cleve as a biogeographer

In general terms it can be said that it was not so much the organisms themselves that occupied his attention, but more how these different organisms could help him to understand the distribution of ocean currents, and how the planktonic organisms could influence fisheries and climate. Cleve held the view that the plankton organisms were strongly tied to the water masses in which they were found. Therefore, based on the organisms found, he thought he could determine the origin of these water masses. Cleve accumulated a huge plankton distributional dataset collected from all over the world, with the basic thought in mind to be able to understand the current systems of the world oceans. Cleve's (1900*b*) voluminous plankton report entitled 'The seasonal distribution ...' etc. remain as a monumental contribution and a solid foundation to studies of Atlantic Ocean plankton biogeography. However, in spite of Cleve's large plankton collection his data were still too few and spanned too short a time interval to make it possible to reconstruct the distribution of the current systems. Cleve was the first Swedish scientist who publicly supported Darwin's theory, both in writing and in oral presentations.

We also have the pleasure to read in Cleve (1903) about his disagreement with the Norwegian scientist H. H. Gran. Hjort & Gran (1899) had attacked Cleve's theory, which Cleve (1903, p. 3) himself summarized as: '… that the plankton-organisms continually drift with the currents to far distant regions and holds that the plankton develops on the spots where found and by the spiring of resting spores, eggs etc.'. Cleve (1903, p. 3) further states: 'Mr. Gran's criticism concerns me in many points, both in his details and its principal standpoint'. Another quote from Cleve (1903, p. 4):

> Mr. Gran has from the beginning made the statement that diatoms which live along the coasts, i.e. the *neritic* ones, produce resting spores, which drop to the bottom and remain there, imbedded in mud, until the circumstances for spiring become favourable. Nobody has, as far as I know, hitherto hatched pelagic diatoms from spores buried in the bottom-mud. Therefore, Mr. Gran's statement is altogether hypothetical.

Cleve was therefore in strong opposition to what he called *Gran's 'Dauersporen'-hypothesis*. Finally Cleve (1903, p. 4) concluded that: 'We must not forget that among neritic species there is a large number, which never have been found with resting spores'. Modern scientific evidence has confirmed Gran's conclusions about the existence of live diatom spores in mud and sediments (O. R. Anderson, pers. comm.; e.g. Hargraves & French, 1983; Smayda, 2011), including viable dormant stages known as resting cells (Anderson, 1976) collected even from the deep ocean (Anderson, 1975) and elsewhere including the East China Sea (Zhang *et al.*, 2010). Cleve continued with the following question: 'How far may plankton-organisms drift in the oceans?' Cleve was of the opinion that this can be quite a distance, while Gran seemed to go for the opposite. As an example Cleve used some of Gran's own data to illustrate his view. Cleve pointed to the fact that there is something that can be called 'foreigners', which should fit to what Gran calls 'nicht als in unterem Gebiete einheimisch'. The diatom *Corethron hystrix* was found at Spitsbergen, and Gran stated that this form 'kommt aber warscheinlich jeden Sommer von Süden durch die Färöer-Shetland Rinne' [but probably comes every summer from the south through the Faroe–Shetland Channel]. Cleve (1903, p. 5) noted that this meant a drift from '60 °–76 ° N., *thus about sixteen degrees*'. 'If Mr. Gran admits such a long drift to a "foreigner" it seems really strange that he will not allow the "native" as much liberty', Cleve (1903, p. 5) stated.

In one section Cleve (1903) discussed 'Currents and indigenous forms'. In this piece he clearly stated that his principal objectives were to study the distribution of plankton to determine what species characterize the different systems of ocean currents. Cleve stated that the large amount of data provided in his paper 'The seasonal distribution of Atlantic Plankton-organisms', '… will fully prove that each current-system carries its own plankton-flora and fauna'. As the different currents are touching each other their plankton is modified as 'euryhaline and eurytherm species pass from one current to another, remain for a longer or shorter time in currents, to which they do not properly belong and give the impression of "indigenous" species'. Cleve (1903) noted that when two currents meet an interchange of species takes place. Above the Newfoundland Banks *tropical* and *arctic* species frequently co-occur in the same haul, and some of the least sensitive species remain for a longer or shorter time in their new environment and seem to belong to it. Arctic species that belong to the cold water currents of the western Atlantic will during the winter and spring propagate eastwards and mix in with plankton from the warm Atlantic water. These species will still remain in the eastern

Atlantic, move northwards to the west of Norway and therefore seem to be indigenous, according to Cleve.

Cleve and his focus on radiolarians

Cleve concentrated his marine plankton research on the vegetative plankton in the samples he had available, but he also had a special focus on the radiolarians. Cleve wrote only two reports where he described and illustrated radiolarians (see References for full information): (1) Cleve (1899) on radiolarians collected during the Swedish expedition to Spitsbergen; (2) Cleve (1900*a*) on radiolarians collected in the North Atlantic. In addition Cleve produced several papers on plankton in the North Atlantic and the North Sea, as well as one from the Indian Ocean (Cleve, 1901), but in these papers he presented only lists of radiolarian names with information on geographical coordinates as well as temperature and salinity, and we have not included them in our reference list.

THE SWEDISH EXPEDITION TO SPITSBERGEN IN 1898

Having reviewed some of Cleve's achievements we turn to the material that was collected during the Swedish Expedition to Spitsbergen in 1898. Cleve (1899) listed a total of 44 radiolarian species (Table 1) (Acantharia 4 (0 new), Phaeodaria 11 (4 new), Spumellaria 8 (3 new) and Nassellaria 21 (8 new): these 15 new species are indicated in bold italics in Table 1 (left column). Cleve did not define any holotypes, but his slide collection, stored at the Swedish Museum of Natural History (SMNH) in Stockholm, Sweden, has been made available for our analysis. This collection has not been analysed by any radiolarian specialist and no specimens have been properly illustrated until now. We have been able to recognize some of Cleve's specimens upon which he based his line drawings. These would have been the real holotypes if Cleve had assigned them, so we have designated them as lectotypes and, in some cases, we have also indicated paralectotypes. We will in the following use the taxonomic names given by Cleve, and discuss his 15 new species (bold italics in Table 1) in alphabetical order. Some of the species have changed genera, and under Remarks to each species we will comment on their present taxonomic assignment according to our best understanding. The structure of our re-examination will be to copy Cleve's (1899) descriptions, and fill in with additional information when necessary. Cleve also circled and named additional species on his slides, and some of these are erroneously identified by Cleve. We will herein also discuss these species. The synonymy list for each species is not complete. However, the last synonym under each species refers the reader in most cases to a more detailed list.

The 1898 expedition was carried out with the research ship *Antarctic*, a barque with three masts and equipped with a steam engine, built in 1871 in Drammen, Norway. Cleve (1899, p. 17) states:

> In the following I give a list of all the organisms, found by me in the plankton-gathering, as well as the dates etc. for every form. By 'Temp.' I denote the temperature of the water in centigrades, by 'Sal.' the salinity pro mille, by 'Fq.' the frequency, whether *rr*, very rare, *r* rare, + not rare, *c* common, *cc* very common, or *ccc* principal constituent of the plankton. The sign X denote dead specimens. By 'Pl.' I understand the ruling plankton-type viz. *C* chaetoplankton, *Ng* arctic neritic plankton, *Nm* southern neritic plankton, *Ns* northern neritic plankton, *S* styliplankton, *T* trichoplankton and *Tp* triposplankton.

These abbreviations are used in the station tables under each species below.

Cleve (1903, p. 3) stated 'I proposed in 1896 to class the plankton of the Atlantic and its tributaries in certain types and formations according to the association of species. For understanding the following it will be necessary first to characterize briefly these plankton types'.

We, therefore, herein give a short summary of Cleve's plankton-types, in part shortened from the original.

(1) **Desmoplankton** (sign *D*). This type dominates the warmest part of the Atlantic, in the Sargasso Sea and in the equatorial current. Temperature between 20 and 28°C, and salinity about 36 p.m. (many radiolarian species).

(2) **Styliplankton** (sign *S*). The region of desmoplankton, which is subject to variation in extent according to seasons, is surrounded by an irregular band of water containing styliplankton. The styliplankton contains two subgroups:

  (A) **Didymusplankton** (sign *Nm*). This plankton-type dominates in the summer and autumn along the southern coasts of the German Ocean [= North Sea] above the 50 m plateau of the bottom. Temperature between 8 and 17°C, salinity between 32 and 33 p.m.

  (B) **Triposplankton** (sign *Tp*) dominates in the summer and autumn in the northern part of the North Sea above the 100 m plateau of the bottom and extends from Scotland to Scandinavia as far as Finmarken. In the spring it is replaced by water with chætoplankton. Temperature between 5°C (winter) and 14°C (summer), with salinity about 34 p.m.

(3) **Chætoplankton** (sign *C*). This plankton type occurs in the western and northern parts of the Atlantic only and during the spring. From March to June or July it can be traced from about the 40° Lat. and 70° Long. to the Newfoundland Banks and to the south of Iceland, from whence it turns across the Färöe Channel and enters the North Sea, replacing its triposplankton. The chætoplankton-water varies usually between 5 and 9°C and the salinity is about 35 p.m.

(4) **Trichoplankton** (sign *T*). This type occurs in the western Atlantic and constitutes in the summer the plankton of the Irminger Sea. Its origin is doubtful. In the summer it is confined to the western and arctic Atlantic, but in the winter it spreads to Scandinavia. Trichoplankton-water varies between 6 and 12°C and the salinity amounts to about 34 p.m (Cleve, 1899, p. 5). Cleve (1903, p. 7) states: 'On the coasts, washed by the trichoplankton-water, there originates a peculiar kind of derived trichoplankton, which I have assigned as': **Northern neritic plankton** (sign *Ns*). This somewhat variable type occurs at the coast of Iceland, in Skagerrak and in the fjords of Sweden during the winter, also in the fjords of Norway and on the Norwegian

Table 1. P. T. Cleve's type collection.

Cleve's (1899) taxonomic names	Regarded as correct name in 2011	Slide #	Lectotype	Paralectotype	
SPUMELLARIA					
Actinomma boreale **CL. n. sp.**	***Actinomma boreale*** **Cleve, 1899**	**23 (M40/3)**	**Type-6116-1**		**Plate 1, fig. 1a–c**
Actinomma boreale **CL. n. sp.**	***Actinomma boreale*** **Cleve, 1899**	**23 (M39/0)**		**Type-6116-2**	**Plate 1, fig. 3a–b**
Cromyomma zonaster (EHB.)	*Larcospira minor* (Jørgensen, 1900)	15 (L40/0)			Plate 8, fig. 9a–b
Heliosphaera actinota HKL.	*Arachnosphæra dichotoma* Jørgensen, 1900	16 (M40/1)			Plate 5, fig 9a–b
Hexadoras borealis **CL. n. sp.**	***Cleveiplegma boreale*** **(Cleve, 1899)**	**32 (M40/3)**	**Type-6125**		**Plate 4, fig. 6a–b**
Hexadoras borealis **CL. n. sp.**	***Cleveiplegma boreale*** **(Cleve, 1899)**	**31 (O38/4)**		**Type-6124**	**Plate 3, fig. 2a–b**
Phorticium pylonium HKL.	*Phorticium clevei* (Jørgensen, 1905)	8 (M35/3)			Plate 5, fig. 2a–b
Trochodiscus echinidiscus HCL.	*Spongotrochus glacialis* Popofsky, 1908	18 (N27/2)			Plate 2, fig. 6
Trochodiscus helioides **CL. n. sp.**	***Spongotrochus helioides*** **(Cleve, 1899)**	**39 (Q38/0)**	**Type-6133**		**Plate 2, fig. 8**
NASSELLARIA					
Acanthocorys umbellifera HKL.	*Acanthocorys umbellifera* Haeckel, 1862	13 (K34/1)			Plate 10, fig. 11a–b
Artostrobus annulatus Bail.	*Artostrobus annulatus* Bailey, 1856	4 (Q44/1)			Plate 9, fig. 4a–b
Botryopyle setosa **CL. n. s.**	***Amphimelissa setosa*** **(Cleve, 1899)**	**25 (O37/3)**	**Type-6118-1**		**Plate 6, fig. 1**
Botryopyle setosa **CL. n. s.**	***Amphimelissa setosa*** **(Cleve, 1899)**	**25 (O36/0)**		**Type-6118-2**	**Plate 6, fig. 2**
Botryopyle setosa **CL. n. s.**	***Amphimelissa setosa*** **(Cleve, 1899)**	**25 (O37/4)**		**Type-6118-3**	**Plate 6, fig. 4**
Dictyophimus gracilipes BAIL.	*Pseudodictyophimus clevei* (Jørgensen, 1900)	17 (G36/0)			Plate 9, fig. 6
Euscenium tricolpium HKL.	*Euscenium corynephorum* Jørgensen, 1905	1 (P38/4)			Plate 10, fig. 12a–b
Lithomitra australis (EHR.)?	*Botryostrobus auritus-australis* (Ehrenberg, 1844*a* & *b*) group	3 (N37/3)			Plate 9, fig. 8
Lithomitra lineata (EHB.)	*Lithomitra lineata* (Ehrenberg, 1839)	6 (N33/3)			Plate 9, fig. 13
Peridium (?) intricatum **CL. n. sp.**	***Plectacantha intricata*** **(Cleve, 1899)**	**33 (N36/4)**	**Type-6127**		**Plate 7, fig. 1a–b**
Peridium (?) laxum **CL. n. sp.**	***Plectacantha laxa*** **(Cleve, 1899)**	**34 (P38/2)**	**Type-6128**		**Plate 7, fig. 3a–b**
Peridium (?) minutum **CL. n. sp.**	***Peridium (?) minutum*** **Cleve, 1899**	**35 (M34/0)**	**Type-6129-1**		**Plate 7, fig. 7a–b**
Peridium (?) minutum **CL. n. sp.**	***Peridium (?) minutum*** **Cleve, 1900*a***	**35 (J34/4)**		**Type-6129-2**	**Plate 7, fig. 6**
Peridium (?) minutum **CL. n. sp.**	***Peridium (?) minutum*** **Cleve, 1901**	**39 (O35/2)**		**Type-6126**	**Plate 7, fig. 5a–b**
Plectanium (?) simplex **CL. n. sp.**	***Protoscenium simplex*** **(Cleve, 1899)**	**6 (S43/1)**	**Type-6112**		**Plate 9, fig. 17a–b**
Plectophora arachnoides (CLAP. & LACHM.) HKL.	*Plagiacantha arachnoides* (Claparède, 1855)	10 (F37/3)			Plate 10, fig. 8a–b
Pterocorys irregularis **CL. n. sp.**	***Lipmanella irregularis*** **(Cleve, 1899)**	**7 (H37/3)**	**Type-6113**		**Plate 10, fig. 9a–b**
Sethoconus galea **CL. n. sp.**	***Ceratocyrtis galeus*** **(Cleve, 1899)**	**37 (N39/2)**	**Type-6131**		**Plate 8, fig. 1a–b**
Sethoconus tabulatus (EHB.) HKL.	*Sethoconus tabulatus* (Ehrenberg, 1873)	11 (P41/0)			Plate 9, fig. 11
Stichopilium davisanum (EHB.)	*Cycladophora davisiana* (Ehrenberg, 1862)	19 (O35/2)			Plate 10, fig. 2
Theocalyptra cornuta BAIL.	*Corocalyptra craspedota* (Jørgensen, 1900)	1 (L37/1)			Plate 6, fig. 19a–b
Theocorys borealis **CL. n. sp.**	***Artobotrys borealis*** **(Cleve, 1899)**	**38 (O32/4)**	**Type-6132**		**Plate 8, fig. 5a–c**
Theocorys borealis **CL. n. sp.**	***Artobotrys borealis*** **(Cleve, 1899)**	**26(J36/1)**		**Type-6119**	**Plate 8, fig. 3a–b**
PHAEODARIA					
Beroetta melo **CL. n. sp.**	***Lirella melo*** **(Cleve, 1899)**	**24 (N36/2)**	**Type-6117**		**Plate 11, fig. 5a–b**
Challengeria Harstonii J. MURRAY	*Protocystis harstonii* (J. Murray, 1885)	19 (P32/0)			Plate 11, fig. 10
Challengeria tridens HKL.	*Protocystis tridens* (Haeckel, 1887)	8 (Q30/1)			Plate 11, fig. 11
Challengeron Nathorstii **CL. n. sp.**	*Challengeron diodon* Haeckel, 1887	27 (K38/1)			Plate 11, fig. 1a–b
Euphysetta Nathorstii **CL. n. sp.**	***Euphysetta nathorstii*** **Cleve, 1899**	**16 (M38/2)**	**Type-6114**		**Plate 11, fig. 9a–b**
Euphysetta Nathorstii **CL. n. sp.**	***Euphysetta nathorstii*** **Cleve, 1900*a***	**28 (M36/2)**		**Type-6121**	**Plate 11, fig. 4a–b**
Polypetta holostoma **CL. n. sp.**	***Porospathis holostoma*** **(Cleve, 1899)**	**36 (P38/0)**	**Type-6130**		**Plate 11, fig. 13a–b**
Polypetta holostoma **CL. n. sp.**	***Porospathis holostoma*** **(Cleve, 1899)**	**19 (M38/0)**		**Type-6115**	**Plate 11, fig. 12**

coast-banks, where it becomes in the summer slowly replaced by triposplankton. This type of plankton seems to invade the coast of Scotland and Scandinavia twice a year, viz. in the spring in company or in connection with the chaetoplankton and in the autumn in connection with the trichoplankton. Temperature in the water with northern neritic plankton varies in Skagerrak from about 4 to 7°C and the salinity is about 32–33 p.m.

(5) **Sira-plankton** (sign *Si*) rules along the coast of Greenland and Baffins Bay, or in the Arctic Ocean proper,

> where it constitutes the plankton of the water with melting drift-ice. As it touches the trichoplankton it becomes frequently mixed with it, so that the distinction of what species belong to the one or the other is a matter of difficulty. The water with sira-plankton has lower temperature than the trichoplankton-water and less salinity, about 32–33 p.m. This type of plankton appears in the Skagerrak usually in February and March. Along the coast of Greenland the sira-plankton becomes mixed with a number of neritic forms and such derive a group distinguished as Arctic neritic plankton (Sign. *Ng*).

With this background we return to Cleve's (1899, p. 3) statement:

> As Dr. C. Aurivillius has charged himself with the examination of the animals in all the tow-net gatherings, I have examined them for vegetable plankton only, with the exception of the radiolarians, which offered a particular interest for my other plankton-researches.

TAXONOMY

Radiolarian taxonomy is currently under rapid development thanks to molecular techniques that are now available. These have already changed the Haeckelian higher rank taxonomy. Traditionally Radiolaria (Haeckel, 1887) was accounted for in four groups: Acantharia, Spumellaria, Nassellaria and Phaeodaria. Recent DNA studies (Krabberød *et al.*, 2011) show, based on combined 18S and 28S phylogeny, that radiolaria are subdivided into Polycystina (Spumellaria and Nassellaria) and Spasmaria (Acantharia and Taxopodida), while Phaeodaria now belongs to Cercozoa.

Cleve described 15 new species, but two had already been described by other authors. Of Cleve's 13 new species, two are Spumellaria, eight are Nassellaria and three are Phaeodaria (the latter group discussed herein as Cleve regarded them as Radiolaria). In the text we are using what we regard as the current correct scientific names. Each species has, therefore, a short synonymy list, referring to other papers with illustrations and a further discussion of the species in question. Several of Cleve's identifications are wrong, which to the best of our knowledge are corrected in the text and in Table 1.

Original slides. Cleve's 39 radiolarian slides are stored in the Swedish Museum of Natural History, Stockholm. The slides have been given a special 'Cleve slide #', the number is indicated in pencil in the lower-left corner of the left label on the slide and Cleve slides #1 to 18 are shown on our Plate 12, while Cleve slides #19 to 39 are shown on Plate 13.

The lectotypes and paralectotypes are denoted as follows (example):

Lectotype. SMNH Type # 6116-1, Plate 1, figs 1a–c, fig. 2. Cleve slide #23 (M40/3). In Table 1 we give the scientific names used by Cleve (1899) in the first column; in the second column are the scientific name used today; in the third column are the slide numbers from 1 to 39, normally in the lower-left corner of each slide, as well as the England finder coordinates for the species in question; the fourth and fifth columns list the Swedish Museum of National History (SMNH) type numbers for lectotypes and paralectotypes respectively; and, finally, in the sixth column are the plate and figure numbers of the types.

Order **Spumellaria**

Actinomma boreale Cleve, 1899

(Pl. 1, figs 1a–c, 3a, b, 4 (not figs 5–7), 8a, b; Pl. 2, figs 1a, b, 2a, b, 3a, b, 4a, b, 5a, b)
1899 *Actinomma boreale* Cleve: 26; pl. 1, fig. 5a–c.
1900 *Cromyomma boreale* (Cleve, 1899); Jørgensen: = Cleve, 1899, 26; pl. 1, fig. 5a–c (*non* a, b).
1905 *Cromyechinus borealis* (Cleve, 1899); Jørgensen: 117–118; pl. 8, fig. 35; pl. 9, figs 36–37.
1998 *Actinomma boreale* Cleve, 1899; Cortese & Bjørklund: 151–152; pl. 1, figs 1–18.
1968 *Cromyechinus borealis* Cleve, 1899; Petrushevskaya: 22–27; figs 13 VIII–IX.
2003 *Actinomma boreale* Cleve, 1899; Itaki *et al.*: pl. 1, figs 13–17.
2009 *Actinomma boreale* Cleve, 1899; Kruglikova *et al.*: 38; pl. 3, figs 16–29.

Original description (Cleve, 1899)

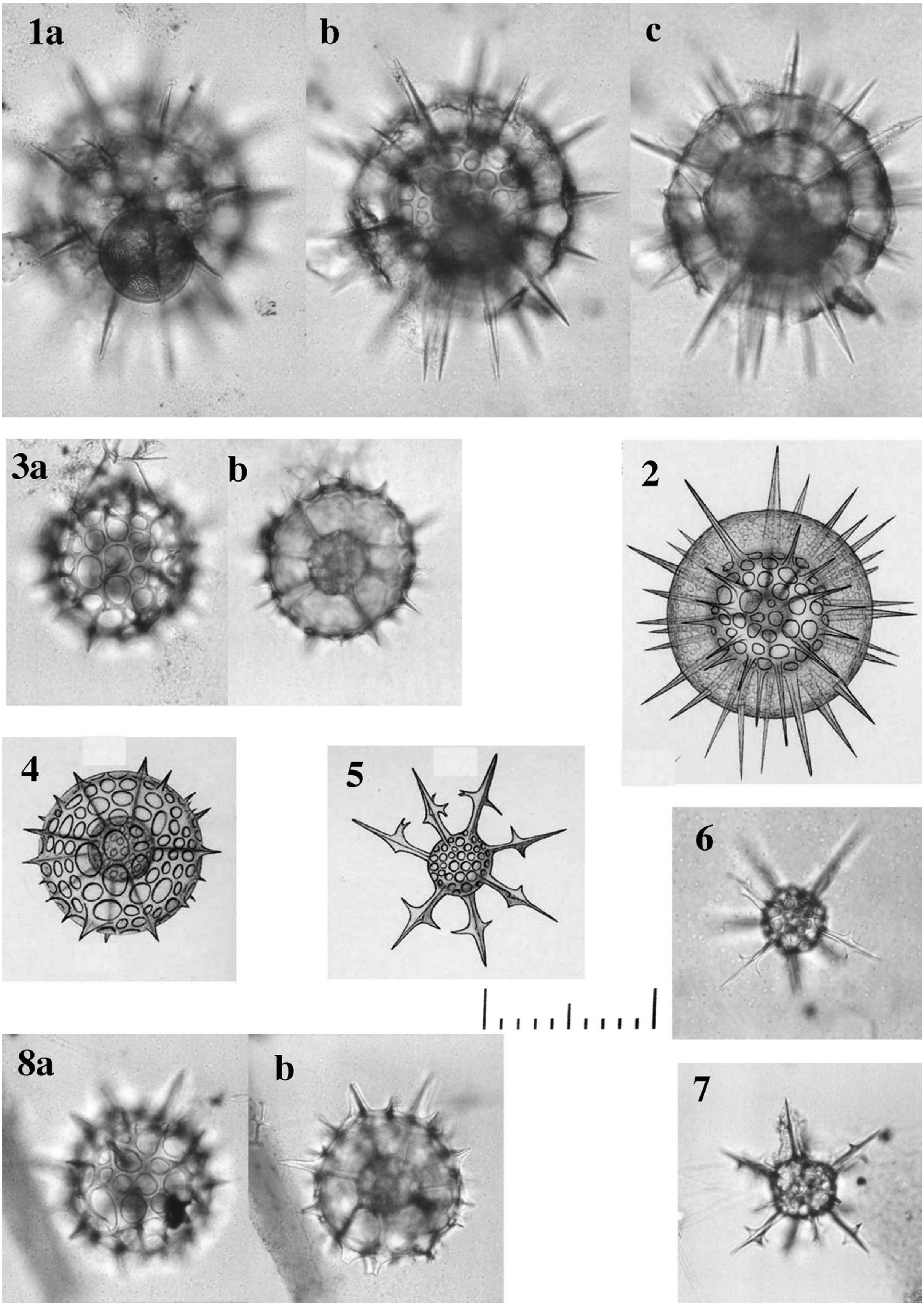
> *Primordial shell*. Thick walled, 0,06 mm. in diameter, with rounded, regular pores (0,003 to 0,005 mm. in diameter), two to three times broader than the bars, four on the radius. Spines in variable number, with triangular and forked apophyses half way to the apex. – Plate I, fig. 5 *a*.
>
> *Secondary* (*Haliomma-*) *shell*. Thick walled, 0,08 mm. in diameter, with rounded pores of unique size (0,01 to 0,02 mm. diameter), three to four on the radius. Bars 0,002 to 0,003 mm. thick. Spines in variable number, stout shorter than the radius, scattered at intervals. – Resembles *Haliomma beroes*. – Fig.: Pl. I, f. 5 *b*.
>
> *Tertiary* (*Actinomma-*) *shell*. Thin walled, 0,1 to 0,12 mm. in diameter, with numerous, small (0,002 to 0,007 mm. in diameter), irregular rounded pores. Bars as broad as the pores. Spines numerous, scattered, half as long as the radius. – Fig.: Pl. I, f. 5 *c; d* structure.
>
> Deep-sea hauls:

Date	Lat. N.	Long.	Depth.	Fq.	Pl.
29-30 VII	78° 13′02° 58′W		2,600–0 m	*r*	*S C*
1 VIII	76° 36′12° 13′E		500–0 m	*r*	*T S*
27 VIII	79° 58′09° 35′E		400–0 m	*r*	*S C*
1 IX	75° 50′15° 25′ E		325–0 m	*r*	*S*
5 IX	71° 50′19° 02′ E		230–0 m	*r*	*S*

Lectotype. SMNH Type # 6116-1, Plate 1, fig. 1a–c, Cleve slide #23 (M40/3); fig. 2, original line drawing by Cleve (1899, pl. 1, fig. 5c).

Paralectotype. SMNH Type # 6116-2, Plate 1, fig. 3a, b, Cleve slide #23 (M39/0); fig. 4, original line drawing by Cleve (1899, pl. 1, fig. 5b).

Remarks. Here we are facing an interesting problem as Cleve assigned this species to *Actinomma*, in which we agree. However, Cleve points out that the tertiary shell, or the *Actinomma*-shell, is his rationale for choice of genus. From our Plate 1, figs 1c, 3b, 7, 8b and Plate 2, figs 1b, 2b, 3b, 4b and 5b, it is obvious that the inner medullar shell is present. If Cleve had observed this innermost shell, he would have had to place this species in either *Cromyomma* or *Cromyechinus*, and if he had seen the pylome


1a
b
c
3a
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8a
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7

structure he would most likely have placed it in *Sphaeropyle*. However, Bjørklund (1976*b*) emended the genus *Actinomma* to be broadened to include astrosphaerids possessing three or four lattice spheres and unbranched spines of either uniform or irregular length. *Actinomma* includes the junior synonyms *Cromyomma, Cromyechinus* and *Echinomma*. The primordial shell, as identified by Cleve, is actually the secondary shell. His assignment to *Actinomma* is therefore correct, according to the emendation made by Bjørklund (1976*b*), even if Cleve's identification was made on an erroneous understanding of the skeletal structure.

Cleve had a rather large number of *Actinomma* individuals in his Spitsbergen material, but he never indicated anything about different morphs. Jørgensen (1905) discussed in detail the typical round four-shelled type with radial spines of almost equal length, as described by Cleve (1899) and Jørgensen (1900), but he also discussed the form with an elongated fourth shell, having an opening (pylome like structure) in one end, surrounded with longer radial spines than on the rest of the skeleton. Jørgensen did not split them into two species, only noted them as different forms, but placed them in the genus *Cromyechinus*.

Actinomma boreale is quite complicated to identify properly – Schröder-Ritzrau (1995), as well as others, grouped *A. boreale* and *A. leptodermum*, the latter species erected by Jørgensen (1900) under the name *Echinomma leptodermum*. Our understanding of the difference between *Actinomma leptodermum* and *Actinomma boreale* is as follows. Cleve's (1899, pl. 1, fig. 5a) illustration is for us *A. leptodermum* due to the few radial spines. Note, in this figure there is no sign of a microsphere or inner shell, which we have observed in all juvenile stages in Cleve's slides (see paralectotype Pl. 1, fig. 3b). Plate 8, fig. 10a, b, identified by Cleve as *A. boreale* (Cleve slide #22 (H37/0), labelled *Actinomma boreale*), is for us a typical specimen of *A. leptodermum* as defined by Jørgensen (1905). In our Plate 1, figs 6–7, we also have two juvenile stages of *A. leptodermum*. It is obvious to us that Cleve's four-shelled *Actinomma boreale*, as indicated in our Plate 1, fig. 1a–c, is the lectotype (compare Cleve's line drawing in Pl. 1, fig. 2). However, pay attention to Cleve's perfectly circular outer shell (his line drawing), while in Plate 1, fig. 1c the lower left part of the outer shell seems flattened or missing, looking like a pylome. Similarly we agree that the paralectotype, the three-shelled form (Pl. 1, fig. 3a–b, microsphere visible in fig. 3b), is the same as drawn by Cleve (our Pl. 1, fig. 4).

The most comprehensive discussion of this species was undertaken by Petrushevskaya (1968). She pointed out that 4-shelled actinommids are found in the Antarctic region (*Chromyechinus antarctica* Dreyer) as well as in the North Pacific (*Sphaeropyle langii* Dreyer) and North Atlantic (*Cromyechinus borealis* Cleve). She used the genus name *Cromyechinus* for this species and agreed with Jørgensen's (1905) observations that this species has two forms. Jørgensen reported on two different morphological types of *C. borealis*. They both have three thick inner shells, with a very thin and delicate outer fourth shell, which is the shell defining the two types. The one type has a rather regular round outline of the fourth shell, while the other type has an eccentric, elongated (egg-shaped) outline and, in the one pole, with largest distance between the third and fourth shell, the fourth shell is incomplete, looking like an opening (pylome) and usually has longer radial spines surrounding this opening. We agree with Jørgensen in his definition of the two forms, but see no reason at present to split these forms into different species. However, Hülsemann (1963) identified the form with a pylome as *Sphaeropyle langii*, and the form without a pylome as *Cromyechinus borealis*. Bjørklund (1974) emended the genus *Actinomma* to also include *Echinomma, Cromyomma* and *Cromyechinus*, an emendation that was accepted and followed by Nigrini & Moore (1979). Similarly Itaki & Bjørklund (2006) reported on conjoined skeletons of *Actinomma leptodermum, A. boreale* and skeletons of what is generally identified as *Sphaeropyle langii*. They therefore concluded that these three species are closely related and should be united in the same genus as *Actinomma*. Bjørklund & Kruglikova (2003) examined the actinommids in the Arctic Ocean deep basins, as well in the shallow Chukchi Sea, and concluded that all 4-shelled tests should be identified as *Actinomma* (*Cromyechinus*) *boreale*, as did Itaki *et al.* (2003).

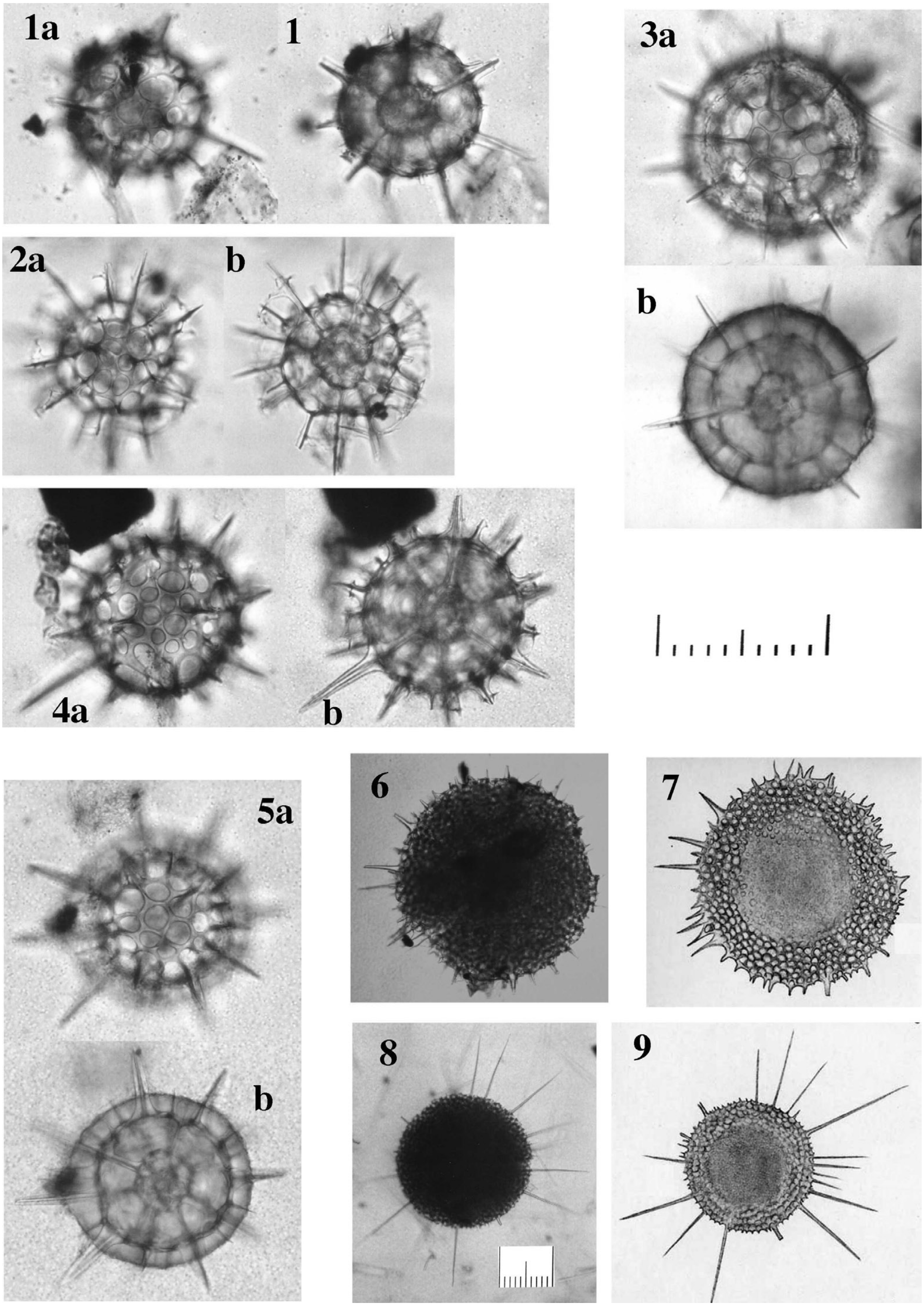
Cleveiplegma boreale (Cleve, 1899)

(Pl. 3, figs 1a, b, 2a, b, 3–8, 9a, b; Pl. 4, figs 1a, b, 2–5, 6a, b, 7–10 (not fig. 9))
1899 *Hexadoras borealis* Cleve: 30; pl. 2, fig. 4a–c.
1900 *Rhizoplegma boreale* (Cleve, 1899); Jørgensen: 61–62 (*non* Cleve, 1899, pl. 2, fig. 4a).
1905 *Rhizoplegma boreale* (Cleve, 1899); Jørgensen: 118; pl. 9, fig. 38; pl. 10, fig. 38e, f.
1908 *Rhizoplegma boreale* (Cleve, 1899); Popofsky: 216–217; pl. 24, fig. 1.
1997 *Rhizoplegma boreale* (Cleve, 1899); Nishimura *et al.*: pl. 1, figs 1–3.
2001 *Rhizoplegma boreale* (Cleve, 1899); Dolven & Bjørklund: 31–33; pl. 1, figs 1–10; pl. 2, figs 1–9; pl. 3, figs 1–8.
2013 *Cleveiplegma boreale* (Cleve, 1899); Dumitrica: pl. 1, figs 1–9.

Original description (Cleve, 1899)

Primordial shell: irregularly spherical, 0,03 to 0,04 mm. in diameter, with irregular, rounded or polygonal pores, 2 to 3 on the radius, and

Explanation of Plate 1. fig. 1. *Actinomma boreale* Cleve, 1899. Lectotype SMNH Type # 6116-1. Three different focus levels. Same specimen as figure 2 drawn by Cleve. Cleve slide #23 (M40/3). **fig. 2.** *Actinomma boreale* Cleve, 1899. Original drawing of lectotype by Cleve (1899, pl. 1, fig. 5c). **fig. 3.** *Actinomma boreale* Cleve, 1899. Paralectotype SMNH Type # 6116-2. Two different focus levels. Same specimen as figure 4 drawn by Cleve. Cleve slide #23 (M39/0). **fig. 4.** *Actinomma boreale* Cleve, 1899. Original drawing of paralectotype drawn by Cleve (1899, pl. 1, fig. 5b). **fig. 5.** *Actinomma boreale* Cleve, 1899. Original figure Cleve (1899, pl. 1, fig. 5a). Not *A. boreale*, but juvenile stage of *A. leptodermum* (Jørgensen). **fig. 6.** *Actinomma boreale* Cleve, 1899. Similar form to figure 5, drawn by Cleve. Not *A. boreale*, but juvenile stage of *A. leptodermum*. Cleve slide #32 (E37/0). **fig. 7.** *Actinomma boreale* Cleve, 1899. Similar form to figure 5, drawn by Cleve. Not *A. boreale*, but juvenile stage of *A. leptodermum*. Cleve slide #34 (L38/2). **fig. 8.** *Actinomma boreale* Cleve, 1899. Two different focus levels. Cleve slide #23 (L39/4). Note: where two or more images (a, b, –) are not otherwise described they represent different focal planes. Scale bar 100 µm.


1a
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thin bars. Spines six, exceptionally more, strong, with triangular apophyses in the middle. Pl. II, fig. 4 *a*.

Outer shell: a rounded or octahedric, more or less intricate net-work of anastomosing, siliceous threads, issuing from the proximal edges of the spines. Spines usually six (rarely as in *Rhizoplegma* 8–10) strong, three-sided slightly spirally twisted, with elegantly aculeate, winged edges.

Diam. 0,12 to 0,16 mm. Spines 0,1 mm. Pl. II, fig. 4 *b, c*.

Habitat: North Atlantic between Shetland and Norway, surface, March 1898 (CL.).

Lectotype. SMNH Type #6125, Plate 4, fig. 6a, b, Cleve slide #32 (M40/3); fig. 7, original line drawing of lectotype by Cleve (1899, pl. 2, fig. 4c).

Paralectotype. SMNH Type #6124, Plate 3, fig. 2a, b, Cleve slide #31 (O38/4).

Remarks. As we were working on this revision we received a paper by Dumitrica for review, wherein he proposes a new genus for this species, namely *Cleveiplegma*. In our present revision we herein accept this as the formal name. Cleve labelled several slides with the name *Hexadoras borealis* and slide SMNH Type #6126 contained 19 specimens, indicating that at certain times this species is rather common in the open ocean. We think we have been able to identify the specimen on which Cleve's illustration (his pl. 2, fig. 4c, our lectotype) is based (see detail at base of spine pointing down in Pl. 4, figs 7 and 6b), but not his other illustrated specimens. Jørgensen (1900) moved this species to *Rhizoplegma* and, as mentioned above, Dumitrica 2013 erected a new genus *Cleveiplegma*. Jørgensen (1905) pointed out that the specimen depicted by Cleve (1899, pl. 2, fig. 4a) is certainly not a juvenile stage of *C. boreale*, a statement that we support. Cleve states that *Cleveiplegma boreale* normally has six radial spines, rarely more. Jørgensen (1905) discussed the 6-spined form (as oceanic) versus the 8- or more spined form (typical for coastal waters). Dolven & Bjørklund (2001) studied *C. boreale* in great detail and could verify the observation made by Jørgensen (1905). Similarly, Nishimura *et al.* (1997) pointed out that *C. boreale* with many spines (>6) was a member of a distinctive coastal assemblage in shallow waters around the Antarctic continent. Jørgensen (1905, pl. 10, fig. 38f) figures a young specimen of a divergent form with 11 main spines. *C. boreale* has been found in the North Atlantic as well as in the North Pacific, and as one of the commonest species in neritic Antarctic assemblages (Nishimura *et al.*, 1997), with a true bipolar distribution (Stepanjants *et al.*, 2006, fig. 2). In the Nordic Seas it has a peak occurrence at about 9880 ±55 years BP, ranging between 9 and 14% (Dolven & Bjørklund, 2001), making it a good species for correlation between cores. We define the 6-spined oceanic form of *C. boreale* as the lectotype, while the 8-spined (and more) coastal form is designated as the paralectotype.

Spongotrochus helioides (Cleve, 1899)
(Pl. 2, figs 6–9)

1899 *Trochodiscus helioides* Cleve: 34; pl. 4, fig. 5.
1899 *Trochodiscus echinidiscus* Haeckel, 1887; Cleve: 34; pl. 4, fig. 4.
1909 *Trochodiscus* sp. Cleve, 1899; Schröder: 40; fig. 25.

Original description (Cleve, 1899)

Shell 0,24 mm. in diameter, with rounded pores (0,005 to 0,007 mm. in diameter), twice as broad as the bars. Margin with numerous, about 20, spines, as long as the diameter.

Pl. IV, fig. 5.

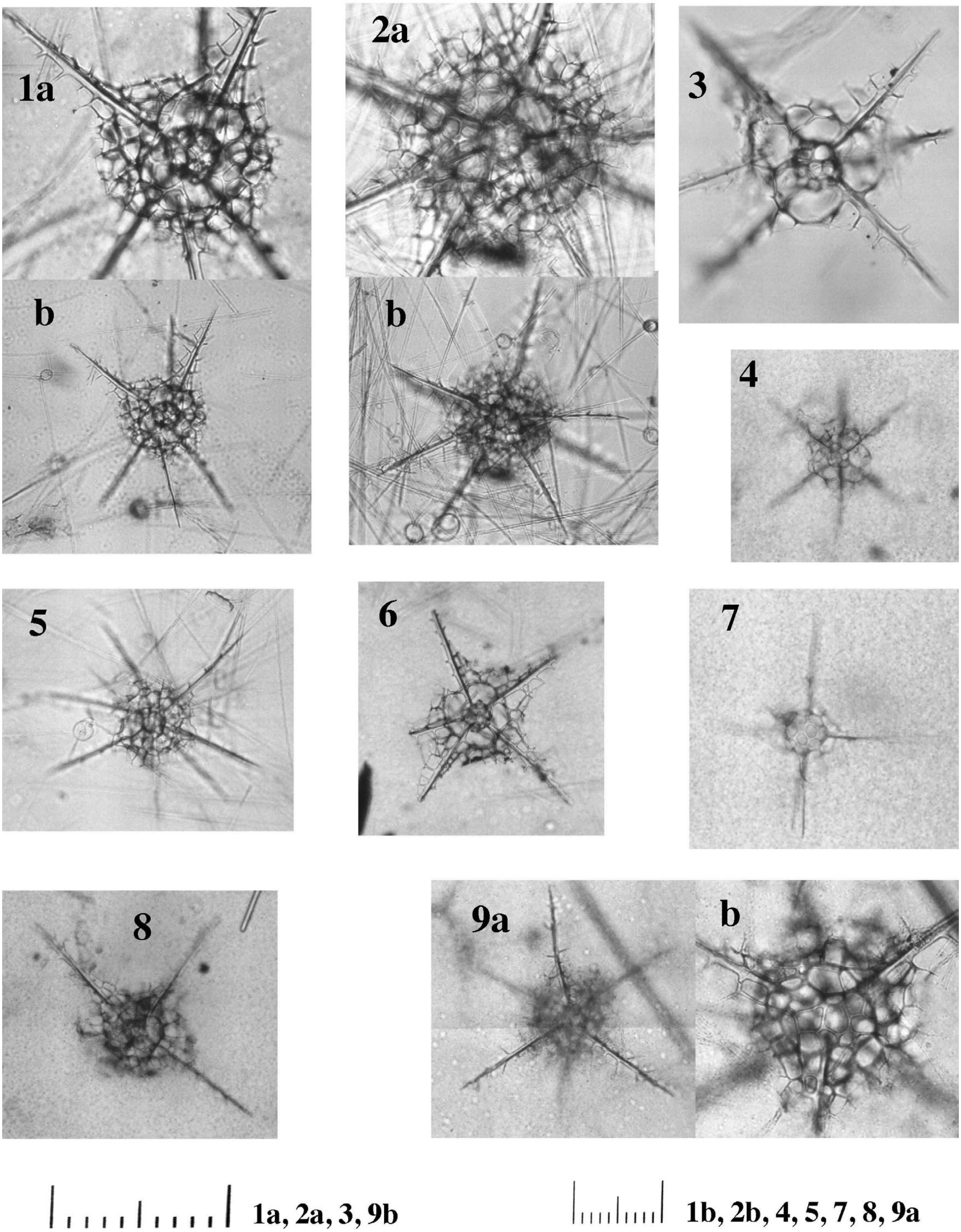
Haul 27 VII. Lat. N. 78° 58′. Long. E. 09° 35′. –400–0 m.

Lectotype. SMNH Type #6133, Pl. 2, fig. 8, Cleve slide #39 (Q38/0); fig. 9, original line drawing of lectotype by Cleve (1899, pl. 4, fig. 5).

Remarks. Cleve (1899) identified 2 spongodiscids, but placed them both in the wrong family (Porodiscidae) as well as the wrong genus (*Trochodiscus*). The *Trochodiscus* specimens on Cleve's slides (our photos Pl. 2, figs 6–9), as well as his description and illustrations are definitely not porodiscids but typical spongodiscids. The species *Trochodiscus echinidiscus* Haeckel (Cleve slide #18, N27/2; correct name should have been *T. echiniscus* Haeckel, 1887, p. 418) was defined as 'nomen dubium' by Lazarus & Suzuki in the IODP taxonomic name list database because of the poor description and the lack of an illustration by Haeckel (1887), and no type material is available (Lazarus, pers comm. July 2012). The Cleve species *T. helioides* (Cleve slide #39, Q38/0) we hereby move to the Spongodiscidae and the genus *Spongotrochus*, as defined: a spongy disc with radial spines. In the rest of this text will use *Spongotrochus helioides. S. helioides* has numerous spines which can be as long as the disc diameter, distributed essentially only along the periphery. A closer examination of Cleve's specimen reveals that, when the slide is facing up, two or probably three spines, broken close to their base, can be observed on the disc itself of the lectotype, about one-third from the periphery. When turning the slide, observing the specimen from the back side, no broken spines can be observed with certainty. It is obvious that this specimen has its long radial spines distributed essentially along the margin, in the equatorial plane, as stated by Cleve. A second individual of *S. helioides* was also found on Cleve's slide #20 (J36/4); also on this specimen no spines could be observed on any sides of the disc.

Spongotrochus helioides is similar to *S. glacialis* Popofsky, 1908. *S. glacialis* is a troublesome species. Most authors refer the large spiny spongodiscids from all the world's oceans to this species. The complexity of this species is implied in Petrushevskaya

Explanation of Plate 2. fig. 1. *Actinomma boreale* Cleve, 1899. Two different focus levels. Cleve slide #20 (O34/2). **fig. 2.** *Actinomma boreale* Cleve, 1899. Two different focus levels. Cleve slide #21 (N35/2). **fig. 3.** *Actinomma boreale* Cleve, 1899. Two different focus levels. Cleve slide #19 (M38/3). **fig. 4.** *Actinomma boreale* Cleve, 1899. Two different focus levels. Cleve slide #23 (N36/4). **fig. 5.** *Actinomma boreale* Cleve, 1899. Two different focus levels. Cleve slide #23 (K35/4). **fig. 6.** *Spongotrochus helioides* (Cleve, 1899) Cleve slide #18 (N27/2). Cleve named this form *Trochodiscus echinidiscus*. **fig. 7.** *Spongotrochus helioides* (Cleve, 1899). Original drawing by Cleve (1899, pl. 4, fig. 4). **fig. 8.** *Spongotrochus helioides* (Cleve, 1899). Lectotype SMNH Type # 6133. Cleve slide #39 (Q38/0). **fig. 9.** *Spongotrochus helioides* (Cleve, 1899). Original drawing of lectotype by Cleve (1899, pl. 4, fig. 5). Scale bar 100 µm.


1a
2a
3
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9a
b
1a, 2a, 3, 9b
1b, 2b, 4, 5, 7, 8, 9a

(1975), Nigrini & Moore (1979) and Itaki (2009) in referring to it as *Spongotrochus glacialis* group Popofsky (1908). Boltovskoy *et al.* (2010, p. 221) similarly concluded: 'Heterogeneous group, probably including more than one species'. Riedel (1958) was the first to use *S. glacialis* in the modern way. He gives illustrations and a good description, and emends the definition based on 25 specimens from the Antarctic. He does not mention Cleve's specimens from the high north (i.e. *S. helioides*). Similarly Petrushevskaya (1968) gives an intensive discussion of *S. glacialis* and a review of similar boreal-austral forms. She had no firm conclusion on the different species and genera she discussed. We infer, however, that Petrushevskaya (1975) used the term *Spongotrochus glacialis* group Popofsky (1908) because of its heterogeneous morphology.

Hülsemann (1963) reported on more than 2000 specimens of what for her is *S. glacialis*, and she gives a good description and discussion of her specimens. All her specimens are equipped with spines, none lacked spines completely. Of the 90 measured specimens 25% have spines only at the margin, while the rest have discs with spines on both sides. These specimens fit with what we can observe in our pictures of the two specimens of *S. helioides* observed in Cleve's slides. Hülsemann (1963) further concluded that in spite of the difference in spine ornamentation on the disc, the two forms are so much alike in other characters, that it is admissible to unite the two morphologies to one species. Hülsemann (1963, p. 20) further stated:

> The arctic specimens have from 5–16 large spines, 9 being the commonest number with the odd numbers outweighing the equal ones. The length of the larger spines does not usually exceed the diameter of the disc. Most of the spines continue within the disc, and some of the radial bars are recognizable through the meshes up to the darker central part.

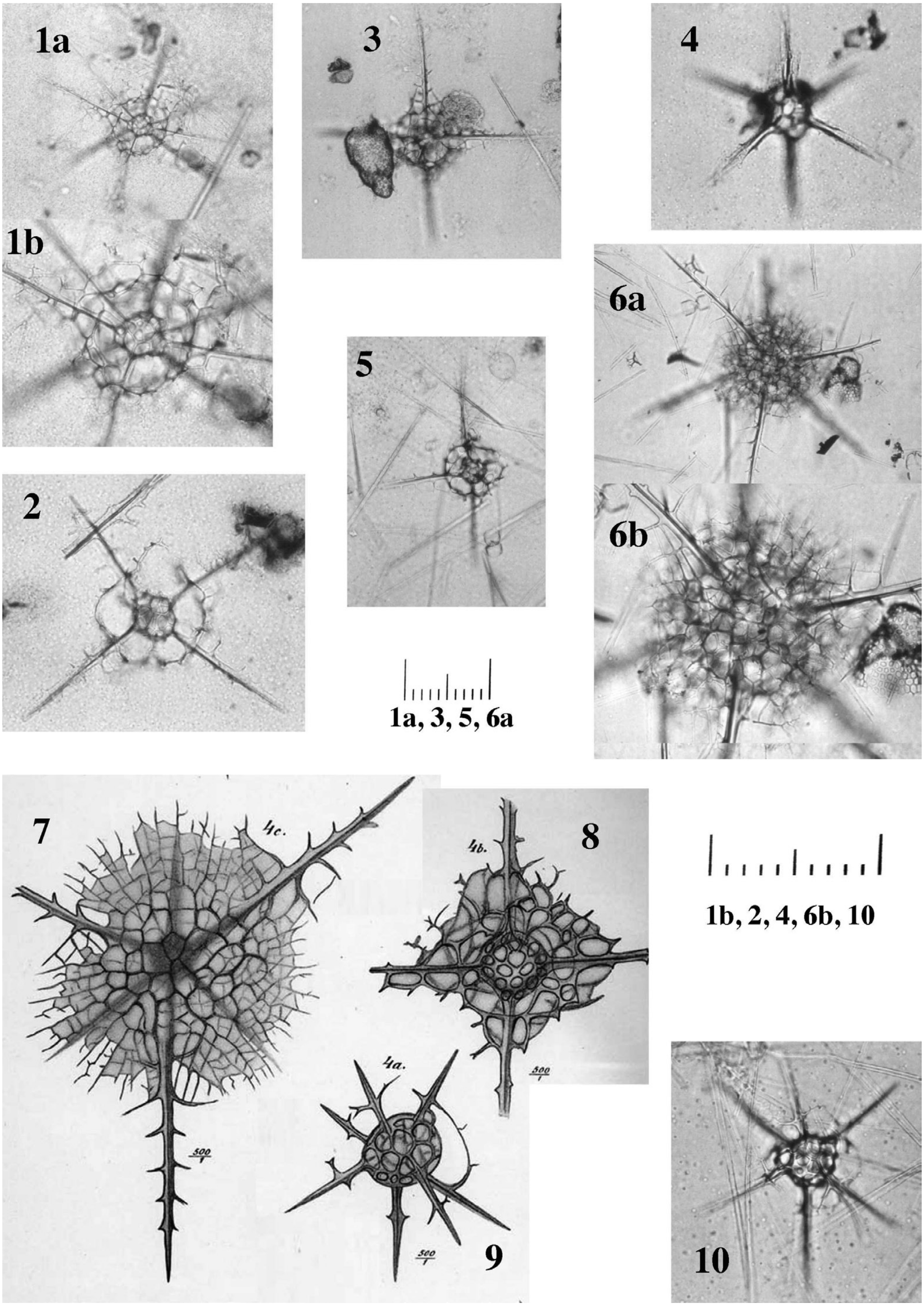
The presence of the so-called pylome, a funnel-like opening in the disc, is another significant characteristic, according to Hülsemann (1963). The pylome is present in about two-thirds of the Arctic specimens, in half more or less inconspicuously and in half it is very distinct. Again those with a pylome can be referred to what Cleve named *T. echinidiscus* (a pylome is visible on Cleve's specimen between 7 and 8 o'clock on the dial, our Pl. 2, figs 6–7), and those without a pylome to *T. helioides* (Pl. 2, figs 8–9). Finally Hülsemann (1963) states that the Antarctic forms described by Riedel (1958) are larger than her Arctic forms, their spines are shorter, the central part of the disc is thickened (not in the Arctic forms) and in adult forms there is a lenticular lattice-shell enclosing the disc. This is the same as what Petrushevskaya (1968, p. 40) called a mantle. This mantle has never been observed in the Arctic forms, according to Hülsemann (1963).

Riedel (1958) states that in the North Pacific there is a widely distributed form, somewhat similar to the Antarctic form, but with a slender, not thickened central disc. Hülsemann (1963) points out that the North Pacific form resembles more the forms she observed in the Arctic Ocean. Interestingly, Petrushevskaya (1968, p. 48) noted that when she examined Dogel & Reshetnyak's (1952) North Pacific slides she found that some slides were labelled *Trochodiscus helioides* in Dogel's handwriting, specimens that Dogel later referred to as juvenile specimens of *Spongotrochus beringianus*. This indicates that at least Dogiel was aware of Cleve's species and at one point saw the similarity between the spongodiscids in the North Atlantic and the North Pacific. Based on the above information we are of the opinion that the Arctic form as discussed by Hülsemann (1963) – where 25% have only radial spines along the margin – is conspecific to the form described as *Spongotrochus helioides* (Cleve, 1899). The remaining 75% of Hülsemann's (1963) specimens could then simply be another growth stage (adult) of *T. helioides*, or it could be a different species. If we keep Hülsemann's evaluation, all of her specimens in question should then be referred to as the same species, in other words, they should all be *S. helioides* (Cleve, 1899). Others might argue that they may be another species, or simply a modification of what is accepted as *S. glacialis* Popofsky, 1908. Petrushevskaya (1968) does not give any explanation for why she excludes the specimens identified by Hülsemann (1963) from *S. glacialis* in her synonymy list. Her well established reputation as an acute observer of radiolarian morphology, however, suggests that she detected that there is something different between the northern and southern form.

No authors other than Bjørklund & Ciesielski (1994) have reported on *Trochodiscus helioides*. In their study they referred only to a table based on species counts of Cleves slides, made by KRB in 1973. During that study KRB observed only the two specimens of *T. helioides*, not the one specimen of *T. echiniscus* on Cleve slide #18. At that time he used only the names on Cleve's slide and publication and did not attempt further taxonomic evaluation. Other North Atlantic radiolarian reports, e.g. Petrushevskaya & Bjørklund (1974), Schröder-Ritzrau (1995), Bjørklund *et al.* (1998), Cortese *et al.* (2003) and Bjørklund & Kruglikova (2003), all report only *Spongotrochus glacialis*; while Dolven *et al.* (2002) used the *S. glacialis* group category as they did not separate juvenile *S. glacialis* from *Spongodiscus resurgens*.

We therefore consider that Spongodiscidae species with a circular outline in the high northern Atlantic waters can be referred to *Spongodiscus resurgens* and *S. osculosa, Spongotrochus helioides*, and also the very variable *S. glacialis*. Most radiolarists are using the term *S. glacialis*, without giving it much taxonomic thought, and it is in practice something of a basket term for several forms. Based on the above discussion we are of the opinion that the southern *S. glacialis* in the Antarctic is different from the northern form in the Arctic Ocean. We regard *S. helioides* (Cleve, 1899) as a valid name until a total revision of this species complex has been undertaken.

Explanation of Plate 3. fig. 1. *Cleveiplegma boreale* (Cleve, 1899). Cleve slide #29 (H41/0). **fig. 2.** *Cleveiplegma boreale* (Cleve, 1899). Paralectotype SMNH Type # 6124, Cleve slide #31 (O38/4). **fig. 3.** *Cleveiplegma boreale* (Cleve, 1899). Cleve slide #34 (U38/3). **fig. 4.** *Cleveiplegma boreale* (Cleve, 1899). Cleve slide #33 (H38/1). **fig. 5.** *Cleveiplegma boreale* (Cleve, 1899). Cleve slide #31 (N40/0). **fig. 6.** *Cleveiplegma boreale* (Cleve, 1899). Cleve slide #26 (H37/1). **fig. 7.** *Cleveiplegma boreale* (Cleve, 1899). Cleve slide #23 (M34/2). **fig. 8.** *Cleveiplegma boreale* (Cleve, 1899). Cleve slide #23 (H37/2). **fig. 9.** *Cleveiplegma boreale* (Cleve, 1899). Cleve slide #27 (O35/0). Scale bars 100 μm.


1a
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6a
6b
1a, 3, 5, 6a
7
4c.
500/1
8
4b.
500/1
4a.
500/1
9
1b, 2, 4, 6b, 10
10

Order **Nassellaria**

Amphimelissa setosa (Cleve, 1899)

(Pl. 6, figs 1–5, 6a, b, 7a, b, 8–18)

1899 *Botryopyle setosa* Cleve: 27; pl. 1, fig. 10a, b – cephalis from below, showing the septum.
1905 *Amphimelissa setosa* (Cleve, 1899); Jørgensen: 136–137; pl. 18, fig. 109.
1914 *Amphimelissa setosa* (Cleve, 1899); Schröder: 106–107; figs 64–66.
1998 *Amphimelissa setosa* (Cleve, 1899); Bjørklund *et al.*: pl. 2, figs 30–33.

Original description (Cleve, 1899)

Length 0,065 mm. Breadth 0,05 mm. Cephalis trilobate, with rounded, irregular pores and some scattered setæ. Thorax twice as long as the cephalis, with very irregular pores of different size.

Deep-sea hauls:

Date	Lat. N.	Long.	Depth.		Fq.	Pl.
29–30 VII	78° 13′	02° 58′W	2,600–0 m	*r*	*S C*	
1 VIII	76° 36′	12° 13′E	500–0 m	*r*	*T S*	
27 VIII	79° 58′	09° 35′E	400–0 m	*r*	*C S*	
1 IX	75° 50′	15° 25′E	325–0 m	*r*	*S*	

Lectotype. SMNH Type # 6118-1, Pl. 6, fig. 1, Cleve slide #25 (O37/3).

Paralectotype 1. SMNH Type # 6118-2, Pl. 6, fig. 2, Cleve slide #25 (O36/0).

Paralectotype 2. SMNH Type # 6118-3, Pl. 6, fig. 4, Cleve slide #25 (O37/4).

Remarks. Even if the description is short, the drawing is very indicative. Jørgensen (1900) moved *Botryopyle setosa* to the genus *Lithomelissa* and this caused some confusion because he, in addition, made a new variety, namely *L.* var. *belonophora*, which has nothing to do with Cleve's *Botryopyle setosa*. Jørgensen (1905) revised the position of *B. setosa* and cleared up this confusion. He also erected a new genus *Amphimelissa*, and placed *B. setosa* therein, while *L.* var. *belonophora* (Jørgensen, 1900) was placed as a variety of a new species, also named *Lithomelissa setosa*. Jørgensen suggested that *L.* var. *belonophora* might be the final stage of *L. setosa. Amphimelissa setosa* is the most common species in surface sediments on the Iceland Plateau (<70%), and is also common in the plankton along the ice edge in the Greenland Sea (25%). Bjørklund & Swanberg (1987) reported two morphotypes of *A. setosa*, a cold-water form on the Iceland Plateau, skeleton rather thick with rounded pores, and a warm water form, occurring in the west Norwegian fjords, skeleton thinner and with pores more irregular to polygonal in outline.

Artobotrys borealis (Cleve, 1899)

(Pl. 8, figs 3a, b, 4, 5a–c, 6a, b, 7a, b, 8)

1899 *Theocorys borealis* Cleve: pl. 3, fig. 5.
1914 *Theocorys borealis* (Cleve, 1899); Schöder: fig. 104.
1971 *Artobotrys borealis* (Cleve, 1899); Petrushevskaya: pl. 82, figs 7–12.
1976*a* *Artobotrys borealis* (Cleve, 1899); Bjørklund: pl. 11, figs 24–27.

Original description (Cleve, 1899)

Cephalis hemispherical, with a short triangular horn and large, irregular, rounded pores. Thorax pear-shaped, with regular, circular pores, as broad as the bars, quincuncially arranged (4 in 0,01 mm.). Abdomen short, narrower than the thorax, with some few, irregular and scattered pores. Mouth somewhat constricted, sometimes with a hyaline peristome.

Length of cephalis 0,015 mm., of thorax 0,03 mm., of abdomen 0,01 to 0,015 mm. Breadth of thorax 0,045 mm. Diameter of the mouth 0,027 mm.

Pl. III, fig. 5.

Resembles *Sethocorys odysseus* HKL. As to the shape and arrangement of the pores.

Deep-sea hauls:

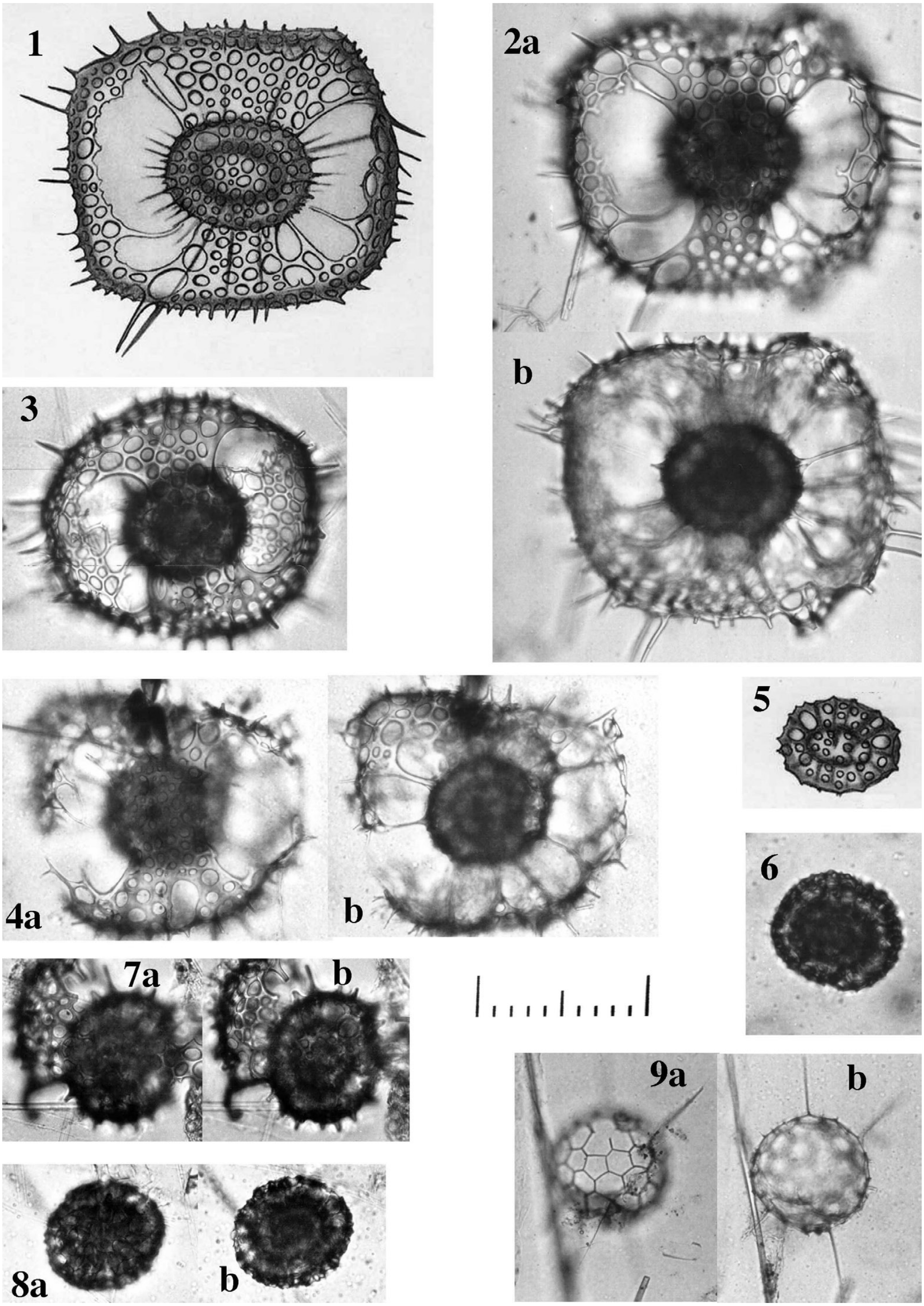
Date	Lat. N.	Long.	Depth.		Fq.	Pl.
29–30 VII	78° 13′	02° 58′ W	2,600 m	r	S C	
27 VIII	79° 58′	09° 35′E	400–0 m	*r*	*C*	
1 IX	75° 50′	15° 25′ E	325–0 m	*r*	*S*	

Lectotype. SMNH Type # 6132, Plate 8, fig. 5a–c, Cleve slide #38 (O32/4); fig. 4, original line drawing of lectotype by Cleve (1899, pl. 3, fig. 5).

Paralectotype. SMNH Type # 6119, Plate 8, fig. 3a, b, Cleve slide #26 (J36/1).

Remarks. This species is common in the warm water region off the Norwegian coast. Cortese *et al.* (2003) showed that it had the second highest scaled varimax factor score in their Factor 4, related to the core of the warm water along the Norwegian Current. This species is not possible to misidentify. Petrushevskaya (1971) transferred this species to genus *Artobotrys*, a position that we agree with. Also found in low numbers in surface sediments in equatorial and northern regions of the Pacific and Atlantic oceans.

Explanation of Plate 4. fig. 1. *Cleveiplegma boreale* (Cleve, 1899). Cleve slide #32 (J38/4). **fig. 2.** *Cleveiplegma boreale* (Cleve, 1899). Cleve slide #23 (O42/2). **fig. 3.** *Cleveiplegma boreale* (Cleve, 1899). Cleve slide #23 (L40/4). **fig. 4.** *Cleveiplegma boreale* (Cleve, 1899). Cleve slide #23 (L39/2). **fig. 5.** *Cleveiplegma boreale* (Cleve, 1899). Cleve slide #32 (G39/0). **fig. 6.** *Cleveiplegma boreale* (Cleve, 1899). Lectotype SMNH Type # 6125, Cleve slide #32 (M40/3). Rotate figure 6a so that radial spine now at 11 o'clock, arrives at 6 o'clock, then it is the same as the original drawing in figure 7. **fig. 7.** *Cleveiplegma boreale* (Cleve, 1899). Original drawing of lectotype by Cleve (1899, pl. 2, fig. 4c). **fig. 8.** *Cleveiplegma boreale* (Cleve, 1899). Original figure Cleve (1899, pl. 2, fig. 4b). **fig. 9.** *Cleveiplegma boreale* (Cleve, 1899). Original figure Cleve (1899, pl. 2, fig. 4a). Possibly a juvenile stage of *Actinomma leptodermum*. **fig. 10.** *Cleveiplegma boreale* (Cleve, 1899). Cleve slide #30 (Q39/0). Scale bar 100 µm.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Ceratocyrtis galeus (Cleve, 1899)
(Pl. 8, figs 1a, b, 2)

1899 *Sethoconus galea* Cleve: 33; pl. 4, fig. 3.
1914 *Sethoconus galea* Cleve, 1899; Schröder: 115–116; fig. 79.
1968 *Sethoconus* (?) *galea* Cleve, 1899; Petrushevskaya: fig. 52.2.
1976*a* *Ceratocyrtis galeus* (Cleve, 1899); Bjørklund: pl. 11, figs 1–3.
2003 *Ceratocyrtis galeus* (Cleve, 1899); Bjørklund & Kruglikova: pl. 6, fig. 26.

Original description (Cleve, 1899)

Shell campanulate or hemispherical, as long as broad (0,12 mm.), with rudimentary cephalis, not distinctly separated from the thorax. One apical spine and several small spines on the thorax. Pores irregularly polygonal, increasing in size from the apex, the largest 0,02 mm. in diameter.

Pl. IV, fig. 3.

Some specimens in the haul 29–30 VII. Lat. 78° 13′. Long. W. 02° 58′. – 2,600 m.

Lectotype. SMNH Type # 6131, Plate 8, fig. 1a, b, Cleve slide #37 (N39/2); fig. 2, original line drawing of lectotype by Cleve (1899, pl. 4, fig. 3).

Remarks. This species is rather similar to *Helotholus histricosus* Jørgensen, 1905, but its size and robustness (very thick skeleton) make it easy to separate the two species. *Sethoconus galeus* has two well-developed cephalic spines, as in *H. histricosus*, which however usually has numerous additional cephalic byspines (see www.Radiolaria.org). Petrushevskaya (1971) transferred *H. histricosus* to the genus *Ceratocyrtis*, while Bjørklund (1976*b*) also moved *S. galeus* to the genus *Ceratocyrtis*. One more specimen of *S. galeus* is located on Cleve slide #25 (M42/4).

Lipmanella irregularis (Cleve, 1899)
(Pl. 10, figs 9a, b, 10)

1899 *Pterocorys irregularis* Cleve: 32–33; pl. 4, fig. 1.
1900 *Dictyoceras acanthicum* (Cleve, 1899); Jørgensen: 84 (not figured).
1905 *Dictyoceras acanthicum* (Cleve, 1899); Jørgensen: 140; pl. 17, fig. 101a; pl. 18, fig. 101b.
1900 *Dictyoceras xiphephorum* (Cleve, 1899); Jørgensen: 84–85; pl. 5, fig. 25.
1905 *Dictyoceras xiphephorum* (Cleve, 1899); Jørgensen: 140 (not figured).
1914 *Pterocorys irregularis* (Cleve, 1899); Schröder: 119–120; fig. 85.
1971 *Lipmanella virchowii* (Cleve, 1899); Petrushevskaya: 220; fig. 100.
1973 ?*Lipmanella irregularis* (Cleve, 1899); Dumitrica: 840; pl. 25, fig. 2.

Original description (Cleve, 1899)

Cephalis nearly spherical, with one apical and one lateral horn. Its pores small and indistinct. Thorax with three strong, downwards directed horns, as long as the breadth of the thorax. Pores rounded, as broad as the bars, variable in size (0,002 to 0,006 mm. in diameter) and scattered without order. The upper part of the thorax provided with some few spines. Abdomen not directly separated from the thorax. Its pores similar to those of the thorax.

Length of cephalis 0,03, of thorax 0,07 mm., of abdomen 0,04 mm. Breadth of thorax 0,07 mm., of abdomen 0.08 mm.

Pl. IV, fig. 1.

The nearest allied form seems to be *P. columba*.

One specimen in the haul 29-30 VII. Lat. 78° 13′. Long. W. 02° 58′. – 2,600 m.

Habitat: Between Shetland and Norway, surface, March 1898.

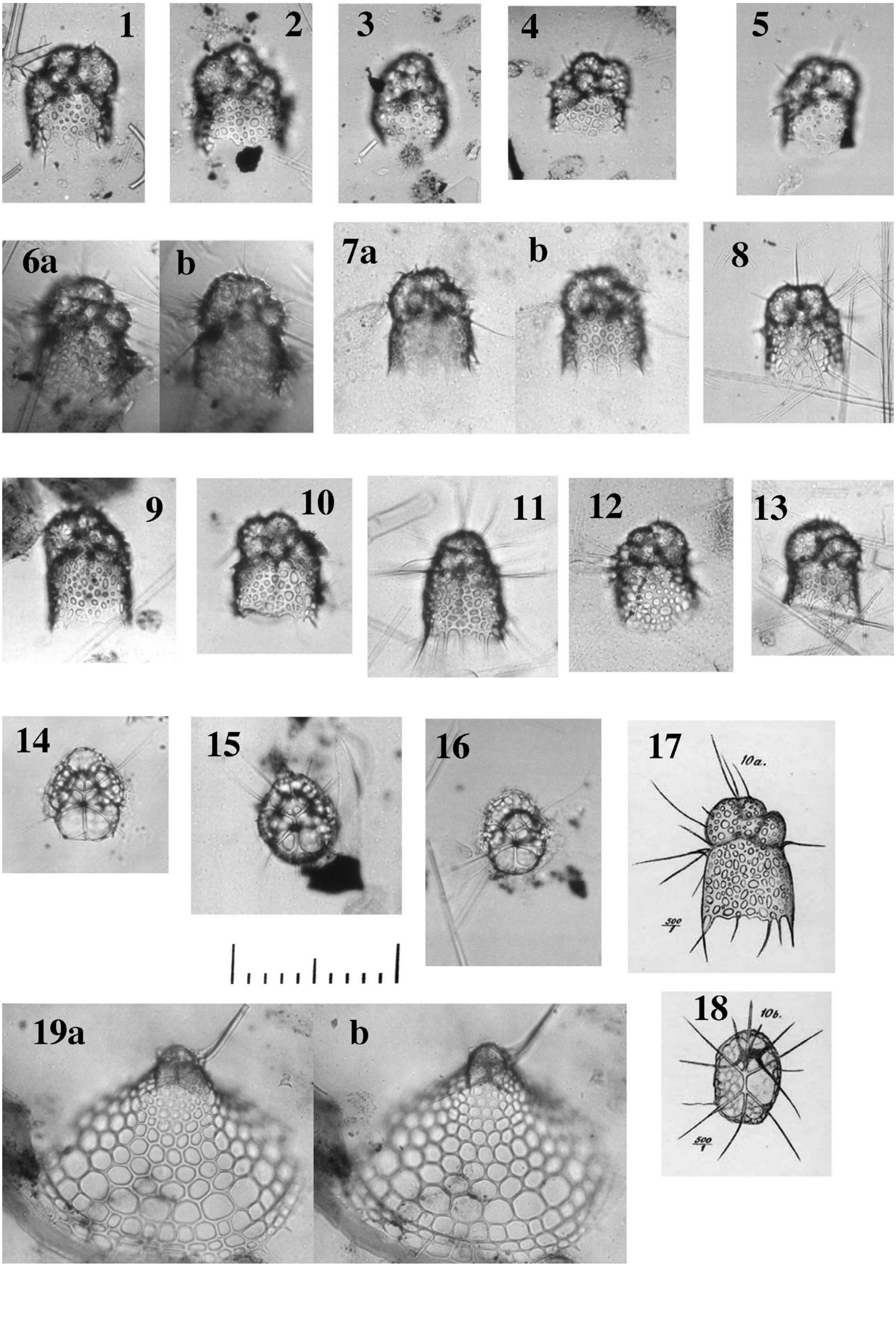
Lectotype. SMNH Type # 6113. Plate 10, fig. 9a, b, Cleve slide #7 (H37/3); fig. 10, original line drawing of lectotype by Cleve (1899, pl. 4, fig. 1).

Remarks. This species is quite rare in Cleve's material, only the lectotype and one other fragment have been observed. Cleve's illustration is based on the lectotype, a broken and incomplete specimen, but its shape is easy to recognize. In his description Cleve points out the three strong, downwards-directed horns on the thorax, as in *Dictyoceras acanthicum* Jørgensen (1905, pl. 18, fig. 101b). We are of the opinion that Jørgensen's two species *Dictyoceras acanthicum* and *D. xiphephorum* are one and the same species, the first being a juvenile stage of the latter, as also suggested by Jørgensen. Jørgensen did not refer to Cleve's species. As we have now located Cleve's type, and have seen Jørgensen's slides and multiple specimens from our fjord samples (sediment and plankton) we are further of the opinion that the two species as named by Jørgensen are identical to Cleve's *D. irregularis*, which has priority. Petrushevskaya (1971, p. 214) states that she considers the genus *Pterocyrtidium* Bütschli, 1882 to include the following species that have been described as *Dictyoceras xiphephorum* Jørgensen, 1900: *D. acanthicum* Jørgensen, 1900; *Pterocorys irregularis* Cleve, 1899, among others. The genus *Dictyoceras* is preoccupied by Eichwold as given in Loeblich & Tappan (1961), who renamed the genus as *Lipmanella* on p. 229. Dumitrica (1973, p. 840; pl. 25, fig. 2) recognized a species in sediments from the Mediterranean Sea which he called ?*Lipmanella irregularis* (Cleve, 1899). We therefore accept *Lipmanella* as the generic name.

Peridium (?) *minutum* Cleve, 1899
(Pl. 7, figs 5a, b, 6, 7a, b, 8a, b, 9a, b)

1899 *Peridium* (?) *minutum* Cleve: 31; pl. 3, fig. 1a–c.

Explanation of Plate 5. fig. 1. *Phorticium clevei* (Jørgensen, 1905). Original figure Cleve (1899, pl. 3, fig. 2a). **fig. 2.** *Phorticium clevei* (Jørgensen, 1905). Cleve slide #8 (M35/3). **fig. 3.** *Phorticium clevei* (Jørgensen, 1905). Cleve slide #32 (H40/3). **fig. 4.** *Phorticium clevei* (Jørgensen, 1905). Cleve slide #16 (F33/4). **fig. 5.** *Phorticium clevei* (Jørgensen, 1905). Original figure of Cleve (1899, pl. 3, fig. 2d). **fig. 6.** *Phorticium clevei* (Jørgensen, 1905). Cleve slide #28. **fig. 7.** *Phorticium clevei* (Jørgensen, 1905). Cleve slide #19 (T33/2). **fig. 8.** *Phorticium clevei* (Jørgensen, 1905). Cleve slide #30 (N39/0). **fig. 9.** *Arachnosphaera dichotoma* Jørgensen, 1900. Cleve slide #16 (M40/1). This species was misidentified as *Heliosphaera actinota* Haeckel by Cleve (1899). Scale bar 100 µm.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Original description (Cleve, 1899)

By this name I denote provisionally a very small shell, which perhaps might be the primordial shell of *Dictyophimus gracilipes* or *Acanthocorys umbellifera*, to which I have not yet succeeded in finding transitional forms. It is represented on Pl. III, fig. 1 *a, b, c*, the two latter being the same shell in different foci. – The diameter of shell 0,03 to 0,04 mm.

Deep-sea hauls:

Date	Lat. N.	Long.	Depth.	Fq.	Pl.
29–30 VII.	78° 13′	02° 58′W	2,600 m.	*r*	*S C*

Lectotype. SMNH Type # 6129-1, Plate 7, fig. 7a, b, Cleve slide #35 (M34/0); Pl. 7, fig. 8a, b, original line drawing of lectotype by Cleve (1899, pl. 3, fig. 1b, c).

Paralectotype-1. SMNH Type # 6129-2, Plate 7, fig. 6, Cleve slide #35 (J34/4).

Paralectotype-2. SMNH Type # 6126, Plate 7, fig. 5a, b, Cleve slide #39 (O35/2).

Remarks. This species is doubtful, as it is based on few specimens, and Cleve's description is not too precise. Cleve himself denoted this as a provisional name and suggested it could be juvenile stages of *Dictyophimus gracilipes* or *Acanthocorys umbellifera*. We do not agree with the latter statement. Jørgensen (1900) reported on both *D. gracilipes* and *A. umbellifera*, in addition to describing *Peridium longispinum*. As such he was therefore quite familiar with the three species. Jørgensen (1905) actually reported on rare specimens of this species, and stated that they may at once be distinguished from the preceding species (*P. longispinum*) on account of the absence of numerous, fine byspines on the upper part of the cephalis. Cleve has written *Peridium minutum* on the slide label and circled the specimen, and there is no doubt that the photograph (Pl. 7, fig. 7a, b) is the same specimen as drawn by Cleve (our Pl. 7, fig. 8a, b), but we are, as was Cleve, not able to draw any final conclusion as to which species this ontogenetic stage belongs. We have found several, almost identical cephalic forms in Cleve's material (our Pl. 7, fig. 9a, b). However, we feel that these skeletal stages are not fully developed and they may be interpreted more comfortably as juvenile, not fully ornamentally developed stages of *P. longispinum* Jørgensen. However, as Cleve's type specimen has been identified, we propose to maintain the name *Peridium minutum*, but realize this certainly is a species for further debate. Cleve (1899), in his description, also signals his uncertainty by writing *Peridium* (?) *minutum*. Further studies will be needed before this species is fully understood. Plankton material from the high north (NE of Svalbard) is now available and may help to solve this problem. This material is now being examined by K.R. Bjørklund and S.B. Kruglikova. We have a high number of similar cephalic forms, which we have identified as *Arachnocorys* sp., although whether this is one or more forms is uncertain. If it turns out that Cleve's *Peridium minutum* is identical to our forms, then Cleve is wrong in his generic identification. This is still a matter we (KRB and SBK) are discussing, but herein we suggest using the name as proposed by Cleve until further revision has been done.

Plectacantha intricata (Cleve, 1899)
(Pl. 7, figs 1a, b, 2a, b)

1899 *Peridium* (?) *intricatum* Cleve: 31; pl. 2, fig. 8a, b.
1900 *Periplecta intricata* (Cleve, 1899); Jørgensen: 73–75.
1914 *Plagiacantha* (?) *intricata* (Cleve, 1899); Schröder: 80; fig. 20a, b.

Original description (Cleve, 1899)

Shell irregularly polyhedral, of a very loose and irregular frame-work with large, polygonal meshes, the apical being the largest. Basal plate with three large meshes of about the same size. Horn short.

Pl. II, fig. 8 *a* and *b* in different foci.

Diameter of the shell 0,08 mm.

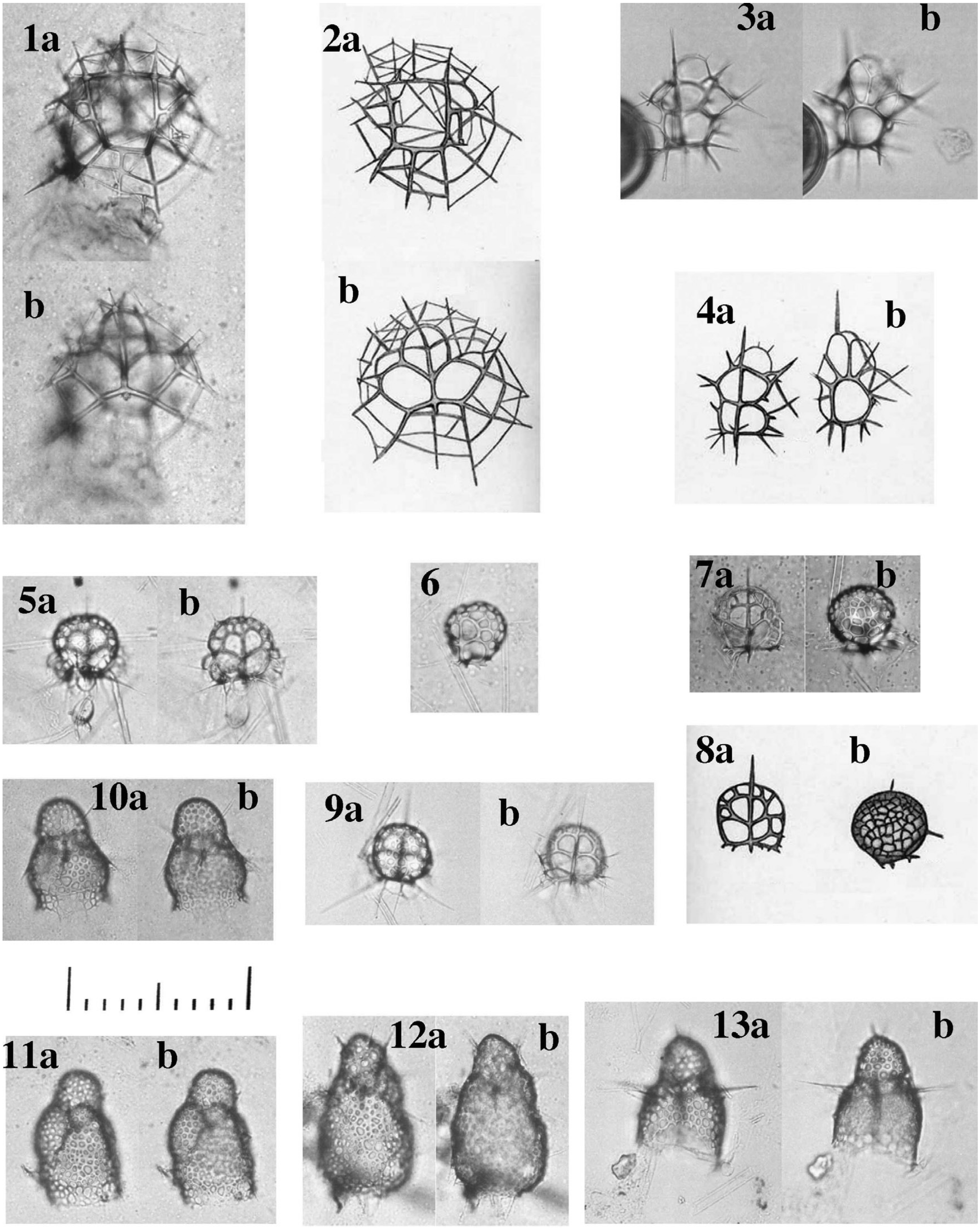
Deep-sea haul: 29–30 VII. Lat. N. 78° 13′. Long. W. 02° 58′W. 2,600 m. One single specimen.

Lectotype. SMNH Type # 6127, Plate 7, fig. 1a, b, Cleve slide #33 (N36/4); fig. 2, original line drawing of lectotype by Cleve (1899, pl. 2, fig. 8a, b).

Remarks. This species has only been cited in the literature a few times. However, we have seen *P. intricata* twice in the surface sediments of the Norwegian Sea. Schröder (1914) moved it from *Peridium* to *Plagiacantha*. Based on Cleve's (1899) description there are not enough data, neither in the text nor in the figures to justify Schröder's (1914) change of genus. We therefore accept the original identification of *Peridium* (?) *intricatum* as made by Cleve (1899). Jørgensen (1900) moved *Peridium intricatum* to *Periplecta intricata*, then Jørgensen (1905, pp. 131–132, pl. 13. figs 50–57) made *P. intricatum* a synonym of his new species *Plectacantha oikiskos*, but stated:

> I at first considered this species to be Cleve's *Peridium intricatum*, and this may be correct, but it cannot be proved to be

Explanation of Plate 6. fig. 1. *Amphimelissa setosa* (Cleve, 1899). Lectotype, SMNH Type # 6118-1. Cleve slide #25(O37/3). **fig. 2.** *Amphimelissa setosa* (Cleve, 1899). Paralectotype 1, SMNH Type # 6118-2. Cleve slide #25(O36/0). **fig. 3.** *Amphimelissa setosa* (Cleve, 1899). Cleve slide #25 (O35/2). **fig. 4.** *Amphimelissa setosa* (Cleve, 1899). Paralectotype 2, SMNH Type # 6118-3.Cleve slide #25(O37/4). **fig. 5.** *Amphimelissa setosa* (Cleve, 1899). Cleve slide #24 (F35/3). **fig. 6.** *Amphimelissa setosa* (Cleve, 1899). Cleve slide #24 (N34/0). **fig. 7.** *Amphimelissa setosa* (Cleve, 1899). Cleve slide #36 (K34/4). **fig. 8.** *Amphimelissa setosa* (Cleve, 1899). Cleve slide #39 (L35/4). **fig. 9.** *Amphimelissa setosa* (Cleve, 1899). Cleve slide #19. **fig. 10.** *Amphimelissa setosa* (Cleve, 1899). Cleve slide #36 (N39/1). **fig. 11.** *Amphimelissa setosa* (Cleve, 1899). Cleve slide #39 (L40/3). **fig. 12.** *Amphimelissa setosa* (Cleve, 1899). Cleve slide #27 (L34/3). **fig. 13.** *Amphimelissa setosa* (Cleve, 1899). Cleve slide #24. **fig. 14.** *Amphimelissa setosa* (Cleve, 1899). Cleve slide #21 (R34/4). **fig. 15.** *Amphimelissa setosa* (Cleve, 1899). Cleve slide #24 (L31/0). **fig. 16.** *Amphimelissa setosa* (Cleve, 1899). Cleve slide #2 (G31/0). **fig. 17.** *Amphimelissa setosa* (Cleve, 1899). Original drawing by Cleve (1899, pl. 1, fig. 10a). **fig. 18.** *Amphimelissa setosa* (Cleve, 1899). Original drawing by Cleve (1899, pl. 1, fig. 10b). **fig. 19.** *Corocalyptra craspedota* (Jørgensen, 1900). Cleve slide #1 (L37/1). This species was identified as *Theocalyptra cornuta* Bailey by Cleve (1899). Scale bar 100 μm.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so from Cleve's illustration nor from his description. As it is, moreover, quite as probable that Cleve's *Peridium* (?) *laxum* also belongs to this species, I consider it best to retain the manuscript name I originally had given the species before Cleve's work was published.

We herein accept Jørgensen's (1905, p. 131) evaluation of the genus *Plectacantha*. Schröder (1914) referred this species to the genus *Plagiacantha*. See also remarks for *Peridium* (?) *laxum* below. In Cleve's material we have found a few individuals of Jørgensen's (1905) *Plectacantha oikiskos*. It seems slightly more open (not with a closed cephalis and does not have the large polygonal pores as illustrated in Cleve (our Pl. 7, fig. 2a, b). We follow the conclusion by Jørgensen (1905) that *Peridium* (?) *intricatum* Cleve, *Peridium* (?) *laxum* Cleve and *Plectacantha oikiskos* Jørgensen should be retained as three species until a more detailed study has been undertaken.

Plectacantha laxa (Cleve, 1899)
(Pl. 7, figs 3a, b, 4a, b)

1899 *Peridium* (?) *laxum* Cleve: 31; pl. 2, fig. 9a, b.
1914 *Plagiacantha* (?) *laxa* (Cleve, 1899); Schröder: 81; fig. 21a, b.

Original description (Cleve, 1899)

Shell irregularly polyhedral of a very loose frame-work, with large polygonal and irregular meshes, the apical being the largest. Basal plate with two cardinal and two jugular meshes of about the same size. Horn a fine bristle, half as long as the shell.

Pl. II, fig. 9 a,b, (in different foci).

Diam. of the shell 0,05 mm.

Deep-sea haul: 5 IX. Lat. N. 71° 50′. Long E. 19° 2′. 230–0 m. One single specimen.

Lectotype. SMNH Type # 6128, Plate 7, fig. 3a, b, Cleve slide #34 (P38/2); Plate 7, fig. 4a, b, original drawing of lectotype by Cleve (1899, pl. 2, fig. 9a, b).

Remarks. This species has been identified by us on slide and as identified by Cleve. As for the previous species, only one specimen has been observed in all of Cleve's slides, indicating that this species is rather rare. Jørgensen (1905) also had doubts about this species, and indicated that *P. laxum* might be a synonym to *Plectacantha oikiskos*, as well as *P. trichoides*; however, Jørgensen decided to keep all three as separate species until their rank had been properly investigated. Schröder (1914) placed *Peridium laxum* and the previous species (*Peridium intricatum*) in the genus *Plagiacnatha*, not in *Plectacantha* as Jørgensen (1905), and this combination is accepted herein.

Protoscenium simplex (Cleve, 1899)
(Pl. 9, figs 15–16, 17a, b)

1899 *Plectanium* (?) *simplex* Cleve: 32; pl. 3, fig. 3.
1905 *Protoscenium simplex* (Cleve, 1899); Jørgensen: pl. 15, fig. 69.
2003 *Protoscenium simplex* (Cleve, 1899); Bjørklund & Kruglikova: pl. 6, fig. 8.

Original description (Cleve, 1899)

Bars thin, cylindrical, each divided at the distal end into three branches, connected by thin threads into delicate polyhedral network (diam. 0,06 mm.).

Pl. III, fig. 3.

One single specimen in the haul 29–30 VII. Lat. 78° 13′. Long. W. 02° 58′. – 2,600 m.

Lectotype. SMNH Type # 6112, Plate 9, fig. 17a, b, Cleve slide #6 (S43/1).

Remarks. Based on Cleve's text it is not possible to recognize this species but, based on his illustration (Cleve 1899, pl.3, fig. 3), it is. We have not been able to find the specimen corresponding to Cleve's illustration, but we have found three other specimens on his slides. Jørgensen (1905) disagreed with Cleve's generic classification and made a careful examination and a description of a new genus *Protoscenium*, with Cleve's species as the only member of this new genus. Jørgensen (1905) also pointed out that this species was rare. However, sufficient specimens have been observed from surface sediments in the Norwegian Sea (Bjørklund unpublished data, photos in www.Radiolaria.org) as well as in the Arctic Ocean (Bjørklund & Kruglikova, 2003, pl. 6, fig. 8) and there is no doubt that this is a good, valid species.

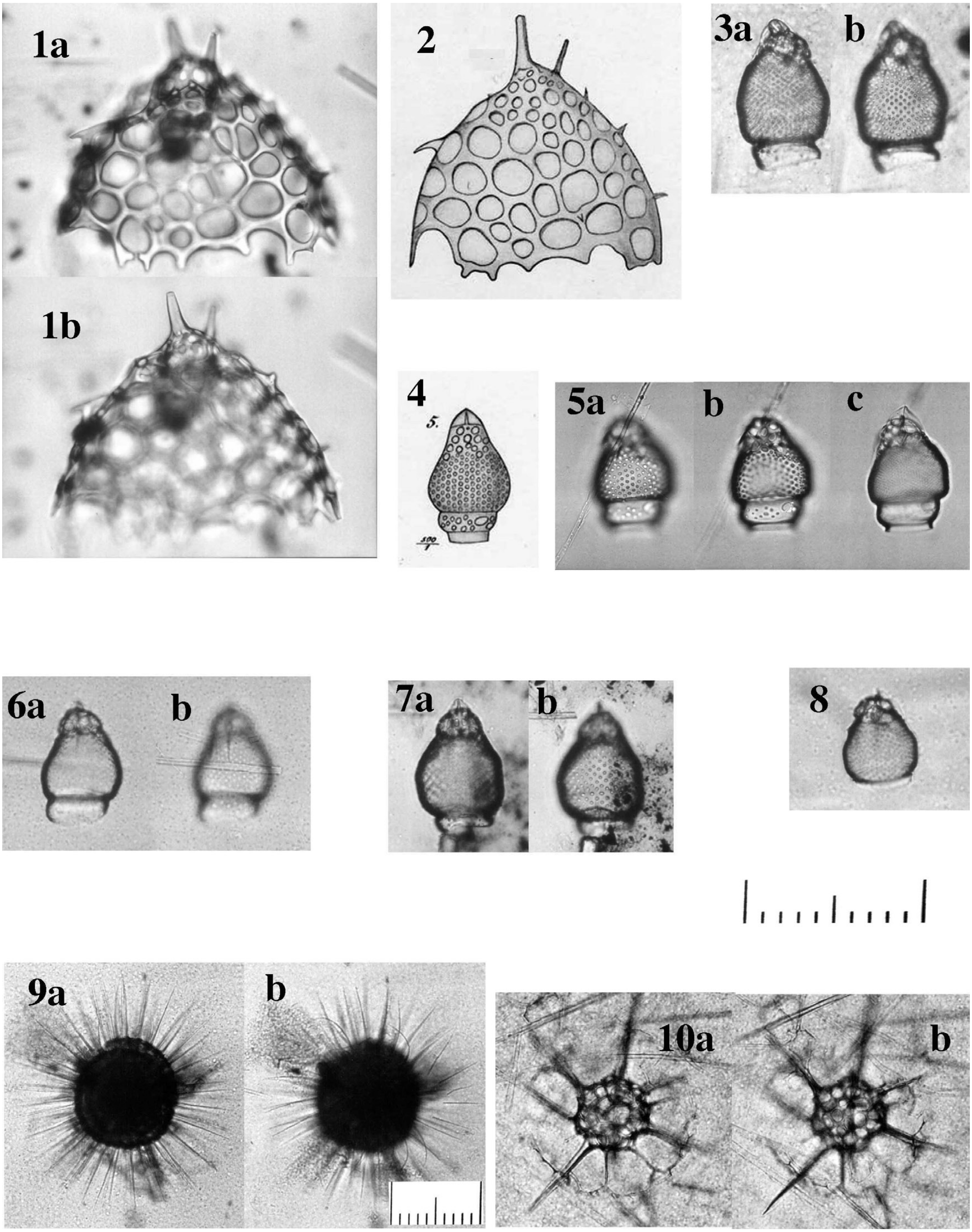
Order **Phaeodaria**
Euphysetta nathorstii Cleve, 1899
(Pl. 11, figs 4a, b, 8, 9a, b)

1899 *Euphysetta nathorstii* Cleve: 29; pl. 2, fig. 3.
1901 *Euphysetta nathorstii* Cleve, 1899; Borgert: 36–37; fig. 44.
1969 *Euphysetta nathorstii* Cleve, 1899; Stadum & Ling: pl. 1, fig. 15.

Original description (Cleve, 1899)

Shell ovate, with a single spine on the apical pole. Structure double: coarser longitudinal (9 in 0,01 mm.) and traverse (8 to 9 in 0,01 mm.) faint ribs crossing each other at right angles and, besides, very small puncta arranged in obliquely decussating rows (17 in 0,01 mm.).

Explanation of Plate 7. fig. 1. *Plectacantha intricate* (Cleve, 1899). Lectotype SMNH Type # 6127, Cleve slide #33 (N36/4). Same specimen as figure 2, drawn by Cleve. **fig. 2.** *Plectacantha intricate* (Cleve, 1899). Original drawing by Cleve (1899, pl. 2, fig. 8). **fig. 3.** *Plectacantha laxa* (Cleve, 1899). Lectotype SMNH Type # 6128, Cleve slide #34 (P38/2). Same specimen as figure 4, drawn by Cleve. **fig. 4.** *Plectacantha laxa* (Cleve, 1899). Original drawing by of Cleve (1899, pl. 2, fig. 9). **fig. 5.** *Peridium* (?) *minutum* (Cleve, 1899). Paralectotype-2 SMNH Type # 6126: (a) focus on opposite side, (b) frontal view. Cleve slide #39 (O35/2). **fig. 6.** *Peridium* (?) *minutum* (Cleve, 1899). Paralectotype-1 SMNH Type # 6129-2. Cleve slide #35 (J34/4). **fig. 7.** *Peridium* (?) *minutum*. (Cleve, 1899). Lectotype SMNH Type # 6129-1: (a) frontal view, (b) different focus. Same specimen as figure 8, drawn by Cleve. Cleve slide #35 (M34/0). **fig. 8.** *Peridium* (?) *minutum* (Cleve, 1899). Original figure of Cleve (1899, pl. 3, fig. 1). **fig. 9.** *Peridium* (?) *minutum* (Cleve, 1899): (a) focus on opposite side, (b) frontal view. Cleve slide #31 (M33/3). **fig. 10.** *Lithomelissa setosa* Jørgensen, 1900: (a) frocus on thoracic pores, (b) focus on outline. Cleve slide # 23 (P40/2). **fig. 11.** *Lithomelissa setosa* Jørgensen, 1900: (a) focus on thoracic pores, (b) focus on cephalic pores. Cleve slide # 23 (O35/2). **fig. 12.** *Lithomelissa setosa* Jørgensen, 1900: (a) focus on thoracic pores, (b) focus on outline. Cleve slide # 23 (L40/4). **fig. 13.** *Lithomelissa setosa* Jørgensen, 1900: (a) focus on thoracic pores, (b) focus on cephalic pores. Cleve slide # 23 (S33/1). Scale bar 100 µm.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Peristome short and wide, with four slender articulate teeth, three of the same length but the fourth much longer. From the middle of the fourth tooth there issues in the middle a small spine.

Length 0,06 mm. Breadth 0,04 mm. Pl. II, fig. 3.

Deep-sea haul: 29–30 VII. Lat. N. 78° 13′. Long. W. 02° 58′W. Fq. *rr*. Depth 2,600 m.

Of the genus *Euphysetta* three species only are known, all from the tropical and southern Atlantic.

Lectotype. SMNH Type- # 6114, Plate 11, fig. 9a, b, Cleve slide #16 (M38/2); fig. 8, original drawing of lectotype by Cleve (1899, pl. 2, fig. 3).

Paralectotype. SMNH Type # 6121, Plate 11, fig. 4a, b, Cleve slide #28 (M36/2).

Remarks. This species is rather rare in Cleve's material. The lectotype (Pl. 11, fig. 9a, b) is the same individual as drawn by Cleve (1899), our Plate 11, fig. 8, but the drawn specimen is slightly thinner. However, the key features – main oral spine is slightly bent, with a process (spine) pointing away from the shell, and with three rather short, straight, conical spines, are all visible in the two illustrated specimens. Resembles *E. pusilla* Cleve (we have not observed this species in Cleve's material) but differs by missing the apical spine and has a considerably less developed main oral spine. The latter species is not furnished with a process on the main oral spine as in *E. nathorstii*.

Lirella melo (Cleve, 1899)
(Pl. 11, figs 5a, b, 6)

1899 *Beroetta melo* Cleve: 27; pl. 1, fig. 8.
1901 *Cadium melo* (Cleve, 1899); Borgert: 50; fig. 58.
1969 *Cadium melo* (Cleve, 1899); Stadum & Ling: 484; pl. 1, figs 6–8.
1981 *Lirella melo* (Cleve, 1899); Takahashi: 301–302; pl. 55, figs 12–18; pl. 56, figs 1–8.

Original description (Cleve, 1899)

Gen. char. Family *Challengerida*. Shell without inner prominent tube of the mouth, with apical tout but without marginal spines. Mouth simple, without peristome. Shell longitudinally furrowed. – *Sp. char.* Shell ovate. Length 0,09 mm. Breadth 0,05 mm. Longitudinal furrows 3 in 0,01 mm. Mouth 0,02 mm. in diameter.

Very rare in the deep-sea gathering: 29–30 VII . Lat. N. 78° 13′. Long. W. 02° 58′. 2,600–0 m.

Pl. 1, fig. 8.

Lectotype. SMNH Type # 6117, Plate 11, fig. 5a, b, Cleve slide #24 (N36/2); fig. 6, original drawing of lectotype by Cleve (1899, pl. 1, fig. 8).

Remarks. Stadum & Ling (1969) reported on two forms, *Cadium melo* (Cleve) and *C. bullatum* n. sp.. Only these two *Cadium* forms have so far been observed in the Nordic seas. They similarly reported unusually abundant, widely scattered, yet somewhat depth-restricted occurrences from the Norwegian Sea. Takahashi (1981) pointed out that this species should be placed in the genus *Lirella* Ehreneberg. In other areas of the world's ocean the longitudinal 'furrows' can be twisted. Whether this is an ecological imprint or a different species has not been settled.

Porospathis holostoma (Cleve, 1899)
(Pl. 11, figs 12, 13a, b, 14)

1899 *Polypetta holostoma* Cleve: 32; pl. 3, fig. 4a, b pore detail.
1901 *Porospathis holostoma* (Cleve, 1899); Borgert: 48–49; figs 56, 56a.
1969 *Porospathis holostoma* (Cleve, 1899); Stadum & Ling: 485–486; pl. 1, figs 16–18.
1981 *Porospathis holostoma* (Cleve, 1899); Takahashi: 302–303; pl. 57, figs 1–8.

Original description (Cleve, 1899)

Shell spherical. Structure: triangular alveoli (1,5 in 0,01 mm.) separated by prominent fine crests. At each point, where these crests cross each other, a short, small thorn arises. On the surface of the shell are scattered without order a number of narrow, structure-less, straight or slightly curved tubes, longer around the proboscis, where they are three to four times as long as the diameter of the shell. Proboscis a cylindrical tube, somewhat shorter than the diameter of the shell. The mouth with a narrow, undivided rim.

Diam. 0,09 to 0,1 mm.

Pl. III, fig. 4 *a; b* structure.

Deep-sea haul: 29–30 VII. Lat. 78° 13′. Long. W. 02° 58′. – 2,600 m. *r*.

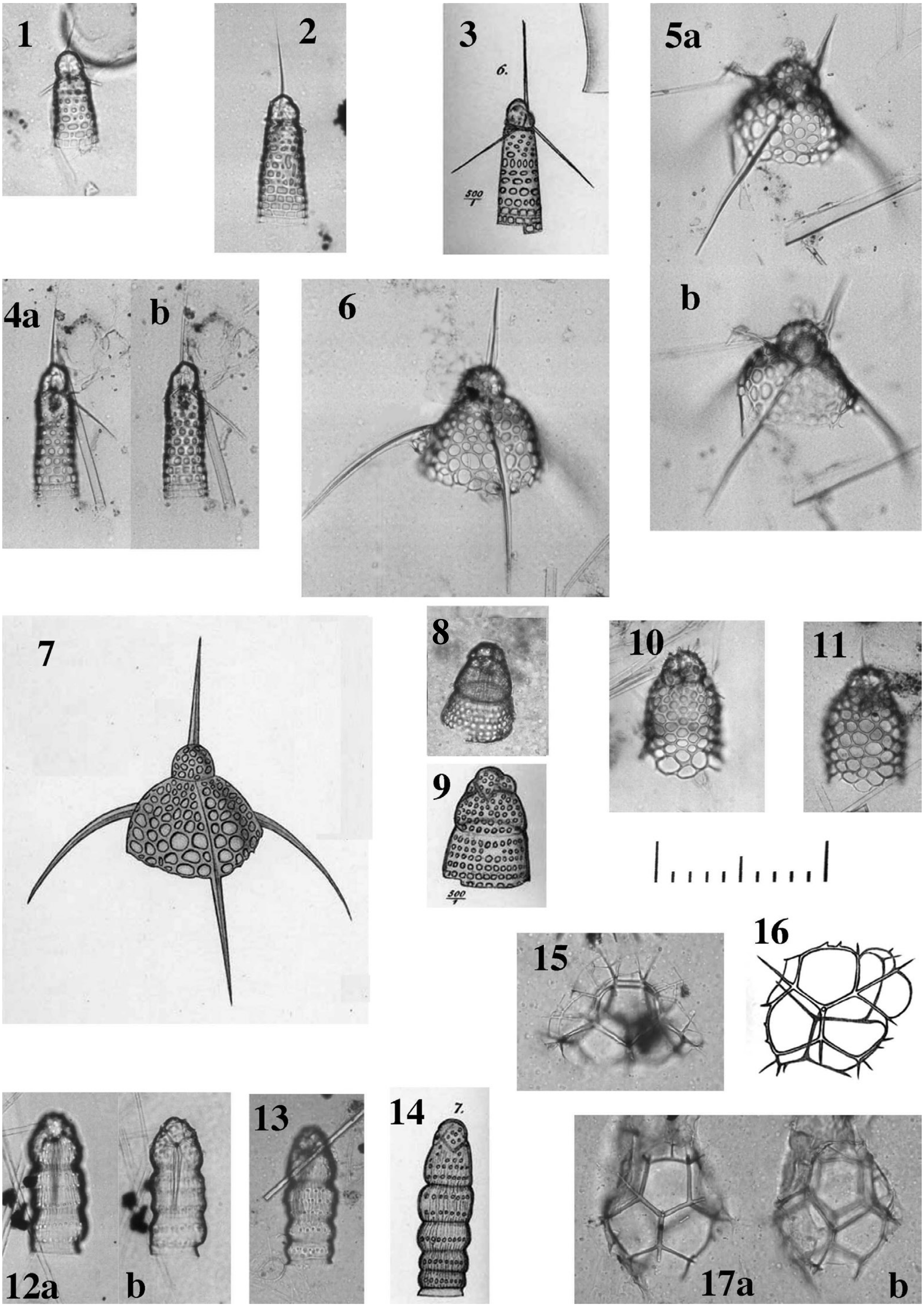
This species agrees in all respects, except the mouth, with *Polypetta tabulata* HKL. From the abyssal depth of the Indian Ocean.

Lectotype. SMNH Type # 6130, Plate 11, fig. 12, Cleve slide #36 (P38/0).

Paralectotype. SMNH Type # 6115, Plate 11, fig. 13a, b, Cleve slide #19 (M38/0).

Remarks. We have not been able to identify the type specimen drawn by Cleve. Most skeletons of this species have been crushed as the Canada balsam dried out, but one complete specimen, on Cleve's type slide, was in good enough condition to be used as lectotype. Specimens in better condition were found on several of the other slides, and one paralectotype has been established. Borgert (1901) erected the genus *Porospathis* in which he placed

Explanation of Plate 8. fig. 1. *Ceratocyrtis galeus* (Cleve, 1899). Lectotype SMNH Type # 6131. Same specimen as figure 2, drawn by Cleve. Cleve slide #37 (N39/2). **fig. 2.** *Ceratocyrtis galeus* (Cleve, 1899). Original drawing by Cleve (1899, pl. 4, fig. 3). **fig. 3.** *Artobotrys borealis* (Cleve, 1899). Paralectotype SMNH Type # 6119. Cleve slide #26(J36/1). **fig. 4.** *Artobotrys borealis* (Cleve, 1899). Original drawing of lectotype by Cleve (1899, pl. 3, fig. 5). **fig. 5.** *Artobotrys borealis* (Cleve, 1899). Lectotype SMNH Type # 6132. Cleve slide #38 (O32/4). Three different focus levels. **fig. 6.** *Artobotrys borealis* (Cleve, 1899). Cleve slide #39 (H41/4). **fig. 7.** *Artobotrys borealis* (Cleve, 1899). Cleve slide #36 (M36/0). **fig. 8.** *Artobotrys borealis* (Cleve, 1899). Cleve slide #24. **fig. 9.** *Larcospira minor* (Jørgensen, 1900). Cleve slide #15 (L40/0). Identified as *Cromyomma zonaster* (Ehrenberg, 1862) by Cleve (1899); originally written as '*Acanthosphaera Haliphormis zonaster*' by Ehrenberg (1862, p. 281). **fig. 10.** *Actinomma leptodermum* (Jørgensen, 1900). Cleve slide #22 (H37/0). Identified as *Actinomma boreale* by Cleve (1899). Scale bar 100 µm.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Cleve's species. There is no doubt that this is a rather common and well-defined species.

Other important species in Cleve's collection arranged alphabetically

Order **Spumellaria**

Arachnosphaera dichotoma Jørgensen, 1900
(Pl. 5, fig. 9a, b)

non Heliosphaera actinota Haeckel, 1860: 803.
non Heliosphaera actinota Haeckel; Haeckel, 1862: 352; pl. 9, fig. 3.
non Heliosphaera actinota Haeckel; Cleve, 1899: 29.
1900 *Arachnosphaera dichotoma* Jørgensen: 60–61; pl. 3, fig. 18.
1909 *Arachnosphaera dichotoma* Jørgensen; Schröder: 33; fig. 22.

Text by Cleve (1899)

Heliosphæra actinota HKL.

One small specimen (Diam. 0,06 mm. Pores three on the radius, 0,013 mm. broad) in the deep-sea hauls 29–30 VII. Lat. N. 78° 13′. Long. W. 02° 58′. 2,600 m.

Habitat: Mediterranean, Canaries, Azores (HKL.).

Type. This species has been recognized by Cleve as *Heliosphaera actinota* Haeckel (1860), and labelled by Cleve on Cleve slide #16 (M40/1). This is, however, a misidentification of *Arachnosphaera dichotoma* Jørgensen, 1900. This species is a juvenile form but its main tribladed radial spines can be seen easily.

Remarks. *Heliosphaera actinota* Haeckel, 1860 has a diameter of 200–250 µm, while the diameter of the specimen identified by Cleve (1899) (Cleve slide #16) is only 60 µm in diameter. The spines on the specimen in Cleve's slide are badly preserved, spines are broken off, but the indications of rather few, strong, tribladed main spines, and many needle-shaped byspines at the nodes can be seen. There is little doubt that this species is a juvenile stage of *Arachnosphaera dichotoma* Jørgensen, 1900, see photos # 1136–1137 in www.Radiolaria.org.

Larcospira minor (Jørgensen, 1900)
(Pl. 8, fig. 9a, b)

1899 *Cromyomma zonaster* (Ehrenberg, 1862); Cleve: 29, not figured.
1900 *Lithelius minor* Jørgensen: 65–66; pl. 5, fig. 24.
1905 *Larcospira minor* (Jørgensen, 1900); Jørgensen: 121, not figured.
1998 *Larcospira minor* (Jørgensen, 1905); Bjørklund *et al.*: pl. 1, fig. 5.

Text by Cleve (1899)

Cromyomma zonaster (EHB.)

Thick walled and obscure, 0,11 mm in diameter, densely covered with thin, flexible, radial spines, as long as the radius. Pores rounded 0,005 to 0,007 mm. in diameter; bars 0.003 to 0,005 mm. broad.

Deep sea haul: 5. IX. Lat. N. 71° 50′. Long. E. 19° 02′. Fq. *rr*. Pl. *S*.

Habitat: Greenland, abyssal.

Remarks. The specimen circled on Cleve slide #15 (K40/4) is a misidentification of *Larcospira minor* (Jørgensen, 1900). The specimen identified by Cleve is so that the different internal structures appear as concentric shells. If rotated, two spirals will appear, and in a special view the internal structures will even appear as a single spiral. Another character typical for *L. minor* is the many needle-shaped spines, 100 or more in number, curved and/or straight (Pl. 8, fig. 9b and a, respectively), a little shorter than the diameter. However, knowing this species from Jørgensen's type material, and from both plankton and sediment samples from the Norwegian Sea and fjords, the circled specimen on Cleve slide #15 is *Larcospira minor*, and is very similar to a specimen on Jørgensen's slide #58 (Q46/3). In Cleve's specimen it is not possible to document the number of turns in the two spirals as the central part of the skeleton is very dark, but with maximum light adjustments in the microscope it is possible to interpret that the number of turns is close to 1.5, which is the same as in Jørgensen's specimen. Many authors refer to this species as *Lithelius minor* (original genus by Jørgensen, 1900), not as *Larcospira minor* (emended genus by Jørgensen, 1905). We follow Jørgensen's discussion that the innermost shell is double, *Larnacilla*-shaped or trizonal and, until this has been firmly settled, we continue to use the genus *Larcospira* for this species.

Phorticium clevei (Jørgensen, 1900)
(Pl. 5, figs 1, 2a, b, 3, 4a, b, 5–6, 7a, b, 8a, b)

non Phorticium pylonium Haeckel, 1887: 709; pl. 49, fig. 10.
1899 *Phorticium pylonium* Haeckel, 1887; Cleve: 31; pl. 3, fig. 2.
1900 *Tetrapylonium clevei* Jørgensen: 64.
1905 *Phorticium pylonium*? Haeckel, 1887; Jørgensen: 120–121; pl. 10, fig. 42; pl. 11, figs 42–45.

Text by Cleve (1899)

Phorticium pylonium HKL.

To this variable and cosmopolitan species I refer the shell figured on Pl. III, fig. 2 *a, b, c*. The fig. *d* represents the *primordial shell*, which

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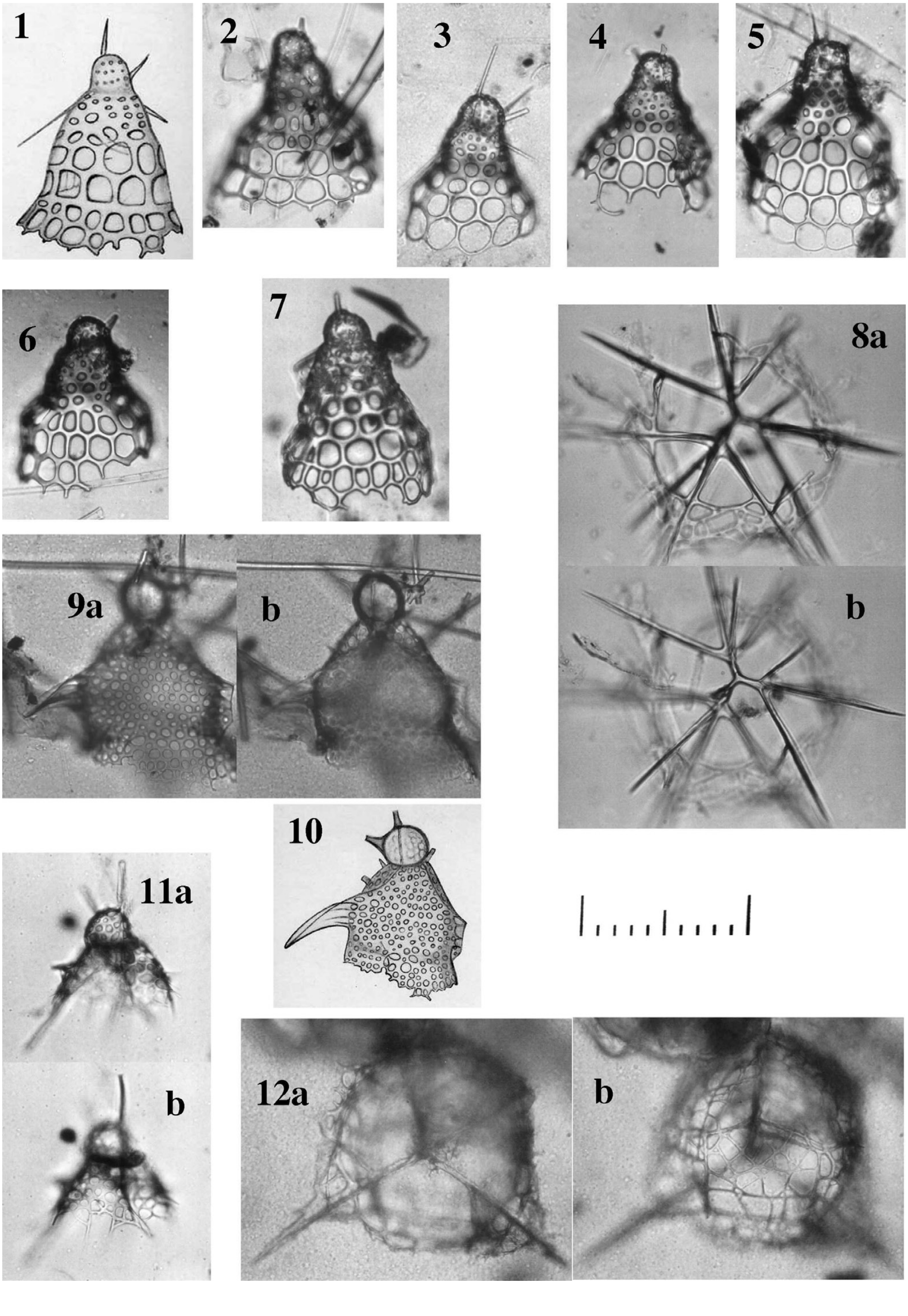
Explanation of Plate 9. fig. 1. *Artostrobus annulatus* (Bailey, 1856). Cleve slide #33 (N42/2). **fig. 2.** *Artostrobus annulatus* (Bailey, 1856). Cleve slide #33 (J34/0). **fig. 3.** *Artostrobus annulatus* (Bailey, 1856). Original figure by Cleve (1899, pl. 1, fig. 6). **fig. 4.** *Artostrobus annulatus* (Bailey, 1856). Cleve slide #4 (Q44/1). **fig. 5.** *Pseudodictyophimus clevei* (Jørgensen, 1900). Cleve slide #4 (K42/4). **fig. 6.** *Pseudodictyophimus clevei* (Jørgensen, 1900). Cleve slide #17 (G36/0). **fig. 7.** *Pseudodictyophimus clevei* (Jørgensen, 1900). Original drawing by Cleve (1899, pl. 2, fig. 2). **fig. 8.** *Botryostrobus auritus-australis* (Ehrenberg, 1844*a* & *b*). Cleve slide #3 (N37/3). Same specimen as figure 9, as drawn by Cleve. **fig. 9.** *Botryostrobus auritus-australis* (Ehrenberg, 1844*a* & *b*). Original drawing by Cleve (1899, pl. 2, fig. 5). **fig. 10.** *Sethoconus tabulatus* (Ehrenberg, 1873). Cleve slide # 2 (M34/0). **fig. 11.** *Sethoconus tabulatus* (Ehrenberg, 1873). Cleve slide # 11 (P41/0). **fig. 12.** *Lithomitra lineata* (Ehrenberg, 1839). Cleve slide #32 (N38/2). **fig. 13.** *Lithomitra lineata* (Ehrenberg, 1839). Cleve slide #6 (N33/3). **fig. 14.** *Lithomitra lineata* (Ehrenberg, 1839). Original drawing by Cleve (1899, pl. 2, fig. 7). **fig. 15.** *Protoscenium simplex* (Cleve, 1899). Cleve slide #16 (N35/2). **fig. 16.** *Protoscenium simplex* (Cleve, 1899). Original figure of Cleve (1899, pl. 4, fig. 3). **fig. 17.** *Protoscenium simplex* (Cleve, 1899). Lectotype SMNH Type # 6112, Cleve slide #6 (S43/1). Scale bar 100 µm.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occurs isolated in the deep-sea gatherings and bears a strong resemblance to *Haliomma æquorea* EHB. (Microg. XIX, 51 from Aegina).

Deep-sea hauls:

Date	Lat. N.	Long.	Depth.	Fq.	Pl.
29–30 VII.	78° 13′	02° 58′W	2,600 m.	*r*	*S C*
1 VIII	76° 36′	12° 13′E	500–0 m	*r*	*T S*
27 VIII	79° 58′	09° 35′E	400–0 m	*r*	*S C*
1 IX	75° 50′	15° 25′ E	325–0 m	*r*	*S*
5 IX	71° 50′	19° 2′E	230–0 m	*r*	*S*

Remarks. The specimen illustrated by Cleve (1899), and recognized by us on Cleve slide #8 (M35/3) (Pl. 5, fig. 2a, b), is not the tropical form of *Phorticium pylonium*, but the northern form described as *Phorticium clevei* Jørgensen, 1900. This is one of the most common species in the Nordic seas and in the west Norwegian fjords, found in many growth stages. Cleve states that this is a 'variable and cosmopolitan species', information he gained from Haeckel (1887), which is a statement that we do not accept. Jørgensen (1900) described *Tetrapylonium clevei*, and pointed out that *T. clevei* was different from *Phorticium pylonium* Haeckel, as described and illustrated by Cleve (1899). Jørgensen (1905) gives a more detailed discussion. He points out that Cleve's illustrations do not have the innermost shell, which would allow him to classify it as *P. pylonium*. Jørgensen observed this innermost shell and he therefore decided to refer this species to the genus *Tetrapylonium*, and describe it as *T. clevei*. Jørgensen (1905, p. 120) also states: 'Cleve has, in a later work accepted this name and remarks that the species is not identical to *Phorticium pylonium* …'. Jørgensen concludes by saying: 'It is, however, quite likely, that at least two species are confused here'. He further states on p. 121 that most of the forms that he described as *Octopyle octostyle* Haeckel *forma minor* Jørgensen, 1900 should be included in *Phorticium clevei*. Petrushevskaya (1968, pp. 56–60) gives an in-depth discussion of these two species and she is of the opinion that *Tetrapylonium clevei* should be maintained as a valid species, but should be placed in genus *Phorticium*, as *P. clevei*, an opinion with which we agree. She takes a definite stand that the northern *P. clevei* is different from the tropical *P. pylonium*. She reports that this northern form is also present in the Antarctic. The intricate morphology in these species makes them difficult to identify properly, see Petrushevskaya (1968, pp. 56 and 59, her synonymy list and comments, respectively).

Order **Nassellaria**

Acanthocorys umbellifera (Haeckel, 1862)
(Pl. 10, fig. 11a, b)

1862 *Arachnocorys umbellifera* Haeckel: 305–306; pl. 6, fig. 12.
1899 *Acanthocorys umbellifera* (Haeckel, 1862); Cleve: 25, not figured.
1905 *Acanthocorys umbellifera* (Haeckel, 1862); Jørgensen: 137; pl. 18, fig. 107.

Text by Cleve (1899)

Acanthocorys umbellifera HKL.

Deep-sea hauls:

Date	Lat. N.	Long.	Depth	Fq.	Pl.
1 VIII	76° 36′	12° 13′	500–0 m	r	TS
27 VIII	79° 58′	9° 35′	400–0 m	r	CS
1 IX	75° 50′	15° 25′	325–0 m	r	S
5 IX	71° 50′	19° 20′	230–0 m	r	S

Habitat Mediterranean (HKL.). Styliplankton of the warmer Atlantic. Färöe Channel (CL.).

Remarks. This species name is used by both Cleve (1899) and Jørgensen (1905). The latter provides a good species description and illustration, and states: 'Hence Cleve considers the species to belong to Styliplankton. It seems, however, judging from the places mentioned where it has been found, to have about the same distribution as *Plectacantha*, and is probably boreal oceanic'. The northernmost position found is 79°58′N, in the 400–0 m water column, representing the major part of the warm northward-flowing Atlantic water. This species is not common in Cleve's material, but seems to us to correspond well with the specimens in Jørgensen's type collection. The adult specimen illustrated was identified and circled by Cleve on Cleve slide #13 (K34/1). Other good examples were found on Cleve slide #15 (S39/0) and slide #23 (N37/1).

Artostrobus annulatus (Bailey, 1856)
(Pl. 9, figs 1–3, 4a, b)

1856 *Cornutella*(?) *annulata* Bailey: 3; pl. 1, figs 5a–b.
1887 *Artostrobus annulatus* (Bailey, 1856); Haeckel: 1481.
1899 *Artostrobus annulatus* (Bailey, 1856); Cleve: 27; pl. 1, fig. 6.

Text by Cleve (1899)

Artostrobus annulatus (BAIL.) HKL. Pl. 1, f. 6.

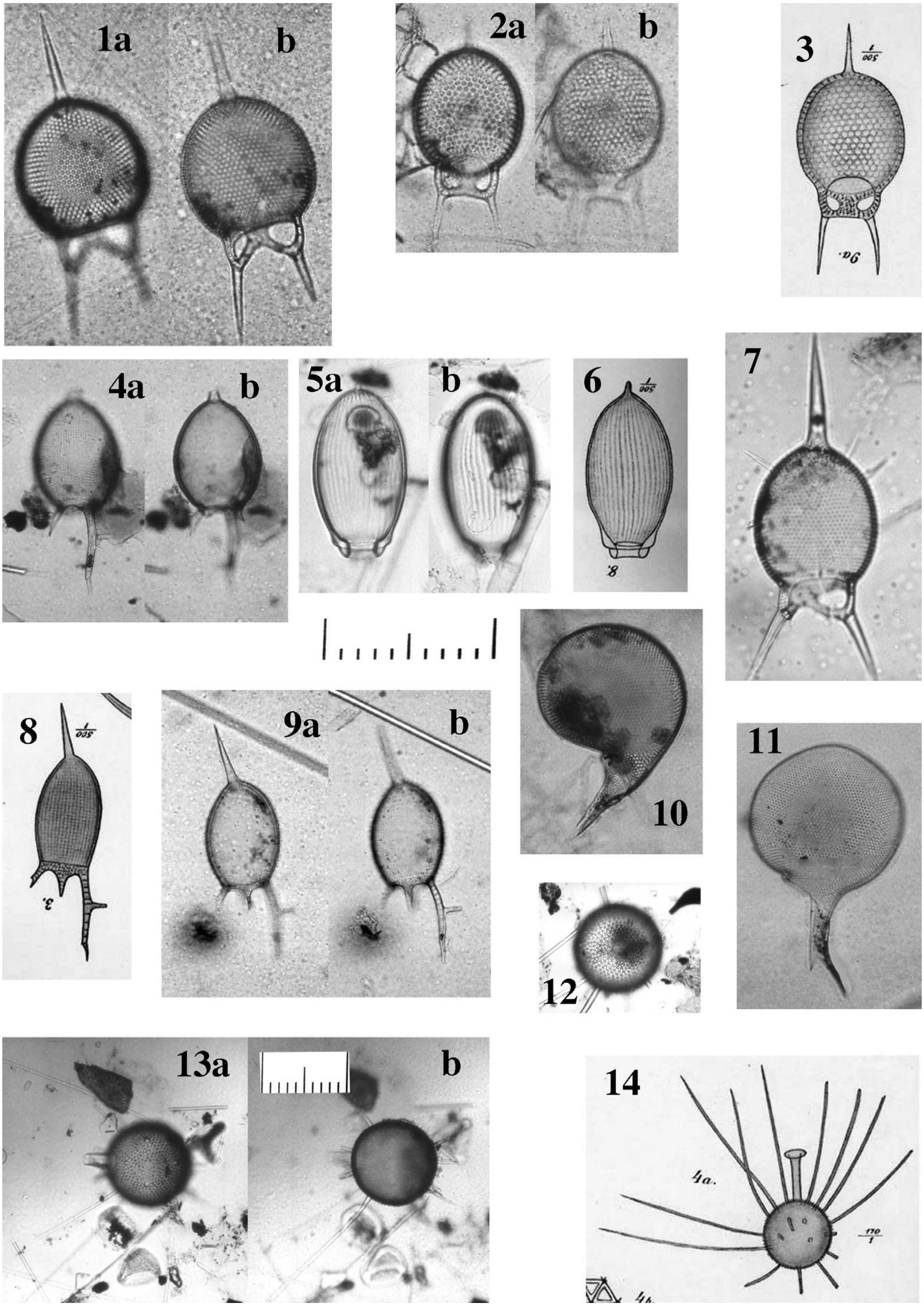
Deep-sea hauls:

Date	Lat. N.	Long.	Depth.	Fq.	Pl.
29–30 VII	78° 13′	02° 58′W	2,600–0 m	*r*	*S C*
1 VIII	76° 36′	12° 13′E	500–0 m	*r*	*T S*

Habitat: Färöe Channel

Remarks. This species is cosmopolitan, normally in low numbers. There is no problem with its identification. In Cleve's material it

Explanation of Plate 10. fig. 1. *Cycladophora davisiana* (Ehrenberg, 1862). Original figure of Cleve (1899, pl. 4, fig. 6). **fig. 2.** *Cycladophora davisiana* (Ehrenberg, 1862). Cleve slide #19 (O35/2). **fig. 3.** *Cycladophora davisiana* (Ehrenberg, 1862). Cleve slide #36. **fig. 4.** *Cycladophora davisiana* (Ehrenberg, 1862). Cleve slide #37. **fig. 5.** *Cycladophora davisiana* (Ehrenberg, 1862). Cleve slide #33 (K39/2). **fig. 6.** *Cycladophora davisiana* (Ehrenberg, 1862). Cleve slide #28. **fig. 7.** *Cycladophora davisiana* (Ehrenberg, 1862). Cleve slide #25. **fig. 8.** *Plagiacantha arachnoides* Claparède & Lachmann, 1858. Cleve slide #31 (F37/3). **fig. 9.** *Lipmanella irregularis* (Cleve, 1899). Lectotype SMHM Type # 6113. Cleve slide # 7 (H37/3). **fig. 10.** *Lipmanella irregularis* (Cleve, 1899). Original figure Cleve (1899, pl. 4, fig. 1). **fig. 11.** *Acanthocorys umbellifera* (Haeckel, 1862). Cleve slide #13 (K34/1). **fig. 12.** *Euscenium corynephorum* Jørgensen, 1900. Cleve slide #1 (P38/4). Misidentified as *Euscenium tricolpium* Haeckel by Cleve (1899). Scale bar 100 μm.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is associated only with deep-water samples. Good specimens are found on Cleve slide #33 (N42/2 and J34/0) as well as on slide #4 (Q44/1).

Botryostrobus auritus-australis (Ehrenberg, 1844*a* & *b*) group
(Pl. 9, figs 8–9)

1844*a* *Lithocampe aurita* Ehrenberg: 84.
1844*b* *Lithocampe australis* Ehrenberg: 187.
1854 *Eucyrtidium auritum* (Ehrenberg); Ehrenberg: pl. 22, fig. 25.
1854 *Eucyrtidium australe* (Ehrenberg); Ehrenberg: pl. 35A, 21, fig. 18.
1899 *Lithomitra australis* (Ehrenberg); Cleve: 30; pl. 2, figs 5–6.
1971 *Artostrobium auritum* (Ehrenberg) group; Riedel & Sanfilippo: 1599; pl. 1H, figs 5–7.
1972 *Botryostrobus auritus* (Ehrenberg) group; Petrushevskaya & Kozlova: 539; pl. 24, figs 15–18.
1972 *Botryostrobus australis* (Ehrenberg) group; Petrushevskaya & Kozlova: 539; pl. 24, figs 12–14.
1977 *Botryostrobus auritus-australis* (Ehrenberg, 1844*a* & *b*) group; Nigrini: 246–248; pl. 1, figs 2–5.

Text by Cleve (1899)

Lithomitra australis (EHR.)? – The shell Pl. II, fig. 5 seems to be the upper joints of *Eucyrtidium australe* EHB. From the South Polar ice (Microg. 35 A XXI, f. 18). It was found very rarely in the haul 29–30 VII. Lat. N. 78° 13′. Long. W. 02° 58′W. 2,600 m.

Fig. 6, Pl. II represents a nearly related form from the same gathering.

Remarks. No complete and well-developed specimens have been observed in Cleve's material. Cleve illustrated two specimens, according to him closely related, which he doubtfully relates to *Eucyrtidium australe* Ehrenberg. Ehrenberg (1844*a, b*) described two species, *Lithocampe aurita* and *Lithocampe australis*, which he illustrated in 1854 as *Eucyrtidium auritum* (Ehrenberg, 1844*a*) in Ehrenberg (1854, pl. 22, fig. 25), and *Eucyrtidium australe* (Ehrenberg, 1844*b*) in Ehrenberg (1854, pl. 35A, 21, fig. 18). At the same time he moved the two species from the genus *Lithocampe* to the genus *Eucyrtidium*. These two species have caused a lot of identification problems and no good criteria for separation have been proposed. Riedel & Sanfilippo (1971) suggested the *Artostrobium auritum* group to be appropriate, Petrushevskaya & Kozlova (1972) suggested the *Botryostrobus auritus* group, while Nigrini (1977) finally suggested the *Botryostrobus auritus-australis* (Ehrenberg) group, an identification now commonly used. Also Schröder (1914) questioned Cleve's identification and referred to it as *Lithomitra* sp. Cleve. As the *Botryostrobus auritus-australis* (Ehrenberg) group is rather rare in the Nordic seas, another opinion could be that this is an undeveloped specimen of *Lithocampe platycephala* Ehrenberg, 1873, a frequent but never common species in the Norwegian Sea surface sediments, see Bjørklund & Kruglikova (2003) as well as www. Radiolaria.org. We cannot with certainty identify the broken specimen found on Cleve slide #3 (N37/3), but we are of the opinion that Cleve's identification is as good as anybody else's. We therefore suggest this specimen be identified as *Botryostrobus auritus-australis* (Ehrenberg) group, as suggested by Nigrini (1977).

Corocalyptra craspedota (Jørgensen, 1900)
(Pl. 6, fig. 19a, b)
non Theocalyptra cornuta (Bailey, 1856); Cleve, 1899: 33
(misidentification).

1900 *Theocalyptra craspedota* Jørgensen: not figured.
1905 *Clathrocyclas craspedota* (Jørgensen, 1900); Jørgensen: pl. 17, figs 98–100.
1914 *Corocalyptra craspedota* (Jørgensen, 1900); Schröder: 122–123; figs 87–90.
1976*a* *Corocalyptra craspedota* (Jørgensen, 1900); Bjørklund: pl. 9, figs 11–15.
1995 *Corocalyptra craspedota* (Jørgensen, 1900); Schröder-Ritzrau: pl. 5, fig. 2.
2003 *Corocalyptra craspedota* (Jørgensen, 1900); Cortese *et al.*: pl. 4, figs 27–28.
2003 *Corocalyptra craspedota* (Jørgensen, 1900); Bjørklund & Kruglikova: pl. 6, fig. 9.

Text by Cleve (1899)

Theocalyptra cornuta Bail.

Length of cephalis 0,02, of thorax 0,08, of abdomen 0,01 mm. Diameter of the opening 0,14 mm. Diam. of the largest pores 0,014 mm.

Deep-sea hauls:

Date	Lat. N.	Long.	Depth.	Fq.
29–30 VII	78° 13′	02° 58′ W	2,600 m	*r*
27 VIII	79° 58′	09° 35′E	400–0 m	*r*
1 IX	75° 50′	15° 25′ E	325–0 m	*r*

Habitat: Kamchatka (BAIL.), Greenland (EHR.).

Remarks. Itaki & Bjørklund (2006) re-examined Bailey's (1856) types and defined both lecto- and paralectotypes of what Bailey named *Halicalyptra*? *cornuta*, which Kruglikova (1969) referred to as *Cycladophora cornuta* (Bailey). Cleve (1899) refers to *Theocalyptra cornuta* Bailey, but the specimens circled (Cleve slide #1 (L37/1) and slide #12 (N37/0)) are misidentification of Bailey's species, and are recognized by us as *Clathrocyclas* (*Theocalyptra*) *craspedota* (Jørgensen, 1900). Schröder (1914)

Explanation of Plate 11. fig. 1. *Challengeron diodon* Haeckel, 1887. Cleve slide #27 (K38/1). **fig. 2.** *Challengeron diodon* Haeckel, 1887. Cleve slide #27 (M33/1). **fig. 3.** *Challengeron diodon* Haeckel, 1887. Original figure by Cleve (1899, pl. 1, fig. 9a). **fig. 4.** *Euphysetta nathorstii* Cleve, 1899. Paralectotype SMNH Type # 6121. Cleve slide #28 (M36/2). **fig. 5.** *Lirella melo* (Cleve, 1899). Lectotype SMNH Type # 6117. Same specimen as figure 6, drawn by Cleve. Cleve slide #24 (N36/2). **fig. 6.** *Lirella melo* (Cleve, 1899). Original figure of Cleve (1899, pl. 1, fig. 8). **fig. 7.** *Challengeron diodon* Haeckel, 1887. Cleve slide #34 (S38/0). **fig. 8.** *Euphysetta nathorstii* Cleve, 1899. Original figure of Cleve (1899, pl. 2, fig. 3). **fig. 9.** *Euphysetta nathorstii* Cleve, 1899. Lectotype SMNH Type # 6114, Cleve slide #16 (M38/2). **fig. 10.** *Protocystis harstonii* (Murray, 1885). Cleve slide #19 (P32/0). **fig. 11.** *Protocystis tridens* (Haeckel, 1887). Cleve slide #8 (Q30/1). **fig. 12.** *Porospathis holostoma* (Cleve, 1899). Lectotype SMNH Type # 6130, Cleve slide #36 (P38/0). **fig. 13.** *Porospathis holostoma* (Cleve, 1899). Paralectotype SMNH Type # 6115, Cleve slide #19 (M38/0). **fig. 14.** *Porospathis holostoma* (Cleve, 1899). Original drawing by Cleve (1899, pl. 2, fig. 4). Scale bar 100 µm.

Explanation of Plate 12. Cleve's slides at the Swedish Museum of Natural History (SMNH), Stockholm.

Explanation of Plate 13. Cleve's slides at the Swedish Museum of Natural History (SMHM), Stockholm.

referred to it as *Corocalyptra craspedota*. Petrushevskaya (1971) emended Haeckel's genus *Eucecryphalus* to also include *Corocalyptra craspedota*, an emendation not followed herein. In August 2010 this species was found in the plankton north of Spitsbergen at 81°18′N and 21°58′E (Bjørklund & Kruglikova, unpublished data).

It is important to point out that when Petrushevskaya (1968) discussed *Cycladophora davisiana* and added two new subspecies, she mentioned that *C. davisiana cornutiodes* very much resembled the north Pacific form *Theocalyptra cornuta*, having a narrow conical thorax outline. In contrast, *Corocalyptra craspedota* has a wide conical thorax outline (Pl. 6, fig. 19), see also www. Radiolaria.org.

Cycladophora davisiana (Ehrenberg, 1862)
(Pl. 10, figs 1–7)

1862 *Cycladophora* (?) *davisiana* Ehrenberg: 297.
1873 *Pterocodon davisianus* (Ehrenberg, 1862); Ehrenberg: pl. 2, fig. 10.
1873 *Cycladophora* (?) *davisiana* (Ehrenberg, 1862); Ehrenberg: pl. 2, fig. 11.
1899 *Stichopilium davisianum* (Ehrenberg, 1862); Cleve: 33; pl. 4, fig. 6.

Text by Cleve (1899)

Stichopilium davisianum (EHB.) – Pl. IV, fig. 6.

Several specimens in the deep sea hauls 29–30 VII. Lat. 78° 13′. Long. W. 02° 58′. – 2,600 m and 1 IX. Lat. 75° 50′. Long. E. 15° 25′. -325–0 m.

Habitat: Greenland, abyssal.

Remarks. *Cycladophora davisiana* is regarded as a cosmopolitan species, associated with deep waters. In Cleve's material this species is regularly found, but only in the deep sea hauls (between 2600 and 500 m). This species is questionable as its morphology shows rather great variability, and it would therefore be better to refer to it as the *C. davisiana* group. The morphological variability seems to be of a regional nature, but whether these differences represent different species or ecotypes is still unresolved. All recent publications treat all the different morphotypes as one and the same species. Because this species is one of the most extensively used taxa in palaeoceanographical research, better understanding of the distribution of the different morphological groups of this species may give a better interpretation of changing ecological and oceanographical conditions through time.

Euscenium corynephorum Jørgensen, 1900
(Pl. 10, fig. 12a, b)

non Euscenium tricolpium Haeckel, 1887; Cleve, 1899: 29 (misidentification).
1900 *Euscenium corynephorum* Jørgensen: 77–78.
1905 *Euscenium corynephorum* Jørgensen, 1900; Jørgensen: 133–134; pl. 15, fig. 70.
1914 *Euscenium corynephorum* Jørgensen, 1900; Schröder: 93–95; figs 40–43.
1976*a Euscenium* (?) *corynephorum* Jørgensen, 1900; Bjørklund: pl. 7, figs 1–4.

Text by Cleve (1899)

Euscenium tricolpium HKL.

Deep-sea haul: 29–30 VII. Lat. N. 78° 13′. Long. W. 02° 58′W. Fq. *rr*. Depth 2,600 m.

Habitat: Central Pacific Ocean, abyssal (HKL.). – Northern Atlantic, between Shetland and Norway, surface (March 1898 CL.).

Remarks. The name *Euscenium tricolpium* is used on Cleve slide #1 (P38/4) and circled. This species is misidentified by Cleve. Jørgensen (1900) recognized *Euscenium tricolpium*, but referred to it as *Cladoscenium tricolpium* (Haeckel). By comparing the circled specimen identified by Cleve (our Pl. 10, fig. 12a, b) as *Euscenium tricolpium* Haeckel, it is evident that in all aspects it corresponds to what Jørgensen (1905, pl. 15, fig. 70) described as *Euscenium corynephorum*. For comparison, Jørgensen (1905, pl. 15, figs 71–72) illustrates the real *Euscenium tricolpium*, but now in a different genus as *Cladoscenium tricolpium*.

Lithomitra lineata (Ehrenberg, 1839)
(Pl. 9, figs 12a, b, 13–14)

1839 *Lithocampe lineata* Ehrenberg: 130 (not figured).
1854 *Lithocampe lineata* Ehrenberg, 1839; Ehrenberg: pl. 22, fig. 26.
1899 *Lithomitra lineata* (Ehrenberg, 1839); Cleve: 30; pl. 2, fig. 7.
1974 *Lithomitra lineata* (Ehrenberg, 1839); Petrushevskaya & Bjørklund: fig. 3.
2003 *Lithomitra lineata* (Ehrenberg, 1839); Bjørklund & Kruglikova: pl. 6, figs 12–14.

Text by Cleve (1899)

L. lineata (EHB.)

Pl. II, fig. 7.

Deep-sea hauls:

Date	Lat. N.	Long.	Depth.	Fq.	Pl.
29–30 VII.	78° 13′	02° 58′W	2,600 m.	*r*	*S C*
27 VIII	79° 58′	09° 35′E	400–0 m	*r*	*S C*
5 IX	71° 50′	19° 2′E	230–0 m	*r*	*S*

Habitat: Mediterranean, Atlantic, Indian and Pacific Oceans (HKL.).

Remarks. A good example is found on Cleve slide #32 (N38/2), our Plate 9, fig. 12a, b. The historical usages of the species complex names *Lithocampe lineata* Ehrenberg, 1839, *Eucyrtidium hyperboreum* Bailey, 1856 and *Eucyrtidium lineatum arachneum* Ehrenberg, 1862 can all be assigned to the genus *Lithomitra*. It is clear that Ehrenberg distinguished two variations of this species, namely *L. lineata lineata* and *L. l. arachnea*, based on surface ornamentation. In addition Ehrenberg (1862) reported on *L. hyperboreum* in the Greenland Sea. Riedel (1958) decided to use the name *L. arachnea* for this group, also referring to and including the Cleve (1899) specimens. Petrushevskaya & Bjørklund (1974), however, mapped the distribution of *L. lineata* in the North Atlantic and concluded that this species occurred with two forms, namely a northern form *L. l. lineata*, confined to the Labrador and Nordic seas, while a southern form *L. l. arachnea* was confined to the warm North Atlantic water. Whether *L. hyperboreum* (Bailey, 1856) is different from *L. l. lineata* (Ehrenberg, 1862) has not yet been settled. Itaki & Bjørklund (2006, p. 454) examined Bailey's (1856) slide collection and illustrated multiple of specimens of *L. hyperboreum* and concluded: '… we are of the opinion that Ehrenberg overlooked Bailey's description and *E. lineatum arachneum* should have been a synonym of *E. hyperboreum*, but this problem is outside the scope of this paper', and the same is the case for our present paper. Lastly Petrushevskaya (1971, pp. 30, 36, 207; 1981, pp. 30, 34, 270) refers to a species named *Lithomitra clevei* Petrushevskaya. This is a species that to our knowledge Petrushevskaya never described, but the name occurs in several of her papers, also as *Lithomitra lineata* (Ehrenebrg) *clevei* Petrushevskaya. What characterizes this species and its distribution pattern, and how it differs from *L. lineata lineata* (Ehrenberg) and *L. l. arachnea* (Ehrenebrg), as defined by Petrushevskaya, is still unknown. This species complex needs much work before we can reach a firm conclusion, but that is outside the scope of this paper.

Plagiacantha arachnoides Claparède & Lachmann, 1858
(Pl. 10, fig. 8a, b)

1858 *Plagiacantha arachnoides* Claparède & Lachmann: 462–463; pl. 22, figs 8–9.
1899 *Plectophora arachnoides* (Claparède & Lachmann, 1858); Cleve: 31 (no fig.).
1914 *Plagiacantha arachnoides* Claparède & Lachmann, 1858); Schröder: 78–80; figs 18–19.

Text by Cleve (1899)

Plectophora arachnoides (CLAP. & LACHM.) HKL. In this species I include also *Plagiacantha arachnoides* (CLAP. & LACHM.) HKL., which represents the young state. The net-work combining the spines is subject to great variation.

Surface:

Date	Lat. N.	Long.	Temp.	Sal.	Fq.	Pl.
10 VI	71° 10′	21° 31′E	6,71	35,20	r	C S
28 VIII	78° 23′	10° 23′E	6,06	34,91	r	T
29 VIII	77° 38′	11° 40′E	6	34,89	r	T S
30 VIII	77°	08° 3′E	5,65	35,03	r	S
30 VIII	76° 45	08° 45′E	5,34	34,92	r	S
31 VIII	76° 27′	10° 43′E	5,35	35,03	r	S
31 VIII	76° 12′	12° 18′E	6,26	35,15	r	S
1 IX	76° 2′	13° 8′E	6,61	35,18	r	S T
2 IX	75° 50′	15° 32′E	5,52	35,01	+	S T
2 IX	75° 21′	16° 47′E	5,64	35,12	r	T (S)
3 IX	74 42′	16,42′E	7,24	35,17	r	T (S)
4 IX	73° 36′	18° 50′E	7,06	35,03	r	S (Ns)
6 IX	70° 23′	20° 32′E	9,37	34,41	r	Tp (Ns)

Deep-sea hauls:

Date	Lat. N.	Long.	Depth.	Fq.	Pl.
1 VIII	76° 36′	12° 13′E	500–0 m	*r*	*T S*
27 VIII	79° 58′	09° 35′E	400–0 m	*r*	*S C*
1 IX	75° 50′	15° 25′E	325–0 m	*r*	*S*

Habitat: Coasts of Scotland and Norway. Newfoundland Banks (CL.).

Remarks. This species seems to be an important cold-water species. On Cleves's slide #27 (75°50′N, 15°25′E, 0–325 m, 1 Sept. 1898) *Plagiacantha arachnoides* was the second most abundant species with 29%, while the phaeodarian *Protocystis tridens* (36%) ranked first and *Amphimelissa setosa* (10%) ranked third. This is also in good agreement with two surface sediment samples from Balsfjorden in northern Norway, where *A. setosa* dominated with 42.9% and 35.2%, followed by *P. arachnoides* with 34.3% and 33.3%, respectively, clearly indicating its cold-water affinity. Specimens are found on Cleve slide #6 (J36/2 and N33/3) as well as on slides #10 (N37/0), #27 (Q36/3, Q36/4) and #31 (F37/3, figured in Pl. 10, fig. 8a, b), and numerous others in different growth stages.

Pseudodictyophimus clevei (Jørgensen, 1900)
(Pl. 9, figs 5a, b, 6–7)

non Dictyophimus gracilipes Bailey, 1856: 4; pl. 1, fig. 8.
1899 *Dictyophimus gracilipes* (Bailey, 1856); Cleve: 29; pl. 2, fig. 2.
1900 *Dictyophimus clevei* Jørgensen: 80; pl. 5, fig. 26.
1971 *Pseudodictyophimus clevei* (Jørgensen, 1900); Petrushevskaya: pls 47–49.

Text by Cleve (1899)

Dictyophimus gracilipes BAIL. *Cephalis* hemispherical, with a single stout horn of variable length. Pores rounded. *Thorax* a three-sided smooth pyramid, with three decurrent ribs, prolonged in long, smooth three-sided feet. Pores rounded, irregular, decreasing in size towards the cephalis.

Cephalis 0,02 mm. long; horn 0,04 – 0,05 mm. Thorax 0,05 mm. long and 0,07 mm. broad. Pl. II, fig. 2.

Deep-sea hauls:

Date	Lat. N.	Long.	Depth.	Fq.	Pl.
29–30 VII.	78° 13′	02° 58′W	2,600 m.	*r*	*C S*
1 VIII	76° 36′	12° 13′E	500–0 m	*r*	*T S*
27 VIII	79° 58′	09° 35′E	400–0 m	*r*	*C S*
1 IX	75° 50′	15° 25′E	325–0 m	*r*	*S*

Habitat: Kamtschatka anf the north Pacific Ocean.

Remarks. The circled specimen on Cleve slide #17 (G36/0) fits in all aspects the description of *Pseudodictyophimus clevei* (Jørgensen, 1900), and is identical to the specimen illustrated in Plate 9, fig. 6, which is the basis for Cleve's original drawing (our Pl. 9, fig. 7). There is still discussion on the taxonomic status of this species. Petrushevskaya (1971) erected the genus *Pseudodictyophimus*, wherein *Dictyophimus gracilipes* was placed. In the Arctic Ocean and its marginal seas there are several different forms with triangular to cylindrical apical, vertical and dorsal spines, and where the lateral (Ll and Lr) spines fork either outside or inside the thorax-wall, with an open or a closed thorax, with few or many cephalic spines, etc. (Bjørklund & Kruglikova, 2003). Whether these are separate species or just ecological variations of one and the same species is still to be determined. However, Jørgensen's (1900, 1905) discussions clearly stressed the importance of growth stages for this species, but acknowledge the very long and slender triangular feet and the very long vertical and apical spines, typical for *Pseudodictyophimus clevei*. Until the complex of morphological types has been sorted out, we agree that the northern form, described as *P. clevei* (Jørgensen, 1900) should be the formal name to use. Petrushevskaya (1968, p. 69) uses the genus *Dictyophimus* and concludes: (1) *D. clevei* is very similar to *D. gracilipes*, but differs from it both in the more distinct horn and in the general form of the shell with its characteristically curved 'legs', (2) … all specimens of *D. gracilipes* are characterized by slender, indistinct, short horn, while those of *D. clevei* have a tough, long, and faceted horn … and finally (3) therefore, species *D. gracilipes* and *D. clevei* should be differentiated … Also in Cleve's material are several forms, such as *P. gracilipes gracilipes, P. g. multispinus, P. g. bicornis* and *P. plathycephalus*. These forms are easy to recognize, however, there seems to be forms intergrading with each other, forms that at present are more difficult to identify. Petrushevskaya (1971) moved these species to the genus *Pseudodictyophimus*.

Sethoconus tabulatus (Ehrenberg, 1873)
(Pl. 9, figs 10–11)

1873 *Cycladophora tabulatus* Ehrenberg: pl. 4, fig. 18.
1899 *Sethoconus tabulatus* (Ehrenberg, 1873); Cleve: 33; pl. 4, fig. 2.
2003 *Sethoconus tabulatus* (Ehrenberg 1873); Bjørklund & Kruglikova: pl. 6, fig. 10.

Text by Cleve (1899)

Sethoconus tabulatus (EHB.) HKL.

Cephalis 0,013 mm. long. Thorax in length 0,06 mm., in breadth 0,045 mm. Largest pores 0,008 mm. in diameter. Cephalis with one delicate horn and several small bristles.

Pl. IV, fig. 2.

This species was found by EHRENBERG in the abyssal depths of the Caribbean sea and by the Challenger Expedition in the abyssal depths between Ascension and Sierra Leone was found in the haul 29–30 VII. Lat. 78° 13′. Long. W. 02° 58′. – 2,600 m.

Remarks. This species is rare in Cleve's material, but consistently present in deep-water plankton hauls. According to previous records this species has probably a cosmopolitan distribution. Petrushevskaya (1968, p. 96) gives a summary of its distribution to be essentially in the North Atlantic (Ehrenberg, 1873; Cleve, 1899), Arctic Ocean (Hülsemann, 1963), while in her own material it is reported from the Indian and Pacific sectors of the Antarctic, with some tests also found in the tropical regions.

Order **Phaeodaria**
Challengeron diodon Haeckel, 1887
(Pl. 11, figs 1–3, 7)

1887 *Challengeron diodon* Haeckel: 1654; pl. 99, fig. 6.
1899 *Challengeron nathorstii* Cleve: 28; pl. 1, fig. 9a, b structure (detail).
1900 *Challengeron heteracanthum* Jørgensen: 91–92; pl. 2, fig. 15, pl. 3, figs 16–17.
1901 *Challengeron diodon* Haeckel, 1887; Borgert: 30; fig. 34.
1905 *Challengeron diodon* Haeckel, 1887; Jørgensen: 141.
1911 *Challengeron diodon* Haeckel, 1887; Borgert: 448; pl. 33, figs 10–11.
1974 *Challengeron diodon* Haeckel, 1887; Bjørklund: 28–29; fig. 10a–i.
1981 *Challengeranium diodon* (Haeckel, 1887); Takahashi: 288; pl. 52, figs 11–16.

Original description of *C. diodon* of Haeckel (1887)
Shell oval, slightly compressed, with a single straight conical spine on the aboral pole, half as long as the radius. Peristome short and broad, collar-shaped, about twice as brood as long, and half as long as the radius, obliquely inclined over the mouth, with two divergent straight teeth, which are conical and longer than the shell-radius; beyond each tooth a large ovate hole in the wall of the peristome.

Original description of *C. nathorstii* of Cleve (1899)

Shell ovate to subspherical, with a single spine at the apical pole, as long as the radius of the shell or longer. Diameter of the mouth half as long as the diameter of the shell. Structure: regular hexagonal alveoli, quincuncially arranged in obliquely decussating rows (3 in 0,01 mm.). Peristome finely punctate, with two long and pointed, hollow, almost parallel horns, and below each of them a triangular or ovate hole.

Diameter of shell 0,06 to 0,08 mm. Pl. 1, f. 9 *a*. Fig. 9 *b* structure.

The nearest relative is *C. diodon* from the south-eastern Pacific Ocean.

Type. No type has been erected, as what Cleve described as *Challengeron nathorstii* is a repetitive description of *C. diodon*, consequently none of the types indicated (circled on slides by Cleve) are valid.

Remarks. *Challengeron nathorstii* is an interesting case. Cleve was certainly aware of *C. diodon* as its closest relative. It is not possible for us to identify the difference between Haeckel's description of *C. diodon* and Cleve's description of *C. nathorstii.* In the waters off Bergen Jørgensen (1900) described *C. heteracanthum*, differing from the two former species by having three to four large, narrow, radial pointing conical spines around the apical spine. Additionally, some smaller spines are also located on the bridge between the two main oral spines. Borgert (1901) synonymized these three species, with which Jørgensen (1905, p. 141) had no problem as he states: 'On more weakly developed (probably young) specimens, the characteristic byspines are wanting. It is therefore certainly most practical to do as Borgert has done and consider as one species, *Challengeron diodon, C. heteracanthum* and *C. Nathorstii* CL'. Looking at our Plate 11, figs 1–3 and fig. 7, these specimens are all identical and fit Cleve's description, but also Haeckel's description. However, looking at Plate 11, fig. 7 it can be seen easily that here we have additional apical spines, and also some lesser developed spines on the bridge, fitting Jørgensen's description – in other words an adult stage with well-developed spines. We feel, as Borgert (1901) and Jørgensen (1905), that Jørgensen's (1900) form is an adult stage of *C. diodon*. Furthermore, Cleve's form is regarded as a juvenile form and a synonym of *C. diodon*.

Finally, Takahashi (1981, p. 287) argued that '… Peristome with two fenestrated perforations. Two oral spines. An apical spine often surrounded by secondary spines' better fitted the definition of genus *Challengeranium* Haecker (1908). However, the secondary spines defining this new genus are already included in the expanded definition of Borgert (1901) and, as also interpreted and argued by

Jørgensen (1905), the secondary spines are a sign of adult forms of *C. diodon*. This was also noticed by Borgert (1911) who also stated that the shell had one aboral main spine, which is usually surrounded by a group of smaller spines. The peristome is collar-shaped, with two simple or multi-pointed spines at the rim of the peristome. The peristome has occasionally two window-like openings. In our specimens the large pores are always at the peristome.

Protocystis harstonii (Murray, 1885)
(Pl. 11, fig. 10)

1885 *Challengeria harstoni* Murray: 226; pl. A, fig. 14a.
1887 *Challengeria harstoni* Murray, 1885; Haeckel: 1650.
1899 *Challengeria harstonii* Murray, 1885; Cleve: 28.
1901 *Protocystis harstoni* (Murray, 1885); Borgert: XV28; fig. 30.
1976*a* *Protocystis harstoni* (Murray, 1885); Bjørklund: pl. 12, figs 5–7.
1981 *Protocystis harstoni* (Murray, 1885); Takahashi & Honjo: pl. 11, fig. 11.
1987 *Protocystis harstoni* (Murray, 1885); Swanberg & Bjørklund: fig. 4M.

Text by Cleve (1899)

Challengeria Harstonii J. MURRAY

Deep-sea hauls:

Date	Lat. N.	Long.	Depth.	Fq.	Pl.
29–30 VII	78° 13′	02° 58′W	2,600–0 m	*r*	*S C*
27 VIII	79° 58′	09° 35′E	400–0 m	*r*	*C S*
1 IX	75° 50′	15° 25′E	325–0 m	*r*	*S*

Habitat: The abyssal depths east of Japan.

Remarks. Cleve gives no description of this species but he has circled one specimen on Cleve slide #9 (P34/0), obliquely positioned, but easily recognizable. Otherwise this species is rare on Cleve's slides. The figured specimen is from Cleve slide #19 (P32/0).

Protocystis tridens (Haeckel, 1887)
(Pl. 11, fig. 11)

1887 *Challengeria tridens* Haeckel: 1651, not figured.
1899 *Challengeria tridens* Haeckel, 1887; Cleve: 28, not figured.
1901 *Protocystis tridens* (Haeckel, 1887); Borgert: 29; fig. 33.
1976*a* *Protocystis tridens* (Haeckel, 1887); Bjørklund: pl. 12, figs 1–3.

Text by Cleve (1899)

C. tridens HKL.

Surface:

Date	Lat. N.	Long.	Temp.	Sal.	Fq.	Pl.
29 VIII	77° 38′	11° 40′E	6	34,89	*r*	*T S*
1 IX	76 20′	13 08′E	6,61	35,13	*r*	*T S*

Deep-sea hauls:

Date	Lat. N.	Long.	Depth.	Fq.	Pl.
29–30 VII.	78° 13′	02° 58′W	2,600 m.	*r*	*C S*
27 VIII	79° 58′	09° 35′E	400–0 m	*r*	*C S*
1 IX	75° 50′	15° 25′E	325–0 m	*r*	*S*
5 IX	71° 50′	19° 2′E	230–0 m	*r*	

Habitat: Färöe Channel.

Remarks. Cleve gave no description of *P. tridens* but he circled 17 specimens on Cleve slide #9, there is a total of 40 *P. tridens* on the slide. Also Cleve slide #8 is rich in *P. tridens* (#8 (Q39/1) Plate 11, fig. 11).

CONCLUSIONS

We have received from the Museum of Natural History, Stockholm, Cleve's 39 slides from the Swedish Expedition to Spitsbergen in 1898. Cleve (1900*a*) gave a rather detailed list of 44 species, but with rather poor descriptions and illustrations of the radiolarian fauna that he observed (five acantharians, not treated herein; 11 phaeodarians; eight spumellarians; 20 nassellarians). We have been able to identify 26 of 28 polycystine species, and six out of eight phaeodarian species. Cleve, as most of the radiolarian scientists at that time, did not assign any holotypes for his new species, but based on his short descriptions, his sketchy illustrations and his radiolarian slides, we were able to recognize most of Cleve's listed species. Our purpose was to identify the new species defined in Cleve (1900*a*), make good illustrations and assign lectotypes and for some species also paralectotypes. We have defined lectotypes for 14 species and paralectotypes for seven species. All new types and all other identified species have been illustrated and provided with information on which slide these specimens were found, accompanied with the England-finder coordinates. Most of the slides are in good condition; however, some have a 'precipitation' making the Canada balsam opaque and the specimens therefore difficult to clearly photograph. Some of the slides are devoted to individual specimens, but most of the slides seem to be oxidized (H_2O_2?) plankton showing the whole fauna. The different faunal slides have great variability in species composition, indicating rapid faunal changes, caused by either sampling different water masses or an effect of patchiness. The faunal slides were prepared from vertical plankton tows, from different depths to the surface. Our re-examination of Cleve's slides should make this important collection more accessible for the general radiolarian student and we hope the illustrations herein will be of general use for ongoing research and future studies.

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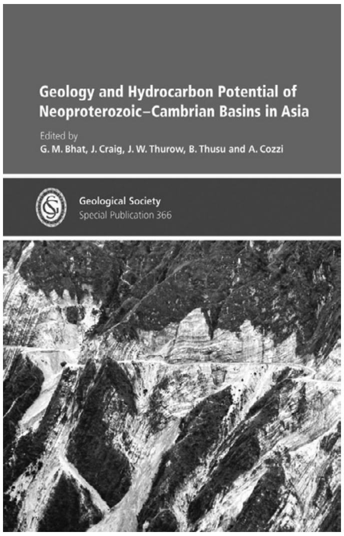

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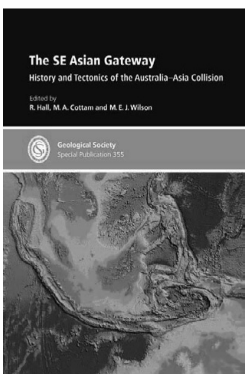

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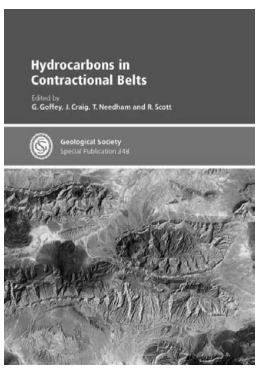

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