Oceanological and Hydrobiological Studies
Vol. XXXII, No. 3

Institute of Oceanography (19-27) University of Gdańsk
2003

Research Article

ARE ALL REPORTS ON DIATOMS OLDER THAN CRETACEOUS NOT CREDIBLE ?

JADWIGA SIEMIŃSKA

W. Szafer Institute of Botany, Polish Academy of Sciences
ul. Lubicz 46, 31-512 Kraków, Poland.
siem@ ib-pan.krakow.pl

Key words: fossil Bacillariophyceae, evolution

Abstract

A review of approximately 30 published reports on fossil diatoms older than Cretaceous is presented. Together with the Proterozoic diatom remnants found in Poland thirty years ago, the latest unquestionable finds of Cambrian diatoms (Vologdin 1962, Allison and Hilgest 1986, Gapeev 1992, 1995) and the recent report of the partial diatom provenance of siliceous grains in Late Devonian shales (Schieber *et al*. 2000) make these discoveries reliable.

INTRODUCTION

The prevailing opinion is that the oldest diatoms date back to the Lower and Middle Cretaceous (Round *et al*. 1990, Hoek and Jahns 1998, Nikolaev and Harwood 2000). Some paleontologists and diatomists consider the Lower Jurassic species *Pyxidicula bollensis* and *P. liassica* to be the oldest. Although the results of molecular research have shifted the age of diatoms somewhat backward in time, according to Medlin *et al.* (2000), it is unlikely that diatoms existed below the border separating the Permian from the Triassic.

KNOWN DISCOVERIES

Galionella halophila [*Melosira* ?] was found by Ehrenberg (1854) in a Lower Triassic salt crystal from a Berchtesgaden salt mine in Germany. More than 30 reports of findings of diatoms older than the Cretaceous have been published. These specimens were found in Jurassic, Triassic, Carboniferous, Devonian, Silurian and Ordovician, and then also in Cambrian and Proterozoic. They were found in fossil sponges and coprolites, sandstones, shales, cherts, limestones and pit-coals. These reports often had no illustrative proof, although they were sometimes accompanied by very primitive or traditional drawings. Sometimes indistinct photographs were included. Not always was information on the size of the specimens provided.

Sometimes only fragments of diatoms or rare frustules were found. This is the case with the following: Jurassic *Coscinodiscus* or *Dictyolampra* (Rüst 1885); *Pyxidicula annulata* (Rothpletz 1900a, b); Devonian centric diatoms (White 1862); distorted Silurian frustules of the *Navicula* type (Rothpletz 1880); Ordovician diatoms from Jutland shales (Edwards 1906). According to Gapeev (1995), Jakovlev reported finding diatoms in the Upper Permian limestone from Sardinia, and Popov and Lutchicky did so in the Carboniferous coals of Kusbas.

At other times several specimens of a few or many species were reported. Cayeux (1892) used very high magnification to detect diatoms in thin sections of Jurassic (and Cretaceous) glauconite sandstones from the Paris Basin. They appeared in such quantities that they were lying on top of each other. Rothpletz (1896) described two abundant *Pyxidicula* species, previously mentioned in this paper, from German Jurassic sponges. Heinrich (1913) found many diatom species, both centric and pennatae, with *Aonoides* from Austria in the Upper Triassic lenticles.

Zanon (1929, 1930) published a long list of species, mostly from the Pennatae group, from Triassic Alpine shales and coals. He included descriptions and drawings, and they were chiefly species known from recent freshwaters. In his 1930 publication, he also reported and documented numerous freshwater species from Upper Permian Sardinia limestones.

Castracane (1876) used the very good incineration method on Carboniferous coal samples from England, and found well-preserved diatoms, mostly freshwater, in the ash. This method allowed him to investigate samples from the inside of coal fragments, and not from their surfaces. One of Castracane's samples was reexamined by Zanon, who dissolved the fragment in acid and certified the discovery (Zanon and Tuffi 1928). Zanon (1930) also soluted samples of coal from various locations in England in acid and found freshwater diatoms exclusively in the sediment. In Poland diatoms were repeatedly found by the late Professor Tadeusz Bocheński when he investigated Carboniferous fern fossils. These findings were never published as he did not want to expose himself to objections that they were only later contamination.

Grüss (1928) noted diatoms of the *Nitzschia* and *Hantzschia* type in thin microsections made from Devonian coal shales collected from Bear Island. His publication includes descriptions and poor quality drawings and photographs.

Schieber *et al*. (2000) found siliceous grains of organic origin in Lower Devonian black shales from the eastern U.S.A. which very likely also originate from diatoms. Although the diatoms were accompanied by radiolaria, spicules of fossil sponges and other fossil organisms, such reports gave rise to stormy discussions among geologists, diatomists and evolutionists. They were not considered credible because the numerous diatom species found belonged chiefly to the Pennatae group and were characteristic of present freshwaters. There was too great a discrepancy with the Cretaceous diatoms which belonged to the Centricae group and had many extinct species and genera.

In reference to publications concerning fossil diatoms discovered from the Jurassic to the Ordovician (not all which would have been known to him), Pia (1931) stated that none of the finds older than the Cretaceous are credible. He postulated that they were the result of the incorrect age determination of deposits from which the diatoms came, or they were the result of various mistakes in the investigation methods. In his opinion, the diatoms or the remains found could also have entered the interior of the rock by various slits or pores. The whole frustules found were particularly suspect in light of the conviction that siliceous organic structures undergo very rapid dissolution, especially in alkaline limestone deposits. Although he appreciated the scrupulousness and caution employed during the investigations by some scientists, for instance Castracane and Zanon, Pia sustained these objections, and his attitude shaped the prevalent opinion among the scientific community.

Later years saw the publication of reports the discoveries of even older Cambrian diatoms. Though quite recent and primarily well documented, to date they have escaped the notice of the global scientific community because they were published in Russian in geological journals which are difficult to access.

Vologdin (1962) found specimens which he did not dare call diatoms in thin transparent sections of Middle and Lower Cambrian limestones which occur in the Tannu-Ola in the Tuva mountain range of an Asian republic near Mongolia. In Russian only, the author described 6 genera and 9 species which he included in the new Disceriaceae family, but which he did not describe. Structures characteristic of diatoms are visible in the photographs of frustules cut in various ways, which are included.

Next, Ergaliev and Azerbaev (1986) found fragments of diatoms in thin sections made from the Cambrian “fteanites” (siliceous rocks enclosing graphite) which occur in the Great Karatau and the Djebaglin Mountains. They wrote that the fragments were similar to contemporary diatoms in that they had elongated or circular pores set in parallel rows. They saw them on replica films taken of the surface of the freshly broken rock investigated with a transmission electron microscope (TEM). However, no written or visual documentation was included in this publication.

At the same time, Allison and Hilgest (1986) presented photos of siliceous specimens distinctly similar to centric diatoms; they were found in thin sections of early Cambrian north-west Canadian limestones. They were distributed only on 35 sections, and none were discovered on another 165 sections.

Following this, Gapeev (1992, 1995) discovered diatoms in thin sections of Early Cambrian phosphorite shales from the Little Karatau, which contains the same siliceous horizon as the Great Karatau and the Djebaglin Mountains. The diatoms, which he initially named problematics, belonged to the Pennatae group. Although they occurred in masses, they were very difficult to discern as they lay very densely and their insides were also filled with silica. It must have been exceedingly difficult to find them under a light microscope (with crossed nicoles) and to photograph their sections. Undoubtedly, it was indeed difficult to detect the outlines of diatoms since never before had anyone paid attention to them, and these phosphorites had been under investigation, as Gapeev wrote, for more than fifty years.

Longitudinal sections showed shapes also typical of recent genera of freshwater diatoms. Their size was considerable and ranged from 70 to 300 (500) µm. Gapeev also photographed oblique sections, and on two cross-sections he noticed the overlapping of two valves which are so characteristic of diatom frustules.

The well-documented Cambrian diatom finds lend verisimilitude to earlier discoveries, to those from younger geological deposits as well as those from still older ones.

Jost (1968) found one siliceous microfossil in a sample taken from the Late Precambrian rocks from White Pine, Michigan, U.S.A. Judging by his description and photos, this was a remnant of a diatom which belonged to the *Cyclotella* genus in silica grains of the Precamrian paragneises of the Sowie Mountains in the Sudety Mountains of Poland.

Gunia (1981) found two organic remnants (60 and 100 µm in size) described as “*Problematica*”, and based on the photographs of them it is plausible that they were fragments of diatom frustules.

During studies of graphite crystals in Late Proterozoic black marble layers in Przeworno (Lower Silesia, Poland), 39 minute perforated fragments and the remnants of diatom frustules (approximately 1-25 x 1-10 µm in size) were found (Kwiecińska and Siemińska 1973, Kwiecińska 2000, Siemińska and Kwiecińska 2000). They were attached to the triafol and bioden replica films taken of the freshly broken surfaces of the pieces of the rock and discovered with a TEM under high magnification. They were located only in 16 preparations of 0.4 mm^2 each. No diatom remains were found in approximately 134 other preparations examined from 1972 to 1978.

Of the fragments found, three specimens were ascribed to the Centricae group - one as a new genus and species *Bolewskia reymanownae*, the other as a fragment with areoles characteristic of the genus *Coscinodiscus*. Nineteen fragments were assigned to Pennatae, and two belonged to Araphidae with the newly described *Protorhaphoneis.* Sixteen fragments were related to Raphidae – three of them to *Navicula* s.l. and as many as 13 to the genus *Nitzschia*.

A few diatom spores were also found and identified as a new species of the extinct Miocene *Xanthiopyxis* genus. Additionally, some cysts were discovered which may have been chrysophyte stomatocysts.

The density and porosity of the marble was checked to assuage doubts that the remnants could have entered the marble through microscopic pores or microfissures. Both values were very low; only cryptopores with a diameter of 8.8 nm (88 A) were detected and density ranged from 2.7334 to 2.7788 g/cc. These figures indicate unequivocally that the diatoms did not penetrate the compact rock at a later period.

CONCLUSIONS

More than thirty reports on nearly forty discoveries of diatoms older than Cretaceous were published in the past century and a half. Today it is difficult to evaluate whether they are reliable. The discovery of diatom remnants which are unquestionably from Cambrian and Proterozoic deposits, however, indicates that diatoms were already living 430 million years earlier than had been previously thought.

Diatom remnants should be sought most vigorously in sedimentary rocks which contain graphite (carbon), quartz (silica) and phosphates, as these elements are, at least partially, what remains of dead cells. However, they are not found often. One method which can be recommended is the study of replicas under high magnification with a TEM. Since this method was successful with Cambrian and Proterozoic remnants, it might also be useful to certify that the Devonian silica grains discovered by Schieber *et al*. (2001) are of diatom origin. This method should be applied in a detailed study of the Cambrian deposits in the Little and Great Karatau, the Djebaglin Mountains and the Tannu Ola range.

By the Upper Proterozoic, the taxonomic composition of diatoms was very diversified in the genera and species of both the Centricae and Pennatae groups, and the latter had representatives both with and without developed raphes. This indicates that diatoms must have come into being still earlier and that Centricae were not necessarily the first ones. Some genera (*Coscinodiscus, Navicula* s.l., *Nitzschia)* have been represented from the Proterozoic to the present day. The simultaneous appearance of diatoms and the probable chrysophycean stomatocysts may support the theory of their close relationship.

At this point, it is worthwhile to recall the theory of Sedlak (1959, 1985) and Samoilov (according to Strelnikova 2000) that silica occurred abundantly and it was primarily utilized as the main component of the skeletons of the first organisms. Only later in the process of evolution did carbon (which has the same ion valence of 4+) more and more frequently replace silica, and carbonates entered the composition of plant and animal skeletons. This theory is also supported by Strelnikova who considers diatoms to be one of the oldest eukaryotic groups of organisms in the history of our planet.

REFERENCES

Allison C. W., Hilgest J. W., 1986, *Scale microfossils from the Early Cambrian of northwest Canada*, J. Paleontol., 60: 973-1015

Castracane F. conte, 1875, *Diatomaceae in the Carboniferous period*, Geol. Mag, London, 2, 414

Castracane F. conte, 1876, *Die Diatomaceen in der Kohlenperiode*, Jahrb. wiss. Botanik, Leipzig, 10, 1

Cayeux L., 1892, *Sur la présence de nombreuses Diatomées dans les gaizes jurassiques et crétacées du Bassin de Paris*, Ann. Soc. Géol. Nord, Lille, 20, 57-60

Edwards A. M., 1893, *The Diatomaceae of the Triassic (?) sandstone of New Jersey*, American Naturalist, Philadelphia, 27, 817

Edwards A. M., 1906, *The magnesian limestone of New Jersey and the search for Bacillaria in it. Nuova Notarisia*, Modena, 21, 174

Ehrenberg Ch. G., 1854, *Mikrogeologie, Das Erden und Felsen schaffende Wirken des unsichtbar kleinen selbstständigen Lebens auf der Erde*, Leipzig

Ergaliev G. Ch., Azebaev N. A., 1986, *Kambrijskaja sistema*, Bolshoj Karatau, [in:] *Geologija i Metallogenija Karatau*, T. 1, Nauka, Alma Ata,.35-40 (in Russian).

Gapeev A. P., 1992, *Problematiki iz ranne kembrijskich otlozhenij Malogo Karatau [On the discovery of diatom-like problematica in early Cambrian deposits of Maly Karatau]*. Paleontologicheskij Zhurnal, 1, 101-104 (in Russian)

Gapeev A. P., 1995, *Kembrijskie formy diatomovych vodoroslej v otlozhenijach Malogo Karatau?* [in:] *Litologia i poleznye iskopaemye*, 236-261 (in Russian)

Grüss J., 1928, *Zur Biologie devonischer Thallophyten*, Palaeobiologica, Wien und Leipzig, 1, 487-518, Tafel XXXIX, XL

Gunia T.**,** 1981, *Mikroflora z paragneisów Gór Sowich (Sudety), (Microflora from the paragneises of the Sowie Mountains, Sudety)*, Geologias Sudetica, 16, 2, 7-21, Pl. I-X.

Heinrich A., 1913, *Untersuchungen über die Mikrofauna des Hallstätter Kalkes*, Verhandl. Keiserl.-Königl. Geol. Reichsanstalt Wien, 225-234

Hoek C. van den, Mann D. G., Jahns H. M., 1998, *Algae, An introduction to phycology*, Cambridge University Press

Jost M., 1968, *Microfossils of problematic systematic position from Precambrian rocks at White Pine*, Michigan. Micropaleontologist, 14, 365-368

Kwiecińska B., 2000, *How the diatoms were found in the Proterozoic marbles at Przeworno*, [in:] *The origin and early evolution of the diatoms: fossil, molecular and biogeographical approaches*, Witkowski A. and Siemińska J. (eds), W. Szafer Institute of Botany, Polish Acad. Sci., Cracow, 75-95

Kwiecińska B., Siemińska J., 2000, *Diatoms Bolewskia reymanownae gen. nov. et sp. nov., Protorhaphoneis stanislai gen. nov. et sp. nov. and Xanthiopyxis polonica sp nov. from the Przeworno marbles in Poland*, Acta Palaeobot,. 40, 1, 3-8

Medlin L. K., Kooistra W. S. H. F., Schmid A.-M. M., 2000, *A review of the evolution of the diatoms - a total approach using molecules, morphology and geology*, [in:] *The origin and early evolution of the diatoms: fossil, molecular and biogeographical approaches*, Witkowski A. and Siemińska J. (eds), W. Szafer Institute of Botany, Polish Acad. Sci., Cracow, 13-35

Nikolaev V. A., Harwood D. M., 2000, *Diversity and system of classification centric diatoms*, [in:] *The origin and early evolution of the diatoms: fossil, molecular and biogeographical approaches*, Witkowski A. and Siemińska J. (eds) W. Szafer Institute of Botany, Polish Acad. Sci., Cracow, 37-53

Pantocsek J., 1889, *Beiträge zur Kenntnis der fossilen Bacillarien Ungarns*, II, Nagy-Tapolosány

Pia J., 1931, *Vorliassische Diatomeen ? Neues Jahrb. Mineral.*, Stuttgart: 107-131.

Rothpletz [A.], 1880, *Radiolarien, Diatomaceen und Sphärosomatiten im silurischen Kieselschiefer vom Langenstriegis im Sachsen*, Zeitschr. Deutsch. Geol. Ges., Berlin, 32, 3, 447-467, Taf. XXI

Rothpletz A., 1896 *Über die Flysch-Fucoiden und einige andere fossile Algen, sowie über liassische Diatomeen führende Hornschwämme*, Zeitschr. Deutsch. Geol. Ges., Berlin, 48, 1, 854-914, Taf. XXII-XXIV

Rothpletz A., 1900a, *Über einen neuen jurassischen Hornschwamm und die darin eingeschlossenen Diatomeen*, Zeitschr. Deutsch. Geol. Ges., Berlin, 52, 1, 152-160

Rothpletz A., 1900b, *Nachtrag zu meinem Aufsatz über einen neuen jurassischen Hornschwamm und die darin eingeschlossenen Diatomeen*, Zeitschr. Deutsch. Geol. Ges., Berlin, 52, 388-389

Round F. E., Crawford R. M., Mann D. G., 1990, *The diatoms. Biology & morphology of the genera*, Cambridge, University Press

Rüst, 1885, *Beiträge zur Kenntiss der fossilen Radiolarien aus Gesteinen des Jura*, Palaeontographica, 31, 272-321

Schieber J., Krinsley D., Riciputi L., 2000, *Diagenetic origin of quartz silt in mudstones and implications for silica cycling*, Nature, 406, 981-985

Sedlak W., 1959, *Ewolucja biochemiczna i teoria silicydów*, Roczniki Filozoficzne,7, 3, 69-112

Sedlak W., 1985, *Kierunek - początek życia; narodziny paleobiochemii krzemu (Direction – the origin of life – the birth of paleobiochemical silica)*, Katolicki Uniwersytet Lubelski, Lublin. (in Polish)

Siemińska J., 2000, *The discoveries of diatoms older than the Cretaceous*, [in:] *The origin and early evolution of the diatoms: fossil, molecular and biogeographical approaches*, Witkowski A. and Siemińska J. (eds), W. Szafer Institute of Botany, Polish Academy of Sciences, Cracow. 55-74

Siemińska J., Kwiecińska B., 2000, *The Protorozoic diatoms from the Przeworno marbles*, [in:] *The origin and early evolution of the diatoms: fossil, molecular and biogeographical approaches*, Witkowski A. and Siemińska J. (eds), W. Szafer Institute of Botany, Polish Academy of Sciences, Cracow, 97-121

Strelnikova N. I., 2000, *Silicium as the basis of existence of the diatoms - one of the oldest group of algae*, [in:] *The origin and early evolution of the diatoms: fossil, molecular and biogeographical approaches*, Witkowski A. and Siemińska J. (eds), W. Szafer Institute of Botany, Polish Academy of Sciences, Cracow, 7-11

Vologdin A. G., 1962, *Diatomoobraznye organizmy kembrija chrebta Tannu-Ola v Tuve*, Doklady Akademii Nauk SSSR, 146, 6, 908-912

White M. C., 1862, *Discovery of microscopic organisms in the siliceous nodules of the Paleozoic rocks of New York*, Amer. J. Sci., New Haven, 33, 2, 385-386

Zanon V., 1929, *Diatomee triassiche,* Atti Academie Nuovi Lincei, Roma, 14, 289-307.

Zanon V., 1930, *Diatomee del Permiano e del Carbonifero,* Mem. Acc. Nuovi Lincei, Roma, 14: 89-124

Zanon V., Tuffi R., 1928, *Le diatomee del carbon fossile*, Mem. Acc. Nuovi Lincei, Roma, 11, 235-263