

SEM Diaries - 40

An Introduction to Coccolithophores

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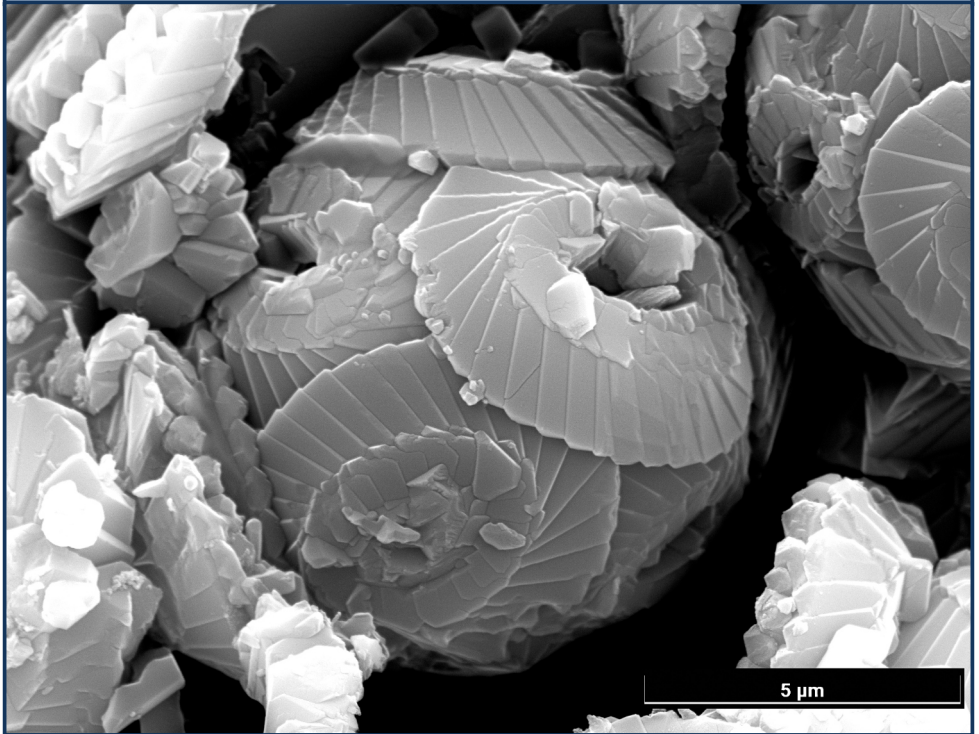


Fig. 1: Fossil Cocosphere from Freshwater Beds

While back now the Plymouth Electron Microscopy Centre ran a series of light-hearted webinars for interested but non-specialist students and lay people. The presenters would select a topic and generate images in real time on either their Jeol desktop SEM or alternatively something with a higher specification.

One such seminar was on diatoms and there was a bit of subject creep onto the

topic of coccoliths - a new word for me at the time. Apparently fossil versions are abundant in chalk cliffs, so I made a mental note that if I were ever near Dover I would collect some material. Some time later, as recounted in SEM Diaries - 32 [1], I actually came across some coccoliths when examining foram material dredged up from the Southern Ocean. Until recently, however, coccolithophores had eluded me.

Coccoliths, Coccolithophores and Coccospheres

So, what are coccolithophores, or indeed coccoliths? Well, coccolithophores are single-celled marine algae that bear a superficial resemblance to diatoms. They are between 5µm and 100µm in size (most often between 5µm and 10µm) and are photosynthetic, removing carbon dioxide from their environment and generating oxygen.

Unlike diatoms, which photosynthesise carbon dioxide into nutrients, coccolithophores convert much of the CO₂ into calcium carbonate (chalk), in the form of circular or elliptical discs (coccoliths) that surround and protect the cell by creating a spherical shell called a coccosphere (Figures 1,2). The fixation of CO₂ by coccolithophores plays an important role in the marine carbon cycle by influencing the efficiency of the biological carbon pump and the oceanic uptake of atmospheric CO₂.

Life Cycle

Reproduction can be asexual (haploid), where the coccolithophore reproduces by binary fission or it can be sexual (diploid) where the haploid cells can reproduce with other haploid cells. The life-cycle is described as “haplo-diplontic”. [The difference between haploid and diploid is that with haploid reproduction there is just one set of chromosomes, whereas with diploid reproduction there are two sets, one from each parent.]

As with other phytoplankton and despite their microscopic size, coccolithophores can exist in enormous “blooms”, visible in the ocean from space.

At or near the end of life for a coccolithophore the coccoliths detach themselves and fall to the ocean bed.

Preparing Specimens for SEM

A study of references will show many SEM images of individual coccolithophores, neatly isolated from their environment against a background of filter material (Figure 2). These are, of course, modern specimens gathered from the oceans. I have yet to collect any live specimens, relying exclusively on the fossil record, where the coccoliths (and sometimes coccolithophores) have been deposited in chalk beds or other geological features many millions of years ago.



Fig. 2: *Calcidiscus leptoporus*, scale bar 5µm [2]

My starting point was chalk, picked up in local fields and during a trip to the Yorkshire coast.

In the absence of guidance on preparation for electron microscopy I bashed the chalk samples with a hammer. Chalk is a very soft stone so it was easy to create small fragments, which I mounted onto a sticky carbon tab on an SEM stub. I sputter coated the resulting preparation with gold/palladium alloy then mounted the stub in the SEM and searched for anything resembling a coccolith. There was nothing of note on the fragments, carefully mounted on the stub, but interestingly I had more luck searching in the “dust” carried over with the rock

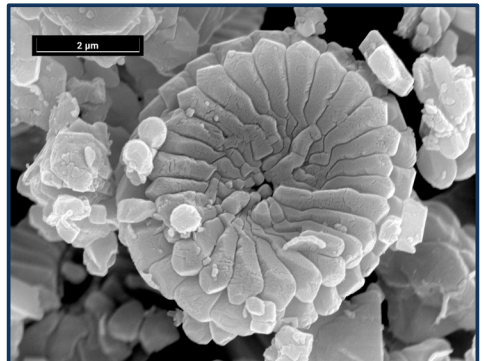


Fig. 3: Coccolith found in chalk (interior view)

fragments more “accidentally”, where I managed to find a few individual coccoliths. There was no sign of any coccolithophores, however.

I was later provided with a sample of rock from the Freshwater Steps Stone Band (near Chapman’s Pool, Dorset). This is limestone with a millimetre scale lamination (and much finer lamination on close examination), with an alternation of pale limestone and darker organic shale (Figures 4a and 4b).

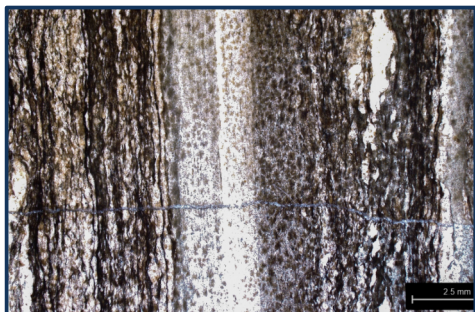
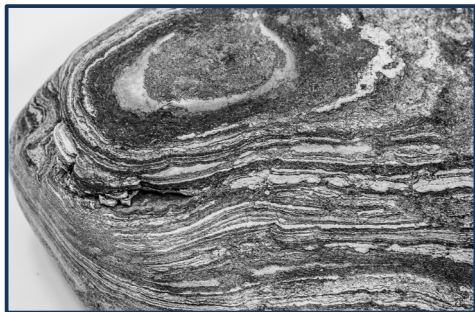


Fig. 4: a) top Sample of rock from Freshwater Steps. Field width approx 20 cm.
 b) bottom Macro photo of cut and polished section of the same rock. Field width 3.5 cm.

I applied the same two preparation methods used on the chalk sample to this specimen. As previously, the best images were from samples of dust rather than more substantial fragments. However, some faces of the fragments could be seen to be made up of a host of individual coccoliths, possibly having detached and fallen to the sea bed when coccolithophores reached the ends of their lives (Figures 5 and 6).

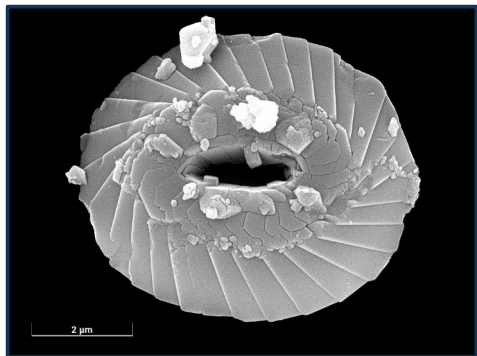


Fig. 5: Individual coccolith, Freshwater steps sample (probably from coccolithophore *Watznaueria fossacincta*)



Fig. 6: Coccolith “graveyard” from Freshwater steps sample

Also this time, in addition to many coccoliths, I was fortunate to find some complete coccolithophores, (Figure 1).

Coccoliths from the Southern Ocean

In SEM Diaries - 32 I showed images I had made of foraminifera collected in the Southern Ocean by my fossil friend Chris when he was a post-graduate student back in the 1970s. These were found attached to the legs of a sampling device lowered to a depth of the order of 1km. Some of the samples were almost pure foram material. I have no idea how old they were; they were loose material so presumably not fossilised, although I suspect they had been dead for a while!

On close inspection of one particular broken foram test (shell) under the SEM, I was very excited to locate an isolated coccolith closely followed by a heap of coccolith-rich debris. Figure 7, which also appeared in SEM Diaries - 32, shows a coccolith from that particular broken foram. Its shape is more truly round than that of the coccoliths from Freshwater Steps or Yorkshire chalk, suggesting that this is from a different species. In fact, there are around 200 different species of coccolithophore known.

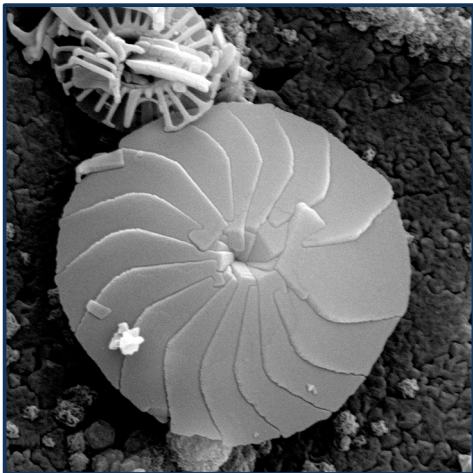


Fig. 7: Coccolith from the Southern Ocean, showing its circular shape (Possibly *Calcidiscus leptoporus* sp.) Field width $\sim 7\mu\text{m}$

Light Microscopy of Coccoliths

I have not tried imaging coccolithophores or coccoliths using light microscopy.

Figure 8 is a copy of Figure 5, but with dimensions superimposed. This shows that the width of the “petals” on a coccolithophore is of the order of 500nm. This is close to the resolution limit of a well set-up light microscope with a good

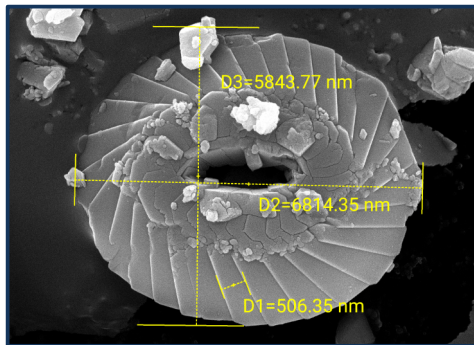


Fig. 8: Coccolith with key dimensions highlighted.

high numerical aperture oil immersion objective.

However, light microscopy was the only way to study coccolithophores and coccoliths prior to the availability of SEM. Reference 3 does show images of a variety of coccoliths from the Dorset Coast taken using crossed-polars and also phase contrast. The phase contrast images do give some indication of the overall shape of the coccoliths.

References

1. SEM Diaries - 32 Conferences, Lectures, and Coccoliths. Balsam Post 139, Pages 92-95, April 2023.
2. https://species.wikimedia.org/wiki/Calcidiscus_leptoporus#/media/File:Calcidiscus_leptoporus.png
This file is licensed under the Creative Commons Attribution-Share Alike 4.0 International license (<https://creativecommons.org/licenses/by-sa/4.0/deed.en>)
3. Fossils of the Kimmeridge Clay Formation, David Martill and Steve Etches (Editors). The Paleontological Association 2020 Page 370