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Thomas Henry Huxley and the strange case of *Bathybius haeckelii*; a possible alternative explanation

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INTRODUCTION

The curious story of *Bathybius haeckelii*, a supposed primitive life-form from the bed of the deep ocean "discovered" by Thomas Henry Huxley in 1868 and discredited only seven years later during the *Challenger* Expedition, has been told many times. Most of these accounts have been brief, simply recounting how Huxley had found a gelatinous material, which he thought was protoplasm, in samples from the deep Atlantic, and then how the *Challenger* chemist, John Young Buchanan, had come to the conclusion that *Bathybius* was nothing more than calcium sulphate which had been precipitated from the sea water in the samples by the alcohol used to preserve them (see, for instance, Hardy (1956) and Hubbard (1969)). A notable exception is the extensive and scholarly treatment of *Bathybius* by Rehbock (1975) who pointed out that previous accounts had also employed a degree of "jocularity which obscures the seriousness of the controversy and the zeal of the debaters". While recognizing the humourous aspects of the whole affair, Rehbock examined *Bathybius* in the context of the scientific climate of the 1860s and 1870s, amply demonstrating that although the concept was undoubtedly an embarrassing error, it fitted perfectly into the background of biological and geological thinking at that time.

The present paper offers evidence from recent observations which suggest that the long-accepted chemical explanation for the phenomenon on which Huxley based his description of *Bathybius* may not be the correct one. However, this in no way lessens either the seriousness of Huxley's error of interpretation or the validity of Rehbock's excellent analysis. In describing the background against which the recent results are presented I have therefore drawn freely on Rehbock's account, but for a much fuller and more critical assessment the reader is strongly recommended to consult the original.

ENTER BATHYBIUS

During June and July 1857 Lt Joseph Dayman R.N., in command of H.M. steam frigate *Cyclops* (Figure 1), undertook a surveying voyage from Valencia in Southern Ireland to Newfoundland and back to obtain a series of soundings in preparation for laying the first trans-Atlantic submarine telegraph cable (Dayman, 1858).

Dayman made 34 soundings, in depths down to 4300m (2400 fms), using a modified Brooke's apparatus (see McConnell, 1982) which, in addition to determining the depth, brought up small samples of the bottom sediments (Figure 2). These samples were sent for examination to T. H. Huxley, then palaeontologist at the London School of Mines. In accordance with Huxley's instructions, the samples had been preserved in "a tolerably strong
Figure 1. Joseph Dayman's sketch of H.M.S. Cyclops, reproduced from his narrative (Dayman, 1858).

Figure 2. Dayman's version of the Brooke sounder (left) in which, among other modifications, the original wire slings supporting the detachable weights were replaced by rigid metal rods. When the sounder struck the sea-floor a mud sample was collected in the hollow lower section of the rod (approx. 30cm long) which is pierced with a small hole at its upper end to allow the enclosed water to escape. On withdrawal, the large iron weights slid off the rod, while the small lead cone was designed to slide to the base where it would close and hold a small spring-loaded valve to retain the sediment sample. The spring on the Dayman sampler is shown closed, incorrectly so on a sounder still carrying its weights. In the standard Brooke sounder (right) the valve is open and the lead cone is descending to close it (see also McConnell, 1982). (Photograph reproduced by courtesy of the Science Museum, London).
alcoholic mixture, so that the presence or absence of soft parts in them might be determined at any future time . . .” (Dayman, 1858: 63).

Huxley made a superficial examination of the samples and his results were published as an Appendix to Dayman’s general account of the voyage. They were found to be uniformly composed of “an excessively fine, light brown, muddy sediment” containing large numbers of dead foraminiferan shells. There was nothing particularly remarkable in this report, for similar results had been reported from both the Atlantic and the Pacific by the microscopists Ehrenberg in Germany and Bailey in the U.S.

But in addition to the foraminifers, Huxley also found the sediment samples to contain small, circular chalky discs, rather like collar studs, which he called coccoliths. These were the dissociated plates of spherical pelagic algae, the coccolithophores, but Huxley was, of course, unaware of this at the time. Although, as early as 1861, G. C. Wallich described coccoliths from Atlantic sediment aggregated over the surface of spherical bodies which he called coccuspheres, (Rice, Burstyn and Jones, 1976), Huxley believed that such aggregations were a secondary phenomenon even when he also encountered coccuspheres on re-examining Dayman’s samples after an interval of ten years.

Why Huxley should have put the Cyclops samples aside for so long, and why he should suddenly have returned to them in 1868, is something of a mystery. But in the spring of that year re-examine them he did, and his startling observations were revealed at the annual meeting of the British Association for the Advancement of Science at Norwich in August. For this more detailed examination revealed not only the coccoliths noted previously, but also Wallich’s coccuspheres and, enveloping both types of particles, a transparent, gelatinous matrix which Huxley became convinced represented the living protoplasm of the simplest organism so far discovered (Figure 3). Huxley christened this new organism *Bathybius haeckelii* (Huxley, 1868a and b).

This was a most auspicious moment for such an organism to burst upon the biological scene and it seized the imagination of scientists both at home and abroad (see Rehbock, 1975: 505). Only ten years previously Darwin had provided an explanation for the diversity of organisms found on earth, but had specifically avoided speculating on the origin of life itself. Several of his zoological contemporaries were not so reticent, however, being convinced that his mechanistic explanation could be extended to embrace “abiogenesis”, or the evolution of living organisms from inorganic matter. To these scientists, and particularly to the German biologist Ernst Haeckel, the search for simpler and simpler organisms to bridge the gap between life and non-life was of paramount importance.

At this level of biological organization it was becoming increasingly difficult to differentiate the simplest animals, the protozoans, from the simplest plants. Haeckel had “solved” this problem in 1866 by establishing a third kingdom, the Protista, for these baffling unicellular organisms. Their simplest representatives, the Monera, were thought by Haeckel to be the lowest forms of life, lacking both a nucleus and an external membrane. In the spring of 1868, just a few months before Huxley announced his discovery of *Bathybius*, Haeckel published a monograph on the Monera (Haeckel, 1868), stressing the similarity of their substance to the protoplasm of all plant and animal cells.

The Monera was subsequently shown to contain a hotch-potch of forms including blue-green algae and bacteria. But at the time his monograph was published, Haeckel saw the next logical step as the discovery of the continuing formation of the non-nucleate proto-
plasm of the Monera from non-living matter. *Bathybius* filled the bill admirably, for it surely represented a continuous network of living protoplasm, carpeting the floor of the deep-sea and being spontaneously generated from inorganic materials. It was clearly important to obtain further evidence for the existence of *Bathybius*, and to investigate the extent of its distribution and variations in its form.

As Huxley was describing the discovery of *Bathybius* to the British Association, such evidence was about to be provided by W. B. Carpenter and Charles Wyville Thomson who were engaged in a dredging cruise to the north and west of Scotland aboard H.M.S. *Lightning*. The last dredge haul of this cruise, obtained on 16 September 1868 at a depth of 650 fathoms (1190m) 250 miles north-west of the Butt of Lewis, brought up a viscous mud which Huxley subsequently examined and declared to contain *Bathybius* (Carpenter, 1868). Three further dredging cruises were undertaken the following year, this time in the much more serviceable vessel H.M.S. *Porcupine*, during the months of May to September. Many of the dredge hauls achieved during these cruises, including the deepest one, obtained on 22 July 1869 at a depth of 2,435 fathoms (4450m) in the Bay of Biscay, brought up more examples of *Bathybius*, demonstrating its wide distribution both in space and time (Thomson, 1873).
The existence of *Bathybius* even further afield was demonstrated by bottom samples obtained by Oscar Schmidt at various depths in the Adriatic during a cruise in June and July 1870 (Schmidt, 1872), while very similar material was dredged from 165m in Smith Sound in August 1872 during the American North Pole Expedition. This arctic material seemed even simpler than *Bathybius*, however, since it lacked coccoliths; it was accordingly christened *Protobathybius* (see Rehbock, 1975: 525).

*Bathybius* was now at the height of its fame, and as the *Challenger* sailed in late 1872 on her epic 3½ year voyage it was confidently expected that the expedition would demonstrate the world-wide distribution of the primordial slime.

However, in Wyville Thomson’s classic account of pre-*Challenger* oceanography, *The Depths of the Sea*, published shortly after the ship sailed, the leader of the *Challenger* scientists had already expressed some doubts about the nature of *Bathybius*. For instance, he was fairly certain that the association of coccoliths with *Bathybius* was purely adventitious. He believed, quite correctly, that the tiny plates were “joints of a minute unicellular alga living on the sea-surface and sinking down and mixing with the sarcode of *Bathybius*...”. Furthermore, and quite prophetically, he thought that much of what had been reported as *Bathybius* from deep-sea sediments was an organic residue “connected either with the growth and multiplication or with the decay – of many different things” (Thomson, 1873: 412).

This scepticism of Wyville Thomson may have discouraged the *Challenger* scientists from uncritically seeing *Bathybius* in every slightly viscous mud sample brought aboard. At any rate, though they looked for it eagerly each time the dredge came to the surface, no fresh examples were found during the first two years of the voyage. Finally, as the ship approached Japan, in the spring of 1875, Buchanan the chemist began to look into the problem more critically. He reasoned that if *Bathybius* existed all over the deep sea floor some evidence of organic material should be found in the near-bottom water samples. No such evidence could be obtained. Meanwhile, his *Challenger* colleague, John Murray, had been preserving bottom samples in alcohol, in accordance with Huxley’s instructions, and had noticed that some of these had developed a “jelly-like aspect” (Murray, 1876: 530). Buchanan likened this substance to “coagulated mucus” and wrote that it “answered in every particular, except the want of motion, to the description of the organism”, that is *Bathybius* (Buchanan, 1876: 605, and 1919).

Murray had found the material in such quantities that Buchanan was convinced that if it was truly organic his search for organic matter in the bottom water samples would certainly have been successful. He therefore came to the conclusion that it was in fact inorganic. When he analysed it his belief was confirmed, for he found it to consist of calcium sulphate which had been precipitated from the sea water in the sediment samples by the addition of the preserving alcohol.

The other *Challenger* scientists gradually became similarly convinced that this was the simple explanation of *Bathybius*, and Thomson wrote to Huxley to inform him, almost apologetically, of Buchanan’s findings (Rehbock, 1975: 528). Thomson was at this stage still hoping that *Bathybius* would be found alive, but Huxley immediately accepted the chemical explanation, publishing extracts of Thomson’s letter in *Nature*, together with his own clear admission that he had been completely mistaken (Huxley, 1875).

Despite Huxley’s retraction, other biologists who had been swept along on the *Bathybius* tide were more reluctant to see it die (see Rehbock, 1975: 529–32). Nevertheless, in
England the last serious attempt to revive it was George Allman's Presidential Address devoted to theories of living matter delivered to the Sheffield meeting of the British Association in 1879. This prompted a clever reply from Huxley in which he once again accepted full responsibility for *Bathybius*, but expressed uncertainty about the explanation of its nature.

Despite this apparent uncertainty, Huxley was content to let *Bathybius* die there. In Germany, however, Haeckel kept the idea alive at least into the 1880s, but by the end of the century even he had reluctantly to admit that *Bathybius* "seems according to the last investigation, not to have the significance ascribed to it" (Haeckel, 1904). Although as noted above, the *Bathybius* story has been referred to frequently during the present century, there has never been any serious doubt expressed about the explanation of what Huxley saw in those small samples of mud in the spring of 1868. Not, that is, until now.

**POST-BATHYBIUS DEVELOPMENTS**

In the 100 years or so since Huxley's *Bathybius* was relegated to the status of an interesting but embarrassing error, knowledge of deep-sea biology has increased enormously, for many thousands of samples both from mid-water and from the deep sea floor have been collected and examined. Consequently, although the deep ocean is still the least well-understood environment on earth because of its relative inaccessibility, some basic facts about its biological processes are now well-established.

Much of this information tends to support the long-standing view of the deep-sea as a food-poor, uniformly cold and dark environment in which life proceeds at a slow and rather constant rate, uninfluenced by the major seasonal perturbations to which shallower communities are subject. Under these circumstances benthic animals in the deep sea would not be expected to have the annual cycles of growth and reproduction typical of shallow-living ones. Indeed, when reproductive patterns began to be examined this seemed to be the case. However, in recent years a small but growing number of cases of seasonal reproduction or recruitment in animals living at depths of 3000m or more have been reported, particularly among the echinoderms (Tyler, Grant, Pain & Gage, 1983). This suggests that environmental conditions at these depths do vary with the time of year.

But which feature or features could be changing in this way? Below depths of about 1000m the physical conditions of temperature, salinity, oxygen concentration, and light seem to be remarkably constant, not only over time but also over wide geographical areas. There is no evidence that any of these features could set the annual reproductive clock and the only other obvious candidate which might vary with the season is the supply of food.

With the exception of the minor local input from the activities of chemo-autotrophic bacteria, the food supply on which all deep sea animals are ultimately dependent originates in the near surface layers. In temperate waters, at least, the surface productivity is very seasonal, being highest in spring and summer when the phytoplankton is growing rapidly, and very low during the winter months. Although some of this material reaches the sea floor in the form of large, fast-sinking carcasses of fishes and whales, the main supply probably arrives as small particles, including the bodies of small plants and animals and faecal pellets, which may take many weeks to sink through the water column. Because of this assumed slow journey to the sea floor, during which the material is subject to the depredations of the various mid-water communities, the temporal and spatial variations
were believed to be largely smoothed out so that the deep sea bed receives a more or less regular but sparse rain of small food particles.

A good deal is known about the influence of variations of the surface productivity on the benthos in shallow waters where not only can the different animal and plant communities be sampled regularly, but the material sinking through the water column can be collected daily or weekly in sediment traps suspended in mid-water (see Smetacek, in press, for a review). These techniques are much more difficult in the open ocean, however, and it was not until 1980 that the results of seasonal sedimentation sampling in the deep water-column were first reported (Deuser and Ross, 1980). These scientists had deployed a moored sediment trap in the Sargasso Sea at a depth of 3200m, some 1000m above the bottom, and samples were removed from it at two-monthly intervals for two years. The total amount of material collected by the trap was closely synchronized with the annual cycle of surface productivity, with a maximum in the spring and a minimum in the autumn. The implication was that material resulting from the surface plankton bloom sinks rapidly down the water column and is not as greatly attenuated as the earlier theories had assumed (Deuser, Ross and Anderson, 1981).

During 1980 three similar traps were deployed on a moored array in the Panama Basin, the traps being respectively 900m, 2600m and 3560m beneath the surface in a total depth of 3860m (Honjo, 1982). As in the Sargasso Sea, these traps collected variable amounts of particulate matter which were closely synchronized with the surface productivity. Thus,

Figure 4. The sea-floor at a depth of 2650m in the Porcupine Seabight photographed in September 1979; it includes a specimen of the starfish, *Hymenaster membranaceus*, but there is no sign of “fluff”.
Figure 5. Two photographs of the sea-floor in the Porcupine Seabight at a depth of 2440m obtained in July 1979. The “out-of-focus” appearance is due to patches of “fluff” which tend to accumulate in and around depressions and mounds on the bottom and, in the upper photograph, around the disc of the brittle star Ophiomusium lymani.
during the February/March period of high surface productivity each of the traps collected a pulse of material including the tests of planktonic foraminifera, opaline shells and faecal pellets. But a second, and much larger, peak occurred in the sediment trap catches in June/July and coincided with a surface bloom of a single coccolithophorid species. The trap catches at this time consisted of a variety of organic and inorganic particles, including coccoliths, all cemented together in an organic mucus clearly associated with the coccolithophorid and assumed to have been formed before the material entered the traps. This material seems remarkably similar to Huxley’s original account of *Bathybius*.

For several years the benthic group at the Institute of Oceanographic Sciences have been investigating the bottom living animals of the Porcupine Seabight, an amphitheatre-shaped section of the continental slope opening onto the abyssal plain to the south-west of Ireland. The sampling gear used has included an epibenthic sledge with an automatic camera photographing the sea floor in the path of the sledge every 15 or 30 seconds as it is towed across the bottom (Rice, Aldred, Darlington and Wild, 1981). From this system we have accumulated several thousands of photographs from depths ranging from 500m to 4500m.

Most of these photographs, including all of those obtained before 1979, were from cruises undertaken during the winter months, that is between September and April; all show the sea bed covered by crystal-clear water with virtually no suggestion of any suspended

![Figure 6](image_url)

Figure 6. Scanning electron micrograph of three types of coccolith from “fluff” collected in July 1982. The most common coccolith is *Emiliana huxleyi*, the large one on the right is *Coccolithus oceanica*, while the less common small form is *Gephyrocapsa oceanica*. 
particulate matter (Figure 4). Since 1979, however, photographs obtained during a series of cruises in the months of May to July have revealed a patchy, fluff-like layer overlying the sediment and aggregated particularly where there are depressions in the mud surface (Figure 5). Moreover, a time lapse camera system (Lampitt and Burnham, in press) deployed at a depth of 2000m, which took photographs of the sea bed at hourly intervals throughout April 1982, recorded the sudden appearance of fluff on the bottom over a period of about 36 hours at the end of the month.

The abrupt arrival of the material on the sea bed suggested that it had been derived from the spring phytoplankton bloom which, in this region, probably occurred some two or three weeks earlier. This suggestion is supported by samples of the detritus collected in May 1981 which were found to consist largely of diatom remains, often bound together in an amorphous organic matrix. Further samples, collected during July 1982, also apparently originated from surface productivity since they again contained diatomaceous material within an amorphous matrix, but this time also including many coccolithophorids (Figure 6), just like Huxley’s Bathybius (Billett, Lampitt, Rice and Mantoura, 1983).

CONCLUSION

Taken together, these results suggest that organic material resulting from surface phytoplankton production sinks rapidly through the water column and forms aggregated masses bound together by an amorphous matrix over wide areas of the deep sea bed. This phenomenon seems to be highly periodic, being associated with periods of particularly rapid phytoplankton growth and, at least in temperate latitudes, is related to the spring phytoplankton bloom and possibly also to later blooms during the summer months. Such a highly seasonal pulse of organic matter to the deep sea could easily explain the cyclic reproductive pattern observed in bathyal species and may therefore be of considerable importance in deep sea biology (Billett et al., 1983).

From an historical point of view, it would be difficult, if not impossible, to prove that Huxley’s original description of Bathybius was based on similar material; but it is equally difficult to ignore the obvious similarities. Moreover, Dayman’s samples, on which Huxley’s observations were based, were collected during June and July, a period when we know that the material occurs on the bottom of at least part of the deep north Atlantic. Similarly, the samples from which Bathybius was subsequently reported were also obtained during the summer months.

However, if Bathybius can indeed be attributed to a mis-interpretation of rapidly sedimented phytoplankton material, and if the phenomenon is as widespread and as consistent from year to year as the preliminary data suggest, it is necessary to explain why similar material was not noted during the Challenger Expedition and subsequent investigations. The answer probably lies in the sampling techniques used, for the material on the sea bed is extremely light and easily disturbed.

The Challenger scientists apparently concentrated their search for Bathybius on samples collected by dredge, so that it is little wonder that they failed to find it. In our own experience we have never noticed any evidence of the “fluff” in epibenthic sledge samples, even when these have been taken in regions where the simultaneously obtained photographs indicate its presence in abundance. Clearly, towed gears such as trawls and dredges, which inevitably churn up the sediment, are totally unsuitable for collecting such flocculent
material in a recognizable form, irrespective of the mesh size of the filtration area. To be successful, a sampler must retrieve the sediment-water interface in a totally, or almost totally, undisturbed condition. Grabs and corers which attempt to do this have been used for many years, but most of them are known to produce a considerable bow wave which forces any particularly light material away from the path of the instrument as it approaches the sea floor. In fact, the Scottish Marine Biological Association multiple corer, which we were fortunate to be able to use, is one of the very few samplers available which consistently retrieves sediment cores with the surface intact. It is therefore not too surprising that the abundance and nature of the fluff had not been appreciated previously. Indeed, our own realization of its significance was dependent upon the use of both efficient photography and efficient sampling, for neither technique alone would have provided sufficient information.

Since the fluff is apparently so difficult to sample adequately today, it is difficult to believe that Dayman was successful in doing so in 1857 since his samples were collected with an unsophisticated sounding rod which essentially consisted of a simple metal tube which was lowered fairly rapidly into the sea bed and was closed by a spring-loaded valve when it was withdrawn (see Figure 2). This is certainly the main problem in equating Huxley's Bathybius with the fluff — and I can offer no convincing explanation.

Nevertheless, despite this major uncertainty it is interesting to speculate that Dayman did collect the fluff and that Huxley described it. If so, Huxley was certainly wrong in his interpretation of it as a new and primitive life form, but his error was not quite as foolish as many of his contemporaries and subsequent commentators have suggested. Perhaps later generations of oceanographers are much more open to criticism for not recognizing a phenomenon of such potential significance for so long!

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