THE MORPHOLOGY OF THE CETACEAN DIATOM GENUS *PLUMOSIGMA* NEMOTO

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ABSTRACT

This report concerns the morphology of the cetacean diatom genus *Plumosigma* which may be obligately associated with sperm whales (*Physeter catodon*). Diatom colonies on sperm whales collected off the Pacific coast of Hokkaido, Japan and off San Francisco, U.S.A. were cleaned using sulfuric acid/potassium permanganate/oxalic acid. The cleaned materials were examined with a light microscope, a scanning electron microscope and a transmission electron microscope. The morphology of the colonies was described as well as the valve morphology of *P. hustedti* and *P. rimosum*, although it was impossible to observe internal valve structure of the latter due to lack of specimens. Additional material of *P. rimosum* needs to be examined to characterize its morphology and ultrastructure.

Key words: cetacean diatom, *Plumosigma*, valve morphology, sperm whale

INTRODUCTION

Diatoms observed on the skin of cetaceans have been studied by Bennett (1920), Hart (1935), Karcher (1940), Usachev (1940), Omura (1950), Hustedt (1952), Okuno (1954), Nemoto (1956, 1958), Kliashtorin (1962), Best (1969), Nemoto, Brownell and Ishimaru (1977), Nemoto, Best, Ishimaru and Takano (1980) and Holmes (1985). Except for some planktonic species found on the skin, which may have been attached accidentally, genuine cetacean diatoms are few and comprise only 4 genera, *Bennettella, Epipellis, Stauroneis, Plumosigma,* and a small number of species.

Cocconeis ceticola, which Nelson described and named in Bennett's (1920)

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paper, was recently transferred to the new genus *Bennettella* after careful examination of diatoms assigned to the genus *Cocconeis* (Holmes, 1985). *Bennettella* includes 3 species (Holmes, 1985). *Epipellis*, a monotypic genus, was established to accommodate the invalid *Cocconeis orcii* Kliashtorin (Holmes, 1985). We report here morphological studies on *Plumosigma* Nemoto, a group not examined since Nemoto established this genus and its two species (*P. hustedti* and *P. rimosum*) in 1956.

MATERIALS AND METHODS

Diatoms examined in this study came from two sources:

1) Skin samples of sperm whales (*Physeter catodon*) with diatom patches collected by T. Nemoto off the Pacific coast of Hokkaido, Japan in 1957.

2) Skin samples of sperm whales with diatom colonies collected west of San Francisco in 1970 by Dr Judith Hansen.

All samples were rinsed in distilled water, treated with sulfuric acid-potassium permanganate and decolorized with oxalic acid. The cleaned material was mounted in Naphrax for light microscopic examination. SEM mounts were prepared by air-drying cleaned material directly on stubs or on cover glasses, affixing the cover glasses to aluminium stubs, and coating the material with gold or gold/palladium. Three different scanning electron microscopes were used: a Hitachi S-415A at University of California, Santa Barbara; a JSM-35 at Ocean Research Institute, University of Tokyo; and a JSM-25 at Otsuchi Marine Research Center, University of Tokyo. For TEM, aqueous suspensions of cleaned cells were air-dried on formvar-coated copper grids. A JEM-100CX located at the Ocean Research Institute, University of Tokyo, was used for transmission electron microscopy.

RESULTS

Plumosigma typically forms circular patches of varying dimensions on the skin of sperm whales. Individual diatoms within the patches attach adnately to the skin (Plate I, Fig. 1). This taxon usually co-occurred with *Stauroneis aleutica, S. olympica, Bennettella ceticola* and *B. constricta* (Plate I, Fig. 2). Although the first three of these diatoms also occur on the Dall's porpoise *Phocoenoides dalli* (Holmes, unpublished) only one specimen of *Plumosigma* has been observed in the many hundreds of Dall's porpoise diatom colonies examined by us. Provisionally, we conclude that *Plumosigma* is obligately associated with sperm whales.

In the samples examined by us, *P. hustedti* (Plate I, Figs 3, 4, 5, 7 and 8; Plate II, Fig. 3) was much more abundant than *P. rimosum* (Plate I, Fig. 6; Plate II, Figs 1 and 2). Nemoto (1956) reported that in his study *P. rimosum* was more abundant than *P. hustedti*. We remain uncertain of the significance of these contradictory observations.

The external valve surface of *Plumosigma* is concave. The raphe rises above the basal siliceous layer forming what appears to be a ridge separating the two halves of the valve face. The valve outline is slightly sigmoid (Plate I, Figs 5, 6, 7 and 8; Plate II, Figs 1 and 3). The central raphe endings terminate in a hyaline area which differs in outline in the two species (Plate I, Figs 5, 6, 7, 8 and 9; Plate II, Fig. 1). The valve mantle is easily deformed and often missing in our photos (Plate I, Figs 7 and 8; Plate II, Figs 1, 6 and 7). Anomalous valves indicated by the presence of two raphes and overlapped puncta were found in our material (Plate II, Fig. 3). Valves somewhat similar to these valves were also illustrated by Nemoto (1956).

The external distal raphe fissures at the poles are curved in opposite directions (Plate I, Figs 5 and 6). These distal raphe endings terminate in the interior of the valve in a thickened U-shaped helictoglossa in *P. hustedti* (Plate I, Fig. 4; Plate II, 5 and 6). The region between the central raphe endings in the interior of the valve is thickened (Plate II, Fig. 5). The exterior surface of the valve mantle is shown in Plate II, Fig. 4.

Nemoto's (1956) illustrations suggest that the puncta of the striae are mostly round in *P. hustedti*. By contrast, those close to the raphe and margin of the valve are long and narrow in *P. rimosum*, although a few rows of round puncta are sometimes present. Our observations confirm this morphology.

Morphometric data on the two species of *Plumosigma* have been published (Nemoto, 1956). Combining Nemoto's morphometric data with our own measurements, the following characteristics may be summarized for *P. hustedti*: length 11-22 μm, width 4.6-7.5 μm, length/width ratio 2.4-3.8, striae in the central region of the valve 31-40 in 10 μm, striae at the valve margin near the valve ends 40-55 in 10 μm, puncta in the central region of the valve 23-30 in 10 μm, puncta at the margin of the valve near the valve ends 30-42 in 10 μm.

We do not have similar data on *P. rimosum* because of the limited number of this species in our samples. According to Nemoto (1956), the striae of *P. rimosum* are denser than those of *P. hustedti*.

DISCUSSION

We have obtained additional information on the valve morphology of *Plumosigma hustedti* using SEM and TEM. We have not found girdle views of frustules nor carried out examination of the internal structure of *P. rimosum*.

The distal raphe endings of *P. hustedti* have an unusual internal structure, which looks rather like an anchor (Plate II, Figs 5 and 6). Unfortunately, it was impossible to observe internal valve structure of *P. rimosum* due to lack of specimens.

We were unable to document the structure of hymenate pore occlusions in either taxon. These occlusions are very delicate and were absent in the sperm whale samples examined, but one specimen of *P. rimosum* found in the sediments of Otsuchi Bay retained hymenate pore occlusions (Nagasawa, Holmes and Nemoto, 1989). The absence of hymenate pore occlusions in the present material and the scarcity of specimens of *P. rimosum* have made it difficult to describe the morphology of this species with any degree of certainty. However, transmission electron microscope photographs of the three valves of *P. rimosum* available for observations suggest the possibility that this taxon represents a stage in the dissolution of the siliceous valve structure of *P. hustedti*. The admixture of circular and elongate puncta along the axial area of *P. rimosum* and the irregular inner margin of the elongate puncta suggest the possibility that the walls between puncta have dissolved, producting "elongate" puncta (Plate II, Figs 1 and 2). On the other hand, the central area is quite different from that of *P. hustedti*. What appear to be very small poroids occur with some frequency along the inter-striae in one of our photographs of *P. rimosum* (Plate II, Fig. 2). Such poroids have not been observed in *P. hustedti*. Clearly, additional material of *P. rimosum* needs to be examined to characterize its morphology and ultrastructure in more detail.

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EXPLANATIONS OF PLATES

PLATE I

Each scale bar indicates 1 μm.

Fig. 1. A colony of *Plumosigma* on the skin of a sperm whale, source 2, SEM.

Fig. 2. Co-occurrence of *Plumosigma* with *Stauroneis* sp. and *Bennettella ceticola* on the skin of sperm whales, source 1, SEM.

Fig. 3. Exterior of *P. hustedti*, source 1, LM.

Fig. 4. Interior of *P. hustedti*, source 1, LM.

Fig. 5. Frustule of *P. hustedti*, source 1, SEM.

Fig. 6. Frustule of *P. rimosum*, source 1, SEM.

Fig. 7. Three valves of *P. hustedti* without girdle bands, source 1, TEM.

Fig. 8. Another valve of *P. hustedti* without girdle bands, source 1, TEM.

PLATE II

Each scale bar indicates 1 μm.

Fig. 1. Valve of *P. rimosum*, source 1, TEM.

Fig. 2. Central area of *P. rimosum*, source 1, TEM.

Fig. 3. Double valves of *P. hustedti*, source 1, TEM.

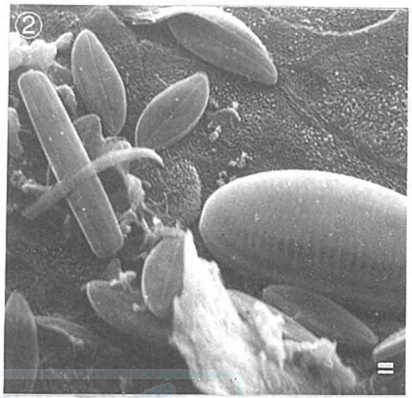
Fig. 4. Exterior of *P. hustedti* with valve mantle, source 1, SEM.

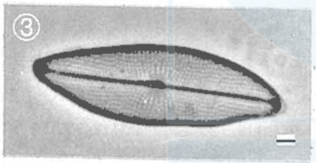
Fig. 5. Interior of *P. hustedti*, source 1, SEM.

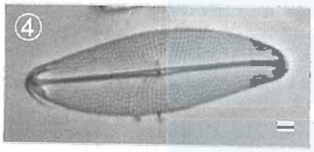
Fig. 6. End of interior valve of *P. hustedti*, source 1, SEM.

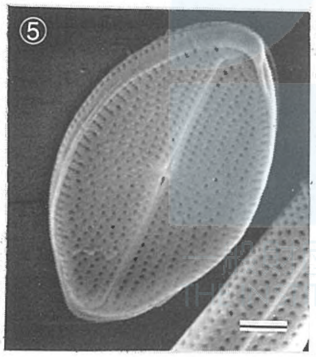
Fig. 7. Detached interior valve mantle of *P. hustedti*, source 1, SEM.

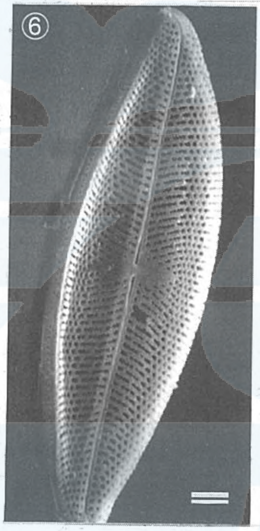
PLATE I

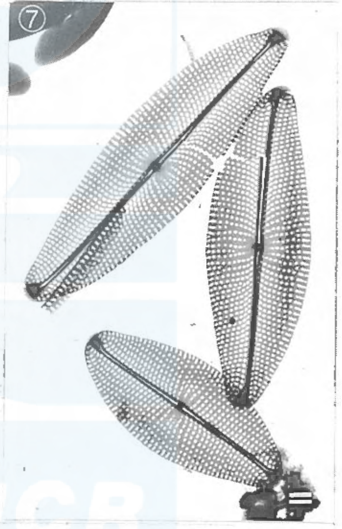












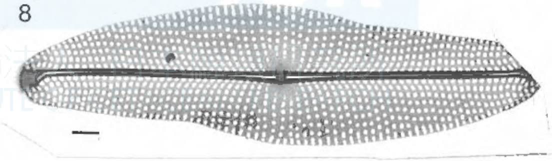


PLATE II