Bull. Natn. Sci. Mus., Tokyo, Ser. C, 19 (3), pp. 91–97, September 22, 1993

Cetacean Diatoms from Sediments at Otsuchi, Iwate-ken, Japan

By

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(Communicated by Ikuwo OBATO)

Abstract The sediment samples from three stations in Otsuchi Bay, Iwate-ken, Japan were studied to determine the origin of a cetacean diatom *Bennettella ceticola* by examining the abundance and distribution of three dominant epipelic diatoms, one planktonic marine species and *B. ceticola*. This cetacean diatom was rare and its distribution differed from the others, supporting the hypothesis that the *B. ceticola* in benthic assemblages is allochthonous. In contrast, sediment samples from Sagami Bay with no whaling history did not contain any cetacean diatoms.

Introduction

Diatom colonies observed on the skin of cetaceans have been studied by many authors (see HOLMES *et al.*, 1993). The diatom taxa from cetaceans have not been found in plankton (HART, 1935). NAGASAWA *et al.* (1989) hypothesized that the cetacean diatoms in benthic assemblages at Otsuchi, Iwate-ken, Japan are derived from the skin films of Dall's porpoise (*Phocoenoides dalli* TRUE) and sperm whale (*Physter catodon* LINNAEUS). Over 1000 Dall's porpoises landed every summer at Otsuchi fish market: some have diatom colonies which probably peel off after the animals are hosed with seawater at the dockside and transported to the nearby seabed (HOLMES *et al.*, 1993). This implies that diatom colonies may be unable to survive in the benthic habitat. The aim of this paper is to confirm the above-mentioned hypothesis which requires quantitative analysis of genuine benthic and planktonic diatoms as well as cetacean diatoms obtained from the sediments.

Materials and Methods

I used sediment samples from two sources; one was from Otsuchi Bay where the sea-bottom is shallower than the other sample source - Sagami Bay, though much emphasis was made on the former.

Otsuchi Bay samples: I employed the standardized method of cleaning diatomaceous deep-sea sediments (TANIMURA, 1981) after samples of bottom sediment were taken at three stations in Otsuchi Bay (Fig. 1) with an Ekman-Birge grab on 21 August 1989.

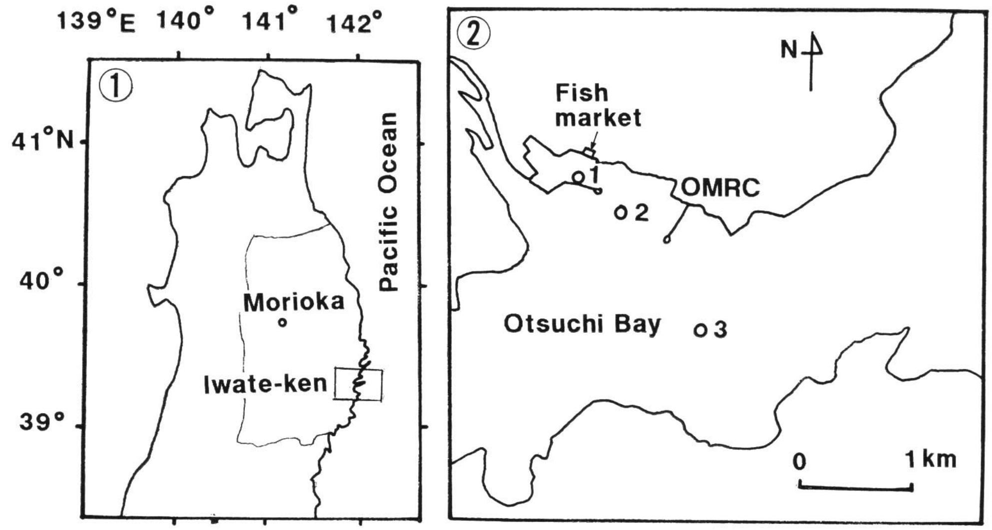

Fig. 1. 1 The location of the major study area is marked by a rectangle. 2 Otsuchi Bay, Iwate-ken, Japan showing the location of three sampling stations (○) and Otsuchi Marine Research Center (OMRC).

Sediment samples from Stns. 1 (16 m in depth) and 2 (20 m in depth) mostly comprised mud with fragments of shell, whereas fine-grained sand was the major component of the sediment sample from Stn. 3 (38 m in depth). A small quantity of raw materials from the three stations was placed in a beaker with a 100 ml GFC filtered seawater. After mixing well, an aliquot of each sample was examined using a Nikon compound microscope equipped with epifluorescent illumination to see if there are cetacean diatoms containing chlorophyll. This observation for each sample was repeated four times.

Cleaning of raw materials and preparation of slides were treated as follows: 1) A lump of each sediment sample was placed in a Petri dish 6 cm in diameter and dried for 24 h at 65°C. 2) One gram of the dried sediment was placed in a 200 ml beaker with a 30–50 ml solution of hydrogen peroxide (H_2O_2, 15%). This mixture was boiled to oxidize the organic matter in the sample. After boiling for about 20 min. a solution of 1 N hydrochloric acid was added to dissolve carbonates. The sample was then further boiled for 20 min. 3) After cooling, the beaker was filled with distilled water up to 200 ml, shaken well, and kept at room temperature for 5 h. Then the fine-grained materials in suspension were carefully removed by decantation, and the beaker was again filled with distilled water of 200 ml. This procedure was repeated three times. 4) The residue was then stirred while adding 0.01 N sodium pyrophosphate to a final volume of 200 ml. The beaker was kept at room temperature for 7 h. Then finer materials in suspension were carefully removed by decantation, and the beaker again filled with 0.01 N sodium pyrophosphate up to 200 ml. This procedure was repeated twice. 5) The final "cleaned" residue was transferred to a plastic vial and the volume of distilled water, including residue, was adjusted to 10 ml. 6) After stirring this cleaned sample, 0.5 ml of the suspension was sucked into a syringe and transferred to a plastic vial while adding distilled water to a final volume of 10 ml. 7) For slide preparation, 0.25 ml of this diluted sample was placed on an 18×18 mm cover glass, although 0.5 ml is generally used in the deep-sea sediments (KANAYA & KOIZUMI, 1966). Thus one slide of my coastal sediment contains 1.25 mg material. After drying, the cover glass was mounted on a slide with Naphrax. Four slides of each sample were prepared. The counting of valve of diatoms mentioned below was done using LM.

Among many species comprising freshwater, marine planktonic and benthic diatoms, I counted four dominant species namely *Diploneis smithii* (BREBISSON) CLEVE, *Pinnularia quadratarea* (A. SCHMIDT) CLEVE, *Nitzschia littoralis* GRUNOW and *Odontella aurita* (LYNGBYE) AGARDH and a cetacean diatom *Bennettella ceticola* (HART) HOLMES while scanning the whole area of cover glass at a magnification of 400×. The first three species are benthic diatoms known as epipelon (ROUND, 1956): species which are found on the surface of the sediment and show movement up and down in the interstitial water. The fourth one is planktonic. A fragmented valve of these diatoms was counted as one valve. Major reference sources for identification are PERAGALLO and PERAGALLO (1897–1908), HUSTEDT (1932), CUPP (1943), CLEVE-EULER (1952, 1953, 1955) and HENDEY (1964).

For scanning electron microscopy (SEM), diluted samples were placed on glass coverslips which in turn were mounted on aluminium stubs. The stubs were then sputter coated with gold. For transmission electron microscopy (TEM), diluted samples were mounted on Formvar coated copper grids. SEM and TEM observations were made using JEOL JSM 35 and JEOL 100 CX.

Sagami Bay samples: I examined a total of four sediment samples collected with a Phleger core sampler from two locations (35°00.0′N, 139°13.5′E; 1181 m deep and 35°06.0′N, 139°20.5′E; 1384 m deep) at the western coastal part of Sagami Bay which has no previous whaling history. This was to establish whether cetacean diatoms exist in this study area. Using submersible research vessel "Shinkai 2000" of the Japan Marine Science and Technology Center (JAMSTEC), two samples each were collected during dive 452 and 453 on 23 and 24 of October 1989, respectively.

Cleaning procedure of these samples and preparation of their slides were the same as mentioned above. Two slides of each sample were prepared and observed with LM.

Results and Discussion

Six diatom species from benthic assemblages collected in Otsuchi Bay are illustrated in Figure 2. These species were either rare or absent in Sagami Bay where other species of centric diatoms and silicoflagellates were dominant. No cetacean diatoms

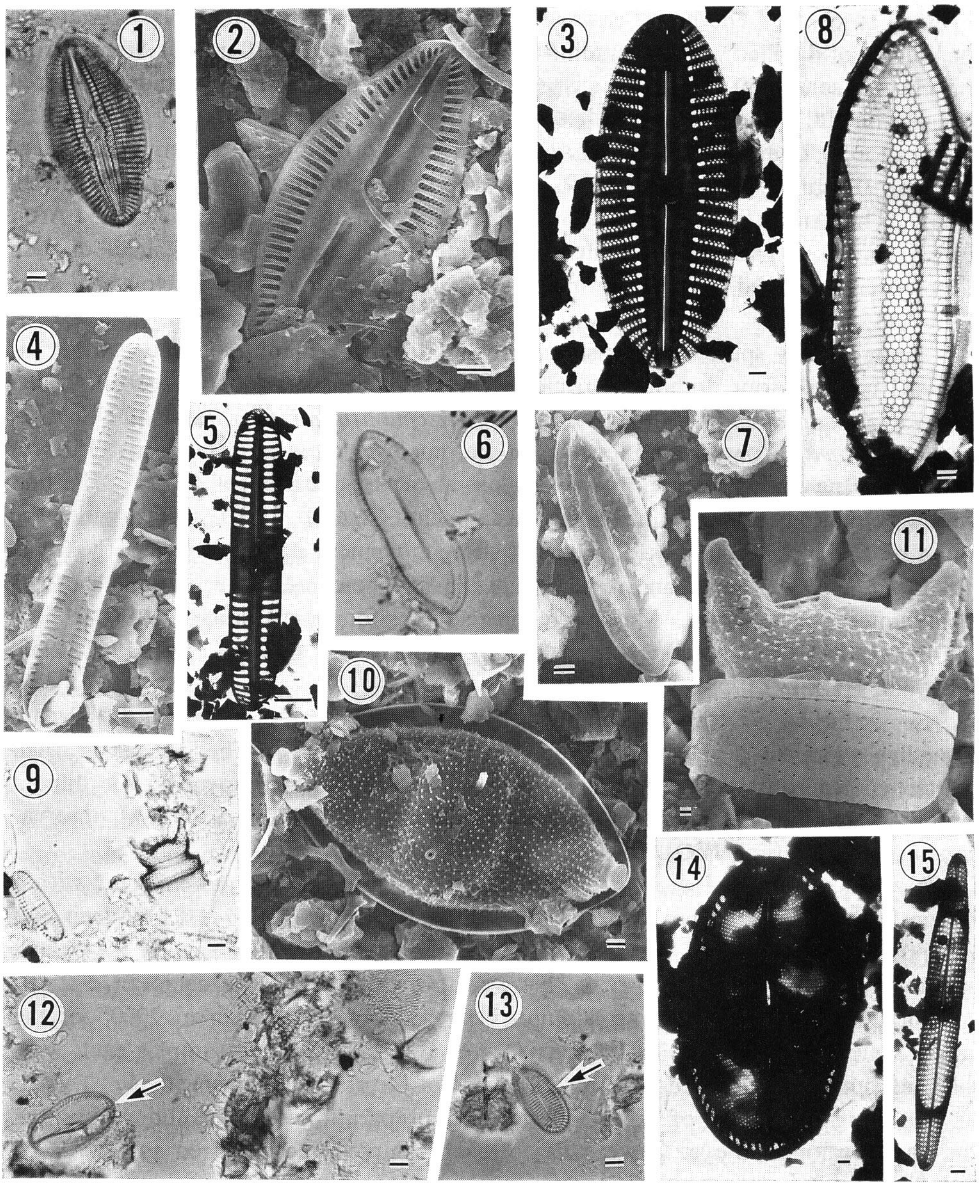

Fig. 2. Diatoms from benthic assemblages collected in Otsuchi Bay and observed with LM (1, 6, 9, 12 and 13), SEM (2, 4, 7, 10 and 11) and TEM (3, 5, 8, 14 and 15). *Diploneis smithii* (1–3), *Pinnularia quadratarea* (4 and 5), *Nitzschia littoralis* (6–8), *Odontella aurita* (9–11: 9, 11 - girdle view; 10 - valve view), *Bennettella ceticola* (12–14: 12, 14 - raphid valve; 13 - araphid valve) and *Epiphalaina aleutica* (15). Scale bars indicate 1 (3, 8, 10, 11, 14 and 15) and 5 (1, 2, 4, 5, 6, 7, 9, 12 and 13) μm.

Table 1. The number of valves per 1.25 mg sediment (±SD) obtained from Otsuchi Bay.

Station No.	*Diploneis smithii*	*Pinnularia quadratarea*	*Nitzschia littoralis*	*Odontella* spp.	*Bennettella ceticola*
1	50±4	28±5	49±5	60±10	0
2	73±6	35±9	50±13	100±15	7±3
3	28±5	2±2	19±2	302±32	1±1*

* At Stn. 3 a small number of *B. constricta* and *Epiphalaina aleutica* were also present.

were found in any sediment samples from Sagami Bay.

Among the three benthic diatoms *Diploneis smithii* is a common marine species and may be considered cosmopolitan as extensively reported from the North Sea (BROCKMANN, 1937), Baltic sediments (SIMONSEN, 1962), the Black Sea coast (BODEANU, 1964), off the California coast at depths ranging from 5–35 m (ROUND, 1971), off the Massachusetts coast (ROUND, 1971), the upper basin of the Pettaquamscutt River, Rhode Island (KENNETT & HARGRAVES, 1984) and from the Pacific coast in Japan (present study).

The average number of valve of the five species from Otsuchi Bay observed on four slides from each sample is presented in Table 1. Instead of *Odontella aurita*, I list *Odontella* spp. in this Table since I may have included in the counts valves or girdle views of *O. longicruris* which also occurs in Otsuchi Bay (AIZAWA & MARUMO, 1979). Another reason is that electron microscope observations are required for precise identification of both species, especially on deformed cells and fragments of valve (TAKANO, 1984).

Valves of the three benthic species, *D. smithii*, *P. quadratarea* and *N. littoralis* were more abundant at Stns. 1 and 2 than Stn. 3 whereas those of *O. aurita* increased in number from Stn. 1 to Stn. 3 (Table 1). Compared with these benthic and planktonic species, cetacean diatoms were few (less than 10 valves per 1.25 mg) and their distribution pattern was different. If *Bennettella ceticola* is of benthic or marine planktonic origin it should probably be found at all stations and show a distribution similar to either the planktonic or benthic taxa. However, this assumption is contrary to the outcome I obtained - the scarcity and sporadic occurrence of *B. ceticola*. When unpreserved sediments were exposed to intense blue light, red plastid fluorescence was observed in each trial of the three samples. However, these specimens having red fluorescence were mostly epipelic diatoms and cetacean diatoms were not found among them. I failed to establish whether the cetacean diatoms have red fluorescence. Thus it was impossible to determine if they are alive or dead. Nevertheless, I often found fragments of *B. ceticola* in the slides of cleaned samples. The difficulty in confirming the presence of living diatoms associated with cetaceans and frequent occurrence of damaged valves of *B. ceticola* led me to conclude that cetacean diatoms found in the Otsuchi sediments are most probably allochthonous in origin.

Seawater used in washing the Dall's porpoise contains skin fragments and associated diatoms (HOLMES *et al.*, 1993). This water flows into the bay where it may be affected by the current heading eastward toward the mouth of the bay. The speed of this current is estimated as 7–8 cm/sec in winter (SHIKAMA, 1990). Such currents may explain why cetacean diatoms are absent at Stn. 1 which is the nearest to the fish market.

Unlike a previous study (NAGASAWA *et al.*, 1989), I observed only four species of cetacean diatoms from these benthic assemblages: *Bennettella ceticola* (Fig. 2–12–14), *Bennettella* sp., *B. constricta* and *Epiphalaina aleutica* (Fig. 2–15). The last two species occurred very rarely at Stn. 3 making a quantitative estimate of their number unreliable. Probably the most abundant of these four rare taxa was *B. ceticola*, although I may have counted *B.* sp. in error as *B. ceticola*. This was sometimes due to the difficulty in distinguishing the araphid valve of both species. The raphid valve of this unidentified *Bennettella*, which has not been reported from Dall's porpoises (HOLMES *et al.*, 1993), is somehow different from *B. ceticola* and quite similar to a taxon dominating skin films of Baird's beaked whale (unpublished data). Interestingly, *B. ceticola* is a rare component in colonies of Dall's porpoise landed at Otsuchi (HOLMES *et al.*, 1993) while *E. aleutica* is numerically dominant in most colonies of the Otsuchi animals. The contradiction in the numerical abundance of the two species from animals and sediments is probably due to the way of their attachment to the animals; *B. ceticola*, which grows adnately on the skin (HOLMES *et al.*, 1933), easily comes off compared with *E. aleutica* in which one end of the frustule penetrates into the skin and individual frustules rise nearly vertically from their point of attachment (HOLMES *et al.*, 1993).

Acknowledgements

I express my sincere thanks to Prof. K. KAWAGUCHI for his interest in this study, Dr. M. TERAZAKI for granting me travel expenses covering part of the research trip to Santa Barbara, the Faculty members of the Otsuchi Marine Research Center for their cooperation and assistance, in particular, Mr. K. MORITA for helping to obtain sediment samples and Dr. T. TANAKA for sharing sediment samples collected during dive 453 in Sagami Bay. Special thanks are also due to Mrs. S. K. MIKHAIL and Mrs. D. KENNETT who assisted in the identification of epipelic diatoms and provided some pertinent publications for references. Finally, I would like to thank Prof. Robert W. HOLMES for his interest and help in this study.

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