ECOLOGY OF SHALLOW-WATER FORAMINIFERA OFF THE COAST OF NOBORIBETSU, SOUTHWESTERN HOKKAIDO, JAPAN

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With 3 Text-figures and 2 Tables

Introduction

In the late summer of 1958, eleven bottom sediments were collected off the coast of Noboribetsu, near Muroran, Hokkaido, by the members of the Japanese Hydrographic Office. The locations, depths, types of sediments and dates of collection of these samples are listed in Table 1 and are shown in Fig. 1.

The sediments were collected by using a dredge, dried on the survey ship. They were dried in an electric oven for a few hours, weighed, then washed by running water through 250-mesh sieve (diameter of the opening is 0.06 mm) in the laboratory. The part retained on the 250-mesh sieve was placed in an evaporating dish, dried in an oven. Foraminifera were floated from the dried sediment by using CCl_4 according to the method developed by Y. OZAWA at the Cushman Laboratory (CUSHMAN, 1940, p. 27). All of floated and unfloated specimens of each sample were analyzed for species quantitatively. Therefore, the Foraminifera assemblages here dealt with are thanatocoenoses, which may include a few living specimens.

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Submarine Topography and Geology

According to the Hydrographic Chart 17 published by the Japanese Hydrographic Office, the submarine topography of this area is simple (see Fig. 1). There is a narrow (*ca.* 15 km wide) continental shelf down to a depth of *ca.* 100 m. The shelf can be divided into two parts. The inner one is a narrow (*ca.* 3.5 km wide), rather steeply sloping (*ca.* 0°35′) zone, the lower edge of which lies at a depth of 50–60 m. The outer one is an almost horizontal terrace. These characters show that the continental shelf of this area is in close agreement with SHEPARD's statistics (1948, p. 144) that the average slope is 0°07′, being somewhat steeper in the inner half than the outer half.

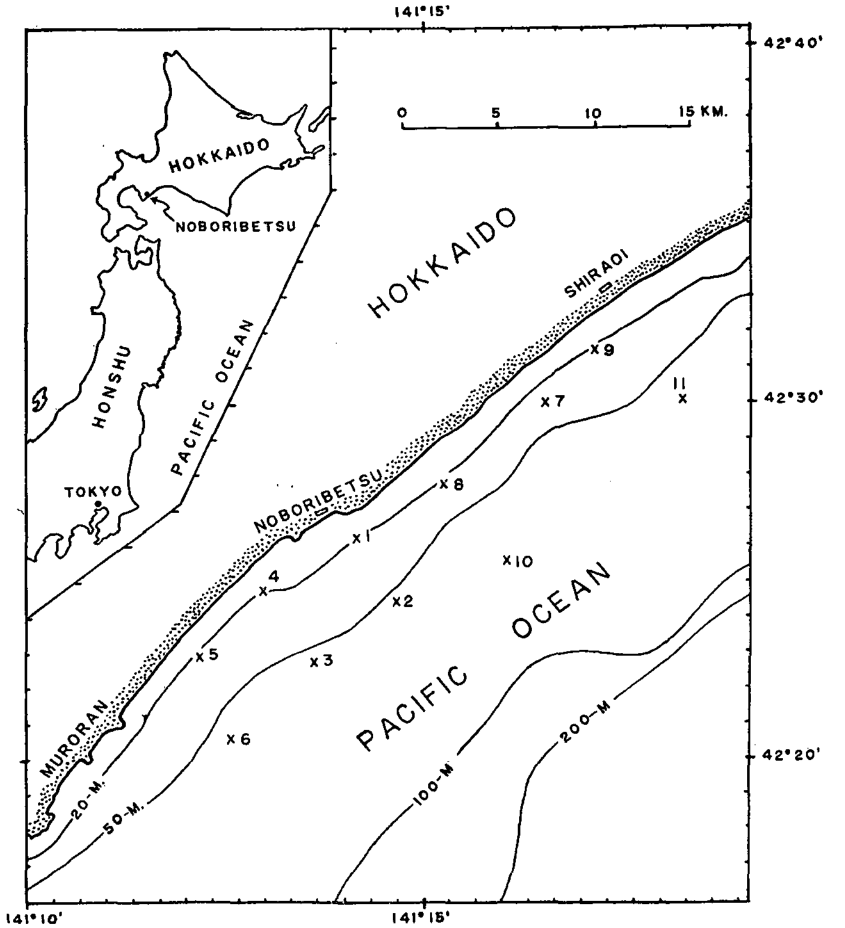

Fig. 1. Locations of stations and the submarine topography of the area.

The bottom shallower than 20 m is covered by sand, and the deeper part by silty sand (mud and sand in Table 1) or silt (mud in Table 1). Frequently these sediments contain a rather large quantity of pumice grain (except at Stations 3 and 4), and also plant fragments to a lesser extent. *Acila* (*Truncacila*) *insignis* (GOULD) is abundant at Station 5, where both (right and left) valves of each individual were tied firmly together. This indicates that the fauna at Station 5 might

Table 1. Locations of stations, depths, types of sediments, and dates of collections.

Station	Location		Depth	Sediment	Date
	N. Lat.	E. Long.	(m)		
1	42° 26′ 11″	141° 12′ 27″	22	Sand & Mud	1958 Aug. 30
2	42° 24′ 24″	141° 13′ 54″	65	Mud	1958 Aug. 30
3	42° 22′ 49″	141° 11′ 02″	59	Mud	1958 Aug. 30
4	42° 24′ 44″	141° 08′ 57″	19	fine Sand	1958 Aug. 30
5	42° 22′ 53″	141° 06′ 35″	28	Mud & Sand	1958 Aug. 30
6	42° 20′ 37″	141° 07′ 44″	56	Mud	1958 Aug. 31
7	42° 30′ 02″	141° 19′ 38″	29	Sand & Mud	1958 Sept. 11
8	42° 27′ 45″	141° 15′ 52″	31	Sand & Mud	1958 Sept. 11
9	42° 31′ 30″	141° 21′ 35″	23	Pumice	1958 Sept. 14
10	42° 25′ 37″	141° 18′ 15″	80	Mud & Sand	1958 Sept. 15
11	42° 30′ 06″	141° 24′ 48″	70	Sand & Mud	1958 Sept. 23

be deposited *in situ*. Grain size analysis of these sediments will be made by Ninko SATO of the Japanese Hydrographic Office in the near future.

Hydrography

Since the Foraminifera assemblages here dealt with are not biocoenoses but thanatocoenoses, there may be no direct relationship between the thanatocoenoses and hydrographic phenomena. Nevertheless, the thanotocoenoses might indirectly be related to the average oceanographic conditions during the past few hundreds or thousands years. It is, therefore, necessary to analyse hydrographic data to understand fully what causes faunal distributions. In the following the writer gives a general picture of the oceanographic conditions in this area and its surroundings.

Very few oceanographic data are available in the area concerned, while so many data have been published in the neighbouring areas every ten days by the Hakodate Marine Observatory and others. The reasons are that this area has importance neither in fishery nor in oceanographic-meteorological observations. There are three surface water masses (warm Tsugaru Current, warm Kuroshio and cold Oyashio) in the general area concerned.

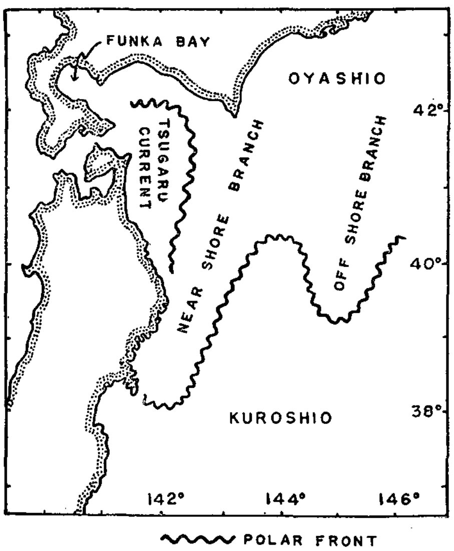

Fig. 2. Generalized pattern of distributions of the three currents in the waters off N.E. Honshû, Japan.

The seasonal and yearly fluctuations of these water masses determine the oceanographic-meteorologic, faunal and floral patterns of the area. A generalized pattern of distributions of the three currents is shown in Fig. 2. As is shown in Fig. 2, the area here studied is almost always covered by a westerly or northwesterly extension, though much modified by mixing with Tsugaru Current, of the nearshore branch of the subarctic Oyashio, but the warm Tsugaru Current may give influences to the area in summer. Below the Oyashio there lies the Intermediate Water, which is characterized by a salinity minimum (less than 33.8‰). The thickness of the Oyashio is variable locally and not well known. According to UDA (1938) the low salinity and low density Oyashio is about 25 m in thickness, and between 50 and 150 m in depth there is the cold Intermediate Water, whose density is high and salinity is nearly constant. He does not mention the layer between 25 and 50 m in depth, but it appears to be a thermocline.

Fig. 3 shows approximate maximum and minimum water temperatures and salinities in this area in relation to depth according to the results of marine meteorological-oceanographical observations published by the Central Meteorological Observatory.

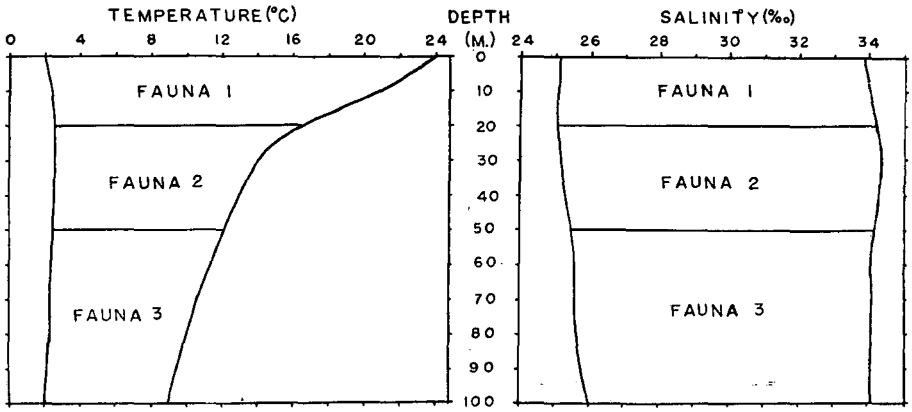

Fig. 3. Maximum and minimum bottom temperatures and salinities in relation to depth.

Maximum temperature of the surface water is 24°C., which is an extreme during the recent 10 years. The average of maximum temperatures in each year will be about 19–20°C. In general temperature and salinity are the lowest in January and February and the highest in August and September, and the reverse is true in the case of oxygen content in waters. Amount of the dissolved oxygen in water in this area is 5–8 cc/L and decrease from the surface toward the deep. The water is oversaturated and sometimes nearly saturated with oxygen within a depth range of 0–100 m.

HIDAKA (1934), from the distributions of temperature and salinity, could find a boundary at about 25 m, which divides waters into two layers along a traverse at the entrance of Funka-wan (Volcanic Bay). Furthermore, he, in the main part of the bay, could find a very distinct boundary at 50 m, above which there are inflow of water from the Pacific Ocean into the bay along the southern shore, a horizontal and clockwise gire, a sinking water at the center of the bay, and an upwelling along the shore of the bay, while below which there is an outflow of water from the bay to the Pacific Ocean along the northern shore of the bay. He also pointed out that the water was stagnant below 90 m in the bay and there was no exchange of water between the bay and Pacific Ocean below that level. MATSUDAIRA and MIZUUCHI (1934) reached the same conclusion from the distribution of oxygen, phosphate, silicate and pH.

Foraminifera Depth Assemblages and Boundaries

The Foraminifera here dealt with are divided into three assemblages, and the deepest one may be subdivided into two. These divisions are based upon the following criteria: shallow and/or deep limit of the various species, and depth range at which the species have the greatest frequency. Occurrences of the species of benthonic Foraminifera are listed in Table 2.

Fauna 1 is represented by only one sample, and more materials are necessary to establish this assemblage. The shallow limit of this assemblage is unknown, and deep one is at depth of *ca.* 20 m. The assemblage is characterized by predominance of *Pseudononion japonicum* ASANO, and also by *Buccella frigida* (CUSHMAN).

The boundary at *ca.* 20 m is based upon great change in frequency occurrences of *Pseudononion japonicum* ASANO, *Eggerella advena* CUSHMAN and *Elphidium clavatum* CUSHMAN.

Fauna 2 is characterized by the predominance of *Eggerella advena* CUSHMAN and *Elphidium clavatum* CUSHMAN. *Pseudononion japonicum* ASANO, *Buccella frigida* (CUSHMAN) and *Elphidium subarcticum* CUSHMAN are also important members of this assemblage.

The boundary at *ca.* 40–50 m is very distinct and is based upon:

1) *Nonionella stella* CUSHMAN & MOYER becomes dominant suddenly.
2) *Eggerella advena* CUSHMAN, *Elphidium clavatum* CUSHMAN become much less dominant.
3) *Pseudononion japonicum* ASANO, *Elphidium subarcticum* CUSHMAN, *Lagenammina diffulgiformis* var. *lagenaria* (BERTHELIN), *Elphidium oregonensis* CUSHMAN & GRANT, *Quinqueloculina* sp. cf. *Q. seminula* (LINNAEUS) and *Streblus japonicus* (HADA) become extinct or almost extinct in Fauna 3.
4) *Textularia earlandi* PARKER, *Trochammina squamata stellata* HÖGLUND, *Epistominella tamana* (KUWANO), *Buccella frigida* (CUSHMAN) and *Reophax communis* LACROIX become more abundant in Fauna 3.
5) *Trochammina pacifica* CUSHMAN, *Goësella flintii* CUSHMAN, *Haplophragmoides bradyi* (ROBERTSON), *Lagena mollis* CUSHMAN, *Fissurina laevigata* REUSS, *Uvigerina cushmani* TODD, *Virgulina* sp., *Alveolophragmium crassimargo*

Table 2. Percentage distribution of the benthonic Foraminifera off the coast of Noboribetsu, Hokkaido, Japan.

Fauna	1	2				3A				3B
Station	4	1	5	7	8	6	3	2	11	10
Depth (m)	19	22	28	29	31	56	59	65	70	80
Pseudnonion japonicum	68	14	20	12	20	—	×	—	—	—
Buccella frigida	14	10	9	5	6	8	2	×	8	3
Elphidium subarcticum	5	14	3	3	3	—	—	—	1	×
Elphidium clavatum	5	20	16	20	14	11	2	—	11	24
Eggerella advena	4	38	44	52	49	18	23	8	5	17
Elphidium oregonense	2	×	×	×	×	—	—	—	—	—
Quinqueloculina cf. *seminula*	2	2	×	—	×	—	—	—	—	—
Lagenammina lagenarium	—	×	1	1	3	×	×	—	—	—
Textularia earlandi	—	×	2	×	1	6	7	1	—	×
Trochammina charlottensis	—	×	—	1	×	—	2	—	2	—
Buliminella elegantissima	—	×	2	2	×	—	×	—	1	×
Streblus japonicus	—	×	—	×	×	—	—	—	—	—
Trocchammina squamata stellata	—	—	×	×	×	8	4	6	8	3
Nonionella stella	—	—	1	×	×	39	47	7	48	×
Epistominella tamana	—	—	×	—	×	7	4	7	2	8
Reophax communis	—	—	×	—	—	—	2	2	—	2
Involutina cf. *minutissimum*	—	—	—	×	—	—	—	—	—	—
Nonion cf. *manpukujiense*	—	—	×	×	×	—	—	—	—	—
Trochammina pacifica	—	—	—	—	—	1	×	×	×	3
Goësella flintii	—	—	—	—	—	1	×	—	—	—
Fissurina laevigata	—	—	—	—	—	1	×	—	—	—
Haplophragmoides bradyi	—	—	—	—	—	×	×	—	—	×
Uvigerina cushmani	—	—	—	—	—	×	×	1	2	16
Alveolophragmium crassimargo	—	—	—	—	—	×	1	×	—	×
Cassidulina nörvangi	—	—	—	—	—	×	—	2	9	9
Glandulina laevigata	—	—	—	—	—	×	×	×	—	—
Cassidulina subglobosa	—	—	—	—	—	×	—	—	×	—
Lagena mollis	—	—	—	—	—	—	×	—	—	×
Lagena striata	—	—	—	—	—	—	×	—	—	—
Virgulina sp.	—	—	—	—	—	—	×	×	—	×
Haplophragmoides (?) sp.	—	—	—	—	—	—	×	×	—	—
Gyroidina cf. *soldanii*	—	—	—	—	—	—	×	—	—	—
Ammotium cassis	—	—	—	—	—	—	×	×	—	—
Asterigerinata cf. *pacifica*	—	—	—	—	—	—	—	×	×	—
Reophax scorpiurus	—	—	—	—	—	—	—	×	—	×
Nonion labradoricum	—	—	—	—	—	—	—	—	—	×
Elphidium bartletti	—	—	—	—	—	—	—	—	—	×
Quinqueloculina cf. *elongata*	—	—	—	—	—	—	—	—	—	×
Cassidulina cf. *laevigata*	—	—	—	—	—	—	—	—	—	×
Benthonic population in 10 gr	56	1130	912	666	550	880	688	1680	164	1170
Planktonic population in 10 gr	3	3	8	2	10	0	0	10	5	20

(NORMAN) and *Ammotium cassis* (PARKER) appear only in Fauna 3.

Fauna 3A is characterized by the predominance of *Nonionella stella* CUSHMAN & MOYER. *Eggerella advena* CUSHMAN is also dominant. *Epistominella tamana* (KUWANO), *Trochammina squamata stellata* HÖGLUND, *Textularia earlandi* PARKER, *Elphidium clavatum* CUSHMAN and *Buccella frigida* (CUSHMAN) are important members.

The boundary at *ca.* 75 m is tentative since only one sample is available to establish Fauna 3B. The boundary is based upon:

1) *Uvigerina cushmani* TODD, *Cassidulina nörvangi* THALMANN become dominant suddenly.
2) *Nonion labradoricum* (DAWSON), *Elphidium bartletti* CUSHMAN, *Quinqueloculina* sp. cf. *Q. elongata* and *Cassidulina* sp, cf. *C. laevigata* D'ORBIGNY, though the occurrences of them are rare, appear only in Fauna 3B.

Fauna 3B is represented by only one sample and more materials are necessary to ascertain this fauna. The deep limit of this fauna is unknown. The fauna is characterized by the abundance of *Uvigerina cushmani* TODD which is considered to be a deep water species. *Elphidium clavatum* CUSHMAN and *Eggerella advena* CUSHMAN are abundant as in Fauna 3A.

As is mentioned in the chapter on the hydrography, there is a distinct boundary at *ca.* 50 m in depth, and there is another boundary at *ca.* 25 m. These two boundaries appear to be well represented by benthonic Foraminifera assemblages. The boundaries also appear to be represented by planktonic organisms. MOTODA and ANRAKU (1952) studied the vertical distribution of plankton at the mouth of Funka Bay and found that warm-water species were concentrated in upper 30 m of water, *Paracalanus parvus*, a shallow-water copepod, disappeared at 50 m, and *Limacina helicina* began to appear at 30 m and suddenly became less abundant at 50 m. Thus physical (HIDAKA, 1934; UDA, 1938), chemical (MATSUDAIRA and MIZUUCHI, 1934) and biological (MOTODA and ANRAKU, 1952) data appear to support the results obtained by the writer in studying benthonic Foraminifera.

Interpretation of these Foraminifera assemblages or boundaries is, for the time being, difficult since the oceanographic data of this area is very scarce. The 20 m boundary may represent the base of the turbulent zone, or the base of the upper water which is, though apparently of Oyashio type, a mixture of Oyashio and Tsugaru Currents. The 50 m boundary may represent the base of the seasonal thermocline. The presence of such arenaceous species as *Haplophragmoides bradyi* (ROBERTSON), *Alveolophragmium crassimargo* (NORMAN) and *Ammotium cassis* (PARKER) in Fauna 3A and 3B suggests that the water mass deeper than *ca.* 50 m may represent the Intermediate Water.

Total benthonic population at Station 4 and 11 is much smaller than that at other stations. This is because the sediment at Station 4 is coarser than at other stations, and the sediment at Station 11 contains abundant pumice grains. In general it appears that the more pumice grains in sediment the less the benthonic population is.

Brief Taxonomic Notes

Elphidium planum HUSEZIMA & MARUHASI is a synonym of *Elphidium subarcticum* CUSHMAN.

Elphidium ezoense ASANO is a synonym of *Elphidium oregonense* CUSHMAN & GRANT.

Cribroelphidium arcticum TAPPAN is a synonym of *Elphidium bartletti* CUSHMAN.

Alveolophragmium ochotonensis STSCHEDRINA is a synonym of *Alveolophragmium crassimargo* (NORMAN).

Uvigerina cushmani TODD may be a synonym of *Uvigerina yabei* ASANO, but it is not sure.

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