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# Fossil benthic foraminifera from Aso-kai Lagoon, central Japan

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**Abstract:** Fossil benthic foraminifera were investigated in the 4 m length core ASC 2 taken from Aso-kai Lagoon, central Japan, to understand paleoenvironmental changes that occurred in the lagoon during the last 1200 years. Based on the presence of foraminiferal taxa, an alternation between relatively oxic (221-241 cm and 301-381 cm sediment core intervals) and seasonally oxygen-poor (281-301 and 161-201 cm intervals) conditions repeated twice in the lower part of the core. Year-round anoxia was established in the upper part of the core (1-121 cm interval) with occasional periods of improved oxygen level (71-81 cm interval). The changes in the oxygen concentration at the lagoonal bottom probably correspond to the opening /closure of the channel between the lagoon and Miyazu Bay.

**Key words:** Aso-kai Lagoon; benthic foraminifera; paleoenvironment

## Introduction

Aso-kai Lagoon is an isolated lagoon separated from Miyazu Bay (Japan Sea coast) by a sand-bar (named Amano-hashidate) (Fig. 1). The lagoon is connected to the bay by a narrow channel at its southeastern corner only and the hypolimnion is in an oxygen-poor condition almost year-round (Nakanishi et al., 1979; Takata et al., in press). During the last millennium, the sand-bar has occasionally been damaged due to extreme storms and the conditions within the lagoon have changed dramatically, according to the historical archive of this lagoon (Naito, pers. comm.). However, the paleo-environment of Aso-kai lagoon is still poorly understood since there is a limited sedimentological study.

A sediment-core ASC 2 was collected from the centre of Aso-kai Lagoon to improve the understanding of its paleoenvironement, in particular because it was expected that a paleoenvironmental analysis of this core could provide useful insight in the environmental changes of the lagoon and the Amano-hashidate sand-bar. In this paper, we report the occurrence of fossil foraminifera in core ASC 2. Detail discussion about environmental change of the lagoon will be presented in another paper (Takata et al., in prep.).

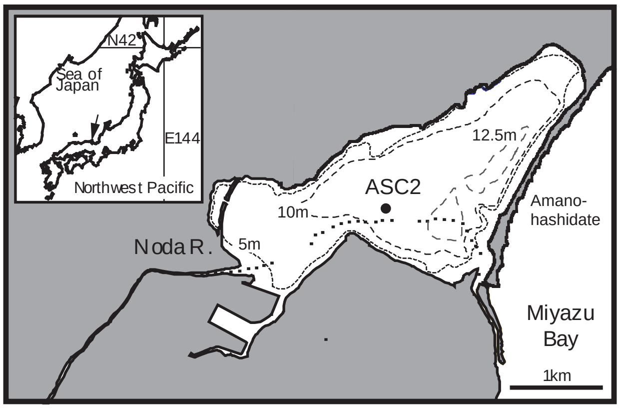


**Fig. 1.** Map of Aso-kai Lagoon, showing the coring site of core ASC 2 as an fixed circle.

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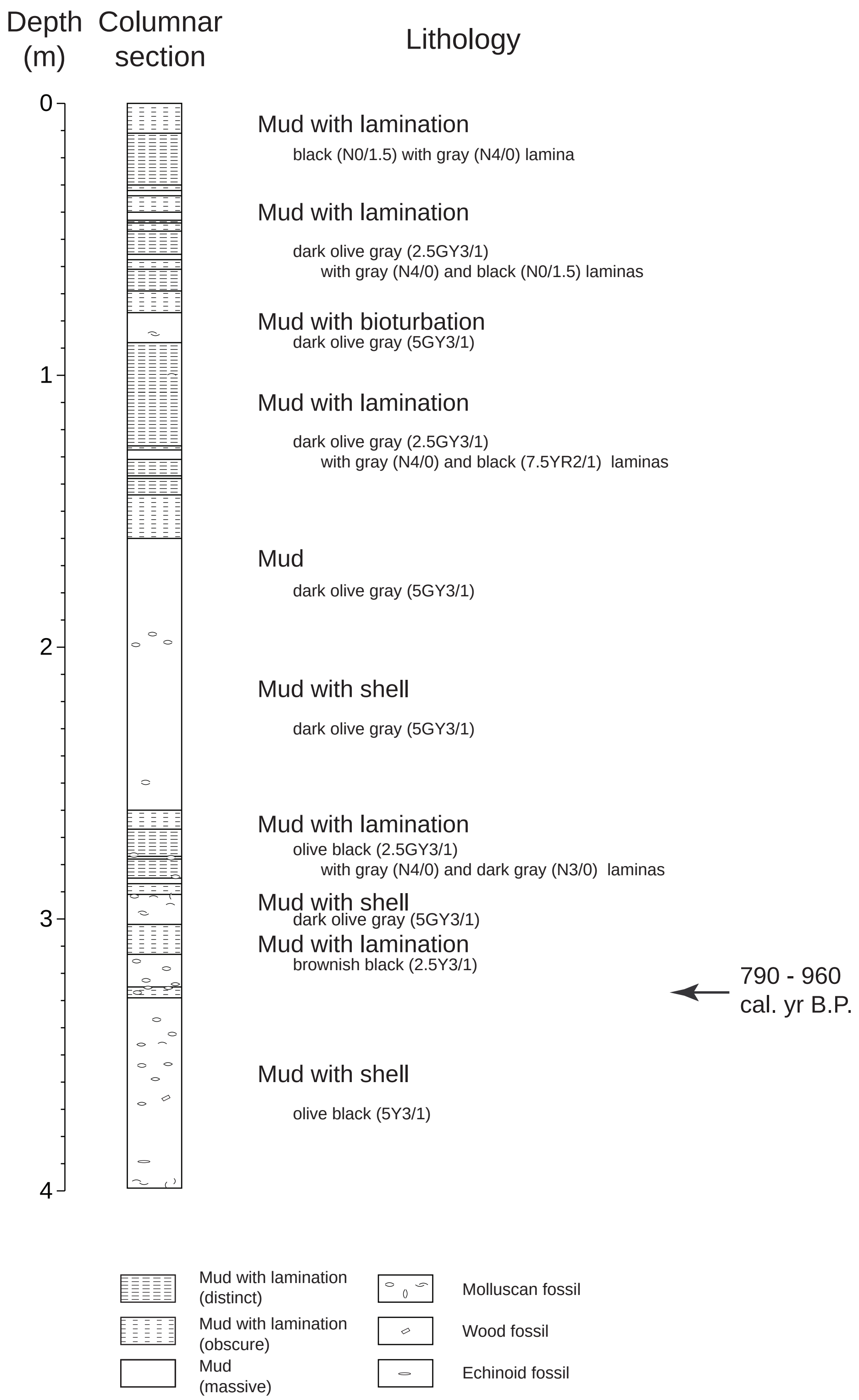


**Fig. 2.** Columnar section of core ASC 2.

## Materials and Method

Core ASC 2 was collected from the central part of Aso-kai Lagoon (N 35° 33.785', E 135° 10.557', 11.4 m water depth) on July 25, 2002 (Fig. 1). Total length of the core was 399 cm. The lithologies of the core consist of black- to dark gray-colored mud with parallel laminations at 0−75 cm, 90−125 cm, 130−160 cm, 260−290 cm and 302−313 cm (Fig. 2). AMS $^{14}$C date (1350 ± 40 yrB.P.) was measured using molluscan fossil found at 327 cm (Laboratory number: Beta−198725) by Geoscience Laboratory Inc., Japan. After conversion of radiocarbon age to calendar age, using age calibration curve INTCAL 98 (Stuiver et al., 1998), 910 (790−960) cal. yrB.P. was obtained for this horizon. Given that 0 and 327 cm imply present time and 910 cal. yrB.P., respectively, the average sedimentation rate of the core was estimated at 3.4 mm/yr. Hence, core ASC 2 has recorded the past 1200 years of paleoenvironmental changes in the central part of Aso-kai Lagoon.

The core was sampled for further analysis at each 1 cm. The samples were subdivided into separate parts for sedimentological and foraminiferal analyses, respectively. Weight of these subsamples was measured immediately after separation. Water content of each horizon was calculated by the difference in weight before and after drying at 70℃ of the subsamples for sedimentological analysis. Dry weights of subsamples for foraminiferal analysis were calculated based on its wet weight and water content of the other subsample.

Subsamples for foraminiferal analysis were washed on a 74 $\mu$m-mesh sieve immediately after collection. The residues were dried at 70℃. Approximately 200 benthic foraminiferal specimens were picked from each of 39 samples corresponding to each ten centimeter stratigraphic interval. These foraminiferal specimens were identified and counted.

## Results and Discussion

The occurrence of benthic foraminifera as observed in core ASC 2 is shown in Table 1. Benthic foraminifera show a continuous occurrence, although they are rare at 91, 141 and 241 cm depth. *Trochammina cf. japonica, Virgulinella fragilis* and *Elphidium somaense* are common, and *Eggerelloides advena, Quinqueloculina* sp. A, *Miliolinella* sp. A, *Ammonia japonica*, *Ammonia* sp. A, *Elphidium excavatum* forma *excavata* and *E. excavatum* forma *selseyensis* subordinate. Stratigraphic distributions of the major species are shown in Fig. 3. *E. somaense* is common in the 221−241 cm and 301−381 cm intervals. *Ammonia japonica* and *Ammonia* sp. A show similar downcore distributions. On the other hand, *T.* cf. *japonica* dominates three horizons (281−301 cm, 161−201 cm and 71−81 cm intervals). *V. fragilis* dominates the 1−121 cm interval, with the exception of the 71−81 cm interval. *Quinqueloculina* sp. A occurs abundantly in the 131-231 cm interval, and is particularly abundant at 131 cm and 151 cm depth in combination with *Miliolinella* sp. A.

Based on the knowledge of modern benthic foraminiferal distribution in Aso-kai Lagoon (Takata et al., in press) and previous literature on other brackish regions (Kosugi et al., 1991; Matsushita and Kitazato, 1990), the paleoenvironmetal changes inferred from core ASC 2 may be as follows. The oxygen level of the lagoonal bottom in the lower sediment core interval (161−381 cm interval) has fluctuated between relatively oxygen-rich and seasonally oxygen-poor conditions several times, as indicated by the alternating dominance of *Elphidium* spp., a common taxon in littoral or outer bay environments (e.g., Kosugi et al., 1991), and *T.* cf. *japonica*, which tolerates seasonal oxygen deficiency (Matsushita and Kitazato, 1990). In the upper sediment core interval (0−161 cm interval), an almost year-round oxygen deficiency in the bottom environment was indicated by *V. fragilis,* which is characteristic in anoxic or near-anoxic conditions (Bernhard, 2004; Takata et al., in press). Seasonally oxygen-poor conditions were apparent in the 71−81 cm interval, based on a high abundance of *T.* cf. *japonica.* It is suggested that the oxygen-level at the bottom in the central part of the Aso-kai Lagoon has changed dramatically during the last 1200 years. A detail discussion about paleoenvironmental change will be presented in another paper (Takata et al., in prep.).

Archives dealing with Aso-kai Lagoon (Naitou, *pers. com.*) show the opening/closure of the channel between the lagoon and the Miyazu Bay, which is closely related to exchange of lagoonal water, has changed during the last millennium. A wider channel at the southeastern part of the lagoon than in the present time is shown in a picture “Amano-hashidate zu” (AD 1501?−AD 1506?) drawn by Sessyu during Muromachi-era. Such wider opening of the channel is likely to correspond to relatively oxic or seasonally oxygen-depleted bottom condition below 130 cm depth in core ASC 2 (before approx. 390 cal. yrB.P.). Additionally, the sand-bar Amano-hashidate was damaged by extreme storms during the Ten-wa period (AD 1681 to AD 1684), the Ten-mei period (AD 1781 to AD 1788) and AD 1871 and the environment of this lagoon changed dramatically due to new channels that emerged due to these storms, based on the archive of Mizoshiri fishery, Kyoto Prefecture, Japan (Naitou, pers. comm.). One of these events probably corresponds to the sudden appearance of foraminifera reflecting seasonally oxygen-poor conditions between the 71 cm and the 81 cm interval (approx. 210−240 cal. yrB.P.). In conclusion, the oxygen -level of lagoonal bottom was probably affected by opening/closure events of the channel between the lagoon and the bay.

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**Table 1.** Benthic foraminifera present per sample (counted numbers of each sample) from core ASC 2 (sample dry weight is shown below)

| Interval (cm) | 0<br>1 | 10<br>11 | 20<br>22 | 30<br>32 | 40<br>43 | 50<br>52 | 61<br>63 | 70<br>72 | 80<br>81 | 90<br>92 | 101<br>103 | 110<br>111 | 120<br>122 | 130<br>131 | 140<br>141 | 150<br>151 | 160<br>161 | 170<br>171 | 180<br>181 | 190<br>191 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Agglutinated Foraminifera** | | | | | | | | | | | | | | | | | | | | |
| *Cribrostomoides* sp. A | | | | | | | | | | | | | | | | | | | | |
| *Eggerelloides advena* | | | | 1 | | | | | | | | | | | | | 107 | 16 | 13 | 10 |
| *Tiphotrocha kelettae* | | | | | | | 1 | | | | | | | | | | | | | |
| *Trochammina* cf. *japonica* | | | | 3 | 8 | 1 | 7 | 21 | 26 | 2 | 2 | | 1 | 2 | | 6 | 255 | 145 | 111 | 52 |
| *Trochammina pacifica* | | 1 | | | | | | | | | | | | | | | | 1 | | |
| Agg. Foram. gen. et sp. indet. | | | | | | | | | | 1 | | | | | | | | | | |
| **Calcareous Porcelaneous Foraminifera** | | | | | | | | | | | | | | | | | | | | |
| *Massilina inaequaris* | | | | | | | | | | | | | | | | | | | | |
| *Massilina secans* | | | | | | | | | | | | | | | | | | | | |
| *Miliolinella sidebottomi* | | | | | | | | | | | | | | | | 3 | 29 | 5 | | 1 |
| *Miliolinella* sp. indet. | | | 1 | | | | | | | | | | | | | | | | | |
| *Miliolinella* sp. A | | | | | 1 | | | 1 | | | | | | 13 | | 25 | 22 | 7 | 7 | |
| *Quinqueloculina elongata* | | | | | | | | | | | | | | | | 1 | | | | |
| *Quinqueloculina* sp. A | | 1 | | | | | | 1 | 1 | | 1 | | | 20 | 1 | 69 | 110 | 39 | 61 | 23 |
| *Quinqueloculina* sp. B | | | | | | | | | | | | | | | | 11 | 1 | 1 | | 1 |
| *Quinqueloculina* sp. C | | | | | | | | | | | | | | | | | | | | |
| *Quinqueloculina* sp. D | | 1 | | | | | | | | | | | | | | | | | | |
| *Quinqueloculina* sp. indet. | | | | | | | | | | | | | | | | 5 | | | | |
| *Triloculina* sp. | | | | | | | | | | | | | | 1 | | | | | | |
| Calc. Porcelaneous Foram. gen. et sp. indet. | 2 | | | 1 | | 1 | 1 | 1 | 2 | | | | 2 | 10 | | 29 | 22 | 10 | 17 | 3 |
| **Calcareous Hyaline Foraminifera** | | | | | | | | | | | | | | | | | | | | |
| *Ammonia beccarii* forma 1 | 3 | | | | | | | | | | | | | | | | | | | |
| *Ammonia beccarii* forma 2 | | | | | | | | | | | | | | | | | | | | |
| *Ammonia japonica* | | | | | | | | | | | | | | 1 | | | 2 | 10 | 2 | 1 |
| *Ammonia* sp. A (compact type) | 1 | | | | | | | | | | | | | | | | 1 | 1 | | 2 |
| *Ammonia* sp. A (inflate type) | | | | | | | | | | | | | | | | 1 | | | | |
| *Ammonia* sp. B | | | | | | | | | | | | | | | | | | | 1 | 2 |
| *Bolivina* sp. A | | | 1 | | | | 1 | | | 1 | | | | | | | | | | |
| *Bolivina* sp. B | | | | | | | | | | | | | | | | | | | | |
| *Bolivina* sp. C | | | | | | | | | | | | | | | | | | | | |
| *Bolivina* sp. D | | | | | | | | | | | | | | | | | | | | |
| *Bolivina* sp. E | | | | | | | | | | | | | | | | | | | | |
| *Bolivina* sp. F | | | | | | | | | | | | 1 | | | | | | | | |
| *Bolivina* sp. indet. | | | | | | | | | | 1 | | | | | | | | | | |
| *Buccella frigida* | | | | | | | | | | | | | | | | | 6 | 2 | | |
| *Buccella* sp. indet. | | | | | | | | | | | | | | | | | | | | |
| *Buccella tenerrima* | | | | | | | | | | | | | | 1 | | 1 | | | | |
| *Bulimina* sp. A | | | | | | | | | | | | | | | | | | | | 1 |
| *Bulimina* sp. B | | | | | | | | | | | | | | | | | | | | |
| *Bulimina* sp. C | | | | | | | | | | | | | | | | | | | | |
| *Buliminella elegantissima* | | | | | | | | | 1 | | | | | 1 | | | 6 | 9 | 4 | 2 |
| *Cymbaloporetta* sp. | | | | | | | | | | | | | | | | | | | | |
| *Elphidium advenum* | | | | | | | | | | | | | | | | | | | 1 | 1 |
| *Elphidium excavatum* forma excavata | | | | | | | | | | | | | | 1 | 1 | 12 | 2 | | 9 | |
| *Elphidium excavatum* forma selseyensis | | | | | | | | | | | 1 | | | | | 1 | 1 | 11 | 9 | 7 |
| *Elphidium jenseni* | | | | | | | | | | | 1 | | | 1 | | | | | | |
| *Elphidium kushiroense* | | | | | | | | | | | | | | | | 1 | 1 | | | |
| *Elphidium reticulosum* | | | | | 1 | | | | | | | | | | | | 1 | 6 | | |
| *Elphidium somaense* | 1 | | | | | | | | | | | | | 2 | | | | 4 | 9 | 7 |
| *Elphidium* sp. A | | | | 1 | | | | | | | | | 2 | 1 | | | 11 | 11 | 7 | |
| *Elphidium* sp. B | | | | | | | | | | | | | | | | | | 5 | | |
| *Elphidium* sp. C | | | | | | | | | | | | | | | | | | | | |
| *Elphidium* sp. D | | | | | | | | | | | | | | | | | | | | |
| *Elphidium* sp. indet. | | | | 2 | 1 | 3 | | | | 1 | | 1 | | | | | | | | 1 |
| *Glabratella* sp. A | | | | | | | | | | | | | | | 1 | | | | | |
| *Glabratella* sp. B | | | 1 | 1 | 1 | | | | | | | | | | | | | | | |
| *Guttulina* spp. | | | | | | | | | | | | | | | | | | | | |
| *Gyroidinoides* sp. | | | | | | | | | | | | | | | | | | | | |
| *Neoconorbina stachi* | | | | | | | | | | | | | | | | | | | | |
| *Nonionella stella* | | | | | | | | | | | | | | | | | 1 | 4 | 1 | |
| *Planograbratella subopercularis* | | | | | | | | | | | | | | | | | | | | |
| *Pseudononion japonicum* | | | | | | | | | | | | | | | | 1 | | | | |
| *Pseudoparrella naraensis* | | | | | | | | | | | | | | | | | 1 | | | |
| *Pseudoparrella tamana* | | | | | | | | | | | | | | | | | | | | |
| *Reussella pacifica* | | | | | | | | | | | | | | | | | | | | 1 |
| *Rosalina bulloides* | | | | | | | | | | | 1 | | | | | | | | | |
| *Rosalina* sp. A | | 1 | | | | | | | | | | 10 | | | 1 | | | | | |
| *Rosalina* sp. B | | | | | 1 | 2 | 1 | | | | | | | | | | 1 | | | |
| *Rosalina* sp. C | | | | 1 | | | | | | | | | | | | | | | | |
| *Rosalina* sp. indet. | | 2 | | | | | | | | | | | | | | | | | | |
| *Stainforthia* sp. | | | | | | | | | | | | | | | | | | | | |
| *Uvigerinella glabra* | | | | | | | | | | | | | | | | | 9 | 2 | 4 | |
| *Valvulineria hamanakoensis* | | 1 | | | | | | | 2 | | | | | | | | 13 | 2 | | |
| *Virgulinella fragilis* | 33 | 56 | 74 | 19 | 28 | 30 | 48 | 17 | 1 | | 19 | 15 | 34 | 5 | | 25 | 3 | 6 | 1 | |
| Calc. Hyaline Foram. gen. et sp. indet. | | | | | | 1 | | | | | | | | | | | | | | |
| Total | 40 | 63 | 77 | 29 | 41 | 38 | 59 | 41 | 33 | 6 | 25 | 27 | 39 | 59 | 4 | 191 | 605 | 297 | 257 | 115 |
| Dry sample weight (g) | 0.41 | 0.62 | 1.10 | 1.54 | 2.79 | 1.95 | 1.47 | 1.31 | 1.09 | 2.23 | 3.85 | 2.54 | 2.42 | 1.26 | 1.31 | 1.48 | 1.25 | 0.94 | 1.53 | 1.28 |
| Split | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

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**Table 1.** continued

| 200<br>201 | 210<br>211 | 220<br>221 | 230<br>231 | 240<br>241 | 250<br>251 | 260<br>261 | 270<br>271 | 280<br>281 | 290<br>291 | 300<br>301 | 310<br>311 | 320<br>321 | 330<br>331 | 340<br>341 | 350<br>351 | 360<br>361 | 370<br>371 | 380<br>381 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | | | | | | | | | | | | | | | |
| 2 | 30 | 20 | 17 | 184 | 75 | 51 | | 4 | 2 | 112 | 12 | 20 | 11 | 29 | 19 | | | 5 |
| 90 | 59 | 31 | 45 | 43 | 10 | 27 | | 70 | 24 | 249 | 93 | 2 | | 5 | 1 | | | |
| | | | | | | | | 1 | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | 1 | |
| | | | | | | | | | | | 1 | | | | | | | |
| | | | 2 | 2 | 3 | 2 | | | 5 | | | 2 | | 3 | 1 | 2 | 7 | 2 |
| 1 | | | | | | | | | | | | | | | | | | |
| | 3 | 1 | | | | 4 | | | 14 | | 2 | 3 | | | | | | |
| | | | | | | | | | | | 1 | | 1 | | | | | |
| 41 | 30 | 79 | 109 | 25 | 15 | 14 | 4 | | 40 | 4 | 99 | 20 | 16 | 45 | 13 | 4 | 6 | 1 |
| | | | 1 | 3 | 1 | | | | 3 | | 2 | 1 | | | | | | |
| | | | | | | | | | | | | | | | | 1 | | |
| | | 1 | | | | | | | | | | | | | | | | |
| 12 | 9 | 17 | 16 | 18 | 8 | 3 | 2 | | 22 | 4 | 9 | 7 | 2 | 7 | 1 | 1 | 4 | |
| 2 | | 1 | | | | | | | | | | | | | | | | |
| 4 | 52 | 66 | 10 | 14 | 23 | | | | 2 | 3 | 5 | 11 | 5 | 13 | | 8 | 12 | 5 |
| 3 | 2 | 4 | 3 | 6 | 46 | 1 | | | | | | 2 | 7 | 9 | 59 | 9 | 28 | 2 |
| | | | | 4 | 27 | | | | | | | | | 4 | 29 | 4 | 10 | 1 |
| | 2 | | 1 | | 5 | | | | | | | 5 | 2 | 4 | | | 5 | |
| | | 1 | 1 | 1 | | 1 | | | | | 1 | | 2 | | 1 | | 2 | |
| | | | | | | | | | | | | | | | 1 | | | |
| | | | | | | | | | | | | | | 1 | | | | |
| | | | | | | | | | | | | 2 | | | | | | |
| | | | | | | | 1 | | | | | | | | | | | |
| | 1 | 2 | | | | | | | | | | | | | | | 2 | |
| | | | | | | | | | | | | | | | | 1 | | |
| | | | | | | | | | | | 1 | 5 | | 2 | 8 | | 2 | |
| | | | | | | | | | | | | 2 | 2 | | 10 | | 2 | 1 |
| | | 1 | | | | | | | | | | | | | | | | |
| 8 | | 6 | 7 | 7 | 7 | 2 | | 1 | 6 | 8 | 10 | 4 | 2 | 1 | | 1 | 1 | |
| | | | | | | | | | | | | | | 1 | | | | |
| | | 9 | 4 | 6 | 8 | | | | | 2 | 6 | 10 | 8 | 6 | 2 | | | 1 |
| 12 | 2 | 7 | 22 | | 8 | | | | 109 | 5 | 15 | 25 | 23 | 10 | 10 | 4 | 9 | |
| 6 | 2 | 1 | 21 | 4 | 9 | | | | 19 | 9 | 3 | 5 | 5 | 6 | 3 | 4 | 5 | 1 |
| | | | | | | | | | | | | | | | 1 | | | |
| | | | | | | | | | | | | 2 | | | | | | |
| | 1 | 9 | 1 | 4 | 4 | 2 | | | | | | 16 | 1 | 1 | 1 | 1 | 1 | 1 |
| 6 | 13 | 90 | 52 | 146 | 37 | 4 | 1 | | 5 | 20 | 61 | 40 | 44 | 100 | 75 | 32 | 37 | 2 |
| | | | 2 | | | | | | 2 | | | 2 | 1 | 1 | | | | |
| | | | | 2 | | | | | | 6 | | | 2 | 1 | | | | |
| | | | | | | | | | | | | | | | | 2 | | |
| 2 | 1 | | 1 | 4 | | 4 | | | 1 | | 2 | 2 | 3 | | 2 | | 2 | 1 |
| | | | | 1 | | | | | | | | | | | | | | |
| | | | | 1 | 2 | | | | | | | 2 | | | | | | |
| | | | | 2 | | | | | | | | | | | | | 1 | |
| | | | 1 | | | | | | | | | | | | | | | |
| 1 | | | 4 | | | | | | | 16 | 8 | 4 | 6 | 2 | 7 | 6 | 10 | 2 |
| | | | | | | | | | | | 1 | | 1 | | | | | |
| | | | | | | | | | | | 2 | | | 1 | 1 | 3 | | |
| | | 8 | 2 | | 4 | | | | | | | 5 | | 2 | 4 | 2 | 3 | 1 |
| | | | | | | | | | | 1 | | | | 1 | | | | |
| | | 2 | | | | | | | | | | | | | | | | |
| | | | 2 | | | | 2 | | 1 | | 1 | 1 | | | 1 | 1 | 3 | |
| | | | | | | | | | | | | 2 | 1 | 2 | 1 | | 1 | |
| | | | | | | | | | | | | | | | | 1 | | |
| | | | | 3 | | | | | | | | | | | | | | |
| 2 | 4 | 16 | 27 | 25 | 11 | 1 | 1 | | | 2 | 22 | 2 | 13 | 20 | 15 | 5 | 3 | |
| | 2 | 2 | | | | | | | | | 1 | | | | 2 | | 1 | |
| 1 | | 1 | | | | | | | 2 | | 1 | | | | | | | |
| 193 | 207 | 375 | 352 | 505 | 303 | 116 | 11 | 76 | 257 | 441 | 359 | 204 | 158 | 277 | 268 | 90 | 162 | 26 |
| 1.27 | 0.94 | 1.28 | 1.26 | 1.32 | 1.57 | 1.70 | 1.24 | 1.55 | 1.57 | 1.19 | 1.42 | 1.32 | 1.46 | 1.52 | 1.73 | 1.42 | 1.55 | 1.60 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 1 |


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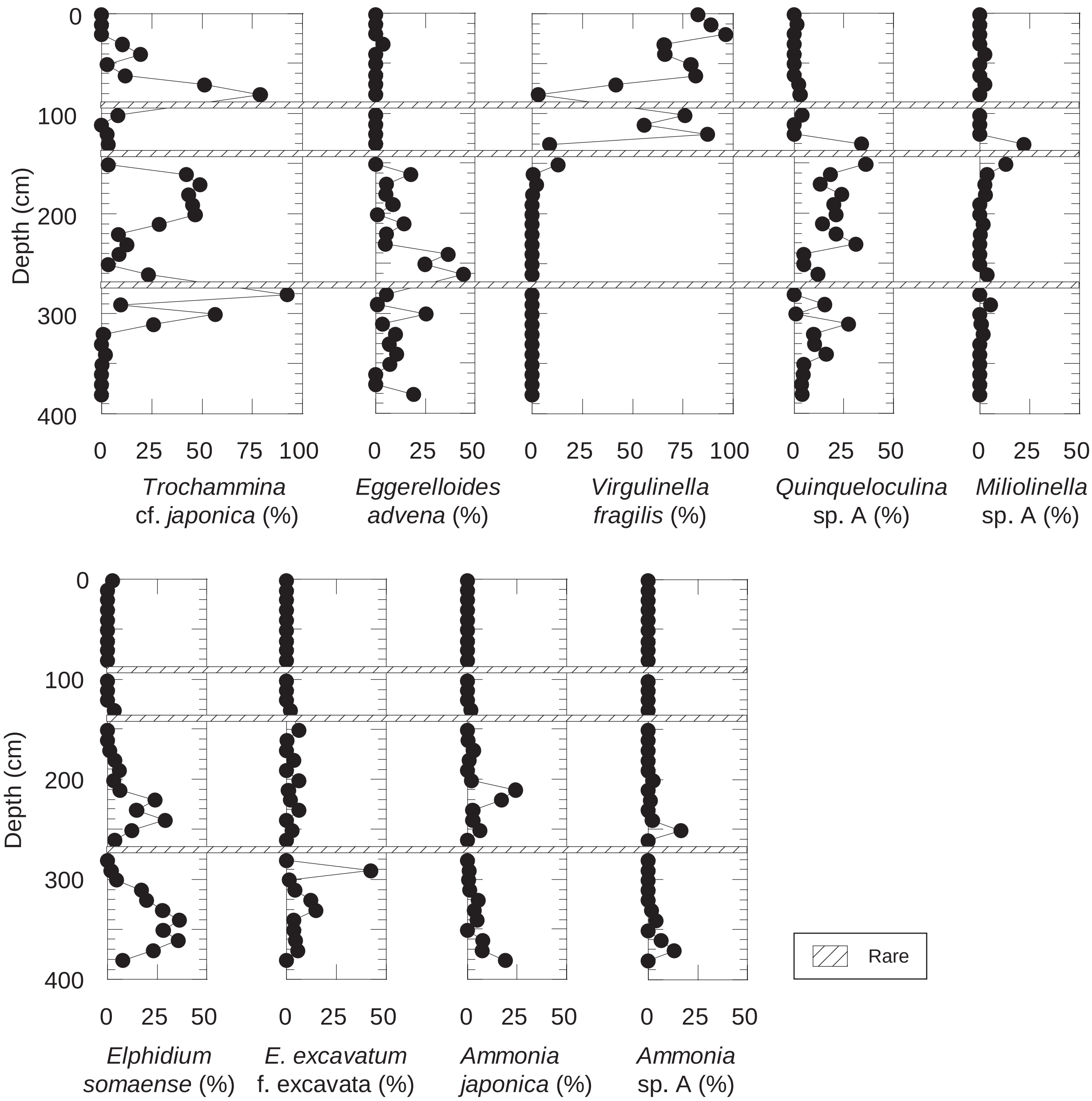


**Fig. 3.** Stratigraphic changes of major species of benthic foraminifera in core ASC 2. Shaded symbol shows rare (< twenty) foraminiferal presence.

98 radiocarbon age calibration, 24000-0 cal BP. Radiocarbon, 40 (3): 1041−1083.

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**Plate 1.** Scanning electron micrographs of foraminiferal fossil from core ASC 2. Scale bar = 100㎛.

1 a-c. *Trochammina* cf. *japonica*
2. *Virgulinella fragilis*
3 a-c. *Ammonia* sp. A (compact type)
4 a, b. *Eggerelloides advena*
5 a, b. *Uvigerinella glabra*
6 a-c. *Ammonia* sp. A (inflate type)
7 a-c. *Ammonia* sp. B
8 a, b. *Buliminella elegantissima*
9. *Bulimina* sp. A

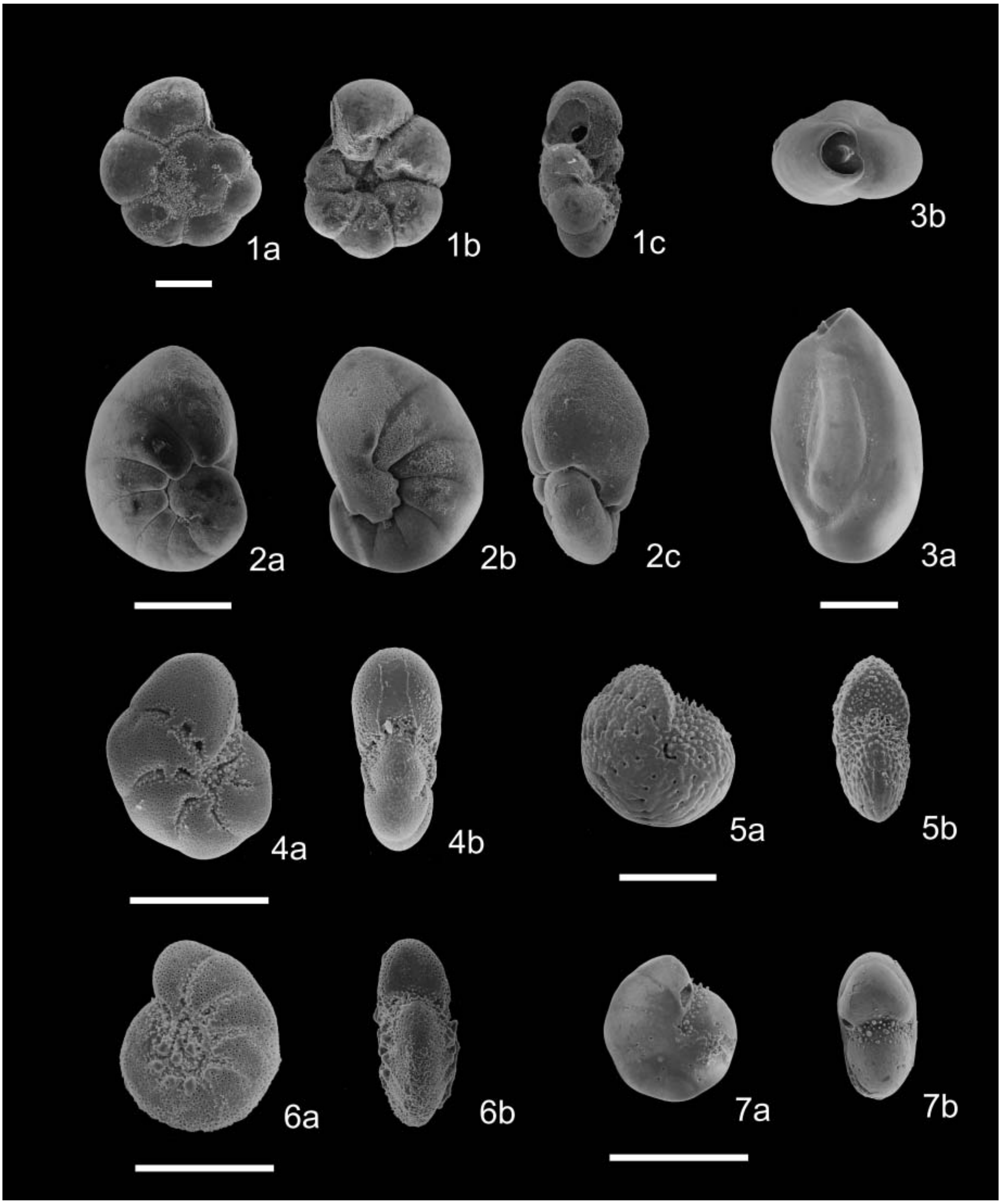


**Plate 2.** Scanning electron micrographs of foraminiferal fossil from core ASC 2. Scale bar = 100μm.

1 a-c. *Ammonia japonica*
2 a-c. *Nonionella stella*
3 a, b. *Quinqueloculina* sp. A
4 a, b. *Elphidium excavatum* forma excacvata
5 a, b. *Elphidium reticulosum*
6 a, b. *Elphidium excavatum* forma selseyensis
7 a, b. *Elphidium somaense*