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# Planktonic foraminifera and biochronology of the Cenomanian-Turonian (Cretaceous) sequence in the Oyubari area, Hokkaido, Japan

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**Abstract.** **A Cenomanian and Turonian (Late Cretaceous) sequence along the Shirakin River, Oyubari area, central Hokkaido, Japan contains seven datum planes of planktonic foraminifera that can be used to establish international correlations. These datum planes are marked by the first appearance of *Praeglobotruncana gibba, Rotalipora greenhornensis, Rotalipora deeckei, Marginotruncana schneegansi* and *Marginotruncana pseudolinneiana*, and the last appearance of *Rotalipora deeckei* and *Rotalipora cushmani*. These datum planes can be correlated with international Cretaceous planktonic foraminiferal zones in the interval KS17-KS22. Seventeen planktonic foraminiferal species are described including five new species: *Hedbergella kyphoma, Praeglobotruncana compressa, Praeglobotruncana inermis, Praeglobotruncana shirakinensis*, and *Dicarinella takayanagii*.**

**Key words: biostratigraphy, Cenomanian, Cretaceous, datum plane, planktonic foraminifera, Turonian, Yezo Group**

## Introduction

The Cretaceous Yezo Group in Hokkaido, Japan yields abundant ammonites and inoceramids that have been used to create a number of regional biostratigraphic zones. However, most of these molluscan fossils cannot be used for high resolution biochronology and international correlation (e.g. Matsumoto, 1942, 1943; Hirano *et al*., 1977, 1981; Hirano, 1982). On the other hand, there have been few biostratigraphic studies of calcareous microfossils in the Yezo Group. A planktonic foraminiferal biostratigraphy of the Yezo Group was first established by Takayanagi in 1960. Subsequently, Takayanagi and Iwamoto (1962) and Takayanagi and Okamura (1977) have reported planktonic foraminiferal occurrences from the group. Maiya and Takayanagi (1977) and Maiya (1985) summarized a Japanese planktonic foraminiferal zonation. However, these zonations have not been adequate for detailed interregional correlation of local Japanese Cretaceous sequences. In this decade, Motoyama *et al*. (1991), Hasegawa and Saito (1993), Hasegawa (1997) and Takashima *et al*. (1997) reported Cretaceous planktonic foraminiferal biostratigraphy from the Oyubari area of central Hokkaido and their reported taxa suggest that age-diagnostic species are available for international correlation. Nishida *et al*. (1993) presented additional data on the biostratigraphic correlation of the Oyubari sequence based on micro- and megafossils. Hasegawa (1995) further clarified the precise stratigraphic position of the last appearances of *Rotalipora greenhornensis* and *Rotalipora cushmani* and of the first appearance of *Marginotruncana schneegansi* near the Cenomanian/Turonian (C/T) boundary. Recently, Hasegawa (1997) used a comprehensive biostratigraphy of planktonic foraminifera to demonstrate interregional synchroneity of carbon isotopic events during Cenomanian-Turonian age. However, with the exception of Kaiho's (1992) work on Campanian species, no descriptive work on planktonic foraminiferal species of the Yezo Group has been presented in recent years.

This study describes seven planktonic foraminiferal datum planes recognized in the Cenomanian-Turonian sequence exposed along the Shirakin River in the Oyubari area and attempts biostratigraphic correlation with the international zonation established by Sliter (1989). Planktonic foraminiferal species, including twelve age-indicative species and five new species, are described.

## Materials and methods

Samples used in this study were collected from the Yezo Group mainly along the Shirakin (=Hakkinzawa) River, Oyubari area, central Hokkaido, Japan (Figures 1, 2). The Yezo Group is interpreted as a forearc basin facies (Okada, 1979, 1983). In the Oyubari area, the Cenomanian- Turonian sequence of the group is represented by the Hikagenosawa and Takinosawa Formations as defined by Motoyama *et al.* (1991). Approximately 300 samples were collected and processed. Near the C/T boundary, sampling was at approximately 2.5 m intervals. Faunal analyses are based on 49 planktonic foraminifera-bearing samples consisting largely of siltstone in the Cenomanian-Turonian section. Samples weighing approximately 240 g were disaggregated using sodium sulfate, naphtha solution (Maiya and Inoue, 1973), and sodium tetraphenylborate plus sodium chloride (Hanken, 1979), washed through a 63 $\mu$m screen and dried. All specimens larger than 180 $\mu$m were identified. Additionally, larger samples (500-800 g) were analyzed in the boundary sequence from 7 m below to 40 m above the C/T boundary. All specimens described herein are deposited in the Department of Geoenvironmental Science, Faculty of Science, Tohoku University.

## Biostratigraphy

The planktonic foraminiferal assemblages are listed in Table 1. A detailed biostratigraphy near the C/T boundary has been established along the Shirakin River, based on continuous occurrences of planktonic foraminifera (Hasegawa, 1995; Hasegawa, 1997). Common occurrence of internationally recognized species, especially those within the genera *Rotalipora* and *Marginotruncana* allow correlation with datum planes as summarized by Caron (1985) and Sliter (1989).

The stratigraphic distribution of planktonic foraminifers in the Oyubari section is shown in Figures 3 and 4. In addition, two late Cenomanian samples collected from the Kashimamigimata River (Figure 2) are included in the data presented in Figure 3. Although the Hikagenosawa Formation (Figure 3) includes a low-diversity assemblage, several species have biostratigraphic utility, including *Rotalipora gandolfii* (Luterbacher and Premoli-Silva) from the lower to middle, and *Praeglobotruncana gibba* Klaus, *Rotalipora greenhornensis* (Morrow) and *Rotalipora deeckei* (Franke) from the uppermost part of the formation. On the other hand, the lower part of the Takinosawa Formation is characterized by highly diversified assemblages including such international zonal species as *Rotalipora cushmani* (Morrow) and *Helvetoglobotruncana helvetica* (Bolli) as well as the age-indicative species *R. greenhornensis*, *R. deeckei* and *Marginotruncana schneegansi* (Sigal). In the middle to upper part of the Takinosawa Formation and in the overlying Shirogane Formation, the planktonic foraminiferal diversity declines again, with only two biochronologically important species, *Marginotruncana pseudolinneiana* Pessagno and *Marginotruncana coronata* (Bolli), having correlational significance.

## Datum planes

Based on the stratigraphic distribution of the species that belong to the genera *Rotalipora* and *Marginotruncana* and other important age-diagnostic species (e.g., *Helvetoglobotruncana helvetica* and *Praeglobotruncana* spp.), seven bioevent horizons (i.e., FAD, first appearance datum; LAD, last appearance datum) were recognized in the Shirakin River section as reliable datum planes. These are discus-

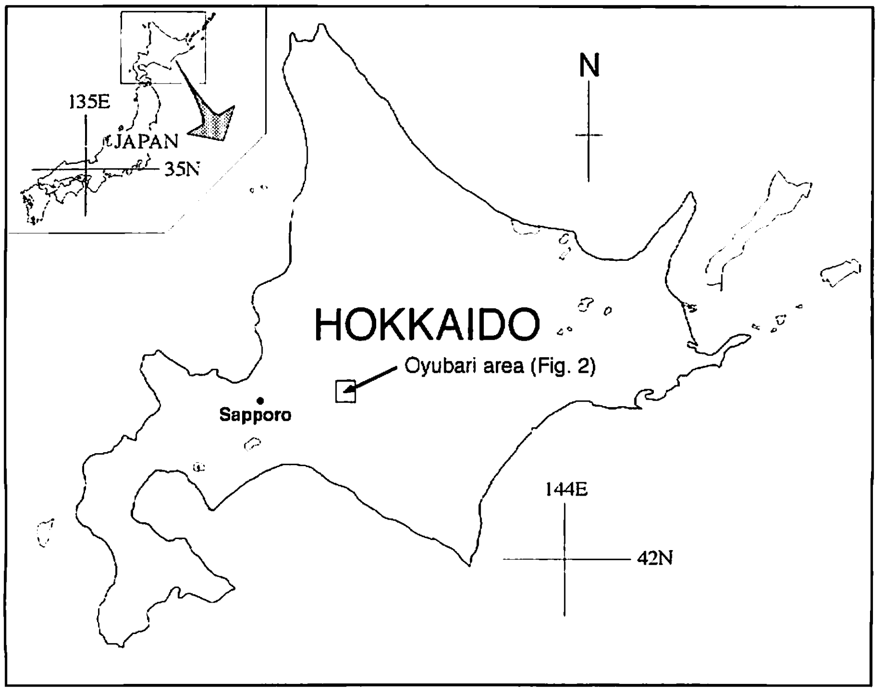


**Figure 1.** Index map showing the locality of the Oyubari area.

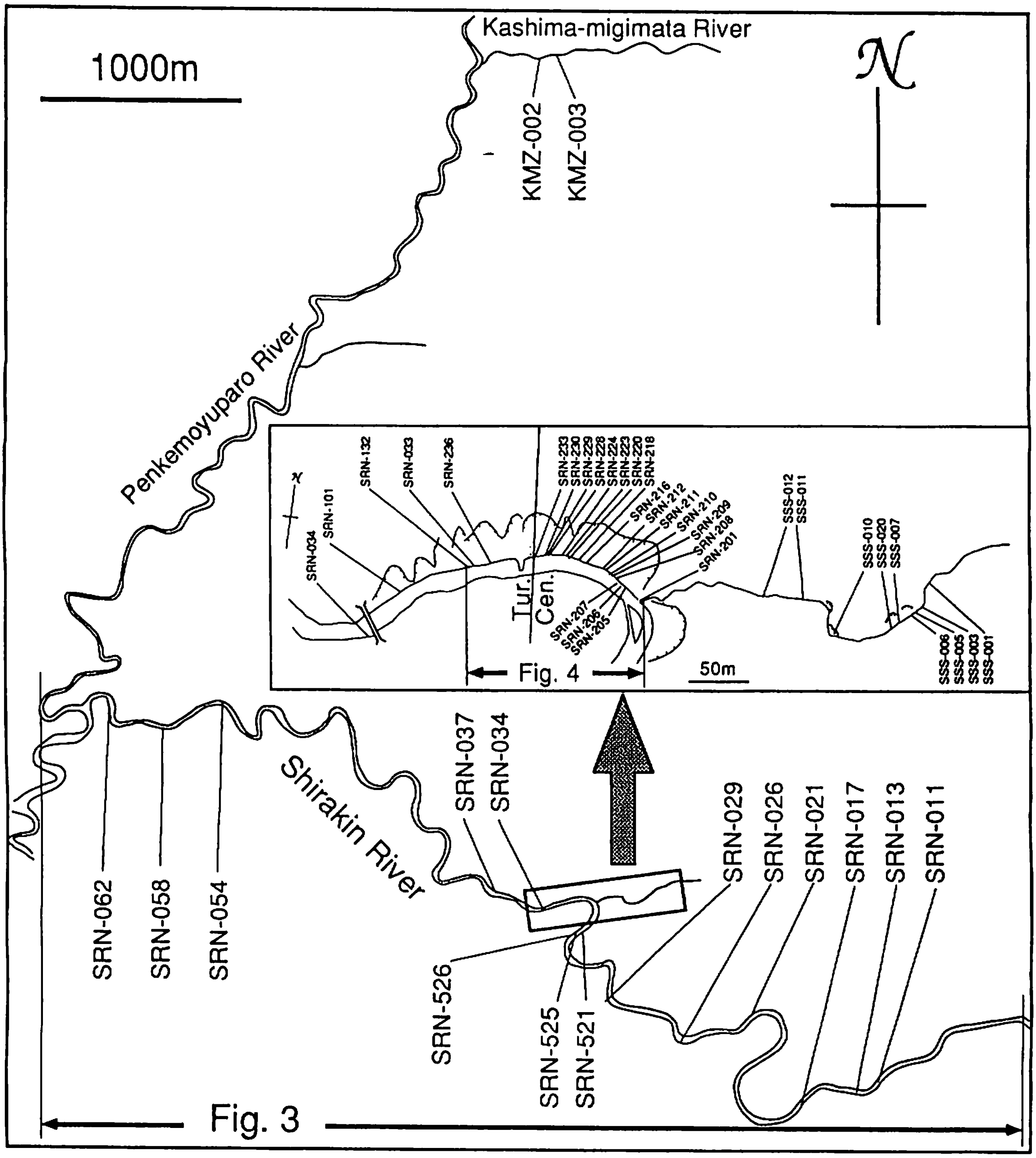


Figure 2. Map showing sampling localities in the Oyubari area.

sed separately below.

**A : FAD of *Praeglobotruncana gibba***

This datum is early Cenomanian. FAD of *P. gibba* in the middle part of the Hikagenosawa Formation is observed about 180 m below the FAD of *R. greenhornensis*. According to Caron (1985), the FAD of *P. gibba* is located just below the FAD of *R. greenhornensis*, which is consistent with its first occurrence in the Oyubari section. *Rotalipora brotzeni* first occurred above this datum, but its occurrence is too rare to establish a reliable datum level. The planktonic foraminiferal assemblage below this datum is mainly composed

**Table 1.** Stratigraphic occurrences of planktonic foraminifera in the Oyubari area. Symbols denote the number 2" or "1/4" written under the total number mean that 1/2 or 1/4 fraction of residues of 240 g rock samples were rences shown with parentheses indicate the inclusion of specimens of which specific name can only be given with

| Species | sample No. | SRN 011 | SRN 013 | SRN 017 | SRN 021 | SRN 022 | SRN 025 | KMZ 003 | SRN 026 | SSS 001 | SSS 003 | KMZ 002 | SSS 005 | SSS 006 | SSS 007 | SSS 020 | SSS 010 | SSS 011 | SSS 012 | SRN 029 | SRN 201 | SRN 205 | SRN 206 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Globigerinelloides* | *ultramicra* | | | | | | | R | | | F | R | | | | | | | | | | | |
| *G.* | cf. *bentonensis* | | | | | | | | | | | | | | | | | | | | | | |
| *G.* | cf. *eaglefordensis* | | | | | | | | | | | | | | | R | | | | | | | |
| *G.* | spp. | | | | | | | | | | | | | | | | | | | | | | |
| *Hedbergella* | *delrioensis* | | C | R | F | | | | R | A | VA | F | C | VA | R | R | R | F | (A) | | | | |
| *H.* | *planispira* | | F | R | R | | | F | | | VA | | R | | | | | R | C | | | | |
| *H.* | *kyphoma* sp. nov. | | | | | | | F | | | | | | | | | | | | | | | |
| *H.* | spp. | | | | | | | | | R | | | | | | | | | | | | | |
| *Rotalipora* | cf. *appenninica* | | | | | | | | | R | | | | | | | | | | | | | |
| *R.* | *gandolfii* | | | | R | | | R | | | | | | | | R | | | | | | | |
| *R.* | *brotzeni* | | | | R | | | R | | | | R | | | | | | | | | | | |
| *R.* | *greenhornensis* | | | | F | | R | C | | | R | F | F | | | | | | | | | R | |
| *R.* | *deeckei* | | | | | | | R | | | | F | | | | | | | | | | | |
| *R.* | *cushmani* | | | | | | | | | | | | F | R | | | | | | | R | | |
| *R.* | spp. | | | | R | | | | | | | R | | | | | | | | | | | |
| *Praeglobotruncana* | *delrioensis* | R | | A | VA | R | | | A | R | A | | C | C | F | | C | A | C | | R | R | |
| *P.* | *stephani* | | | C | VA | R | R | | A | VA | C | F | VA | F | | R | A | VA | C | A | R | A | F |
| *P.* | *gibba* | | | F | A | | | | A | A | C | | A | F | F | F | R | A | C | F | R | A | C |
| *P.* | *anumalensis* | | | | R | | | | | VA | VA | R | VA | VA | | | | VA | A | F | | A | C |
| *P.* | *shirakinensis* sp. nov. | | | | A | | | | | C | | | | | | | | | | | | C | |
| *P.* | *inermis* sp. nov. | | | | | | | | R | A | C | | F | F | R | | | C | R | | | A | |
| *P.* | *compressa* sp. nov. | | | | | | | | | | | | | | R | | F | F | | R | R | C | |
| *P.* | spp. | | | | | | | | | A | C | | C | R | | | | A | F | | R | A | |
| *Whiteinella* | cf. *archaeocretacea* | | | | | | | | | A | R | | | F | R | | R | | | | | R | |
| *W.* | *aprica* | | | | | R | | R | | | | | | | | | | C | (F) | | | | |
| *W.* | *baltica* | | | | | | | | | | A | | F | A | | | | | C | | | | |
| *W.* | *brittonensis* | | | | | | | | | F | A | | | | | | | R | (R) | | | | |
| *W.* | *inornata* | | | | | | | | | | | | | | | | | | | | | | |
| *W.* | spp. | | | | | | | | | C | | | | F | | | R | C | A | | | C | |
| *Dicarinella* | *imbricata* | | | | | | | | R | F | | | | | R | | | | R | | | F | |
| *D.* | *canaliculata* | | | | | | | | | A | | | | | | | | | | | | | |
| *D.* | *takayanagii* sp. nov. | | | | | | | | | A | | | (R) | | | | | | | | | | |
| *D.* | *hagni* | | | | | | | | | | | | | | | | | | (R) | | | | |
| *D.* | *roddai* | | | | | | | | | | | | | | | | | | | | | | |
| *D.* | *japonica* | | | | | | | | | | | | | | | | | | | | | | |
| *D.* | spp. | | | | | | | | | R | | | | | R | | | | | | | | |
| *Helvetoglobotruncana* | *helvetica* | | | | | | | | | | | | | | | | | | | | | | |
| *Marginotruncana* | *marginata* | | | | | | | | | | | | | | | | | | | | | | |
| *M.* | *schneegansi* | | | | | | | | | | | | | | | | | | | | | | |
| *M.* | *pseudolinneiana* | | | | | | | | | | | | | | | | | | | | | | |
| *M.* | cf. *coronata* | | | | | | | | | | | | | | | | | | | | | | |
| Indeterminable specimens | | 1 | 4 | 1 | | 1 | 0 | 0 | 9 | 34 | 11 | 1 | 30 | 24 | 10 | 1 | 3 | 23 | 11 | 2 | 0 | 17 | 0 |
| Total number | | 2 | 14 | 28 | 335 | 7 | 2 | 20 | 56 | 132 (1/2) | 103 (1/2) | 22 | 164 | 154 (1/2) | 25 | 9 | 29 | 100 | 109 | 15 | 9 | 110 | 19 |

of long-ranging species such as *Hedbergella delrioensis* (Carsey), *Hedbergella planispira* (Tappan), *Globigerinelloides ultramicra* (Subbotina), *Praeglobotruncana delrioensis* (Plummer) and *Praeglobotruncana stephani* (Gandolfi).

**B : FAD of *Rotalipora greenhornensis***

This datum is early-middle Cenomanian. The FAD of *Rotalipora greenhornensis* occurs in the upper part of the Hikagenosawa Formation. According to Caron (1985) and Sliter (1989), *R. greenhornensis* and *R. cushmani* have the same FAD. However, *Rotalipora cushmani* first occurs above the FAD of *R. greenhornensis* in the Oyubari section. The first occurrence of *R. cushmani* in the Oyubari section is observed above the LAD of *Rotalipora deeckei* and even above the first-occurrence horizon of the genus *Dicarinella*. This delayed first occurrence of *R. cushmani* is interpreted as a migration event of this species in this area. The stratigraphic relationship of the FAD of *R. greenhornensis* with other bioevents is concordant with that shown by Caron (1985) and Sliter (1989). The planktonic foraminiferal assemblage between the FAD of *P. gibba* and the FAD of *R. greenhornensis* is similar to that occurring below the FAD of *P. gibba*.

**C : FAD of *Rotalipora deeckei***

This datum is late Cenomanian. *Rotalipora deeckei* is a short-ranging age-diagnostic species of late Cenomanian age. According to Sliter (1989) and Robaszynski and Caron (1979), the total range of *R. deeckei* characterizes the upper part of the *Rotalipora cushmani* Zone (the range of *Rotalipora deeckei* is not shown in the range distribution chart of Caron, 1985). Stratigraphically, the FAD of *R. deeckei* lies near the top of the Hikagenosawa Formation. The occurrences of *Whiteinella* spp. and *Dicarinella* spp. within the total range of

of specimens included in each 240 g rock sample. VA : >21 specimens, A : 10∼20,C : 6∼9, F : 3∼5, R : 1 or 2. "1/
examined. The abundance of those samples are indicated by converted number into 240 g equivalent. The occur-
"cf.". The specimens of which species name bear "aff." are indicated by italic.

| SRN 207 | SRN 208 | SRN 209 | SRN 210 | SRN 211 | SRN 212 | SRN 216 | SRN 218 | SRN 220 | SRN 223 | SRN 224 | SRN 228 | SRN 229 | SRN 230 | SRN 233 | SRN 521 | SRN 236 | SRN 525 | SRN 033 | SRN 132 | SRN 526 | SRN 101 | SRN 034 | SRN 037 | SRN 054 | SRN 058 | SRN 062 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | R | | VA | F | | R | | | | |
| | | | | R | | | | | | | | | | | | | R | | | R | | | | | | |
| | | | | | | | | R | | R | | | | | | | | | C | F | | | | | | |
| | R | | | | | | | | | | | | | | | R | | | | | | | | | | |
| R | | | | | | | VA | A | | C | | | | | | A | A | A | VA | A | R | C | A | R | | |
| R | | | | | | | VA | R | | F | | | | | | F | A | | VA | A | F | VA | | | | |
| | | | | | | | | | | | | | | | | | A | | | F | | | | | | |
| | | | | | | | | | | R | | | | | | | F | | | R | | F | | | | |
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| R | | | R | | | | F | R | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | R | | | F | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | VA | C | | A | | | | | | | | | | | | | | | | |
| A | | R | C | R | F | | VA | A | | VA | | F | | | R | R | R | R | | | | | | | | |
| R | | F | F | | F | | VA | VA | | A | | F | | | R | R | | | | F | | R | | | | |
| A | | F | C | VA | F | | VA | VA | | VA | | | | | | R | R | A | | F | | | | | | |
| F | | C | C | A | C | R | VA | VA | F | VA | (R) | | R | | | F | R | | R | F | | | | | | |
| A | | R | R | F | R | | VA | A | R | A | | | | | | | R | C | | | | | | | | |
| | | | | F | R | | VA | R | | A | | | | F | | R | | | | | | | | | | |
| F | R | | F | C | R | R | VA | VA | R | VA | | R | | | | C | | | R | R | | | | | | |
| *F* | | | | | | | VA | F | | | | R | | | | | R | R | | | R | F | C | | R | |
| (R) | | | | | | | (VA) | (F) | | | | | | | | | (F) | | | (R) | | R | | | | |
| (F) | | | R | R | | R | (VA) | (A) | | (A) | (R) | | | | | R | R | | F | | | C | R | | | |
| | | | | | | (R) | (VA) | (F) | | (R) | | | | | | | | (C) | | R | | (R) | | | | |
| | | | | | | | | | | | | | | | | | | R | | | | R | | | | |
| R | | R | | | | | VA | C | R | F | | | R | | | F | R | R | | R | | | F | | | |
| | | | | | R | | | R | R | F | | | | | | F | R | | | | F | R | | | | |
| R | | | | F | | | F | R | | C | | R | R | | | | | | | (R) | R | | | | | |
| F | | | | | | | | | F | F | | | | | | R | | | R | | (VA) | (R) | | | | |
| | | | | | | | | | | | | | | | | (R) | | | | | | (R) | | | | |
| | | | | | (R) | | VA | F | F | | | R | | | | F | F | | VA | R | C | VA | | | | |
| | | | | | | | | | | | | | | | | F | | | | | | F | | | | |
| | | | | | | | | | | | | | | | | F | | | | | F | F | | | | |
| | | | | | | | | | | | | | | | | | | | | | R | | | | | |
| | | | | | | | | | | | | | | | | | | | (F) | | (R) | | | | | |
| | | | | | | | | | | | | | | | | | | | C | R | (R) | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | F | A | | F |
| | | | | | | | | | | | | | | | | | | | | | | | R | | | |
| 14 | 0 | 4 | 0 | 1 | 0 | 0 | 86 | 79 | 2 | 81 | 2 | 5 | 1 | 3 | 0 | 19 | 11 | 19 | 12 | 13 | 12 | 17 | 8 | 8 | 0 | 0 |
| 80 | 3 | 24 | 30 | 62 | 24 | 5 | 572 | 298 | 26 | 627 | 4 | 15 | 5 | 8 | 3 | 84 | 81 | 62 | 214 | 74 | 64 | 105 | 42 | 24 | 1 | 3 |
| | | | | | | | (1/4) | | | | | | | | | | | | | | | | | | | |

*R. deeckei* indicate that both the FAD and LAD of *R. deeckei* are reliable datum planes in the Oyubari section. Between FADs of *R. greenhornensis* and *R. deeckei*, the species *Praeglobotruncana anumalensis* (Sigal) and *Praeglobotruncana shirakinensis* n. sp. appear. However, the constituent species of the assemblage are similar to those occurring below the FAD of *R. greenhornensis*. The last occurrence of *Rotalipora gandolfii* Luterbacher and Premoli-Silva is observed at the same level as the FAD of *R. deeckei*, which shows considerable inconsistency with their stratigraphic relationship as summarized by Sliter (1989) and Caron (1985). Apparently *R. gandolfii* survived later in the northwestern Pacific.

### D : LAD of *Rotalipora deeckei*

This datum is late Cenomanian. The LAD of *Rotalipora deeckei* is recognized near the bottom of the Takinosawa Formation. A drastic faunal turnover was observed within the total range of *R. deeckei*. This faunal modification is characterized by the entry of *Dicarinella* spp., *Whiteinella* spp. and *Praeglobotruncana inermis* n. sp.

### E : LAD of *Rotalipora cushmani*

This datum is latest Cenomanian. The last occurrence of *Rotalipora cushmani* is observed at the same horizon as that of *Rotalipora greenhornensis*. Caron (1985) and Sliter (1989) reported the LAD of *R. greenhornensis* just below the LAD of *R. cushmani*. However, recent precise biostratigraphical studies of planktonic foraminifera indicate that these LADs are almost synchronous. Leckie (1985) described a Cenomanian/Turonian planktonic foraminiferal biostratigraphy in Pueblo, Colorado, for one of the best studied Cenomanian/Turonian boundary sections, in which *R. greenhornensis* and *R. cushmani* show synchronous last

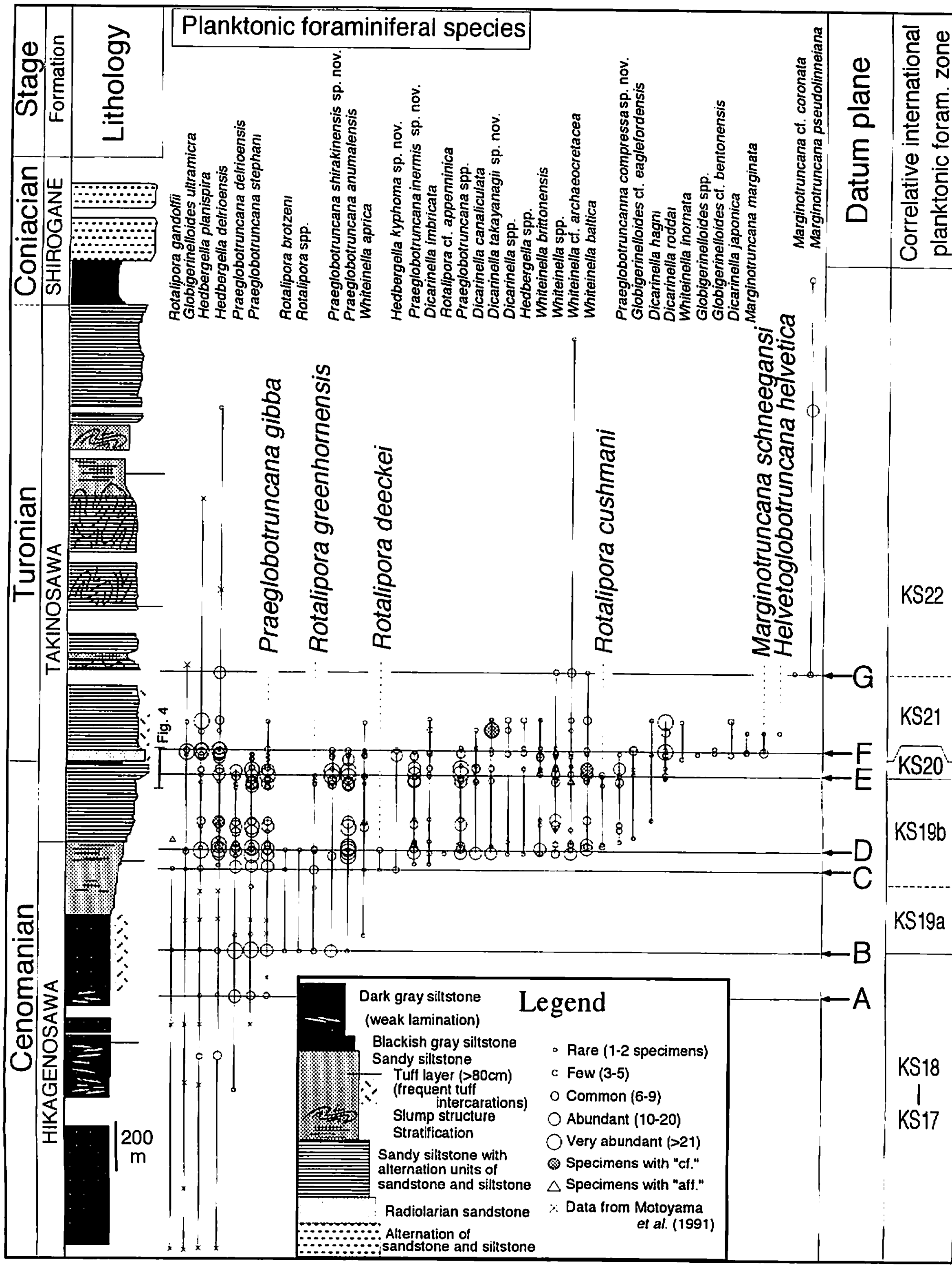



**Figure 3.** Stratigraphic distribution of planktonic foraminiferal species along the Shirakin River and the tributary of Penkemoyuparo River in the Oyubari area (reproduced from Hasegawa, 1997, with permission from Elsevier Science). Seven reliable datum planes are recognized in the section (see text for notation of datum planes). Symbols denote the number of specimens included in each 240 g rock sample.

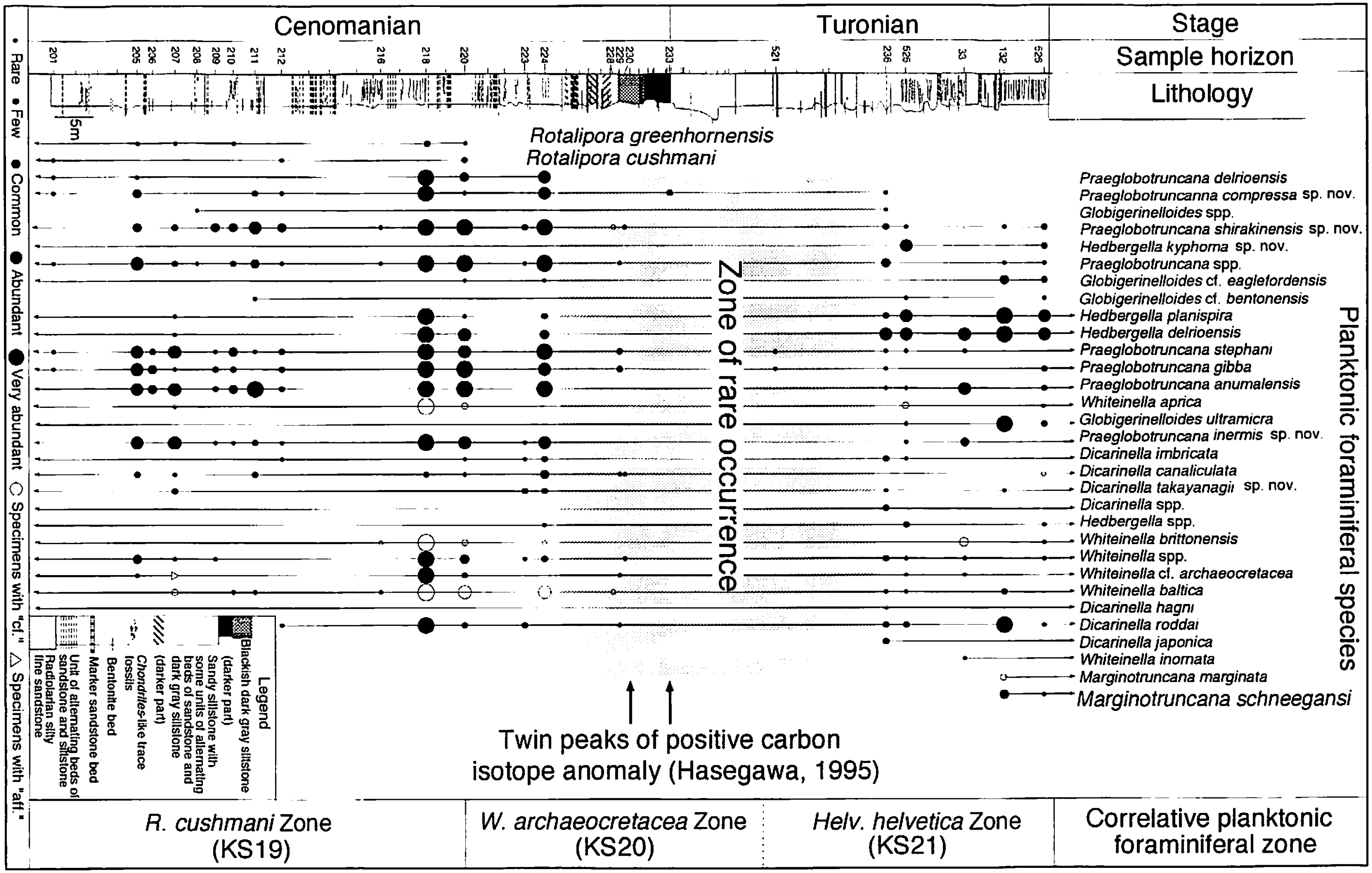



**Figure 4.** Stratigraphic distribution of planktonic foraminiferal species just across the Cenomanian/Turonian boundary along the Shirakin River (Hasegawa, 1995: Reproduction permitted by the Geological Society of Japan). Horizons of twin peaks of positive $\delta^{13}C$ anomaly and stratigraphic range of rare planktonic foraminiferal occurrences are also indicated. Symbols denote the number of specimens included in each 240 g rock sample. Very abundant: >21 specimens, Abundant: 10~20, Common: 6~9, Few: 3~5, Rare: 1 or 2.

occurrences. Jarvis *et al.* (1988) and Hart and Leary (1989) also noted nearly synchronous last occurrences of these two species in Southeast England. Therefore, the LAD of *R. cushmani* observed in Hokkaido is regarded as a reliable datum plane for interregional correlation. The planktonic foraminiferal assemblage between the LAD of *R. deeckei* and LAD of *R. cushmani* shows the highest diversity in the Oyubari area. The most abundant species of the assemblage are *Praeglobotruncana* spp. with common *Whiteinella* spp. and less *Rotalipora* spp. and *Dicarinella* spp.

In the northern Oyubari area, Takashima *et al.* (1997) attempted to recognize KS zones (Sliter, 1989). Rare occurrences of *Rotalipora* species did not allow them to correlate their upper Cenomanian sequences to KS zones directly with zone-indicative species. Such rare occurrences of *Rotalipora* may partly depend on the marine paleoenvironment of the northern Oyubari area being a shallower one than in the southern area, where the samples of this study were collected.

**F: FAD of *Marginotruncana schneegansi***

This datum is early Turonian. The FAD of *Marginotruncana schneegansi* occurs just above the "Radiolarian sandstone" (Hasegawa and Saito, 1993; Hasegawa, 1995) developed in the lower-middle part of the Takinosawa Formation. *Helvetoglobotruncana helvetica*, which is a commonly used datum species for the recognition of early Turonian age occurred above the FAD of *M. schneegansi*. According to Caron (1985) and Sliter (1989), the concurrent range of these two species is quite restricted. Therefore, the FAD of *M. schneegansi* is interpreted to be a reliable datum plane in Hokkaido. The planktonic foraminiferal assemblage between the LAD of *R. cushmani* and the FAD of *M. schneegansi* is also a high-diversity assemblage except in the middle part of the interval (Figure 4). Between SRN-224 and SRN-236, planktonic foraminifers are rare and the diversity is low despite a high density of large samples (500-800 g). This low-diversity event has also been recognized in other areas of the world (e.g. Hart and Leary, 1989). An oceanic event termed "Oceanic Anoxic Event (OAE)" (Schlanger and Jenkyns, 1970) or "Cenomanian Turonian Boundary Event (CTBE)" (Thurow and Kuhnt, 1986) may be responsible for this worldwide synchronous phenomenon.

**G: FAD of *Marginotruncana pseudolinneiana***

This datum is middle Turonian. The FAD of *Marginotruncana pseudolinneiana* is located in the middle of the Takinosawa Formation and this species is a common one in the middle Turonian and Coniacian interval. The stratigraphic distributions of other international species across this datum in the Oyubari section are consistent with occurrences known from other parts of the world (e.g. Robaszynski and Caron, 1979; Caron, 1985; Sliter, 1989). Therefore, the FAD of *M. pseudolinneiana* is considered to be a reliable datum plane. The stratigraphic interval between the FAD of *M. schneegansi* and the FAD of *M. pseudolinneiana* yields a moderately diversified assemblage. However, the upper part of this interval and sequence above the FAD of *M. pseudolinneiana* yield less abundant and lowly diverse assemblages.

## Recognition of zonal boundary

Stratigraphic units equivalent to the international planktonic foraminiferal zones are recognized in the Oyubari section (Figures 3 and 4) by correlating these datum planes with those shown by Sliter (1989) and Caron (1985). The upper limit of each zone is drawn as follows:

KS18: at the FAD of *R. greenhornensis*;

KS19a: estimated to lie just below the FAD of *R. deeckei* and above the FAD of *R. greenhornensis*;

KS19b: at the LAD of *R. cushmani*;

KS20: estimated to lie just below the FAD of *Pseudaspidoceras flexuosum* (an ammonoid) below the FAD of *M. schneegansi* (see Hasegawa, 1995 for further discussion). At the north of the studied area, Takashima *et al.* (1997) recognized the zonal marker species, *Helvetoglobotruncana helvetica*;

KS21: estimated to occur near the FAD of *M. pseudolinneiana*.

## Systematic paleontology

Superfamily Rotaliporacea Sigal, 1958

Family Hedbergellidae Loeblich and Tappan, 1961

Subfamily Hedbergellinae Loeblich and Tappan, 1961

Genus ***Hedbergella*** Bronnimann and Brown, 1958

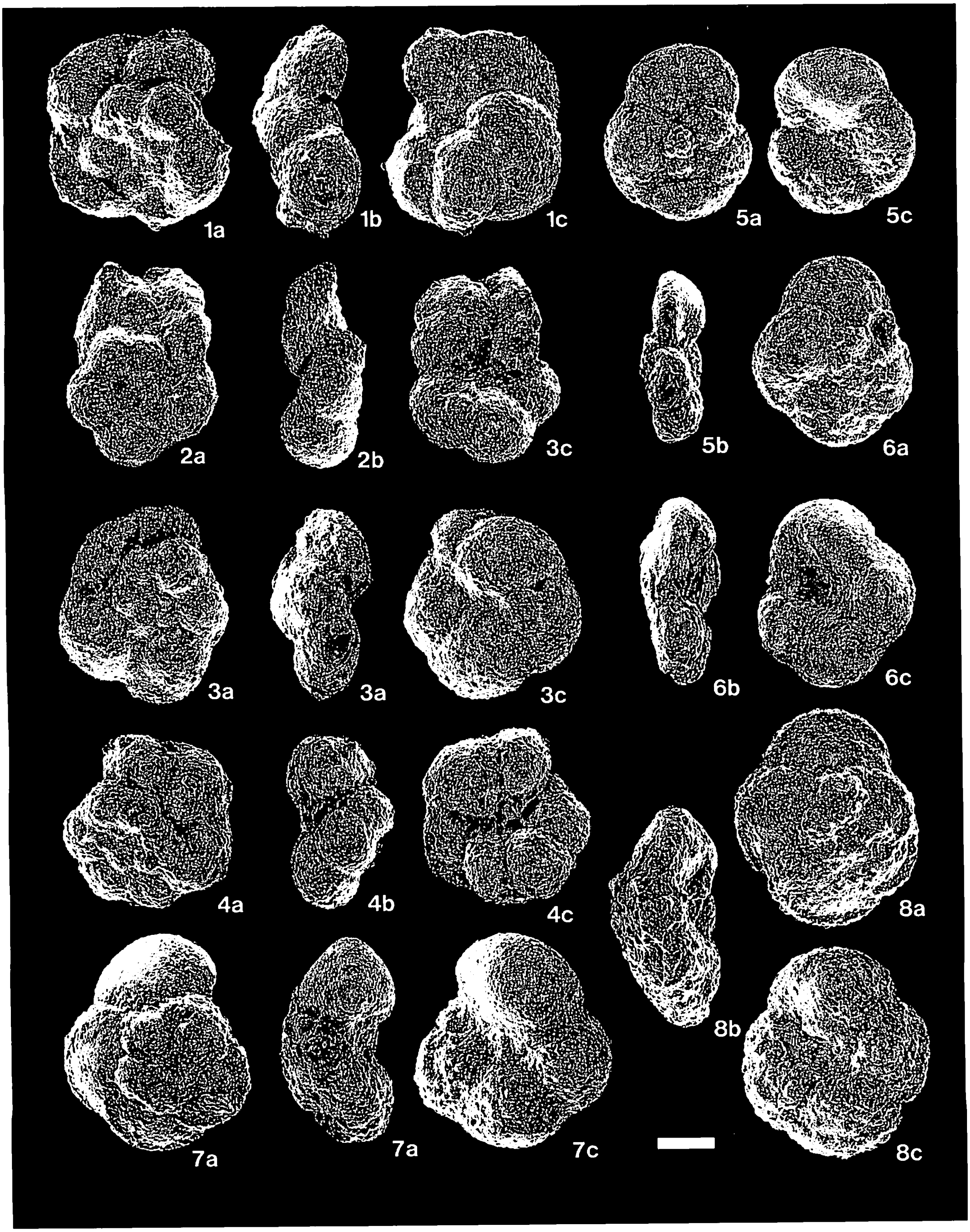
### ***Hedbergella kyphoma*** sp. nov.

Figures 5-1–4

*Diagnosis.*—A low trochospiral species of *Hedbergella* with last four chambers umbilically shifted, compressed, and spirally elongate. Umbilicus narrow, sutures of last four chambers slightly curved.

*Description.*—Test of medium size, initially very low tro-

**Figure 5.** **1–4.** *Hedbergella kyphoma* sp. nov. **1.** Holotype, IGPS No. 102504, sample loc. no. SRN-525A, lower part of the Takinosawa Formation, lower Turonian. **2.** Paratype, IGPS No. 102505, sample loc. no. SRN-525A, lower part of the Takinosawa Formation, lower Turonian. **3.** Paratype, IGPS No. 102506, sample loc. no. SRN-525A, lower part of the Takinosawa Formation, lower Turonian. **4.** Paratype, IGPS No. 102507, sample loc. no. SRN-525A, lower part of the Takinosawa Formation, lower Turonian. **5, 6.** *Praeglobotruncana compressa* sp. nov. **5.** Holotype, IGPS No. 102707, sample loc. no. SRN-207, lower part of the Takinosawa Formation, upper Cenomanian. **6.** Paratype, IGPS No. 102708, sample loc. no. SRN-207, lower part of the Takinosawa Formation, upper Cenomanian. **7.** Intermediate form between *Praeglobotruncana inermis* sp. nov. and *Praeglobotruncana shirakinensis* sp. nov., IGPS No. 102508, sample loc. no. SRN-210, lower part of the Takinosawa Formation, upper Cenomanian. **8.** *Praeglobotruncana shirakinensis* sp. nov., holotype, IGPS No. 102523, sample loc. no. SRN-210, lower part of the Takinosawa Formation, upper Cenomanian. Scale bar = 100 μm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8c

chospiral, later becoming medium trochospiral, equatorial periphery lobulate; chambers initially globular, later slightly compressed and spirally elongated, 11 to 14 in all arranged into 2.5 to 3 whorls, enlarging gradually in size as added except for last 3 or 4 which enlarge irregularly, 6 or 7 in last whorl, last 3 or 4 characteristically elongated, compressed and shifted toward umbilicus, last chamber variable in size and shape; sutures initially radial and depressed on dorsal side except for last 3 or 4 chambers in which they are curved, slightly curved and depressed on ventral side; coiling axis initially stable, later rapidly tilted for last 3 or 4 chambers, as a result, initial umbilicus occasionally being covered by last 3 or 4 chambers; umbilicus shallow, very narrow, less than 1/5 of maximum diameter of test; primary aperture bordered by a narrow lip, interiomarginal, umbilical-extraumbilical, extending to periphery; wall calcareous, surface poorly ornamented.

*Remarks*.—This species resembles *Hedbergella planispira* (Tappan) in its initially very low trochospiral shape and the number of chambers in the last whorl, but differs from the latter species in having a narrower umbilicus and umbilically shifted and compressed last 3 or 4 chambers.

*Etymology*.—From *kyphoma*, a Greek noun referring to the humpbacked nature of the pattern of chamber growth in this species.

*Material*.—Holotype IGPS No. 102504, paratypes IGPS No. 102505-102507.

*Dimensions*.—Maximum diameter of holotype 0.36 mm, maximum thickness 0.20 mm.

*Type locality and horizon*.—The holotype and paratypes are all from sample SRN-525A (43°2.50'N, 142°9.72'E), lower part of the Takinosawa Formation, lower Turonian.

Subfamily Rotundininae Bellier and Salaj, 1977
Genus ***Praeglobotruncana*** Bermudez, 1952

***Praeglobotruncana compressa*** sp. nov.

Figures 5-5, 6

*Diagnosis*.—A low trochospral species of *Praeglobotruncana* with compressed and wedge-shaped chambers in last whorl.

*Description*.—Test of medium to small size, very low trochospiral, equatorial periphery slightly lobulate; chambers wedge-shaped on dorsal side, triangular and slightly inflated on ventral side, about 10 chambers in all, enlarging rapidly in size as added, about 4.5 chambers in last whorl, with a peripheral band formed of aligned pustules; final chamber occasionally obliquely shifted toward umbilical direction; chambers in last whorl diagnostically elongated toward spiral direction; sutures on dorsal side gently curved, depressed, ventrally radial or slightly curved and depressed; umbilicus shallow, medium in size, about 1/3-1/4 of maximum diameter of test, umbilical flaps extending into an umbilicus from each chamber; primary aperture bordered by a narrow lip, interiomarginal, umbilical-extraumbilical; wall calcareous, earlier chambers pustulated.

*Remarks*.—This species is distinguished from *Praeglobotruncana compressiformis* (originally described as *Praeglobotruncana hessi compressiformis* by Pessagno, 1962) and other species of *Praeglobotruncana* in possessing wedge-shaped chambers having depressed sutures in the last whorl on the dorsal side, spirally elongated chambers in the last whorl, and in its generally compressed shape.

*Etymology*.—From Latin, *compressa* referring to the compressed feature of chambers compared with other species of *Praeglobotruncana*.

*Material*.—Holotype IGPS No. 102707, paratype IGPS No. 102708.

*Dimensions*.—Maximum diameter of holotype 0.30 mm, maximum thickness 0.10 mm.

*Type locality and horizon*.—The holotype and paratype specimens are both from sample SRN-207 (43°2.60'N, 142°9.78'E), lower part of the Takinosawa Formation, upper Cenomanian.

***Praeglobotruncana gibba*** Klaus, 1960

Figure 6-5

*Praeglobotruncana stephani* (Gandolfi) var. *gibba* Klaus, 1960, p. 304-305, holotype designated in Reichel, 1950, pl. 16, fig. 6, pl. 17, fig. 6.
*Praeglobotruncana stephani* (Gandolfi). Loeblich and Tappan, 1961, p. 280-284, pl. 6, figs. 4a, b, 5a-c, 6, 7a-c.
*Praeglobotruncana gibba* Klaus. Robaszynski and Caron, 1979, p. 33-38, pl. 44, figs. 1a-c, 2a-c, pl. 45, figs. 1a-c, 2a-c; Caron, 1985, p. 65, pl. 30-5a-c, 6a-c.

*Remarks*.—This species is easily distinguished from *Praeglobotruncana stephani* by its high trochospire and from *Praeglobotruncana inermis* n. sp. by its distinct raised suture with a beaded keel on the dorsal side. This species is abundant in the upper part of the *R. cushmani* Zone.

*Material*.—Hypotype IGPS No. 102503.

*Locality and horizon*.—The figured specimen is from sample SSS-020, lowermost part of the Takinosawa Formation, upper Cenomanian.

***Praeglobotruncana inermis*** sp. nov.

Figures 6-1—4

*Diagnosis*.—A high trochospiral species of *Praeglobotruncana* with slight peripheral pustule lines, distinct lip near umbilicus and 4 smooth-walled chambers in last whorl.

*Description*.—Test of medium to large size, medium to high trochospiral, equatorial periphery lobulate; chambers petaloidal in shape on dorsal side, trapezoidal to subglobular, inflated on dorsal side, about 12 in all arranged into 2 to 2.5 whorls, enlarging gradually in size as added, characteristically 4 chambers in final whorl, with a weak peripheral band formed of an aligned concentration of pustules which tends to be shifted toward spiral side; final chamber shifted toward umbilical direction; sutures on dorsal side radial and depressed except for that of first chamber in last whorl which occasionally is raised, ventrally radial and depressed; umbilicus shallow, medium to narrow in size, less than 1/4 of maximum diameter of test; primary aperture bordered by a

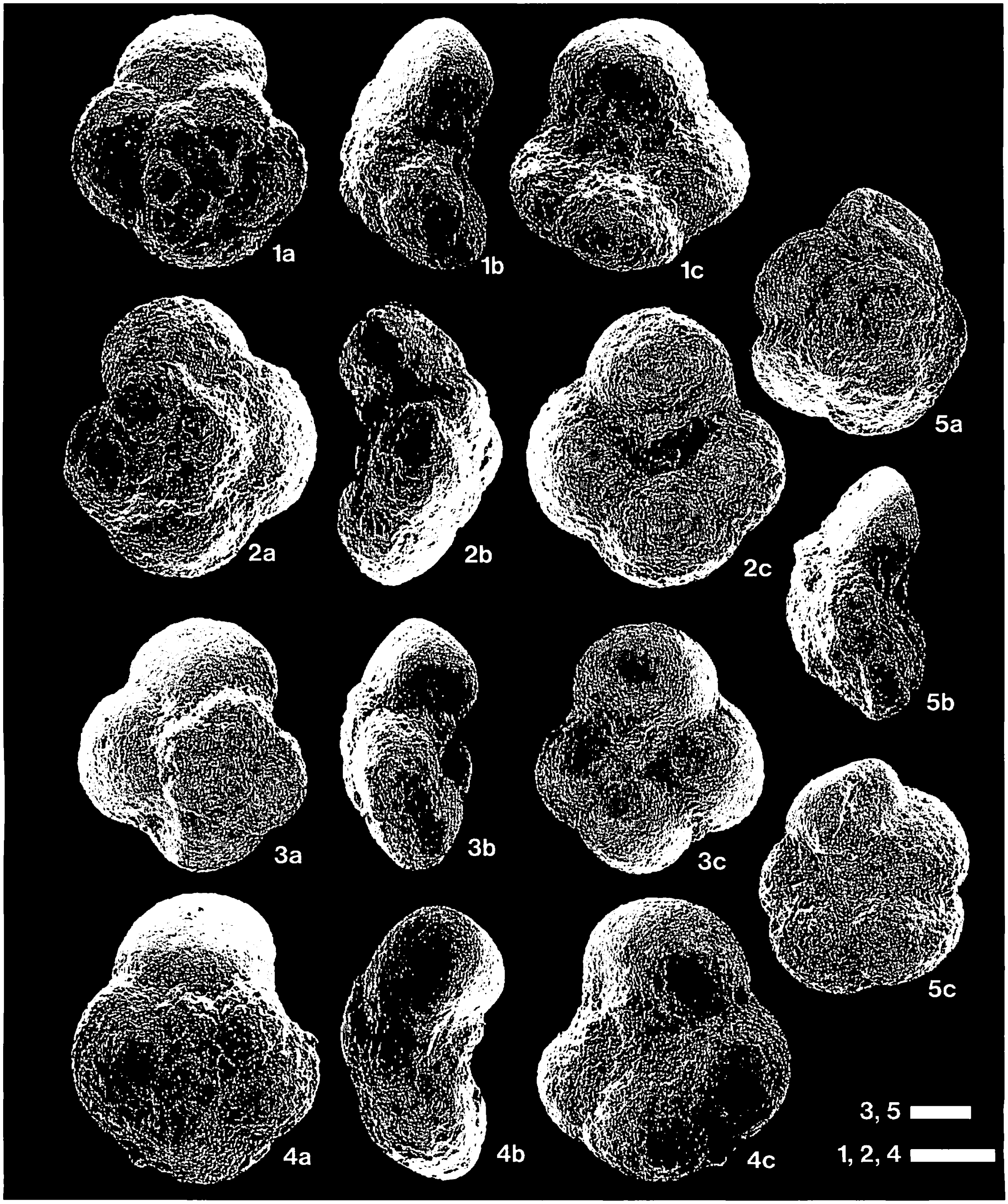



**Figure 6.** **1—4.** *Praeglobotruncana inermis* sp. nov. **1.** Paratype, IGPS No. 102703, sample loc. no. SRN 220, lower part of the Takinosawa Formation, uppermost Cenomanian. **2.** Holotype, IGPS No. 102704, sample loc. no. SRN-220, lower part of the Takinosawa Formation, uppermost Cenomanian. **3.** Paratype, IGPS No. 102705, sample loc. no. SRN-220, lower part of the Takinosawa Formation, uppermost Cenomanian. **4.** Paratype, IGPS No. 102706, sample loc. no. SRN-220, lower part of the Takinosawa Formation, uppermost Cenomanian. **5.** *Praeglobotruncana gibba* Klaus, IGPS No. 102503, sample loc. no. SSS-020, lower part of the Takinosawa Formation, upper Cenomanian. Scale bars = 100 μm.

distinct lip that expands markedly near umbilicus, interiomarginal, umbilical-extraumbilical; wall calcareous, surface smooth, earlier chambers weakly pustulated.

*Remarks.*—This species closely resembles *Praeglobotruncana anumalensis* (Sigal), but differs in lacking the conspicuous pustules on earlier chambers, in having diagnostically 4 chambers in the last whorl, more lobulated periphery and more inflated chambers.

*Etymology.*—From Latin, *inermis* referring to the smooth-walled chambers of this species compared with other species of *Praeglobotruncana*.

*Material.*—Holotype IGPS No. 102704; paratypes IGPS No. 102703, 102705, 102706.

*Dimensions.*—Maximum diameter of holotype 0.34 mm, maximum thickness 0.21 mm.

*Type locality and horizon.*—The holotype and paratypes are all from sample SRN-220 (43°2.60′N, 142°9.72′E), lower part of the Takinosawa Formation, uppermost Cenomanian.

***Praeglobotruncana shirakinensis*** sp. nov.

Figure 5-8

*Praeglobotruncana* sp. Leckie, 1985, p. 139-149, pl. 3, figs 9-15.

*Diagnosis.*—A medium trochospiral species of *Praeglobotruncana* with about 5 moderately compressed and slightly lobulated chambers of last whorl.

*Description.*—Test of medium size, medium trochospiral, equatorial periphery slightly lobulate; chambers initially inflated and globigerine-like, later ones becoming petaloidal on dorsal side, trapezoidal in shape on ventral side, about 10 to 12 chambers in all arranged into about 2.5 whorls, enlarging gradually in size as added, about 5 slightly compressed chambers in final whorl, with a peripheral band formed of an aligned concentration of pustules paralleling periphery; sutures on dorsal side curved, raised and beaded, ventrally radial or slightly curved, depressed; umbilicus shallow and narrow, its width about 1/4 of maximum diameter of test; primary aperture bordered by a wide distinct lip, interiomarginal, umbilical-extraumbilical, extending nearly halfway to periphery; wall calcareous, with marked accumulation of pustules on early chambers.

*Remarks.*—This species resembles *Praeglobotruncana stephani*, but differs in the following characters: spirally slightly elongated and ventrally more inflated chambers of the last whorl; fewer chambers (normally 4 to 5) having almost similar size in the last whorl; less lobulated periphery; and thinner spiral sutures. An intermediate form between *P. inermis* and *P. shirakinensis* is also figured (Figure 5.7).

*Etymology.*—With reference to the type locality (the Shirakin River) where the holotype specimen occurred.

*Material.*—Holotype IGPS No. 102523.

*Dimensions.*—Maximum diameter of holotype 0.38 mm, maximum thickness 0.20 mm.

*Type locality and horizon.*—The holotype specimen is from sample SRN-210 (43°2.60′N, 142°9.77′E), lower part of the Takinosawa Formation, upper Cenomanian.

Subfamily Helvetoglobotruncaninae Lamolda, 1976
Genus ***Helvetoglobotruncana*** Reiss, 1957

***Helvetoglobotruncana helvetica*** (Bolli, 1945)

Figure 9-1

*Globotruncana helvetica* Bolli, 1945, p. 226, pl. 9, fig. 6.
*Praeglobotruncana helvetica* (Bolli). Robaszynski and Caron, 1979, p. 39-42, pl. 46, figs. 1a-c, 2a-c.
*Helvetoglobotruncana helvetica* (Bolli). Wonders, 1980, p. 117, pl. 3, fig. 2a-c; Caron, 1985, p. 60, figs. 30-7, 8a-c; Loeblich and Tappan, 1988, p. 463-464, pl. 498, figs. 4-7.

*Remarks.*—Poorly preserved specimens of this species were obtained from only one horizon. Nevertheless, the figured specimen is identified as *H. helvetica* on the basis of its asymmetrical planoconvex lateral view, thick single keel that is shifted toward the spiral side, and staircase-like imbricate structures on the spiral side. This species is very rare in the area of study; however, it is quite important for interregional correlation.

*Materail.*—Hypotype IGPS No. 102517.

*Locality and horizon.*—The figured specimen is from sample SRN-101, middle part of the Takinosawa Formation, middle Turonian.

Subfamily incertae sedis
Genus ***Dicarinella*** Porthault, 1970

***Dicarinella hagni*** (Scheibnerova, 1962)

Figure 7-5

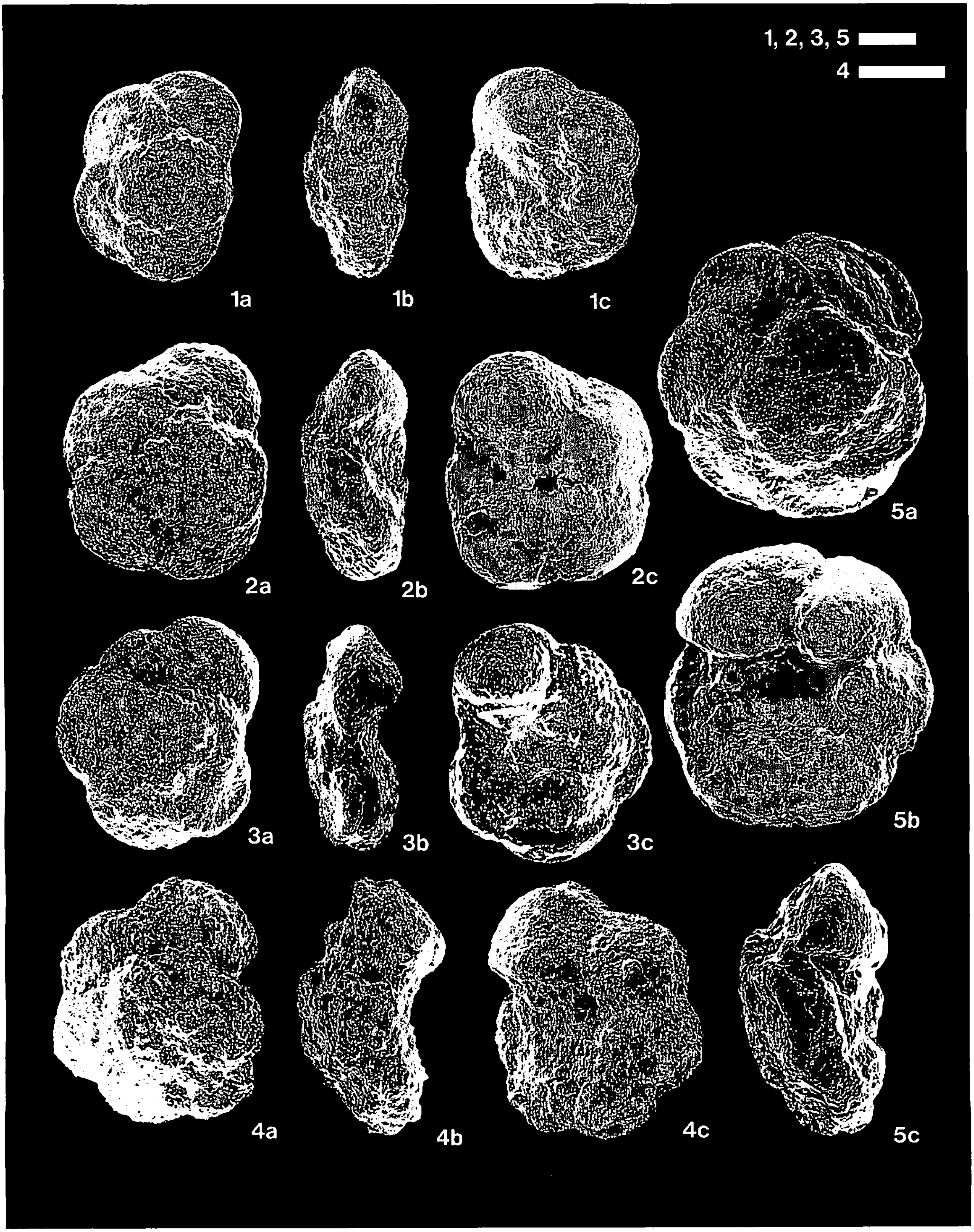
*Praeglobotruncana hagni* Scheibnerova, 1962, p. 219, figs. 6a-c.
*Praeglobotruncana* sp. cf. *P. hagni* Scheibnerova. Butt, 1966, p. 174, figs. 2a-c (not 1a-c, 3a-4c).
*Globotruncana kupperi* Thalmann. Marianos and Zingula, 1966, p. 340-341, pl. 39, figs. 6a-c.
*Dicarinella hagni* (Scheibnerova). Robaszynski and Caron, 1979, p. 79-86, pl. 56, figs. 1a-c, 2a-c, pl. 57, figs. 1a-c, 2a-d; Caron, 1985, p. 45, figs. 18-2a-c, 3a-c.

*Remarks.*—This species differs from *Dicarinella roddai* in having chambers which increase their size more gradually and in having a greater number of chambers in the last whorl.

*Material.*—Hypotype IGPS No. 102509.

*Locality and horizon.*—The figured specimen is from sample SRN-034, middle part of the Takinosawa Formation,

**Figure 7.** **1—3.** *Dicarinella roddai* (Marianos and Zingula). **1.** IGPS No. 102520, sample loc. no. SRN-220, lower part of the Takinosawa Formation, uppermost Cenomanian. **2.** IGPS No. 102511, sample loc. no. SRN-132, lower-middle part of the Takinosawa Formation, lower Turonian. **3.** IGPS No. 102512, sample loc. no. SRN-034, middle part of the Takinosawa Formation, middle Turonian. **4.** *Dicarinella imbricata* (Mornod), IGPS No. 102510, sample loc. no. SRN-034, middle part of the Takinosawa Formation, middle Turonian. **5.** *Dicarinella hagni* (Scheibnerova), IGPS No. 102509, sample loc. no. SRN-034, middle part of the Takinosawa Formation, middle Turonian. Scale bars = 100 μm.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5a
5b
5c

middle Turonian.

**Dicarinella imbricata** (Mornod, 1950)

Figure 7-4

*Globotruncana* (*Globotruncana*) *imbricata* Mornod, 1950, p. 589-590, figs. 5 (III a-d).
*Dicarinella imbricata* (Mornod). Robaszynski and Caron, 1979, p. 87-92, pl. 58, figs. 1a-c, 2a-d, pl. 59, figs. 1a-c, 2a-c ; Caron, 1985, p. 45, figs. 18-4a-c, 5a-c.

*Remarks*.—This species is easily distinguished from other species by its diagnostic stair-like imbrication of chambers on the dorsal side.

*Material*.—Hypotype IGPS No. 102510.

*Locality and horizon*.—The figured specimen is from sample SRN-034, middle part of the Takinosawa Formation, middle Turonian.

**Dicarinella roddai** (Marianos and Zingula, 1966)

Figures 7-1—3

*Globotruncana roddai* Marianos and Zingula, 1966, p. 340, pl. 39, 5a-c.
non *Praeglobotruncana roddai* (Marianos and Zingula). Douglas, 1969, p. 171-172, pl. 2, 2a-c.

*Description*.—Test medium to large in size, initially a low to medium-height trochospire, equatorial periphery slightly lobulate ; chambers dorsally semicircular, ventrally trapezoidal in shape, somewhat inflated on ventral side, about 9 to 11 chambers in all arranged into 2 to 2.5 whorls, enlarging gradually in size as added, last 4 chambers almost similar in size, 5 slightly imbricated chambers in final whorl, with distinct double peripheral keels ; sutures on dorsal side curved, raised with a keel which continues to one of double peripheral keels, ventrally radial, depressed, occasionally slightly raised ; umbilicus shallow, its width about 1/4 of maximum diameter of test ; primary aperture bordered by distinct, narrow- to medium-width lip, interiomarginal, umbilical-extraumbilical extending nearly to periphery ; wall calcareous, weakly pustulated on earlier chambers.

*Discussion*.—This species resembles *Dicarinella hagni* but is distinguished by having less inflated chambers on ventral side, fewer and slightly imbricated chambers. Although Takayanagi (1965) described this species as *Globotruncana marginata*, Jirová's neotype figures of *G. marginata*, (Jirová, 1956, p. 253, figs. 1a-c) and one of the figured specimens of Reuss's syntypes which was later selected as the lectotype by Bolli *et al*. (1957) (Jirová's neotype has priority) are apparently different from Takayanagi's (1965, figs. 3a-c, 4a-c) figures in having more chambers in the last whorl which are more globular and inflated, more gradually increasing in size as added, equatorial periphery more lobulate, narrower spaced keels, and a wider umbilicus. Marianos and Zingula (1966) stated that *D. roddai* (originally described as *Globotruncana roddai*) was a good marker for the lower Turonian in the type locality of this species, however, the stratigraphic distribution of this species in the area of study is restricted to the uppermost Cenomanian to lower part of the middle Turonian (Figure 3). In this stratigraphic range, this species occurs commonly. Therefore, it may be a useful supplemental species to locate the interval of the Cenomanian/Turonian boundary in Japan.

*Material*.—Hypotype IGPS No. 102520, 102511, 102512.

*Locality and horizon*.—The specimen IGPS No. 102520 is from SRN-220, lower part of the Takinosawa Formation, upper Cenomanian. IGPS No. 102511 is from sample SRN-132, lower-middle part of the Takinosawa Formation, middle Turonian. IGPS No. 102512 is from sample SRN-034, middle part of the Takinosawa Formation, middle Turonian.

**Dicarinella takayanagii** sp. nov.

Figures 8-1—4

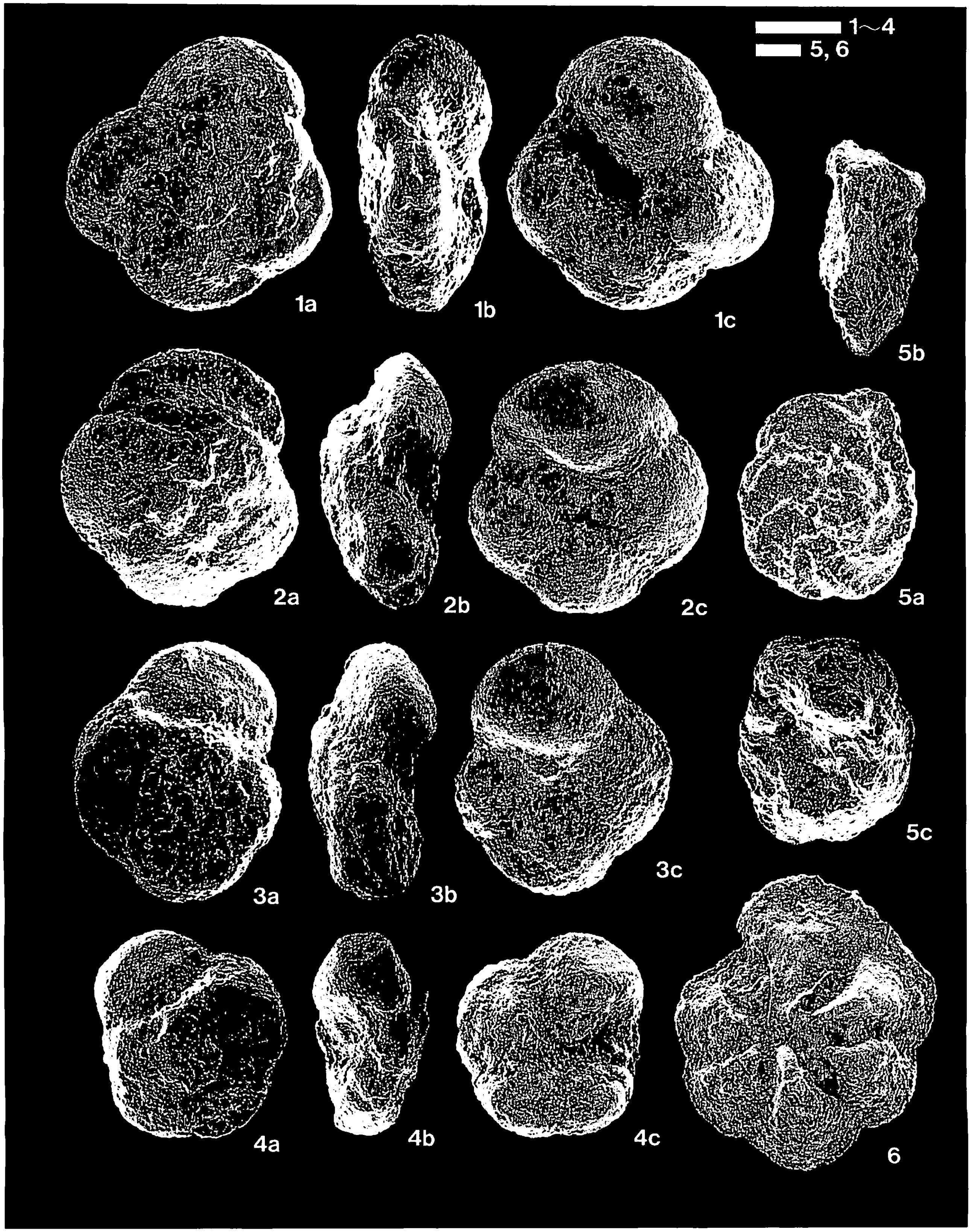
*Diagnosis*.—A low trochospiral species of *Dicarinella* with wedge-shaped chambers in last whorl and small umbilicus.

*Description*.—Test of medium to large size, low trochospiral, equatorial periphery lobulate ; chambers initially globigerine-like, later ones becoming wedge-shaped and flat on dorsal side, triangular and inflated in shape on ventral side, about 10 chambers in all, enlarging rapidly in size as added, about 4.5 chambers in last whorl, with widely separated weak double peripheral keels, one of which is shifted toward spiral side ; final chamber obliquely shifted toward umbilical direction, as a result, keels being discontinuous to final chamber ; final chamber diagnostically elongated in spiral direction, occasionally lacking peripheral keels ; sutures on dorsal side gently curved, raised with keels that are continuous to one of peripheral keels, sutures on ventral side radial and depressed ; umbilicus shallow and narrow, its width about 1/4 of maximum diameter of test ; primary aperture bordered by a distinct lip, interiomarginal, umbilical-extraumbilical ; wall calcareous, earlier chambers weakly pustulated.

*Remarks*.—This species is distinguished from other species of *Dicarinella* in possessing wedge-shaped chambers in the last whorl on the dorsal side, spirally elongated final chamber and a narrower umbilicus.

*Etymology*.—In honor of Prof. Emeritus Y. Takayanagi in recognition of his contribution to the study of Cretaceous

**Figure 8.** **1—4.** *Dicarinella takayanagii* sp. nov. **1.** Paratype, IGPS No. 102513, sample loc. no. SRN-223, lower part of the Takinosawa Formation, uppermost Cenomanian. **2.** Paratype, IGPS No. 102514, sample loc. no. SRN-223, lower part of the Takinosawa Formation, uppermost Cenomanian. **3.** Holotype, IGPS No. 102515, sample loc. no. SRN-223, lower part of the Takinosawa Formation, uppermost Cenomanian. **4.** Paratype, IGPS No. 102516, sample loc. no. SRN-223, lower part of the Takinosawa Formation, uppermost Cenomanian. **5.** *Rotalipora deeckei* (Franke), IGPS No. 102519, sample loc. no. KMZ-002, the uppermost part of the Hikagenosawa Formation, upper Cenomanian. **6.** *Rotalipora cushmani* (Morrow), IGPS No. 102472, sample loc. no. SRN-220 (last occurrence horizon of *R. cushmani*), lower part or the Takinosawa Formation, uppermost Cenomanian. Same specimen as that shown in Hasegawa and Saito (1993). Scale bars = 100 $\mu$m.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3b
3c
5c
4a
4b
4c
6

foraminifera in Japan.

*Material.*—Holotype IGPS No. 102515; paratypes IGPS No. 102513, 102514, 102516.

*Dimensions.*—Maximum diameter of holotype 0.29 mm, maximum thickness 0.17 mm.

*Type locality and horizon.*—The holotype and all paratypes are from sample SRN-223 (43°2.60′N, 142°9.73′E), lower part of the Takinosawa Formation, uppermost Cenomanian.

Family Rotaliporidae Sigal, 1958
Subfamily Rotaliporinae Sigal, 1958
Genus ***Rotalipora*** Brotzen, 1942

### ***Rotalipora cushmani*** (Morrow, 1934)

Figures 8-6; 9-4

*Globorotalia cushmani* Morrow, 1934, p. 199, pl. 31, fig. 4a-b.
*Rotalipora cushmani* (Morrow). Loeblich and Tappan, 1961, p. 297-298, pl. 8, figs. 1-8, 10 (not fig. 9); Pessagno, 1967, p. 292-293, pl. 51, figs. 6-9; Robaszynski and Caron, 1979, p. 69-74, pl. 7, figs. 1a-c, pl. 8, figs. 1a-c, 2a-c; Wonders, 1980, p. 125-126, pl. 3, fig. 3a-c; Caron, p. 69, figs. 31-8-11.

*Remarks.*—This species is distinguished from other species of *Rotalipora* by having a lobulated periphery, semi-circular chambers ornamented by pustules in the last whorl, pronounced supplementary apertures with developed lips. The last occurrence of this species corresponds to that of the genus *Rotalipora* in this study. This species is a very important index in Japan for interregional correlation.

*Material.*—Hypotypes IGPS No. 102471, 102472.

*Locality and horizon.*—Two figured specimens are from SRN-220 (last occurrence horizon of *R. cushmani*), lower part of the Takinosawa Formation, uppermost Cenomanian.

### ***Rotalipora deeckei*** (Franke, 1925)

Figure 8-5

*Rotalia deeckei* Franke, 1925, p. 88, 90, pl. 8, figs. 7a-c (This inaccessible literature is indirectly accessible from "Ellis and Messina, 1940 et seq., Catalogue of Foraminifera").
*Rotalipora deeckei* (Franke). Robaszynski and Caron, 1979, p. 75-80, pl. 9, figs. 1a-2c, pl. 10, 1a-2c.

*Remarks.*—This species is very similar to *Rotalipora reicheli*, but differs in having periumbilical ridges extended from raised sutures on the ventral side and narrower umbilicus.

*Material.*—Hypotype IGPS No. 102519.

*Locality and horizon.*—The figured specimen is from KMZ-002, uppermost part of the Hikagenosawa Formation, upper Cenomanian.

### ***Rotalipora*** sp. aff. ***R. gandolfii*** Luterbacher and Premoli-Silva, 1962

Figure 9-3

*Remarks.*—This species resembles *Rotalipora gandolfii*, but differs in having the hemispherical last two chambers. This morphological feature is rather reminiscent of *Rotalipora cushmani*.

*Material.*—Hypotype IGPS No. 102524.

*Locality and horizon.*—The specimen IGPS No. 102524 is from SSS-020, lowermost part of the Takinosawa Formation, upper Cenomanian.

### ***Rotalipora greenhornensis*** (Morrow, 1934)

Figure 9-5

*Globorotalia greenhornensis* Morrow, 1934, p. 199, pl. 31, figs. 1a-c.
*Rotalipora greenhornensis* (Morrow). Loeblich and Tappan, 1961, p. 299-301, pl. 7, figs. 5-10; Pessagno, 1967, p. 295-297, pl. 50, fig. 3, pl. 51, figs. 15-17, 19-21 (not figs. 13, 14, 18); Pessagno, 1967, p. 289-292, pl. 50, figs. 4-6; Robaszynski and Caron, 1979, p. 85-90, pl. 12, figs. 1a-c, 2a-c, pl. 13, figs. 1a-c, 2a-c; Caron, 1985, p. 69, text-figs. 32-1, 2.

*Remarks.*—This species is easily distinguished from other species of *Rotalipora* by having greater number of chambers in the last whorl and crescent-shaped chambers which are often concave on the dorsal side. The last occurrence of this species is at the same stratigraphic horizon as that of *Rotalipora cushmani* in the area of study.

*Material.*—Hypotype IGPS No. 102473.

*Locality and horizon.*—The figured specimen is from SRN-220, lower part of the Takinosawa Formation, uppermost Cenomanian.

Subfamily Globotruncaninae Brotzen, 1942
Genus ***Marginotruncana*** Hofker, 1956

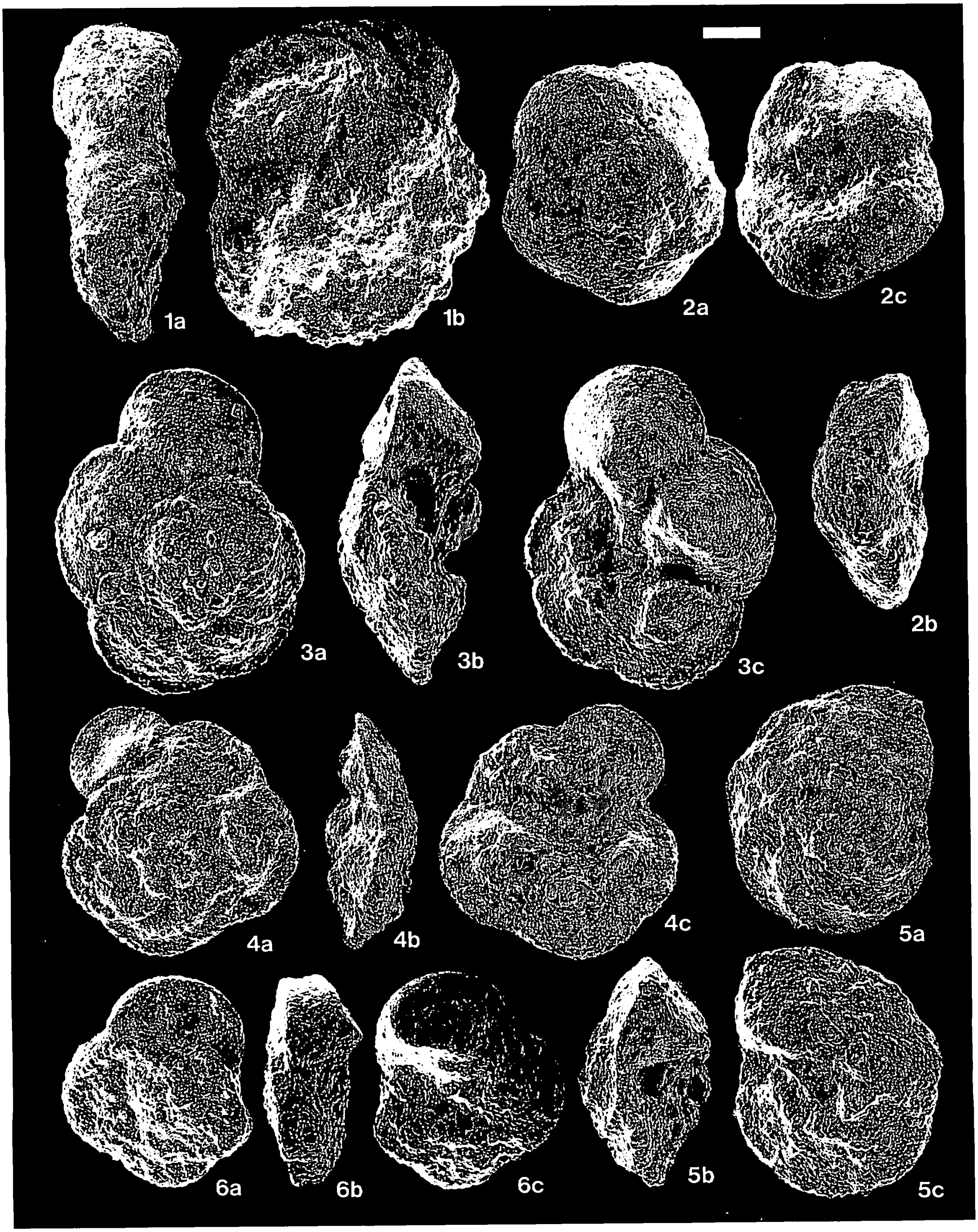
### ***Marginotruncana pseudolinneiana*** Pessagno, 1967

Figure 9-6

*Marginotruncana pseudolinneiana* Pessagno, 1967, p. 310, pl. 65, figs. 24-27; Robaszynski and Caron, 1979, p. 123-128, pl. 67, 1a-2d, pl. 68, 1a-2c; Caron, 1985, p. 61, text-figs. 26-7, 8.

*Remarks.*—This species is easily distinguished from other

**Figure 9. 1.** *Helvetoglobotruncana helvetica* (Bolli), IGPS No. 102517, sample loc. no. SRN-101, middle part of the Takinosawa Formation, middle Turonian. **2.** *Marginotruncana schneegansi* (Sigal), IGPS No. 102521, sample loc. no. SRN-132, lower-middle part of the Takinosawa Formation, lower Turonian. **3.** *Rotalipora* sp. aff. *R. gandolfii* Luterbacher and Premoli-Silva, IGPS No. 102524, sample loc. no. SSS-020, lowermost part of the Takinosawa Formation, upper Cenomanian. **4.** *Rotalipora cushmani* (Morrow), IGPS No. 102471, sample loc. no. SRN-220 (last occurrence horizon of *R. cushmani*), lower part or the Takinosawa Formation, uppermost Cenomanian. Same specimen as that shown in Hasegawa and Saito (1993). **5.** *Rotalipora greenhornensis* (Morrow), IGPS No. 102473, sample loc. no. SRN-220, lower part of the Takinosawa Formation, uppermost Cenomanian. Same specimen as that shown in Hasegawa and Saito (1993). **6.** *Marginotruncana pseudolinneiana* Pessagno, IGPS No. 102522, sample loc. no. SRN-062, lower part of the Shirogane Formation, upper Turonian. Scale bar = 100 μm.


1a
1b
2a
2c
3a
3b
3c
2b
4a
4b
4c
5a
6a
6b
6c
5b
5c

species by its diagnostically rectangular shape in lateral view. This species characterizes the middle Turonian to Coniacian interval in Japan.

*Material*.—Hypotype IGPS. No. 102522.

*Locality and horizon*.—The figured specimen is from SRN-062, lower part of the Shirogane Formation, upper Turonian.

***Marginotruncana schneegansi*** (Sigal, 1952)

Figure 9-2

*Globotruncana schneegansi* Sigal, 1952, p. 33, text-fig. 34.
*Marginotruncana schneegansi* (Sigal). Robaszynski and Caron, 1979, p. 135-140, pl. 70, fig. 1a-2e, Pl. 71, 1a-2d ; Caron, 1985, p. 61, text-figs. 27, 3-6.

*Remarks*.—The first occurrence of this species characterizes the lower Turonian in Japan.

*Material*.—Hypotype IGPS No. 102521.

*Locality and horizon*.—The figured specimen is from SRN-132, lower-middle part of the Takinosawa Formation, lower Turonian.

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