Mesorbitolina (Cretaceous larger foraminifera) from the Yezo Group in Hokkaido, Japan and its stratigraphic and paleobiogeographic significance

By Yasuhiro IBA*),**),†) and Shin-ichi SANO***)

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Abstract: In this paper, we describe an Aptian (Early Cretaceous) larger foraminiferal species *Orbitolina* (*Mesorbitolina*) *parva* from the limestone olistoliths in the lower part of the Yezo Group in the Yubari–Ashibetsu area, central Hokkaido and from limestone pebbles in the lowermost part of the Yezo Group in the Nakagawa area, northern Hokkaido. This is the first report of this species from the circum-North Pacific regions. Based on its occurrences, the shallow-marine carbonates, re-deposited in the lower part of the Yezo Group, are precisely assigned in age to the Late Aptian. Comparison of the lower part of the Yezo Group in central and northern Hokkaido indicates differences of the Aptian–Albian depositional history between the two areas. This study reveals that after Late Aptian, Mesogean key taxa (typical Cretaceous Tethyan biota) demised in the Northwest Pacific.

Key words: Aptian; Mesogean; orbitolinid; *Mesorbitolina parva*; Yezo forearc basin; North Pacific.

Introduction. The Orbitolinidae is a larger benthic foraminiferal family, which was most diversified during Early and mid-Cretaceous times. Species of this family flourished in shallow-marine carbonate facies of the whole Tethys region. They had relatively short biochronological ranges and provide valuable chronostratigraphic information (e.g., Arnaud-Vanneau, 1998).[1] This is important, because usually shallow marine carbonates are poorly dated by index fossils in Japan.

Shallow-marine carbonates are intercalated as olistoliths and pebbles in the lower part of the Yezo Group in central and northern Hokkaido, northern Japan (e.g., Sano, 1995; Iba *et al.*, 2005).[2,3] They contain abundant rudists and a dasycladacean alga, both of which are key taxa for identification of the Cretaceous Tethyan biotic realm (i.e., the Mesogean *sensu* Masse (1992)[4]) (e.g., Sano, 1995),[2] and constitute the largest Cretaceous carbonate bodies in Japan. An olistostrome containing shallow-marine carbonates and correlative conglomeratic gravity flow deposits, has been considered as one of the important key units in the Yezo Group (Takashima *et al.*, 2004; Iba *et al.*, 2005).[5,3] In spite of this paleobiogeographic and stratigraphic importance, the age of the shallow-marine carbonates in Hokkaido remains unsettled, because of their allochthonous occurrences and absence of index fossils such as ammonites and planktonic foraminifers.

We recently found well-preserved orbitolinid specimens identified as *Orbitolina* (*Mesorbitolina*) *parva* from the lower part of the Yezo Group in central (Locs. 1 and 2 in Fig. 1) and northern (Loc. 3 in Fig. 1) Hokkaido. In this paper, we give the systematic description of this species and discuss the age of shallow-marine carbonates of the Yezo Group and correlation of the strata within the Yezo basin. Furthermore, we discuss the implications of our findings from the viewpoint of Cretaceous paleobiogeography. This paper is the first report of this species from the circum-North Pacific regions.

Geological settings. The Yezo Group comprises Aptian to Paleocene forearc basin deposits extending from southern Hokkaido to the Sakhalin Island (Far East Russia) (e.g., Okada, 1983; Takashima *et al.*, 2004).[6,5] This group represents

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*) JSPS Research Fellow.

**) Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo, Tokyo, Japan.

***) Fukui Prefectural Dinosaur Museum, Fukui, Japan.

†) Department of Earth and Planetary Science, Graduate School of Science, University of Tokyo, 7–3–1 Hongo, Bunkyo-ku, Tokyo 113–0033, Japan (e-mail; iba@eps.s.u-tokyo.ac.jp).

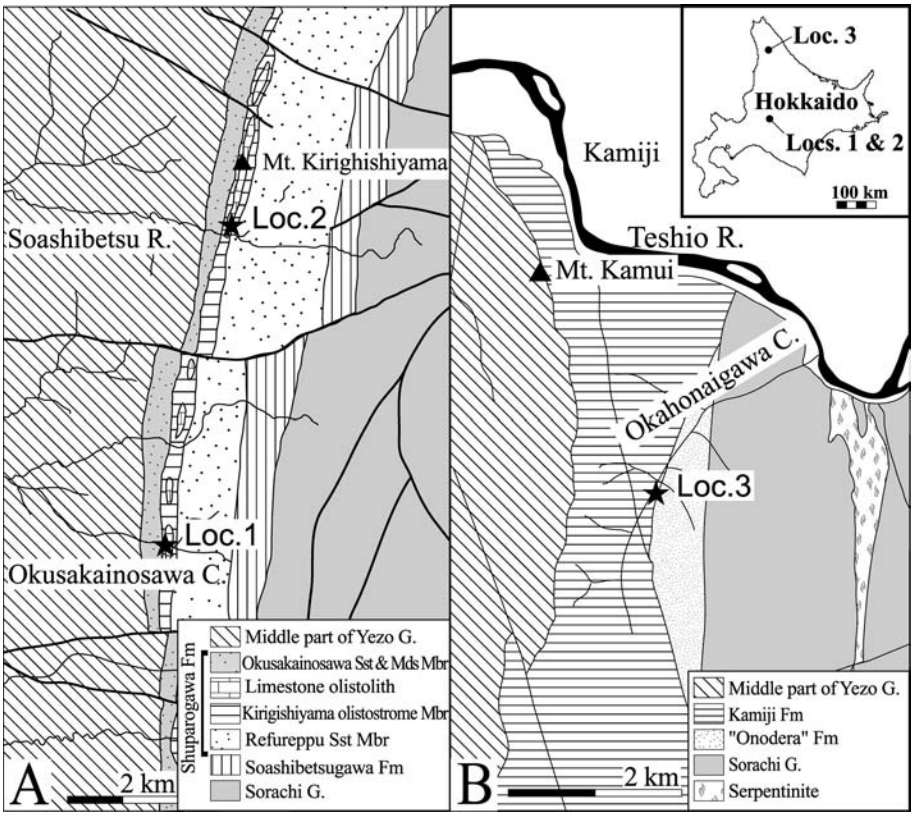

Fig. 1. Locality map of *Orbitolina* (*Mesorbitolina*) *parva* in the Yezo Group, Hokkaido. A. Yubari–Ashibetsu area, central Hokkaido (Loc. 1; MF 29172, Loc. 2; MF 29173). Geological information is based on Takashima *et al.* (2004).5) B. Nakagawa area, northern Hokkaido (Loc. 3; MF 29174). Geological information is based on Nagao (1962).46) Note that the "Onodera Formation" of Nagao (1962)46) is now considered as a locally-developed lithologic facies within the Kamiji Formation (e.g., Kawaguchi, 1997).32)

a reference marine Cretaceous succession in the circum-North Pacific regions, and contains abundant macro- and microfossils at various horizons, especially in the Upper Cretaceous (e.g., Matsumoto, 1942).7)

In central Hokkaido, many limestone olistoliths (= "*Orbitolina* limestones": Yabe, 1901)8) are intercalated in the Kirigishiyama Olistostrome Member of the Shuparogawa Formation, the lower part of the Yezo Group (Takashima *et al.*, 2004)5) (Fig. 1–A). Abundant Mesogean key taxa (rudists and a dasycladacean alga) and other carbonate platform biota, such as miliolid and orbitolinid foraminifers, hermatypic hexacorals, nerineacean gastropods, and calcareous red algae, are found in the limestone olistoliths (e.g., Sano, 1995, 2000; Hirano and Takagi, 1998).2), 9), 10) Sano (1995, 2000)2), 9) reconstructed a carbonate platform in its original depositional environment, based on the distribution of litho- and biofacies within these limestone olistoliths.

In northern Hokkaido, pebbles of shallow-marine calcareous sediments were discovered from a gravity flow deposit in the lower part of the Yezo Group (Iba *et al.*, 2005)3) (Fig. 1–B). This gravity flow deposit containing limestone pebbles is intercalated in the lowermost part of the Yezo Group in this region (Iba *et al.*, 2005).3) The carbonate pebbles contain rudist fragments (Mesogean key taxa) and other carbonate platform biota such as orbitolinid foraminifera and calcareous red algae. Similarities of bio- and lithofacies between the limestone olistoliths in central Hokkaido and the limestone pebbles in northern Hokkaido were pointed out by Iba *et al.* (2005).3) These limestone olistoliths and pebbles from central and northern Hokkaido were originally deposited in a shallow-marine shelf adjacent to the continental arc in the eastern margin of the Asian Continent. They were later transported into a deeper part of the basin (Sano, 1995; Iba *et al.*, 2005).2), 3)

Orbitolinid taxonomy: previous works. The Orbitolinidae is classified into two "subfamilies", the Orbitolininae and the Dictyoconinae. In the subfamily Orbitolininae, structure and size of the embryonic apparatus are significant for generic- and species-level classification (e.g., Hofker, 1963; Schroeder, 1963; 1975).11)–13) Hofker (1963)11) recognized only one phylogenetic lineage within the Orbitolininae, which was summarized as one evolutionary species "*Orbitolina lenticularis*". He divided "*O. lenticularis*" into five Form Groups (Form Group I to V in ascending order) based mainly on the size difference of the embryonic apparatus. Younger forms have a larger and more complicated embryonic apparatus than older ones.

Since the first report by Yabe (1901),8) orbitolinid foraminifers have been reported from several localities in Japan. Yabe and Hanzawa (1926)14) proposed several new orbitolinid species. Hofker (1963)11) regarded all of the previously known Japanese orbitolinids, including new species described by Yabe and Hanzawa (1926),14) as belonging to one species "*Orbitolina lenticularis*". Subsequently, Japanese researchers have followed Hofker's classification (e.g., Ujiié and Kusukawa, 1968; Matsumaru, 1971; Matsumaru *et al.*, 1976).15)–17)

On the other hand, Schroeder (1975, 1979)13), 18) paid attention to the developmental pattern of the orbitolinid embryonic apparatus, and recognized several phylogenetic lineages within the Orbitolininae. He classified the Orbitolininae into several short-ranging genera and species based on the concepts of phylogenetic lineages (e.g., *Eopalorbitolina*–*Palorbitolina* lineage; *Praeorbitolina*–*Mesorbitolina* lineage). Schroeder's taxonomy is now widely accepted and used for biostratigraphic studies (e.g., Moullade *et al.*, 1985; Simmons and Williams, 1992; Husinec *et al.*, 2000).19)–21) Following Schroeder's classification scheme, Iba *et al.* (2005)3) reported the occurrences of "*Mesorbitolina texana*–*parva* group" from the basal part of the Yezo Group in the Nakagawa area, northern Hokkaido. Systematic description in this paper follows Schroeder's classification.

Systematic Paleontology

Family Orbitolinidae MARTIN 189022)
Genus *Orbitolina* ORBIGNY 185023)
Subgenus *Mesorbitolina* SCHROEDER 196224)
Orbitolina (*Mesorbitolina*) *parva* DOUGLASS 196025)

Table I. Measurements of specimens of *Orbitolina* (*Mesorbitolina*) *parva* from the Yezo Group

Sample No.	Diameter of protoconch	Diameter of embryonic apparatus
UMUT MF 29172	0.07 mm	0.17 mm
UMUT MF 29173	0.08 mm	0.17 mm
UMUT MF 29174	0.15 mm	0.25 mm

Type specimen: Holotype P5494 deposited in the U.S. National Museum of the Natural History from the Peak Formation, Lower Albian, Grant County, New Mexico, USA.

Material: Three specimens (UMUT MF 29172–29174) recovered from the lower part of the Yezo Group in Hokkaido are identified to the present species (see Fig. 1 for their detailed localities). They are deposited in the University Museum, the University of Tokyo. UMUT MF 29172 and 29173 came from limestone olistoliths in the Yubari–Ashibetsu area, central Hokkaido (Fig. 1–A). UMUT MF 29174 was recovered from a limestone pebble in the Nakagawa area, northern Hokkaido (Fig. 1–B). All the three specimens are axially sectioned, but a horizontal section has not yet been observed due to inadequate state of the preservation.

Description: External characters: The test is small, low conical, the base of which is concave (Fig. 2–1a, 2a) and convex (Fig. 2–3a). The diameter of the test varies from 1.02 to 5.30 mm, the height varies from 0.50 to 1.00 mm. Thickness of the test from 0.83 to 0.93 mm. The apex of the megalospheric form is slightly rounded.

Internal characters (embryonic apparatus): The megalospheric embryonic apparatus is centrally situated in the tip of the test, and consists of a protoconch and a deuteroconch with a small, developed and subdivided subembryonic zone. It is small, with a mean diameter of 0.20 mm. The protoconch is globular, not ellipsoidal. The diameter of protoconch ranges from 0.07 to 0.15 mm. The deuteroconch is about two times as large as the protoconch. The subembryonic zone is simple and divided by a small number of regular septula making a reticulum. The lower surface of the subembryonic zone is evenly rounded. This zone is always smaller than the deuteroconch. Measurements of the examined species are given in Table I.

Distribution: This species is widely distributed

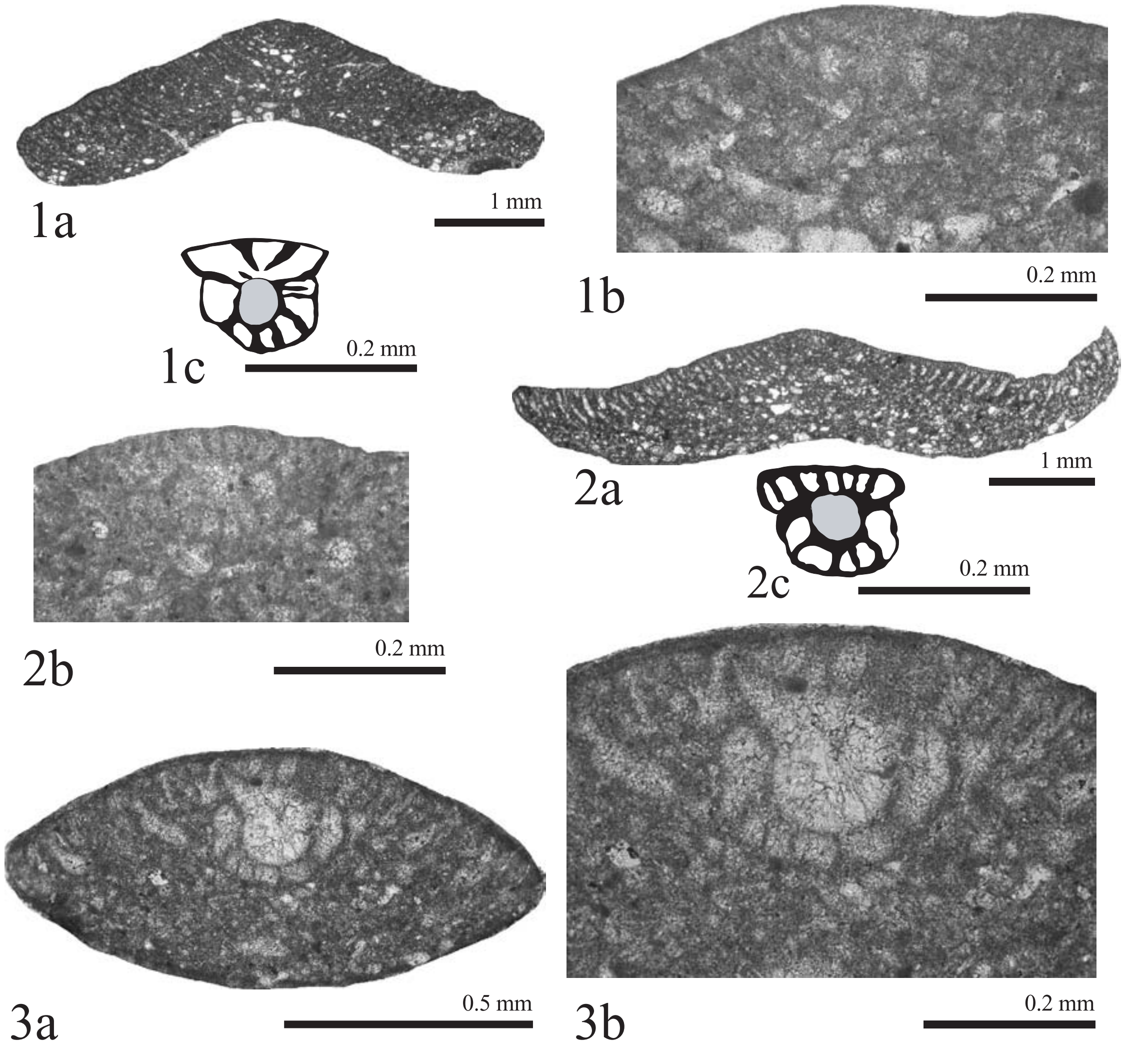

Fig. 2. Photomicrographs and drawings of *Orbotolina* (*Mesorbitolina*) *parva* of the Yezo Group. 1: UMUT MF 29172 (Loc. 1), axial section of megalospheric specimen. a, general view; b–c, detail of the embryonic apparatus. 2: UMUT MF 29173 (Loc. 2), axial section of megalospheric specimen. a, general view; b–c, detail of the embryonic apparatus. 3: UMUT MF 29174 (Loc. 3), axial section of megalospheric specimen. a, general view; b, detail of the embryonic apparatus.

in the whole Mesogean (i.e., the Cretaceous Tethyan biotic realm), known from circum-Mediterranean, Middle East, India, Tibet, Japan, Pacific guyots, Caribbean, and the southern part of the Western Interior Seaway.

Comparison and remarks: The present species is morphologically closely related to *Orbitolina* (*Mesorbitolina*) *lotzei* (Schroeder, 1964)[26] and *O.* (*M.*) *texana* (Roemer, 1849).[27] Schroeder (1979)[18] discussed phylogenetic relationships of *Orbitolina* (*Mesorbitolina*) species and proposed an evolutionary lineage starting from *O.* (*M.*) *lotzei* to *O.* (*M.*) *texana* via *O.* (*M.*) *parva*. *O.* (*M.*) *lotzei* ranges from the uppermost Barremian to the Lower Aptian, *O.* (*M.*) *parva* from the Upper Aptian to the Middle Albian, and *O.* (*M.*) *texana* from the Upper Aptian to the Upper Albian (Arnaud-Vanneau, 1998).[1] The megalospheric embryonic apparatus shows an overall increase in size through time for these three species. Generally, the diameters of the embryonic apparatuses of *O.* (*M.*) *lozei*, *O.* (*M.*) *parva*, and *O.* (*M.*) *texana* are 0.10–0.12, 0.16–0.26, 0.24–0.81 mm respectively (e.g., Douglass, 1960; Schroeder, 1979; Zhang, 1982).[25,18,28] The shape of the protoconch changes phylogenetically, i.e., globular in the earlier form, becoming slightly elliptical with a flat base in the later form (e.g., *taxana*; Douglass, 1960, plate 6).[25] In the same way, the alveolar layer of the deuteroconch becomes more complicated with through time.

Age: Late Aptian (see discussion below)

Discussion. *1. Age of Mesorbitolina-bearing carbonates of the Yezo Group, Hokkaido, northern Japan.* Since shallow-marine carbonates in Hokkaido occur as olistoliths or pebbles, their age assignment should be based on the index fossils recovered from the carbonates themselves. Matsumaru (1971)[16] studied orbitolinid specimens from the limestone olistoliths in the lower part of the Yezo Group in central Hokkaido, and identified them as "*Orbitolina lenticularis* Form Group II" *sensu* Hofker (1963).[11] The inferred Late Aptian–Early Albian age of the shallow marine carbonates, based on the identification and occurrences of "*O. lenticularis* Form Group II", has been followed by previous studies (e.g., Sano, 1995; Takashima *et al.*, 2004).[2, 5] However, Matsumaru (1971)[16] did not show the detail of the morphology of the embryonic apparatus, which is the most important character in orbitolinid classification, so that the occurrence of "*Orbitolina lenticularis* Form Group II" from Hokkaido needs to be confirmed using better-preserved material. Recently Matsumaru (2005)[29] proposed a new genus of orbitolinid foraminifer, *Praeorbitolinoides*, based on the materials from limestone olistoliths in central Hokkaido and assigned its age to the Early Aptian due to the co-occurrence of "*Palorbitolina lenticularis*" and *Mesorbitolina parva*. However, he documented the occurrence of *Mesorbitolina parva* without any descriptions and figures. "*Palorbitolina lenticularis*" figured in his paper does not show sufficient diagnostic characters of *Palorbitolina*, and in this respect his species assignment needs to be reconsidered.

Orbitolina (*Mesorbitolina*) *parva* had a range from Late Aptian to Middle Albian (Arnaud-Vanneau, 1998).[1] The olistostrome bed containing the limestone olistoliths in the Yezo Group in central Hokkaido has been assigned in age to the Late Aptian, based on planktonic foraminiferal biostratigraphy and chemostratigraphy (e.g., Nishi *et al.*, 2003; Takashima *et al.*, 2004).[30, 5] The source carbonate sediments, which were later transported as olistoliths to a deeper part of the Yezo basin, were originally deposited in the Late Aptian or earlier. Thus the age of carbonate deposits in the Yubari–Ashibetsu area, central Hokkaido (Locs. 1 and 2) is regarded as the Late Aptian. In the Nakagawa area, northern Hokkaido, a Late Aptian ammonite *Parahoplites colossus* was reported by Matsumoto (1984)[31] from the Kj 2 Member of the Kamiji Formation, which lies above the carbonate clast-bearing conglomerate. Therefore, the age of carbonate deposits of this area (Loc. 3) is also assigned to the Late Aptian.

Iba *et al.* (2005)[3] pointed out the similarities in the bio- and lithofacies between the limestone olistoliths in central Hokkaido and the limestone pebbles in northern Hokkaido. Thus, Late Aptian carbonate platforms possibly developed about 200 km length from south to north in Hokkaido.

2. Comparison of the lower part of the Yezo Group between central and northern Hokkaido. In the Yubari–Ashibetsu area, central Hokkaido, the Yezo Group conformably overlies the Shirikishimanaigawa Formation (tuffaceous mudstone unit) of the upper part of the Sorachi Group in the Yubari–Ashibetsu area (Takashima *et al.*, 2004)[5] (Fig. 3–A). The lower part of the Yezo Group in this area is composed of the Soashibetsugawa Formation (Lower Aptian mudstone unit) and the Shuparogawa Formartion (Lower Aptian–lower Upper Albian sandstone-dominant turbidite unit) in ascending order (Takashima *et al.*, 2004)[5] (Fig. 3–A). In the Nakagawa area, northern Hokkaido, the Kamiji Formation (Aptian–Albian sandstone and mudstone unit) of the lower part of the Yezo Group overlies the Pechikunnai Formation (tuffaceous mudstone unit), the uppermost formation of the Sorachi Group (Kawaguchi, 1997)[32] (Fig. 3–B). This study reveals that the lowermost part of the Kamiji Formation is assigned to the Late Aptian.

As discussed above, the Kirigishiyama Olistostrome Member of the Shuparogawa Formation in the Yubari–Ashibetsu area, which contains the limestone olistoliths, can be correlated with the lowermost part of the Yezo Group in the Nakagawa area (Fig. 3). Olistostromes or conglomeratic gravity flow deposits containing shallow-marine carbonates, which have been considered as one of the important key units in the Yezo Group (Takashima *et al.*, 2004),[5] are now traceable from central to northern Hokkaido, i.e., more widely than previous thought.

An important radiolarian datum plane correlated to the Early Barremian time, the last occurrence of *Cecrops septemporatus*, was identified in the middle-to-upper part of the Shirikishimanaigawa

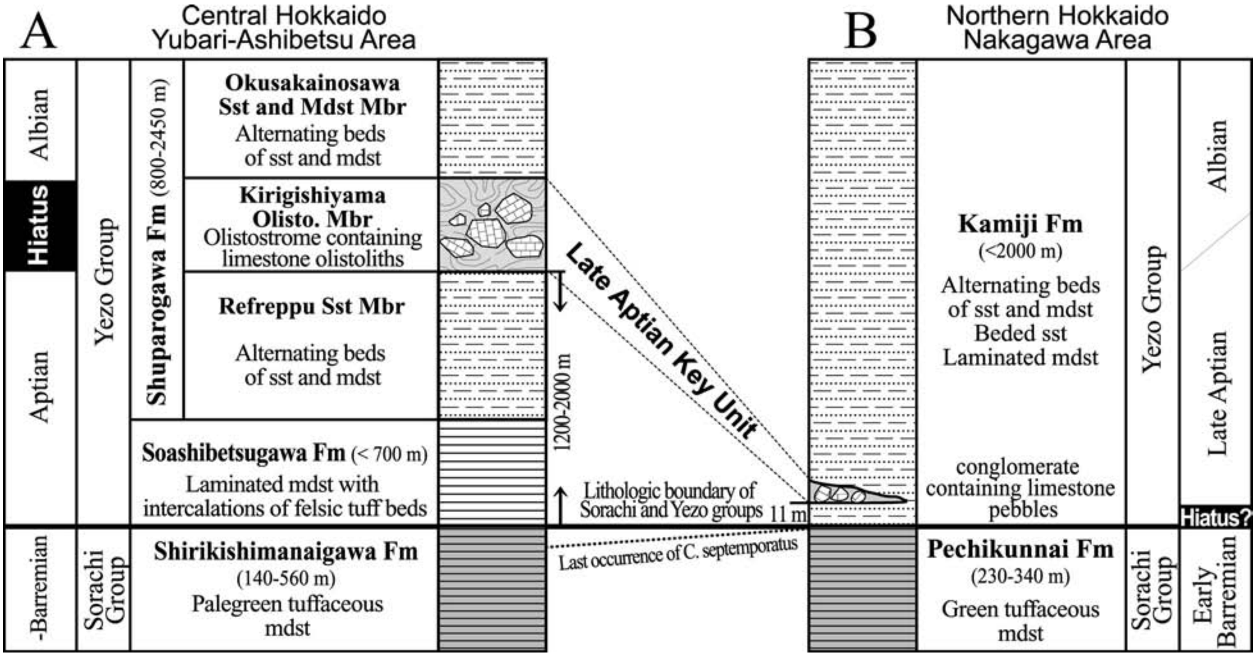

Fig. 3. Comparison of the lower part of the Yezo Group between central and northern Hokkaido. Geological data are based on Takashima *et al.* (2004, 2006)5), 34) for central Hokkaido and Kawaguchi (1997)32) and Iba *et al.* (2005)3) for northern Hokkaido.

Formation in the Yubari–Ashibetsu area (Takashima *et al.*, 2001, 2006)33), 34) and in the uppermost part of Pechikunnai Formation in the Nakagawa area (Kawaguchi, 1997; Mitsugi and Hirano, 1998).32), 35) Thus the upper part of the Sorachi Group of both areas is almost synchronous based on radiolarian biostratigraphy (Fig. 3).

Kirigishiyama Olistostrome Member is intercalated at 1200 to 2000 m above the boundary between the Sorachi and Yezo groups (Takashima *et al.*, 2004).5) On the other hand, in Nakagawa area, the conglomeratic gravity flow deposits that contain limestone pebbles in the lowest part of the Kamiji Formation is intercalated only 11 m above the boundary between the Sorachi and Yezo groups (Fig. 3: Iba *et al.*, 2005).3) In the Nakagawa area, a hiatus possibly ranging from Late Barremian to Early Aptian is supposed to occur between the uppermost part of the Sorachi Group (Lower Barremian) and conglomerate of the lowermost part of the Yezo Group (Upper Aptian). Such a hiatus is not recognized in the Yubari–Ashibetsu area, because the uppermost part of the Shirikishimanaigawa (possibly in some routes), the Soashibetsugawa and the lower part of the Shuparogawa formations were all deposited during this time interval (Takashima *et al.*, 2001, 2004).33), 5) On the contrary, a hiatus ranging from Late Aptian to around the Aptian–Albian boundary is recognized within the Shuparogawa Formation of the Yubari–Ashibetsu area, based on the lack of planktonic foraminiferal zones, and this missing horizon may have been eroded away during the deposition of a thick olistostrome unit (Takashima *et al.*, 2004).5) In the Nakagawa area, however, sedimentation of terrigenous clastics continued during the Late Aptian to the Albian (Hashimoto *et al.*, 1967; Iba *et al.*, 2005).36), 3)

In summary, the upper part of the Sorachi Group in both the Yubari–Ashibetsu and Nakagawa areas is similar in lithology and depositional age (Fig. 3). The Aptian–Albian depositional history was, however, significantly different between the two areas, although they were located within the same Yezo fore-arc basin. Thus differentiation of local sedimentary sub-basins within the Yezo fore-arc basin during the Aptian is inferred, when the deposition of the Yezo Group started. On the other hand, shallow-marine carbonates contemporaneously deposited in a shallower part of the basin, and subsequently in the Late Aptian, they were transported as olistoliths or pebbles to a deeper part of the basin in central to northern Hokkaido.

3. Paleobiogeographic significance. Mesogean key taxa *sensu* Masse (1992),[4] comprising a typical infralittoral warm-water association of rudists, dictyoconiane foraminifers and dasycladacean algae, are very important for recognizing the Tethyan biotic realm during the Cretaceous (Masse, 1992).[4] In the Late Aptian, carbonate platforms that contain many Mesogean key taxa developed about 200 km length from south to north in Hokkaido and represent a widest distribution in the Northwest Pacific during the Cretaceous Period. Not only the Late Aptian carbonate platforms in Hokkaido, but also the Upper Aptian unit of the Miyako Group on the Pacific coast of northern Honshu, northern Japan, contain rudists, a representative of the Mesogean key taxa (e.g., Hanai *et al.*, 1968; Sano, 1991).[37),38] Furthermore, occurrences of the rudists were reported to occur from the Upper Aptian of the Pre-Sotoizumi Group in Southwest Japan (Tashiro and Ikeda, 1987).[39] The wide distribution of Mesogean key taxa in Japan indicates that the Late Aptian was a warm period in the Northwest Pacific.

Late Aptian shallow-marine carbonates of the Yezo Group that contain Mesogean key taxa represent the latest stratigraphic record of this faunal and floral assemblage in the Northwest Pacific. It is a very important aspect for considering the paleobiogeography and faunal changes of Cretaceous North Pacific. Occurrences of Mesogean key taxa and other carbonate platform biota (e.g., hermatypic corals) during the Early Cretaceous are commonly reported from Japan (e.g., Tashiro and Ikeda, 1987; Morino *et al.*, 1989; Sano, 1995).[39),40),2] Rudists and dasycladacean algae are also known to occur in the Upper Jurassic (Tamura, 1961; Mimoto *et al.*, 1990).[41),42] The temporal distribution of Mesogean key taxa and other carbonate platform biota in Japan indicates that the Northwest Pacific belonged to the Tethyan biotic realm during the Late Jurassic to Late Aptian interval. However, there are no records of Mesogean key taxa in the Northwest Pacific after the Late Aptian. Although some carbonate platform biota (e.g., orbitolinid foraminifers) flourished in Northeast Japan during Early Albian (Yezo and Miyako groups: Hanai *et al.*, 1968; Poyarkova, 1987),[37),43] they also disappeared in this region after the Early Albian. Thus the occurrence of Mesogean key taxa from the Yezo Group represents the latest stratigraphic record of this faunal and floral assemblage in the Northwest Pacific. Such a drastic disappearance of the Mesogean key taxa after the Late Aptian has never been recognized in the Mediterranean, Caribbean or other Tethyan regions.

In addition, Late Cretaceous marine bivalves in the Northwest Pacific also include many endemic taxa, which began to appear in the middle Albian (e.g., Hayami and Yoshida, 1991; Tashiro, 2000).[44),45] Thus the demise of Mesogean key taxa is undoubtedly the most important paleobiogeographic event in the Northwest Pacific, indicating the independence of the North Pacific from the Tethyan biotic province after the Late Aptian.

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