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Upper Albian to Lower Cenomanian biostratigraphy in the Oyubari area, Hokkaido, Japan: toward a Cretaceous biochronology for the North Pacific

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ABSTRACT:

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An integrated planktonic foraminifer and ammonoid biostratigraphy for the Oyubari area, Hokkaido, Japan, provides new insights into the late Albian to early Cenomanian biochronology of the North Pacific province. The following foraminifers extend Tethyan zonation to the Oyubari area: *Biticinella breggiensis* (lower Upper Albian), *Rotalipora subticinensis - Rotalipora ticinensis* (middle Upper Albian), *Rotalipora appenninica* (upper Upper Albian), and *Rotalipora globotruncanoides* (Lower Cenomanian) zones. Co-occurring age-indicative ammonoids such as *Mortoniceras rostratum*, *Mariella bergeri*, and *Mantelliceras saxbii*, are in accord with these foraminifer ages. The base of the Cenomanian stage in Hokkaido is recognized as the first occurrence of *Rotalipora globotruncanoides*, which is close to the horizon of the occurrence of *Mantelliceras*. The first occurrence of *Desmoceras* (*Pseudouhligella*) *japonicum*, regarded as a Cenomanian marker species in the North Pacific province, is of latest Albian age in the global biochronological scale.

Key words: Albian/Cenomanian boundary, Ammonoids, Biochronology, Hokkaido, Pacific, Planktonic foraminifers.

INTRODUCTION

The Albian-Cenomanian transition is noteworthy for paleoenvironmental changes that took place during the Cretaceous greenhouse period. An oceanic anoxic event evidently occurred in the latest Albian in the Atlantic and Tethyan regions (OAE 1d, ERBACHER & *al*. 1996, ERBACHER & THUROW 1997, NEDERBRAGT & *al*. 2001, STRASSER & *al*. 2001, WILSON & NORRIS 2001), and oxygen isotope records from lower Cenomanian strata in mid-latitude areas suggest that a rapid cooling event took place (CLARKE & JENKYNS 1999, STOLL & SCHRAG 2000). Well-documented placement of the Albian/Cenomanian boundary worldwide is necessary not only for biostratigraphic studies but also for future research on Cretaceous environmental change. The basal-boundary criterion for the Cenomanian stage, as proposed at the Second International Symposium on

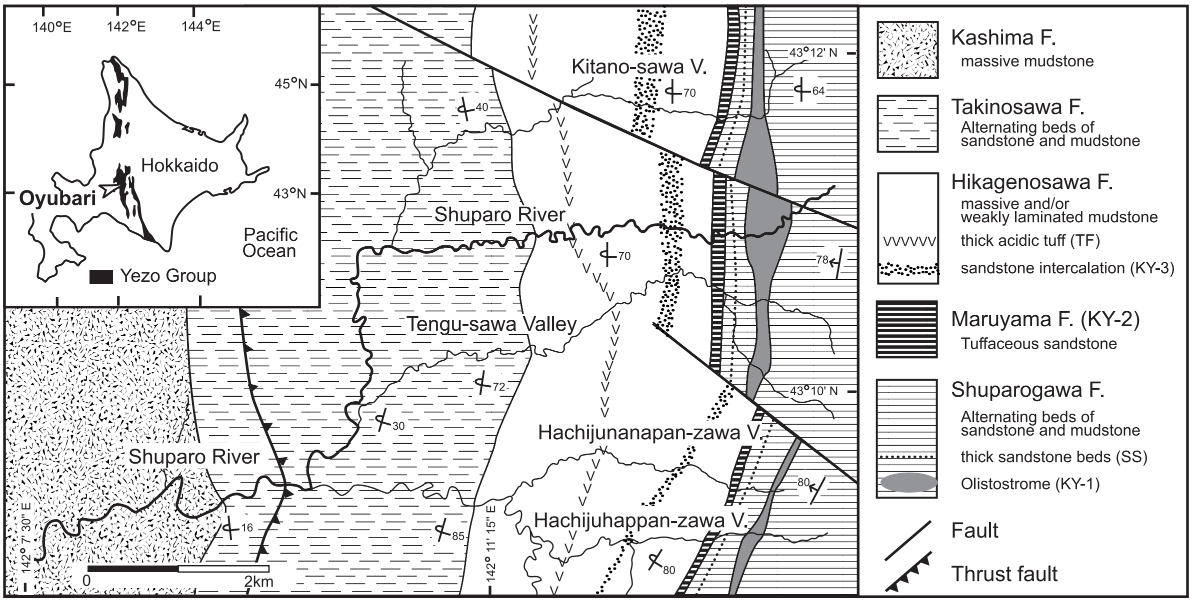

Fig. 1. Generalized geological map for the northern part of the Oyubari area, Hokkaido, Japan. Modified after KAWABE & *al*. (1996, fig. 2) and TAKASHIMA & *al.* (1997, fig. 2)

Cretaceous Stage Boundaries, in Brussels in 1995, is the first occurrence of the planktonic foraminifer *Rotalipora globotruncanoides* SIGAL, which is just below that of the ammonoid *Mantelliceras mantelli* (J. SOWERBY) (TRÖGER & KENNEDY 1996). Both Tethyan and Boreal macrofaunas are present in the stratotype in southeastern France, where the first occurrences of the ammonoid *Mantelliceras mantelli* and other ammonoids of the *M. mantelli* Zone are proxy boundary criteria (GALE & *al*. 1996). In similar fashion, detailed inter-regional correlations of the Upper Albian to Lower Cenomanian transition have been achieved for several land-based stratigraphic sections in Europe (e.g., LÓPEZ-HORGUE & *al*. 1999, WIEDMANN & OWEN 2001).

Hokkaido Island lies along the western margin of the North Pacific biogeographic province, and its macrofauna exhibited a high degree of endemism during the Cretaceous. However, faunal assemblages there do contain some Tethyan-type ammonoids (MATSUMOTO 1973). In addition, typical Tethyan planktonic foraminifer species commonly migrated into the mid-latitude Northwest Pacific during middle Albian to early Turonian time (NISHI & *al*. in press). The Cretaceous Yezo Group in central Hokkaido, northern Japan, is composed of a thick, continuous, and widely occurring sequence of Aptian to Maastrichtian marine sediments with abundant mega- and microfossils. As a result, the Yezo Group is of central importance for establishing an Upper Albian to Lower Cenomanian biochronology for the Northwest Pacific. In the past decade, knowledge of Albian to Cenomanian faunas in Hokkaido has significantly improved for planktonic foraminifers (MOTOYAMA & *al*. 1991, TAKASHIMA & *al*. 1997, NISHI & *al*. in press), ammonoids and inoceramid bivalves (KAWABE & *al*. 1996, KAWABE 2000). These studies have shown that the Albian-Cenomanian transition in Japan is best exposed along the upper reaches of the Shuparo River and its tributaries, in the northern part of the Oyubari area, Hokkaido, Japan (Text-fig. 1).

We evaluated the biostratigraphic succession in the Oyubari area and then documented the presence of global age-indicative criteria, including the first-occurrence datum of the foraminifer *Rotalipora globotruncanoides* and the first-occurrence of the ammonoid genus *Mantelliceras*. The objective of this study is to present a stratigraphic analysis of the Albian-Cenomanian succession in the northern part of the Oyubari area. We present an integrated ammonoid and planktonic foraminiferal biostratigraphy as the basis for a precise definition of the Albian-Cenomanian transition in Hokkaido, as a means of facilitating inter-regional correlations with other North Pacific areas.

GEOLOGIC SETTING AND LITHOLOGY

Early Cretaceous-Paleocene forearc-basin sediments occur widely across a 200-km-wide and 1400-km-long belt from northeastern Japan to western Sakhalin Island, Russia (ANDO in press). Forearc sediments in

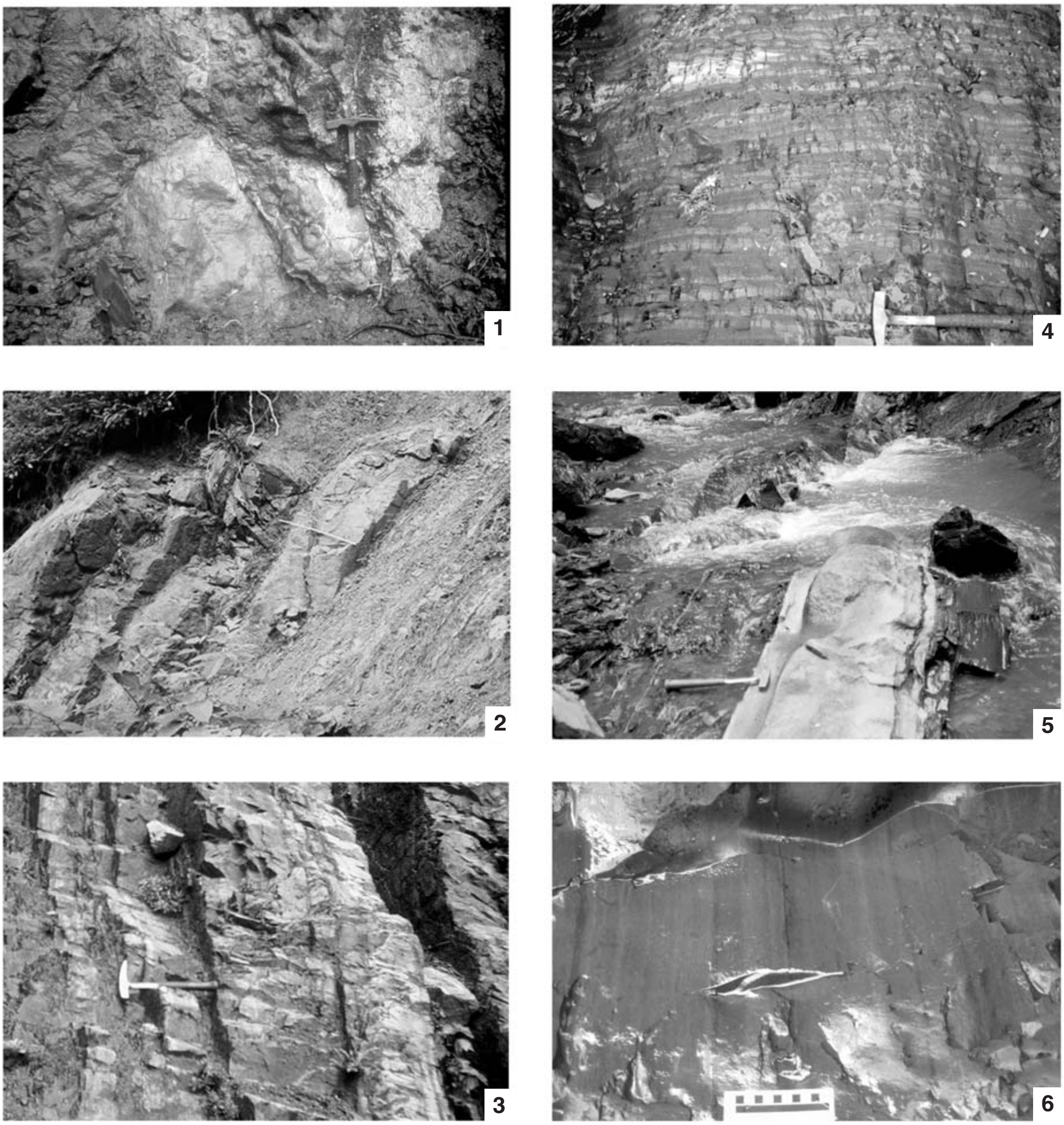

Fig. 2. 1 – Olistostrome unit in the middle part of the Shuparogawa Formation (key marker KY-1); 2 – Sandstone beds in the upper part of the Shuparogawa Formation (key marker SS); 3 – Felsic, tuffaceous sandstones in the Maruyama Formation (key marker KY-2); 4 – Thin, turbiditic sandstone beds in the lower part of the Hikagenosawa Formation (key marker KY-3); 5 – Thick, felsic tuff bed in the middle part of the Hikagenosawa Formation (key marker TF); 6 – Weakly laminated mudstone in the lower part of the Hikagenosawa Formation

Hokkaido are grouped together as the Yezo Group and have no significant stratigraphic gaps.

The Yezo Group is well exposed along the Shuparo River and its tributaries in the Oyubari area of central Hokkaido. These strata strike north-south, become younger to the west, are overturned in their central to western portions, and exhibit a homoclinal structure dipping acutely east (Text-fig. 1). The group ranges from Aptian to Campanian in our study area and represents an offshore mudstone-dominated facies more than 8,000 m thick (MOTOYAMA & *al.* 1991). The paleodepth of these mudstones is inferred to be upper bathyal, based on benthic foraminiferal assemblages (KAIHO & *al.* 1993). The Yezo Group in the Oyubari area is lithostratigraphically divided into the following five formations, in ascending order (MOTOYAMA & *al.*

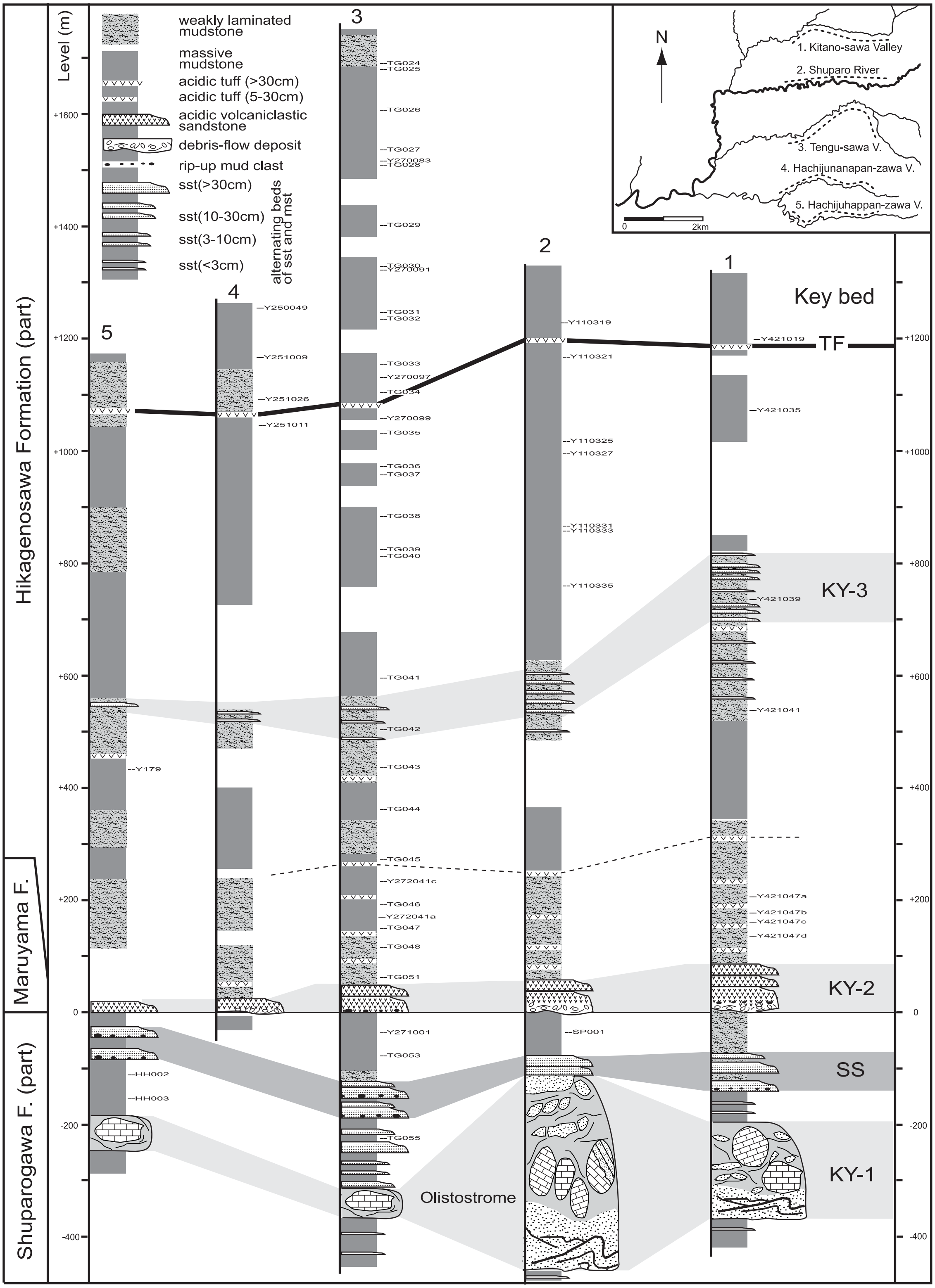

Fig. 3. Lithologic sections for the Albian-Cenomanian transition in the northern part of the Oyubari area. Five key marker beds are recognized in this sequence: KY-1, olistostrome containing "*Orbitolina* Limestone" blocks; SS, thick turbiditic sandstones; KY-2, felsic tuffaceous sandstones (Maruyama Formation); KY-3, turbiditic sandstones; and TF, thick felsic tuff. Sampling horizons are shown on each columnar section: the prefixes TG, HH and SP refer to planktonic foraminifer samples, and the prefix Y to ammonoid and inoceramid samples. For sampling points, see KAWABE & *al.* (1996, fig. 4) and TAKASHIMA & *al.* (1997, fig. 10)

1991, TAKASHIMA & *al*. 2001): the basal Shuparogawa Formation, which lies upon volcaniclastic rocks of the Sorachi Group, is mainly composed of alternating beds of terrigenous, turbiditic sandstones and hemipelagic mudstones intercalated with an olistostrome unit containing "*Orbitolina*-rudist Limestone" blocks in its middle part; the Maruyama Formation consists of felsic, tuffaceous sandstones associated with debris-flow deposits; the Hikagenosawa Formation consists of massive and/or weakly laminated mudstones (Text-fig. 2.6) intercalated with felsic tuff beds and lesser turbiditic sandstones; the Takinosawa Formation consists of alternating beds of thickening-upward turbiditic sandstones and mudstones; and the Kashima Formation consists of massive mudstones.

We examined five sections within a continuous sequence from the middle part of the Shuparogawa Formation to the upper part of the Hikagenosawa Formation (Text-fig. 3). This whole sequence is composed mainly of massive or weakly laminated mudstone with *Phycosiphon*- and *Planolites*-like burrows, and episodic intercalations of other sediments. The following five lithostratigraphic markers comprise the episodic deposits, in ascending order: KY-1 is an olistostrome unit in the Shuparogawa Formation (Text-fig. 2.1); SS is a unit of thick (30-100 cm), turbiditic, fine-grained sandstones with uniformly parallel or convoluted laminations, containing frequent plant remains and rip-up mud clasts, in the upper part of the Shuparogawa Formation (Text-fig. 2.2); KY-2 is the Maruyama Formation, which is composed of felsic tuff beds and tuffaceous sandstones with debris-flow deposits (Text-fig. 2.3); KY-3 is a unit intercalated with thin turbiditic sandstones in the lower part of the Hikagenosawa Formation (Text-fig. 2.4); TF is a thick (40-50 cm), felsic, coarse-grained tuff bed with abundant biotite in the middle part of the Hikagenosawa Formation (Text-fig. 2.5). The olistostrome (KY-1) and the Maruyama Formation (KY-2) are widely traceable, from the Oyubari area to northwestern Hokkaido (TAKASHIMA & NISHI 1999), while the other markers are traceable only locally in the Oyubari area and adjacent areas.

BIOSTRATIGRAPHY

Materials and methods

The paleontological data are mostly derived from the biostratigraphic studies of KAWABE & *al*. (1996), KAWABE (2000), TAKASHIMA & *al*. (1997) and NISHI & *al*. (in press).

Hard mudstones were systematically sampled for microfossils, with most samples coming from the Tengu-sawa section, which has the best exposures (Text-fig. 3). All samples, approximately 250 g each, were treated first with sodium sulfate and later with tetraphenylborate. The disaggregated samples were washed in a 63 μm sieve, and specimen abundance was defined as follows: 1-2 specimens is rare; 3-5 specimens is few; 6-9 specimens is common; and >10 specimens is abundant.

Albian and Cenomanian successions throughout Hokkaido contain sparse megafossils, and we obtained a small number of macrofossil specimens from the Tengu-sawa section only. We propose a macrofossil biostratigraphy based on these specimens and those from four adjacent sections. The sampling horizons in each section were calibrated with reference to the five lithostratigraphic marker beds mentioned above (Text-fig. 3). Ammonoids and inoceramids were extracted from mudstones or matrix-supported calcareous concretions within the mudstones, but not from sandstones. We avoided the use of float shells when plotting the stratigraphic ranges of the macrofossils.

In this study, fossil occurrences are described in ascending order (Text-fig. 4), with the base of this sequence coincident with the base of the Maruyama Formation (KY-2), which is easily recognized in the field.

Repositories of the specimens are as follows: Department of Earth Science, Graduate School of Social and Cultural Studies, Kyushu University, Fukuoka, for planktonic foraminifers; and Department of Earth Sciences, School of Education, Waseda University, Tokyo (WE) and Mikasa City Museum, Mikasa (MCM), for ammonoids and inoceramids.

Foraminifer succession

Twenty species of planktonic foraminifers occur from the uppermost part of the Shuparogawa Formation to the upper part of the Hikagenosawa Formation. They are abundant in the lowermost +100-m of this sequence as follows: common and/or abundant, *Hedbergella delrioensis* (CARSEY), *H. planispira* (TAPPAN), *Ticinella roberti* (GANDOLFI), *Favusella washitensis* (CARSEY) and *Biticinella breggiensis* (GANDOLFI); rare, *H. simplex* (MORROW), *T. raynaudi* SIGAL, *F. nitida* MICHAEL and *Rotalipora subticinensis* (GANDOLFI).

Assemblages in the +150 to +700-m interval are characterized by scattered and very scarce specimens. Planktonic foraminifers are absent from +500 to +700-m, although this barren zone (Text-fig. 4) contains abundant radiolarian specimens.

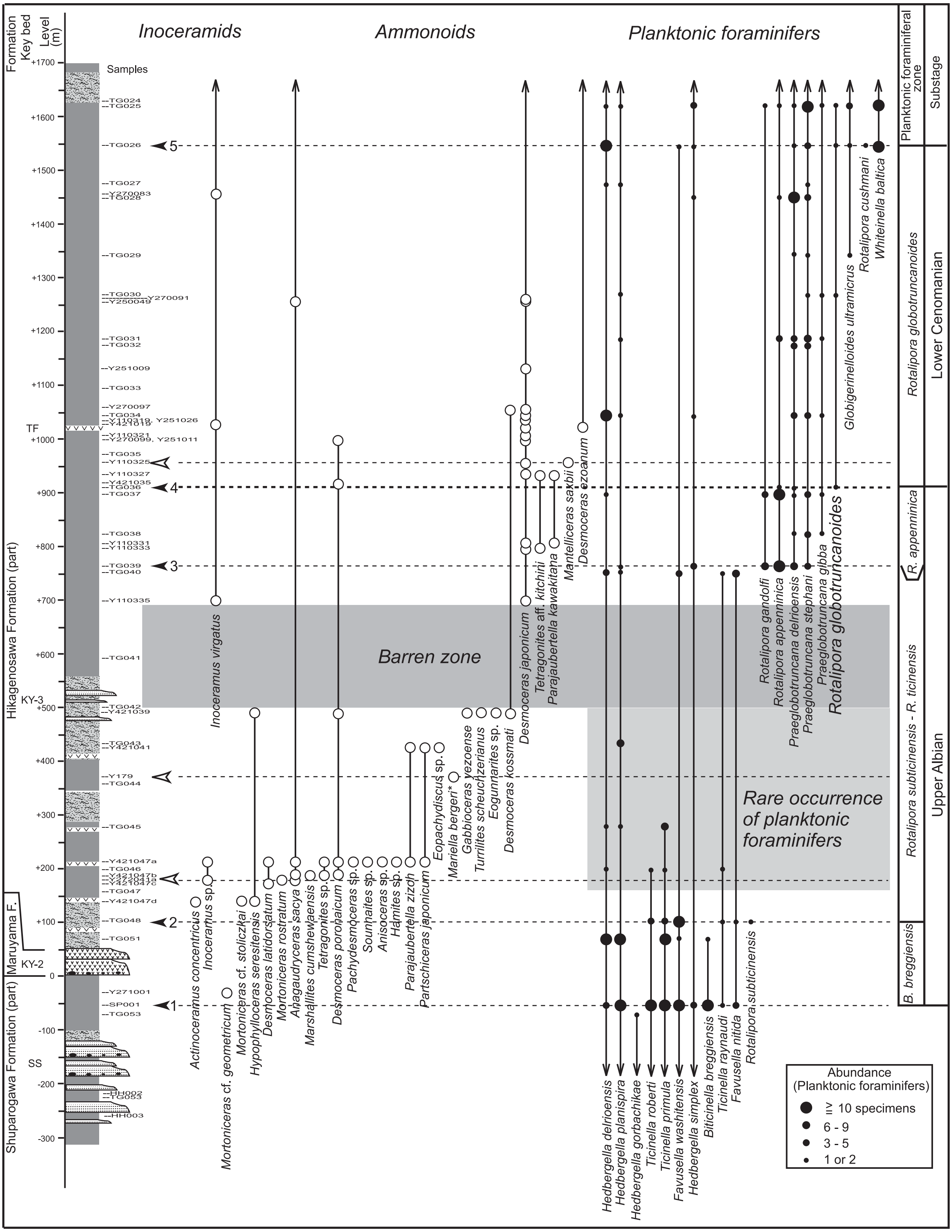

Fig. 4. Stratigraphic distribution of ammonoids, inoceramids and planktonic foraminifers within the Albian-Cenomanian transition in the northern part of the Oyubari area. The planktonic foraminiferal zonation is adopted from Nishi & *al.* (in press, fig. 5). An ammonoid with an asterisk is from MATSUMOTO & NISHIDA (2000). Solid arrows are FOs of age-indicative planktonic foraminifer species; open arrows are occurrences of Tethyan age-indicative ammonoid species

Planktonic foraminifers occur continuously from the +750-m level upward. *Hedbergella delrioensis*, *H. planispira*, *H. simplex* and *Favusella washitensis* extended their ranges from the lower portion of this entire sequence, whereas *Praeglobotruncana* spp. and *Rotalipora* spp. are recruits that occur frequently only above the +760-m level.

The following five biochronostratigraphically important horizons are (Text-fig. 4): (1) the first occurrence (FO) of *Biticinella breggiensis* at the –50-m level; (2) the occurrence of *Rotalipora subticinensis* at the +100-m level; (3) the FO of *Rotalipora appenninica* (RENZ), as well as *R. gandolfii* LUTERBACHER & PREMOLI-SILVA, *Praeglobotruncana delrioensis* (PLUMMER) and *P. stephani* (GANDOLFI), at the +760-m level; (4) the FO of *Rotalipora globotruncanoides* at the +910-m level; and (5) the FO of *Whiteinella baltica* DOUGLAS & RANKIN and the occurrence of *Rotalipora cushmani* (MORROW) at the +1,550-m level.

Ammonoid and inoceramid succession

The macrofauna is diverse, and the stratigraphic position of the barren zone for macrofossils is consistent with that for planktonic foraminifers (Text-fig. 4).

The fauna of the –30 to +175-m interval is characterized by occurrences of *Mortoniceras*: *M.* (*M.*) cf. *geometricum* SPATH at the –30-m level; *M.* (*M.*) cf. *stoliczkai* (SPATH) and *Actinoceramus concentrica* (PARKINSON) at the +140-m level; *M.* (*M.*) *rostratum* (J. SOWERBY) at the +175-m level. The stratigraphic interval spanning +170 to +210-m contains both Tethyan species such as *Desmoceras* (*D.*) *latidorsatum* (MICHELIN) and *Anagaudryceras sacya* (FORBES), and regional North Pacific taxa such as *Marshallites cumshewaensis* (WHITEAVES), *Sounnaites* sp. and *Desmoceras* (*Pseudouhligella*) *poronaicum* YABE.

Ammonoids in the +410 to +490-m interval, around key marker KY-3, occur in calcareous concretions, whereas inoceramids are absent. *Parajaubertella zizoh* MATSUMOTO is common (> 5 individuals) at the +410-m level. Calcareous concretions at the +490-m level contain numerous *Desmoceras* (s.l.) (> 30 individuals) along with a few individuals of other ammonoids.

The fauna of the +700 to +1,450-m interval, above the barren zone, is characterized by sporadic occurrence of ammonoids and inoceramids, in a mudstone matrix rather than in calcareous concretions. The following two biostratigraphically important species are present: the first occurrence of *Desmoceras* (*P.*) *japonicum* YABE at the +700-m level, and the occurrence of *Mantelliceras saxbii* (SHARPE) at the +960-m level.

INTER-REGIONAL CORRELATIONS

Correlation with the Tethyan standard

The stratotype of the Albian-Cenomanian succession is in the Vocontian Basin, southeastern France, where typical Tethyan macro- and microfossil faunas are common (TRÖGER & KENNEDY 1996, GALE & *al*. 1996). A worldwide biochronologic scheme for Cretaceous planktonic foraminifers has been established based on assemblages in the Tethyan region (e.g., CARON 1985, ROBASZYNSKI & CARON 1995), where the following sequence of five Upper Albian to Lower Cenomanian zones is present, in ascending order: the *Ticinella praeticinensis*, *Rotalipora subticinensis*, *R. ticinensis*, *R. appenninica* and *R. globotruncanoides* zones (Text-fig. 5).

Ammonoid occurrences in Upper Albian to Lower Cenomanian sequences have recently been examined in detail not only in the Vocontian Basin (GALE & *al*. 1996) but also near Estella-Lizarra in the Basque-Cantabrian Basin, north-central Spain (LÓPEZ-HORGUE & *al*. 1999). These studies show the precise macro- and microfossil occurrences on lithologic sections. LÓPEZ-HORGUE & *al.* (1999) adopted the ROBASZYNSKI & CARON's (1995) zonation scheme for planktonic foraminifers, and proposed a new scheme for Upper Albian ammonoids, based on the following worldwide species, in ascending order: the *Diploceras cristatum*, *Hysteroceras varicosum*, *Mortoniceras inflatum* and *Stoliczkaia dispar* zones (Text-fig. 5). This zonation applies to the Tethyan province and elsewhere, to a greater degree than does the so-called standard ammonoid zonation for the European fauna, which is based on endemic Boreal elements such as hoplitids and anahoplitids. The *Hysteroceras varicosum* Zone correlates with the interval containing both the *H. orbignyi* Subzone and the *H. varicosum* Subzone of the European faunal scheme, whereas the *Mortoniceras inflatum* Zone is with the *Callihoplites auritus* Subzone of the European faunal scheme (LÓPEZ-HORGUE & *al*. 1999, OWEN 1999). HARDENBOL & *al*. (1998) summarized Cretaceous biochronostratigraphy, using zonal boundaries based on the time scale of GRADSTEIN & *al.* (1995). Planktonic foraminifer and ammonoid zones in the Tethyan province are integrated in Text-fig. 5.

The stratigraphic distribution of planktonic foraminifers in our study area provides a standard biostratigraphy for the upper Albian to lower Cenomanian interval in Japan, for the purposes of inter-regional correlation. We propose the following zones in the Oyubari area, in ascending order (Text-fig. 4; see NISHI & *al.* in press, for details): the *Biticinella breggiensis*, *Rotalipora subticinensis-R. ticinensis*, *R. appenninica*, and *R.*

globotruncanoides zones. Their bases are defined as the FOs of the nominate index species. The occurrences of globally age-indicative macrofossils support the stratigraphic placement of the bases of the *Biticinella breggiensis* and *Rotalipora subticinensis-R. ticinensis* zones. The FO of *Mortoniceras*, an Upper Albian indicator, is just above the FO of *Biticinella breggiensis*. *Mortoniceras* cf. *stoliczkai* and *Actinoceramus concentrica*, which are representatives of the *Hysteroceras varicosum* Zone (synchronous with the *Rotalipora subticinensis* Zone) in the Tethyan province, occur just above the FO of *Rotalipora subticinensis*.

Based on our fossil records, the base of the *Rotalipora appenninica* Zone is at the +760-m level, just above the barren zone for planktonic foraminifers. In the Tethyan province, the *R. appenninica* Zone is characterized by occurrences of species representing the *Stoliczkaia dispar* Zone (e.g., GALE & *al*. 1996, LÓPEZ-HORGUE & *al*. 1999). *Mortoniceras* (*M.*) *rostratum*, a representative of the lower *Stoliczkaia dispar* Zone, occurs at our +175-m level. In addition, MATSUMOTO & NISHIDA (2000) have reported the occurrence of *Mariella* (*M.*) *bergeri* (BRONGNIART), a representative of the upper *S. dispar* Zone, at the +375-m level. Both stratigraphic levels are within the regionally defined *Rotalipora subticinensis-R. ticinensis* Zone, in which planktonic foraminifers are scattered and scarce. Taking into account occurrences of age-indicative macrofossils and rare occurrences of planktonic foraminifers (Text-fig. 4), the stratigraphic position of the first occurrence of *Rotalipora appenninica* would be in the lower part of the *Rotalipora subticinensis-R. ticinensis* Zone. In other words, the *Rotalipora appenninica* Zone in the Oyubari area is correlative with the upper part of the *Rotalipora appenninica* Zone of the Tethyan province (Text-fig. 5).

The Albian/Cenomanian boundary is generally placed in the interval between the last occurrence (LO) of *Mortoniceras* and the FO of *Mantelliceras*. This interval is characterized by *Graysonites* species in Texas (MANCINI 1979, YOUNG 1986), Spain (WIEDMANN & KAUFFMAN 1978), Brazil (BENGSTON 1983), California (MATSUMOTO 1959) and southwestern Japan (MATSUMOTO 1960). Although *Graysonites* is absent in the northern European fauna, the FO of *Graysonites adkinsi* YOUNG was tentatively proposed as a criterion for the basal Cenomanian, at the Copenhagen meeting on Cretaceous stage boundaries in 1984 (BIRKELUND & *al*. 1984). This occurrence is approximately coincident with the FO of *Rotalipora appenninica* in Texas (HANCOCK 1984). *Graysonites* is known from sites in Hokkaido, including the Oyubari area, but only as float specimens (NISHIDA & *al*. 1996, MATSUMOTO & NISHIDA 2000).

In contrast, based on proposals at the Brussels meeting on Cretaceous stage boundaries in 1995, the Albian/Cenomanian boundary is defined as the FO of the planktonic foraminifer *Rotalipora globotruncanoides* (TRÖGER & KENNEDY 1996). This occurrence is 6 m below the base of the globally recognized *Mantelliceras mantelli* Zone, which contains typical Tethyan and Boreal-type species, in the proposed Global Stratotype Section and Point at Mont Risou, southeastern France (GALE & *al.* 1996). This definition is concordant with fossil occurrences in the middle part of the Hikagenosawa Formation in the Oyubari area, where the FO of *Rotalipora globotruncanoides* is located at the +910-m level. Although *Mantelliceras mantelli* is absent from the Oyubari area, *M. saxbii*, a representative of the upper part of the *M. mantelli* Zone in Tethys, occurs 50 m above the FO of *R. globotruncanoides* (Text-fig. 4). A similar integration of planktonic foraminifer and ammonoid biostratigraphy is also present in the Tappu area, northwestern Hokkaido (personal observations of F. KAWABE and R. TAKASHIMA).

Implications for North Pacific ammonoid biochronology

Upper Albian to lower Cenomanian deposits are widespread in Japan, Far-Eastern Russia, Alaska, British Columbia and California, and these areas within the North Pacific bioprovince are characterized by a high degree of macrofaunal endemism. Desmoceratid ammonoids in particular were widespread and abundant during the Cretaceous in the North Pacific. In addition, *Desmoceras* (*Pseudouhligella*) species have routinely served as zonal indices to facilitate correlation among North Pacific regions. In general, it has been thought that *D.* (*P.*) *dawsoni* (WHITEAVES) and/or *Mortoniceras* spp. characterize the upper Albian, whereas *D.* (*P.*) *japonicum* characterizes the Cenomanian. However, KAWABE & HAGGART (2003) have shown that the Japanese subspecies *D.* (*P.*) *dawsoni shikokuense* (YABE & SHIMIZU) is a junior synonym of *D.* (*P.*) *poronaicum*. There are no reports of *D.* (*P.*) *dawsoni* (s.l.) from either Japan or Far-Eastern Russia; *D.* (*P.*) *dawsoni* was endemic only in the eastern reaches of the North Pacific. In contrast, *D.* (*P.*) *japonicum* certainly appears throughout the North Pacific (Text-fig. 5), and its FO defines the base of the Cenomanian in Alaska (JONES 1967) and the Queen Charlotte Islands (MCLEARN 1972, JELETZKY 1977). *D.* (*P.*) *japonicum* is representative of the *Neogastroplites kamchatkaensis* Subzone, which suggests that the basal Cenomanian in Kamchatka (ALABUSHEV 1995) and the base of the *Desmoceras japonicum-D. ezoanum* Zone lies just above the base of the Cenomanian in Japan (TOSHIMITSU & *al.* 1995).

The following FOs of *Desmoceras* species are recognized in the Oyubari area, in ascending order: *D.* (*P.*) *poronaicum*, *D.* (*D.*) *kossmati*, and *D.* (*P.*) *japonicum*. As discussed above, calibrations based on age-indicative

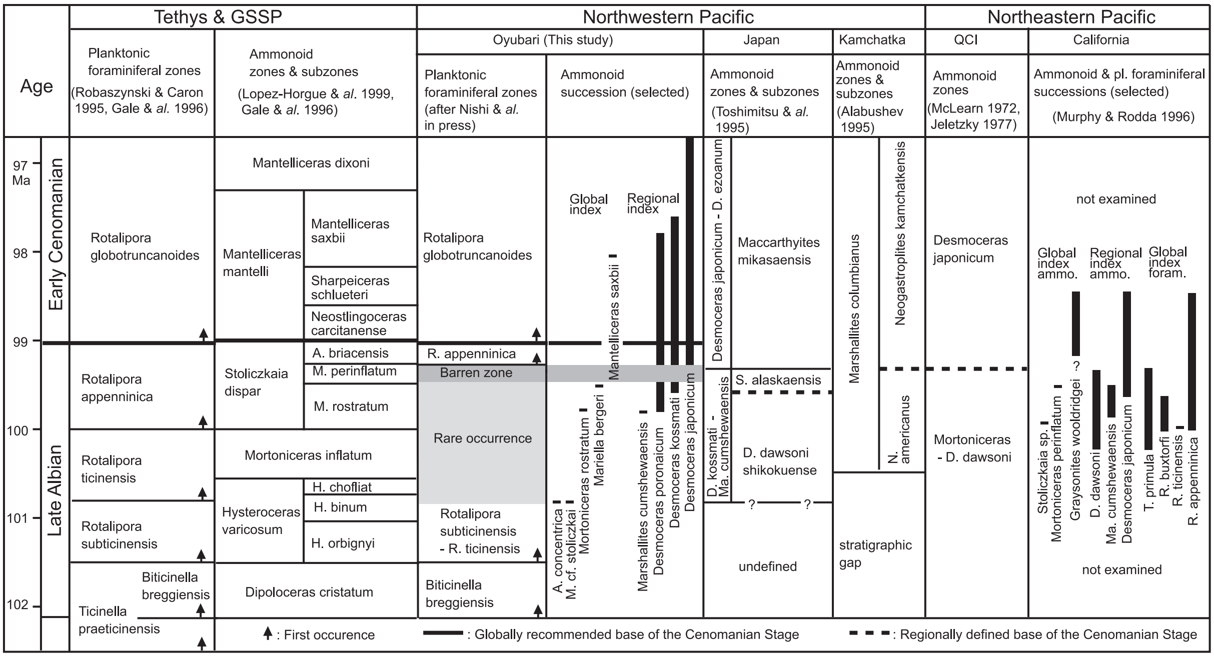

Fig. 5. Correlation of the Oyubari area biostratigraphic scheme with published schemes for Tethyan and Pacific regions. The numerical time-scale is adopted from GRADSTEIN & *al.* (1995). Note that *Rotalipora brotzeni* and *Desmoceras dawsoni shikokuense* are junior synonyms of *Rotalipora globotruncanoides* and *Desmoceras poronaicum*, respectively (ROBASZYNSKI & CARON 1995, KAWABE & HAGGART 2003). Abbreviations: GSSP, Global Stratotype Section and Point for the Cenomanian Stage (SE France); QCI, Queen Charlotte Islands, western Canada; R., *Rotalipora*; T., *Ticinella*; H., *Hysteroceras*; M., *Mortoniceras*; A., *Arrhaphoceras*; D., *Desmoceras*; S., *Sounnaites*; Ma., *Marshallites*; N., *Neogastroplites*

Tethyan macro- and microfossil records suggest that these FOs are within the *Rotalipora appenninica* Chronozone and/or the *Stoliczkaia dispar* Chronozone (Text-fig. 5). Similarly, the FO of *D.* (*P.*) *japonicum* is also present within this chron in California, where it occurs with the globally age-indicative species *Mortoniceras perinflatum* and *R. appenninica* (MURPHY & RODDA 1996, AMÉDRO 2002; see also Text-fig. 5). Thus, *D.* (*P.*) *japonicum*, previously regarded as a Cenomanian indicator in the North Pacific region, ranges down to the Late Albian; its FO defines the *Rotalipora appenninica* Chronozone in the globally recognized chronostratigraphic scale.

CONCLUDING REMARKS

We propose an integrated biostratigraphy for foraminifers, ammonoids and inoceramids in an upper Albian to lower Cenomanian sequence in Japan, based on their documented stratigraphic occurrences in measured stratigraphic sections. We conclude that: (1) the Oyubari faunal succession correlates well with the Tethyan standard succession; (2) the base of the Cenomanian stage is defined as the first occurrence of *Rotalipora globotruncanoides*, which is close to the horizon of the occurrence of *Mantelliceras saxbii*; and (3) the first occurrence of *Desmoceras* (*Pseudouhligella*) *japonicum*, previously regarded as a Cenomanian indicator in the North Pacific region, characterizes the latest Albian.

The Tethyan, Atlantic and equatorial Pacific upper Albian successions contain a great number of organic carbon-rich layers (black shales). One of these, from the *Rotalipora appenninica* Chronozone, is synchronous in several basins and has been identified as the Breistroffer level (BRÉHÉRET 1988, GALE & *al*. 1996, WILSON & NORRIS 2001), which is coeval with the oceanic anoxic event (OAE) 1d (ERBACHER & *al*. 1996, ERBACHER & THUROW 1997, NEDERBRAGT & *al*. 2001, STRASSER & *al*. 2001, WILSON & NORRIS 2001). In Hokkaido, however, it is difficult to recognize the stratigraphic position of this event level based on lithologic changes, owing to a lack of black shales. However, the present study documents a zone barren of both planktonic foraminifers and ammonoids in the upper part of the *Rotalipora subticinensis-R. ticinensis* Zone, which we show to be correlative with the *R. appenninica* Chronozone. This barren zone is characterized by a conspicuous abundance of radiolarians. Similarly, in the Oyubari area, calcareous microfossils and ammonoids are scarce, whereas siliceous microfossils (radiolarians and diatoms) are abundant, in a horizon just above the positive carbon isotope anomaly of the Cenomanian/Turonian boundary global event (OAE 2)

(HASEGAWA 1997). Ongoing high-resolution studies of bio-, litho- and chemostratigraphy are expected to elucidate the relationship between bioevents and global (or regional) environmental changes.

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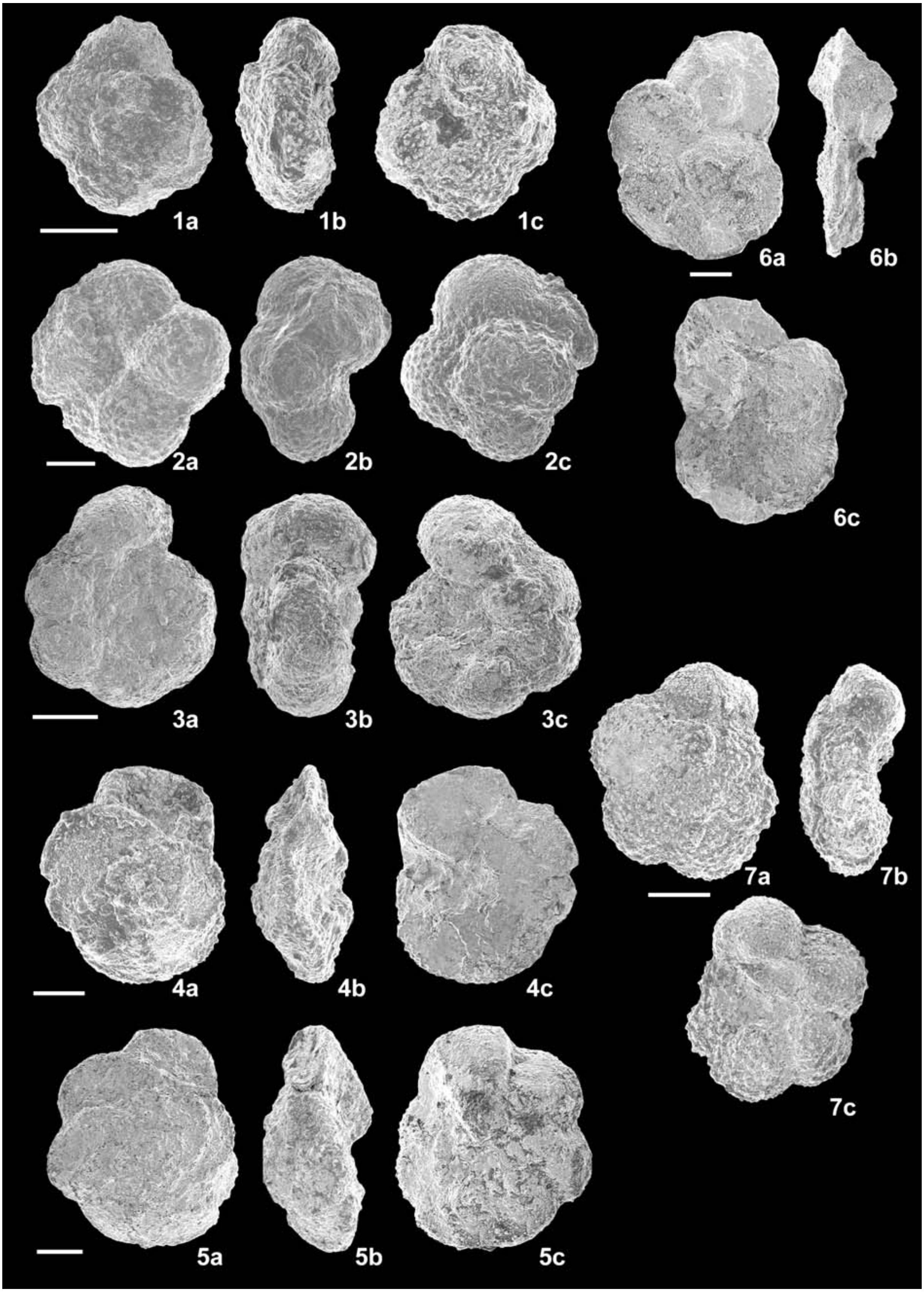
PLATE 1

1 – *Rotalipora subticinensis* (GANDOLFI), sample TG048, Shuparo River section.
2 – *Favusella washitensis* (CARSEY), sample SP001, Shuparo River section.
3 – *Biticinella breggiensis* (GANDOLFI), sample SP001, Shuparo River section.
4 – *Rotalipora appenninica* (RENZ), sample TG040, Tengu-sawa Valley section.
5 – *Rotalipora globotruncanoides* SIGAL, sample TG036, Tengu-sawa Valley section.
6 – *Rotalipora cushmani* (MORROW), sample TG026, Tengu-sawa Valley section.
7 – *Praeglobotruncana stephani* (GANDOLFI), sample TG040, Tengu-sawa Valley section.

Scale bars = 100 μm


1a
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7c
5a
5b
5c

PLATE 2

1 – *Mantelliceras saxbii* (SHARP), left lateral view, WE. A 256Y, from Y110325, Shuparo River section; × 1.

2 – *Desmoceras* (*Pseudouhligella*) *japonicum* YABE, right lateral (a) and ventral (b) views, WE. A 266Y, from Y110333, Shuparo River section; × 1.

3 – *Marshallites cumshewaensis* (WHITEAVES), right lateral view, WE. A400Y, from Y421047b, Kitano-sawa Valley section; × 1.2.

4 – Cluster of *Desmoceras* (*Pseudouhligella*) *poronaicum* YABE in a calcareous concretion, WE. A404Y, from Y421047b, Kitano-sawa Valley section; × 0.8.

5 – *Actinoceramus concentrica* (PERKINSON), from Y421047d, Kitano-sawa Valley section; × 0.8.

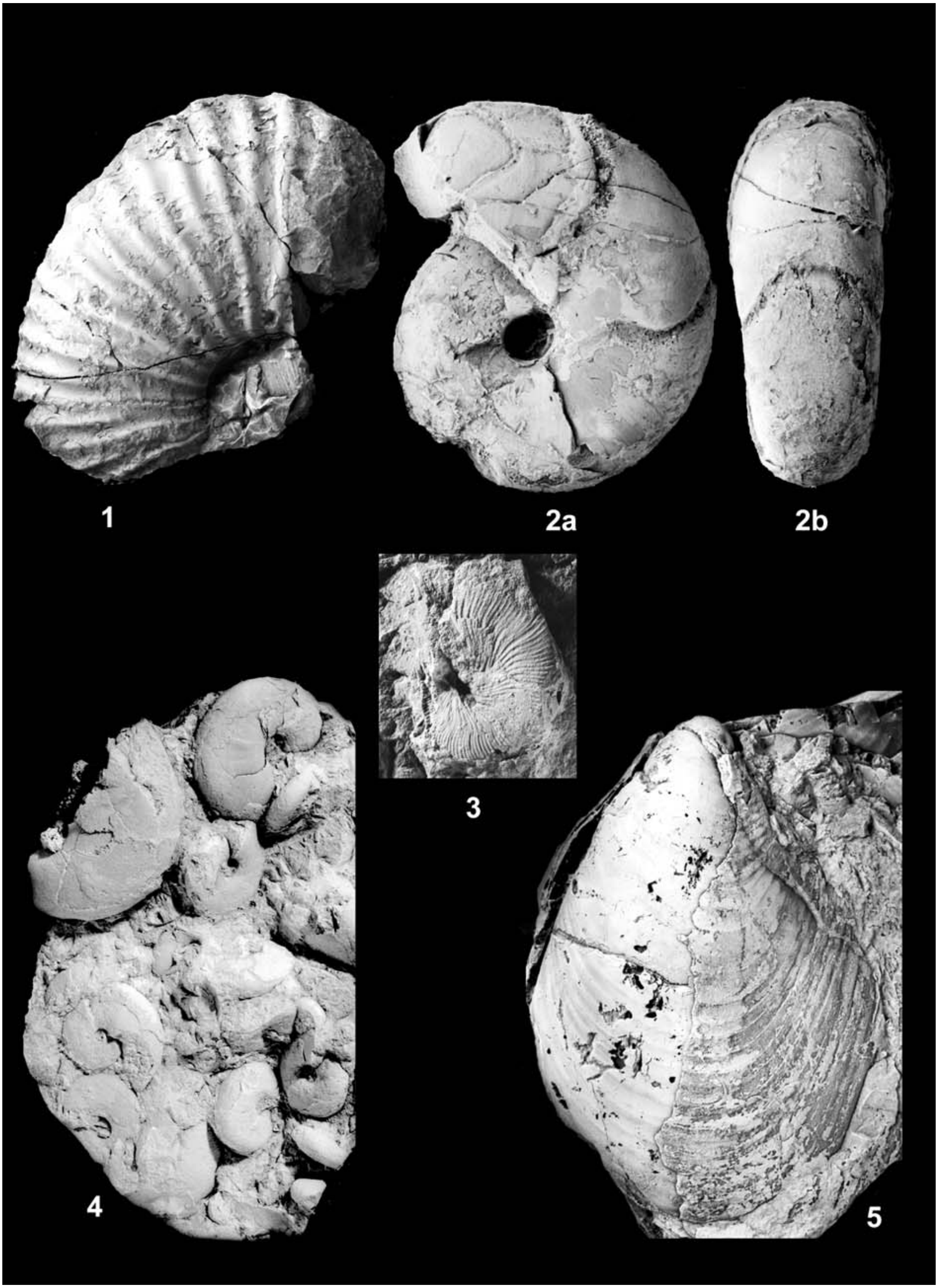
1
2a
2b
3
4
5

PLATE 3

Mortoniceras (*Mortoniceras*) *rostratum* (SOWERBY), right-lateral view, MCM. A 533, from Y272041, Tengu-sawa Valley section; × 1.