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An early Maastrichtian (latest Cretaceous) ammonoid fauna from the Soya Hill area, Hokkaido, northern Japan

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Abstract

An early Maastrichtian (latest Cretaceous) ammonoid fauna is reported from the middle part of the Etanpakku Formation of the Yezo Group exposed along the Onishibetsu and Sarukotsu rivers in the Soya Hill area, northernmost Hokkaido, northern Japan. The fauna comprises nine ammonoid species belonging to eight genera: *Neophylloceras hetonaiense* Matsumoto, *Tetragonites popetensis* Yabe, *T. terminus* Shigeta, *Gaudryceras izumiense* Matsumoto and Morozumi, *Anagaudryceras matsumotoi* Morozumi, *Pachydiscus* sp., *Diplomoceras* sp., *Nostoceras* sp. and *Baculites regina* Obata and Matsumoto. The fauna correlates with the lower part of the *Gaudryceras izumiense* Zone of the upper lower Maastrichtian in the Izumi Group of Southwest Japan. Zircon geochronology also reveals that the ages of the tuffs from the lowest and uppermost parts of the Etanpakku Formation in the Soya Hill area are 72.6±1.6 Ma and 70.6±1.2 Ma, respectively, which infer a late Campanian to earliest middle Maastrichtian age.

Key wards: ammonoid, Cretaceous, Hokkaido, Maastrichtian, Soya Hill
(Recieved 1 October 2016)

Introduction

Strata of the Campanian–Maastrichtian Yezo Group are widely distributed in northernmost Hokkaido (Osanai *et al*., 1959; Matsushita *et al*., 1964; Takahashi and Ishiyama, 1968; Matsumoto and Ohara, 1971). Cape Soya at the northernmost point of Hokkaido has been a classic locality for Campanian ammonoid research since the early work of Jimbo (1894). Matsumoto and Miyauchi (1984) described 30 ammonoid species from the western coastal area of the cape, and Matsumoto (1984b) established a biostratigraphic scheme for the Campanian of Hokkaido. Although Ando and Ando (2002) reported the occurrence of several ammonoid specimens of probable Maastrichtian age from the Soya Hill area, ammonoids representative of this particular stage have not well been studied in northernmost Hokkaido.

To ensure precise stratigraphic attribution of Maastrichtian ammonoids in northernmost Hokkaido, field expeditions were carried out by the authors (Y. S. and M. I.) in 2015 along the Onishibetsu and Sarukotsu rivers in the Soya Hill area (Figure 1). We discovered an early Maastrichtian ammonoid fauna including *Gaudryceras izumiense* Matsumoto and Morozumi, 1980 and *Baculites regina* Obata and Matsumoto, 1963, which are common to the Izumi Group in Southwest Japan. In this paper, we document the fauna and discuss its biostratigraphic implications. We also provide a zircon-based geochronology of the Etanpakku Formation based on its intercalated tuffs.

Outline of stratigraphy

The Yezo Group along the upper course of the Onishibetsu and Sarukotsu rivers can be divided into two units, the Karibetsu and Etanpakku formations in ascending order, as defined by Matsushita *et al*. (1964). These strata are cut and displaced by two major faults striking NNW–SSE (Figures 2, 3). The Karibetsu Formation, consisting of mudstone and sandy mudstone, is mainly exposed in the western part of the area, whereas the Etanpakku Formation, which is composed of various types of sandstone as well as sandy mudstone and conglomerate, is distributed in the middle part of the area between the two major faults.

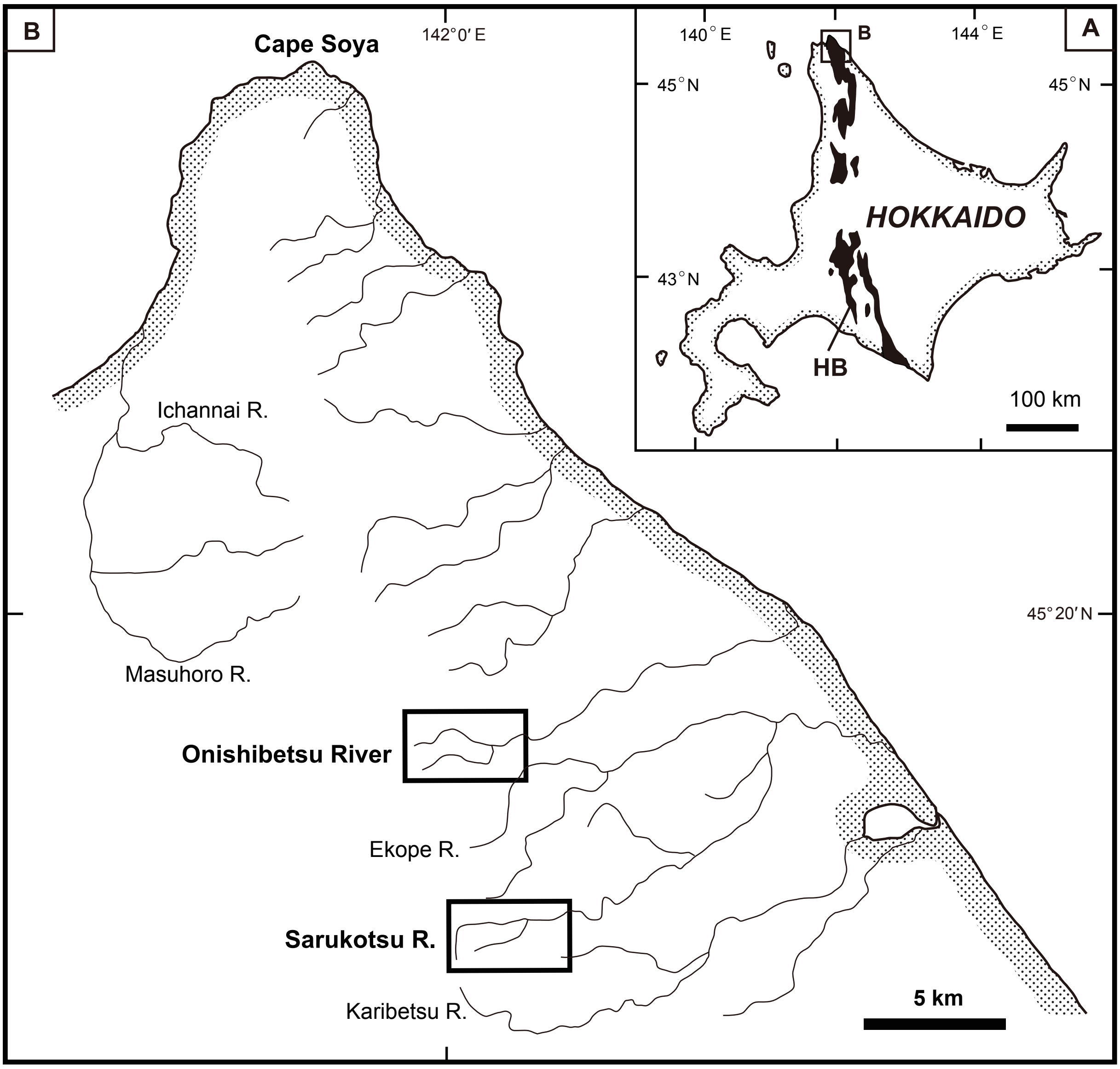

Figure 1. Index maps showing distribution of Yezo Group (black areas) in Hokkaido (**A**) and the studied areas in the Soya Hill area (**B**). HB, Hobetsu.

The Etanpakku Formation is in fault contact with the Karibetsu Formation in the western part and with the Miocene Soya Formation in the eastern part of the area.

The structure in the middle part of the area in the upper course of the Onishibetsu River between the two major faults consists of an anticline with strata on the western limb striking N5–10° westward and dipping 10–30° westward, while beds of the eastern limb strike N20–30° westward and dip 10–30° eastward. In contrast, the structure in the upper course of the Sarukotsu River area consists of a syncline with strata on the northern limb striking N50–60° westward and dipping 10–20° southward, while those of the southern limb strike N30–40° eastward and dip 10–20° northward.

Karibetsu Formation

The Karibetsu Formation is equivalent to the Orannai Formation in the Cape Soya area (Osanai *et al.*, 1959) and the Kamikoma Formation in the Nakatonbetsu area (Osanai *et al.*, 1963), which is located approximately 40 km southeast of the Soya Hill area.

Exposure.—Uppermost course of the Onishibetsu and Sarukotsu rivers, and middle course of the Rokugousen River, a tributary of the Onishibetsu River (Figures 2, 3).

Thickness.—Greater than 25 m in the Rokugousen River section.

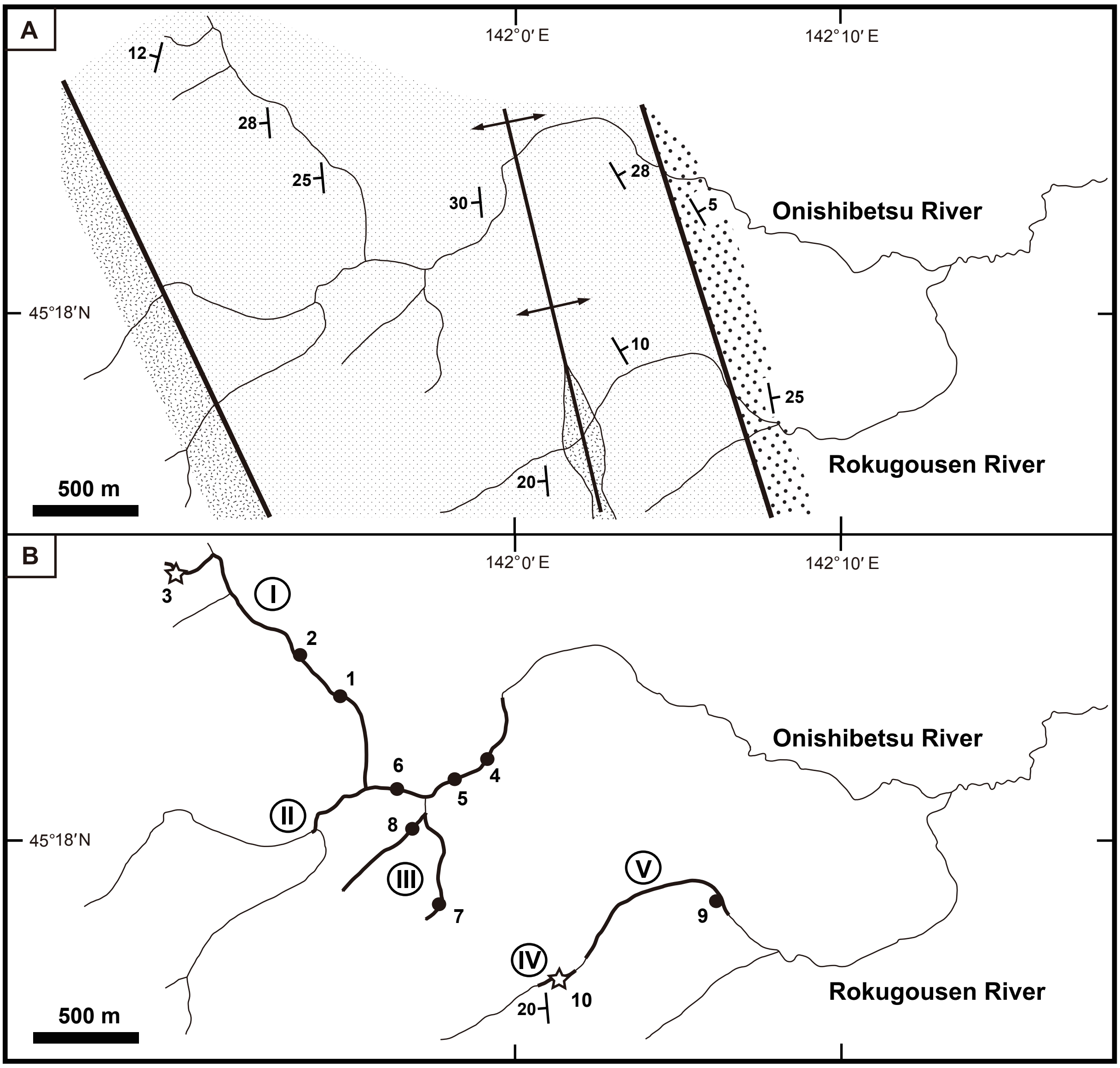

Figure 2. Geological map (**A**) and locality map (**B**) showing study sections (I through V) and fossil localities along the Onishibetsu River and its tributaries in the Soya Hill area, Hokkaido. See Figure 3 for legend.

Stratigraphic relationship.—The Karibetsu Formation is conformably overlain by the Etanpakku Formation. The uppermost part is exposed along the axis of an anticline in the Rokugousen River section, but the stratigraphic position of the formation's outcrops in the uppermost course of the Onishibetsu and Sarukotsu rivers is uncertain.

Lithology.—The formation consists of dark grey, massive mudstone (Figure 4), but detailed sedimentological features are uncertain because of poor exposures.

Fossils.—Although a few calcareous concretions were observed in the mudstone, the formation has not yet yielded megafossils.

Etanpakku Formation

The Etanpakku Formation is equivalent to the Heitarouzawa Formation in the Nakatonbetsu area (Osanai *et al*., 1963).

Exposure.—Upper course of the Onishibetsu and Sarukotsu rivers and their tributaries (Figures 2, 3).

Thickness.—Greater than 600 m.

Stratigraphic relationship.—The Etanpakku Formation conformably overlies the Karibetsu Formation, but its top portion is in fault contact with the Karibetsu Formation in the uppermost course of the Onishibetsu River.

Lithology.— The lower part of the formation (200-m thick) consists of gray to greenish gray, fine-grained, bedded or massive sandstone intercalated with a 3-m

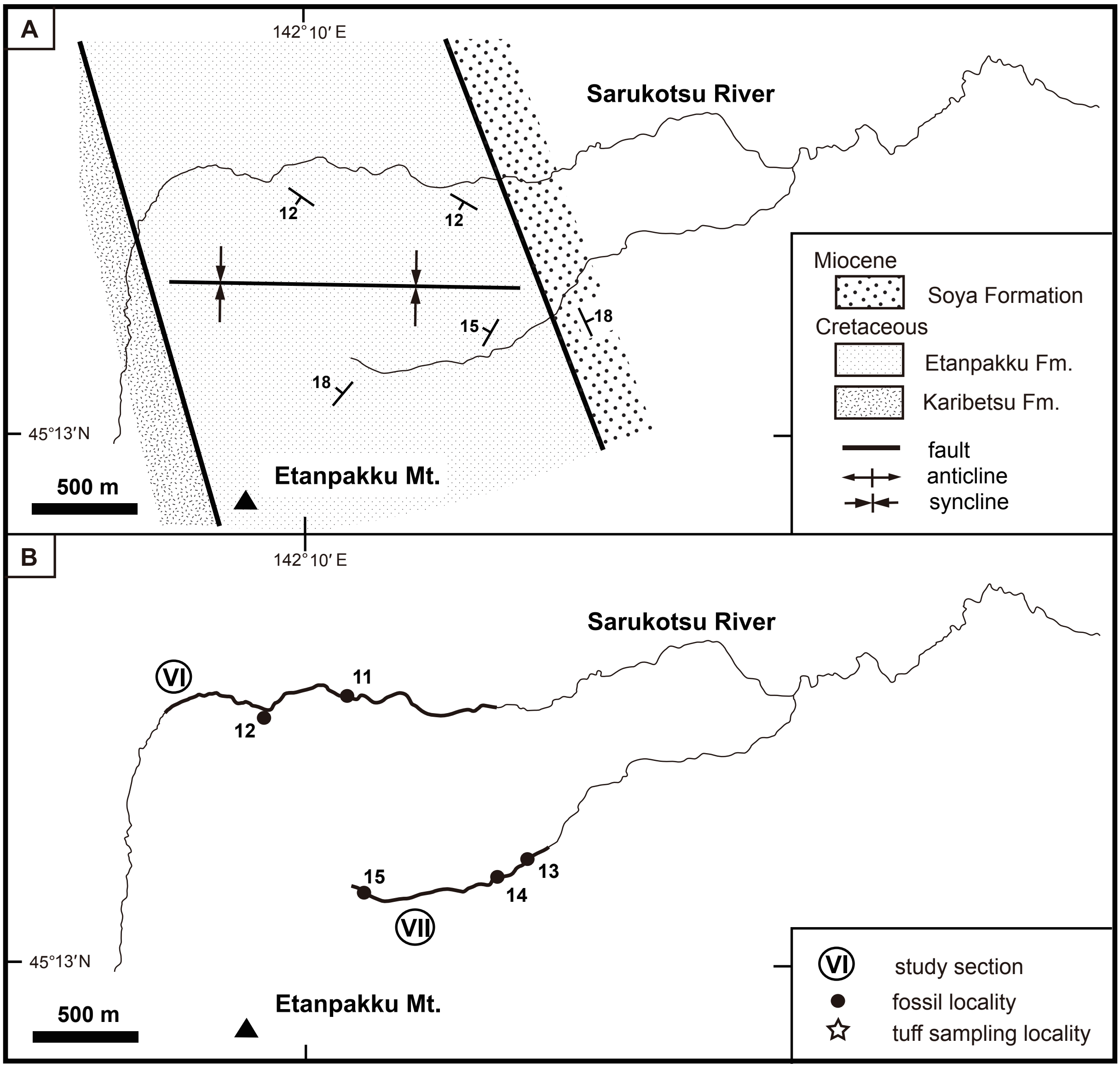

Figure 3. Geological map (**A**) and locality map (**B**) showing study sections (VI, VII) and fossil localities along the Sarukotsu River and its tributary in the Soya Hill area, Hokkaido.

thick white, vitric tuff bed and alternating beds of coarse-grained sandstone and conglomerate composed mainly of rounded to subrounded pebbles and cobbles in greenish gray, medium- to course-grained sandstone matrix (Figure 4).

The middle part of the formation (250-m thick) consists of gray to greenish gray, fine- to course-grained, bedded or massive sandstone in association with dark gray, intensely bioturbated muddy sandstone and sandy mudstone beds (Figure 4). Spherical calcareous concretions containing ammonoids, bivalves and gastropods are common in the muddy sandstone.

The upper part of the formation (150-m thick) also consists of gray to greenish gray, fine- to course-grained, bedded or massive sandstone (Figure 4), but some of the sandstone beds are characterized by low-angle, hummocky cross-stratification. A 2–3-m thick white, vitric tuff bed is intercalated in the uppermost part.

Fossils.—From the lower part of the formation, inoceramid bivalves were collected from the alternating beds of coarse-grained sandstone and conglomerate and fine-grained, massive sandstone (Figures 5, 7A–C).

The muddy sandstone in the middle part of the formation is fossiliferous and inoceramid bivalves (Figures 5, 6, 7D–S, 8) as well as the following ammonoids were collected from calcareous concretions (Figures 5, 6, 12–24): *Neophylloceras hetonaiense*

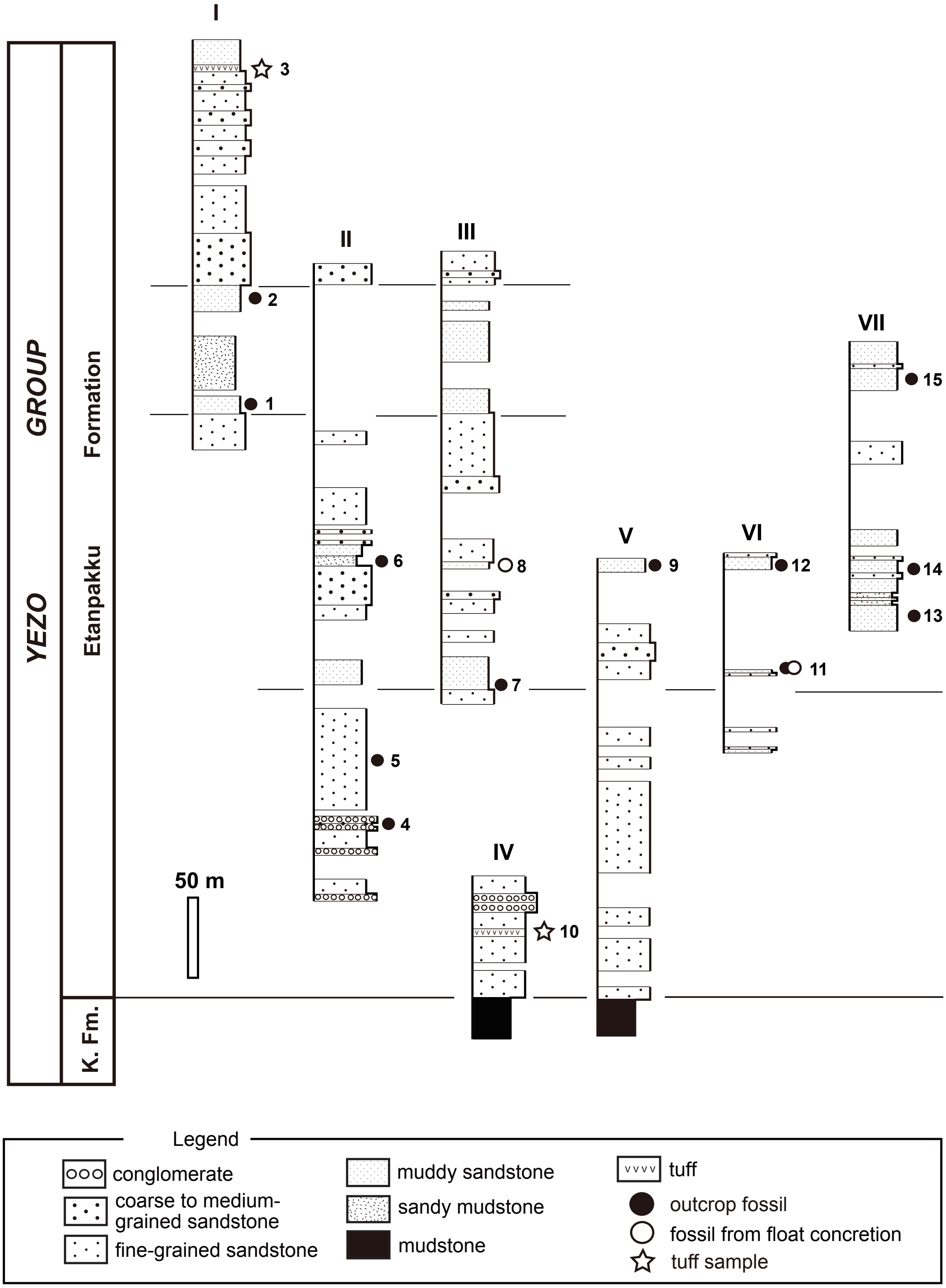

Figure 4. Columnar sections showing localities from which fossils and tuff samples were collected in the Soya Hill area, Hokkaido.

Matsumoto, 1942a, *Tetragonites popetensis* Yabe, 1903, *T. terminus* Shigeta, 1989, *Gaudryceras izumiense* Matsumoto and Morozumi, 1980, *Anagaudryceras matsumotoi* Morozumi, 1985, *Pachydiscus* sp., *Baculites regina* Obata and Matsumoto, 1963, *Diplomoceras* sp. and *Nostoceras* sp.

No fossils were found in the upper part of the formation.

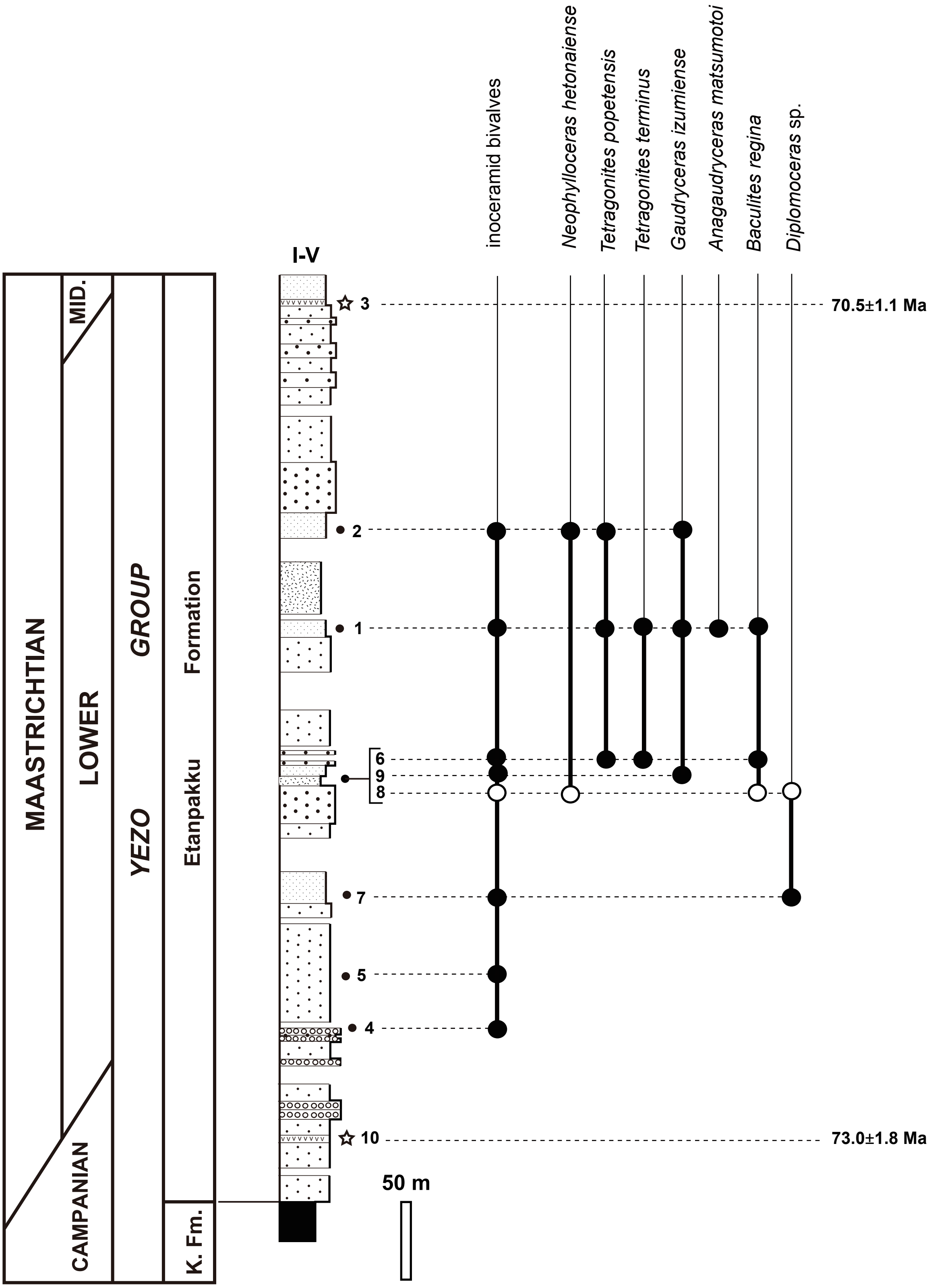

Figure 5. Stratigraphic occurrence of ammonoids and inoceramid bivalves, and U–Pb zircon ages of tuffs in the Etanpakku Formation along the Onishibetsu River and its tributaries in the Soya Hill area, Hokkaido.

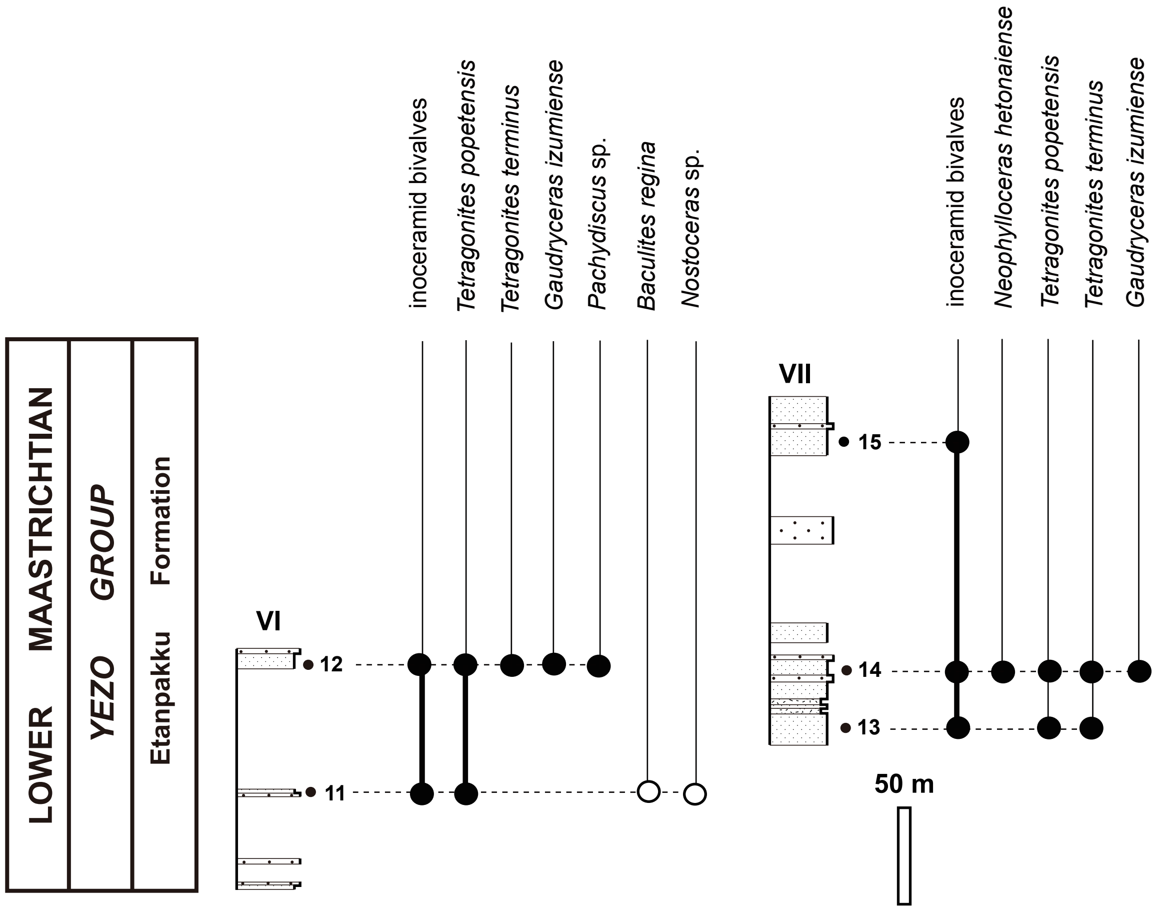

Figure 6. Stratigraphic occurrence of ammonoids and inoceramid bivalves in the Etanpakku Formation along the Sarukotsu River and its tributary in the Soya Hill area, Hokkaido.

Radiometric ages of zircons in tuffs

Material.—Two tuff samples from the Etanpakku Formation were examined for zircon-based radiometric age analyses. The first sample, taken at Loc. 10, was collected from a 2–3-m thick white, vitric tuff bed intercalated in the lowest part of the formation. The other sample, taken at Loc. 3, was collected from a 2–3-m thick white, vitric tuff bed intercalated in the uppermost part of the formation.

Method.—Zircon grains were extracted by standard techniques: crushing, heavy liquid separation and handpicking. Then, the zircon grains, the zircon standard TEMORA2 (^{206}Pb/^{238}U = 0.06679; Black *et al.*, 2004), and the glass standard SRM610 were mounted in epoxy resin and polished until the surface was flat with the center of each grain exposed. Images of both the backscattered electron and cathodoluminescence of the zircon grains were used to select the sites for analysis. U–Pb dating of these samples was carried out using LA-ICP-MS, which was performed on an instrument consisting of a NWR213 laser ablation system (Electro Scientific Industries) and an Agilent 7700x quadrupole ICP-MS (Agilent Technologies) that is installed at the National Museum of Nature and Science at Tsukuba, Japan. The experimental conditions and procedures for the measurements were based on the methods described in Tsutsumi *et al*. (2012). The spot size of the laser was 25 µm. Corrections for common Pb was made on the basis of the measured ^{207}Pb/^{206}Pb ratio or ^{208}Pb/^{206}Pb and Th/U ratios (e.g. Williams, 1998) as well as the model for common Pb compositions proposed by Stacey and Kramers (1975). In this paper, we adopt the ^{207}Pb correction for age discussion because it is more effective in calculating the Phanerozoic ^{238}U–^{206}Pb* age than the ^{208}Pb correction (e.g. Williams, 1998). The pooled ages presented in this study were calculated using Isoplot/Ex software (Ludwig, 2003). The uncertainties in the mean ^{238}U–^{206}Pb* ages represent 95% confidence intervals (95% conf.). ^{206}Pb* indicates

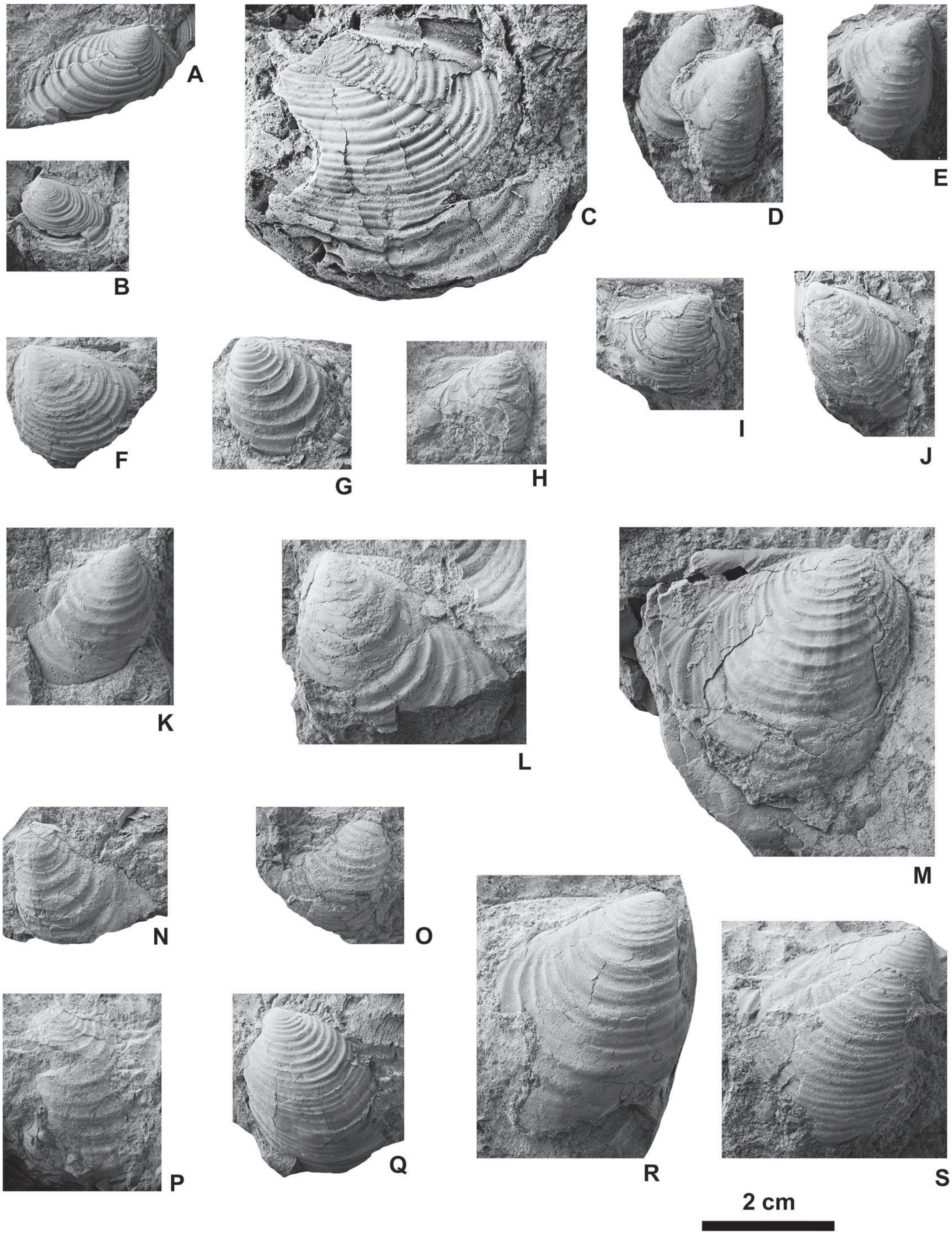

Figure 7. Inoceramid bivalves from the Etanpakku Formation. **A,** HMG-1755 from Loc. 4; **B,** HMG-1756 from Loc. 4; **C,** HMG-1757 from Loc. 5; **D, E,** HMG-1758, 1759 from a float calcareous concretion found near Loc. 8; **F, G,** HMG-1760, 1761 from a float calcareous concretion found near Loc. 8; **H–L,** HMG-1762–1766 from Loc. 6; **M,** HMG-1767 from Loc. 9; **N–P,** HMG-1768–1770 from Loc. 1; **Q,** HMG-1771 from a float calcareous concretion found near Loc. 1; **R, S,** HMG-1772, 1773 from a float calcareous concretion found near Loc. 1.

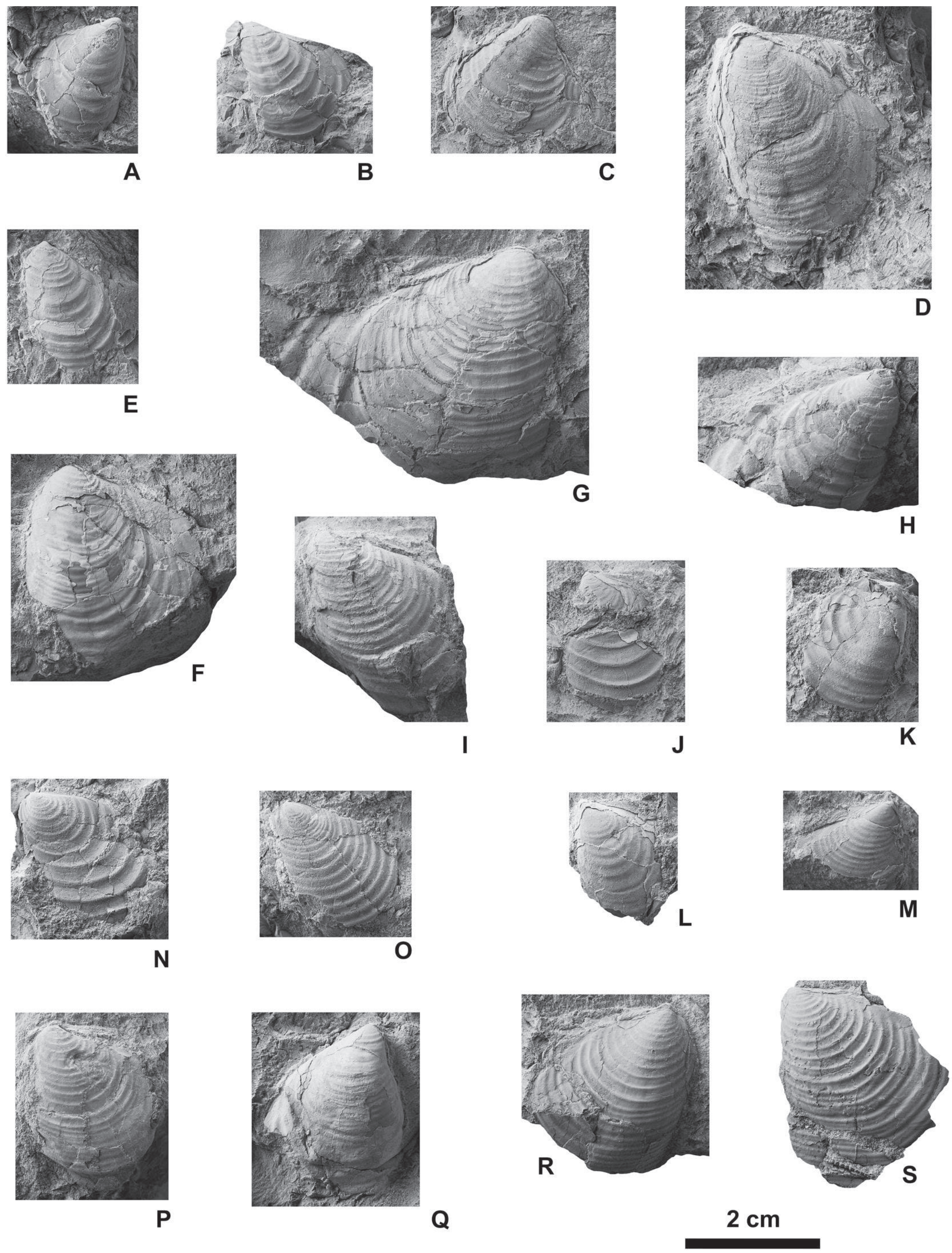

Figure 8. Inoceramid bivalves from the Etanpakku Formation. **A–F,** HMG-1774–1779 from Loc. 2; **G,** HMG-1780 from a float calcareous concretion found near Loc. 2; **H,** HMG-1781 from a float calcareous concretion found near Loc. 2; **I,** HMG-1782 from Loc. 11; **J–M,** HMG-1783–1786 from Loc. 12; **N, O,** HMG-1787, 1788 from a float calcareous concretion found near Loc. 14; **P,** HMG-1789 from a float calcareous concretion found near Loc. 14; **Q,** HMG-1790 from Loc. 13; **R, S,** HMG-1791, 1792 from Loc. 15.

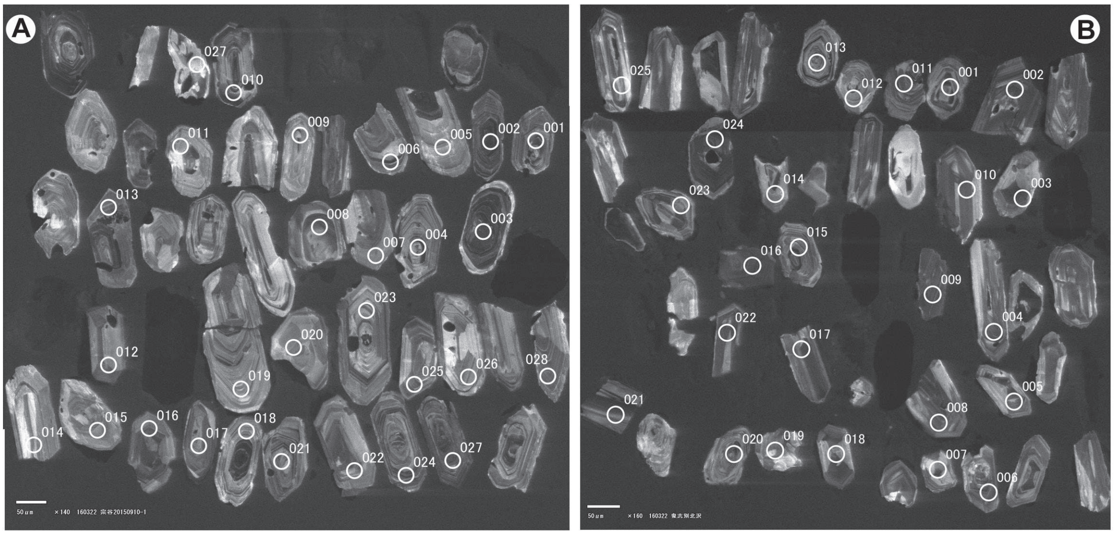

Figure 9. Cathodoluminescence image (CL) of zircon grains from the tuff samples collected at loc. 10 (**A**) and Loc. 3 (**B**). Circles on the grain represent spots analyzed by LA-ICP-MS. Spots are 25 μm across.

radiometric ^{206}Pb.

U–Pb zircon age.—Zircon data in terms of the fraction of common ^{206}Pb, U, and Th concentrations, Th/U, ^{238}U/^{206}Pb*, and ^{207}Pb*/^{206}Pb* ratios, and radiometric ^{238}U/^{206}Pb* ages are listed in Appendix 1. All errors are 1 sigma level. All zircons in the samples show rhythmic oscillatory and/or sector zoning on cathodoluminescence images (Figure 9), which is commonly observed in igneous zircons (e.g. Corfu *et al*., 2003), and their higher Th/U ratios (> 0.1) also support their igneous origin (Williams and Claesson, 1987; Schiøtte *et al*., 1988; Kinny *et al*., 1990; Hoskin and Black, 2000). Figure 10 shows Tera-Wasserberg concordia diagrams and age distribution plots for all analyzed spots of samples from Loc. 3 and Loc. 10 by LA-ICP-MS. The U–Pb ages of 28 zircon grains from the Loc. 10 sample show three peaks *ca.* 73, 85 and 105 Ma (Figure 10C). One Late Cretaceous, one Triassic and Two Proterozoic zircon grains also exist. The ages of 25 zircon grains from the Loc. 3 sample show three peaks *ca.* 70, 85 and 95 Ma (Figure 10D), and some older grains up to 420 Ma exist as well. The youngest age clusters for Loc. 10 and Loc. 3 are in the range 70–76 Ma and 68–75 Ma, and the weighted mean ages yield 73.0±1.8 Ma (MSWD = 1.7; 95% conf.) and 70.5±1.1 Ma (MSWD = 1.5; 95% conf.), respectively. These values are thought to indicate magmatism/deposition age of the tuff samples.

Discussion

Zircon geochronology reveals that the ages of the tuffs from the lowest and uppermost parts of the Etanpakku Formation in the Soya Hill area are 73.0±1.8 Ma and 70.5±1.1 Ma, respectively, which infer late Campanian to earliest middle Maastrichtian age.

The newly discovered ammonoid fauna from the Etanpakku Formation is characterized by *Gaudryceras izumiense*, which occurs frequently in the upper lower Maastrichtian in the Izumi Group of Southwest Japan and the Hakobuchi Formation in the Hobetsu area in south-central Hokkaido as well as the southern Talkeetna Mountains in southern Alaska (Matsumoto and Morozumi, 1980; Shigeta *et al*., 2010). According to Matsumoto and Morozumi (1980), the *Gaudryceras izumiense*-bearing beds (= *G. izumiense* Zone) include two distinct ammonoid faunas: *Pachydiscus kobayashii* (Shimizu, 1935), *Pachydiscus tanii* (Masumoto and Morozumi, 1980), *Nostoceras* aff. *hetonaiense* Matsumoto, 1977 and *Baculites regina* Obata and Matsumoto, 1963 in the lower part and *P*. aff. *flexuosus* Matsumoto, 1979, *P*. cf. *gracilis* Matsumoto, 1979 and *N*. aff. *kernense* (Anderson, 1958) in the upper part. Because the ammonoid fauna in the Soya Hill area includes *B*. *regina*, it is a correlative of the lower part of the *Gaudryceras izumiense* Zone of the upper lower Maastrichtian (Figure 11).

The *Gaudryceras izumiense* Zone, which is well

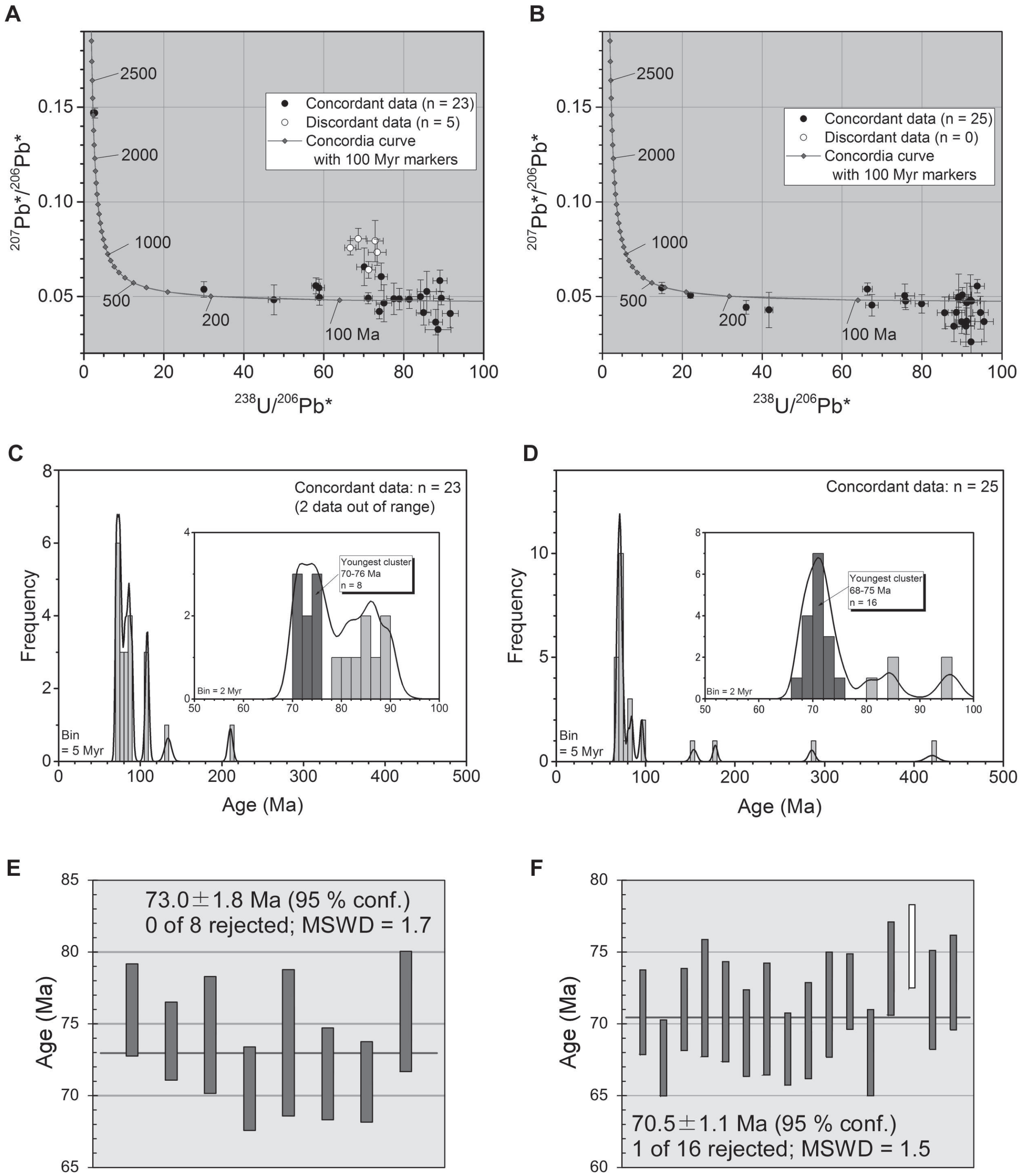

Figure 10. U-Pb zircon ages of tuff samples collected at Loc. 10 (**A, C, E**) and Loc. 3 (**B, D, F**). A, B, Tera-Wasserburg U–Pb concordia diagram of all data; C, D, Probability distribution diagrams of zircon ages (100 to 50 Ma); E, F, Age distribution plots of zircon ages in the youngest clusters. The uncertainties in the mean ^{238}U–$^{206}Pb^*$ ages represent 95% confidence intervals. $^{207}Pb^*$ and $^{206}Pb^*$ indicate radiometric ^{207}Pb and ^{206}Pb, respectively.

known in the upper part of Unit IVc of the Hakobuchi Formation in the Hobetsu area, contains *G. izumiense* as well as *Pachydiscus gracilis* and *P. kobayashii* (Matsumoto, 1979; Matsumoto and Toshimitsu, 1992; Shigeta *et al.*, 2010). This fauna is probably identical to the upper part of the *Gaudryceras izumiense* Zone in the Izumi Group (Figure 11).

Because of the discontinuous occurrence of megafossils due to the predominance of coarse-grained sandstone, a complete succession of the *Gaudryceras izumiense* Zone is not recorded in the Hobetsu and Soya Hill areas. However, faunas in the *Gaudryceras*

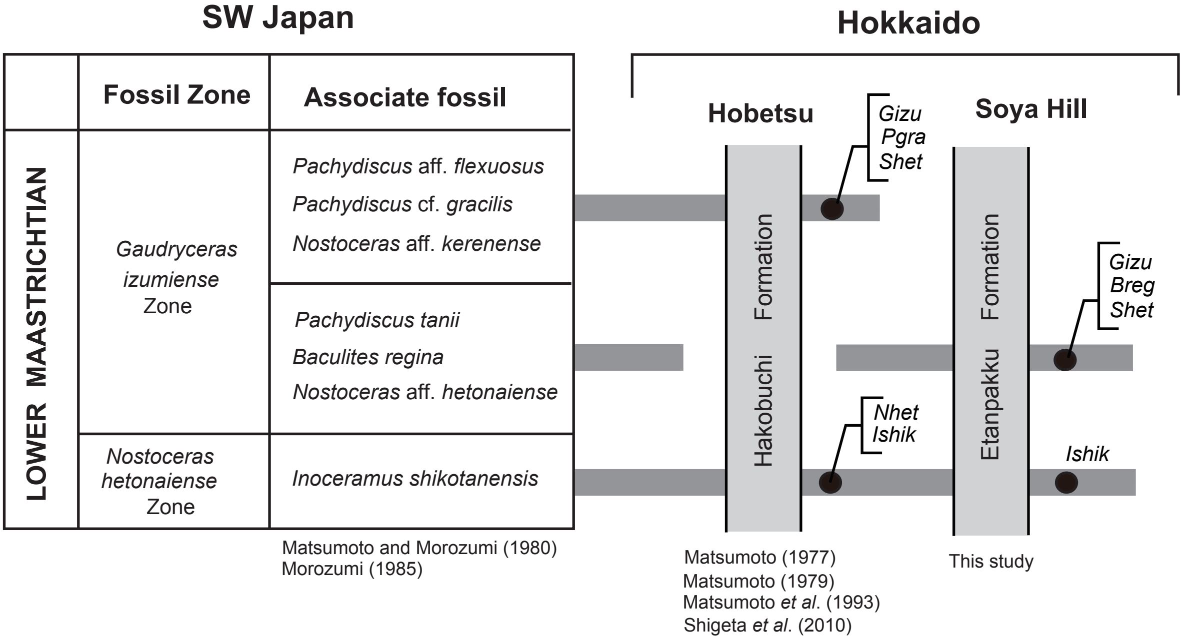

Figure 11. Diagram showing biostratigraphic correlation of the lower Maastrichtian in Southwest Japan (left) and Hokkaido (right). Breg, *Baculites regina*; Gizu, *Gaudryceras izumiense*; Ishik, *Inoceramus shikotanensis*; Nhet, *Nostoceras hetonaiense*; Pgra; *Pachydiscus gracilis*; Shet, *Sphenoceramus hetonaianus*.

izumiense Zone in Hokkaido suggest that similar faunas may have existed in the North Pacific realm during late early Maastrichtian time.

Paleontological description

Morphological terms are those used in Arkell (1957). Quantifiers used to describe the shape of ammonoid shell replicate those proposed by Matsumoto (1954, p. 246) and modified by Haggart (1989, table 8.1). All specimens were collected from the middle part of the Etanpakku Formation of the Yezo Group (= the *Gaudryceras izumiense* Zone of the upper lower Maastrichtian) exposed along the Onishibetsu and Sarukotsu rivers in the Soya Hill area.

Abbreviations for shell dimensionss.—D = shell diameter; U = umbilical diameter; H = whorl height; W = whorl width.

Institution abbreviations.—GK = Department of Earth and Planetary Sciences, Kyushu University, Fukuoka; HMG = Hobetsu Museum, Mukawa; NMNS = National Museum of Nature and Science, Tsukuba.

Suborder Phylloceratina Arkell, 1950

Superfamily Phylloceratoidea Zittel, 1884

Family Phylloceratidae Zittel, 1884

Subfamily Phylloceratinae Zittel, 1884

Genus ***Neophylloceras*** Shimizu, 1934

Type species.—*Ammonites* (*Scaphites*?) *ramosus* Meek, 1857.

Remarks.—*Neophylloceras*, established by Shimizu (1934, p. 61), has been regarded as either a synonym of *Hypophylloceras* Salfeld, 1924, a subgenus of *Hypophylloceras* or *Phylloceras* Suess, 1865, or as an independent genus (Murphy and Rodda, 2006). We herein follow the interpretation of Murphy and Rodda (2006).

Neophylloceras hetonaiense Matsumoto, 1942a

Figure 12

Neophylloceras hetonaiense Matsumoto, 1942a, p. 675, text-fig. 1; Spath, 1953, p. 5, pl. 1, fig. 2; Matsumoto, 1959, p. 5, pl. 3, fig. 1; Jones, 1963, p. 23, pl. 6, figs. 9, 10, pl. 7, figs. 1–5, text-fig. 12; Zonova *et al.*, 1993, p. 145, pl. 103, fig. 1; Yazykova, 1994, p. 288, pl. 1, figs. 5–7.

Neophylloceras lambertense Usher, 1952, p. 50, pl. 1, figs. 1–3.

Hypophylloceras (*Neophylloceras*) cf. *hetonaiense* Matsumoto. Matsumoto and Morozumi, 1980, p. 6, pl. 1, figs. 1–4.

non *Neophylloceras hetonaiense* Matsumoto. Matsumoto, 1984a, p. 11, pl. 1, figs. 4, 5; Matsumoto and Miyauchi, 1984, p. 38, pl. 10, fig. 1

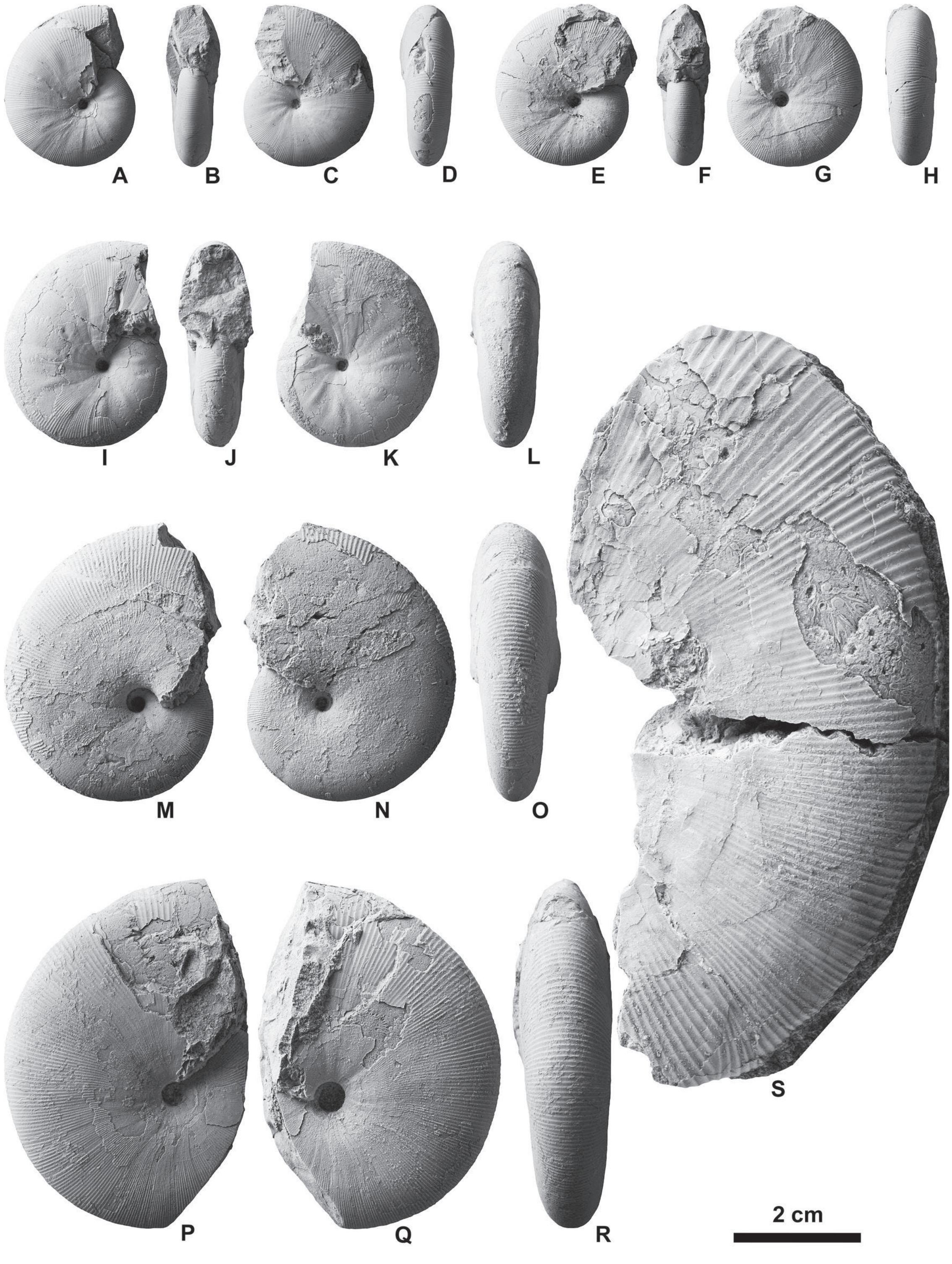

Figure 12. *Neophylloceras hetonaiense* Matsumoto, 1942a from the Etanpakku Formation. **A–D,** HMG-1703 from Loc. 2; **E–H,** HMG-1704 from Loc. 2; **I–L,** HMG-1706 from Loc. 14; **M–O,** HMG-1707 from a float calcareous concretion found near Loc. 14; **P–R,** HMG-1702 from a float calcareous concretion found near Loc. 1; **S,** HMG-1705 from a float calcareous concretion found near Loc. 8.

Hypophylloceras (*Neophylloceras*) *hetonaiense* Matsumoto. Morozumi, 1985, p. 15, pl. 1, figs. 1–5.
Neophylloceras nera (Forbes). Matsumoto and Toshimitsu, 1996, p. 3, pls. 1, 2.
Neophylloceras cf. *nera* (Forbes). Maeda *et al*., 2005, p. 55, fig. 24.1–24.4.
Neophylloceras sp. Shigeta *et al*., 2015, p. 110, fig. 3A–L.

Lectotype.—Specimen designated by Matsumoto (1959, p. 5) is GK. H3801a. This is the original of

Matsumoto (1942, p. 675) from the sandy mudstone of Unit IVb of the Hakobuchi Formation at loc. H12b (Matsumoto, 1942b) in the Hobetsu area, Hokkaido.

Material examined.—One specimen, HMG-1702, from a float calcareous concretion found near Loc. 1; two specimens, HMG-1703, 1704, from Loc. 2; one specimen, HMG-1705, from a float calcareous concretion found near Loc. 8; one specimen, HMG-1706, from Loc. 14; one specimen, HMG-1707, from a float calcareous concretion found near Loc. 14.

Description.—Very involute, very compressed shell with elliptical whorl-section, arched venter, rounded ventral shoulders and slightly convex flanks with maximum whorl width at mid-flank. Umbilicus very narrow and deep with moderately high, vertical wall and rounded shoulders. Ornamentation consists of fine, dense, weak flexuous lirae, which arise at umbilical seam, sweep gently forward across inner flank, and then strengthen and become rectiradiate at mid-flank before passing straight across venter. Lirae gradually develop into slightly more distant, narrowly raised ribs, which increase in strength as diameter increases. Broad undulations sometimes appear on inner flank. Suture line consists of numerous deeply incised elements with phylloid terminals.

Measurements (mm):

Specimen no.	*D*	*U*	*H*	*W*	*U/D*	*W/H*
HMG-1704	23.0	1.9	13.2	7.9	0.08	0.60
HMG-1703	24.8	1.9	14.0	8.0	0.08	0.57
HMG-1706	31.1	2.4	17.1	10.3	0.08	0.60
HMG-1702	39.0	3.1	21.8	11.7	0.08	0.54
HMG-1707	43.1	3.5	24.5	13.0	0.08	0.53

Remarks.—Matsumoto and Toshimitsu (1996) assigned three specimens from the lower Maastrichtian (Unit IVc of the Hakobuchi Formation) in the Hobetsu area to *Neophylloceras nera* (Forbes, 1846), but these specimens are identical to *N. hetonaiense* in having very weak flexuous lirae or ribs. *Neophylloceras nera* is characterized by sigmoidal lirae on its inner flanks (Kennedy and Henderson, 1992, p. 389, pl. 1, figs. 10–12, pl. 15, figs. 1, 2). Juvenile specimens reported as *N.* cf. *nera* by Maeda *et al*. (2005) from the Maastrichtian in the Makarov area, southern Sakhalin and *Neophylloceras* sp. by Shigeta *et al*. (2015) from the upper Maastrichtian in the Akkeshi Bay area, eastern Hokkaido should probably be assigned to *N. hetonaiense*, because they have very weak flexuous lirae. *Neophylloceras lambertense* Usher, 1952 from Vancouver Island, British Columbia was earlier regarded as a synonym of *N. hetonaiense* by Jones (1963).

Juvenile specimens reported as *Neophylloceras hetonaiense* from the Campanian in northern Hokkaido by Matsumoto (1984a) and Matsumoto and Miyauchi (1984) should probably be assigned to *N. ramosum* (Meek, 1857), because juveniles of both species are sometimes very close and larger specimens referable to *N. hetonaiense* have never been collected from northern Hokkaido.

Occurrence.—*Neophylloceras hetonaiense* is known from the upper Campanian in Antarctica (Spath, 1953), the Maastrichtian in Southwest Japan (Matsumoto and Morozumi, 1980; Morozumi, 1985), Hobetsu and Akkeshi Bay areas in Hokkaido (Matsumoto, 1942a; Shigeta *et al*., 2015), southern Sakhalin (Zonova *et al*., 1993), southern Alaska (Jones, 1963), Vancouver Island (Usher, 1952) and California (Matsumoto, 1959).

Suborder Ammonitina Hyatt, 1889

Superfamily Desmoceratoidea Zittel, 1895

Family Pachydiscidae Spath, 1922

Genus ***Pachydiscus*** Zittel, 1884

Type species.—*Ammonites neubergicus* Hauer, 1858.

Pachydiscus sp.

Figure 13A–C

Material examined.—One specimen, HMG-1708, from Loc. 12.

Description.—Moderately involute, fairly compressed shell with elliptical whorl-section, arched venter, rounded ventral shoulders, and slightly convex flanks with maximum whorl width at mid-flank. Fairly narrow umbilicus with moderately high, nearly vertical wall and rounded umbilical shoulders. Ornamentation consists of radial primary ribs that begin at elongate umbilical bullae and intercalated secondary rib that begin on the umbilical shoulder. Both sets of ribs pass over venter in a broad convex arch.

Remarks. —The described specimen is very similar

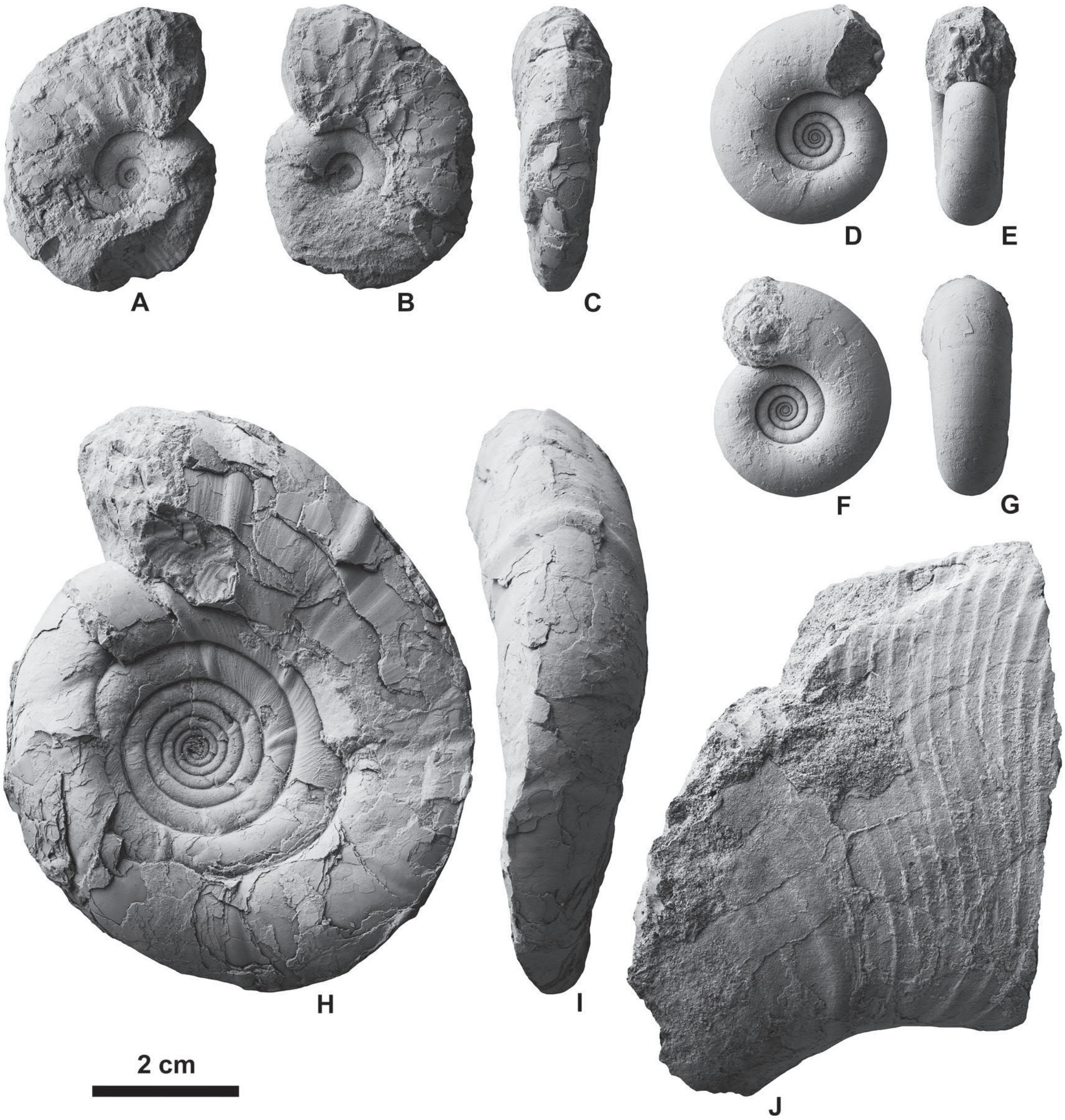

Figure 13. *Pachydiscus*, *Anagaudryceras* and *Gaudryceras* from the Etanpakku Formation. **A–C,** *Pachydiscus* sp., HMG-1708 from Loc. 12; **D–G,** *Anagaudryceras matsumotoi* Morozumi, 1985, HMG-1709 from Loc. 1; **H–J,** *Gaudryceras izumiense* Matsumoto and Morozumi, 1980; H, I, HMG-1712 from Loc. 2; J, HMG-1714 from Loc. 12.

to the juvenile shells of *Pachydiscus kamishakensis* Jones, 1963 and *P. hazzardi* Jones, 1963 from the Maastrichtian of southern Alaska, but a definitive assignment cannot be made.

Suborder Lytoceratina Hyatt, 1889

Superfamily Tetragonitoidea Hyatt, 1900

Family Gaudryceratidae Spath, 1927

Genus ***Anagaudryceras*** Shimizu, 1934

Type species.—Ammonites sacya Forbes, 1846.

Anagaudryceras matsumotoi Morozumi, 1985

Figure 13D–G

Anagaudryceras matsumotoi Morozumi, 1985, p. 29, pl. 9, fig. 1, text-fig. 7; Matsumoto, 1985, p. 27, pl. 4, figs. 1–10; Matsumoto, 1988, p. 183, pl. 51, fig. 3; Ando *et al*., 2001, pl. 1, figs. 12–14; Maeda *et al*., 2005, p. 81, fig. 39.1–39.15; Shigeta *et al*., 2015, p. 112, figure 5A–P.

Zelandites varuna (Forbes). Zonova *et al*., 1993, p. 148, pl. 98, fig. 4; Yazykova, 1994, p. 289, pl. 1, fig. 8.

Holotype.—GK. H6882, figured by Morozumi (1985, p. 29, pl. 9, fig. 1, text-fig. 7), from the Maastrichtian *Pachydiscus* aff. *subcompressus* Zone in the Shimonada Formation of the Izumi Group on Awaji Island, Southwest Japan.

Material examined.—One specimen, HMG-1709,

Figure 14. *Gaudryceras izumiense* Matsumoto and Morozumi, 1980 from the Etanpakku Formation. **A–C,** HMG-1716 from Loc. 14; **D–F,** HMG-1710 from Loc. 1.

from Loc. 1.

Description.—Fairly evolute shell with whorl nearly as high as broad. Whorl-section circular with arched venter, indistinct ventral shoulders and gently convex flanks. Maximum whorl width occurs at a slight distance below mid-flank. Umbilicus moderately wide with moderately high, rounded umbilical wall. Ornamentation consists of very fine slightly sinuous growth lines, which pass straight across venter.

Measurements (mm):

Figure 15. *Gaudryceras izumiense* Matsumoto and Morozumi, 1980 from the Etanpakku Formation. **A, B,** HMG-1717 from a float calcareous concretion found near Loc. 14; **C, D,** HMG-1718 from a float calcareous concretion found near Loc. 14**; E**, HMG-1710 from Loc. 1.

Specimen no.	*D*	*U*	*H*	*W*	*U/D*	*W/H*
HMG-1709	29.0	10.8	11.6	12.0	0.37	1.03

Remarks.—Zonova *et al*. (1993, pl. 98, fig. 4) and Yazykova (1994, pl. 1, fig. 8) assigned a specimen from the Maastrichtian in the Pugachevo area, southern Sakhalin, to *Zelandites varuna*, but as Maeda *et al*. (2005) and Shigeta *et al*. (2015) earlier pointed out, the specimen is identical to *Anagaudryceras matsumotoi* with respect to whorl-section, mode of coiling and ornamentation.

Figure 16. *Gaudryceras izumiense* Matsumoto and Morozumi, 1980 from the Etanpakku Formation. **A, B,** HMG-1711 from Loc. 2; **C, D,** HMG-1715 from a float calcareous concretion found near Loc. 12; **E, F,** HMG-1713 from Loc. 9.

Occurrence.—Anagaudryceras matsumotoi is known from the Maastrichtian of southern Sakhalin (Matsumoto, 1988; Zonova *et al*., 1993; Maeda *et al*., 2005), northern Hokkaido (Matsumoto, 1985), eastern Hokkaido (Matsumoto, 1985; Shigeta *et al*., 2015) and Southwest Japan (Morozumi, 1985).

Genus ***Gaudryceras*** Grossouvre, 1894

Type species.—Ammonites mitis Hauer, 1866.

Gaudryceras izumiense Matsumoto and Morozumi, 1980

Figures 13H–J, 14–16

Gaudryceras tenuiliratum Yabe. Kobayashi, 1931, p. 639, pl. 10.

Gaudryceras izumiense Matsumoto and Morozumi, 1980, p. 12, pl. 11, fig. 1, pl. 12, fig. 1, pl. 13, fig. 1; Shigeta *et al*., 2010, p. 205, figs. 2–5.

Gaudryceras venustum Matsumoto, 1984c, p. 5, pl. 3, figs. 1, 2; Matsumoto and Toshimitsu, 1995, p. 2, pls. 1–8.

Holotype.—OMNH.M1125, figured by Matsumoto and Morozumi (1980, p. 13, pl. 11, fig. 1), from the Maastrichtian Azenotani Formation of the Izumi Group at a roadside cliff about 800 m west of Sobura (Loc. 8), Kaizuka, Osaka Prefecture, Southwest Japan.

Material examined.—One specimen, HMG-1710, from Loc. 1; two specimens, HMG-1711, 1712, from Loc. 2; one specimen, HMG-1713, from Loc. 9; one specimen, HMG-1714, from Loc. 12; one specimen, HMG-1715, from a float calcareous concretion found near Loc. 12; one specimen, HMG-1716, from Loc. 14; two specimens, HMG-1717, 1718, from float calcareous concretions found near Loc. 14.

Description.—Early to middle growth stages (up to 80 mm in diameter): Very evolute, slightly depressed shell with arched venter, indistinct ventral shoulders, and slightly convex flanks with maximum whorl width at mid-flank. Umbilicus wide with moderately high, vertical wall and rounded shoulders. Ornamentation consists of very fine, dense, slightly sinuous lirae, which arise at umbilical seam and pass over venter in a broad convex arch. Intercalation of lirae occurs on umbilical shoulder and lower flank. Each whorl has variable dense or distant, rounded, collar-like ribs, running parallel to lirae; and each rib is immediately followed by a shallow constriction.

Later growth stage (over 80 mm in diameter): As shell grows larger, whorl section becomes more compressed. Lirae gradually develop into slightly more distant, narrowly raised ribs, which increase in strength as diameter increase. On body chamber of mature shell, ribs become much coarser and distant, and collar-like ribs become more frequent.

Measurements (mm):

Specimen no.	*D*	*U*	*H*	*W*	*U/D*	*W/H*
HMG-1715	47.0	26.1	14.2	15.3	0.56	1.08
HMG-1711	52.1	28.0	13.9	15.0	0.54	1.08
HMG-1710	99.0	52.0	37.0	35.0	0.53	0.95
HMG-1716	115.0	48.2	39.1	36.2	0.42	0.93
HMG-1718	173.0	58.5	68.0	—	0.34	—
HMG-1717	181.0	56.0	70.0	—	0.31	—
HMG-1710	220.0	66.0	88.2	74.1	0.30	0.84

Remarks. —Shigeta *et al*. (2010) considered *Gaudryceras venustum* to be conspecific with *G. izumiense* because specimen HMG-1541 from the Hobetsu area exhibits ornamentation characteristic of *G. izumiense* on one side, while the other side is abraded and appears very similar to *G. venustum*.

Occurrence.—*Gaudryceras izumiense* is known from the lower Maastrichtian in Southwest Japan (Matsumoto and Morozumi, 1980), the Hobetsu area in Hokkaido (Shigeta *et al*., 2010) and southern Alaska (Shigeta *et al*., 2010).

Family Tetragonitidae Hyatt, 1900

Genus ***Tetragonites*** Kossmat, 1895

Type species.—Ammonites timotheanus Pictet, 1847.

Tetragonites terminus Shigeta, 1989

Figure 17

Tetragonites terminus Shigeta, 1989, p. 338, figs. 11E, F, 13.8–13.10; Ando and Ando, 2002, pl. 1, figs. 7, 8.

Holotype.—UMUT MM18635-1, figured by Shigeta (1989, p. 338, fig. 13.8), from the sandy mudstone of Unit IVb of the Hakobuchi Formation at loc. H12d (Matsumoto, 1942b) in the Hobetsu area, Hokkaido.

Material examined.—Two specimens, HMG-1719, 1720, from Loc. 1; two specimens, HMG-1721, 1722, from Loc. 6; two specimens, HMG-1723, 1724, from Loc. 12; one specimen, HMG-1725, from Loc. 13, one specimen, HMG-1726, from Loc. 14.

Description.—Fairly involute, fairly depressed shell with sub-rectangular whorl section, broadly rounded venter, rounded ventral shoulders, and slightly convex flanks with maximum whorl width near umbilical shoulder. Umbilicus fairly narrow with moderately high, nearly vertical wall and rounded shoulders. Ornamentation consists only of distant constrictions and very fine, growth lines, which are prorsiradiate on flanks, but become slightly sinuous at ventral shoulders before crossing venter in a very shallow concave arch.

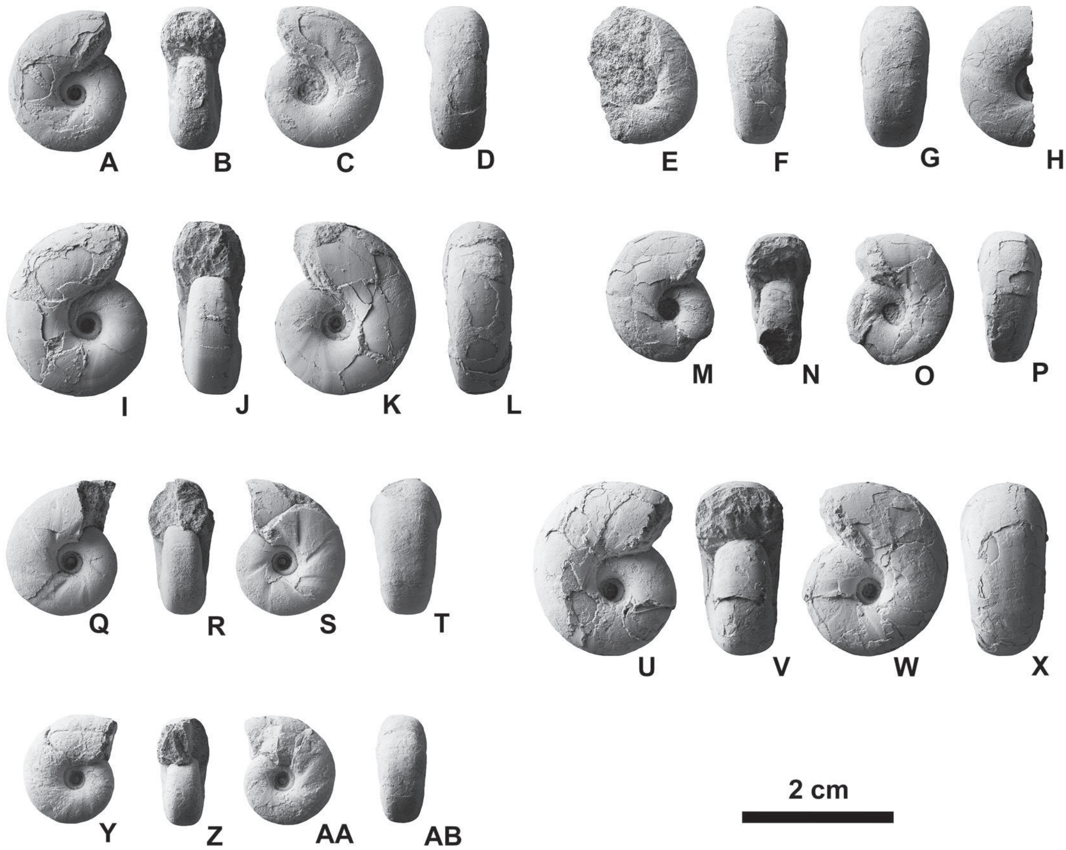

Figure 17. *Tetragonites terminus* Shigeta, 1989 from the Etanpakku Formation. **A–D,** HMG-1719 from Loc. 1; **E, F,** HMG-1721 from Loc. 6; **G, H,** HMG-1722 from Loc. 6; **I–L,** HMG-1720 from Loc. 1; **M–P,** HMG-172**3** from Loc. 12; **Q–T,** HMG-1724 from Loc. 12; **U–X,** HMG-1726 from Loc. 14 ; **Y–AB,** HMG-1725 from Loc. 13.

Measurements (mm):

Specimen no.	*D*	*U*	*H*	*W*	*U/D*	*W/H*
HMG-1725	13.1	3.1	5.9	6.5	0.24	1.10
HMG-1724	16.0	3.8	6.7	8.4	0.24	1.26
HMG-1722	19.0	4.6	8.3	9.2	0.24	1.11
HMG-1719	19.6	4.8	8.2	8.2	0.24	1.00
HMG-1720	22.4	5.5	9.0	9.3	0.25	1.03
HMG-1726	22.6	5.6	10.7	11.2	0.25	1.05

Remarks.—Shigeta (1989) studied the early internal shell morphology of *Tetragonites terminus* and revealed that the initial chamber and ammonitella sizes range from 0.925 to 1.050 mm and 1.700 to 1.900 mm in diameter respectively, which are unusually large for Mesozoic ammonoids (Landman *et al*., 1996; De Baets *et al*., 2015). Such large initial chambers and ammonitellas are partly visible in HMG-1719, 1720, 1722, 1724, 1725 and 1726.

Occurrence.—*Tetragonites terminus* is known from the lower Maastrichtian *Nostoceras hetonaiense* Zone in the Hobetsu area, Hokkaido (Shigeta, 1989).

Tetragonites popetensis Yabe, 1903

Figures 18–21

Tetragonites popetensis Yabe, 1903, p. 48, pl. 7, figs. 4, 6; Matsumoto and Miyauchi, 1984, p. 52, pl. 23, fig. 3; Matsumoto, 1988, p. 178, pl. 50, figs. 3, 4; Zonova *et al*., 1993, p. 155, pl. 209, fig. 2; Yazykova, 1994, p. 293, pl. 3, fig. 1; Naruse *et al*., 2000, fig. 3.4; Ando and Ando, 2002, pl. 2, figs. 4, 5; Maeda *et al*., 2005, p. 88, figs. 38.9–38.11, 38.14, 38.15, 42.5–42.11, 43, 44; Kurihara and Kano, 2006, pl. 3, fig. 2; Takahashi *et al*., 2007, pl. 1, fig. 4; Misaki and Maeda, 2009, fig. 8E, F; Shigeta *et al*., 2016, p. 333, figs. 7D–H, 8D, E, 24A, B.

Epigoniceras epigonum (Kossmat). Usher, 1952, pl. 2, figs. 6, 7, pl. 3, fig. 1.

Lytoceras (*Tetragonites*) *henleyense* Anderson, 1958, p. 185, pl. 12, fig. 5, pl. 41, fig. 7.

Tetragonites superstes (Hoepen). Matsumoto and Miyauchi, 1984, p. 52, pl. 23, fig. 2.

Tetragonites glabrus (Jimbo). Shigeta, 1989, p. 334, fig. 12.4–12.7.

Saghalinites maclurei (White). Haggart, 1989, p. 186, pl. 8.1, figs. 7–11.

Saghalinites cala (Forbes). Zonova *et al*., 1993, p. 155, pl. 209, figs. 3, 4.

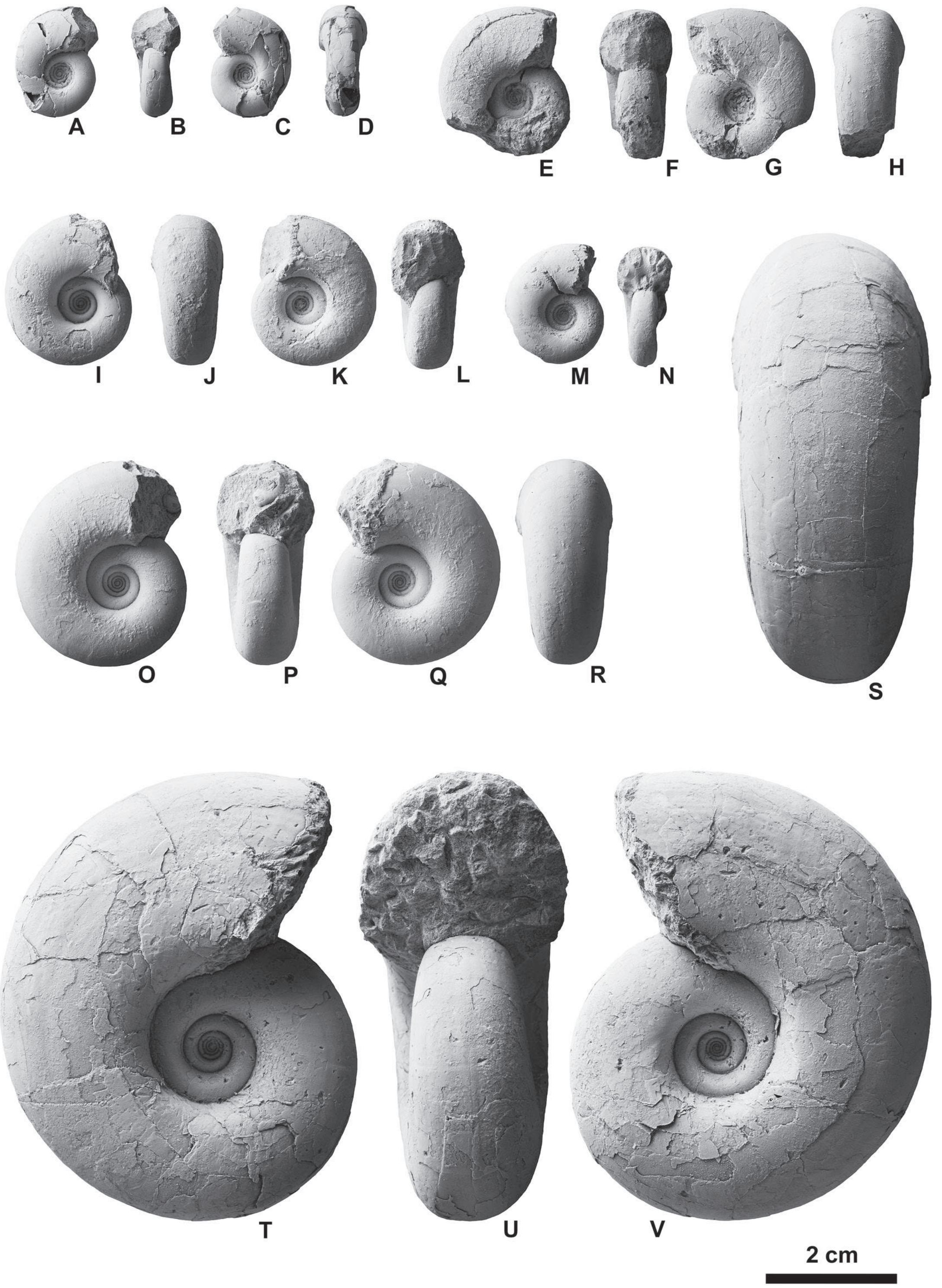

Figure 18. *Tetragonites popetensis* Yabe, 1903 from the Etanpakku Formation. **A–D,** HMG-1730 from Loc. 2; **E–H,** HMG-1732 from Loc. 6; **I–L,** HMG-1735 from Loc. 12; **M, N,** HMG-1733 from Loc. 12; **O–R,** HMG-1738 from Loc. 14; **S–V,** HMG-1728 from a float calcareous concretion found near Loc. 1.

Holotype.—UNUT MM7460, figured by Yabe (1903, p. 48, pl. 7, fig. 4), from the Upper Cretaceous of the Sanushube (Sanushibe) River area in the Hobetsu area, Hokkaido.

Material examined.—One specimen, HMG-1727, from Loc. 1; two specimens, HMG-1728, 1729, from float calcareous concretions found near Loc. 1; two specimens, HMG-1730, 1731, from Loc. 2; one specimen, HMG-1732, from Loc. 6; one specimen,

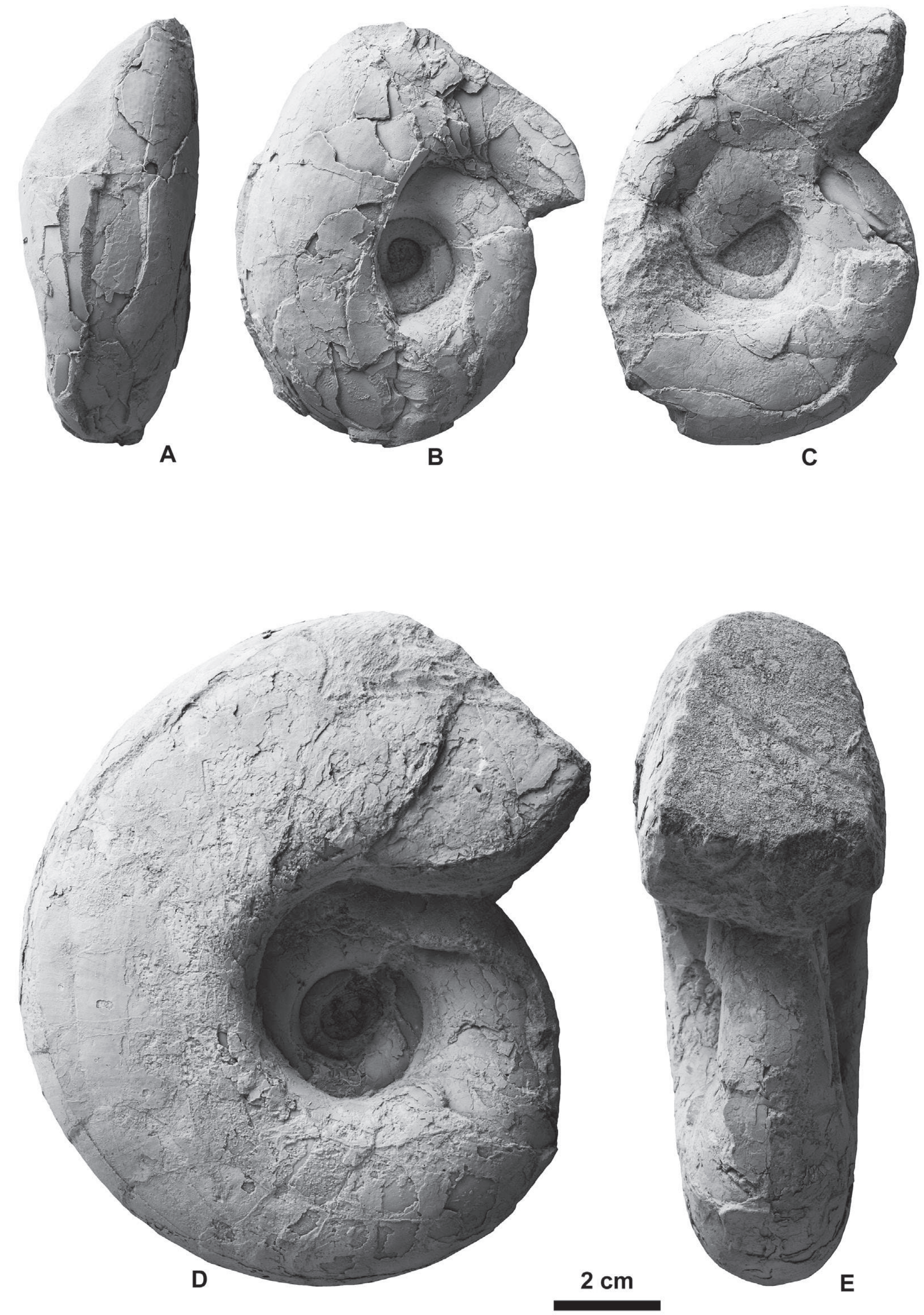

Figure 19. *Tetragonites popetensis* Yabe, 1903 from the Etanpakku Formation. **A, B,** HMG-1736 from a float calcareous concretion found near Loc. 12; **C,** HMG-1731 from Loc. 2; **D, E,** HMG-1729 from a float calcareous concretion found near Loc. 1.

Figure 20. *Tetragonites popetensis* Yabe, 1903 from the Etanpakku Formation. **A–C,** HMG-1727 from Loc. 1; **D, E,** HMG-1729 from a float calcareous concretion found near Loc. 1.

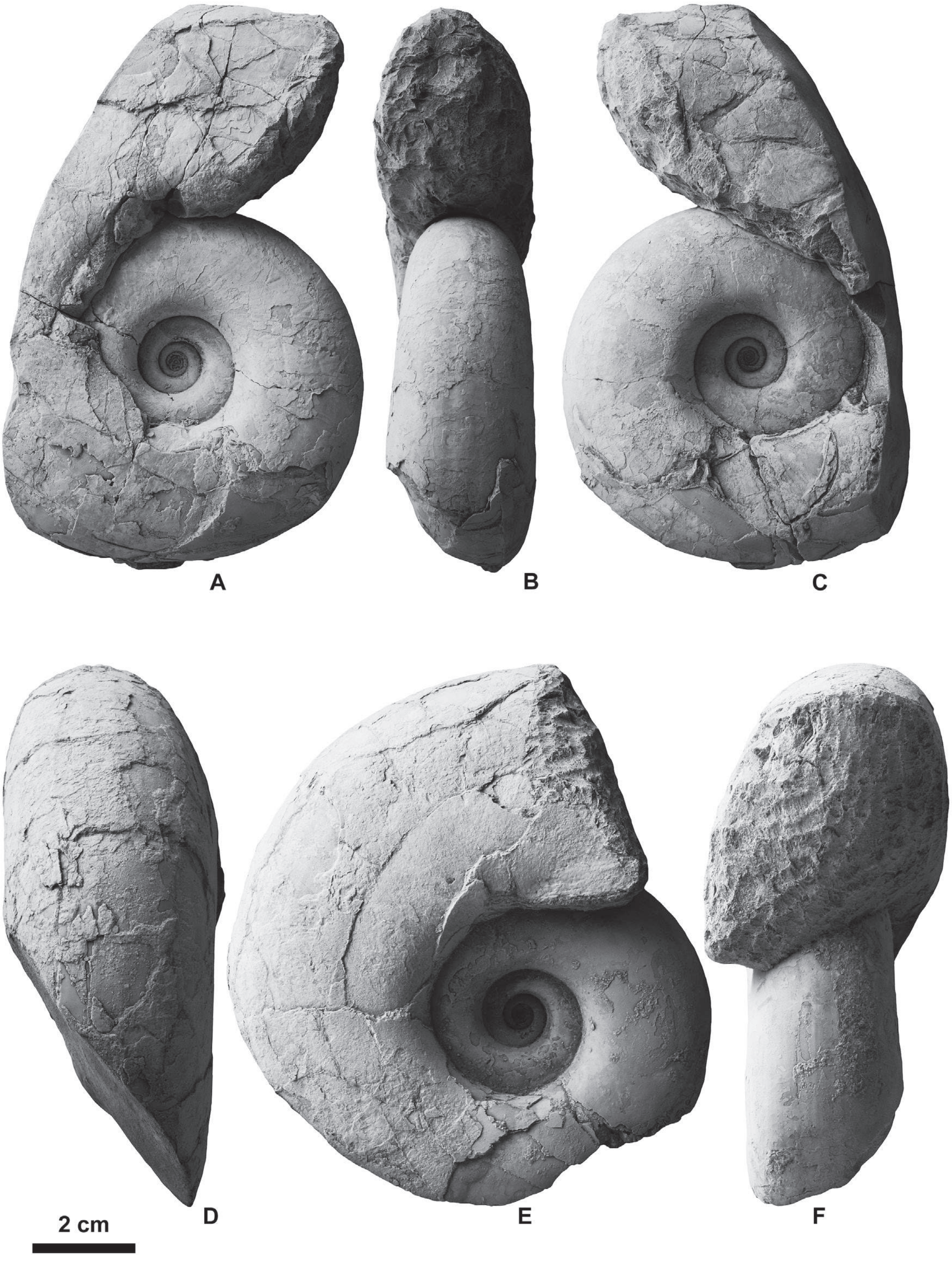

Figure 21. *Tetragonites popetensis* Yabe, 1903 from the Etanpakku Formation. **A–C,** HMG-1734 from a float calcareous concretion found near Loc. 11; **D–F,** HMG-1737 from Loc. 13.

HMG-1733, from Loc. 11; one specimen, HMG-1734, from a float calcareous concretion found near Loc. 11; one specimen, HMG-1735, from Loc. 12; one specimen, HMG-1736, from a float calcareous concretion found near Loc. 12; one specimen, HMG-1737, from Loc. 13; one specimen, HMG-1738, from Loc. 14.

Description.—Moderately evolute, fairly depressed shell (early growth stages) to fairly compressed shell (later growth stages) with sub-quadrate whorl section, broadly rounded venter, rounded ventral shoulders, and slightly convex flanks with maximum whorl width near umbilical shoulder. Umbilicus moderately wide with moderately high, nearly vertical wall and rounded shoulders. Ornamentation consists only of very fine, growth lines, which are prorsiradiate on flanks, but become slightly sinuous at ventral shoulders before crossing venter in a shallow concave arch. Specimen HMG-1729 (Figure 19D) exhibits a conspicuous constriction near its aperture.

Measurements (mm):

Specimen no.	*D*	*U*	*H*	*W*	*U/D*	*W/H*
HMG-1730	11.7	3.9	4.7	5.0	0.33	1.06
HMG-1733	18.6	5.7	30.6	31.2	0.28	1.02
HMG-1732	20.1	6.5	7.9	8.3	0.31	1.05
HMG-1735	22.7	7.0	9.6	10.5	0.31	1.09
HMG-1738	30.0	9.4	12.4	14.0	0.31	1.13
HMG-1734	61.2	19.0	26.2	28.2	0.31	1.08
HMG-1737	63.0	19.1	27.0	28.6	0.30	1.06
HMG-1728	71.0	19.9	30.6	31.2	0.28	1.02
HMG-1729	127.4	42.8	49.0	48.2	0.34	0.98

Remarks.—Shigeta (1989) demonstrated that *Tetragonites glabrus* of Turonian to Campanian age, exhibits a remarkably wide variation in shell form and regarded *T. popetensis* as a synonym of *T. glabrus*. However, Shigeta's specimens, which exhibit a small umbilicus that he assigned to *T. glabrus* from sample AW1001A, should actually be attributed to *Pseudophyllites indra* (Forbes, 1846). Because Shigeta's sample (AW1001A) was heterogeneous and consisted of specimens of both *Pseudophyllites indra* (Forbes, 1846) and *T. popetensis*. *Tetragonites popetensis* should be regarded as an independent species as earlier pointed out by Maeda *et al*. (2005, p. 88).

Certain specimens assigned to *Saghalinites* by Haggart (1989, pl. 8.1, figs. 7–11) and Zonova *et al*., (1993, pl. 209, figs. 3, 4) as well as a specimen described as *Tetragonites superstes* by Matsumoto and Miyauchi (1984, pl. 23, fig. 2) and specimens described as *Epigoniceras epigonum* by Usher (1952, pl. 2, figs. 6, 7, pl. 3, fig. 1) are identical to *Tetragonites popetensis* in having a moderately evolute shell with a sub-quadrate whorl section and should be synonymized with *T. popetensis*. The holotype of *Lytoceras* (*Tetragonites*) *henleyense* exhibits a similar shell shape and ornamentation as *T. popetensis*, and is probably conspecific. However, it is necessary to study a large number of specimens in order to define the variation in shell form of *L.* (*T.*) *henleyense*.

All specimens of *Tetragonites popetensis* reported from the Campanian are less than 70 mm in diameter (Shigeta, 1989). A mature shell, which is characterized by septal approximation of the last two septa, was reported from the Campanian in the Cape Soya area by Matsumoto and Miyauchi (1984, pl. 23, fig. 3) and its diameter is over 65 mm. In contrast, the largest specimen of *T. popetensis* from the Soya Hill area (HMG-1729) is 127.4 mm in diameter, which is nearly twice as large as the Campanian mature specimens. This evidence suggests that the mature shell size of *T. popetensis* increased significantly during the Maastrichtian.

Occurrence.—*Tetragonites popetensis* is abundant from the Santonian to the lower Maastrichtian in Hokkaido and Sakhalin (Shigeta, 1989; Maeda *et al*., 2005; Shigeta *et al*., 2016) and from the middle Campanian in Wakayama, southwestern Japan (Misaki and Maeda, 2009). The species is also known from the Coniacian to Campanian in California, Washington and British Columbia (Usher, 1952; Anderson, 1958; Haggart, 1989).

Suborder Ancyloceratina Wiedmann, 1966

Superfamily Turrilitoidea Gill, 1871

Family Diplomoceratidae Spath, 1926

Genus ***Diplomoceras*** Hyatt, 1900

Type species.—*Baculites cylindracea* Defrance, 1816.

Diplomoceras sp.
Figure 22A–E

Material examined.—One specimen, HMG-1739, from Loc. 7; one specimen, HMG-1740, from a float calcareous concretion found near Loc. 8.

Description.—HMG-1740, a curved portion of phragmocone, with elliptical whorl section (H = 20.2 mm, W = 18.0 mm, W/H = 0.89). HMG-1739 is a body chamber fragment. Ornamentation consists of numerous, regularly spaced, straight ribs.

Remarks.—The fragmental nature of the specimens preclude a definitive assignment.

Family Nostoceratidae Hyatt, 1894
Genus **_Nostoceras_** Hyatt, 1894

Type species.—Nostocras santoni Hyatt, 1894.

Nostoceras sp.
Figure 22F, G

Material examined.—One specimen, HMG-1741, from a float calcareous concretion found near Loc. 11.

Description.—HMG-1741 consists of fragments of a phragmocone, probably the last portion of sinistrally helical coiling, and a body chamber. Whorl cross section nearly circular for phragmocone (H = 24.1 mm, W = 23.3 mm, W/H = 0.97) and elliptical for body chamber (H = ca. 49 mm). Shell surface ornamented with dense, oblique ribs and two rows of tubercles, which appear rather irregularly on every second to fourth rib. As shell grows, ribs increase in strength and tubercles become stronger.

Remarks.—The described specimen is somewhat similar to *Nostoceras hornbyense* (Whiteaves, 1895), but the fragmental nature precludes a definitive species assignment.

Family Baculitidae Gill, 1871
Genus **_Baculites_** Lamarck, 1799

Type species.—Baculites vertebralis Lamarck, 1801.

Baculites regina Obata and Matsumoto, 1963
Figures 23, 24

Baculites regina Obata and Matsumoto, 1963, p. 85, pl. 22, figs. 3–6, pl. 23, figs. 1, 2, pl. 24, figs. 1–5, pl. 25, figs. 3–5, pl. 27, figs. 1, 6, 7, 9, text-figs. 191–196, 200–214; Matsumoto and Morozumi, 1980, p. 24; Klinger and Kennedy, 2001, p. 192.

Holotype.—UNUT MM7716b, figured by Obata and Matsumoto (1963, p. 85, pl. 24, fig. 1, text-fig. 210), from the lower Maastrichtian Azenotani Shale Member of the Izumi Group at Kuratani, Shinke, Sennan, Osaka Prefecture, Southwest Japan.

Material examined.—One specimen, HMG-1742, from Loc. 1; one specimen, HMG-1743, from Loc. 6; five specimens, HMG-1744–1748, from float calcareous concretions found near Loc. 8; five specimens, HMG-1749–1753, from Loc. 11; one specimen, HMG-1754, from a float calcareous concretion found near Loc. 11.

Description.—Moderately tapered, straight or gently arched shell. Whorl section rounded subtrigonal, with narrowly rounded venter, indistinct ventral shoulders, gently convex flanks, flattened or broadly rounded dorsum. As shell grows in length, whorl section becomes more compressed. Shell surface almost smooth in early growth stage, but as shell grows, it develops weak to strong crescentic nodes on flanks and numerous, fine, oblique ribs on ventral half of flank.

Measurements (mm):

Specimen no.	H	W	W/H
HMG-1745	5.9	4.8	0.81
HMG-1750	7.6	6.0	0.79
HMG-1751	7.6	5.9	0.78
HMG-1749	8.6	6.5	0.76
HMG-1754	8.8	6.6	0.75
HMG-1752	9.3	6.8	0.73
HMG-1746	10.8	7.3	0.68
HMG-1748	10.8	7.9	0.72
HMG-1753	13.3	9.2	0.69
HMG-1747	14.3	10.1	0.70
HMG-1742	14.4	10.0	0.69
HMG-1744	19.7	11.0	0.56

Remarks.—Baculites regina closely resembles *B. subanceps* Haughton, 1925 in having crescentic nodes on its flanks, but differs by having numerous, fine, oblique ribs on the ventral half of its flank. *Baculites subanceps* has a corrugated venter and oval whorl section.

Occurrence.—Baculites regina is known from the Lower Maastrichtian Azenotani Shale Member of the

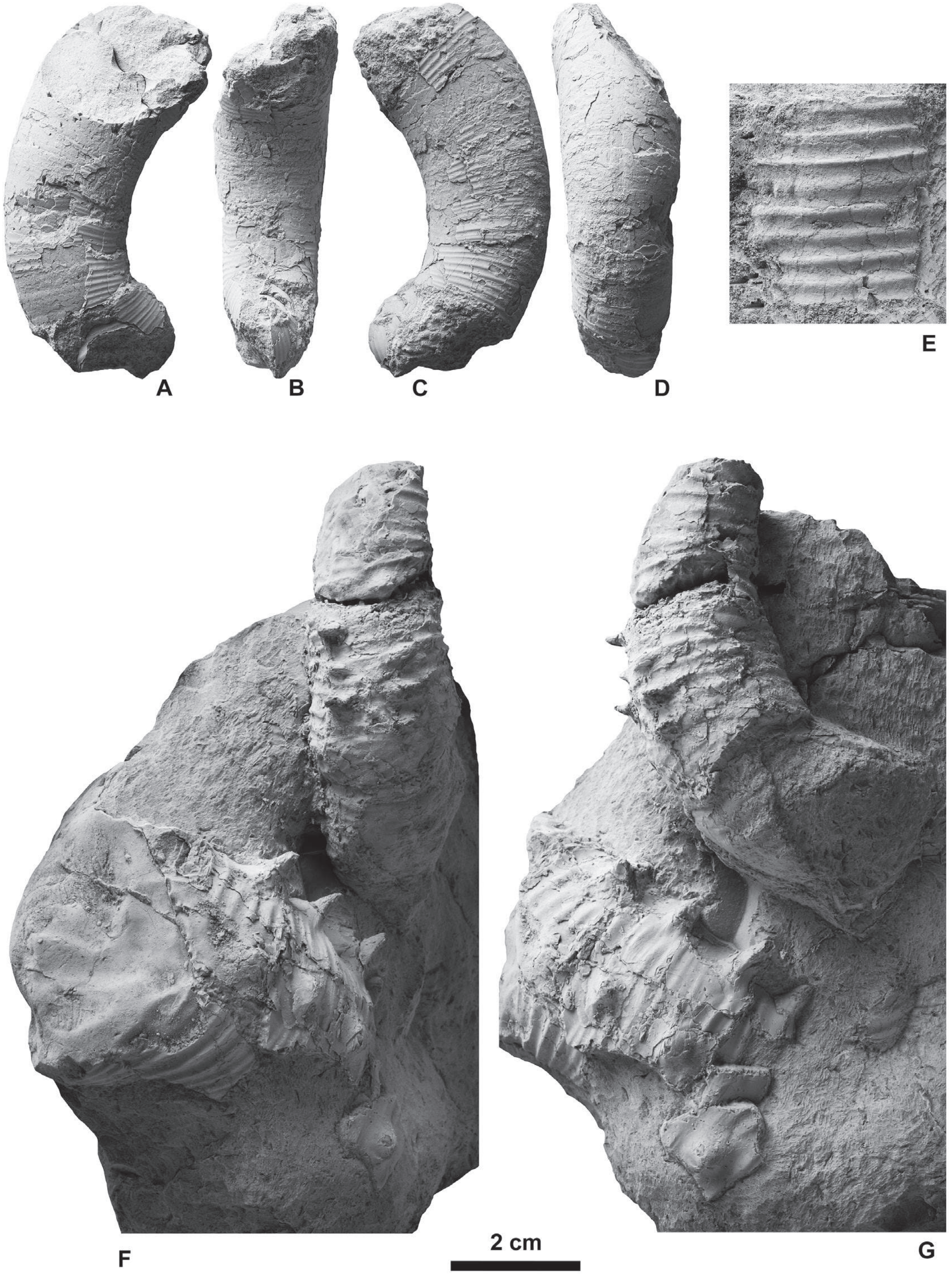

Figure 22. *Diplomoceras* and *Nostoceras* from the Etanpakku Formation. **A–E,** *Diplomoceras* sp.; A–D, HMG-1740 from a float calcareous concretion found near Loc. 8; E, HMG-1739 from Loc. 7; **F, G,** *Nostoceras* sp., HMG-1741 from a float calcareous concretion found near Loc. 11.

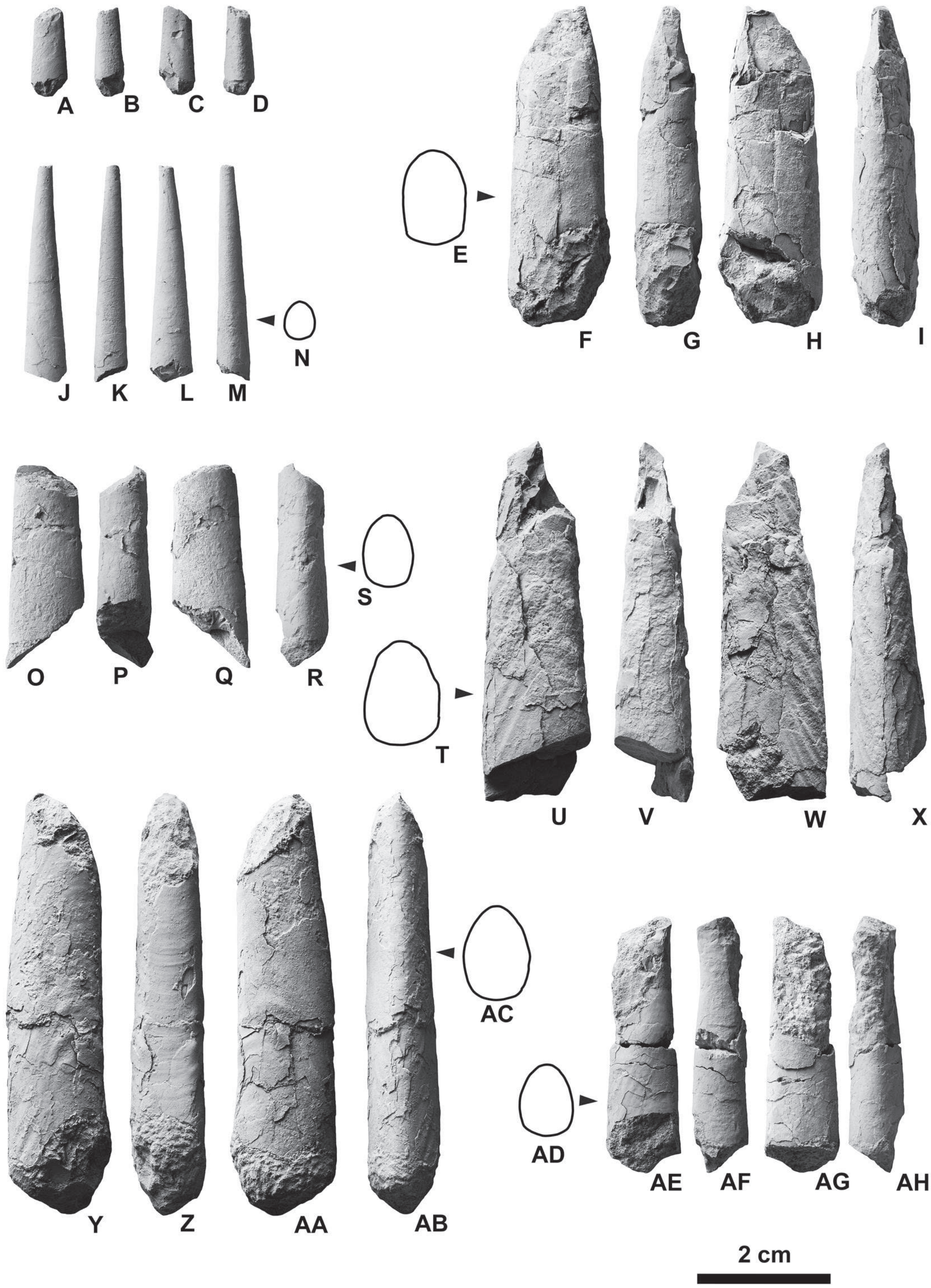

Figure 23. *Baculites regina* Obata and Matsumoto, 1963 from the Etanpakku Formation. **A–D,** HMG-1743 from Loc. 6; **E–I,** HMG-1742 from Loc. 1; **J–X,** specimens from a float calcareous concretion found near Loc. 8; J–N, HMG-1745; O–S, HMG-1746; T–X, HMG-1744; **Y–AH,** specimens from a float calcareous concretion found near Loc. 8; Y–AC, HMG-1747; AD–AH, HMG-1748.

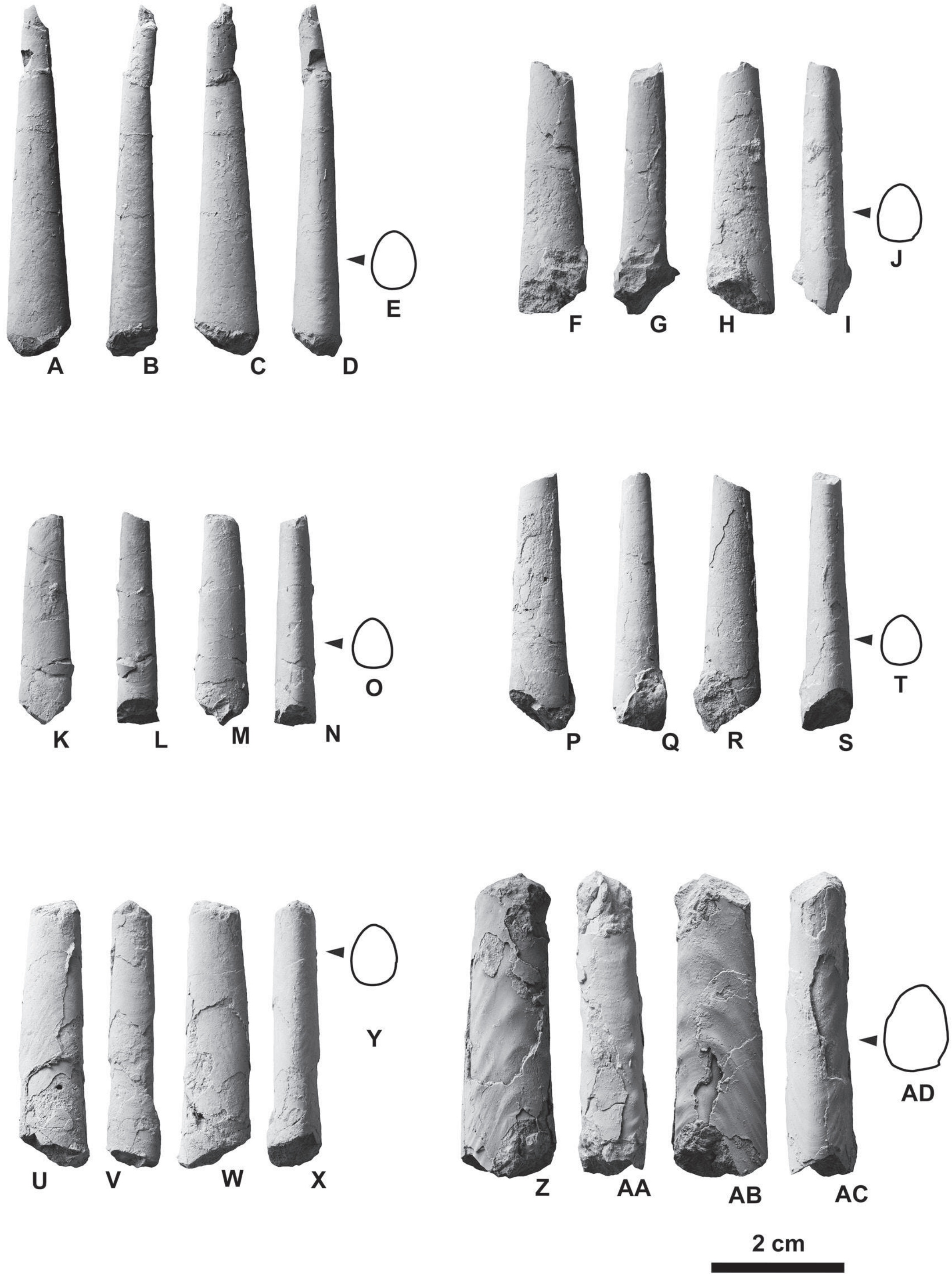

Figure 24. *Baculites regina* Obata and Matsumoto, 1963 from the Etanpakku Formation. **A–E,** HMG-1754 from a float calcareous concretion found near Loc. 11; **F–AD,** specimens from a float calcareous concretion found near Loc. 11; F–J, HMG-1749; K–O, HMG-1750; P–T, HMG-1751; U–Y, HMG-1752; Z–AD, HMG-1753.

Izumi Group at Sennan, Osaka Prefecture, Southwest Japan.

Conclusions

1. Zircon geochronology reveals that the ages of the tuffs from the lowest and uppermost parts of the Etanpakku Formation in the Soya Hill area are 72.6±1.6 Ma and 70.6±1.2 Ma, respectively, which infer a late Campanian to earliest middle Maastrichtian age.

2. An early Maastrichtian (latest Cretaceous) ammonoid fauna is reported from the middle part of the Etanpakku Formation of the Yezo Group exposed along the Onishibetsu and Sarukotsu rivers in the Soya Hill area, northernmost Hokkaido, northern Japan.

3. The fauna comprises nine species belonging to eight genera: *Neophylloceras hetonaiense*, *Tetragonites popetensis*, *T. terminus*, *Gaudryceras izumiense*, *Anagaudryceras matsumotoi*, *Pachydiscus* sp., *Baculites regina*, *Diplomoceras* sp. and *Nostoceras* sp.

4. The fauna correlates with the lower part of the *Gaudryceras izumiense* Zone of the upper lower Maastrichtian in the Izumi Group in Southwest Japan.

5. The *Gaudryceras izumiense* Zone in Hokkaido suggests that similar faunas may have existed in the North Pacific realm during late early Maastrichtian time.

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重田康成・伊豆倉正隆・堤之恭，2017．北海道宗谷丘陵地域から産出した白亜紀末期・マーストリヒチアン前期アンモナイト．むかわ町穂別博物館研究報告，32，7–41.

（要　旨）

北海道北部・宗谷丘陵地域の鬼志別川および猿骨川沿いに露出する蝦夷層群エタンパック層中部からマーストリヒチン前期（白亜紀末期）のアンモナイトの産出を報告した．アンモナイトは8属9種で，*Neophylloceras hetonaiense* Matsumoto，*Tetragonites popetensis* Yabe，*T. terminus* Shigeta，*Gaudryceras izumiense* Matsumoto and Morozumi，*Anagaudryceras matsumotoi* Morozumi，*Pachydiscus* sp.，*Diplomoceras* sp.，*Nostoceras* sp.，*Baculites regina* Obata and Matsumoto を含む．このアンモナイト群は，*Gaudryceras izumiense* と *Baculites regina* を含むことから，西南日本に分布する和泉層群の下部マーストリヒチアン階上部・*Gaudryceras izumiense* 帯の下部に対比できる．エタンパック層の最下部と最上部に挟在する凝灰岩中のジルコンの放射年代は，72.6±1.6 Ma と 70.6±1.2 Ma であり，エタンパック層の年代がカンパニアン後期からマーストリヒチアン中期の最前期であることを示す．

Appendix 1. LA-ICP-MS analyzed data of zircons in the tuff samples collected from Loc. 3(OS001-025) and Loc. 10 (SY001-028) and calculated ages. Errors are 1 sigma. Pbc and Pb* indicate the common and radiogenic portions, respectively.

Labels	$^{206}Pb_c$ (1) (%)	U (ppm)	Th (ppm)	Th/U	$^{238}U/^{206}Pb*$ (1)	$^{207}Pb*/^{206}Pb*$ (1)	$^{238}U/^{206}Pb*$ age (1) (Ma)	$^{238}U/^{206}Pb*$ age (2) (Ma)
OS001	0.72	475	280	0.60	91.17 ± 2.01	0.0369 ± 0.0069	70.3 ± 1.5	70.8 ± 1.5
OS002	0.00	611	717	1.20	93.82 ± 1.80	0.0555 ± 0.0036	68.3 ± 1.3	67.7 ± 1.3
OS003	0.77	931	1452	1.60	90.97 ± 2.16	0.0344 ± 0.0108	70.5 ± 1.7	71.0 ± 1.4
OS004	0.00	306	298	1.00	89.10 ± 2.49	0.0488 ± 0.0046	71.9 ± 2.0	71.8 ± 2.0
OS005	0.00	474	609	1.32	90.08 ± 2.19	0.0508 ± 0.0039	71.2 ± 1.7	70.9 ± 1.7
OS006	0.74	668	749	1.15	92.40 ± 2.09	0.0475 ± 0.0078	69.4 ± 1.6	69.4 ± 1.5
OS007	1.04	313	198	0.65	91.21 ± 2.63	0.0466 ± 0.0104	70.3 ± 2.0	70.4 ± 2.0
OS008	1.71	845	970	1.18	94.63 ± 1.94	0.0414 ± 0.0086	67.8 ± 1.4	68.3 ± 1.3
OS009	1.65	380	567	1.53	92.11 ± 2.56	0.0481 ± 0.0134	69.6 ± 1.9	69.6 ± 1.7
OS010	3.84	308	314	1.05	92.26 ± 2.66	0.0260 ± 0.0135	69.5 ± 2.0	71.4 ± 1.8
OS011	0.00	478	337	0.72	66.30 ± 1.22	0.0539 ± 0.0033	96.5 ± 1.8	95.8 ± 1.8
OS012	1.90	187	163	0.89	41.71 ± 1.01	0.0428 ± 0.0093	152.7 ± 3.6	153.9 ± 3.5
OS013	0.00	169	111	0.67	14.85 ± 0.25	0.0545 ± 0.0030	420.2 ± 6.9	420.2 ± 6.9
OS014	1.27	555	287	0.53	79.92 ± 1.61	0.0461 ± 0.0049	80.2 ± 1.6	80.3 ± 1.6
OS015	1.12	466	219	0.48	67.42 ± 1.57	0.0454 ± 0.0057	94.9 ± 2.2	95.2 ± 2.2
OS016	3.75	947	405	0.44	89.91 ± 1.67	0.0366 ± 0.0061	71.3 ± 1.3	72.3 ± 1.3
OS017	3.50	502	602	1.23	95.53 ± 2.31	0.0368 ± 0.0106	67.1 ± 1.6	68.0 ± 1.5
OS018	1.35	437	376	0.88	87.95 ± 2.09	0.0343 ± 0.0081	72.9 ± 1.7	73.9 ± 1.6
OS019	0.74	409	320	0.80	85.61 ± 1.83	0.0414 ± 0.0083	74.9 ± 1.6	75.4 ± 1.5
OS020	0.48	740	279	0.39	75.91 ± 1.29	0.0475 ± 0.0045	84.4 ± 1.4	84.4 ± 1.4
OS021	1.31	803	305	0.39	35.97 ± 0.53	0.0442 ± 0.0036	176.8 ± 2.6	178.0 ± 2.6
OS022	1.64	323	322	1.02	89.17 ± 2.38	0.0497 ± 0.0121	71.9 ± 1.9	71.7 ± 1.7
OS023	0.98	448	300	0.69	88.59 ± 2.09	0.0415 ± 0.0076	72.4 ± 1.7	72.9 ± 1.7
OS024	0.00	792	460	0.60	22.08 ± 0.29	0.0506 ± 0.0016	285.5 ± 3.7	285.5 ± 3.7
OS025	0.00	215	297	1.42	75.69 ± 2.46	0.0504 ± 0.0062	84.6 ± 2.7	84.3 ± 2.8
SY001	1.73	562	382	0.70	84.98 ± 1.85	0.0414 ± 0.0065	75.4 ± 1.6	76.0 ± 1.6
SY002	0.84	1697	587	0.36	71.16 ± 1.03	0.0490 ± 0.0029	90.0 ± 1.3	89.8 ± 1.3
SY003	0.00	732	194	0.27	2.46 ± 0.03	0.1471 ± 0.0012	2197.3 ± 22.6	2177.3 ± 22.6
SY004	3.28	812	736	0.93	74.38 ± 1.54	0.0605 ± 0.0073	86.1 ± 1.8	84.7 ± 1.7
SY005	0.00	302	111	0.38	68.63 ± 1.99	0.0805 ± 0.0055	93.3 ± 2.7	89.5 ± 2.7
SY006	0.00	474	650	1.41	66.61 ± 1.41	0.0757 ± 0.0038	96.1 ± 2.0	92.7 ± 2.0
SY007	0.00	387	295	0.78	71.24 ± 1.72	0.0641 ± 0.0044	89.9 ± 2.2	88.0 ± 2.2
SY008	0.29	429	294	0.70	30.01 ± 0.44	0.0537 ± 0.0041	211.3 ± 3.0	210.4 ± 2.9
SY009	1.83	119	28	0.24	47.54 ± 1.48	0.0482 ± 0.0079	134.2 ± 4.1	134.3 ± 4.1
SY010	1.68	589	392	0.68	88.03 ± 1.71	0.0364 ± 0.0067	72.8 ± 1.4	73.8 ± 1.4
SY011	1.73	194	125	0.66	85.77 ± 2.42	0.0526 ± 0.0108	74.7 ± 2.1	74.2 ± 2.0
SY012	1.59	576	546	0.97	91.66 ± 1.98	0.0410 ± 0.0075	69.9 ± 1.5	70.5 ± 1.5
SY013	2.05	516	166	0.33	78.87 ± 1.53	0.0486 ± 0.0056	81.2 ± 1.6	81.1 ± 1.5
SY014	3.43	150	97	0.67	88.60 ± 3.23	0.0326 ± 0.0149	72.3 ± 2.6	73.7 ± 2.6
SY015	0.00	292	135	0.47	81.38 ± 2.04	0.0485 ± 0.0049	78.7 ± 2.0	78.6 ± 2.0
SY016	0.00	576	326	0.58	89.43 ± 1.97	0.0490 ± 0.0035	71.7 ± 1.6	71.5 ± 1.6
SY017	0.57	231	133	0.59	2.72 ± 0.03	0.1470 ± 0.0026	2015.3 ± 20.2	1971.4 ± 20.1
SY018	0.60	397	338	0.87	72.89 ± 2.00	0.0793 ± 0.0109	87.8 ± 2.4	84.4 ± 2.2
SY019	1.82	277	144	0.53	70.15 ± 1.94	0.0657 ± 0.0100	91.3 ± 2.5	89.2 ± 2.4
SY020	1.14	278	233	0.86	75.07 ± 1.91	0.0465 ± 0.0097	85.3 ± 2.2	85.4 ± 2.0
SY021	0.23	732	280	0.39	58.05 ± 1.08	0.0556 ± 0.0042	110.1 ± 2.0	109.1 ± 2.0
SY022	0.00	598	276	0.47	89.08 ± 1.78	0.0584 ± 0.0056	72.0 ± 1.4	71.0 ± 1.4
SY023	0.63	327	215	0.67	84.20 ± 2.40	0.0498 ± 0.0090	76.1 ± 2.2	75.9 ± 2.1
SY024	0.34	747	195	0.27	58.91 ± 1.04	0.0494 ± 0.0041	108.5 ± 1.9	108.3 ± 1.9
SY025	1.77	420	238	0.58	77.54 ± 1.79	0.0488 ± 0.0083	82.6 ± 1.9	82.5 ± 1.8
SY026	0.00	242	142	0.60	73.39 ± 2.23	0.0734 ± 0.0069	87.2 ± 2.6	84.4 ± 2.7
SY027	0.16	807	276	0.35	73.93 ± 1.16	0.0420 ± 0.0038	86.6 ± 1.3	86.8 ± 1.3
SY028	0.00	303	107	0.36	58.79 ± 1.37	0.0545 ± 0.0046	108.7 ± 2.5	107.9 ± 2.6

Errors are 1-sigma; Pb_c and Pb* indicate the common and radiogenic portions, respectively.

(1) Common Pb corrected by assuming $^{206}Pb/^{238}U$-$^{208}Pb/^{232}Th$ age-concordance

(2) Common Pb corrected by assuming $^{206}Pb/^{238}U$-$^{207}Pb/^{235}U$ age-concordance

Appendix 2. List of ammonoids and inoceramids from the Etanpakku Formation of the Yezo Group exposed along the Onishibetsu and Sarukotsu rivers in the Soya Hill area, northernmost Hokkaido, northern Japan. Locality, sample (= concretion) and Hobetsu Museum (HMG) specimen numbers are shown. Suffix "p" of sample number means that the concretion was found as float. *Amat*, *Anagaudryceras matsumotoi*; *Breg*, *Baculites regina*; *Dipl*, *Diplomoceras* sp.; *Gizm*, *Gaudryceras izumiense*; *Nhet*, *Neophylloceras hetonaiense*; *Nost*, *Nostoceras* sp.; *Pachy*, *Pachydiscus* sp.; *Tpop*, *Tetragonites popetensis*; *Tter*, *Tetragonites terminus*.

locality	Sample	inoceramids	*Nhet*	*Amat*	*Gizm*	*Tter*	*Tpop*	*Pachy*	*Dipl*	*Nost*	*Breg*
1	20150907-1					1720					
	20150907-3				1710						
	20150907-4										1742
	20150908-5	1768, 1769, 1770					1727				
	20151007-1			1709							
	20151007-2					1719					
	20150514-1p	1771					1728				
	20150514-3p						1729				
	20150610-1p		1702								
	20150907-4p	1772, 1773									
2	20150514-9	1777			1712						
	20150514-10	1774, 1775, 1776									
	20150908-1	1779									
	20150908-2	1778	1703, 1704		1711		1730				
	20150908-3						1731				
	20150514-7p	1780									
	20150514-8p	1781									
4	20150909-7	1755, 1756									
5	20150909-6	1757									
6	20150514-11					1721	1732				1743
	20150514-12					1722					
	20150909-2	1764, 1765, 1766									
	20150909-3	1762, 1763									
7	20150515-5								1739		
8	20150515-2p	1760, 1761	1705						1740		1744, 1745, 1746
	20150911-1p	1758, 1759									1747, 1748
9	20150513-1				1713						
	20150513-4	1767									
11	20150515-14	1782					1733				1749, 1750, 1751, 1752, 1753
	20150911-3p									1741	
	20160525-2p						1734				
	20160525-3p										1754
12	20150911-4				1714						
	20150911-5	1783, 1784, 1785, 1786									
	20150912-1					1723	1735	1708			
	20151006-5					1724					
	20150515-15p				1715		1736				
13	20160523-4	1790				1725	1737				
14	20150609-2				1716						
	20150710-1		1706								
	20150710-2						1738				
	20151008-2					1726					
	20150515-8p	1787, 1788									
	20150515-9p	1789									
	20150515-10p		1707								
	20150515-11p				1718						
	20150609-1p				1717						
15	20150609-3	1791, 1792									