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A new species of *Anagaudryceras* (Ammonoidea, Gaudryceratidae) from the lowest Maastrichtian of Hokkaido, Japan

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Abstract. ***Anagaudryceras compressum*** **sp. nov., the most slender of this genus, is newly described from the *Nostoceras hetonaiense* Zone of earliest Maastrichtian age (Late Cretaceous), in the Hobetsu area, Hokkaido, northern Japan. Its shell is fairly small (< 80 mm in diameter) and compressed with a highly arched venter. The last whorl is ornamented with low, broad, gently flexed band-like ribs. Its ornamentation is very similar to *A. matsumotoi*, thus suggesting a close phylogenetic relationship with this taxon, which is probably its descendant.**

Key words: ammonoid, *Anagaudryceras*, Cretaceous, Hobetsu, Hokkaido, Maastrichtian

Introduction

One of the best uppermost Cretaceous sections in the North Pacific realm occurs in the Hobetsu area in south-central Hokkaido, northern Japan (Matsumoto, 1942, 1954). The Hakobuchi Formation, occupying the uppermost part of the Yezo Group, is widely distributed in this area and numerous well preserved ammonoids and inoceramid bivalves occur at various horizons. In particular, the sandy mudstone of Unit IVb (Matsumoto, 1942), which is a correlative of the lowest Maastrichtian, is especially fossiliferous. Over the past 65 years, nine species of ammonoids have been described from this unit (Matsumoto, 1947, 1954, 1977; Matsumoto and Obata, 1955; Shigeta, 1989; Shigeta and Nishimura, 2013a, b).

Anagaudryceras Shimizu, 1934 is one of the most common ammonoid genera in Albian to Maastrichtian-aged sediments in the Northwest Pacific, and more than ten species have been described from Japan and the Russian Far East (Yabe, 1903; Matsumoto, 1984, 1985, 1988, 1995; Matsumoto and Kanie, 1985; Morozumi, 1985; Zonova *et al*., 1993; Yazykova, 1994; Shigeta and Maeda, 2005). Specimens assigned to the genus are fairly abundant in Albian to lower Campanian sediments as well as those of the upper Maastrichian, and the intraspecific and ontogenetic shell variations of a few species have been extensively studied (Matsumoto, 1995; Shigeta and Maeda, 2005). In contrast, *Anagaudryceras* from the upper Campanian to lower Maastrichtian is very rare and consequently, its diversity and stratigraphic occurrences are practically unknown.

The late Mr. Yoshitaro Kawashita (1934–2000) first began collecting fossils in Hokkaido in the early 1960's, and his huge collection was subsequently donated to the National Museum of Nature and Science by his family in 2001 (Shigeta, 2001). The "Kawashita Collection" contains several specimens referable to *Anagaudryceras* from the lowest Maastrichtian in the Hobetsu area. Furthermore, we studied a few additional specimens assignable to *Anagaudryceras* that are housed in the Hobetsu Museum (Mukawa, Hokkaido). These specimens were collected from the lowest Maastrichtian in the Hobetsu area by G. Tanaka (Kumamoto University, Kamiamakusa), H. Yamato (Sapporo, Hokkaido), K. Sugawara (previous staff of the Hobetsu Museum), and coauthor T. Nishimura. In this paper, we describe these specimens as a new species of *Anagaudryceras* and discuss the evolution of *Anagaudryceras* during Maastrichtian time in the Northwest Pacific realm.

Notes on stratigraphy

The 800 m-thick Hakobuchi Formation, which occupies the uppermost part of the Yezo Group in Hokkaido,

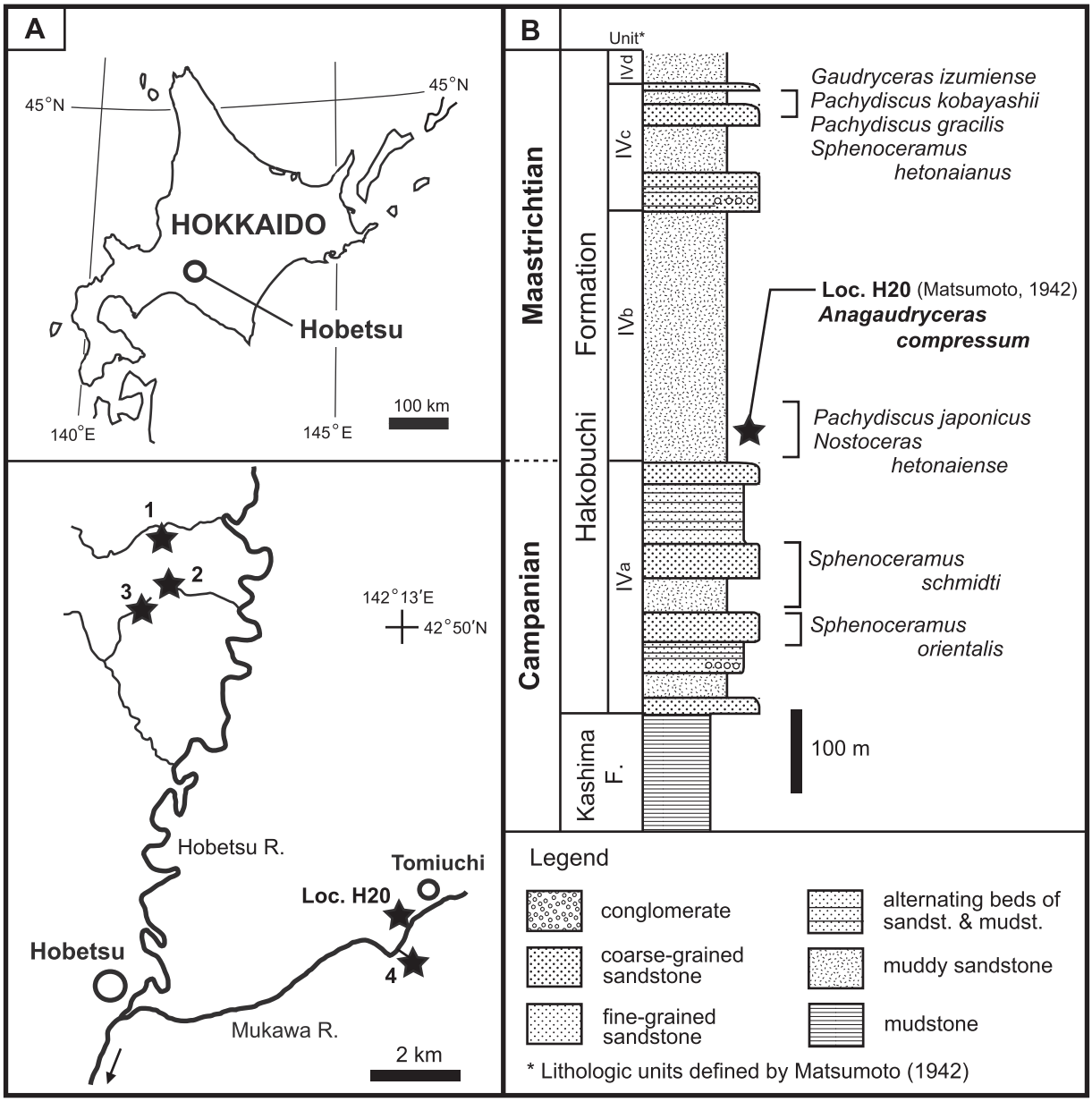

Figure 1. Localities (A) and horizon (B) of the *Anagaudryceras compressum* Shigeta and Nishimura sp. nov. specimens described (indicated by stars). 1, Sososhi-sawa River; 2, Shirafune-no-sawa River; 3, Shirakaba-no-sawa River; 4, Omagari-no-sawa River; Loc. H20 in Matsumoto (1942). The columnar section is modified from pl. 6 of Matsumoto (1954) and fig. 4 of Tanaka (1960).

is widely distributed in the Hobetsu area (Figure 1). It consists mainly of sandstone and was divided into four lithologic units (IVa–IVd) by Matsumoto (1942). The formation conformably overlies the Kashima Formation, which consists mainly of monotonous mudstone.

Unit IVa, composed mainly of sandstone in association with conglomerate, sandy mudstone and coal beds, contains the Campanian index inoceramid bivalve *Sphenoceramus schmidti* (Michael, 1899) and *S. orientalis* (Sokolov, 1914) in the middle part (Tanaka, 1960). Unit IVb, dominated by sandy mudstone, contains *Nostoceras hetonaiense* Matsumoto, 1977 and *Pachydiscus japonicus* Matsumoto, 1947, both of which are indicative of the lowest Maastrichtian (Matsumoto, 1947, 1954, 1977; Tanaka, 1960). Unit IVc, consisting of sandstone with intercalations of conglomerate and sandy mudstone beds, includes the late early Maastrichtian fossils *P. kobayashii* (Shimizu, 1935), *P. gracilis* Matsumoto, 1979, *Gaud-*

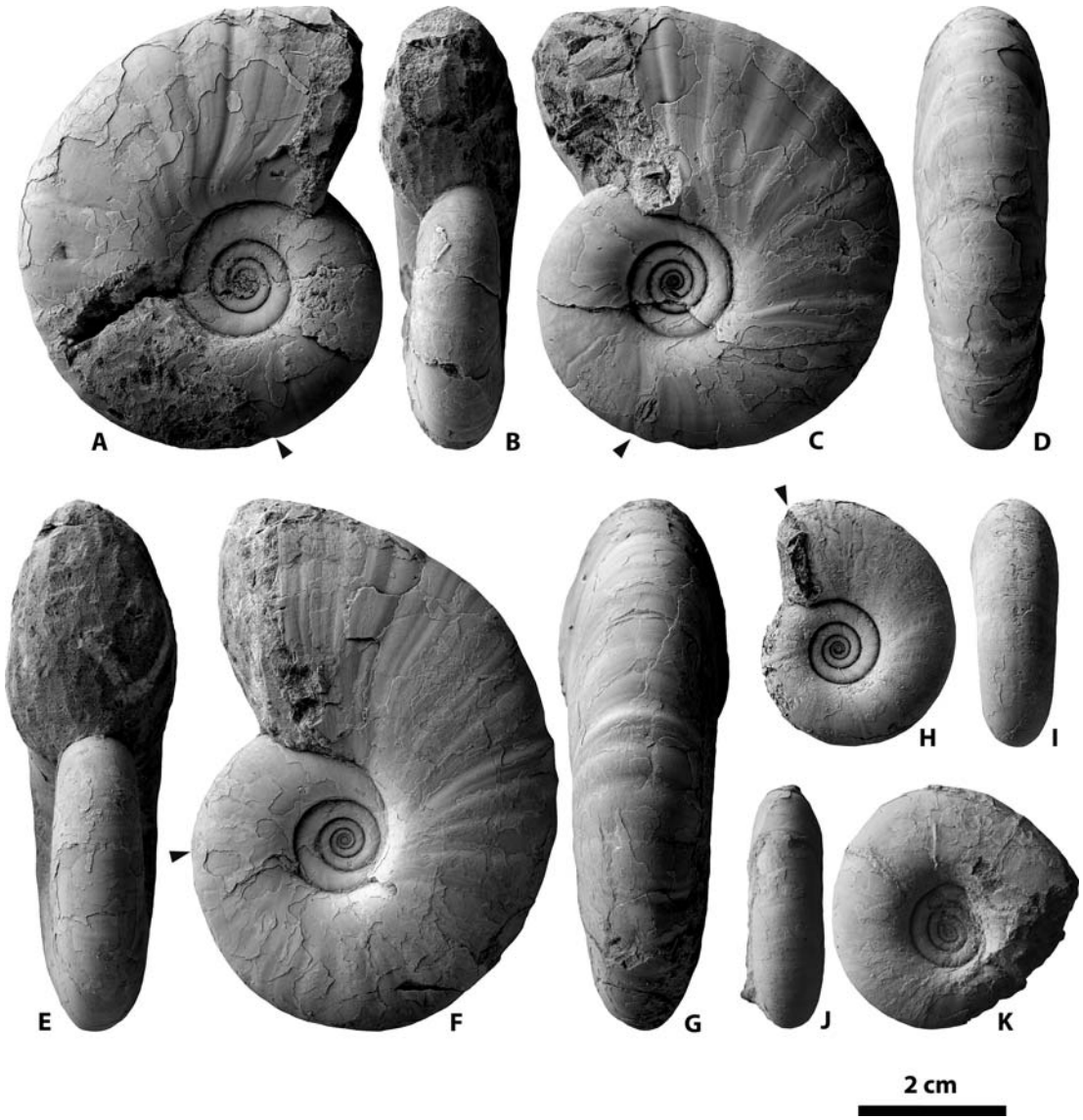

Figure 2. *Anagaudryceras compressum* Shigeta and Nishimura sp. nov. from the Hobetsu area, Hokkaido. **A–D**, HMG-136 (holotype); A, left lateral view; B, apertural view; C, right lateral view; D, ventral view; **E–G**, NMNS PM16995 (paratype); E, apertural view; F, right lateral view; G, ventral view; **H–I**, HMG-1597 (paratype); H, right lateral view; I, ventral view; **J–K**, HMG-1626 (paratype); J, ventral view; K, left lateral view. Arrow indicates position of last septum.

ryceras izumiense Matsumoto and Morozumi, 1980, and *S. hetonaianus* (Matsumoto, 1952) (Matsumoto, 1979; Matsumoto and Toshimitsu, 1992; Matsumoto *et al*., 1993; Shigeta *et al*., 2010). Unit IVd consists mainly of unfossiliferous sandy mudstone.

The specimens upon which we based our new species of *Anagaudryceras* were obtained from the lower part of Unit IVb (Figure 1) and float calcareous concretions that most likely came from the sandy mudstone of Unit IVb in the Hobetsu area.

Paleontological description

Systematic descriptions basically follow the classification established by Klein *et al*. (2009) and Hoffmann (2010), and morphological terms are those used in the *Treatise on Invertebrate Paleontology* (Moore, 1957). Quantifiers used to describe the shape of the ammonoid shell replicate those proposed by Matsumoto (1954, p. 246) and modified by Haggart (1989, table 8.1).

Abbreviations for shell dimensions.—D = shell diameter; *U* = umbilical diameter; *H* = whorl height; *W* =

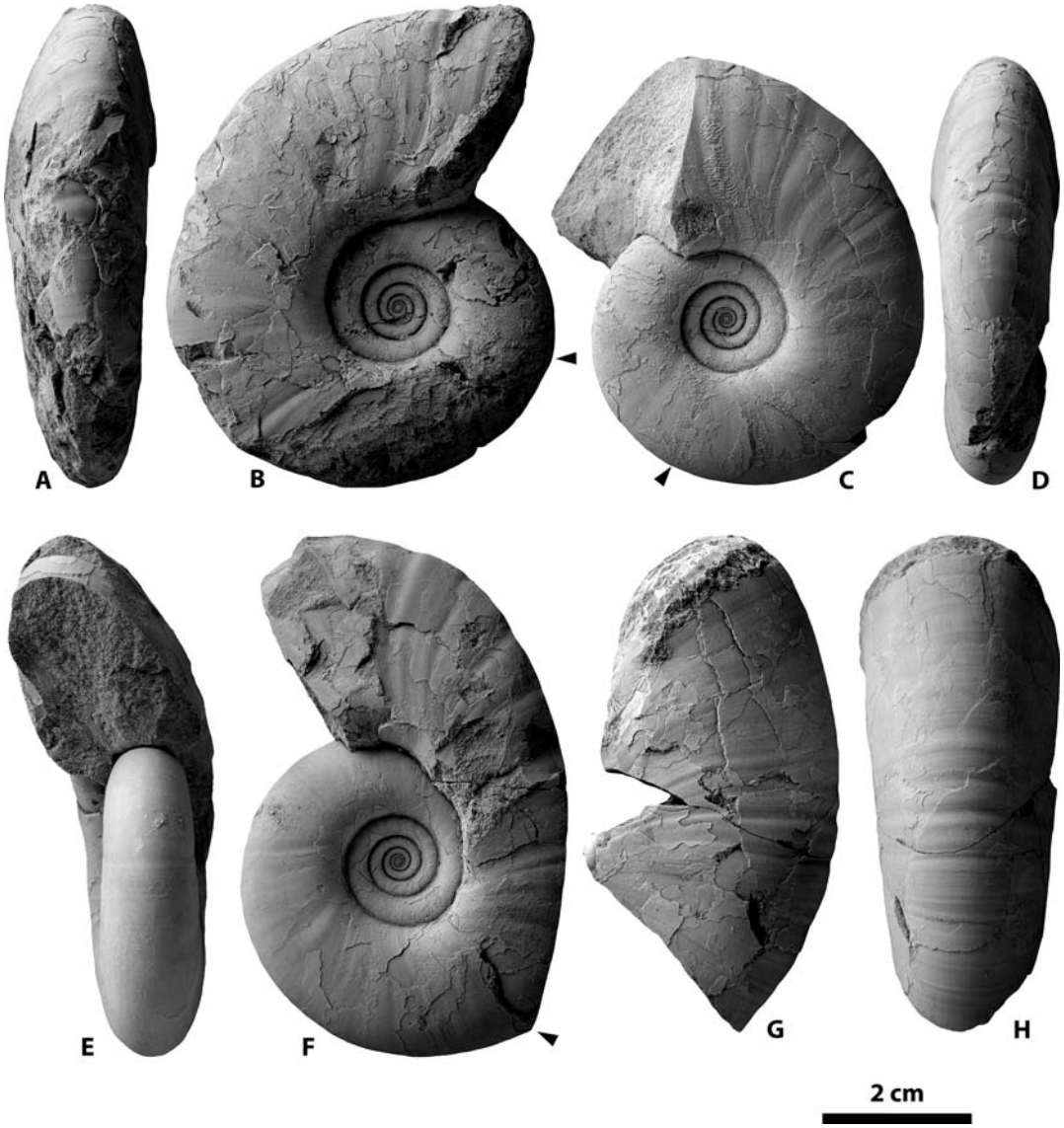

Figure 3. *Anagaudryceras compressum* Shigeta and Nishimura sp. nov. from the Hobetsu area, Hokkaido. **A–B**, NMNS PM23453 (paratype); A, ventral view; B, left lateral view; **C–D**, NMNS PM23454 (paratype); C, right lateral view; D, ventral view; **E–H**, NMNS PM23455 (paratype); E, apertural view; F, right lateral view; G, right lateral view; H, ventral view. Arrow indicates position of last septum.

whorl width.

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

Superfamily Tetragonitoidea Hyatt, 1900
Family Gaudryceratidae Spath, 1927
Genus ***Anagaudryceras*** Shimizu, 1934

Type species.—*Ammonites sacya* Forbes, 1846.

Anagaudryceras compressum sp. nov.

Figures 2–6

Anagaudryceras politissimum (Kossmat, 1895). Matsumoto, 1985, p. 23, pl. 3, figs. 1–6.

Type specimens.—Holotype, HMG-136 (Figures 2A–D, 6A), measuring about 63.0 mm in diameter, was extracted from a float calcareous concretion in the Shirafune-no-sawa River, a tributary of the Hobetsu River, in the Hobetsu area. This specimen consists of the phragmocone and a majority of the body chamber, which

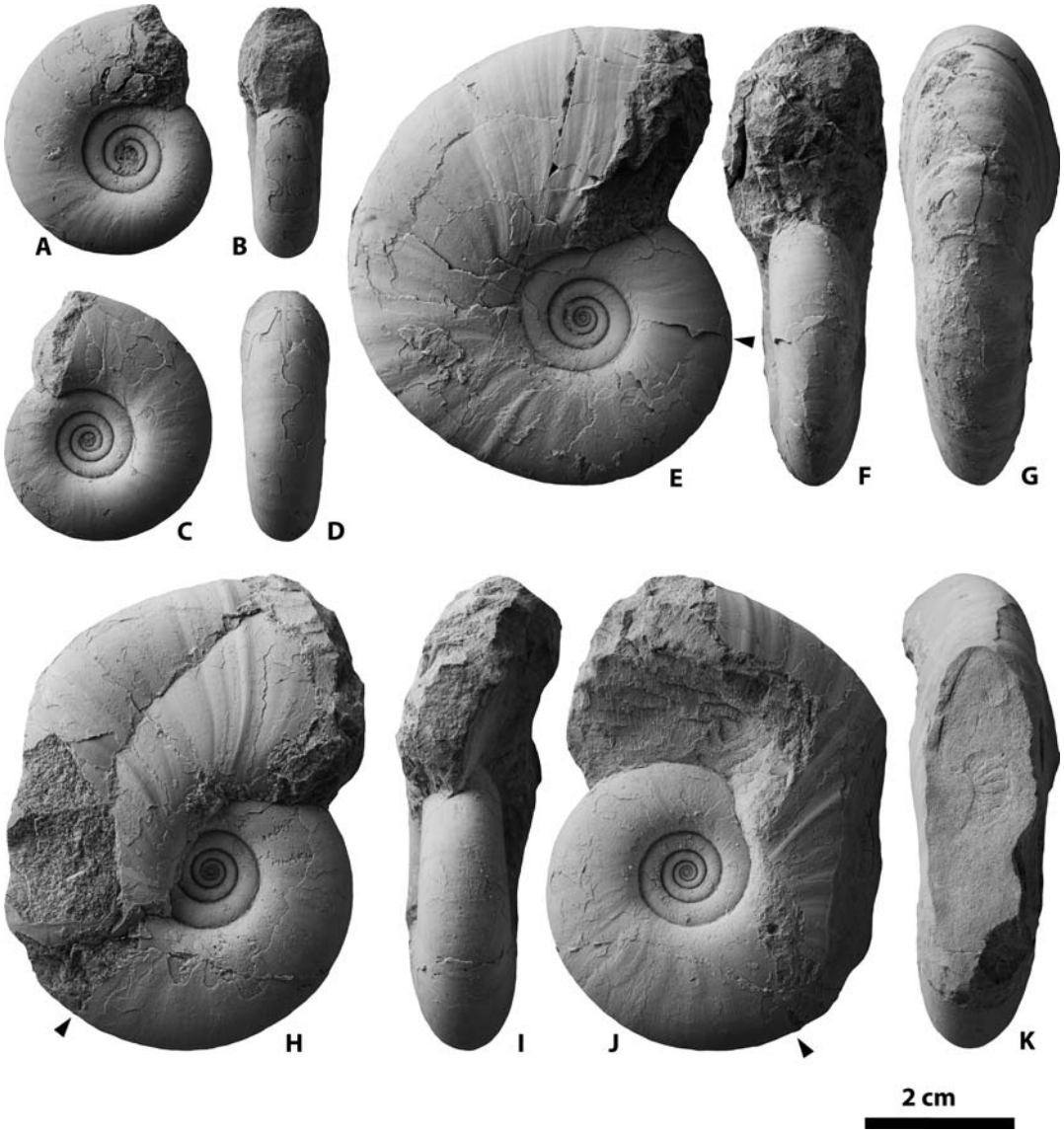

Figure 4. *Anagaudryceras compressum* Shigeta and Nishimura sp. nov. from the Hobetsu area, Hokkaido. **A–D**, HMG-1594 (paratype); A, left lateral view; B, apertural view; C, right lateral view; D, ventral view; **E–G**, HMG-1596 (paratype); E, left lateral view; F, apertural view; G, ventral view; **H–K**, HMG-1595 (paratype); H, left lateral view; I, apertural view; J, right lateral view; K, ventral view. Arrow indicates position of last septum.

begins at a diameter of about 34.0 mm and occupies nearly four-fifths of the outer whorl.

Paratypes, NMNS PM16995, 23453–23455 were extracted from float calcareous concretions in the Shirakaba-no-sawa River, a tributary of the Hobetsu River, in the Hobetsu area. NMNS PM16995 (Figures 2E–G, 6B), measuring 73.0 mm in diameter, consists of the phragmocone and a majority of the body chamber, which begins at about 35.0 mm in diameter and occupies nearly four-fifths of the outer whorl. NMNS PM23453 (Figures 3A–B, 6F), measuring about 67.0 mm in diameter, consists of the phragmocone and a majority of the body chamber, which begins at about 37.0 mm in diameter and occupies nearly four-fifths of the outer whorl. NMNS PM23454 (Figures 3C–D, 5, 6G) consists of the phragmocone and a majority of the body chamber, which begins at about 34.0 mm in diameter and occupies nearly four-fifths of the outer whorl. NMNS PM23455 (Figures 3E–H, 6E) consists of the phragmocone and a majority of the body chamber, which begins at a diameter of about 45.0 mm and occupies nearly four-fifths of the outer whorl.

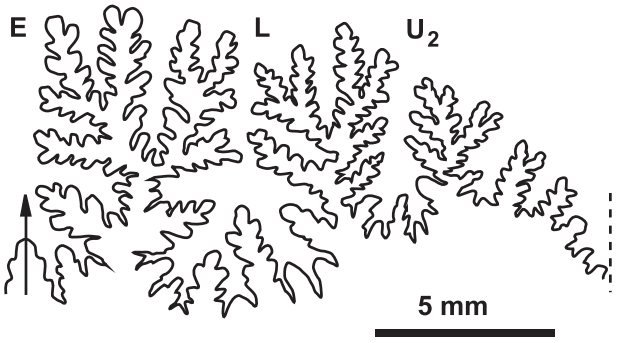

Figure 5. Suture line of *Anagaudryceras compressum* Shigeta and Nishimura sp. nov., NMNS PM23454, from the Hobetsu area, Hokkaido, at H = 14.0 mm. Solid line represents the siphuncle, and broken line indicates the position of the umbilical shoulder. E: external (ventral) lobe, L: lateral lobe, U_2: second umbilical lobe.

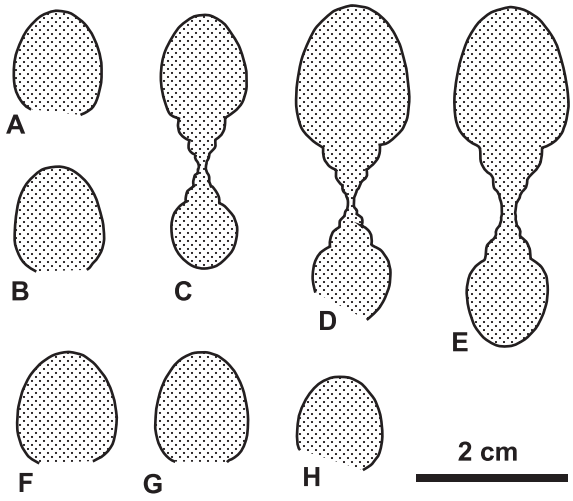

Figure 6. Whorl cross sections of *Anagaudryceras compressum* Shigeta and Nishimura sp. nov., from the Hobetsu area, Hokkaido at last septum. **A**, HMG-136 (holotype); **B**, NMNS PM16995 (paratype); **C**, HMG-1597 (paratype); **D**, HMG-1595 (paratype); **E**, NMNS PM23455 (paratype); **F**, NMNS PM23453 (paratype); **G**, NMNS PM23454 (paratype); **H**, HMG-1596 (paratype).

Paratype, HMG-1597 (Figures 2H–I, 6C), measuring about 34.0 mm in diameter and consisting of only a phragmocone, was collected from a float calcareous concretion in the Omagari-no-sawa River, a tributary of the Mukawa River, in the Hobetsu area.

Paratype, HMG-1626 (Figure 2J–K) was collected from an *in-situ* calcareous concretion in the lower part of Unit IVb at Loc. H20 of Matsumoto (1942, pl. 17), 1.0 km southwest of Tomiuchi Village, Hobetsu area. It consists of the phragmocone and part of the body chamber.

Table 1. Measurements (in mm) of herein described *Anagaudryceras compressum* Shigeta and Nishimura sp. nov. specimens from the Hobetsu area, Hokkaido.

Specimen no.	D	U	H	W	U/D	W/H
HMG-1594	33.0	12.3	13.5	12.1	0.37	0.90
HMG-1597	34.0	11.5	13.8	11.6	0.34	0.84
HMG-1595	42.4	14.4	19.1	14.9	0.34	0.78
NMNS PM23455	45.8	15.4	18.9	15.0	0.34	0.79
NMNS PM23454	55.8	16.2	24.3	17.2	0.29	0.71
HMG-136	63.0	16.4	28.8	20.0	0.26	0.69
NMNS PM16995	73.0	19.0	34.0	22.4	0.26	0.65

Paratypes, HMG-1594 and 1595 were extracted from a float calcareous concretion in a small tributary of the Sososhi-sawa River, which is also a tributary of the Hobetsu River, in the Hobetsu area. HMG-1594 (Figure 4A–D), measuring about 33.0 mm in diameter, consists only of a phragmocone. HMG-1595 (Figures 4H–K, 6D), measuring about 64.0 mm in diameter, consists of the phragmocone and a majority of the body chamber, which begins at a diameter of about 42.4 mm and occupies about half of the outer whorl.

Paratype HMG-1596 (Figures 4E–G, 6H), measuring about 61.0 mm in diameter, was extracted from a float calcareous concretion in the Sososhi-sawa River, a tributary of the Hobetsu River, in the Hobetsu area. It consists of the phragmocone and a majority of the body chamber, which begins at a diameter of about 42.4 mm and occupies nearly four-fifths of the outer whorl.

Diagnosis.—Fairly small-sized and compressed *Anagaudryceras* with highly arched venter and low, broad, gently flexed band-like ribs on last whorl.

Etymology.—Species name refers to its lateral compression, from the Latin word: *compressus*.

Description.—During earlier growth stages: moderately involute, fairly compressed shell with rounded whorl section, highly arched venter, indistinct ventral shoulders, and slightly convex flanks with maximum whorl width slightly below mid-flank. Umbilicus of moderate width with moderately high, rounded wall. Ornamentation consists of very fine, sinuous growth lines. As growth proceeds, whorl section tends to become slightly compressed and umbilical width becomes smaller. Last whorl ornamented with low, broad, gently flexed band-like ribs. Suture line typical gaudryceratid type, with large, incised, bifid saddles and lobes and retracted suspensive lobes (Figure 5).

Measurements.—See Table 1.

Comparison.—Anagudryceras compressum sp. nov. is

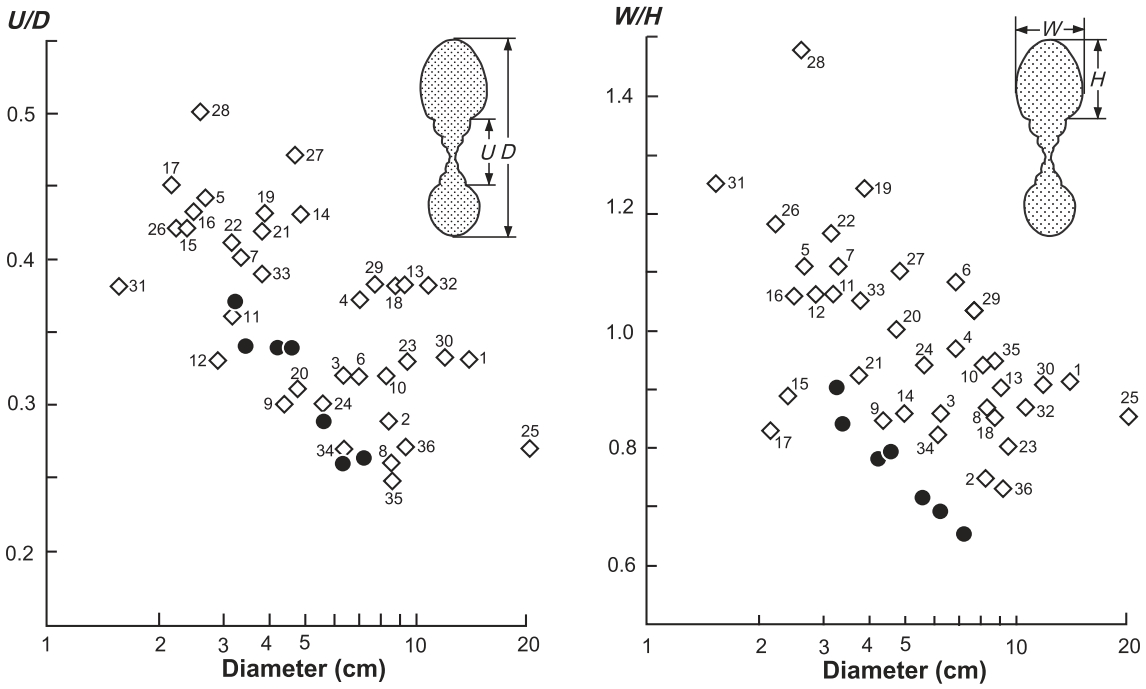

Figure 7. Scatter diagrams of umbilical diameter/shell diameter (*U*/*D*) versus shell diameter (*D*) and whorl width/whorl height (*W*/*H*) versus shell diameter (*D*) for seven specimens of *Anagaudryceras compressum* Shigeta and Nishimura sp. nov. (black circles) and thirty-six selected type (holotype and lectotype) specimens assigned to *Anagaudryceras* by Klein *et al*. (2009) (white squares). Klein *et al*. (2009) listed fifty-three species of *Anagaudryceras*, but shell measurements for fifteen of the species are not provided and the generic assignment for two species is incorrect: *A. matsumotoi* (Grabovskaya in Zakharov *et al*., 1981) clearly belongs to *Zelandites* and *A. rouvillei* (Grossouvre, 1894) belongs to *Pseudophyllites* Kossmat, 1895. Number in each square corresponds as follows. 1, *A. aureum* (Anderson, 1958), holotype; 2, *A. aurarium* (Anderson, 1938), holotype; 3, *A. cappsi* (Imlay, 1960), holotype; 4, *A. coagmentatum* (Collignon, 1963), holotype; 5, *A. crenatum* (Marshall, 1926), holotype; 6, *A. enigma* (Matsumoto *et al*., 1972), holotype; 7, *A. filicinctum* (Whiteaves, 1876), lectotype; 8, *A. howarthi* Matsumoto, 1995, holotype; 9, *A. involvulum* (Stoliczka, 1865), holotype; 10, *A. limatum* (Yabe, 1903), holotype; 11, *A. madraspatanum* (Stoliczka, 1865), lectotype; 12, *A. matsumotoi* Morozumi, 1985; 13, *A. mikobokense* Collignon, 1956, holotype; 14, *A. multiplexum* (Stoliczka, 1865), holotype; 15, *A. nanum* Matsumoto, 1985, holotype; 16, *A. particostatum* (Marshall, 1926), lectotype; 17, *A.*? *pauli* (Coquand, 1862), holotype; 18, *A. politissimum* (Kossmat, 1895), holotype; 19, *A. pulchrum* (Crick, 1907), holotype; 20, *A. pulvinatum* (Collignon, 1964), holotype; 21, *A. revelatum* (Stoliczka, 1865), holotype; 22, *A. sacya* (Forbes, 1846), holotype; 23, *A. sakalavum* (Collignon, 1949), holotype; 24, *A. salinarium* (Douvillé, 1931), holotype; 25, *A. seymouriense* Macellari, 1986, holotype; 26, *A. subsacya* (Marshall, 1926), lectotype; 27; *A. tennenti* Henderson, 1970, holotype; 28, *A. tenuilineatum* (Hoepen, 1921), holotype; 29, *A. tetragonum* Matsumoto and Kanie, 1985, holotype; 30, *A. utaturense* Shimizu, 1935, holotype; 31, *A. valudayurense* (Kossmat, 1895), holotype; 32, *A. whitneyi* (Gabb, 1869), holotype; 33, *A. woodsi* Henderson, 1973, holotype; 34, *A. yamashitai* (Yabe, 1903), holotype; 35, *A. yokoyamai* (Yabe, 1903), holotype; 36, *A. yokoyamaiforme* Collignon, 1969, holotype.

characterized by having the most slender shell among all the species assigned to *Anagaudryceras* with a shell diameter in excess of 30 mm (Figure 7). This new species is the closest to *A. yokoyamaiforme* Collignon, 1969 in having a narrow umbilicus and highly arched venter, but differs by its more compressed whorls and smaller adult size. It is also close to *A. matsumotoi* Morozumi (1985, p. 29) in having low, broad, gently flexed band-like ribs on the adult body chamber, but differs by its more compressed whorls and highly arched venter. Although Morozumi (1985) and Matsumoto (1985) reported *W*/*H* values taken at unspecified points on the body chamber of *A. matsumotoi* (GK. H6882 and GK. H5980a) in the range of 0.73 to 0.81, the body chambers of these specimens have been laterally compressed by compaction and their actual *W*/*H* values would be much higher. According to Morozumi (1985) and Matsumoto (1985), with *A. matsumotoi* shell diameters of 24.8 to 33.0 mm correspond to *W*/*H* values of 1.05 to 1.07, in that order. In contrast, with *A. compressum* sp. nov. shell diameters of 33.0 to 34.0 mm correspond to *W*/*H* values of 0.92 to 0.84, in that order (Table 1). The new species is also somewhat similar to the inner whorls of *A. yamashitai* (Yabe, 1903) in having a relatively narrow umbilicus and rhythmic faint furrows on the shell surface, but differs by its more compressed whorls and highly arched venter. *A. yamashitai* has a circular venter and an adult body chamber ornamented with distinct, narrow grooves.

Remarks.—Two of the three specimens described as *Anagaudryceras politissimum* (Kossmat, 1895) by Matsumoto (1985), which were collected from the lowest Maastrichtian in the Hobetsu area (GK. H3823, 3824), have a much more compressed shell and narrower umbilicus than *A. politissimum* and are identical to *A. compressum* sp. nov. The third specimen, from the upper lower Campanian in the Naiba area, southern Sakhalin (GK. H2302), is not identical and is probably assignable to a species of *Zelandites* Marshall, 1926, judging from its compressed shell with periodic, gently prorsiradiate weak constrictions. A specimen described as *A. politissimum* by Matsumoto (1995, fig. 36) from the Naiba area (UMUT MM19779) is somewhat similar to *A. compressum* sp. nov., but this specimen is probably a deformed *Gaudryceras striatum* (Jimbo, 1894), because its ornamentation, characterized by fine, dense lirae and narrow, rounded, gently flexed, collar-like ribs, is very similar to that of *G. striatum*.

Occurrence.—One specimen was obtained from an *in-situ* calcareous concretion in the lower part of Unit IVb, but all others described herein were collected from float calcareous concretions in the Hobetsu area. Although the exact horizon(s) from which the concretions came is uncertain, judging from where they were found and their lithology, they almost certainly came from the sandy mudstone of Unit IVb of the Hakobuchi Formation, which is correlated with the *Nostoceras hetonaiense* Zone (= lowest Maastrichtian, Toshimitsu *et al*., 1995).

Discussion

A few specimens assignable to *Anagaudryceras* have been described from the lower Maastrichtian of Hokkaido. Matsumoto and Kanie (1985) described *A. tetragonum* based on a single specimen from the lower Maastrichtian in the Urakawa area, but this species should be assigned to *Gaudryceras* Grossouvre, 1894, because the specimen has a much wider umbilicus than most species of *Anagaudryceras* (Figure 7) and its ornamentation consisting of slightly flexuous constrictions and weak ribs that project forward on the venter, are characters that match well with *Gaudryceras*. As discussed above, two specimens described as *A. politissimum* by Matsumoto (1985) from the lowest Maastrichtian in the Hobetsu area are identical to *A. compressum* sp. nov. Therefore, *A. compressum* sp. nov. is the only known early Maastrichtian species of *Anagaudryceras* in the Northwest Pacific realm.

Anagaudryceras compressum sp. nov. is very close to *A. yokoyamaiforme* from the lower Campanian of Madagascar and is somewhat similar to the inner whorls of *A. yamashitai* from the lower Campanian of Hokkaido, but differs by its more compressed whorls. Because the intraspecific and ontogenetic shell variations, stratigraphic ranges and geographical distributions of these lower Campanian species have not been extensively studied, their phylogenetic relationships are still unclear, and consequently, the ancestor of this new species remains uncertain. Furthermore, this lack of understanding is made even more uncertain because *Anagaudryceras* has not yet been reported from the upper Campanian in the Northwest Pacific realm. Its eventual discovery in these younger sediments would no doubt cast light on the origin of *A. compressum* sp. nov.

The last whorl of *Anagaudryceras compressum* sp. nov. is ornamented with low, broad, gently flexed band-like ribs, and similar ribs are observed on the last whorl of *A. matsumotoi* from the lower (?) and upper Maastrichtian (Morozumi, 1985; Matsumoto, 1985; Maeda *et al*., 2005). This evidence strongly suggests a close phylogenetic relationship between the two taxa, and because the distribution of *A. matsumotoi* is restricted to southwestern Japan, Hokkaido and Sakhalin, it probably evolved from *A. compressum* sp. nov. and flourished in the Northwest Pacific realm during Maastrichtian time.

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