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Authors: Shigeta, Yasunari, Izukura, Masataka, Nishimura, Tomohiro, and Tsutsumi, Yukiyasu

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Middle and late Campanian (Late Cretaceous) ammonoids from the Urakawa area, Hokkaido, northern Japan

YASUNARI SHIGETA[1], MASATAKA IZUKURA[2], TOMOHIRO NISHIMURA[3] AND YUKIYASU TSUTSUMI[1]

[1]*Department of Geology and Paleontology, National Museum of Nature and Science, 4-1-1 Amakubo, Tsukuba, Ibaraki 305-0005, Japan (e-mail: shigeta@kahaku.go.jp)*
[2]*N28 E21-1-3, Higashi-ku, Sapporo, Hokkaido 065-0028, Japan*
[3]*Hobetsu Museum, 80-6 Hobetsu, Mukawa, Hokkaido 054-0211, Japan*

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Abstract. Twelve species of middle and late Campanian (Late Cretaceous) ammonoids, of which one is a newly described species, are reported from the Chinomigawa Formation of the Yezo Group in the Urakawa area, southern central Hokkaido, northern Japan. Furthermore, two ammonoid biozones, the *Metaplacenticeras subtilistriatum* and *Baculites subanceps* in ascending order, are recognized. Zircon radiometric ages reveal that the ages of tuffs immediately below the *B. subanceps* Zone are 75.1±0.9 Ma and 76.0±1.3 Ma respectively, which infer an early late Campanian age. Therefore, the *Metaplacenticeras subtilistriatum* and *Baculites subanceps* zones correlate with the upper middle Campanian and lower upper Campanian, respectively. The latter zone is probably a correlative of the lower part of the *Didymoceras* sp. Zone of the Izumi Group in Southwest Japan because of the discovery of the herein newly described species, *Didymoceras hidakense* Shigeta sp. nov. Since *Didymoceras* and *Baculites subanceps* flourished in other regions during late middle Campanian time, their occurrence in the Urakawa area suggests that they extended their geographic distribution from other areas to the Northwest Pacific region in early late Campanian time.

Key words: ammonoid, Campanian, Cretaceous, *Didymoceras*, Hokkaido, Urakawa

Introduction

The Cretaceous Yezo Group, widely distributed in a north-south direction in central Hokkaido and the West Sakhalin Mountains (Matsumoto, 1954; Vereshchagin, 1977; Shigeta and Maeda, 2005), exhibits a lateral change of litho- and biofacies, which infers an eastward-deepening setting for the "Yezo Basin" (Matsumoto and Okada, 1971; Tanaka, 1977). Various megafossils have been mainly reported from the western part (Matsumoto, 1954; Tanabe *et al*., 1977; Toshimitsu, 1988 etc.), which has led to the establishment of an accurate biostratigraphic zonation scheme for the Cretaceous based on the ammonoids and inoceramid bivalves (Toshimitsu *et al*., 1995). However, a complete succession of marine fossil assemblages spanning the Campanian–Maastrichtian interval has not yet been recorded for the western part of the Yezo Basin, because regressive deltaic facies become predominant in the uppermost part of the Cretaceous and megafossil occurrences are discontinuous and sporadic (Matsumoto, 1954; Maeda, 1986; Maeda *et al*., 2005). Therefore, the biostratigraphic framework for the uppermost Cretaceous remains ambiguous in the western part of the Yezo Basin.

In contrast, fossiliferous mudstone and sandy mudstone facies are still dominant in the uppermost part of the Cretaceous in the eastern part of the Yezo Basin. However, the complicated geologic structure in this particular area has precluded the establishment of a biostratigraphic scheme (Kanie, 1966; Obata *et al*., 1973; Matsumoto *et al*., 1980; Kawaguchi and Kanie, 1985; Ando *et al*., 2001). We recently discovered a continuous succession yielding Campanian megafossil assemblages in the Urakawa area, southern central Hokkaido, which is located in the southeastern part of the Yezo Basin (Figure 1).

In this paper, we document and discuss the middle and upper Campanian ammonoid zones in the Urakawa area, provide a zircon-based geochronology for the intercalated tuffs, and, finally, establish an up-to-date biostratigraphic zonation scheme for the Campanian in the Yezo Group.

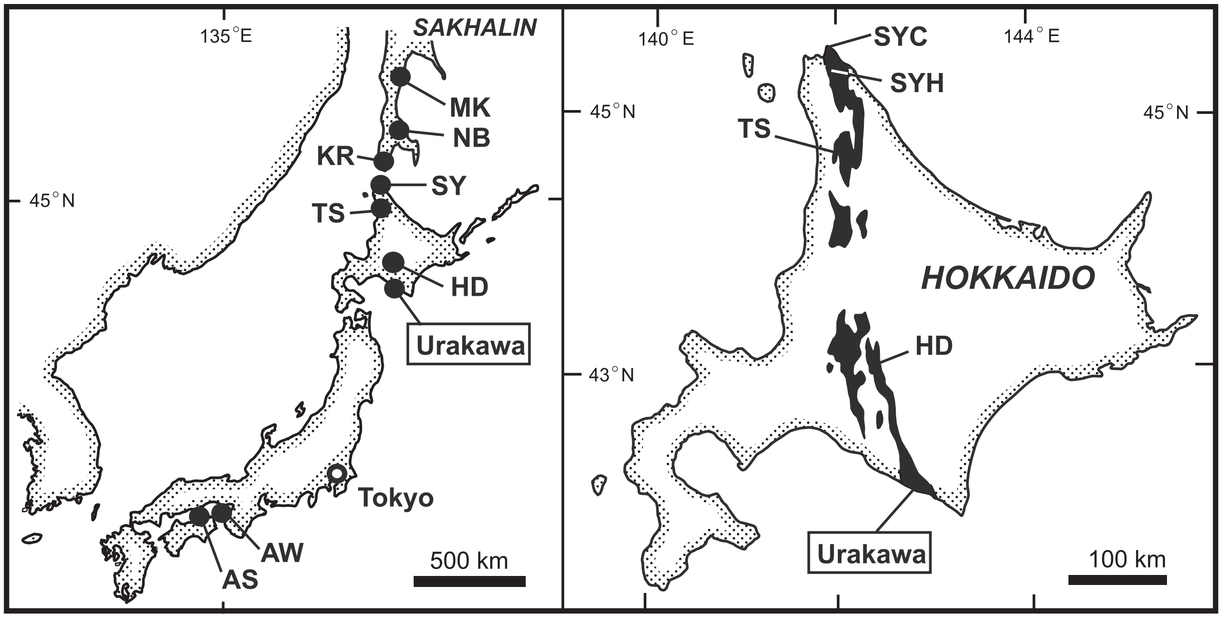

Figure 1. Index map showing distribution of Yezo Group (black areas) in Hokkaido, Japan, as well as fossil localities mentioned in the text. AS, Asan Mountains; AW, Awaji Island; HD, Hidaka; KR, Kura; MK, Makarov; NB, Naiba; SYC, Soya Cape; SYH, Soya Hill; TS, Teshio Mountains.

Biostratigraphic scheme of the Campanian in Japan

The biostratigraphic zonation scheme established for the Campanian in Japan is based mainly on ammonoids and inoceramid bivalves from the Yezo Group of Hokkaido and the Izumi Group of southwestern Japan (Toshimitsu *et al*., 1995). The Japanese Campanian is informally divided into a lower substage and an upper substage. Two ammonoid zones comprise the lower Campanian, the *Anapachydiscus naumanni* and *Canadoceras kossmati* zones in ascending order. The inoceramid bivalve *Inoceramus japonicus* Nagao and Matsumoto, 1940 is a representative of the lowermost Campanian (Toshimitsu, 1988) and inoceramid *Sphenoceramus schmidti* (Michael, 1899) is characteristics of the *Canadoceras kossmati* Zone. Three ammonoid zones comprise the upper Campanian, the *Metaplacenticeras subtilistriatum*-*Hoplitoplacenticeras monju* (or *Anapachydiscus fascicostatus*), *Didymoceras awajiense* (or *Patagiosites laevis*) and *Pravitoceras sigmoidale* (*Pachydiscus awajiensis*) in ascending order.

The Campanian is generally subdivided into three substages of approximately equal duration, but there are as yet no formal recommendations for primary markers or boundary stratotypes for substages (Ogg and Hinnov, 2012). According to Kodama (1990), who recognized four reverse magnetic chrons (C33r, C32r, C32.1r, C31r in ascending order) in the Izumi Group, the beds bearing *Sphenoceramus schmidti* correlate with the uppermost part of polarity chron C33r. Tsutsumi *et al.* (2014) recently reported that the age of the tuff in the C Formation (Tanaka and Teraoka, 1973) of the Himenoura Group, which contains *S. schmidti* in the Koshiki-jima area, southwestern Japan is 79.7±0.7 Ma (95% conf.). This evidence suggests that the *S. schmidti*-bearing beds, which are nearly equal to the *Canadoceras kossmati* Zone, correlate with the lower middle Campanian under the three-subdivision scheme for the Campanian. Kodama (1990) also revealed that the beds bearing *Metaplacenticeras subtilistriatum* correlate with the middle part of polarity chron C33n, i.e., the upper middle Campanian, and beds bearing *Didymoceras awajiense* correlate with polarity chron C32.2n, i.e., the upper upper Campanian.

The previously recognized ammonoid zones in Japan therefore correlate as follows under the three-subdivision scheme for the Campanian: the *Anapachydiscus naumanni* Zone with the lower Campanian, the *Canadoceras kossmati* Zone with the lower middle Campanian, the *Metaplacenticeras subtilistriatum*-*Hoplitoplacenticeras monju* Zone with the upper middle Campanian, and the *Didymoceras awajiense* and *Pravitoceras sigmoidale* zones with the upper upper Campanian. Morozumi

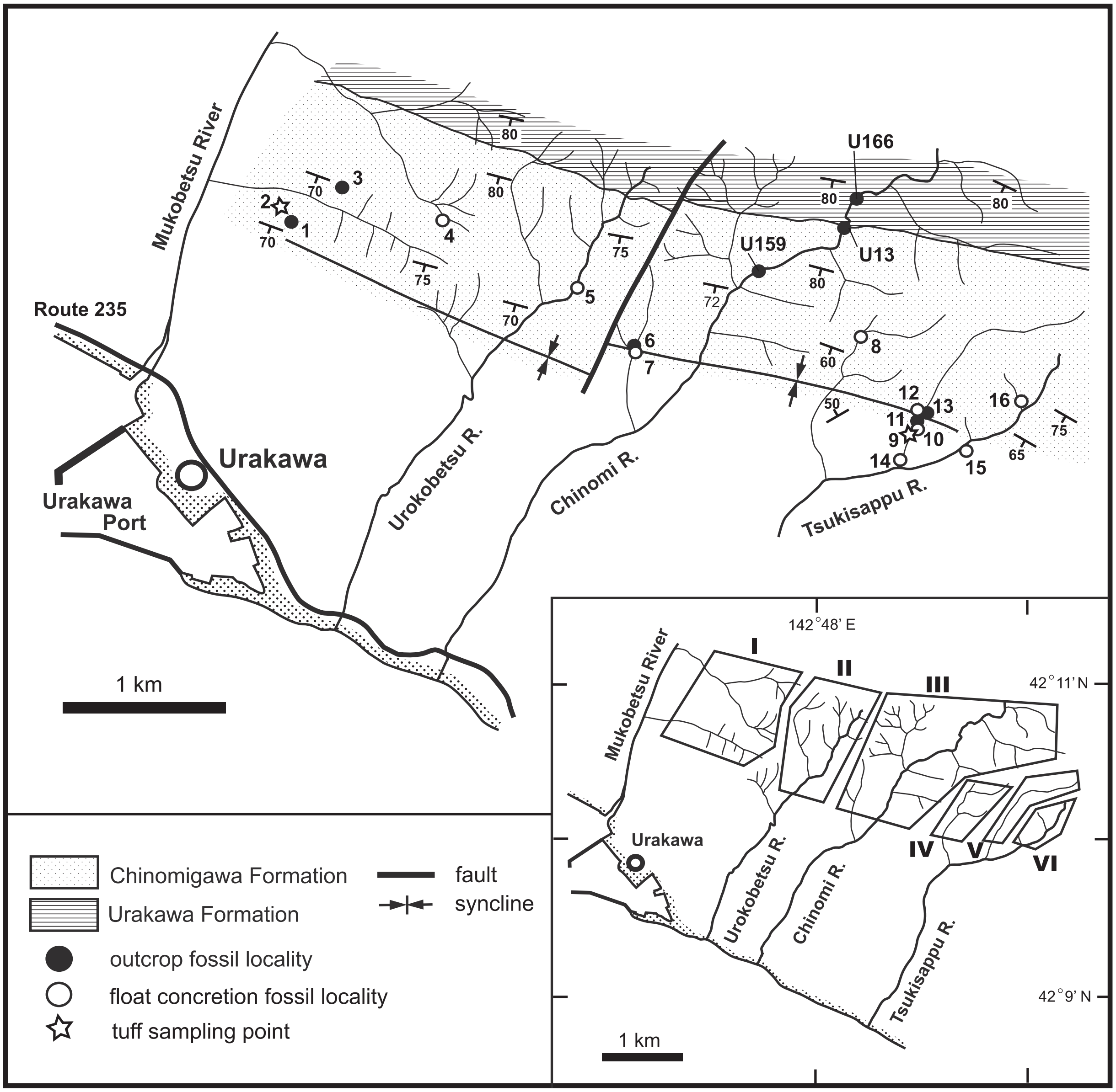

Figure 2. Geological map showing fossil and tuff localities and study sections (I through VI) in the Urakawa area, southern central Hokkaido, northern Japan. For details of localities with prefix "U" see Sakai and Kanie (1986, fig. 46).

(1985) proposed two additional zones between the *M. subtilistriatum* and *D. awajiense* zones in the Izumi Group, namely the *Baculites kotanii* and *Didymoceras* sp., in ascending order. According to Kodama (1990), the former zone probably correlates with the uppermost middle Campanian and the latter zone with the lower upper Campanian.

Notes on stratigraphy

The Yezo Group in the Urakawa area is complexly folded and faulted (Matsumoto, 1942; Kanie, 1966; Sakai and Kanie, 1986; Kanie and Sakai, 2002; Tamaki *et al*., 2008), but a continuous Upper Cretaceous succession is well exposed along the eastern tributaries of the lower course of the Mukobetsu River and the upper courses of the Urokobetsu, Chinomi and Tsukisappu rivers (Figure 2). The structure in this area consists of a syn-

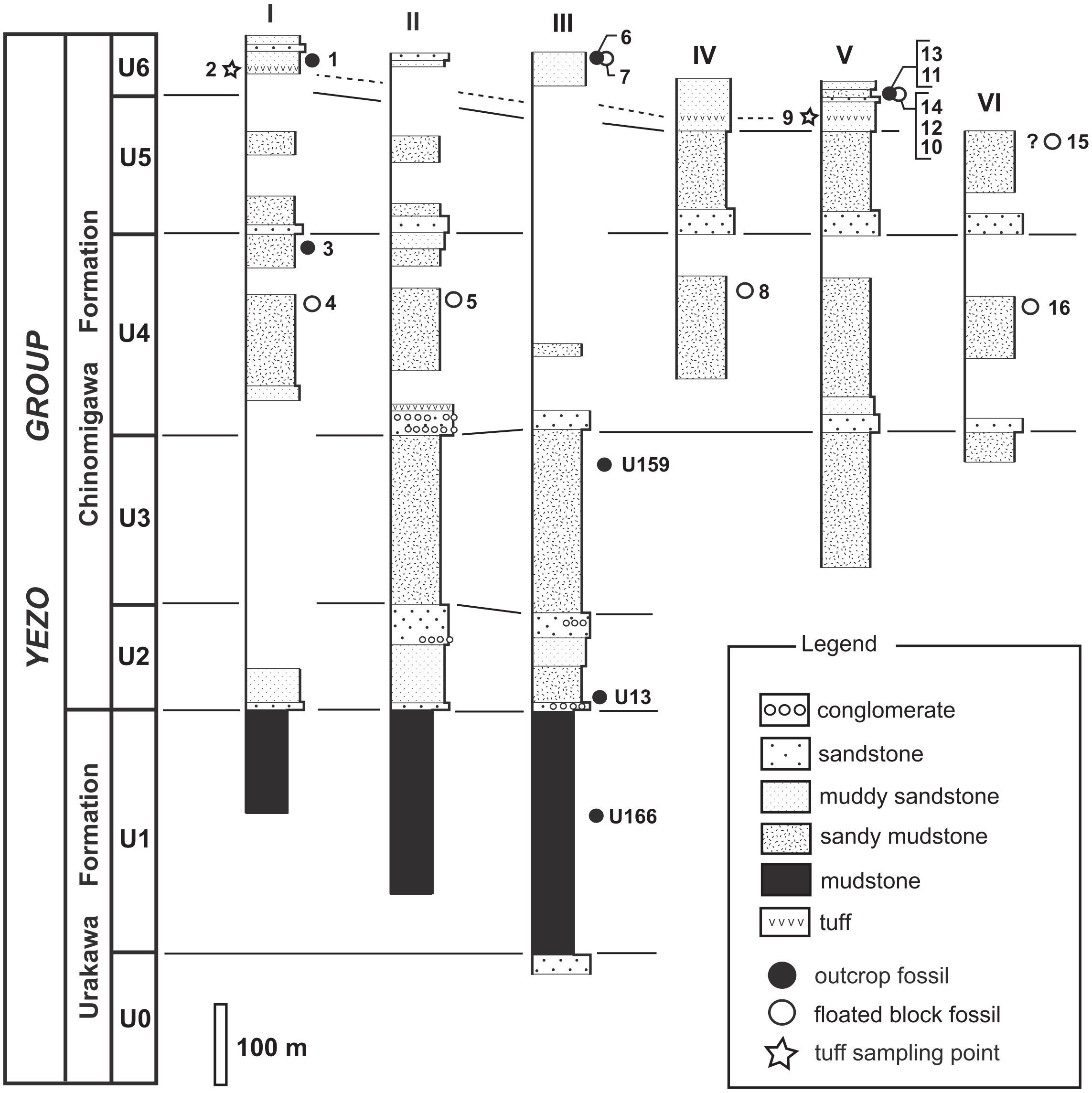

Figure 3. Columnar sections showing localities from which fossils were collected and tuff horizons in the Urakawa area. Lithologic units were defined by Kanie (1966).

cline with strata on the northern limb striking N60–80° westward and dipping 70–80° southward, while that of the southern limb strikes N60–70° eastward and dips 40–50° northward. These strata are divided into the Urakawa and Chinomigawa formations in ascending order (Kanie, 1966; Sakai and Kanie, 1986; Tamaki *et al*., 2008; Figure 3).

The 670–950 m thick Urakawa Formation consists predominately of mudstone and was subdivided into two lithologic units (U0, U1) by Kanie (1966). Unit U0, composed mainly of mudstone in association with tuff beds in the lower and middle parts and tuffaceous sandstone, contains the Coniacian index inoceramid bivalve *Inoceramus uwajimensis* Yehara, 1924 in the upper part (Kanie, 1966). Only the uppermost part of the unit is exposed along the Chinomi River (Sakai and Kanie, 1986). Unit U1, dominated by mudstone, contains the Santonian index inoceramid *Inoceramus amakusensis* Nagao and Matsumoto, 1940 in the middle part (Sakai and Kanie, 1986).

The 800–1600 m thick Chinomigawa Formation, composed mainly of sandy mudstone in association with conglomerate, sandstone and muddy sandstone, was divided into five lithologic units (U2–U6) by Kanie (1966). Unit U2, composed mainly of sandy mudstone in association with conglomerate, sandstone and muddy sandstone, contains the Campanian inoceramid *Sphenoceramus orientalis* (Sokolov, 1914) in the lower part (Kanie, 1966; Sakai and Kanie, 1986). Unit U3, dominated by sandy mudstone, includes the early middle Campanian index inoceramid *Sphenoceramus schmidti*, which is found in abundance, both in calcareous concretions and the host rock (Kanie, 1966; Sakai and Kanie, 1986). Unit U4 is composed of sandstone and conglomerate in the lowermost part and sandy mudstone in the main part. The late middle Campanian ammonoid *Metaplacenticeras subtilistriatum* (Jimbo, 1894) was collected by Kanie (1982) from a float concretion that most likely came from the middle part of the unit. Unit U5 consists mainly of sandy mudstone with a widely traceable, 30–35 m thick sandstone bed in the basal part. Unit U6 is composed mainly of muddy sandstone, in which a 50–100 cm thick white, vitric tuff bed is intercalated in the lower part.

Sample designation

The investigated area includes exposures in several river/tributary drainages, most of which occur on the northern limb of the above described syncline (Figure 2). Sampling points, designated as fossil locality numbers, actually represent different fossiliferous levels or tuff beds within the area, which may be either bedded outcrops or float concretions. These various localities are grouped (I through VI) according to the particular drainage in which they occur (Figure 2), and columnar sections for these drainage groups, including their various fossiliferous levels and/or tuff beds, are shown in Figure 3.

Radiometric ages of zircons in tuffs

Material.—Two tuff samples from Unit U6 of the Chinomigawa Formation were investigated for zircon-based radiometric age analyses. The first sample (designated as Loc. 2) was taken from a 50 cm thick white, vitric tuff bed, which outcrops in a quarry about 20 m below Loc. 1 (Figure 3). The other sample was collected at Loc. 9 from a 100 cm thick white, vitric tuff bed that outcrops about 25 m below Loc. 11 (Figure 3). Because only one tuff bed is observed in the lower part of Unit U6 in I, IV and V sections (Figure 3), the two tuff samples probably represent the same tuff bed.

Method.—The zircon grains were extracted by standard techniques: crushing, heavy liquid separation and handpicking. Then, the zircon grains, the zircon standard FC1 (^{206}Pb/^{238}U = 0.1859; Paces and Miller, 1993), 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 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 and 2. All errors are 1 sigma level. All zircons in the samples show rhythmic oscillatory and/or sector zoning on cathodoluminescence images (Figure 4), which is commonly observed in igneous zircons (e.g. Corfu *et al*., 2003), and their higher Th/U ratios (> 0.1) also support that they are igneous in origin (Williams and Claesson, 1987; Schiøtte *et al*., 1988; Kinny *et al*., 1990; Hoskin and Black, 2000). Figure 4 shows Tera-Wasserberg concordia diagrams and age distribution plots for all analyzed spots of samples from Loc. 2 and Loc. 9 by LA-ICP-MS. Most of the zircon age data for Loc. 2 and Loc. 9 cluster in the range 69–82 Ma and 67–83 Ma, and the weighted mean ages yield 75.1±0.9 Ma (MSWD = 1.7; 95% conf.) and 76.0±1.3 Ma (MSWD = 1.9; 95% conf.), respectively. The age is thought to indicate magmatism/deposition age of the tuff samples.

Fossil occurrences

Localities and horizons from which fossils were collected in Unit U4 to U6 of the Chinomigawa Formation in the Urakawa area are shown in Figures 2, 3 and 5. The

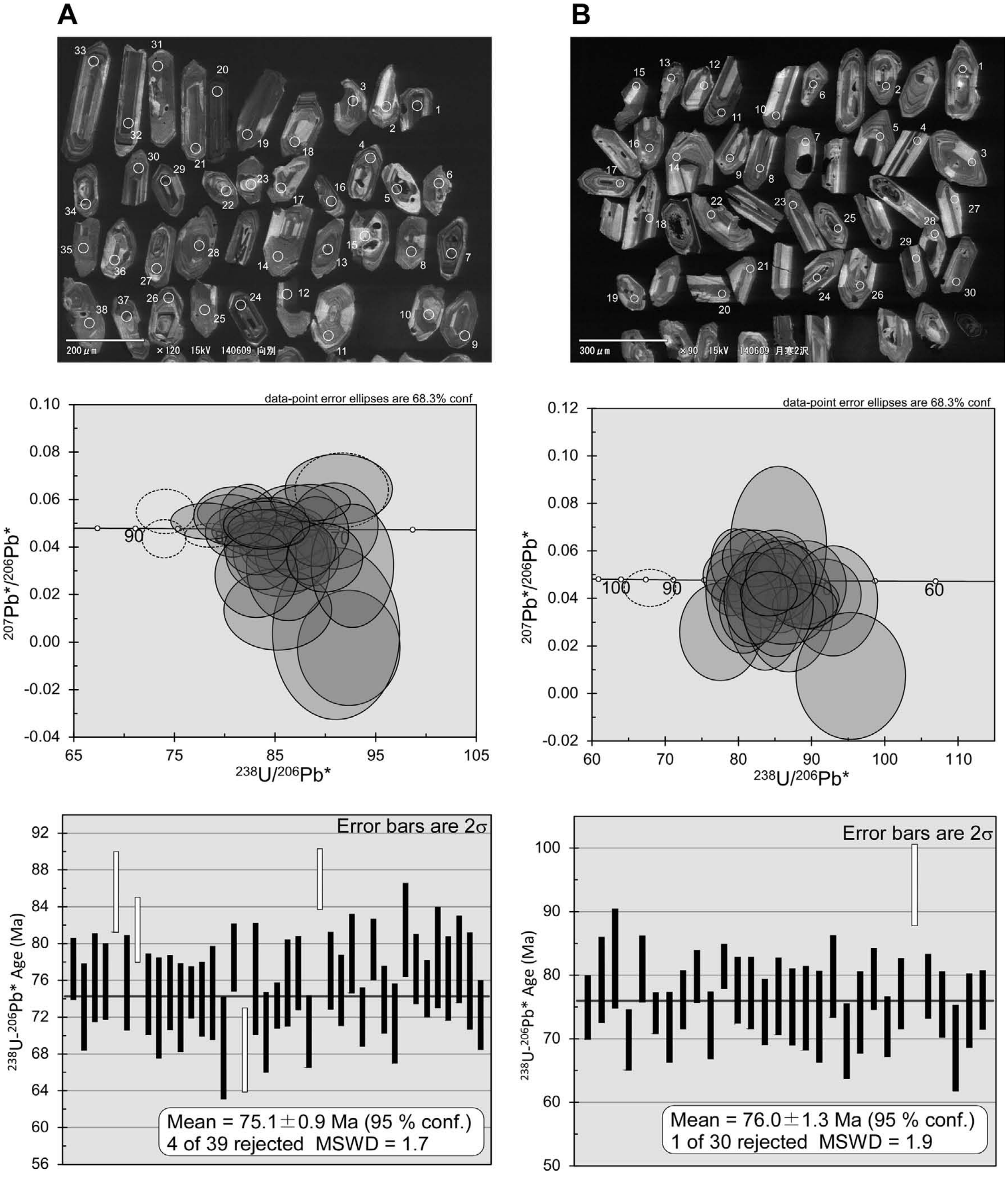

Figure 4. U–Pb zircon ages of tuff samples collected at Loc. 2 (**A**) and Loc. 9 (**B**). Upper, Cathodoluminescence image (CL) of zircon grains from the samples. Circles on the grain represent spots analyzed by LA-ICP-MS. Spots are 25 μm across. Middle, Tera-Wasserburg U–Pb concordia diagram of zircon sample. Lower, Age distribution plot of zircon sample. 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.

sandy mudstone in Unit U4 is fossiliferous and the following fossils were collected at Loc. 3 (42°11′3.4″N, 142°46′39.1″E): ammonoids—*Metaplacenticeras subtilistriatum*, *Saghalinites teshioensis* Matsumoto, 1984a, *Desmophyllites diphylloides* (Forbes, 1846), *Canadoceras multicostatum* Matsumoto, 1954, *Baculites* sp., and a bivalve—*Inoceramus* sp. *Metaplacenticeras subtilistriatum* was also collected from float concretions at Loc. 5

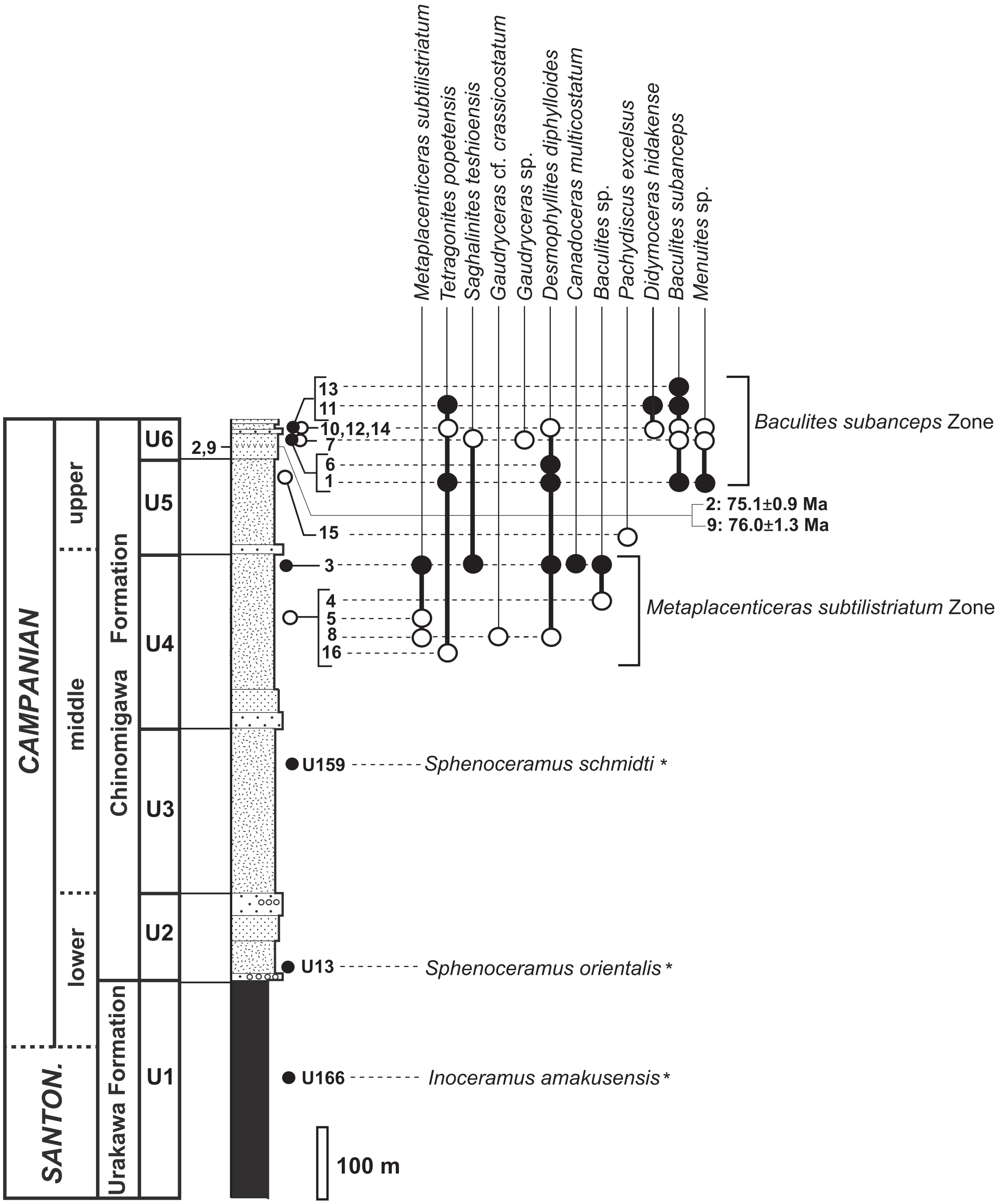

Figure 5. Stratigraphic occurrence of ammonoids and inoceramids, and U-Pb zircon ages of tuffs in the Chinomigawa Formation. Lithologic units were defined by Kanie (1966). See Figure 2 for legend. *, Sakai and Kanie (1986, table 6).

(42°10′43.3″N, 142°47′46.5″E) and Loc. 8 (42°10′32.6″N, 142°49′1.4″E). In addition, *Gaudryceras* cf. *crassicostatum* (Jimbo, 1894) and *D. diphylloides* were also collected from the concretion found at Loc. 8. *Baculites* sp. was collected from a float concretion at Loc. 4 (42°10′55.1″N, 142°47′11.3″E) and *Tetragonites popetensis* Yabe, 1903 was collected from another float concretion at Loc. 16 (42°10′19.3″N, 142°49′43.7″E). These concretions most likely came from the middle part of Unit U4, judging from their lithology and where they were found.

The muddy sandstone in Unit U6 is fossiliferous and the following fossils were collected at Loc. 1 (42°10′55.3″N, 142°46′32.2″E): ammonoids—*Baculites subanceps*, *Desmophyllites diphylloides*, *Tetragonites popetensis*, *Menuites* sp., a bivalve—*Inoceramus* sp. and an echinoid—“*Cidaris*” sp. *Desmophyllites diphylloides* was also collected from the muddy sandstone at Loc. 6 (42°10′30.6″N, 142°48′2.2″E), which is the same horizon as Loc. 1. Float concretions found at Loc. 7 (42°10′29.8″N, 142°48′1.5″E), which most likely came from the level represented by Loc. 6, contained *Saghalinites teshioensis*, *Gaudryceras* sp., *B. subanceps* and *Menuites* sp.

The sandy mudstone in the topmost part of Unit U6 is also fossiliferous and the following ammonoids were collected at Loc. 11 (42°10′16.5″N, 142°49′16.8″E): *Didymoceras hidakense* Shigeta sp. nov., *Baculites subanceps* Haughton, 1925, and *Tetragonites popetensis*. *Baculites subanceps* was also collected from the sandy mudstone at Loc. 13 (42°10′17.3″N, 142°49′17.8″E), which is the same horizon represented by Loc. 11 on the other limb of the syncline. A float concretion found at Loc. 12 (42°10′17.1″N, 142°49′17.3″E), which is intermediate to Loc. 11 and Loc. 13, contained *D. hidakense* sp. nov. and *B. subanceps*. An additional float concretion at Loc. 12 contained *Menuites* sp. A float concretion found at Loc. 10, which almost certainly came from the same horizon as Loc. 11, contained *Tetragonites popetensis* and *Desmophyllites diphylloides.* A float concretion found at Loc. 14 (42°10′8″N, 142°49′11.3″E) contained *B. subanceps*, and a fragment of a large *Pachydiscus excelsus* Matsumoto, 1979 specimen was found in a float concretion at Loc. 15 (42°9′6″N, 142°49′126.4″E).

Ammonoid biozones

Based on our detailed geological survey and carefully controlled bed by bed sampling, we recognized two Campanian ammonoid biozones, the *Metaplacenticeras subtilistriatum* and *Baculites subanceps* zones in ascending order, in Unit U4 to U6 of the Chinomigawa Formation (Figure 5). A zone represents a taxon-range zone of the index species, and consists of two or many more fossil beds. The boundary between such zones remains obscure because of intermittent fossil occurrence.

Metaplacenticeras subtilistriatum Zone

This zone is defined by the range of *Metaplacenticeras subtilistriatum*. The zone, which is well documented in Unit U4, is characterized by the association of *Saghalinites teshioensis*, *Desmophyllites diphylloides*, *Canadoceras multicostatum* and *Baculites* sp. at Loc. 3.

Remarks.—Identical assemblages are known from the Teshio Mountains and the Soya Cape and Soya Hill areas (Matsumoto, 1984a; Ando and Ando, 2002). Although *Metaplacenticeras subtilistriatum* has not yet been reported from Sakhalin, a similar assemblage is known from the Krasnoyarka Formation in the Naiba and Makarov areas (Kodama *et al*., 2002; Maeda *et al*., 2005). Beds containing this assemblage are a correlative of the *M. subtilistriatum* Zone in the Asan Mountains, Southwest Japan (Morozumi, 1985). A specimen collected from the Soya Cape area was assigned to *Baculites kotanii* by Matsumoto and Miyauchi (1984), which is a diagnostic ammonoid of the zone immediately above the *M. subtilistriatum* Zone in the Asan Mountains, but its identification is questionable because the specimen’s fragmental nature precludes a definitive assignment.

Baculites subanceps Zone

This zone contains the index ammonoid *Baculites subanceps* as well as *Tetragonites popetensis, Menuites* sp., *Didymoceras hidakense* sp. nov., *Desmophyllites diphylloides*, *Saghalinites teshioensis* and *Gaudryceras* sp. The zone is well documented at Locs. 1, 6, 11 and 13 in Unit U6.

Remarks.—Morozumi (1985) proposed a new ammonoid zone with *Didymoceras* sp. as the index fossil, between the *Baculites kotanii* and *Didymoceras awajiense* zones in the Asan Mountains, but according to Tsujino (2004), Morozumi (2007), Nishiyama *et al.* (2009), Ishida *et al.* (2010) and Y. Tsujino personal communication in 2014, *Didymoceras* sp., which was called as *Didymoceras* sp. A by Morozumi (2007), is restricted to the lower part of the *Didymoceras* sp. Zone and a *Bostrychoceras*-like ammonoid occurs in the upper part of the zone. Because *D. hidakense* sp. nov. closely resembles *Didymoceras* sp. (or *Didymoceras* sp. A), the *Baculites subanceps* Zone is probably a correlative of the lower part of the *Didymoceras* sp. Zone. The *Menuites* sp.-bearing beds also occur in the Krasnoyarka Formation in the Kura area (Shigeta *et al*., 1999) and in the Ichannai Formation in the Soya Hill area (Ando and Ando, 2002), but *B. subanceps* and *D. hidakense* sp. nov have not yet been collected from either formation.

Discussion

Biostratigraphic implications

Although *Baculites subanceps* is known from the late middle to early late Campanian of westernmost North America (Ward *et al*., 2012), most ammonoids described herein are endemic species restricted to the northwestern

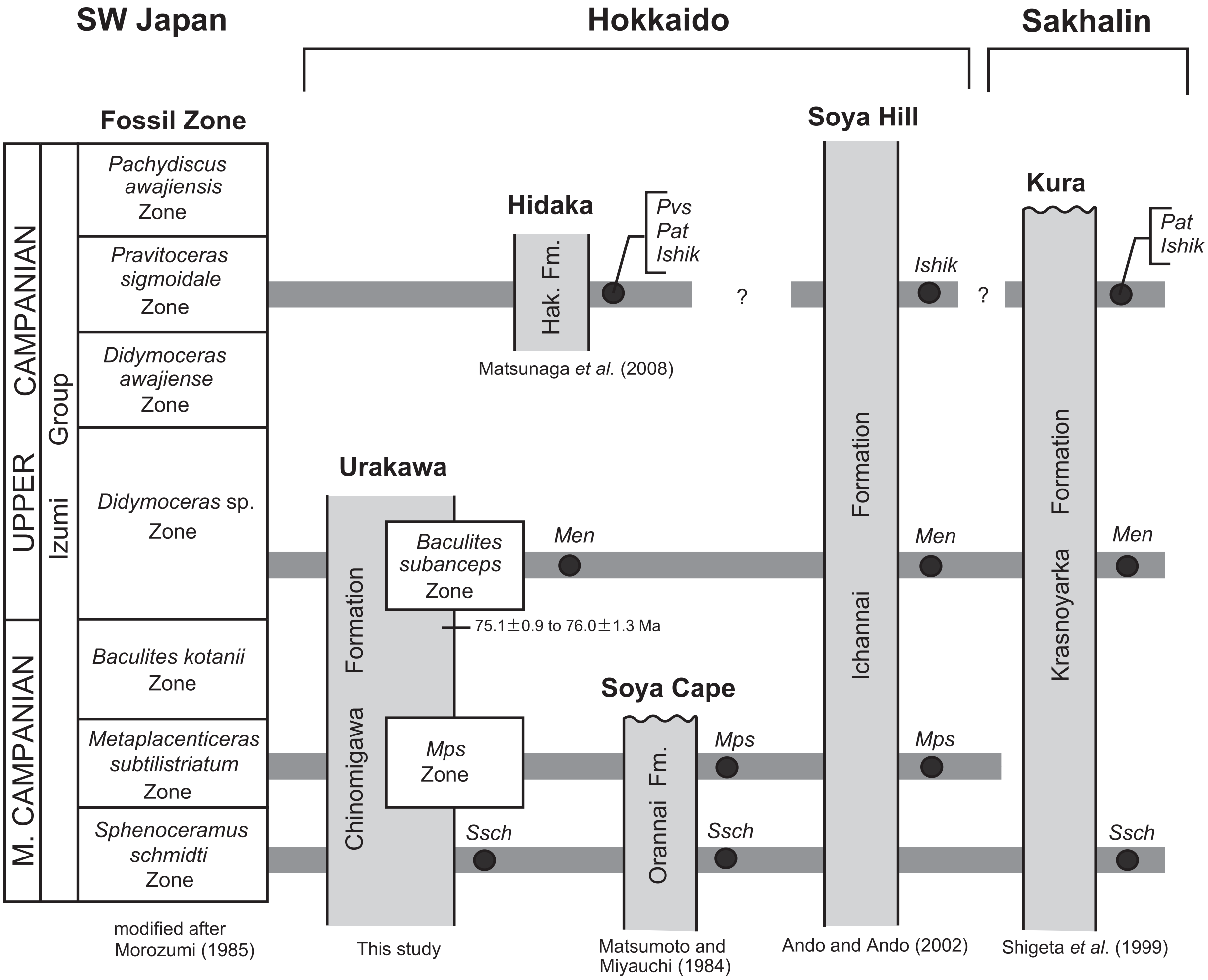

Figure 6. Diagram showing biostratigraphic correlation between middle and upper Campanian deposits in Southwest Japan (left), Hokkaido (center) and Sakhalin (right). Hak, Hakobuchi; *Ishik*, *Inoceramus shikotanensis*; *Men*, *Menuites* sp.; *Mps*, *Metaplacenticeras subtilistriatum*; *Pat*, *Patagiosites alaskensis*; *Pvs*, *Pravitoceras sigmoidale*; *Ssch*, *Sphenoceramus schmidti*.

Pacific area, and thus the lack of common zonal-index taxa makes it difficult to directly correlate these local faunas with other global regions. Zircon geochronology reveals that the age of the tuff immediately below the *Baculites subanceps* Zone is 76.0±1.3 Ma to 75.1±0.9 Ma, which infer an early late Campanian age (Figure 6). Therefore, the *Metaplacenticeras subtilistriatum* and *Baculites subanceps* zones can be correlated with the upper middle Campanian and lower upper Campanian, respectively. The former correlation is also supported by the magnetostratigraphy of the Izumi Group by Kodama (1990), who revealed that the beds containing *M. subtilistriatum* correlate with the middle part of polarity chron C33n, i.e., the upper middle Campanian. Although the occurrence of the *B. subanceps* Zone in the upper middle Campanian is still uncertain in the northwestern Pacific area, *B. subanceps* is a good index taxon for biostratigraphic correlation of the lower upper Campanian on both sides of the North Pacific.

Tamaki *et al*. (2008) studied paleomagnetic polarities along the Chinomi River in the Urakawa area and concluded that Unit U3 and U4 correlate with polarity chrons from C33r through C32r, i.e., the middle to upper Campanian. This correlation is partly supported by the occurrence of the early middle Campanian index inoceramid *Sphenoceramus schmidti* in Unit U3, but the occurrence of the late middle Campanian ammonoid *Metaplacenticeras subtilistriatum* in Unit U4 does not agree with the correlation. Because strata of the unit are not well exposed along the Chinomi River and Tamaki *et al*. (2008) identified the magnetic polarity based on only one horizon, the accuracy of the magnetostratigraphic correlation of Unit U4 is debatable.

Kodama *et al.* (2000) recognized 13 magnetozones in the Upper Cretaceous sedimentary strata in the Naiba area, southern Sakhalin, and concluded that the geomagnetic polarity sequence can be correlated with polarity chrons from C34n through C30n. According to Kodama *et al.* (2000), the *Sphenoceramus schmidti*-bearing beds are correlated with the bottom of polarity chron C32r, i.e., the middle upper Campanian. This assignment, however, disagrees with our result from the Urakawa area, where the *S. schmidti* Zone clearly occurs below the *Metaplacenticeras subtilistriatum* Zone in the upper middle Campanian (Figure 6). Because strata just below the *S. schmidti* Zone are not well exposed in the Naiba area, the accuracy of the magnetostratigraphic correlation of this interval is debatable (Kodama *et al.*, 2002).

Aspects of middle and upper Campanian ammonoid faunas

Didymoceras Hyatt, 1894 is known from the Campanian worldwide, but it is best known from the Western Interior of North America (Kennedy *et al.*, 2000), where each ammonoid zone has been dated by K–Ar and/or other radioisotope methods (Obradovich and Cobban, 1975; Ogg and Hinnov, 2012). *Didymoceras* is found in zones ranging from the middle middle Campanian *Baculites gregoryensis* Zone to the middle upper Campanian *Didymoceras cheyennense* Zone (Kennedy *et al.*, 2000). In the Northwest Pacific region, the early late Campanian herein newly described *Didymoceras hidakense* sp. nov. and most likely *Didymoceras* sp. (or *Didymoceras* sp. A) of the Asan Mountains are the oldest known species of *Didymoceras* in the region. This evidence suggests that *Didymoceras* extended its geographical distribution from other regions to the Northwest Pacific region in early late Campanian time.

Baculites subanceps occurs in Egypt (Luger and Gröschke, 1989) and Angola (Howarth, 1965), but it is best known from the upper middle to lower upper Campanian of the western coastal region of North America, where the biostratigraphy and magnetostratigraphy of the Campanian–Maastrichtian was recently integrated (Ward *et al.*, 2012). Although its ancestry and evolution are unknown, its occurrence in the Northwest Pacific region suggests that *B. subanceps* extended its geographical distribution from the other regions to the Northwest Pacific region in early late Campanian time.

A similar phenomenon is known for *Pseudophyllites indra* (Forbes, 1846), which extended its geographical distribution from the Indian region to the North Pacific region in late middle Campanian time (Shigeta, 1992). Although the migration process has not yet been studied in detail, *Desmophyllites*, *Saghalinites* and *Metaplacenticeras* probably originated in other regions and extended their geographical distribution to the North Pacific region during late middle Campanian time as well. In contrast, *Tetragonites popetensis* is widely distributed in Santonian to Maastrichtian successions throughout Hokkaido and Sakhalin (Shigeta, 1989; Maeda *et al.*, 2005). In actuality, this may be one of the indigenous ammonoids of the Northwest Pacific region.

This evidence suggests that the middle and late Campanian ammonoid faunas of the Northwest Pacific region may have been formed by adding "foreign taxa" that migrated from the other regions to the existing indigenous ammonoids, which themselves may also have included descendants of earlier "foreign taxa".

Paleontological description

(by Y. Shigeta)

Morphological terms are those used in Arkell (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* = whorl width.

Institution abbreviations.—BMNH = Natural History Museum, London; CAS = California Academy of Sciences, San Francisco; GK = Department of Earth and Planetary Sciences, Kyushu University, Fukuoka; GLKU = Geological Laboratory, Kagawa University, Takamatsu; HMG = Hobetsu Museum, Mukawa; NMNS = National Museum of Nature and Science, Tsukuba; SAM = South African Museum; UMUT = University Museum, University of Tokyo; USNM = United State National Museum, Washington, D. C.

Suborder Lytoceratina Hyatt, 1889
Superfamily Tetragonitoidea Hyatt, 1900
Family Tetragonitidae Hyatt, 1900
Genus ***Saghalinites*** Wright and Matsumoto, 1954

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

Saghalinites teshioensis Matsumoto, 1984a

Figure 7A–C

Saghalinites teshioensis Matsumoto, 1984a, p. 27, pl. 9, figs. 1–3; Matsumoto, 1988, p. 179, pl. 51, fig. 1; Maeda *et al.*, 2005, p. 90, fig. 45; Takahashi *et al.*, 2007, pl. 5, figs. 6, 7.

Holotype.—GK. H5971, figured by Matsumoto (1984a, p. 27, pl. 9, fig. 1), from the upper Campanian of the

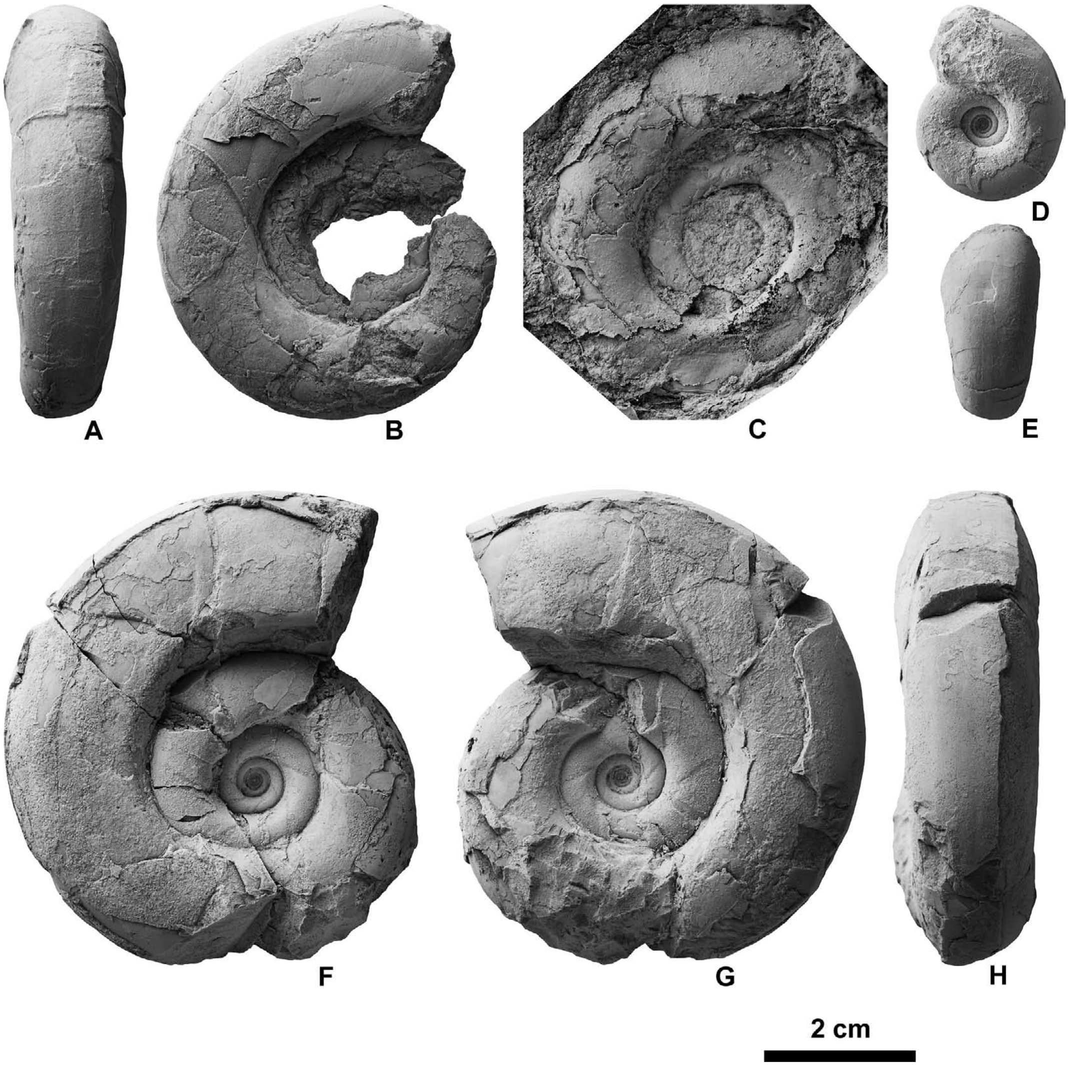

Figure 7. *Saghalinites* and *Tetragonites* from the Chinomigawa Formation. **A–C,** *Saghalinites teshioensis* Matsumoto, 1984a; A, B, HMG-1650 from Loc. 7; A, ventral view; B, left lateral view; C, NMNS PM35016 from Loc. 3, left lateral view (rubber cast of outer mold); **D–H,** *Tetragonites popetensis* Yabe, 1903; D, E, NMNS PM35017 from Loc. 1; D, right lateral view; E, ventral view; F–H, NMNS PM35018 from Loc. 16; F, left lateral view; G, right lateral view; H, ventral view.

Uttsu River area in the Teshio Mountains, northern Hokkaido.

Material examined.—One specimen, HMG-1650, from a float concretion found at Loc. 7 by Yukinobu Yoshikawa (Niikappu, Hokkaido) and one specimen, NMNS PM35016, from Loc. 3.

Description.—Very evolute shell with rounded whorl section, low arched venter, rounded ventral shoulders, and slightly convex flanks with maximum whorl width at mid-flank. Umbilicus fairly wide with 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 over venter with shallow concave arch.

Measurements.—Taken at D = 55.7 mm of HMG-1650, U = 26.4 mm, H = 15.3 mm, W = 15.8 mm, U/D = 0.47, W/H = 1.03.

Remarks.—*Saghalinites teshioensis* is very similar to *S. maclurei* (White, 1889) from the upper Campanian of Washington State in that it has a very evolute shell with a rounded whorl section. The holotype of *S. maclurei* (USNM 20085) consists of a portion of the body chamber and crushed inner whorls. Although the ontogeny and intraspecific shell variation of *S. teshioensis* have been well studied by Matsumoto (1984a), relatively little is known of *S. maclurei*. Haggart (1989) attributed two specimens from British Columbia and Washington State to *S. maclurei*, but they are actually assignable to *Tetragonites popetensis*. Presently, there is not yet enough material to conclude that both species are conspecific.

Occurrence.—Described specimens were collected from the *Metaplacenticeras subtilistriatum* Zone of the upper middle Campanian and the *Baculites subanceps* Zone of the lower upper Campanian in the Chinomigawa Formation, Urakawa area. *Saghalinites teshioensis* occurs in the *Schluterella kawadai*-bearing beds in the Teshio Mountains and Soya Cape area, Hokkaido (Matsumoto, 1984a, b). It is also known from the Naiba and Makarov areas, southern Sakhalin (Matsumoto, 1988; Maeda *et al.,* 2005).

Genus ***Tetragonites*** Kossmat, 1895

Type species.—*Ammonites timotheanus* Pictet, 1847.

Tetragonites popetensis Yabe, 1903

Figures 7D–H, 8D, E, 24A, B

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.

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, figs. 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.

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, NMNS PM35017, from Loc. 1, one specimen, NMNS PM35018, from a float concretion found at Loc. 16, one specimen, HMG-1651, from Loc. 11, and one specimen, HMG-1652, from a float concretion found at Loc. 10.

Description.—Moderately evolute, fairly depressed shell (early growth stages) to fairly compressed shell (later growth stages) with subquadrate whorl section, broadly rounded venter, rounded ventral shoulders, slightly convex flanks with maximum whorl width near umbilical shoulder. Umbilicus moderately wide (early growth stages) to fairly wide (later growth stages) 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 over venter with shallow concave arch.

Measurements.—Taken at D = 19.7 mm of NMNS PM35017, U = 6.3 mm, H = 8.1 mm, W = 10.0 mm, U/D = 0.32, W/H = 1.23, and at D = 65.0 mm of NMNS PM35018, U = 27.0 mm, H = 21.0 mm, W = 19.5 mm, U/D = 0.42, W/H = 0.93.

Remarks.—Shigeta (1989) demonstrated that *Tetragonites glabrus* exhibits a remarkable variation in shell form and regarded *T. popetensis* as a synonym of *T. glabrus*. However, Shigeta and Maeda in Maeda *et al.* (2005, p. 88) pointed out that Shigeta's sample (AW1001A) was heterogeneous and consisted of specimens of both *Pseudophyllites indra* (Forbes, 1846) and *T. popetensis*. Shigeta's specimens with a small umbilicus that he assigned to *T. glabrus* in 1989 are actually specimens of *P. indra*. Therefore, *T. popetensis* should be regard as an independent species.

Haggart (1989, pl. 8.1, figs. 7–11) and Zonova *et al.* (1993, pl. 209, figs. 3, 4) assigned some specimens to *Saghalinites*, but their whorl section and mode of coiling enable us to assign them to *Tetragonites popetensis*. A specimen described as *T. 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 also assignable to *T. popetensis*. The holotype of *Lytoceras* (*Tetragonites*) *henleyense* shows a similar shell shape and ornamentation to *T. popetensis*, and is probably conspecific. However, it is necessary to study the variation in shell form of *L.* (*T.*) *henleyense* based on a large sample.

Occurrence.—Described specimens were collected from the *Baculites subanceps* Zone of the lower upper Campanian and a float concretion that probably came from the *Metaplacenticeras subtilistriatum* Zone of the upper middle Campanian in the Chinomigawa Formation, Urakawa area. *Tetragonites popetensis* is abundant from the Santonian to the lower Maastrichtian in Hokkaido and Sakhalin (Shigeta, 1989; Maeda *et al.*, 2005) and from the middle Campanian in Wakayama, southwestern Japan (Misaki and Maeda, 2009). This species is also known from the Coniacian to Campanian in California, Washington and British Columbia (Usher, 1952; Anderson, 1958; Haggart, 1989).

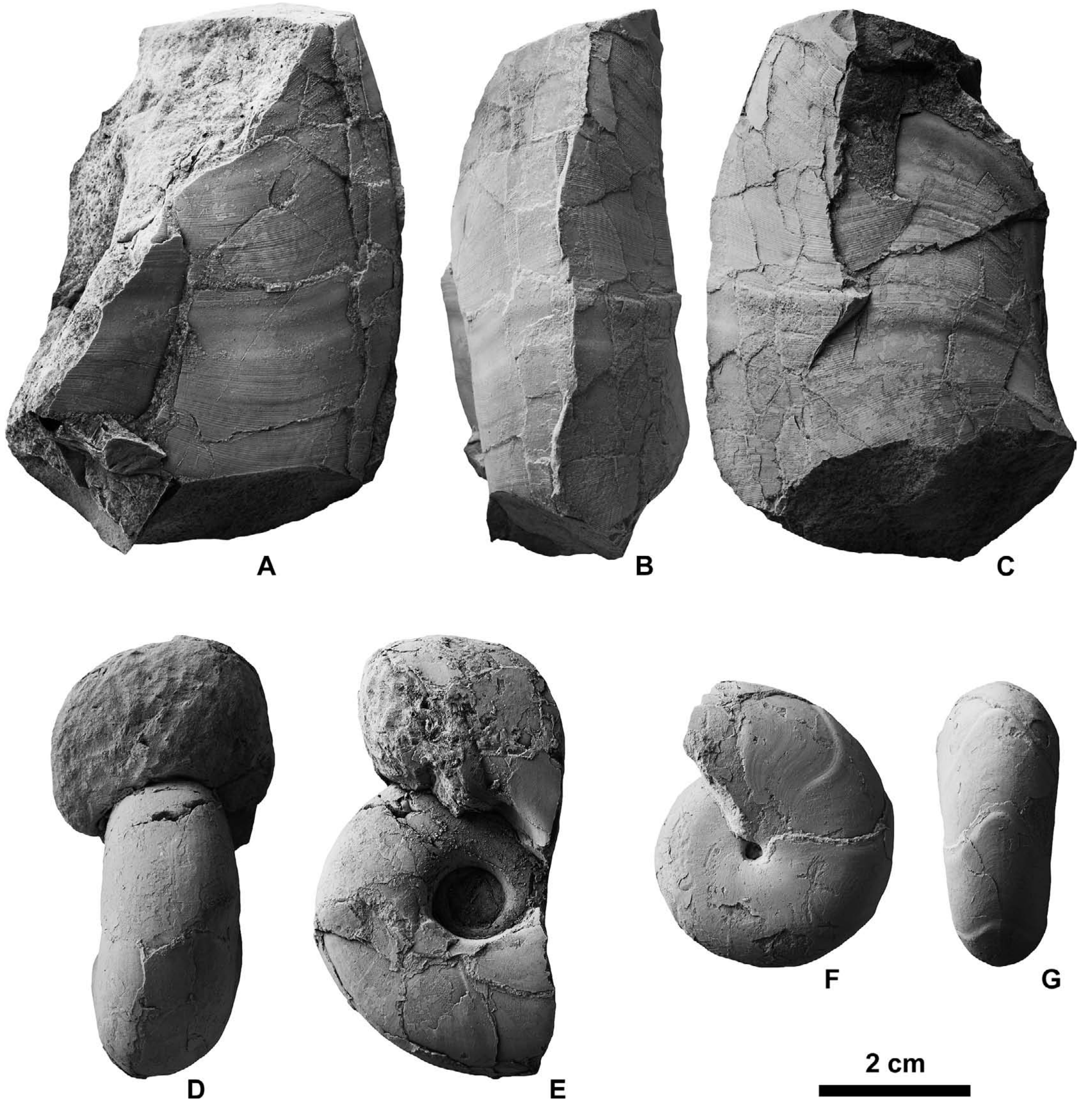

Figure 8. *Gaudryceras*, *Tetragonites* and *Desmophyllites* from the Chinomigawa Formation. **A–C,** *Gaudryceras* cf. *crassicostatum* (Jimbo, 1894), NMNS PM35019 from Loc. 8; A, right lateral view; B, ventral view; C, left lateral view.; **D, E,** *Tetragonites popetensis* Yabe, 1903, HMG-1652 from Loc. 10; D, apertural view; E, right lateral view; **F, G,** *Desmophyllites diphylloides* (Forbes, 1846), HMG-1655 from Loc. 10; F, right lateral view; G, ventral view.

Family Gaudryceratidae Spath, 1927

Genus ***Gaudryceras*** Grossouvre, 1894

Type species.—*Ammonites mitis* Hauer, 1866.

Gaudryceras cf. ***crassicostatum*** (Jimbo, 1894)

Figure 8A–C

cf. *Lytoceras crassicostatum* Jimbo, 1894, p. 182, pl. 22, fig. 7.

Material examined.—One specimen consisting of a body chamber fragment, NMNS PM35019, from a float concretion found at Loc. 8.

Description.—Fairly large shell with elliptical cross section, very fine, dense lirae and collar-like ribs, which arise at umbilical seam and become slightly sigmoidal before passing over venter with a broad convex arch.

Remarks.—The pre-adult shell of *Gaudryceras crassicostatum* is very similar to *G. striatum* (Jimbo, 1894) in having fine lirae and collar-like ribs, but is distinguished from the latter by having numerous, much finer lirae on the venter. Although the described specimen is only a fragment, its distinctive features enable me to assign it with reasonable confidence to *G. crassicostatum.*

Occurrence.—Described specimen was collected from a float concretion that also contained *Metaplacenticeras subtilistriatum*, the index ammonoid of the upper middle Campanian. *Gaudryceras crassicostatum* is known from the late middle Campanian in the Soya Cape area of Hokkaido and from several areas in southern Sakhalin (Matsumoto *et al*., 1985; Shigeta *et al*., 1999; Maeda *et al*., 2005). Matsumoto (1984c) reported a well preserved specimen of this species from a float concretion in the upper course of the Tsukisappu River, Urakawa.

Gaudryceras sp.

Figure 9

Material examined.—One specimen, HMG-1653, from a float concretion found at Loc. 7 by Yukinobu Yoshikawa (Niikappu, Hokkaido).

Description.—Early whorls (up to 50 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. Flanks and venter covered by extremely fine, dense lirae that result from branching and intercalation of main lirae, which occur on umbilical shoulder to lower flank. Each whorl has periodic (4–5 per whorl), rounded, collar-like ribs, running parallel to lirae, that are followed immediately by shallow constrictions.

Middle and later whorls (over 50 mm in diameter): As shell grows, whorl section becomes more compressed, while umbilical width becomes progressively smaller. Lirae gradually develop into slightly more distant, narrowly raised ribs, which become finer and denser further out on flank because of additional branching and intercalation, resulting in very fine, dense ribs on venter. Large, prominent collar-like ribs and constrictions (4–5 per whorl) are themselves covered with very fine ribs. Suture line not visible.

Measurements.—Taken at $D = 90.0$ mm of HMG-1653, $U = 38.9$ mm, $H = 29.6$ mm, $W = 24.0$ mm, $U/D = 0.43$, $W/H = 0.81$.

Remarks.—The described specimen closely resembles the middle whorls of late middle Campanian *Gaudryceras crassicostatum* (Jimbo, 1894) and Maastrichtian *G. hamanakense* Matsumoto and Yoshida, 1979 from Hokkaido and Sakhalin, but differs by having much coarser and more distant ribs. *Gaudryceras crassicostatum* has strong major ribs separated by wide interspaces on its later whorls (Matsumoto, 1984c; Matsumoto *et al*., 1985; Maeda *et al*., 2005). The middle whorls of Maastrichtian *G. tombetsense* Matsumoto, 1984c from the northwestern Pacific area also resemble the described specimen, but as the shell grows, its ribs become much coarser and more distant than the described specimen (Maeda *et al*., 2005; Shigeta *et al*., 2012). *Gaudryceras* sp. is somewhat similar to early middle Campanian *G. striatum* (Jimbo, 1894) in having very fine dense, slightly sinuous ribs (Maeda *et al*., 2005), but differs by the extremely fine, dense ribs covering its flanks and venter, distinctly coarser ribs in the area of the umbilical shoulder, and a more evolute, compressed shell.

The described specimen likely represents a new species, but I hesitate to propose a new specific name because it probably is only a pre-adult shell. As the shell matures, the collar-like ribs in most species of *Gaudryceras* become more frequent, (Matsumoto, 1995; Maeda *et al*., 2005), but such a rib pattern is not observed on the described specimen, thus suggesting a pre-adult stage.

Occurrence.—Described specimen was collected from a float concretion that probably came from the *Baculites subanceps* Zone of the lower upper Campanian in the Chinomigawa Formation, Urakawa area.

Suborder Ammonitina Hyatt, 1889
Superfamily Desmoceratoidea Zittel, 1895
Family Desmoceratidae Zittel, 1895
Genus ***Desmophyllites*** Spath, 1929

Type species.—*Desmoceras larteti* Seunes, 1891.

Desmophyllites diphylloides (Forbes, 1846)

Figures 8F, G, 10, 11

Ammonites diphylloides Forbes, 1846, p. 105, pl. 8, fig. 8.

Desmophyllites diphylloides (Forbes). Matsumoto and Obata, 1955, p. 121, pl. 24, figs. 1, 5, pl. 30, fig. 1; Matsumoto, 1959, p. 9, pl. 3, fig. 3, text-fig. 2; Howarth, 1965, p. 388, pl. 11, fig. 3; Matsumoto, 1984a, p. 12, pl. 1, fig. 2; Henderson and McNamara, 1985, p. 54, pl. 4, figs. 1–4; Haggart, 1989, p. 193, pl. 8.4, figs. 1–13; Kennedy and Henderson, 1992, p. 405, pl. 6, figs. 1–9, pl. 16, figs. 1–3, 7, 8, pl. 17, figs. 4–7, text-fig. 3F; Alabushev and Wiedmann, 1997, p. 22, pl. 6, figs. 3–5; Ando and Ando, 2002, pl. 3, fig. 4; Ifrim *et al*., 2004, p. 1594, text-fig. 9F; Maeda *et al*., 2005, p. 104, figs. 53.7–53.14; Takahashi *et al*., 2007, pl. 5, figs. 4, 5; Misaki and Maeda, 2009, fig. 8I–L.

non Desmophyllites diphylloides (Forbes). Matsumoto and Obata, 1955, p. 121, pl. 24, figs. 2–4, text-fig. 1.

Lectotype.—Specimen designated by Matsumoto and Obata (1955, p. 122), BMNH C22682, is the original of Forbes (1846, p. 105, pl. 8, fig. 8) from the Maastrichtian? of Pondicherry, southern India.

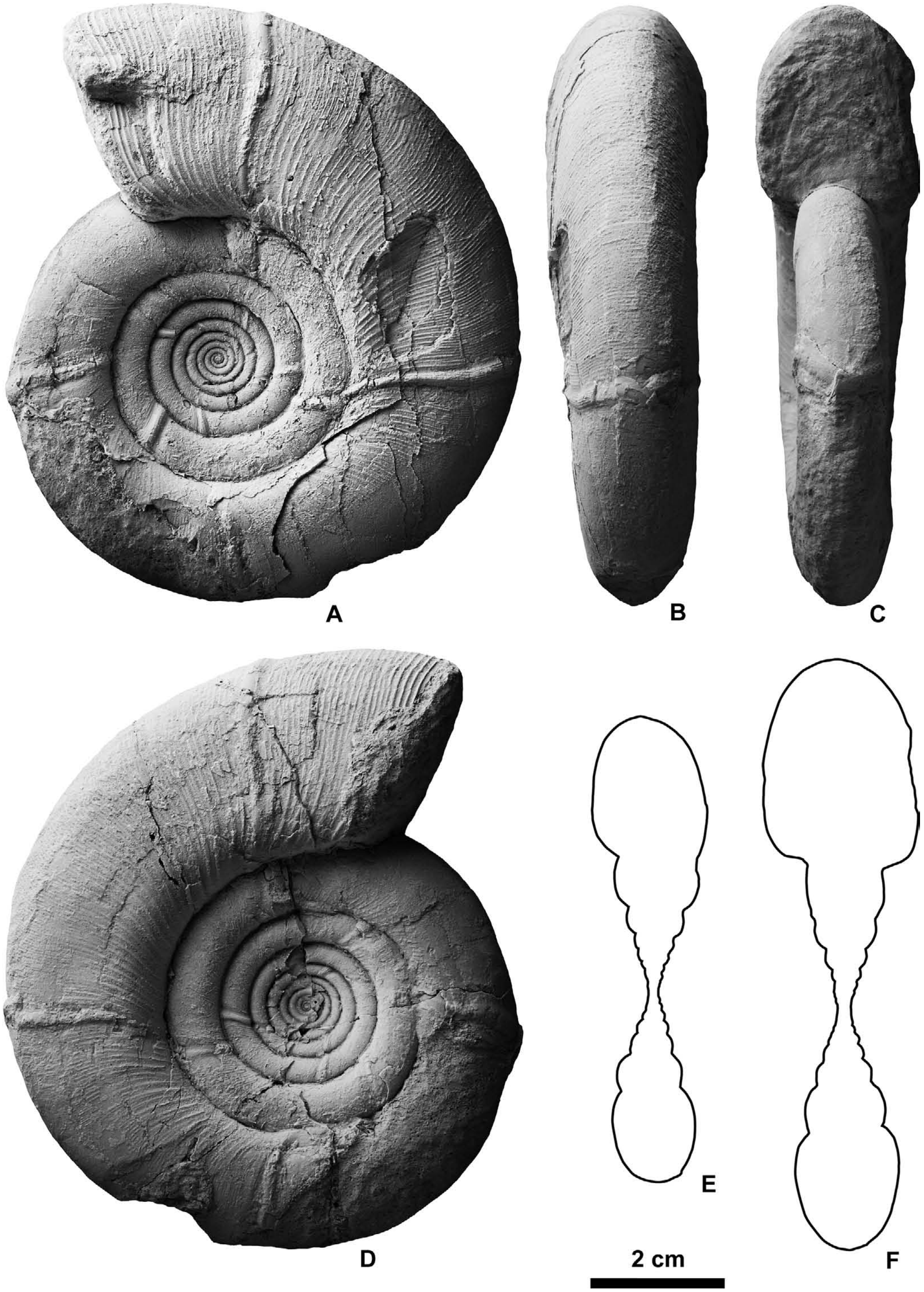

Figure 9. *Gaudryceras* sp., HMG-1653, from Loc. 7 in the Chinomigawa Formation. **A,** right lateral view; **B,** ventral view; **C,** apertural view; **D,** left lateral view; **E,** whorl cross section at D = 70.0 mm; **F,** whorl cross section at D = 89.0 mm.

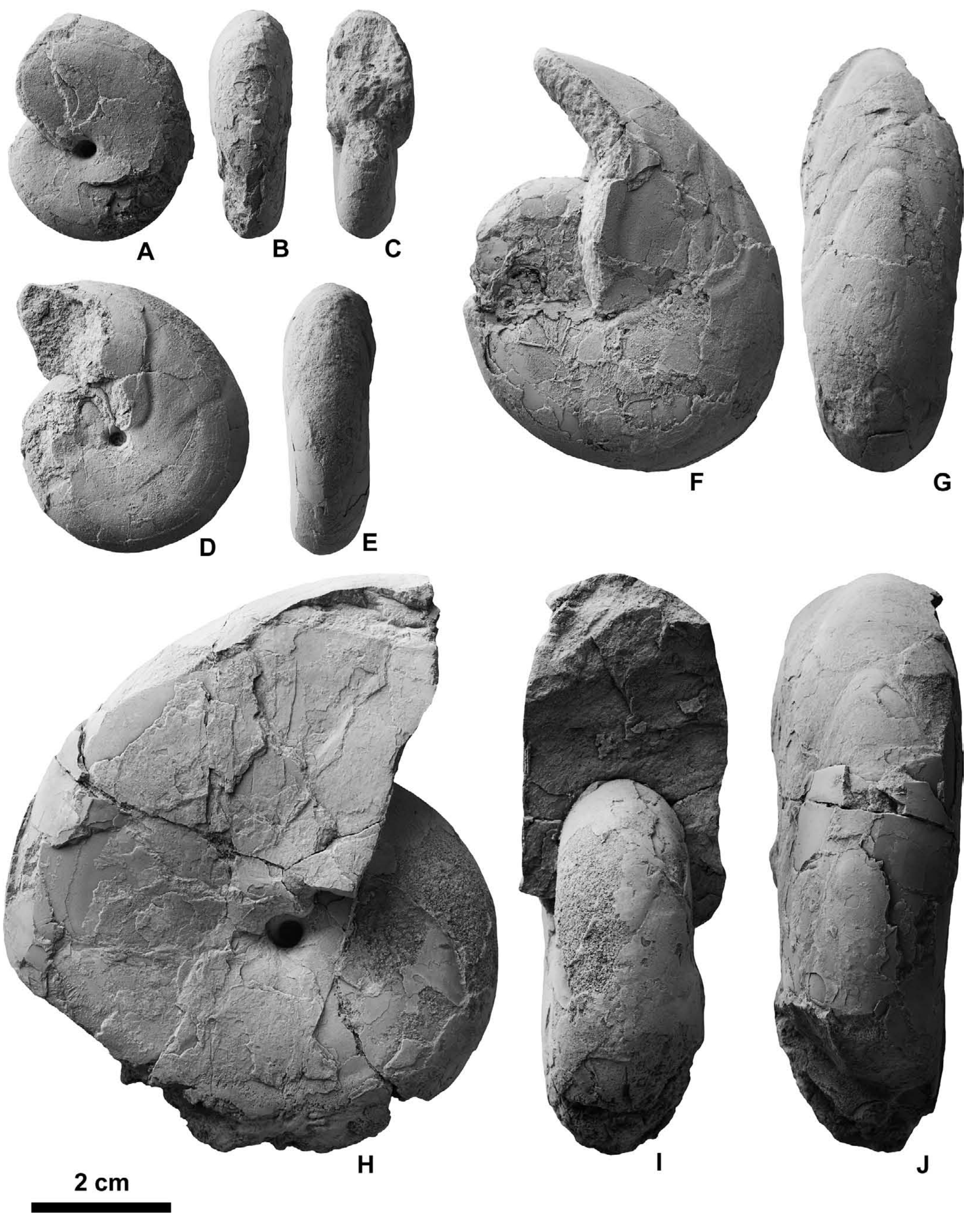

Figure 10. *Desmophyllites diphylloides* (Forbes, 1846) from the Chinomigawa Formation. **A–C,** NMNS PM35020 from Loc. 1; A, right lateral view; B, ventral view; C, apertural view; **D, E,** NMNS PM35021 from Loc. 1; D, right lateral view; E, ventral view; **F, G,** NMNS PM35022 from Loc. 6; F, right lateral view; G, ventral view; **H–J,** NMNS PM35023 from Loc. 3; H, left lateral view; I, apertural view; J, ventral view.

Material examined.—Two specimens, NMNS PM35020, 35021, from Loc. 1, one specimen, NMNS PM35023, from Loc. 3, one specimen, NMNS PM35022, from Loc. 6, two specimens, NMNS PM35024, 35025, from a float concretion found at Loc. 8, and one specimen, HMG-1655, from a float concretion found at Loc. 10.

Description.—Very involute, fairly compressed shell

Figure 11. *Desmophyllites diphylloides* (Forbes, 1846) from Loc. 8 in the Chinomigawa Formation. **A–D,** NMNS PM35024; A, left lateral view; B, apertural view; C, right lateral view; D, ventral view; **E–G,** NMNS PM35025; E, left lateral view; F, right lateral view; G, ventral view.

with elliptical whorl section, rounded venter, rounded ventral shoulders, and nearly flat flanks with maximum whorl width at ventral shoulder. Umbilicus deep and very narrow with vertical wall and rounded shoulders. Ornamentation consists only of distant constrictions and very fine, growth lines, which arise at umbilical seam, become slightly sigmoidal on inner to mid-flank, and bend sharply forward on outer flank before passing over venter with a narrow, convex arch.

Remarks.—Matsumoto and Obata (1955) assigned several small desmoceratids from the lower middle Campanian *Sphenoceramus schmidti* Zone of the Abeshinai area, northern Hokkaido to *Desmophyllites diphylloides*, but in actuality their specimens are identical to the juvenile shells of *Damesites*.

Occurrence.—Described specimens were collected from the *Metaplacenticeras subtilistriatum* Zone of the upper middle Campanian and the *Baculites subanceps* Zone of the lower upper Campanian in the Chinomigawa Formation, Urakawa area. *Desmophyllites diphylloides* is known from the Santonian to the upper Maastrichtian in southern India (Kennedy and Henderson, 1992), Western Australia (Henderson and McNamara, 1985), northeastern Mexico (Ifrim *et al*., 2004) and Angola (Howarth, 1965), but it has been reported only from the middle to upper Campanian interval in Hokkaido (Matsumoto, 1984a, b), southern Sakhalin (Maeda *et al*., 2005), Vancouver (Haggart, 1989) and from the middle Campanian in Wakayama, southwestern Japan (Misaki and Maeda, 2009).

Family Pachydiscidae Spath, 1922
Genus ***Menuites*** Spath, 1922

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

Menuites sp.

Figures 12–14

Pseudomenuites sp. Shigeta *et al*., 1999, pl. 5, figs. 1, 2; Ando and Ando, 2002, pl. 2, figs. 1–3.

Material examined.—Two specimens, NMNS PM35026 and HMG-1656, from Loc. 1, one specimen, HMG-1657, from a float concretion found at Loc. 7 by Yukinobu Yoshikawa (Niikappu, Hokkaido), and one specimen, HMG-1658, from a float concretion found at Loc. 12.

Description.—Moderately involute shell with circular whorl section, rounded venter, indistinct ventral shoulders, and gently convex flanks with maximum whorl width at mid-flank. Umbilicus moderately wide with high, convex wall and rounded shoulders. Complex ornamentation includes long, robust umbilical and ventrolateral spines on last part of phragmocone and main part of body chamber. Distant, prorsiradiate ribs arising from umbilical seam, from which both spines arise, develop on last quarter whorl of body chamber and pass over venter in a convex arch. Ribs become stronger near apertural part of body chamber, but spines simultaneously become weaker or obscure.

Measurements.—Taken at D = 87.5 mm of HMG-1656, U = 26.4 mm, H = 36.8 mm, W = 38.0 mm, U/D = 0.30, W/H = 1.03, at D = 96.5 mm of NMNS PM35026, U = 29.6 mm, H = 40.0 mm, U/D = 0.31, at D = 78.0 mm of HMG-1658, U = 26.5 mm, H = 33.0 mm, W = 37.0 mm, U/D = 0.34, W/H = 1.12, and at D = 73.0 mm of HMG-1657, U = 21.4 mm, H = 32.6 mm, U/D = 0.29.

Remarks.—The described specimens differ from the late middle Campanian *Menuites sanadai* Matsumoto, 1984a from the Teshio Mountains, early Campanian and Santonian *Menuites* from Hokkaido and Sakhalin (Matsumoto, 1955) and late middle Campanian *Pseudomenuites* sp. from the Soya Cape area (Matsumoto and Miyauchi, 1984) by their more evolute shell, wider umbilicus and strong ribs on last quarter-whorl of body chamber, and they likely represent a new species. However, I hesitate to propose a new specific name because of their poor preservation. Specimens illustrated as *Pseudomenuites* sp. by Shigeta *et al*. (1999, pl. 5, figs. 1, 2) from the upper Campanian in the Kura area, southern Sakhalin and by Ando and Ando (2002, pl. 2, figs. 1–3) from the upper Campanian in the Soya Hill area are very close to the described specimens, and may be identical.

Occurrence.—Described specimens were collected from the *Baculites subanceps* Zone and a float concretion that probably came from the lower upper Campanian beds in the Chinomigawa Formation, Urakawa area.

Genus ***Canadoceras*** Spath, 1922

Type species.—*Ammonites newberryanus* Meek, 1876.

Canadoceras multicostatum Matsumoto, 1954

Figure 15

Canadoceras multicostatum Matsumoto, 1954, p. 304, pl. 34, figs. 1, 2, text-fig. 28; Matsumoto, 1984a, p. 18, pl. 3, figs. 1–3; Matsumoto and Miyauchi, 1984, p. 47, pl. 18, figs. 1, 2, pl. 20, fig. 2; Maeda *et al*., 2005, fig. 12.3, 12.4; Takahashi *et al*., 2007, pl. 5, figs. 9, 10.

Mesopuzosia densicostata Matsumoto. Matsumoto, 1984a, p. 13, pl. 2, figs. 1, 2.

Holotype.—UNUT MM9118, figured by Matsumoto (1954, p. 304, pl. 34, fig. 1), from the Upper Cretaceous in the Togushi (= Gorbusha) area of the Nishinotoro (= Kril'on) Peninsula, southern Sakhalin.

Material examined.—One incomplete specimen, NMNS PM35027, from Loc. 3.

Description.—Moderately evolute, fairly compressed shell with elliptical whorl section, rounded venter, indistinct ventral shoulders, and gently convex flanks with maximum whorl width at mid-flank. Umbilicus moderately wide with moderately high, vertical wall and rounded shoulders. Constrictions, major ribs and umbilical tubercles distinct on inner whorl. Outer whorl ornamented by numerous, prorsiradiate ribs strongly projected forward on outer flank.

Remarks.—Matsumoto (1984a, p. 13) assigned specimens from the upper middle Campanian in the Teshio Mountains to *Mesopuzosia densicostata* based on a lack of umbilical tubercles on the major ribs of the inner

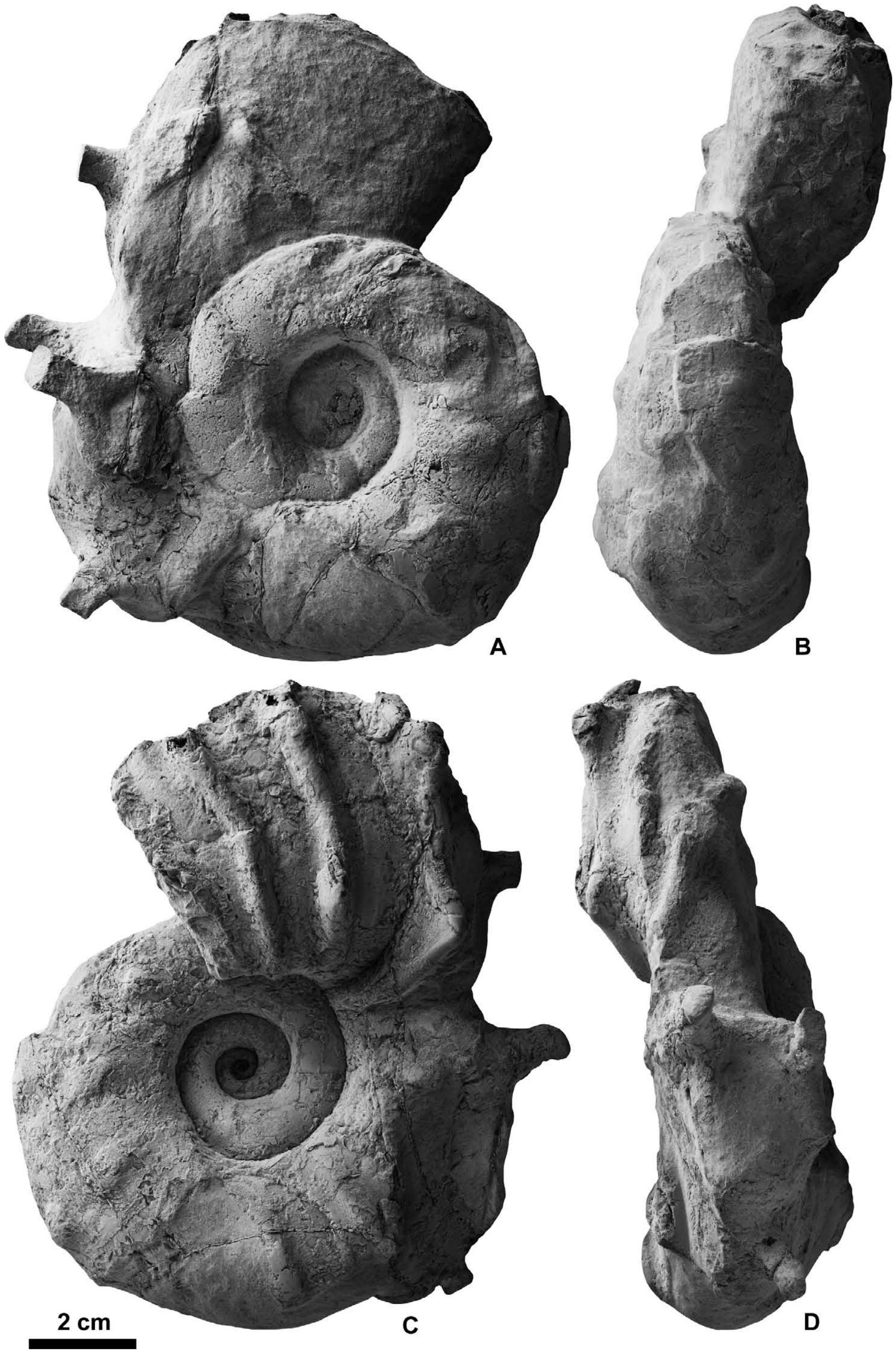

Figure 12. *Menuites* sp., HMG-1658, from Loc. 12 in the Chinomigawa Formation. **A,** left lateral view; **B,** apertural view; **C,** right lateral view; **D,** ventral view.

Figure 13. *Menuites* sp., NMNS PM35026, from Loc. 1 in the Chinomigawa Formation. **A,** left lateral view; **B,** apertural view; **C,** right lateral view; **D,** ventral view.

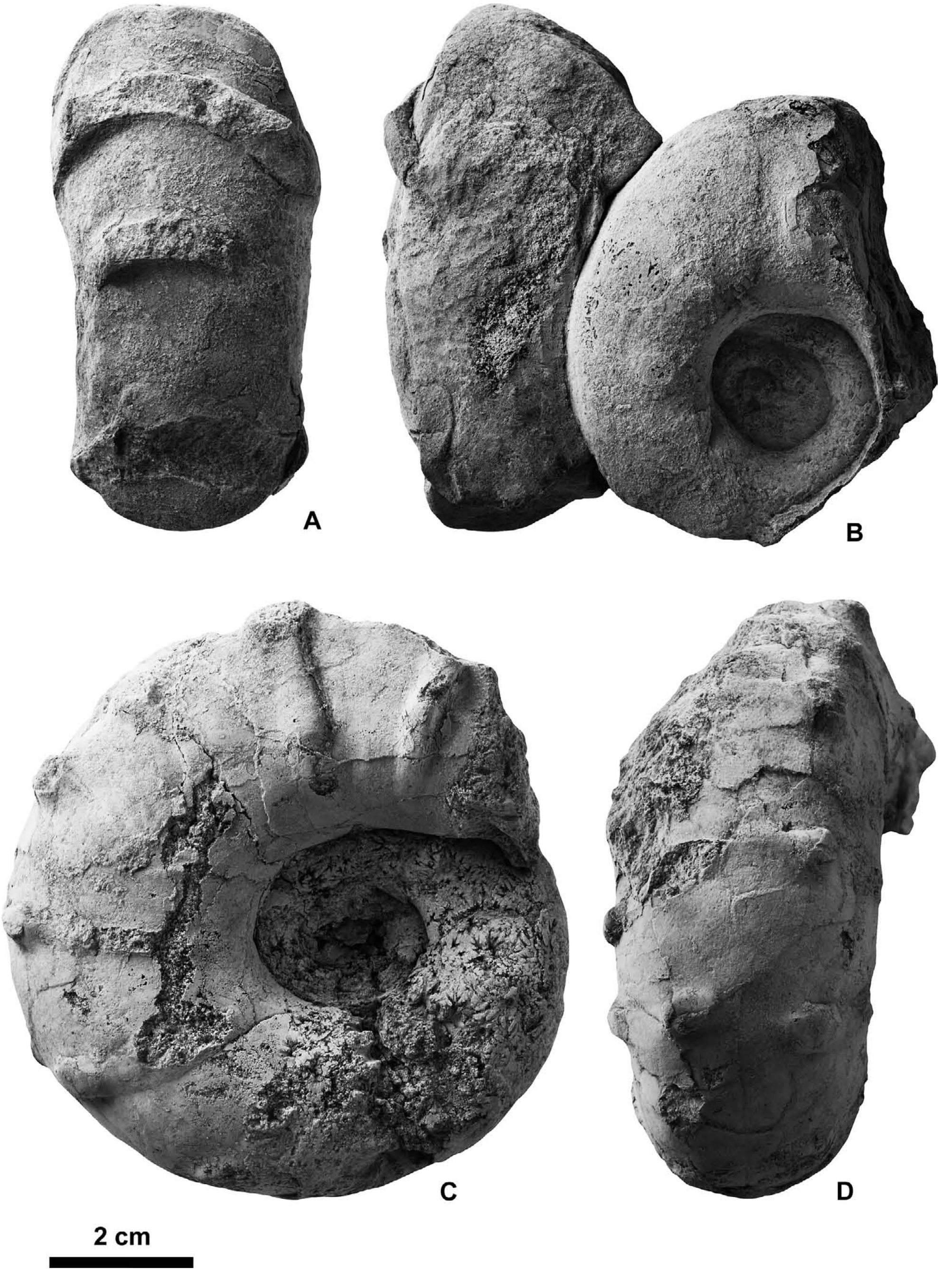

Figure 14. *Menuites* sp. from the Chinomigawa Formation. **A, B,** HMG-1657 from Loc. 7; A, ventral view; B, left lateral view; **C, D,** HMG-1656 at Loc. 1; C, left lateral view; D, ventral view.

whorls. However, the shell (test) on the inner whorls is mostly missing and the actual lack of umbilical tubercles is undeterminable. Their shell form, shape and mode of ribbing are very similar to *Canadoceras multicostatum*, and I assign them with certainty to *C. multicostatum*.

Occurrence.—Described specimen was collected from the *Metaplacenticeras subtilistriatum* Zone of the upper middle Campanian in the Chinomigawa Formation, Urakawa area. *Canadoceras multicostatum* is known from the Teshio Mountains and Soya Cape area in

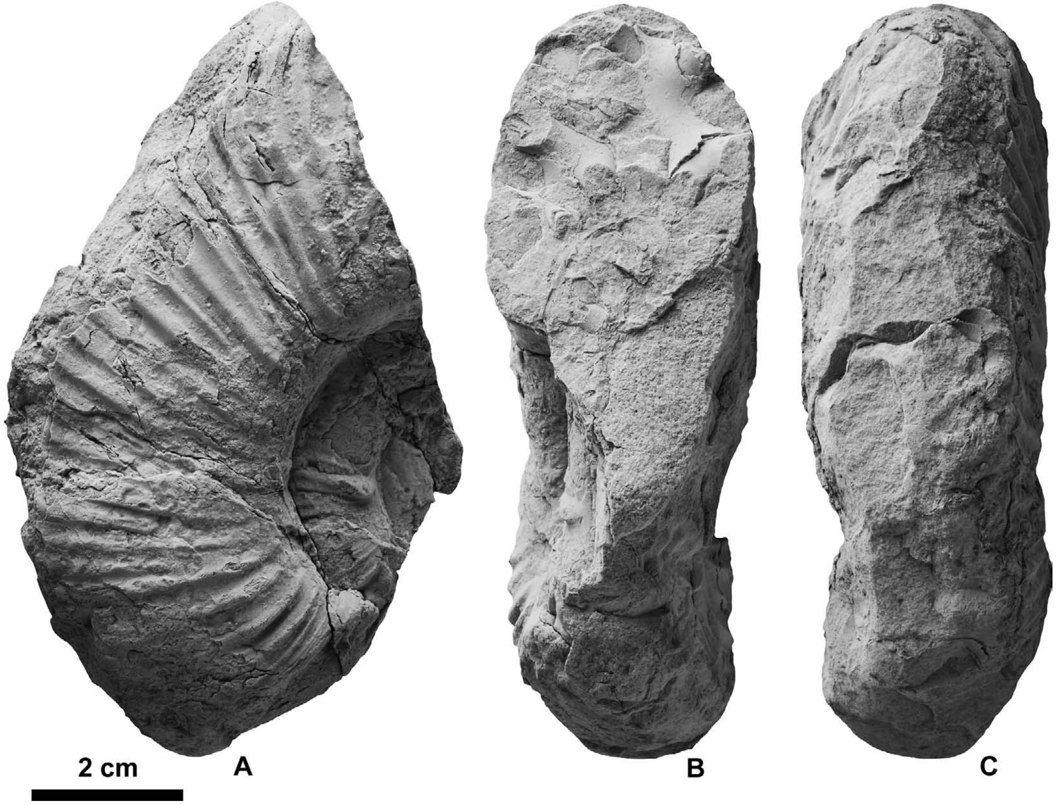

Figure 15. *Canadoceras multicostatum* Matsumoto, 1954, NMNS PM35027, from Loc. 3 in the Chinomigawa Formation. **A,** left lateral view; **B,** apertural view; **C,** ventral view.

Hokkaido and the Naiba and Makarov areas in southern Sakhalin (Matsumoto, 1954, 1984a; Matsumoto and Miyauchi, 1984; Maeda *et al.*, 2005).

Genus ***Pachydiscus*** Zittel, 1884

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

Pachydiscus excelsus Matsumoto, 1979

Figure 16

Pachydiscus excelsus Matsumoto, 1979, p. 50, pl. 8, fig. 1, text-fig. 2.

Holotype.—GK. H5895, figured by Matsumoto (1979, p. 50, pl. 8, fig. 1), from the lower part of the Hakobuchi Formation (probably the upper Campanian), along the Sanushube (Sanushibe) River in the Hobetsu area, Hokkaido.

Material examined.—One specimen (whorl fragment), NMNS PM35050, collected from a float concretion found at Loc. 15.

Description.—Very large, fairly compressed shell with rounded venter and indistinct ventral shoulders. Ornamentation consists of fairly dense, regular ribs confined to ventrolateral shoulders and venter.

Occurrence.—Even though the described specimen was collected from a float concretion, its lithology suggests it probably came from the sandy mudstone in the upper part of the Chinomigawa Formation. *Pachydiscus excelsus* is known from probable upper Campanian deposits of Hokkaido (Matsumoto, 1979).

Superfamily Hoplitoidea Douvillé, 1890
Family Placenticeratidae Hyatt, 1900
Genus ***Metaplacenticeras*** Spath, 1926

Type species.—*Placenticeras pacificum* Smith, 1900.

Metaplacenticeras subtilistriatum (Jimbo, 1894)

Figure 17

Placenticeras subtilistriatum Jimbo, 1894, p. 171, pl. 1, fig. 1.
Metaplacenticeras (*Paraplacenticeras*) *subtilistriatum* (Jimbo). Matsumoto, 1953, p. 140, pl. 13, figs. 1–4, text-figs. 1–9.

Figure 16. *Pachydiscus excelsus* Matsumoto, 1979, NMNS PM35050, from Loc. 15 in the Chinomigawa Formation. **A,** ventral view; **B,** right lateral view.

Metaplacenticeras subtilistriatum (Jimbo). Matsumoto, 1963, p. 42, pl. 60, fig. 1; Matsumoto, 1984a, p. 21, pl. 6, figs. 1, 2, pl. 7, figs. 1–4; Matsumoto and Miyauchi, 1984, p. 51, pl. 22, figs. 1, 2; Bando and Hashimoto, 1984, pl. 1, figs. 1–6, pls. 2, 3; Tashiro *et al*., 1993, pl. 1, figs. 4, 6; Ando and Ando, 2002, pl. 3, fig. 3; Wani, 2006, figs. 4, 5; Takahashi *et al*., 2007, pl. 5, figs. 2, 3, 8.

Lectotype.—Specimen designated by Matsumoto (1984a, p. 21), UMUT MM7502, is the original of Jimbo (1894, pl. 1, fig. 1) from the Wembetsu-Rubeshibe River in the Teshio Mountains.

Material examined.—One specimen, NMNS PM35028, from Loc. 3, one specimen, HMG-1659, from a float concretion found at Loc. 5, and one specimen, NMNS PM35029, from a float concretion found at Loc. 8.

Description.—Very involute, very compressed shell with high trapezoidal cross section, narrow, tricarinate venter with low median keel and sharp marginal keels, and slightly convex flanks with maximum whorl width near umbilical shoulders. Umbilicus narrow with low, steeply inclined wall and angular shoulders. Ornamentation consists of fine, prorsiradiate, sigmoidal ribs, lirae and umbilical tubercles.

Remarks.—Kanie (1982) reported the occurrence of *Metaplacenticeras subtilistriatum* in the Urakawa area, but he did not describe or illustrate any specimens.

Occurrence.—Described specimens were collected from the *Metaplacenticeras subtilistriatum* Zone and float concretions that probably came from the upper middle Campanian beds in the Chinomigawa Formation, Urakawa area. *Metaplacenticeras subtilistriatum* is known from the Teshio Mountains, Soya Cape and Soya Hill areas in Hokkaido (Matsumoto, 1984a; Matsumoto and Miyauchi, 1984; Ando and Ando, 2002) and the Asan Mountains, Shikoku, Southwest Japan (Bando and Hashimoto, 1984).

Suborder Ancyloceratina Wiedmann, 1966
Superfamily Turrilitoidea Gill, 1871

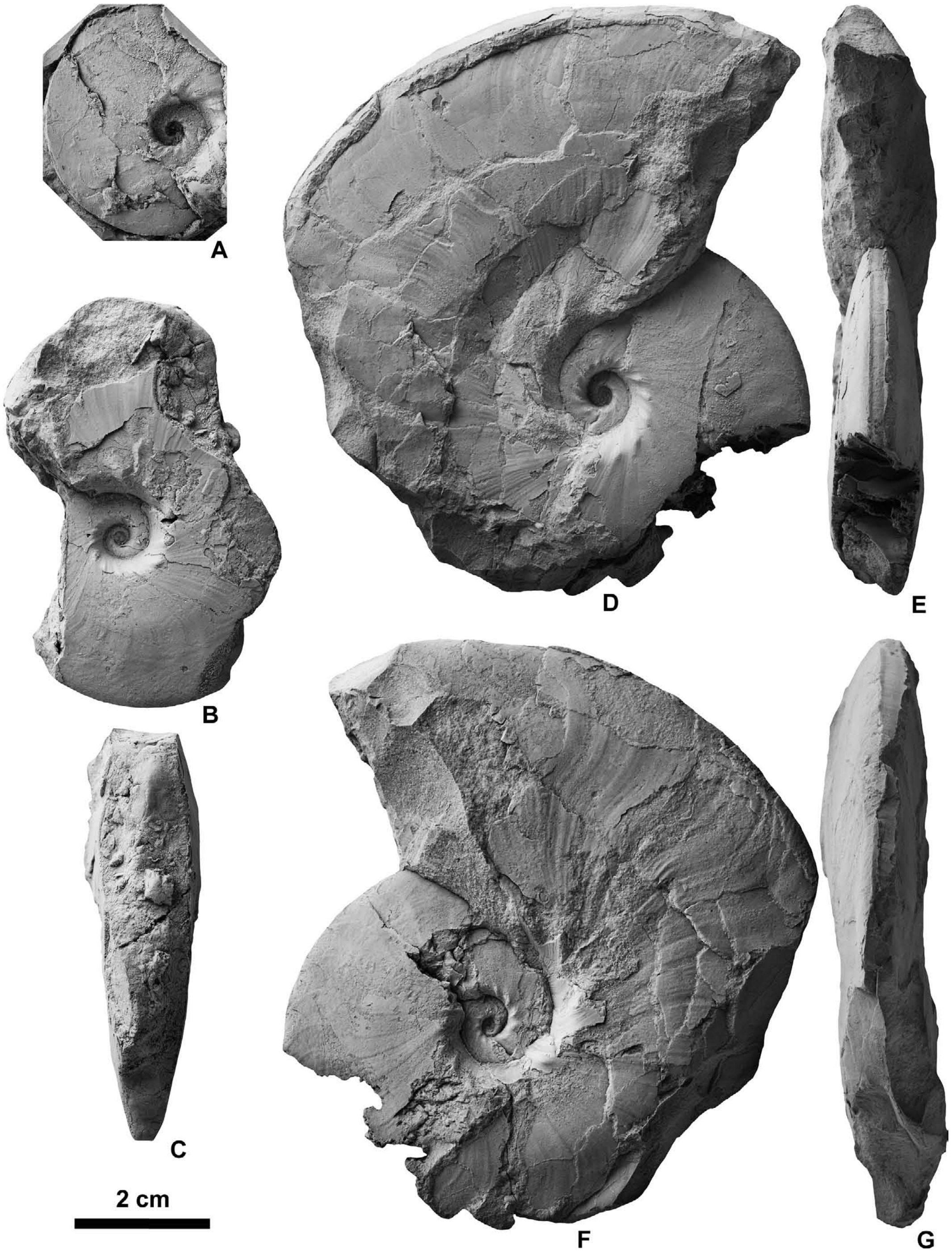

Figure 17. *Metaplacenticeras subtilistriatum* (Jimbo, 1894) from the Chinomigawa Formation. **A,** NMNS PM35028 from Loc. 3, left lateral view (rubber cast of outer mold); **B, C,** HMG-1659 from Loc. 5; B, right lateral view; C, ventral view; **D–G,** NMNS PM35029 from Loc. 8; D, left lateral view; E, apertural view; F, right lateral view; G, ventral view.

Family Nostoceratidae Hyatt, 1894

Genus ***Didymoceras*** Hyatt, 1894

Type species.—*Ancyloceras*? *nebrascense* Meek and Hayden, 1856.

Didymoceras hidakense Shigeta sp. nov.

Figures 18–23, 24C–E

Didymoceras sp. Shigeta, 2001, pl. 40, fig. 1.

Type specimens.—Holotype, HMG-1660, from Loc. 11; paratypes, five specimens, HMG-1661–1665 from Loc. 11, and one specimen, HMG-1666, from a float concretion found at Loc. 12. HMG-1664 and 1665 were collected by Yukinobu Yoshikawa (Niikappu, Hokkaido).

Material examined.—Five specimens, NMNS PM35030–35034, from float concretions found in the Tsukisappu River area by the late Minoru Yamashita in 1980, and three specimens, NMNS PM16663a–c, from a float concretion found in the Tsukisappu River area by the late Yoshitaro Kawashita in 1980 (Shigeta, 2001, pl. 40, fig. 1).

Diagnosis.—*Didymoceras* characterized by loose helical middle whorls followed by recurved hook-like body chamber with aperture facing upward. Ornamentation consists of distant, highly elevated ribs among dense, narrowly raised ribs and two rows of tubercles, which become weaker or obscure on last whorls: upper row on mid-line of outer whorl face or slightly below, lower row on ventrolateral shoulder. Apertural edge (peristome) characterized by distinctively strong rib preceded by a deep apertural constriction.

Etymology.—Named after Hidaka province, southern central Hokkaido.

Description.—Early whorls, less than 15 mm in diameter, not preserved. Middle whorls, 15–100 mm in diameter, helically coiled dextrally or sinistrally, not in contact, forming apical angle of 65–75°. Late whorls, over 100 mm in diameter, uncoiled with recurved hook-like body chamber that ends with aperture facing upward. Whorl cross section nearly circular. Shell surface ornamented with dense, oblique ribs and two rows of tubercles. Distant but strong, highly elevated ribs followed by a shallow constriction occur periodically among narrowly raised ribs, which occur sequentially at nearly regular intervals. Ribs rursiradiate on lower and outer whorl faces, but curve forward on upper face and cross over dorsum in a slight convexity. Ribs on all growth stages become less intense as they cross dorsum. Two rows of tubercles appear rather irregularly on every second to fourth rib: upper row situated on mid-line of outer whorl face, on or near siphuncle, or slightly below, and lower row on ventrolateral shoulder. As shell grows, ribs increase in strength. Peristome characterized by deep constriction followed immediately by a strong rib. Tubercles become weaker or obscure on last whorls. Suture line finely and deeply incused, partly visible.

Comparison.—*Didymoceras hidakense* sp. nov. is easily distinguished from the other species of *Didymoceras* described from Japan, *D. awajiensis* (Yabe, 1901) and *D. nakaminatoense* (Saito, 1958), by its more loosely coiled helical whorls in the middle growth stage. Both of the other species have their helical whorls in contact at the middle growth stage. The middle growth stage of the new species is somewhat similar to *D. hornbyense* (Whiteaves, 1895) from British Columbia, Canada, but the whorls of *D. hornbyense* are initially in contact and then gradually become separated during the middle helicoid stage, and are then followed by a long retroversal hook at the late growth stage. Its ribs are coarser than *D. hidakense* sp. nov.

Didymoceras nebrascense (Meek and Hayden, 1856) and *D. cochleatum* (Meek and Hayden, 1858) from the Western Interior of USA and *D. postremum* Blaszkiewicz, 1980 from Poland are somewhat similar to the new species at the middle to later growth stages, but their ribs and tubercles are much stronger than those of the new species. Although the earliest whorls of the new species are as yet unknown, its early whorls form a loose helix. In contrast, the early whorls of *D. nebrascense* consist of straight limbs connected by elbows, followed by a gently curved limb, all of which occur in a loose planispire (Kennedy *et al*., 2000) and those of *D. cochleatum* are coiled in an open planispire, followed by a large open elliptical whorl.

The middle growth stage of *Didymoceras australis* Klinger and Kennedy, 2003 and *D. howarthi* Klinger and Kennedy, 2003 from South Africa and *D. subtuberculatum* Howarth, 1965 from Angola are also somewhat similar to the middle growth stage of the new species in having loosely helical whorls, but their shells are much elongated longitudinally.

Remarks.—The specimens illustrated as *Didymoceras* sp. by Bando and Hashimoto (1984, pl. 5) and *Didymoceras* sp. A by Morozumi (2007) from the upper Campanian in the Asan Mountains, Shikoku, are characterized by slowly enlarging, loosely helical whorls at the middle growth stage. Although their whorls at the late growth stage are as yet unknown, judging from their similar ornamentation, they are closely related to *Didymoceras hidakense* sp. nov.

Occurrence.—Described specimens were collected from the *Baculites subanceps* Zone and float concretions that probably came from the lower upper Campanian beds in the Chinomigawa Formation, Urakawa area.

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

Type species.—*Baculites vertebralis* Lamarck, 1801.

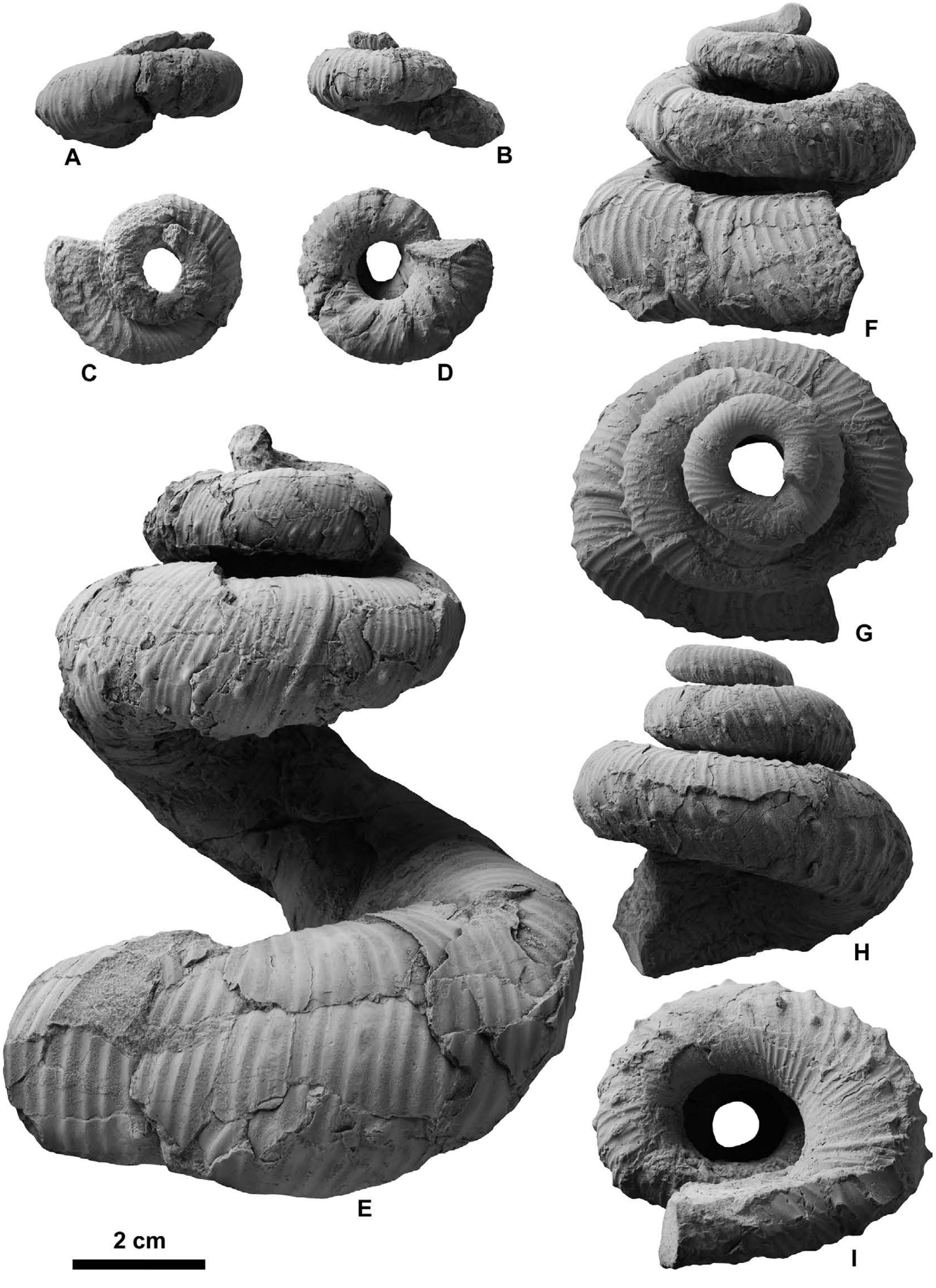

Figure 18. *Didymoceras hidakense* Shigeta sp. nov. from the Chinomigawa Formation. **A–D,** HMG-1662 (paratype) from Loc. 11; A, lateral view; B, lateral view rotated 180 degrees from A; C, apical view; D, basal view; **E,** HMG-1663 (paratype) from Loc. 11, lateral view; **F–I,** HMG-1666 (paratype) from Loc. 12; F, lateral view; G, apical view; H, lateral view rotated 180 degrees from F; I, basal view.

Figure 19. *Didymoceras hidakense* Shigeta sp. nov., HMG-1660 (holotype), from Loc. 11 in the Chinomigawa Formation. **A,** lateral view; **B,** apical view; **C,** basal view; **D,** lateral view rotated 90 degrees from A.

Figure 20. *Didymoceras hidakense* Shigeta sp. nov., HMG-1660 (holotype), from Loc. 11 in the Chinomigawa Formation. **A,** lateral view rotated 90 degrees from D in Figure 19; **B,** apical view; **C,** basal view; **D,** lateral view rotated 90 degrees from A.

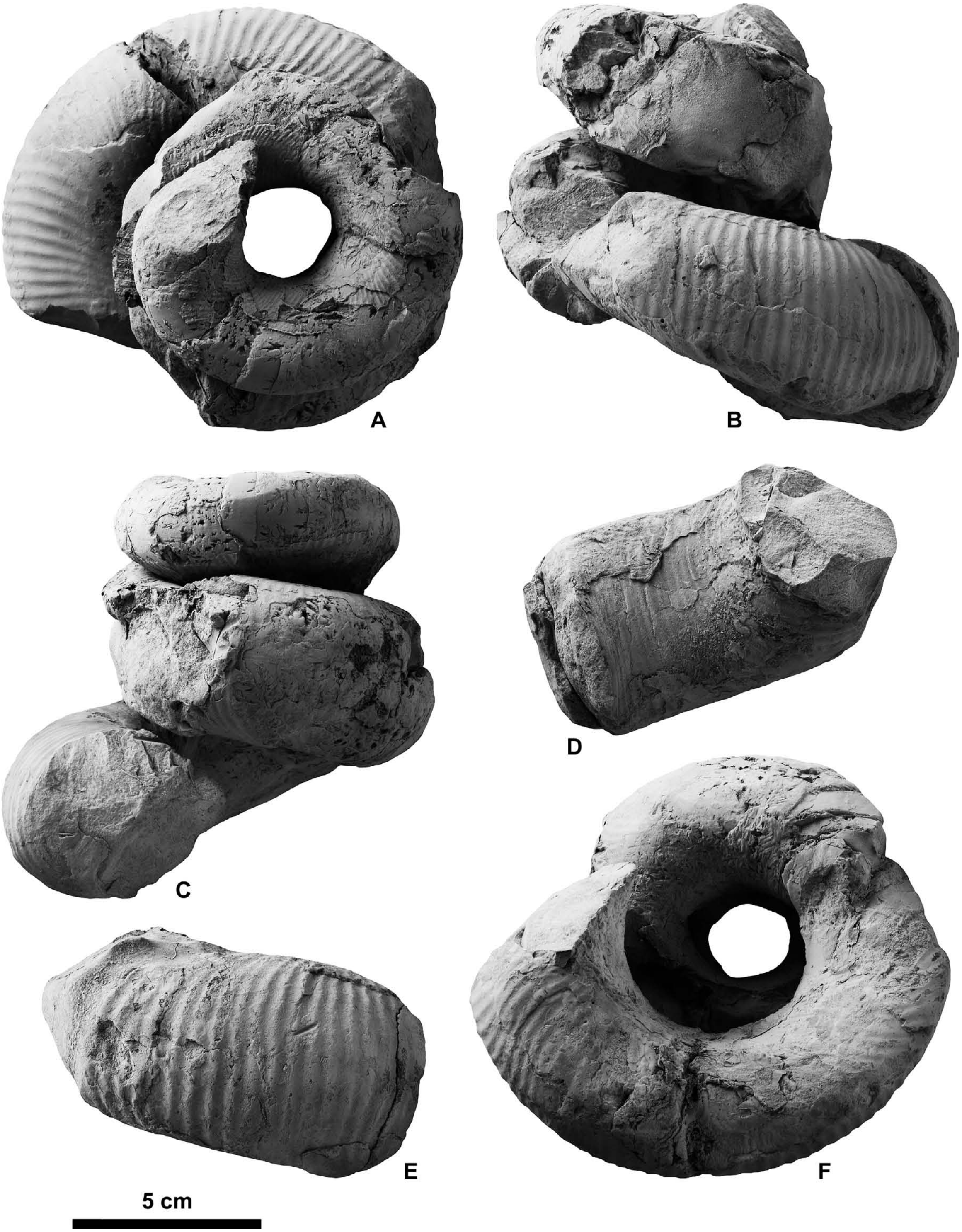

Figure 21. *Didymoceras hidakense* Shigeta sp. nov., HMG-1661 (paratype), from Loc. 11 in the Chinomigawa Formation. **A,** apical view; **B,** lateral view; **C,** lateral view rotated 180 degrees from B; **D,** lateral view of body chamber fragment; **E,** lateral view rotated 180 degrees from D; **F,** basal view.

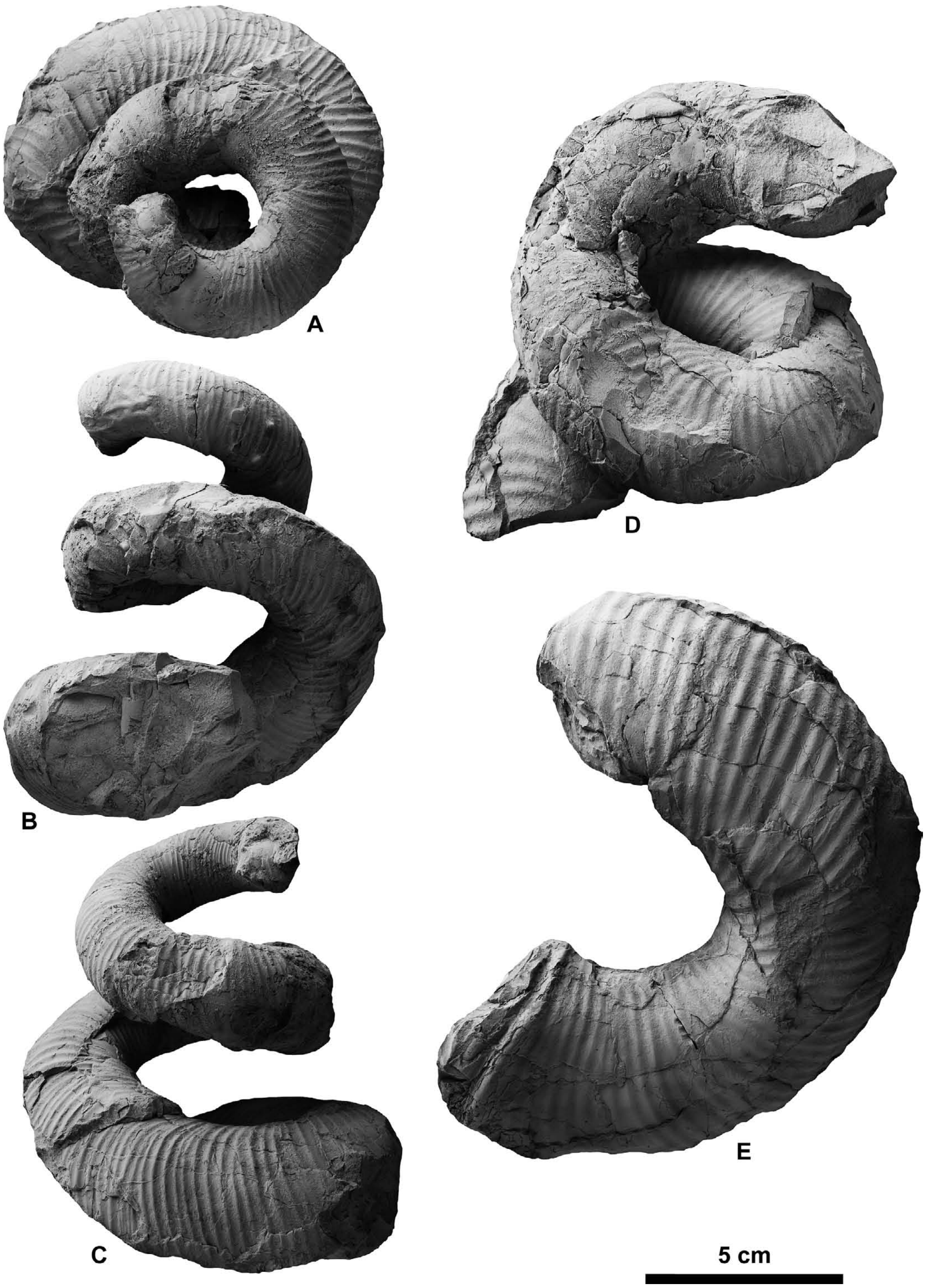

Figure 22. *Didymoceras hidakense* Shigeta sp. nov. from the Chinomigawa Formation in the Tsukisappu River area. **A–C,** NMNS PM35030; A, apical view; B, lateral view; C, lateral view rotated 180 degrees from B; **D, E,** NMNS PM35031; D, lateral view of phragmocone; E, lateral view of body chamber.

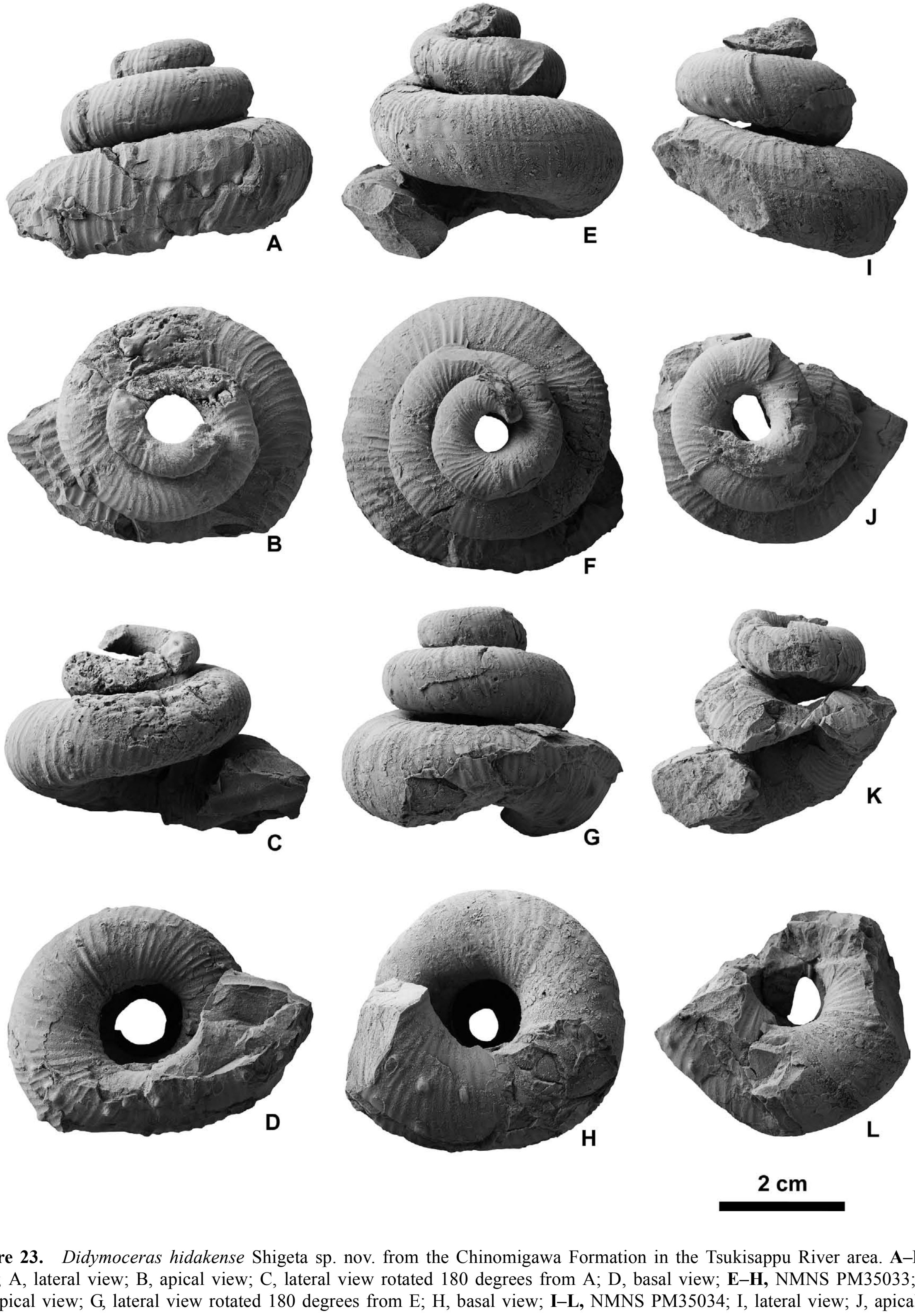

Figure 23. *Didymoceras hidakense* Shigeta sp. nov. from the Chinomigawa Formation in the Tsukisappu River area. **A–D,** NMNS PM35032; A, lateral view; B, apical view; C, lateral view rotated 180 degrees from A; D, basal view; **E–H,** NMNS PM35033; E, lateral view; F, apical view; G, lateral view rotated 180 degrees from E; H, basal view; **I–L,** NMNS PM35034; I, lateral view; J, apical view; K, lateral view rotated 180 degrees from I; L, basal view.

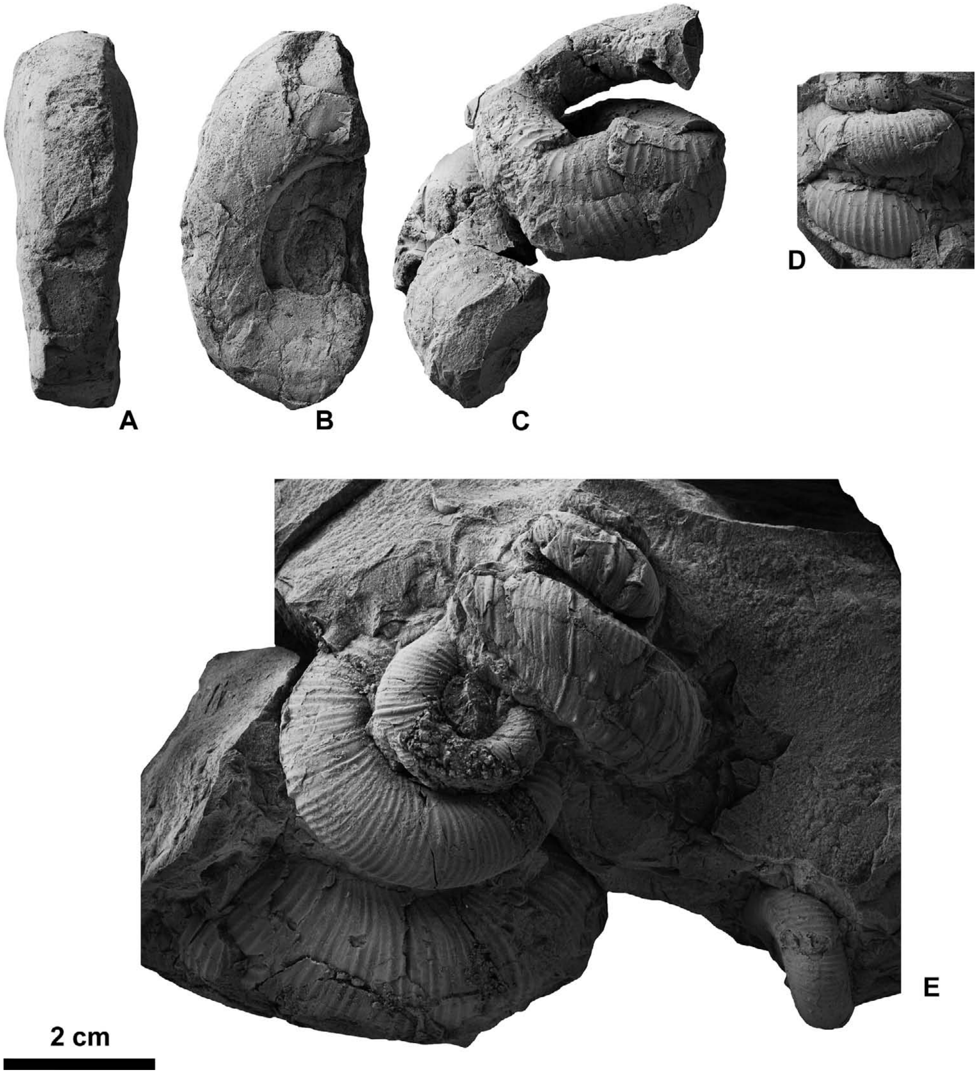

Figure 24. *Tetragonites* and *Didymoceras* from the Chinomigawa Formation. **A, B,** *Tetragonites popetensis* Yabe, 1903, HMG-1651 from Loc. 11; A, ventral view; B, left lateral view; **C–E,** *Didymoceras hidakense* Shigeta sp. nov.; C, HMG-1664 from Loc. 11, lateral view; D, HMG-1665 from Loc. 11, lateral view; E, NMNS PM16663a–c from the Tsukisappu River area. Specimens, HMG-1651, 1664 and 1665, were collected from the same concretion.

Baculites subanceps Haughton, 1925

Figures 25–28

Baculites subanceps Haughton, 1925, p. 278, pl. 14, figs. 6–8; Howarth, 1965, p. 368, pl. 5, fig. 3, pl. 6, figs. 6, 7, text-figs. 4, 13–15; Klinger and Lock, 1978, p. 77, fig. 5a–l; Luger and Gröschke, 1989, p. 400, pl. 49, fig. 1, text-fig. 15a–h; Klinger and Kennedy, 1997, fig. 131; Klinger and Kennedy, 2001, p. 203.

Baculites aff. *anceps* Lamarck, 1822. Matsumoto, 1959, p. 130, pl. 34, fig. 3, pl. 35, fig. 1, text-figs. 42, 43.

Baculites anceps pacificus Matsumoto and Obata, 1963, p. 59, pl. 20, fig. 3, text-figs. 145, 146, 156; Ward, 1978, p. 1152, pl. 2, figs. 1–4, 8, text-fig. 6.

Lectotype.—Specimen designated by Howarth (1965, p. 368), SAM-6829, is the original of Howarth (1965, p. 368, pl. 6, fig. 6) from the upper Campanan–lower Maastrichtian of Carimba, Angola.

Material examined.—Three specimens, HMG-1667–1669, from Loc. 13, one specimen, HMG-1670, from a float concretion found at Loc. 12, four specimens, HMG-1671–1674, from Loc. 11, two specimens, HMG-1675, 676, from a float concretion found at Loc. 14 by Yukinobu Yoshikawa (Niikappu, Hokkaido), six specimens, NMNS PM35044–35049, from Loc. 1, and one specimen, HMG-1654, from a float concretion found at

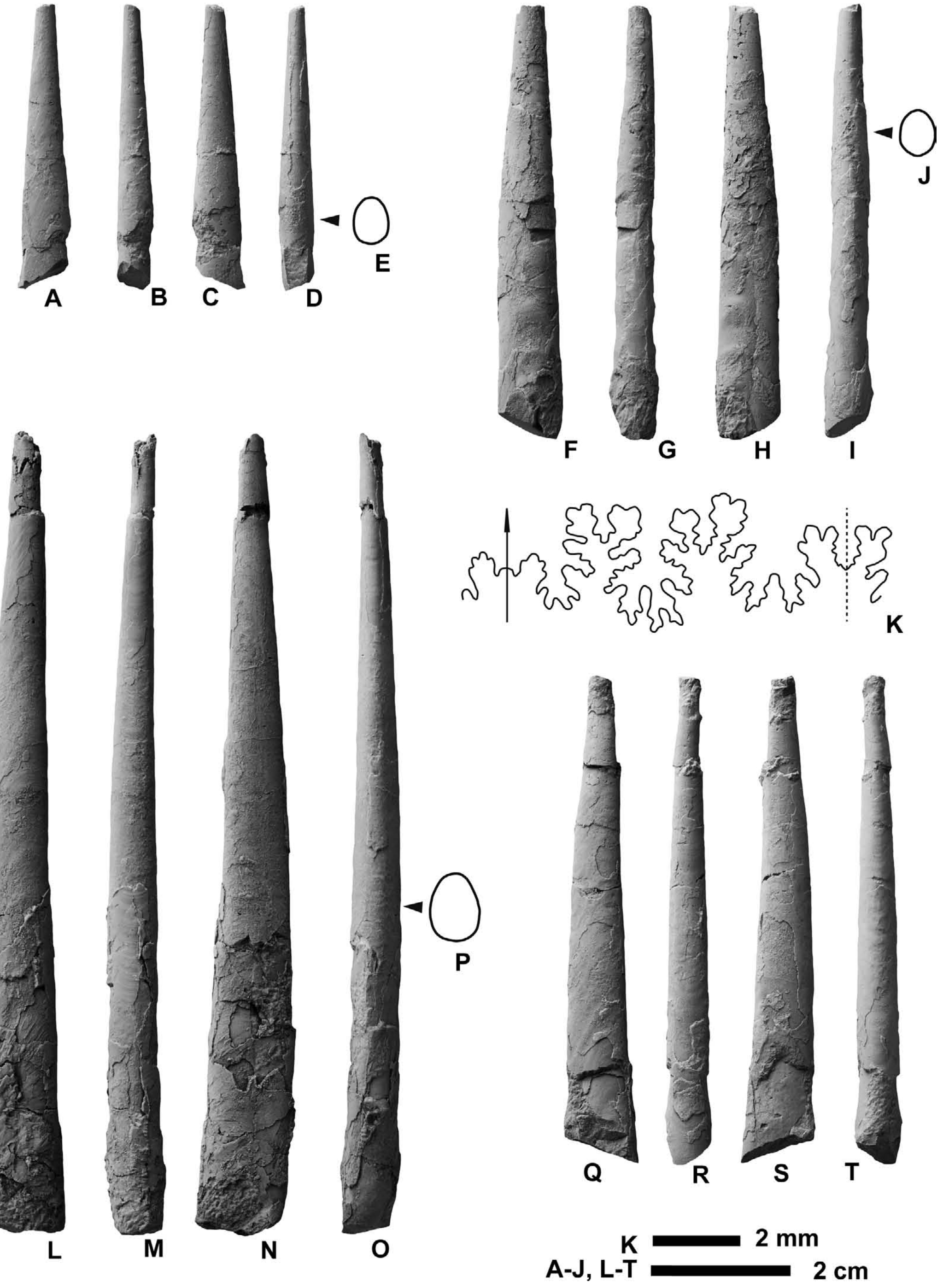

Figure 25. *Baculites subanceps* Haughton, 1925 from the Chinomigawa Formation. **A–E,** HMG-1667 from Loc. 13; A, lateral view; B, dorsal view; C, lateral view rotated 90 degrees from A; D, ventral view; E, whorl cross section at $H = 6.8$ mm; **F–K,** HMG-1668 from Loc. 13; F, lateral view; G, dorsal view; H, lateral view rotated 90 degrees from F; I, ventral view; J, whorl cross section at $H = 7.0$ mm; K, suture line at $H = 5.2$ mm, Solid line represents the siphuncle and broken line indicates the middle dorsal position; **L–P,** HMG-1669 from Loc. 13; L, lateral view; M, dorsal view; N, lateral view rotated 90 degrees from L; O, ventral view; P, whorl cross section at $H = 10.0$ mm; **Q–T,** HMG-1670 from Loc. 12; Q, lateral view; R, dorsal view; S, lateral view rotated 90 degrees from Q; T, ventral view.

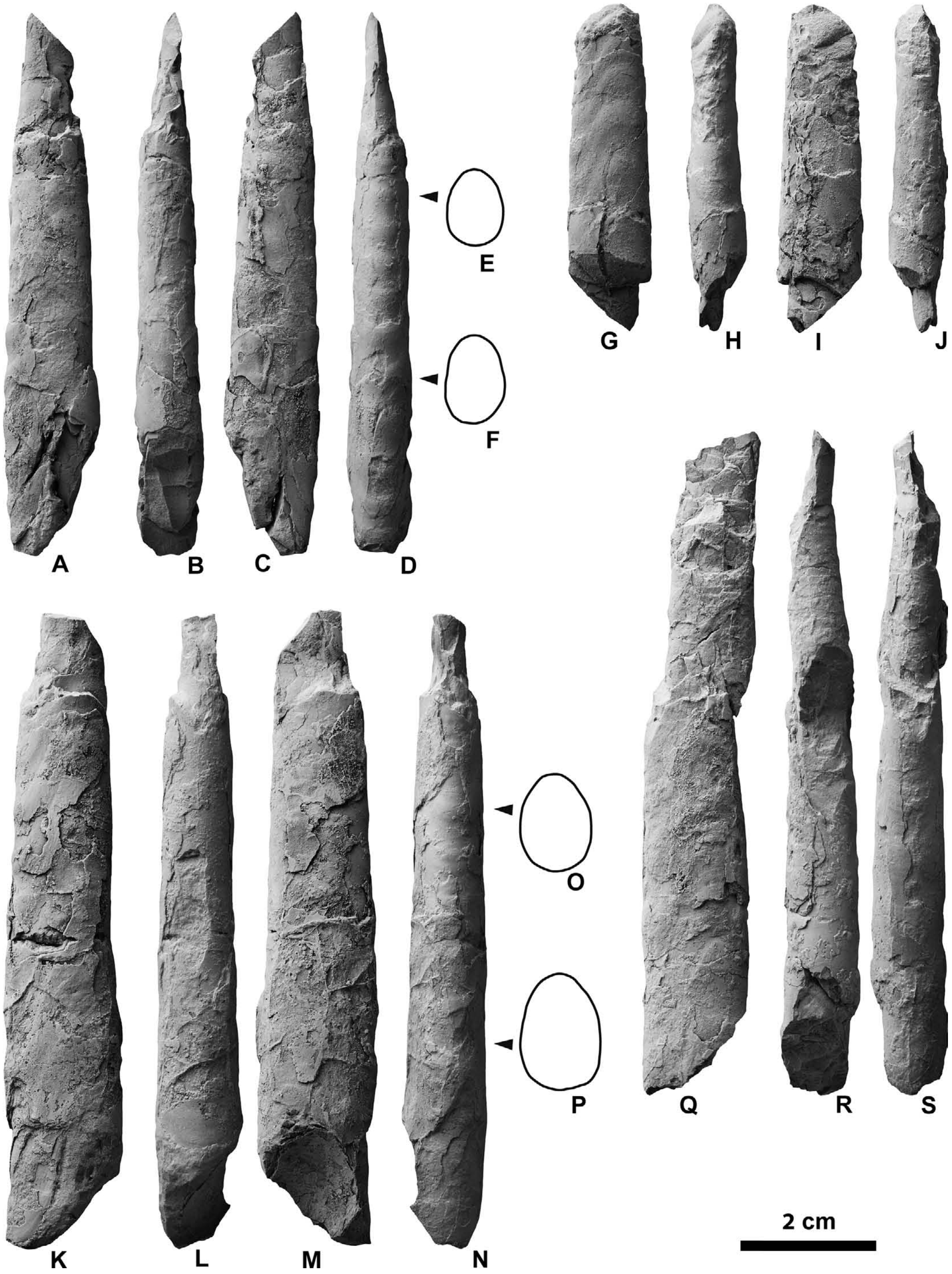

Figure 26. *Baculites subanceps* Haughton, 1925 from Loc. 11 in the Chinomigawa Formation. **A–F,** HMG-1671; A, lateral view; B, dorsal view; C, lateral view rotated 90 degrees from A; D, ventral view; E, whorl cross section at H = 11.4 mm; F, whorl cross section at H = 13.3 mm; **G–J,** HMG-1672; G, lateral view; H, dorsal view; I, lateral view rotated 90 degrees from G; J, ventral view; **K–P,** HMG-1673; K, lateral view; L, dorsal view; M, lateral view rotated 90 degrees from K; N, ventral view; O, whorl cross section at H = 14.6 mm; P, whorl cross section at H = 17.4 mm; **Q–S,** HMG-1674; Q, lateral view; R, dorsal view; S, ventral view.

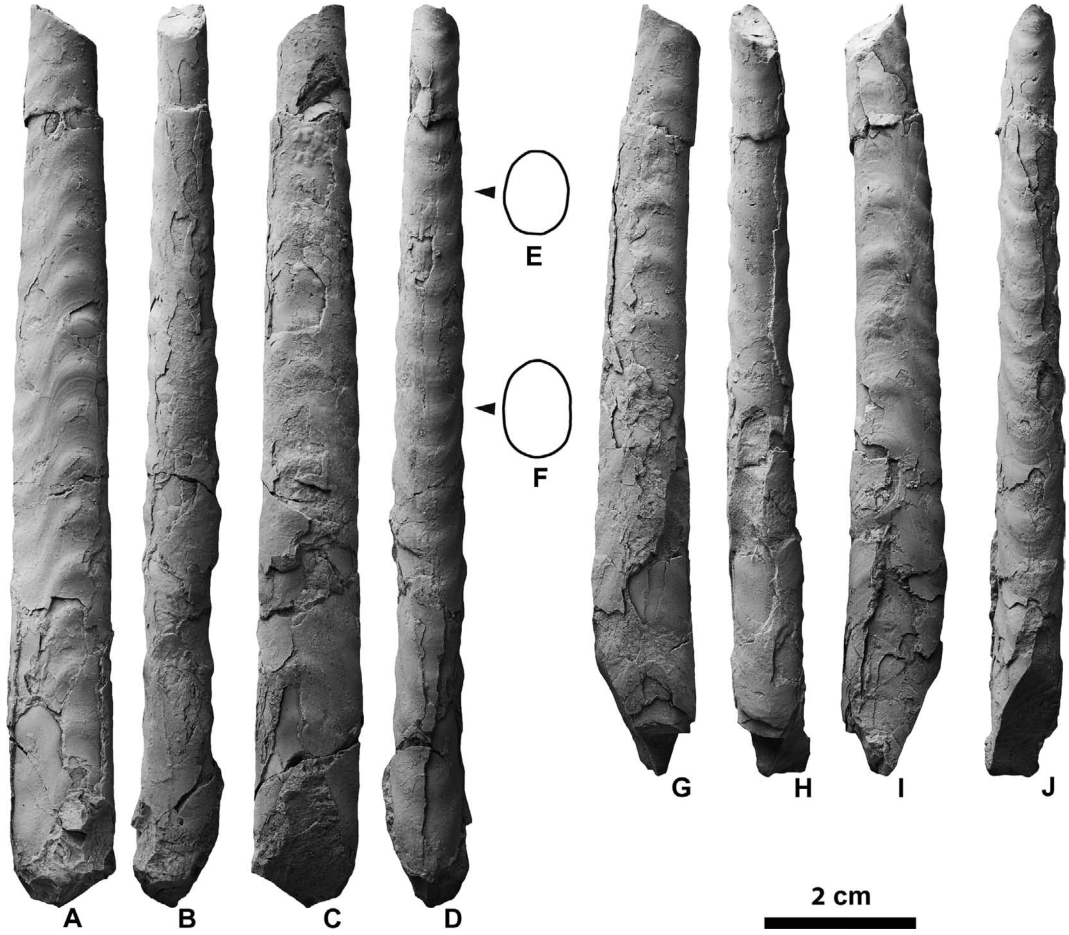

Figure 27. *Baculites subanceps* Haughton, 1925 from Loc. 14 in the Chinomigawa Formation. **A–F,** HMG-1675; A, lateral view; B, dorsal view; C, lateral view rotated 90 degrees from A; D, ventral view; E, whorl cross section at $H = 11.2$ mm; F, whorl cross section at $H = 12.8$ mm; **G–J,** HMG-1676; G, lateral view; H, dorsal view; I, lateral view rotated 90 degrees from G; J, ventral view.

Loc. 7 by Y. Yoshikawa.

Description.—Shell straight or gently arched, tapers fairly rapidly in early growth stage and moderately in late stage. Whorl section oval, with narrowly rounded venter, indistinct ventral shoulders, gently convex flanks with maximum whorl width at mid-flank or slightly below mid-flank, broadly rounded dorsum. As shell grows, whorl section becomes more compressed. Shell surface almost smooth in early growth stage, but as shell grows, weak to strong crescentic nodes develop on flanks and venter becomes corrugated. Dorsum smooth. Suture line moderately incised, with bifid saddles and lobes. First lateral saddle slightly lower and narrower than second lateral saddle. First lateral lobe deep. Second lateral lobe broader and shallower than first lateral lobe.

Remarks.—*Baculites subanceps* closely resembles *B. occidentalis* Meek, 1862 from the upper Campanian of British Columbia and California (Matsumoto, 1959; Ward, 1978; Ward *et al*., 2012) and *B. regina* Obata and Matsumoto, 1963 from the lower Maastrichtian in the Izumi Mountains, Southwest Japan in having crescentic nodes on its flanks, but differs by its corrugated venter and oval whorl section with a narrowly rounded venter. The whorl section of *B. occidentalis* has a subtrigonal shape with shallow grooves on both sides of the narrowly rounded venter, a subangular dorsal shoulder and a nearly flat dorsum. *Baculites regina* has numerous, fine, oblique ribs on the ventral half of the flank.

Occurrence.—Described specimens were collected from the *Baculites subanceps* Zone and float concretions that probably came from the lower upper Campanian beds in the Chinomigawa Formation, Urakawa area. *Baculites subanceps* is known from the upper middle to lower upper Campanian of the western coastal region of

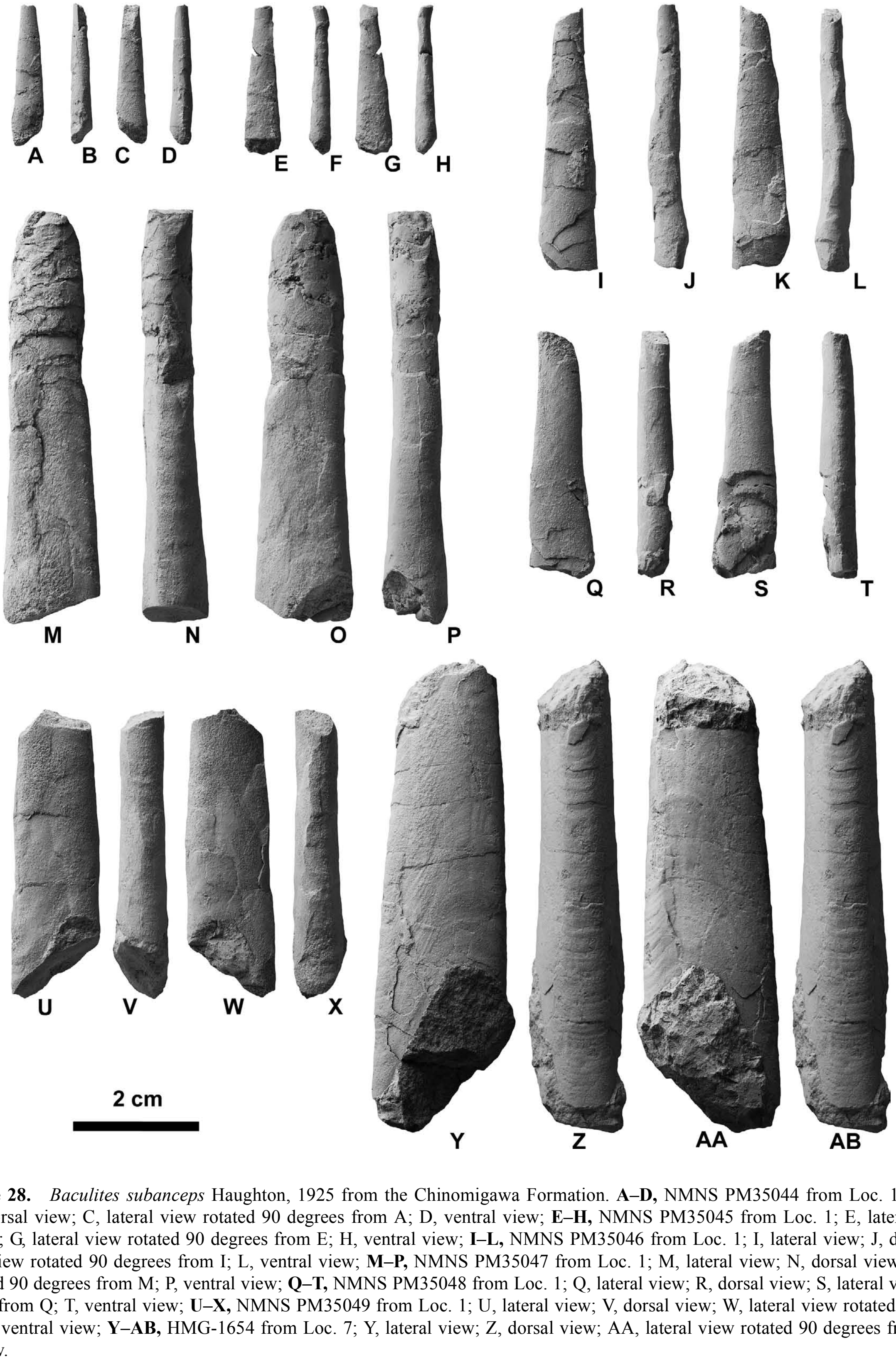

Figure 28. *Baculites subanceps* Haughton, 1925 from the Chinomigawa Formation. **A–D,** NMNS PM35044 from Loc. 1; A, lateral view; B, dorsal view; C, lateral view rotated 90 degrees from A; D, ventral view; **E–H,** NMNS PM35045 from Loc. 1; E, lateral view; F, dorsal view; G, lateral view rotated 90 degrees from E; H, ventral view; **I–L,** NMNS PM35046 from Loc. 1; I, lateral view; J, dorsal view; K, lateral view rotated 90 degrees from I; L, ventral view; **M–P,** NMNS PM35047 from Loc. 1; M, lateral view; N, dorsal view; O, lateral view rotated 90 degrees from M; P, ventral view; **Q–T,** NMNS PM35048 from Loc. 1; Q, lateral view; R, dorsal view; S, lateral view rotated 90 degrees from Q; T, ventral view; **U–X,** NMNS PM35049 from Loc. 1; U, lateral view; V, dorsal view; W, lateral view rotated 90 degrees from U; X, ventral view; **Y–AB,** HMG-1654 from Loc. 7; Y, lateral view; Z, dorsal view; AA, lateral view rotated 90 degrees from Y; AB, ventral view.

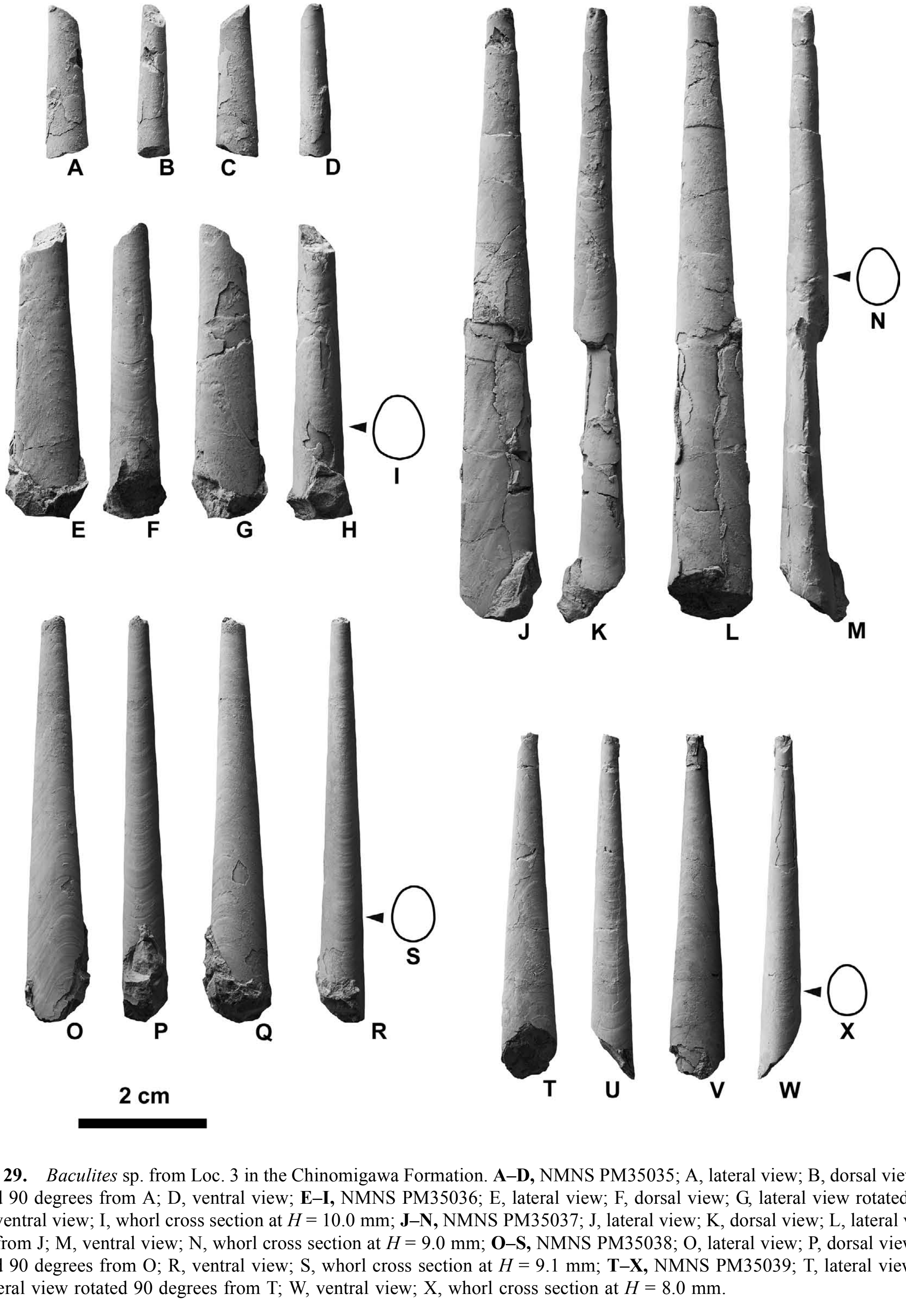

Figure 29. *Baculites* sp. from Loc. 3 in the Chinomigawa Formation. **A–D,** NMNS PM35035; A, lateral view; B, dorsal view; C, lateral view rotated 90 degrees from A; D, ventral view; **E–I,** NMNS PM35036; E, lateral view; F, dorsal view; G, lateral view rotated 90 degrees from E; H, ventral view; I, whorl cross section at $H = 10.0$ mm; **J–N,** NMNS PM35037; J, lateral view; K, dorsal view; L, lateral view rotated 90 degrees from J; M, ventral view; N, whorl cross section at $H = 9.0$ mm; **O–S,** NMNS PM35038; O, lateral view; P, dorsal view; Q, lateral view rotated 90 degrees from O; R, ventral view; S, whorl cross section at $H = 9.1$ mm; **T–X,** NMNS PM35039; T, lateral view; U, dorsal view; V, lateral view rotated 90 degrees from T; W, ventral view; X, whorl cross section at $H = 8.0$ mm.

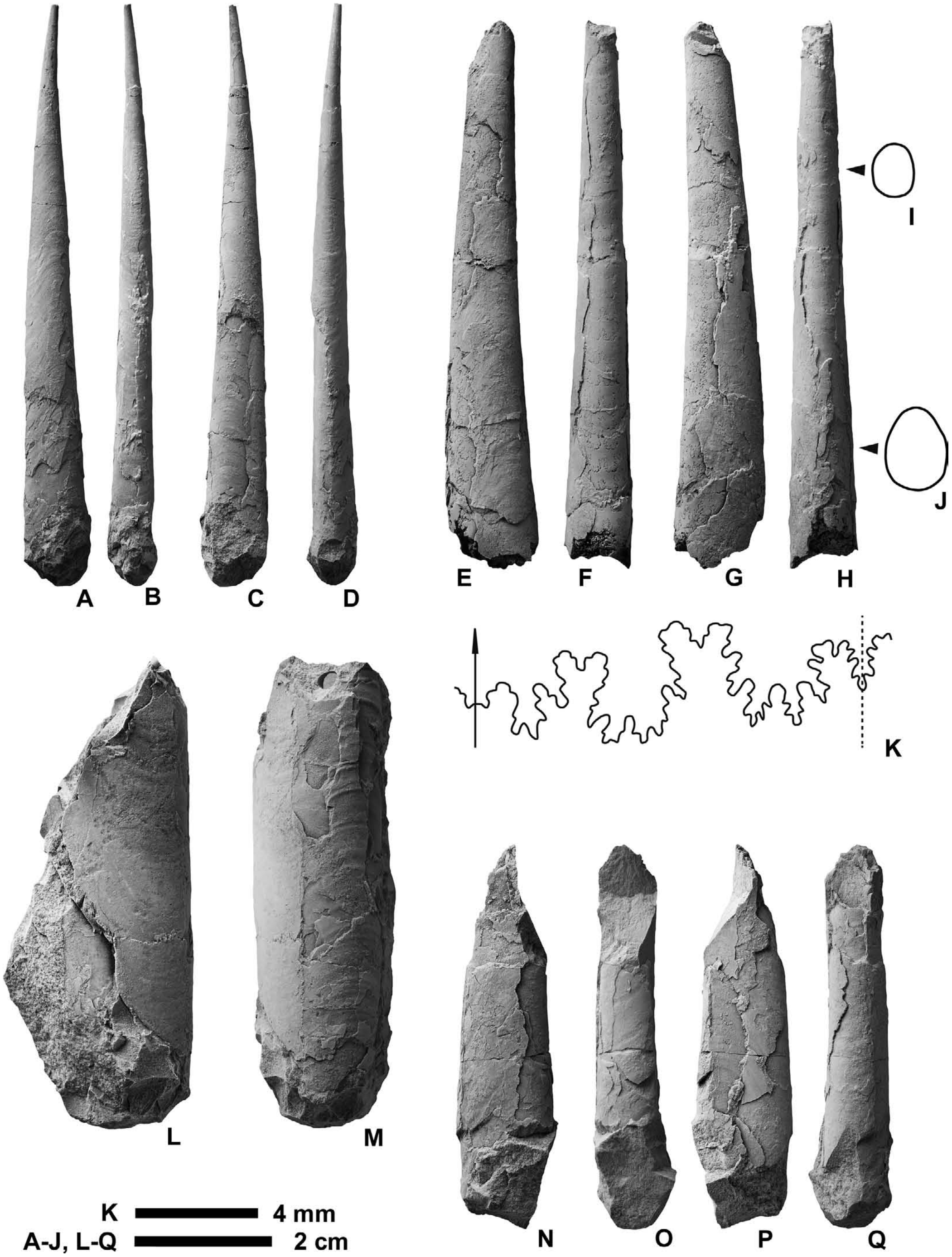

Figure 30. *Baculites* sp. from Loc. 4 in the Chinomigawa Formation. **A–D,** NMNS PM35040; A, lateral view; B, dorsal view; C, lateral view rotated 90 degrees from A; D, ventral view; **E–K,** NMNS PM35041; E, lateral view; F, dorsal view; G, lateral view rotated 90 degrees from E; H, ventral view; I, whorl cross section at $H = 8.0$ mm; J, whorl cross section at $H = 12.2$ mm; K, suture line at $H = 8.3$ mm, Solid line represents the siphuncle and broken line indicates the middle dorsal position; **L, M,** NMNS PM35042; L, lateral view; M, dorsal view; **N–Q,** NMNS PM35043; N, lateral view; O, dorsal view; P, lateral view rotated 90 degrees from N; Q, ventral view.

North America (Ward *et al*., 2012), upper Campanian of Egypt (Luger and Gröschke, 1989), and upper Campanian (lower Maastrichtian?) of Angola (Howarth, 1965).

Baculites sp.

Figures 29, 30

Material examined.—Five specimens, NMNS PM35035–35039, from Loc. 3, and four specimens, NMNS PM35040–35043, from a float concretion found at Loc. 4.

Description.—Fairly rapidly tapered, straight or gently arched shell. Whorl section oval, with narrowly rounded venter, indistinct ventral shoulders, gently convex flanks with maximum whorl width at mid-flank or slightly below, and broadly rounded dorsum. Ornamentation consists only of fine growth lines. Suture line moderately incised, with asymmetrical bifid saddles and lobes. First lateral saddle lower and narrower than second lateral saddle. First lateral lobe deep. Second lateral lobe broader and shallower than first lateral lobe. Folioles have somewhat phylloid terminals.

Remarks.—The described specimens are similar to *Baculites inornatus* Meek, 1862 in having a somewhat phylloid terminal of folioles, but the poor preservation of their mature shells prevents a definitive species assignment. The specimens are somewhat similar to *B. subanceps* in their early growth stage, but differ by their smooth shell surface in middle to late growth stages. As *B. subanceps* grows, weak to strong crescentic nodes develop on its flanks and its venter becomes corrugated.

Occurrence.—Described specimens were collected from the *Metaplacenticeras subtilistriatum* Zone and a float concretion that likely came from the upper middle Campanian beds in the Chinomigawa Formation, Urakawa area.

Concluding remarks

In the past, the biostratigraphic correlation of Campanian strata of the Izumi and Yezo groups has been less than precise. Only a few fossil zones, the *Sphenoceramus schmidti*, *Metaplacenticeras subtilistriatum*, and *Pravitoceras sigmoidale* zones, in ascending order, were known to be common to both groups (Shigeta *et al*., 2010). However, the newly discovered ammonoid assemblages and the zircon geochronology of tuffs intercalated in the Urakawa area have resulted in a much more precise biostratigraphic correlation between the Izumi and Yezo groups (Figure 6). Although ammonoid faunas in the upper part of the upper Campanian beds of the Yezo Group have not been well documented, a more detailed documentation of ammonoid successions in Hokkaido and Sakhalin is a prerequisite for the establishment of a precise biostratigraphic framework for the Campanian as well as subsequent diversity, phylogenetic and paleogeographic analyses of the Northwest Pacific realm.

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References

Alabushev, A. and Wiedmann, J., 1997: Upper Cretaceous ammonites from southern Sakhalin and northwestern Kamchatka (North-East Russia). *Palaeontographica Abteilung A*, Band 244, p. 1–36.

Anderson, F. M., 1958: Upper Cretaceous of the Pacific Coast. *Geological Society of America Memoir*, vol. 71, p. 1–378.

Ando, H., Tomosugi, T. and Kanakubo, T., 2001: Upper Cretaceous to Paleocene Hakobuchi Group, Nakatonbetsu area, northern Hokkaido—lithostratigraphy and megafossil biostratigraphy. *Journal of the Geological Society of Japan*, vol. 107, p. 142–162. (*in Japanese with English abstract*)

Ando, M. and Ando, H., 2002: Depositional facies and megafossil biostratigraphy of the Upper Cretaceous Hakobuchi Group in the Soya Hill area, northern Hokkaido. *Bulletin of the Nakagawa Museum of Natural History*, vol. 5, p. 1–21. (*in Japanese with English abstract*)

Arkell, W. J., 1957: Introduction to Mesozoic Ammonoidea. *In*, Arkell, W. J., Furnish, W. M., Kummel, B., Miller, A. K., Moore, R. C., Schindewolf, O. H., Sylvester-Bradley, P. C. and Wright, C, W. *eds*., *Treatise on Invertebrate Paleontology*, *Part L*, *Mollusca 4*, *Cephalopoda*, *Ammonoidea*, p. L81–129. Geological Society of America, New York and University of Kansas Press, Lawrence.

Bando, Y. and Hashimoto, H., 1984: Biostratigraphy and ammonite fauna of the Izumi Group (Late Cretaceous) in the Asan Mountains. *Memoirs of the Faculty of Education*, *Kagawa University*, *Part 2*, vol. 34, p. 11–39. (*in Japanese with English summary*)

Blaszkiewicz, A., 1980: Campanian and Maastrichtian ammonites of the Middle Vistula Valley, Poland. *Prace Instytutu Geologicznego*, vol. 92, p. 1–63.

Corfu, F., Hanchar, J. M., Hoskin, P. W. O. and Kinny, P., 2003: An atlas of zircon textures. *In*, Hanchar, J. M. and Hoskin, P. W. O.

eds., *Zircon: Reviews in Mineralogy and Geochemistry*, p. 278–286. Mineralogical Society of America, Washington, DC.

Douvillé, H., 1890: Sur la classification des Cératites de la Craie. *Bulletin de la Société Géologique de France, Série 3*, vol. 18, p. 275–292.

Forbes, E., 1846: Report on the fossil Invertebrata from southern India, collected by Mr. Kaye and Mr. Cunliffe. *Transactions of the Geological Society of London*, *Series 2*, vol. 7, p. 97–174.

Gill, T., 1871: Arrangement of the families of mollusks. *Smithsonian Miscellaneous Collections*, vol. 227, p. 1–49.

Grossouvre, A. de., 1894: Recherches sur la Craie supérieure. Deuxième partie: paléontologie. Les ammonites de la Craie supérieure. *Mémoires du Service de la Carte Géologique Detaillée de la France*, p. 1–264.

Haggart, J. W., 1989: New and revised ammonites from the Upper Cretaceous Nanaimo Group of British Columbia and Washington State. *Geological Survey of Canada Bulletin 396*, p. 181–221.

Hauer, F. R. von., 1858: Über die Cephalopoden der Gosauschichten. *Beiträge zur Paläontographie von Österreich*, Band 1, p. 7–14.

Hauer, F. R. von., 1866: Neue Cephalopoden aus den Gosaugebilden der Alpen. *Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften in Wien*, *Mathematisch-Naturwissenschafliche Klasse*, Band 53, p. 300–308.

Haughton, S. H., 1925: Notes on some Cretaceous fossils from Angola (Cephalopoda and Echinoidea). *Annals of the South African Museum*, vol. 22, p. 263–288.

Henderson, R. A. and McNamara, K. J., 1985: Maastrichtian non-heteromorph ammonites from the Miria Formation, Western Australia. *Palaeontology*, vol. 28, p. 35–88.

Hoskin, P. W. and Black, L. P., 2000: Metamorphic zircon formation by solid-state recrystallization of protolith igneous zircon. *Journal of Metamorphic Geology*, vol. 18, p. 423–439.

Howarth, M. K., 1965: Cretaceous ammonites and nautiloides from Angola. *Bulletin of the British Museum (Natural History)*, *Geology*, vol. 10, p. 335–412.

Hyatt, A., 1889: Genesis of the Arietidae. *Smithsonian Contributions to Knowledge*, no. 673, p. 1–238.

Hyatt, A., 1894: Phylogeny of an acquired characteristic. *Proceedings of the American Philosophical Society*, vol. 32, p. 349–647.

Hyatt, A., 1900: Cephalopoda. *In*, Zittel, K. A. *ed*., *Textbook of Palaeontology*, *English ed*., *Translated by C. R. Eastman*, p. 502–592. Macmillan, London and New York.

Ifrim, C., Stinnesbeck, W. and López-Oliva, J. G., 2004: Maastrichtian cephalopods from Cerralvo, north-eastern Mexico. *Palaeontology*, vol. 47, p. 1575–1627.

Ishida, K., Nishiyama, K., Nakao, K., Tsujino, Y., Morie, T. and Shinoaki, S., 2010: The geology and landform of Awa City, Shikoku, Japan: origin and landscape conservation of Awa-no-dochu. *Proceedings of Awagakkai*, vol. 56, p. 1–12. (*in Japanese; original title translated*)

Jimbo, K., 1894: Beiträge zur Kenntniss der Fauna der Kreideformation von Hokkaido. *Paläontologische Abhandlungen*, *Neue Folge*, Band 2, p. 1–48.

Kanie, Y., 1966: The Cretaceous deposits in the Urakawa district, Hokkaido. *Journal of the Geological Society of Japan*, vol. 72, p. 315–328. (*in Japanese with English abstract*)

Kanie, Y., 1982: Geological occurrence of Late Cretaceous ammonite, *Metaplacenticeras subtilistriatum*, in the Urakawa area, southern-central Hokkaido. *Science Report of the Yokosuka City Museum*, no. 29, p. 5–8. (*in Japanese with English abstract*)

Kanie, Y. and Sakai, A., 2002: *Geology of the Urakawa District*, *Scale 1:50,000*, 43 p. Geological Survey of Japan, Tsukuba. (*in Japanese with English abstract*)

Kawaguchi, M. and Kanie, Y., 1985: Upper Cretaceous deposits in the Shimukappu district, central Hokkaido. *Journal of the Geological Society of Japan*, vol. 91, p. 73–86. (*in Japanese with English abstract*)

Kennedy, W. J. and Henderson, R. A., 1992: Non-heteromorph ammonites from the upper Maastrichtian of Pondicherry, South India. *Palaeontology*, vol. 35, p. 381–442.

Kennedy, W. J., Landman, N. H., Cobban, W. A. and Scott, G. R., 2000: Late Campanian (Cretaceous) heteromorph ammonites from the Western Interior of the United States. *Bulletin of the American Museum of Natural History*, no. 251, p. 1–88.

Kinny, P. D., Wijbrans, J. R., Froude, D. O., Williams, I. S. and Compston, W., 1990: Age constraints on the geological evolution of the Narryer Gneiss Complex, Western Australia. *Australian Journal of Earth Sciences*, vol. 37, p. 51–69.

Klinger, H. C. and Kennedy, W. J., 1997: Cretaceous faunas from Zululand and Natal, South Africa. The ammonite family Baculitidae Gill, 1871 (excluding the genus *Eubaculites*). *Annals of the South African Museum*, vol. 105, p. 1–206.

Klinger, H. C. and Kennedy, W. J., 2001: Stratigraphic and geographic distribution, phylogenetic trends and general comments on the ammonite family Baculitidae Gill, 1871 (with an annotated list of species referred to the family). *Annals of the South African Museum*, vol. 107, p. 1–290.

Klinger, H. C. and Kennedy, W. J., 2003: Cretaceous faunas from Zululand and Natal, South Africa. The ammonite families Nostoceratidae Hyatt, 1894 and Diplomoceratidae Spath, 1926. *Annals of the South African Museum*, vol. 110, p. 219–336.

Klinger, H. C. and Lock, B. E., 1978: Upper Cretaceous sediments from the Igoda River mouth, East London, South Africa. *Annals of the South African Museum*, vol. 75, p. 71–83.

Kodama, K., 1990: Magnetostratigraphy of the Izumi Group along the Median Tectonic Line in Shikoku and Awaji Islands, Southwest Japan. *Journal of the Geological Society of Japan*, vol. 96, p. 265–278. (*in Japanese with English abstract*)

Kodama, K., Maeda, H., Shigeta, Y., Kase, T. and Takeuchi, T., 2000: Magnetostratigraphy of Upper Cretaceous strata in South Sakhalin, Russian Far East. *Cretaceous Research*, vol. 21, p. 469–478.

Kodama, K., Maeda, H., Shigeta, Y., Kase, T. and Takeuchi, T., 2002: Integrated biostratigraphy and magnetostratigraphy of the upper Cretaceous System along the River Naiba in southern Sakhalin, Russia. *Journal of the Geological Society of Japan*, vol. 108, p. 366–384. (*in Japanese with English abstract*)

Kossmat, F., 1895: Untersuchungen über die Südindische Kreideformation. Teil 1. *Beiträge zur Paläontologie und Geologie Österreich-Ungarns und des Orients*, Band 9, p. 97–203.

Kurihara, K. and Kano, M., 2006: Minoru Yamashita's collction donated to the Mikasa City Museum. *Bulletin of the Mikasa City Museum*, no. 10, p. 1–35. (*in Japanese with English abstract*)

Lamarck, J. B. P. A. de M. de, 1799: Prodrome d'une nouvelle classification des coquilles, comprenant une rédaction appropriée des caractères génériques, et l'établissement d'un grand nombre de genres nouveaux. *Mémoires de la Société d'Histoire Naturelle de Paris*, p. 63–90.

Lamarck, J. B. P. A. de M. de, 1801: *Système des Animaux sans Vertèbres*, 432 p. Deterville, Paris.

Lamarck, J. B. P. A. de M. de, 1822: *Histoire Naturelle des Animaux sans Vertèbres*, *Tome 7*, 711 p. Verdière, Paris.

Ludwig, K. R., 2003: *User's manual for Isoplot 3.00. A Geochronological Toolkit for Microsoft Excel. Berkeley Geochronology Center Special Publication No. 4*, 70 p. Berkeley Geochronology Center, Berkeley.

Luger, P. and Gröschke, M., 1989: Late Cretaceous ammonites from the Wadi Qena area in the Egyptian Eastern Desert. *Palaeontology*, vol. 32, p. 355–407.

Maeda, H., 1986: Stratigraphy and fossil molluscans fauna of the Upper Cretaceous System in the Bibai area, Hokkaido, north Japan. *Journal of the Geological Society of Japan*, vol. 92, p. 135–153. (*in Japanese with English abstract*)

Maeda, H., Shigeta, Y., Fernando, A. G. S. and Okada, H., 2005: Stratigraphy and fossil assemblages of the Upper Cretaceous System in the Makarov area, southern Sakhalin, Russian Far East. *National Science Museum Monographs*, no. 31, p. 25–120.

Matsumoto [= Matumoto], T., 1942: Fundamentals in the Cretaceous stratigraphy of Japan, Part 1. *Memoirs of the Faculty of Science*, *Kyushu Imperial University*, *Series D*, *Geology*, vol. 1, p. 129–280.

Matsumoto, T., 1953: The ontogeny of *Metaplacenticeras subtilistriatum* (Jimbo). *Japanese Journal of Geology and Geography*, vol. 23, p. 139–150.

Matsumoto, T., 1954: *The Cretaceous System in the Japanese Islands*, 324 p. Japan Society for the Promotion of Science, Tokyo.

Matsumoto, T., 1955: The bituberculate pachydiscids from Hokkaido and Saghalien. *Memoirs of the Faculty of Science*, *Kyushu University*, *Series D*, *Geology*, vol. 5, p. 153–184.

Matsumoto, T., 1959: Upper Cretaceous ammonites of California. Part 2. *Memoirs of the Faculty of Science*, *Kyushu University*, *Series D*, *Geology*, special vol. 1, p. 1–172.

Matsumoto, T., 1963: A survey of fossils from Japan illustrated in classical monographs, Part 10. *In*, Matsumoto, T. *ed*., *A Survey of Fossils from Japan Illustrated in Classical Monographs (Primarily a Nomenclatorial Revision)*, p. 42–48. Palaeontological Society of Japan 25th Anniversary Volume, Palaeontological Society of Japan, Tokyo.

Matsumoto, T., 1979: Palaeontological descriptions Part 1. Some new species of *Pachydiscus* from the Tombetsu and the Hobetsu valleys. *Memoirs of the Faculty of Science*, *Kyushu University*, *Series D*, *Geology*, vol. 24, p. 50–64.

Matsumoto, T., 1984a: Ammonites from the Upper Campanian of the Teshio Mountains. *Palaeontological Society of Japan*, *Special Paper*, no. 27, p. 5–32.

Matsumoto, T., 1984b: Concluding remarks. *Palaeontological Society of Japan*, *Special Paper*, no. 27, p. 77–91.

Matsumoto, T., 1984c: Some gaudryceratid ammonites from the Campanian and Maastrichtian of Hokkaido Part 1. *Science Report of the Yokosuka City Museum*, no. 32, p. 1–10.

Matsumoto, T., 1988: Notes on some Cretaceous ammonites from South Sakhalin held at Tohoku University, Sendai. *Science Report of the Tohoku University*, *2nd Series (Geology)*, vol. 59, p. 177–190.

Matsumoto, T., 1995: Notes on gaudryceratid ammonites from Hokkaido and Sakhalin. *Palaeontological Society of Japan*, *Special Paper*, no. 35, p. 1–152.

Matsumoto, T., Kinoshita, K., Inoma, A., Kido, H., Nishijima, S. and Kato, S., 1980: Stratigraphy of the Upper Cretaceous of the Tombetsu Valley, Hokkaido. *Science Reports*, *Department of Geology*, *Kyushu University*, vol. 13, p. 265–275. (*in Japanese with English abstract*)

Matsumoto, T. and Miyauchi, T., 1984: Some Campanian ammonites from the Soya area. *Palaeontological Society of Japan*, *Special Paper*, no. 27, p. 33–76.

Matsumoto, T., Miyauchi, T. and Kanie, Y., 1985: Some gaudryceratid ammonites from the Campanian and Maastrichtian of Hokkaido Part 2. *Science Report of the Yokosuka City Museum*, no. 33, p. 19–36.

Matsumoto, T. and Obata, I., 1955: Some Upper Cretaceous desmoceratids from Hokkaido and Saghalien. *Memoirs of the Faculty of Science*, *Kyushu University*, *Series D*, *Geology*, vol. 5, p. 119–151.

Matsumoto, T. and Obata, I., 1963: A monograph of the Baculitidae from Japan. *Memoirs of the Faculty of Science*, *Kyushu University*, *Series D*, *Geology*, vol. 13, p. 1–116.

Matsumoto, T. and Okada H., 1971: Clastic sediments of the Cretaceous Yezo Geosyncline. *Memoirs of the Geological Society of Japan*, vol. 6, p. 61–74.

Matsumoto, T. and Yoshida, S., 1979: A new gaudryceratid ammonite from eastern Hokkaido. *Transactions and Proceedings of the Palaeontological Society of Japan*, *New Series*, no. 114, p. 65–76.

Meek, F. B., 1862: Descriptions of new Cretaceous fossils collected by the Northwestern Boundary Commission, on Vancouver and Sucia Islands. *Proceedings of the Academy of Natural Sciences of Philadelphia*, vol. 13, p. 314–318.

Meek, F. B., 1876: Descriptions and illustrations of fossils from Vancouver's and Sucia Islands and other Northwestern localities. *Bulletin of the United State Geological and Geographical Survey of the Territories*, vol. 2, p. 351–374.

Meek, F. B. and Hayden, F. V., 1856: Descriptions of new species of Gastropoda and Cephalopoda from the Cretaceous formations of Nebraska Territory. *Proceedings of the Academy of Natural Sciences of Philadelphia*, vol. 8, p. 70–72.

Meek, F. B. and Hayden, F. V., 1858: Descriptions of new organic remains collected in Nebraska Territory, together with some remarks on the geology of the Black Hills and portions of the surrounding county. *Proceedings of the Academy of Natural Sciences of Philadelphia*, vol. 10, p. 41–59.

Michael, R., 1899: Über Kreidefossilien von der Insel Sachalin. *Jahrbuch der Königlichen Preussischen Geologischen Landsanstalt und Bergakademie zu Berlin*, Band 18, p. 153–164.

Misaki, A. and Maeda, H., 2009: Lithostratigraphy and biostratigraphy of the Campanian-Maastrichtian Toyajo Formation in Wakayama, southwestern Japan. *Cretaceous Research*, vol. 30, p. 1398–1414.

Morozumi, Y., 1985: Late Cretaceous (Campanian and Maastrichtian) ammonites from Awaji Island, Southwest Japan. *Bulletin of the Osaka Museum of Natural History*, no. 39, p. 1–58.

Morozumi, Y., 2007: Nostoceratid ammonoids from the Asan Mountains. *Museum News*, *Tokushima Prefectural Museum*, no. 66, p. 2–3. (*in Japanese; original title translated*)

Nagao, T. and Matsumoto, T., 1940: A monograph of the Cretaceous *Inoceramus* of Japan, Part II. *Journal of the Faculty of Science*, *Hokkaido Imperial University*, *Series IV*, *Geology and Mineralogy*, vol. 6, p. 1–64.

Naruse, H., Maeda, H. and Shigeta, Y., 2000: Newly discovered Late Cretaceous molluscan fossils and inferred K/T boundary in the Nemuro Group, eastern Hokkaido, northern Japan. *Journal of the Geological Society of Japan*, vol. 106, p. 161–164. (*in Japanese with English abstract*)

Nishiyama, K., Ishida, K., Nakao, K., Tsujino, Y., Morinaga, H., Morie, T., Hashimoto, H., Ito, Y. and Yamazaki, K., 2009: The geology and paleontology of Mima-cho in Mima City, Shikoku, Japan: Izumi Group, Pliocene–Pleistocene and landslide landform. *Proceedings of Awagakkai*, vol. 55, p. 1–12. (*in Japanese; original title translated*)

Obata, I., Maehara, T. and Tsuda, H., 1973: Cretaceous stratigraphy of the Hidaka area, Hokkaido. *Memoirs of the National Science Museum*, *Tokyo*, vol. 6, p. 131–145. (*in Japanese with English summary*)

Obata, I. and Matsumoto, T., 1963: A monograph of the Baculitidae from Japan. Part 2. *Memoirs of the Faculty of Science*, *Kyushu*

University, *Series D*, *Geology*, vol. 13, p. 77–92.

Obradovich, J. D. and Cobban, W. A., 1975: A time scale for the Late Cretaceous of the Western Interior of North America. *Geological Association of Canada*, *Special Paper*, vol. 13, p. 31–54.

Ogg, J. G. and Hinnov, L. A., 2012: Cretaceous. *In*, Gradstein, F. M., Ogg, J. G., Schmitz, M. D. and Ogg, G. M. *eds*., *The Geologic Time Scale 2012*, *Volume 2*, p. 793–853. Elsevier, Amsterdam.

Paces, J. B. and Miller, J. D., 1993: Precise U–Pb ages of Duluth Complex and related mafic intrusions, northeastern Minnesota: geochronological insights to physical, petrogenetic, paleomagnetic, and tectonomagmatic processes associated with the 1.1 Ga midcontinent rift system. *Journal of Geophysical Research*, *Solid Earth*, vol. 98, p. 13997–14013.

Pictet, F. J., 1847: Description des mollusques fossiles qui se trouvent dans le Grès Vers des environs de Genève. *Mémoires de la Société de Physique et d'Histoire Naturelle de Genève*, vol. 11, p. 257–412.

Saito, T., 1958: Notes on some Cretaceous fossils from the Nakaminato Formation, Nakaminato City, Ibaraki Prefecture, Japan. Part 1. *Bulletin of the Faculty of Liberal Arts*, *Ibaraki University*, *Natural Science*, *Geology*, vol. 8, p. 83–94.

Sakai, A. and Kanie, Y., 1986: *Geology of the Nishicha District*, *Scale 1:50,000*, 92 p. Geological Survey of Japan, Tsukuba. (*in Japanese with English abstract)*

Schiøtte, L., Compston, W. and Bridgwater, D., 1988: Late Archaean ages for the deposition of clastic sediments belonging to the Malene supracrustals, southern West Greenland: evidence from an ion probe U–Pb zircon study. *Earth and Planetary Science Letters*, vol. 87, p. 45–58.

Seunes, J., 1891: Contribution à l'étude des céphalopodes du Crétacé Supérieur de France. I. Ammonites du Calcaire à *Baculites* du Contentin (Suite). II. Ammonites du Campanien de la region sous-pyrénéenne. Département de Landes. *Mémoires de la Société Géologique de France*, *Série Paléontologique*, vol. 2, p. 8–22.

Shigeta, Y., 1989: Systematics of the ammonite genus *Tetragonites* from the Upper Cretaceous of Hokkaido. *Transactions and Proceedings of the Palaeontological Society of Japan*, *New Series*, no. 156, p. 319–342.

Shigeta, Y., 1992: A record of *Pseudophyllites indra* (Lytoceratina, Tetragonitidae) from the Upper Cretaceous of Hokkaido and Sakhalin. *Transactions and Proceedings of the Palaeontological Society of Japan*, *New Series*, no. 166, p. 1157–1163.

Shigeta, Y., 2001: *Ammonitology*, 155 p. Tokai University Press, Tokyo. (*in Japanese with English title*)

Shigeta, Y., Maeda, H., Uemura, K. and Solov'yov, A. V., 1999: Stratigraphy of the Upper Cretaceous System in the Kurl'on Peninsula, South Sakhalin, Russia. *Bulletin of the National Science Museum*, *Series C*, vol. 25, p. 1–27.

Shigeta, Y., Misaki, A. and Ohara, M., 2012: *Gaudryceras tombetsense* Matsumoto, a Maastrichtian ammonoid from the Aridagawa area, Wakayama, southwestern Japan. *Paleontological Research*, vol. 16, p. 244–251.

Shigeta, Y., Tanabe, K. and Izukura, M., 2010: *Gaudryceras izumiense* Matsumoto and Morozumi, a Maastrichtian ammonoid from Hokkaido and Alaska and its biostratigraphic implications. *Paleontological Research*, vol. 14, p. 202–211.

Smith, J. P., 1900: The development and phylogeny of *Placenticeras*. *Proceedings of the California Academy of Sciences*, *Series 3*, *Geology*, vol. 1, p. 181–240.

Sokolov, D. V., 1914: Cretaceous *Inoceramus* of Russian Sakhalin. *Trudy Geologicheskogo Komiteta*, *Novaya Seriya*, vol. 83, p. 1–95. (*in Russian and German; original title translated*)

Spath, L. F., 1922: On the Senonian ammonite fauna of Pondoland. *Transactions of the Royal Society of South Africa*, vol. 10, p. 113–148.

Spath, L. F., 1926: On new ammonites from the English Chalk. *Geological Magazine*, vol. 63, p. 77–83.

Spath, L. F., 1927: Revision of the Jurassic cephalopod fauna of Kachh (Cutch), part 1. *Memoirs of the Geological Survey of India*, *Palaeontologia Indica*, *New Series*, vol. 9, memoir 2, p. 1–71.

Spath, L. F., 1929: Corrections of cephalopod nomenclature. *Naturalist*, vol. 871, p. 269–271.

Stacey, J. S. and Kramers, J. D., 1975: Approximation of terrestrial lead isotope evolution by a two-stage model. *Earth and Planetary Science Letters*, vol. 26, p. 207–221.

Takahashi, A., Hikida, Y., Jenkins, R. G. and Tanabe, K., 2007: Stratigraphy and megafauna of the Upper Cretaceous Yezo Supergroup in the Teshionakagawa area, northern Hokkaido, Japan. *Bulletin of the Mikasa City Museum*, no. 11, p. 25–59.

Tamaki, M., Oshimbe, S. and Itoh, Y., 2008: A large latitudinal displacement of a part of Cretaceous forearc basin in Hokkaido, Japan: paleomagnetism of the Yezo Supergroup in the Urakawa area. *Journal of the Geological Society of Japan*, vol. 114, p. 207–217.

Tanabe, K., Hirano, H., Matsumoto, T. and Miyata, Y., 1977: Stratigraphy of the Upper Cretaceous deposits in the Obira area, northwestern Hokkaido. *Science Reports*, *Department of Geology*, *Kyushu University*, vol. 12, p. 181–202. (*in Japanese with English abstract*)

Tanaka, K., 1977: Cretaceous System. *In*, Tanaka, K. and Nozawa, T. *eds*., *Geology and Mineral Resources of Japan*, p. 182–206. Geological Survey of Japan, Kawasaki.

Tanaka, K. and Teraoka, Y., 1973: Stratigraphy and sedimentation of the Upper Cretaceous Himenoura Group in Koshiki-jima, Southwest Kyushu, Japan. *Bulletin of the Geological Survey of Japan*, vol. 24, p. 157–184. (*in Japanese with English abstract*)

Tashiro, M., Yamagata, K. and Yamasaki, M., 1993: On some interesting fossil assemblage beds from the Izumi Group at Kagawa Prefecture and its adjacent areas. *Research Reports of Kochi University*, *Natural Science*, vol. 42, p. 29–38. (*in Japanese with English abstract*)

Toshimitsu, S., 1988: Biostratigraphy of the Upper Cretaceous Santonian stage in northwestern Hokkaido. *Memoirs of the Faculty of Science*, *Kyushu University*, *Series D*, *Geology*, vol. 26, p. 125–192.

Toshimitsu, S., Matsumoto, T., Noda, M., Nishida, T. and Maiya, S., 1995: Towards an integrated mega-, micro- and magneto-stratigraphy of the Upper Cretaceous in Japan. *Journal of the Geological Society of Japan*, vol. 101, p. 19–29. (*in Japanese with English abstract*)

Tsujino, Y., 2004: Lithofacies and faunal assemblages of the Upper Cretaceous Izumi Group in Kanewari area, Kagawa Prefecture, Japan. *Bulletin of the Tokushima Prefectural Museum*, no. 14, p. 1–13. (*in Japanese with English abstract*)

Tsutsumi, Y., Horie, K., Sano, T., Miyawaki, R., Momma, K., Matsubara, S., Shigeoka, M. and Yokoyama, K., 2012: LA-ICP-MS and SHRIMP ages of zircons in chevkinite and monazite tuffs from the Boso Peninsula, Central Japan. *Bulletin of the National Museum of Nature and Science*, *Series C*, vol. 38, p. 15–32.

Tsutsumi, Y., Miyake, Y. and Komatsu, T., 2014: LA-ICP-MS zircon U–Pb dating of acidic tuffs from the Upper Cretaceous Himenoura Group, Koshiki-jima area, southwest Japan. *Abstract with Programs*, *the 2014 Annual Meeting of the Palaeontological Society of Japan*, p. 25. (*in Japanese*)

Usher, J. L., 1952: Ammonite faunas of the Upper Cretaceous rocks of Vancouver Island, British Columbia. *Geological Survey of*

Canada Bulletin 21, p. 1–182.

Vereschagin, V. N., 1977: The Cretaceous System of Far East. *Trudy Vsesoyunogo Nauchno-Issledovatel'skogo Geologicheskogo Instituta (VSEGEI)*, *New Series*, vol. 245, p. 1–207. (*in Russian; original title translated*)

Wani, R., 2006: The peculiar taphonomy of the streamlined late Campanian ammonite *Metaplacenticeras subtilistriatum* from northern Hokkaido, Japan. *Cretaceous Research*, vol. 27, p. 863–871.

Ward, P. D., 1978: Baculitids from the Santonian–Maastrichtian Nanaimo Group, British Columbia, Canada and Washington State, USA. *Journal of Paleontology*, vol. 52, p. 1143–1154.

Ward, P. D., Haggart, J. W., Mitchell, R., Kirschvink, J. L. and Tobin, T., 2012: Integration of macrofossil biostratigraphy and magnetostratigraphy for the Pacific Coast Upper Cretaceous (Campanian–Maastrichtian) of North America and implications for correlation with the Western Interior and Tethys. *Geological Society of America Bulletin*, vol. 124, p. 957–974.

White, C., 1889: On invertebrate fossils from the Pacific Coast. *Bulletin of the United States Geological Survey*, vol. 51, p. 435–532.

Whiteaves, J. F., 1895: Notes on some fossils from the Cretaceous rocks of British Columbia, with descriptions of two species that appear to be new. *Canadian Record of Science*, vol. 6, p. 313–318.

Wiedmann, J., 1966: Stammesgeschichte und System der posttriadischen Ammonoideen, ein Überblick (2. Teil). *Neues Jahrbuch für Geologie und Paläontologie*, *Abhandlungen*, Band 127, p. 13–81.

Williams, I. S., 1998: U–Th–Pb geochronology by ion microprobe. *In*, McKibben, M. A., Shanks, W. C. P. and Ridley, W. I. *eds*., *Applications of Microanalytical Techniques to Understanding Mineralizing Processes*, p. 1–35. Reviews in Economic Geology 7, Society of Economic Geologists, Littleton.

Williams, I. S. and Claesson, S., 1987: Isotopic evidence for the Precambrian provenance and Caledonian metamorphism of high grade paragneisses from the Seve Nappes, Scandinavian Caledonides. *Contributions to Mineralogy and Petrology*, vol. 97, p. 205–217.

Wright, C. W. and Matsumoto, T., 1954: Some doubtful Cretaceous ammonite genera from Japan and Saghalien. *Memoirs of the Faculty of Science*, *Kyushu University*, *Series D*, *Geology*, vol. 4, p. 107–134.

Yabe, H., 1901: Note on three Upper Cretaceous ammonites from Japan, outside of Hokkaido. *Journal of the Geological Society of Japan*, vol. 8, p. 1–4.

Yabe, H., 1903: Cretaceous Cephalopoda from the Hokkaido. Part 1: *Lytoceras*, *Gaudryceras*, and *Tetragonites*. *Journal of the College of Science*, *Imperial University of Tokyo*, vol. 18, p. 1–55.

Yazykova [= Yazikova], E. A., 1994: Maastrichtian ammonites and biostratigraphy of the Sakhalin and the Shikotan Islands, Far East Russia. *Acta Geologica Polonica*, vol. 44, p. 277–303.

Yehara, S., 1924: On the Izumi sandstone group in the Onogawa Basin in Prov. Bungo and the same group in Uwajima, Prov. Iyo. *Japanese Journal of Geology and Geography*, vol. 3, p. 24–40.

Zittel, K. A., 1884: Cephalopoda. *In*, Zittel, K. A. *ed*., *Handbuch der Paläontologie*, *Band 1*, *Abt. 2*, *Lief 3*, p. 329–522. Oldenbourg, Munich and Leipzig.

Zittel, K. A., 1895: *Grundzüge der Paläontologie*, 971 p. Oldenbourg, Munich and Leipzig.

Zonova, T. D., Kazintsova, L. I. and Yazykova, E. A., 1993: *Atlas of Index Fossils in the Cretaceous Fauna of Sakhalin*, 327 p. Nedra, St. Petersburg. (*in Russian; original title translated*)

Appendix 1. LA-ICP-MS analyzed data of zircons in the tuff sample collected from Loc. 2 and calculated ages. Errors are 1 sigma. $\mathrm{Pb_c}$ and Pb* indicate the common and radiogenic portions, respectively.

Labels	$^{206}\mathrm{Pb_c}^{(1)}$ (%)	U (ppm)	Th (ppm)	Th/U	$^{238}\mathrm{U}/^{206}\mathrm{Pb}^{*\,(1)}$	$^{207}\mathrm{Pb}^{*}/^{206}\mathrm{Pb}^{*\,(1)}$	$^{238}\mathrm{U}/^{206}\mathrm{Pb}^{*}$ age $^{(1)}$ (Ma)	$^{238}\mathrm{U}/^{206}\mathrm{Pb}^{*}$ age $^{(2)}$ (Ma)
MKB.001	0.26	486	359	0.76	82.38±1.90	0.0527±0.0091	77.8±1.8	77.3±1.7
MKB.002	5.10	270	263	1.00	92.35±3.37	–0.0025±0.0161	69.4±2.5	73.1±2.4
MKB.003	0.00	215	163	0.78	83.67±2.53	0.0503±0.0069	76.6±2.3	76.3±2.4
MKB.004	1.31	402	268	0.68	85.09±2.39	0.0413±0.0092	75.3±2.1	75.9±2.0
MKB.005	0.30	475	174	0.38	74.07±1.91	0.0550±0.0062	86.4±2.2	85.7±2.2
MKB.006	1.13	309	238	0.79	85.54±3.12	0.0375±0.0121	74.9±2.7	75.8±2.6
MKB.007	0.00	770	422	0.56	78.56±1.71	0.0449±0.0033	81.5±1.8	81.5±1.8
MKB.008	0.00	292	193	0.68	85.99±2.55	0.0381±0.0054	74.5±2.2	74.5±2.2
MKB.009	3.64	222	305	1.41	91.08±4.18	0.0036±0.0239	70.4±3.2	73.0±2.7
MKB.010	1.40	389	290	0.77	86.78±2.51	0.0383±0.0112	73.9±2.1	74.7±2.0
MKB.011	0.00	201	118	0.60	86.89±2.75	0.0549±0.0075	73.8±2.3	73.1±2.4
MKB.012	1.44	1280	848	0.68	85.92±1.65	0.0460±0.0048	74.6±1.4	74.7±1.4
MKB.013	0.00	338	231	0.70	86.34±2.30	0.0502±0.0046	74.2±2.0	74.0±2.0
MKB.014	0.00	233	124	0.54	85.82±2.93	0.0426±0.0055	74.7±2.5	74.7±2.5
MKB.015	0.00	183	116	0.65	91.33±3.53	0.0644±0.0098	70.2±2.7	68.7±2.8
MKB.016	0.00	360	143	0.41	81.61±1.91	0.0467±0.0043	78.5±1.8	78.5±1.8
MKB.017	0.35	281	120	0.44	91.65±3.06	0.0640±0.0104	70.0±2.3	68.5±2.3
MKB.018	1.37	186	89	0.49	85.26±3.54	0.0138±0.0113	75.2±3.1	76.2±3.0
MKB.019	0.67	271	198	0.75	90.91±2.88	0.0489±0.0120	70.5±2.2	70.4±2.2
MKB.020	1.50	1274	1594	1.28	88.79±1.68	0.0355±0.0078	72.2±1.4	73.3±1.2
MKB.021	9.08	283	134	0.49	86.30±2.74	0.0313±0.0148	74.3±2.3	75.8±2.3
MKB.022	0.24	265	160	0.62	83.61±2.32	0.0371±0.0100	76.6±2.1	76.8±2.0
MKB.023	10.98	355	198	0.57	92.71±2.71	0.0322±0.0172	69.2±2.0	70.5±2.0
MKB.024	1.03	678	333	0.50	73.95±1.45	0.0435±0.0053	86.6±1.7	87.0±1.7
MKB.025	0.00	314	196	0.64	83.13±2.27	0.0440±0.0050	77.1±2.1	77.1±2.1
MKB.026	0.00	458	389	0.87	84.79±2.12	0.0541±0.0045	75.6±1.9	75.0±1.9
MKB.027	0.00	320	137	0.44	80.50±2.13	0.0541±0.0054	79.6±2.1	78.9±2.1
MKB.028	1.37	655	427	0.67	89.07±2.14	0.0466±0.0097	72.0±1.7	72.1±1.6
MKB.029	0.08	477	335	0.72	80.78±1.80	0.0462±0.0069	79.3±1.8	79.4±1.7
MKB.030	1.24	431	303	0.72	87.64±2.24	0.0387±0.0080	73.1±1.9	73.9±1.8
MKB.031	0.00	321	182	0.58	88.53±2.63	0.0587±0.0051	72.4±2.1	71.4±2.2
MKB.032	0.00	375	239	0.65	78.25±2.40	0.0510±0.0051	81.9±2.5	81.5±2.5
MKB.033	0.29	506	337	0.68	83.14±2.12	0.0397±0.0075	77.1±2.0	77.3±1.9
MKB.034	0.00	708	729	1.06	85.28±1.75	0.0446±0.0030	75.1±1.5	75.1±1.5
MKB.035	0.00	209	109	0.53	81.03±2.71	0.0530±0.0082	79.1±2.6	78.5±2.7
MKB.036	0.00	270	158	0.60	84.03±2.46	0.0479±0.0053	76.3±2.2	76.2±2.3
MKB.037	1.63	270	164	0.62	83.17±2.72	0.0282±0.0117	77.0±2.5	78.3±2.4
MKB.038	0.00	225	117	0.53	84.16±2.84	0.0493±0.0067	76.1±2.6	76.0±2.6
MKB.039	1.40	417	243	0.60	90.0±2.5	0.0355±0.0095	71.27±1.97	72.28±1.87

(1) Common Pb corrected by assuming $^{206}\mathrm{Pb}/^{238}\mathrm{U}$–$^{208}\mathrm{Pb}/^{232}\mathrm{Th}$ age-concordance
(2) Common Pb corrected by assuming $^{206}\mathrm{Pb}/^{238}\mathrm{U}$–$^{207}\mathrm{Pb}/^{235}\mathrm{U}$ age-concordance

Appendix 2. LA-ICP-MS analyzed data of zircons in the tuff sample collected from Loc. 9 and calculated ages. Errors are 1 sigma. Pb$_c$ 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)
TSP.001	0.86	231	164	0.73	85.69±2.92	0.0457±0.0133	74.8±2.5	75.0±2.5
TSP.002	0.00	177	97	0.56	80.79±3.43	0.0472±0.0076	79.3±3.4	79.3±3.4
TSP.003	0.00	93	61	0.67	77.50±3.68	0.0260±0.0136	82.7±3.9	82.7±3.9
TSP.004	0.18	236	112	0.49	91.84±3.28	0.0415±0.0100	69.8±2.5	69.9±2.4
TSP.005	0.00	163	81	0.51	78.85±2.44	0.0496±0.0073	81.2±2.5	81.0±2.6
TSP.006	0.00	512	355	0.71	86.54±1.88	0.0455±0.0036	74.1±1.6	74.1±1.6
TSP.007	0.56	179	95	0.55	89.40±3.54	0.0457±0.0123	71.7±2.8	71.9±2.8
TSP.008	0.00	249	309	1.28	84.13±2.53	0.0432±0.0056	76.2±2.3	76.2±2.3
TSP.009	0.25	342	285	0.85	79.45±2.11	0.0553±0.0092	80.6±2.1	79.9±2.0
TSP.010	0.00	165	94	0.59	88.81±3.26	0.0394±0.0068	72.2±2.6	72.2±2.6
TSP.011	0.43	487	212	0.45	79.00±1.77	0.0411±0.0055	81.1±1.8	81.4±1.8
TSP.012	0.00	175	105	0.62	82.46±2.78	0.0416±0.0065	77.7±2.6	77.7±2.6
TSP.013	0.83	156	153	1.01	83.63±3.46	0.0374±0.0182	76.6±3.2	77.3±2.8
TSP.014	0.00	199	114	0.59	85.03±2.90	0.0592±0.0063	75.4±2.6	74.3±2.6
TSP.015	0.00	104	58	0.57	83.52±3.31	0.0434±0.0103	76.7±3.0	76.7±3.0
TSP.016	0.00	188	128	0.70	85.42±3.45	0.0473±0.0078	75.0±3.0	75.0±3.0
TSP.017	2.98	178	110	0.64	86.85±4.03	0.0361±0.0179	73.8±3.4	74.9±3.3
TSP.018	1.46	112	84	0.77	85.49±4.33	0.0631±0.0216	75.0±3.8	73.5±3.6
TSP.019	1.85	157	119	0.78	80.65±3.37	0.0432±0.0173	79.4±3.3	79.9±3.2
TSP.020	1.78	155	110	0.72	92.97±4.04	0.0390±0.0153	69.0±3.0	69.7±2.9
TSP.021	0.00	142	88	0.63	86.33±3.75	0.0328±0.0080	74.2±3.2	74.2±3.2
TSP.022	0.92	234	140	0.61	81.39±2.64	0.0357±0.0106	78.7±2.5	79.4±2.4
TSP.023	0.00	183	162	0.91	89.10±2.94	0.0369±0.0063	71.9±2.4	71.9±2.4
TSP.024	0.00	183	143	0.80	82.10±2.84	0.0568±0.0079	78.0±2.7	77.1±2.8
TSP.025	0.00	248	163	0.68	67.90±2.33	0.0444±0.0051	94.2±3.2	94.2±3.2
TSP.026	0.71	222	148	0.68	82.40±2.88	0.0401±0.0127	77.8±2.7	78.3±2.5
TSP.027	0.50	185	164	0.91	85.35±3.25	0.0384±0.0151	75.1±2.8	75.5±2.6
TSP.028	1.99	109	53	0.49	95.38±4.95	0.0074±0.0177	67.2±3.5	68.6±3.4
TSP.029	0.00	130	63	0.50	85.80±3.18	0.0497±0.0097	74.7±2.8	74.5±2.9
TSP.030	0.00	223	423	1.95	84.15±2.56	0.0420±0.0062	76.2±2.3	76.2±2.3

(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