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Aptian–Albian (Lower Cretaceous) ammonite biostratigraphy of the Miyako Group, Japan based on supplementary and revised ammonite taxa

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Abstract

The Early Cretaceous ammonite standard zonation based on the Tethyan Realm is found in western Europe. Because marine faunas also thrived in the Tethyan, Boreal (Arctic), and Pacific regions during the Early Cretaceous, it is important to establish additional biochronological scales based on the faunas of each of these paleogeographic regions. Since the North Pacific region formed its own paleobiogeographic realm by the late Early Cretaceous, it is necessary to develop a standard ammonite zonation for this region, and to establish a relative biochronological time scale and coordinate it with that of Western European standard stratigraphy.

The ammonite standard zonation of the upper Aptian–lower Albian stages for the North Pacific region can be established based on the ammonite-bearing strata of the Miyako Group of northeast Japan. Fifty-eight species of 39 genera including one new genus (*Pseudolithancylus*) and nine new species (*Phyllopachyceras iwatense*, *Puzosia* (*P.*) *shimizui*, *Desmoceras* (*Pseudouhligella*) *sanrikucum*, *Pseudolithancylus tohokuense*, *Ephamulina monotuberculata*, *Idiohamites pacificum*, *Lechites* (*L.*) *komorii*, *Parachelonicer as kazuoi* and *Douvilleiceras bifurcatum*) are described systematically.

A total of 92 species belonging to 49 genera based on 909 specimens have been described from the Miyako Group. These ammonite assemblages can be divided into three ammonite biostratigraphic zones (*Epicheloniceras* sp. Taxon-range Zone, *Hypacanthoplites subcornuerianus* Taxon-range Zone, *Douvilleiceras bifurcatum* Interval Zone), which can be defined in the succession from the Tanohata to Sakiyama formations. These three zones can be correlated with the ammonite standard zonation of Barremian–Albian stages of the west Mediterranean Province of the Tethyan Realm. The Aptian–Albian boundary occurs within the *Hypacanthoplites subcornuerianus* Taxon-range Zone, because the zone can be correlated to the *H. plesiotypicus* Zone, found at the GSSP of the Albian Stage in France.

Ammonites of the Miyako Group diversified morphologically during times of transgression. In the expansion of ammonite habitat accompanying transgression, both ornate planispiral and smooth or weakly ornate planispiral forms appeared first, followed by dominant heteromorph forms. Ornate planispiral forms of the Miyako Group are characterized by new species, but smooth or weakly ornate planispiral form shares common species with North America and the Tethyan area. This suggests that the ornate planispiral form speciated near the Miyako area, while the smooth or weakly ornate planispiral forms migrated from that area and biogeographically expanded in their habitats during the transgressive episodes. *Douvilleiceras* sp., which is the typical ornate planispiral form, co-occurred with Aptian ammonite species of the Miyako Group, and this occurrence is thus the earliest recorded occurrence of the genus. *Douvilleiceras* sp. first appeared in the Miyako area and /or its adjacent area in the northern Pacific Province.

Keywords: systematic description, ammonite biostratigraphic zones, Aptian–Albian transition, morphological analysis, early douvilleiceratid evolution

Introduction

Most of the Lower Cretaceous standard sections are in Western Europe, and the Early Cretaceous biochronological time scale has been established based on the biostratigraphic distribution of Tethyan ammonite species found in that region. Because marine faunas also thrived in the Tethyan, Boreal (Arctic), and Pacific regions during the early Cretaceous world, with many unique species not found in the Western European successions, it is thus necessary to establish additional biochronological scales based on the faunas of each of these paleogeographic regions. A unique relative geological time scale should be applied in those areas, but which hitherto has not been established of the regional scale. Since the North Pacific region formed its own paleobiogeographic realm in the late Early Cretaceous, it

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is necessary to develop a standard ammonite zonation for this region, and to establish a relative biochronological time scale correlated with that of Western European standard stratigraphy.

Matsukawa and his colleagues have established an Early Cretaceous ammonite zonation and biochronological time scale in Japan, on the western side of the North Pacific region (*e.g*., Obata & Matsukawa, 2007, 2009, 2018; Matsukawa & Obata, 2015; Matsukawa, 2021; Matsukawa & Shibata, 2023). The ammonite-bearing strata of the Miyako Group are the representative succession from upper Aptian to lower Albian in this region of the North Pacific Province (Obata & Matsukawa, 2018). The abundant ammonite species contained in the group have been systematically described in several publications (Shimizu, 1931; Obata, 1967a, b, 1969, 1973, 1975; Obata & Futakami, 1991, 1992; Obata & Matsukawa, 1980, 2012, 2018; Obata *et al*., 2010; Matsukawa & Oji, 2022; Matsukawa & Shibata, 2023). In this paper, we provide supplementary descriptions of the remaining ammonite species, and revision of some taxa described previously. This paper completes the species' descriptions and analyses the taxonomic composition of this fauna. Accordingly, we establish the ammonite biostratigraphy of the Miyako Group and identify ammonite biozone divisions. We are thus able to establish a relative biochronological time scale correlatable with that of Western European standard stratigraphy. We also review the taxonomic composition of the fauna according to shell morphologies and their temporal changes, enabling an assessment of the relationship between ecological evolution and environmental changes.

Study history of the Miyako Group and the remaining issues

The Cretaceous System that is distributed discontinuously along about 35 km of the Sanriku coast facing the Pacific Ocean (Fig. 1) is called the Miyako Group. It is exposed in Bentenzaki Cape, Aketo hamlet, Hiraname hamlet, Raga hamlet, Hiraiga hamlet, Haipe beach, Koikorobe beach, Shimanokoshi hamlet (area enclosed in a square A in Fig. 1), Mizujirizaki Cape, Tairajima Islet, Matsushima Islet, Moshi coast, Oshima Islet (square B in Fig. 1), Masaki Cape, Sannoiwa rock natural monument, Taro coastal (square C in Fig. 1) and residential districts, Sakiyama Hideshima coast, Hideshima Island, Takonohama beach, Kuwagasaki Cape (square D in Fig. 1) between the northern limit at Bentenzaki Cape, Tanohata Village, Iwate Prefecture and the southern limit at the hill on the west side of Miyako port.

A concept of lithostratigraphy

Yaegashi (1900) found that fossil-bearing strata of Miyako, Sakiyama Hideshima coast, and Taro areas were of Cretaceous age, based on many fossils found there. Yabe & Yehara (1913) discovered Cretaceous rocks in three additional regions, revealing that the Cretaceous strata are distributed discontinuously in five total regions, Raga, Moshi, Taro, Hideshima and Kuwagasaki. They divided the Cretaceous strata in each region based on lithostratigraphic units that they then correlated among the five regions, which was the basis for geological maps. Based on the many characteristic fossil taxa, they compared the Miyako fossils with those from the Cretaceous in other parts of Japan and overseas to establish their geological ages. There was, at the time, no clear understanding of overall lithostratigraphy, and a biostratigraphy framework was not established for any fossil taxa.

Hanai (1949) divided the Cretaceous strata distributed in the five regions that were studied by Yabe & Yehara (1913) into the lower and upper Miyako formations of the Miyako Group, based on cyclical grain-size changes. Hanai *et al*. (1968) later divided the group into four units, the Raga, Tanohata, Hiraiga, and Aketo formations in the Tanohata region, in ascending stratigraphic order, based on Hanai's (1949) methods. They asserted that the four stratigraphic units could be identified in all the five regions.

Shimazu *et al*. (1970) applied the lithostratigraphic scheme of Hanai *et al*. (1968) to the successions in the Sakiyama region, with some modifications, and divided the Miyako Group in the Hideshima coast and Ebisudana Islet of the Sakiyama region into the Tanohata, Hiraiga, and Sakiyama formations, in ascending stratigraphic order. The Miyako Group found at the Hideshima Islet was referred to as the Hideshima Formation of unknown relationship with other formations in the region (Shimazu *et al*., 1970). For the lithostratigraphic divisions of the Miyako Group, the Tanohata region serves as the lithostratigraphic type section for the four regions, except for the Sakiyama region, and this arrangement has been accepted by many geologists. However, a difference of interpretation exists in the Sakiyama region. In an attempt to provide a unified lithostratigraphic framework for the Miyako Group, we herein propose a lithostratigraphy for the group distributed across all five regions.

A concept of biostratigraphy

Shimizu (1931) described nine ammonite species from the Miyako Group, as well as a *Cymatoceras* species. He also proposed six ammonite biozones in the Miyako Group, five of which were in the Hiraiga Sandstone and one in the Aketo Sandstone of Yabe & Yehara (1913). To estimate the geological age range of these two units, Shimizu (1931) compared their ammonite faunas with the geological age ranges of the Europe, Caucasus and Tunisia, where allied species occur. As a result, Shimizu

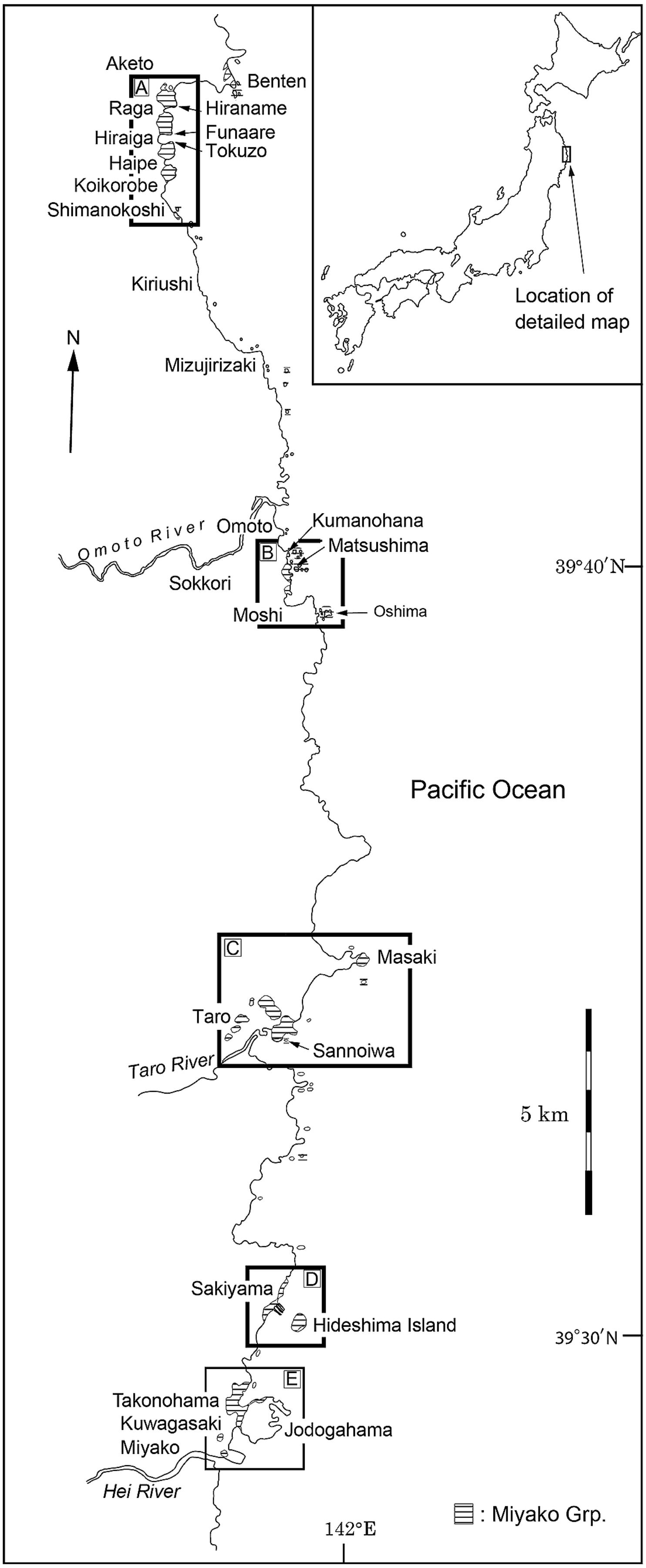

FIGURE 1. Map showing the distribution of the Miyako Group in northeast Japan. After Obata & Matsukawa (2018).

(1931) regarded the Hiraiga Sandstone as lower Aptian to lower Albian, and the Aketo Sandstone as middle Albian. His concept of biozone was a stratigraphic level that yields an ammonite species, which corresponds to the modern biostratigraphic horizon definition.

Hanai *et al*. (1968) established ammonite and bivalve biostratigraphies based on representative species from the Miyako Group, recognizing three ammonite biozones, and two bivalve biozones. They compared the ammonite species contained in these biozones with ammonite species from upper Aptian to lower Albian of the Cretaceous standard stratigraphy of Western Europe and ascertained that the Miyako Group ranges from the upper Aptian to the lower Albian. Hanai *et al*. (1968) did not specifically define those biozones, but as the boundaries of the biozones are marked by dashed lines in their diagram, we assume they created the biozones according to the biostratigraphic distributions of each species. Although these ranges are not shown in the lithostratigraphy, it seems that Hanai *et al*. (1968) regarded the biozones as range zones.

Obata & Matsukawa (2018) presented biostratigraphic distributions for each ammonite species found in the Miyako Group, regarding them as range zones, and they created biozones based on the concept of the concurrent zone. Originally, when assembling the biostratigraphy for each region, a lithostratigraphic framework was established, and a biozone was constructed based on ammonite occurrence levels and their stratigraphic range. The five regions were then correlated lithostratigraphically and biozones established across the whole regions. However, in their study, this procedure has not been followed.

Other studies

Since Yaegashi (1900) discovered the presence of Cretaceous strata in the Sanriku coast, many paleontological studies have been undertaken on the abundant diverse well-preserved fossil group from the Miyako Group, such as trigonians by Yehara (1915), *Orbitolina* larger foraminifers by Yabe & Hanzawa (1926), mollusks by Nagao (1934) and Hayami (1965a, b, 1966), echinoids by Nishiyama (1950) and Tanaka & Obata (1982), corals by Eguchi (1948), belemnites by Hanai (1953), ammonites by Obata (1967a, b, 1969, 1973, 1975), gastropods by (Kase, 1984), and crinoids by Oji (1985). The bulk of these studies were not biostratigraphical contributions, although some bivalve biostratigraphic studies were attempted.

Recent sedimentological studies have revealed that a tsunami event was preserved in the Miyako Group (Fujino *et al*., 2006). The sedimentary environments of the Miyako Group and their temporal changes were discussed by Fujino & Maeda (2013), based on sedimentary facies analysis combined with fossil assemblages. These analyses form an important component of our understanding of the ecological evolution of ammonites from the Miyako Group.

Lithostratigraphy of the Miyako Group (by Shibata, K. & Matsukawa, M.)

General lithostratigraphy

For the most part, we follow the lithostratigraphy for the Miyako Group established by Hanai *et al*. (1968) and Shimazu *et al*. (1970), with some modifications by Matsukawa & Oji (2022) and Matsukawa & Shibata (2023). The lithostratigraphy is described for each of the five regions (Tanohata, Moshi, Taro, Sakiyama, and Miyako) as below.

Raga Formation

Definition. It forms the base of the Miyako Group and is mainly composed of conglomerates and alternating beds of conglomerate and conglomeratic sandstone, which fill erosional topography with unconformity. The basal part includes breccias of the older rocks. Reddish claystones or purple reddish sandstones are intercalated locally (Hanai *et al*., 1968).

Designation. Yabe & Yehara (1913) assigned the basal boulder- to pebble-sized conglomerates in the Raga and Taro regions under the name of the Raga conglomerate. Subsequently, Hanai *et al*. (1968) redescribed the conglomerate as the Raga Formation.

Type locality. Hiraiga, Tanohata Village, Iwate Prefecture (Hanai *et al*., 1968).

Distribution. Tanohata, Taro, and Miyako regions.

Synonymy. Tanohata region: the Raga Conglomerate of Yabe & Yehara (1913); the Raga Formation of Hanai *et al*. (1968), Kase (1984), Oji (1985), Fujino *et al*. (2006), Fujino & Maeda (2013), Oji & Oishi (2014), and Obata & Matsukawa (2018). Taro region: the Raga Conglomerate of Yabe & Yehara (1913); the Raga Formation of Shimazu *et al*. (1970), Tanaka (1978), Kase (1984), and Matsukawa & Oji (2022). Miyako region: conglomerates in the Kuwagasaki region of Yabe & Yehara (1913); alternating beds of conglomerate and gravelly sandstone in Takonohama and Kuwagasaki of Hanai *et al*. (1968); the Raga Formation of Yoshida & Katada (1984) and Kase (1984); unnamed conglomeratic strata of Obata & Matsukawa (2013).

Thickness. Up to 36 m in the Tanohata region.

Lithology. Conglomerates are commonly clast-supported. Matrix-supported breccia is observed locally in the Tanohata region. Trough cross-stratification is developed locally in the conglomerates and conglomeratic sandstones, especially in the Taro region. The formation represents on overall fining-upward trend.

Stratigraphic relationships. The Raga Formation unconformably overlies the basement rocks consisting of granodiorites, acidic volcanic rocks, and deposits of the pre-Aptian accretionary prism, and is conformably overlain by the Tanohata Formation.

Tanohata Formation

Definition. Composed of conglomerates, pebbly sandstones, cross-stratified sandstones, and sandy mudstones or muddy sandstones (Hanai *et al*., 1968).

Designation. Yabe & Yehara (1913) described the Cretaceous rocks, which consist of sandstones and sandy shales, in the Tanohata, Moshi, Taro, and Sakiyama regions under the names of the Moshi sandstone and Tanohata sandy shale, respectively. Subsequently, Hanai *et al*. (1968) integrated these sandstones and sandy shales into the Tanohata Formation.

Type locality. Hiraiga coast, Tanohata Village, Iwate Prefecture (Hanai *et al.*, 1968).

Distribution. Tanohata, Moshi, Taro, and Sakiyama regions.

Synonymy. Tanohata region: the Moshi sandstone and the Tanohata sandy shale of Yabe & Yehara (1913); the Tanohata Formation of Hanai *et al*. (1968), Oji (1985), Fujino *et al*. (2006), Fujino & Maeda (2013), Oji & Oishi (2014), and Obata & Matsukawa (2018). Moshi region: the Moshi sandstone of Yabe & Yehara (1913); the first cycle sediments of the Miyako Group of Hayami (1966); the lower and middle parts of the Tanohata Formation of Tanaka (1978); the Tanohata Formation of Murai *et al*. (1983), Kase (1984), and Obata & Matsukawa (2018). Taro region: almost equivalent to the Moshi sandstone and the Tanohata sandy shale of Yabe & Yehara (1913); the Tanohata, Hiraiga, and Sakiyama formations of Shimazu *et al*. (1970) and Tanaka (1978); equivalent to the Tanohata Formation of Kase (1984) and Matsukawa & Oji (2022). Sakiyama region: the Moshi sandstone of Yabe & Yehara (1913); the sequence of the Lower, Middle, and Upper members of the Tanohata Formation of Shimazu *et al*. (1970), Tanaka (1978), and Tanaka & Obata (1982); the lithostratigraphic units 1 and 2 of the Tanohata Formation of Kase (1984); the lower part of the Tanohata Formation of Obata & Matsukawa (2018); and the Tanohata Formation of Matsukawa & Shibata (2023).

Thickness. Up to 45 m in the Tanohata region.

Stratigraphic relationships. The Tanohata Formation overlies the Raga Formation conformably or basement rocks unconformably and is covered by the Hiraiga Formation conformably.

Lithology. Hummocky cross-stratified fine-grained sandstones are common in the lower part of the formation in the Tanohata and Sakiyama regions. In contrast, medium- to very coarse-grained sandstones showing trough cross-stratification are dominated in the Tanohata, Moshi, Taro, and Sakiyama regions. Sandy mudstones and muddy sandstones (= "Tanohata sandy shale" by Yabe & Yehara, 1913) are found commonly in the upper part of the formation in the Tanohata, Taro, and Sakiyama regions. The formation represents an overall fining-upward trend.

Hiraiga Formation

Definition. Composed of well-sorted medium- to fine-grained calcareous sandstones intercalated locally with mudstones and coquinoid sandstones. These sandstones and mudstones change northward into bioclastic sandstones containing numerous *Orbitolina* sp. (Hanai *et al*., 1968).

Designation. This formation was initially named the Hiraiga sandstone by Yabe & Yehara (1913) for sandstones that overlie the Tanohata sandy shale (upper part of the Tanohata Formation in the present paper) on the Hiraiga coast, Tanohata region. Subsequently, Hanai *et al*. (1968) defined and named this lithostratigraphic unit as the Hiraiga Formation.

Type locality. Hiraiga and Raga coasts, Tanohata Village, Iwate Prefecture (Hanai *et al*., 1968).

Distribution. Tanohata, Moshi, Taro, and Sakiyama regions.

Synonymy. Tanohata region: the Hiraiga sandstone and the *Orbitolina* sandstone of Yabe & Yehara (1913); the Hiraiga Formation and the *Orbitolina* facies or sandstone of Hayami (1966) and Hanai *et al*. (1968); the Hiraiga Formation of Kase (1984), Oji (1985), Fujino *et al*. (2006), Fujino & Maeda (2013), Oji & Oishi (2014), and Obata & Matsukawa (2018). Moshi region: the Hiraiga sandstone of Yabe & Yehara (1913); the second cycle sediments of the Miyako group of Hayami (1966); the upper part of the Tanohata Formation of Tanaka (1978); the Hiraiga Formation of Kase (1984), Murai *et al*. (1983), and Obata & Matsukawa (2018). Taro region: a part of the Hiraiga Formation of Shimazu *et al*. (1970) and Tanaka (1978), the Hiraiga Formation of Kase (1984) and Matsukawa & Oji (2022). Sakiyama region: the lower part of the Hiraiga sandstone of Yabe & Yehara (1913); the upper part of the first cycle of the sediments of Hayami (1966); the Lower and Upper members of the Hiraiga Formation of Shimazu *et al*. (1970), Tanaka (1978), and Tanaka & Obata (1982); the lithostratigraphic units 3 and 4 of the Tanohata Formation of Kase (1984), the "Hiraiga Formation" of Inose *et al*. (2013); the upper part of the Tanohata Formation of Obata & Matsukawa (2018); and the Hiraiga Formation of Matsukawa & Shibata (2023).

Thickness. About 90 m in the Tanohata region.

Lithology. Hummocky cross-stratified fine-grained sandstones are dominated in the lower part of the formation in the Tanohata region. Trough cross-stratified medium- to very coarse-grained sandstone beds are occasionally intercalated. Mudstone layers are distinct in the middle and upper parts of the Hiraiga Formation in the Tanohata region, and in the upper part of the formation in the Sakiyama region. These sandstones and mudstones transition into bioclastic sandstones that include numerous *Orbitolina* sp. in the northern and upper parts of the formation in the Tanohata region. The formation represents an overall fining-upward trend.

Stratigraphic relationships. The Hiraiga Formation conformably overlies the Tanohata Formation, and is conformably covered by the Aketo or Sakiyama formations. Locally, the formation unconformably overlies the basement rocks directly.

Sakiyama Formation

Definition. Mainly composed of silty sandstones (Shimazu *et al*., 1970).

Designation. This formation was named by Shimazu *et al*. (1970) for sandstones exposed at Ebisudana Islet off the Hideshima coast, Sakiyama region.

Type locality. Hideshima coast, Sakiyama, Miyako City, Iwate Prefecture (Shimazu *et al*., 1970).

Distribution. The formation is distributed in the Ebisudana Islet and a bench on the west side of the Ebisudana Islet in the Sakiyama region.

Synonymy. Generally equivalent to the upper part of the Hiraiga sandstone of Yabe & Yehara (1913); the second cycle sediments of the Miyako Group of Hayami (1966); the Sakiyama Formation of Shimazu *et al*. (1970), Tanaka (1978), and Inose *et al*. (2013); and the Hiraiga Formation of Kase (1984) and Obata & Matsukawa (2018). Equivalent to the Sakiyama Formation of Matsukawa & Shibata (2023).

Thickness. More than 20 m.

Lithology. Hummocky cross-stratification and wave ripples occur locally on the sandstones. The formation represents an overall coarsening-upward trend.

Stratigraphic relationships. The Sakiyama Formation conformably overlies the Hiraiga Formation. The lithologic change from the underlying Hiraiga Formation is gradual. The topmost part of the Sakiyama Formation is not observed.

Aketo Formation

Definition. Mainly composed of greenish grey or grey-coloured, silty fine-grained sandstones (Hanai *et al*., 1968).

Designation. This formation exposed along the northern sea cliff of Hiraiga, Tanohata region was first named the Akito sandstone by Yabe & Yehara (1913) for sandstones that cover the Hiraiga Sandstone (= Hiraiga Formation in the present paper). Subsequently, Hanai *et al*. (1968) renamed this lithostratigraphic unit the Aketo Formation.

Type locality. Hiraname and Aketo coast, Tanohata Village, Iwate Prefecture (Hanai *et al*., 1968).

Distribution. Around Hiraname, Tanohata Village, Iwate Prefecture in the Tanohata region.

Synonymy. The Akito sandstone of Yabe & Yehara (1913); the Aketo Formation of Hayami (1966), Hanai *et al*. (1968), Kase (1984), Fujino *et al*. (2006), Fujino & Maeda (2012), Oji & Oishi (2014), and Obata & Matsukawa (2018).

Thickness. More than 15 m.

Lithology. Hummocky cross-stratification is developed commonly in silty fine-grained sandstone.

Stratigraphic relationships. The Aketo Formation conformably overlies the Hiraiga Formation. The top part of the Aketo Formation is not observed.

Hideshima Formation

Definition. Mainly composed of alternating beds of sandstone and mudstone. Sandstones and conglomerates also develop in the uppermost part of the formation (Shimazu *et al*., 1970).

Designation. Yabe & Yehara (1913) called the Cretaceous rocks exposed in the Hideshima Islet as the Hideshima sandstone and shale. Shimazu *et al*. (1970) renamed the lithostratigraphic unit the Hideshima Formation.

Type locality. Hideshima Islet, Miyako City, Iwate Prefecture (Murai *et al*., 1983).

Distribution. Hideshima Islet in the Sakiyama region.

Synonymy. The Hideshima sandstone and shale of Yabe & Yehara (1913), and the Hideshima Formation of Shimazu *et al*. (1970), Tanaka (1978) and Urakawa *et al*. (2017).

Thickness. More than 70 m (Tanaka, 1978; Urakawa *et al*., 2017).

Lithology. Sandstones in the alternating beds develop parallel laminations, cross-bedding, and convolute laminations. Slump structures are also observed in some levels (Shimazu *et al*., 1970; Tanaka, 1978; Urakawa *et al*., 2017).

Stratigraphic relationships. Stratigraphic relationships of the formation are unknown because the formation is the sole exposure on an isolated islet. On the basis of the location of the islet, however, the formation is interpreted to be the uppermost lithostratigraphic unit of the Miyako Group (Shimazu *et al*., 1970; Tanaka, 1978; Urakawa *et al*., 2017).

Regional lithostratigraphy

1) Tanohata region

In the Tanohata region, the type region of the Miyako Group, the Raga, Tanohata, Hiraiga, and Aketo formations are distributed discontinuously in ascending order along the coast of Tanohata Village, Iwate Prefecture (Hanai *et al*., 1968) (Figs 2, 3). The basal Raga Formation unconformably overlies the siliceous slates and arkosic sandstones of the lowermost Cretaceous Rikuchu Group at Hiraiga, Haipe, Koikorobe, and Shimanokoshi (Hanai *et al*., 1968; Yoshida *et al*., 1983). It consists of clast-supported or matrix-supported conglomerates and breccias, intercalated with reddish claystones and purple reddish sandstones. The Tanohata Formation conformably overlies the Raga Formation at Hiraiga, Haipe, Koikorobe, and Shimanokoshi, while it unconformably covers the basement rocks (*i.e*., rhyolites) of the Harachiyama Formation, Rikuchu Group at Bentenzaki (Hanai *et al*., 1968). The lower, middle, and upper parts of the Tanohata Formation consist of pebble-sized conglomerates, fine-grained pebbly sandstones, and sandy siltstones, respectively. The Hiraiga Formation conformably overlies the Tanohata Formation at Hiraiga, Haipe, and Koikorobe, and unconformably covers the basement siliceous slates and arkosic sandstones of the Rikuchu Group at Raga and Aketo. The Hiraiga Formation consists mainly of alternating beds of fine-grained sandstones and sandy siltstones and includes medium- to very coarse-grained bioclastic sandstones as *Orbitolina* facies at Hiraiga, Raga, and Aketo. Fine-grained sandstones of the Aketo Formation occur around he Hiraname coast of Raga and Aketo in the Tanohata region. Hummocky cross-stratification is well developed in the fine-grained sandstones of the Tanohata, Hiraiga, and Aketo formations.

2) Moshi region

The Tanohata and Hiraiga formations, in ascending stratigraphic order, crop out along the Moshi coast and the offshore some islets of Iwaizumi Town and Miyako City, Iwate Prefecture (Murai *et al*., 1983) (Figs 4, 5). The Tanohata Formation unconformably overlies the basement andesite of the Harachiyama Formation, Rikuchu Group (Murai *et al*., 1983). Trough cross-stratification is commonly developed in medium- to coarse-grained pebbly sandstones of the unit. The upper part of the formation contains bioturbated fine-grained sandstones (Murai *et al*., 1983). The Hiraiga Formation is distributed mainly at the Matsushima and Oshima offshore islets. The boundary between the Tanohata and Hiraiga formations can be observed at a part of the Moshi coast and Oshima Islet (Murai *et al*., 1983). The Hiraiga Formation consists mainly of calcareous medium- to fine-grained sandstones containing abundant nodules (Murai *et al*., 1983). Although Tanaka (1978) assigned all of the Miyako Group that is exposed at the Moshi region to the Tanohata Formation, finer-grained sandstones in the middle part of the sequence separate the group into two sedimentary cycles. These two cycles correspond to the Tanohata and Hiraiga formations.

3) Taro region

The Raga, Tanohata, and Hiraiga formations in ascending stratigraphic order are distributed at the coastal and inland residential districts of the Taro, Miyako City, Iwate Prefecture (Matsukawa & Oji, 2022) (Figs 6, 7). The Raga Formation and the lower part of the Tanohata Formation are well exposed in the coastal district, including at the natural monument "Sannoiwa". The Raga Formation consists of clast-supported conglomerates and conglomeratic sandstones, and unconformably overlies the Early Cretaceous granodiorite of the Taro granites (Shimazu *et al*., 1970; Yoshida *et al*., 1983). The clast-size is larger than that of the Raga Formation in the Tanohata region. Trough cross-stratification is common in the conglomerates and conglomeratic sandstones. Reddish deposits are absent in the Raga Formation of the Taro region. The lower part of the Tanohata Formation consists of trough cross-stratified medium- to very coarse-grained pebbly sandstones. In contrast, the upper part of the formation consists of silty sandstones and is distributed in the inland residential district. The Hiraiga Formation has a quite limited distribution. Previously, the lowermost part of the formation, which is composed of pebbly sandstone, had been exposed in the inland residential district (Matsukawa & Oji, 2022). The outcrops were lost by tsunami caused by the Great East Japan Earthquake in 2011. Shimazu *et al*. (1970) and Tanaka (1978) mapped the distribution of the upper part of the Hiraiga Formation and Sakiyama Formation in the inland residential district. These are, however, regarded as the upper part of the Tanohata Formation (Matsukawa & Oji, 2022; this paper).

4) Sakiyama region

The Tanohata, Hiraiga, and Sakiyama formations in ascending stratigraphic order are distributed along the Hideshima coast including the Ebisudana Islet of the Sakiyama region, Miyako City, Iwate Prefecture (Shimazu *et al*., 1970; Matsukawa & Shibata, 2023) (Figs 8, 9). The Hideshima Formation is also exposed at the Hideshima Islet, off the Hideshima coast (Shimazu *et al*., 1970). The Tanohata Formation is distributed around the natural monument "Shiofukiana" and in the western hillsides of parking lots of the Hideshima fishing port. It unconformably overlies the basement acidic volcanic rocks of the Harachiyama Formation, Rikuchu Group (Shimazu *et al*., 1970). The lower part of the Tanohata Formation is composed mainly of alternating beds of pebble- to boulder-sized clast-supported conglomerate and trough cross-stratified coarse- to medium grained sandstone and/or hummocky cross-stratified fine-grained calcareous sandstone. The uppermost part of the formation consists of alternating beds of parallel laminated very fine-grained

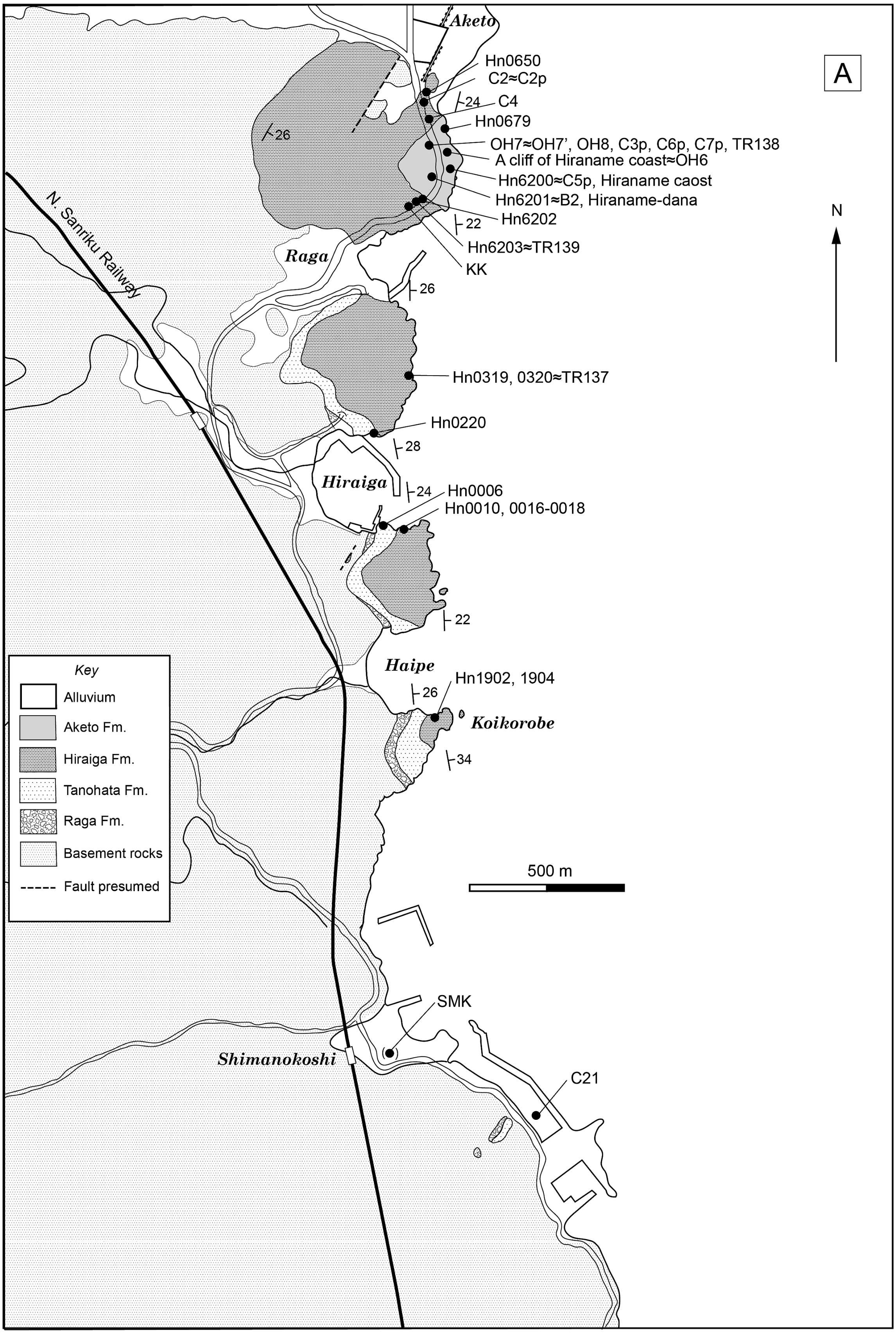

FIGURE 2. Geological map of the Miyako Group in the Tanohata region. Ammonites described were collected from the Tanohata, Hiraiga, and Aketo formations of the group in Tanohata Village, Iwate Prefecture. Locations of the ammonites are illustrated. The A in the upper right corner indicates the location of A in Fig. 1.

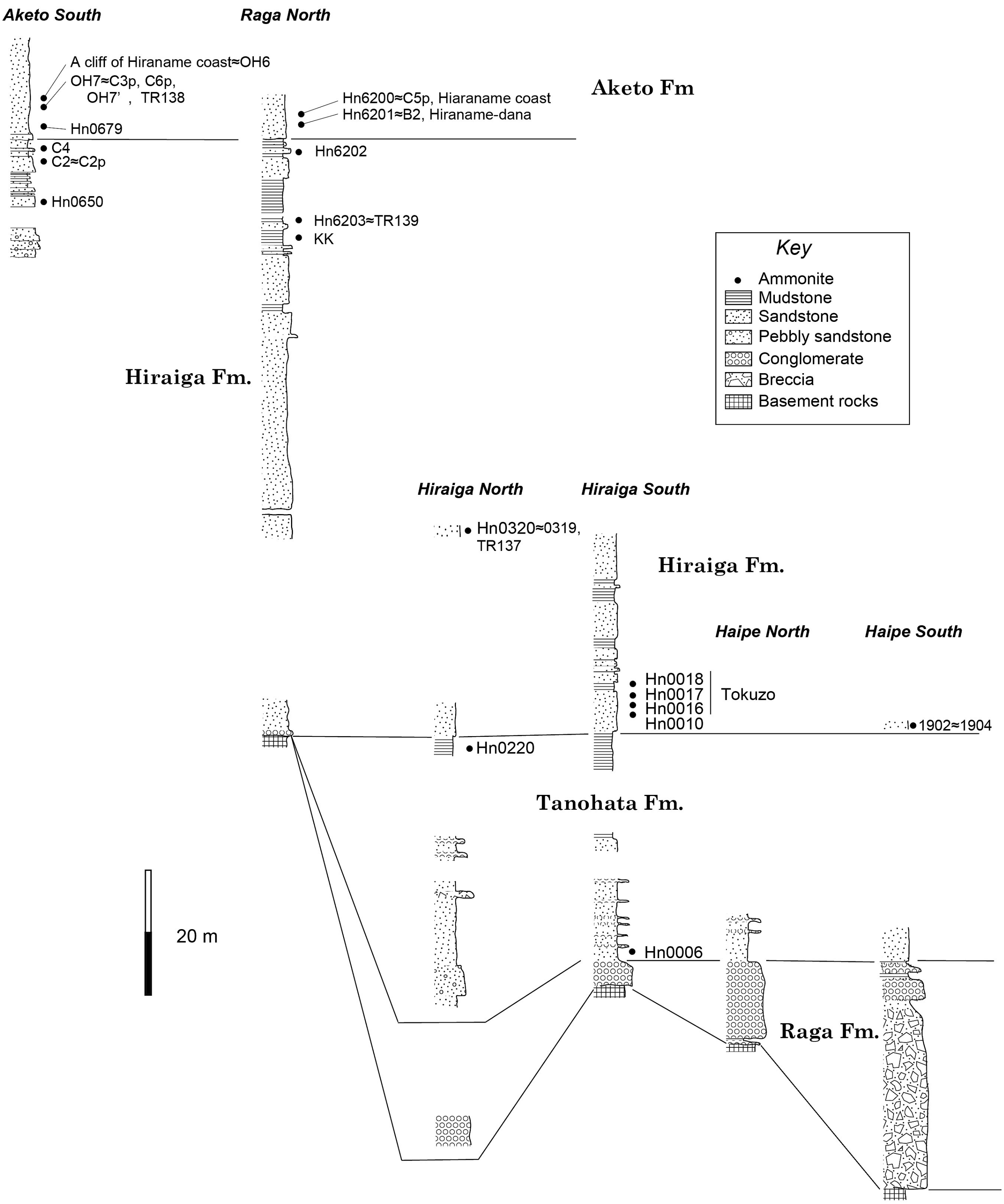

FIGURE 3. Correlation of the ammonite-bearing sections of the Miyako Group in the Tanohata region.

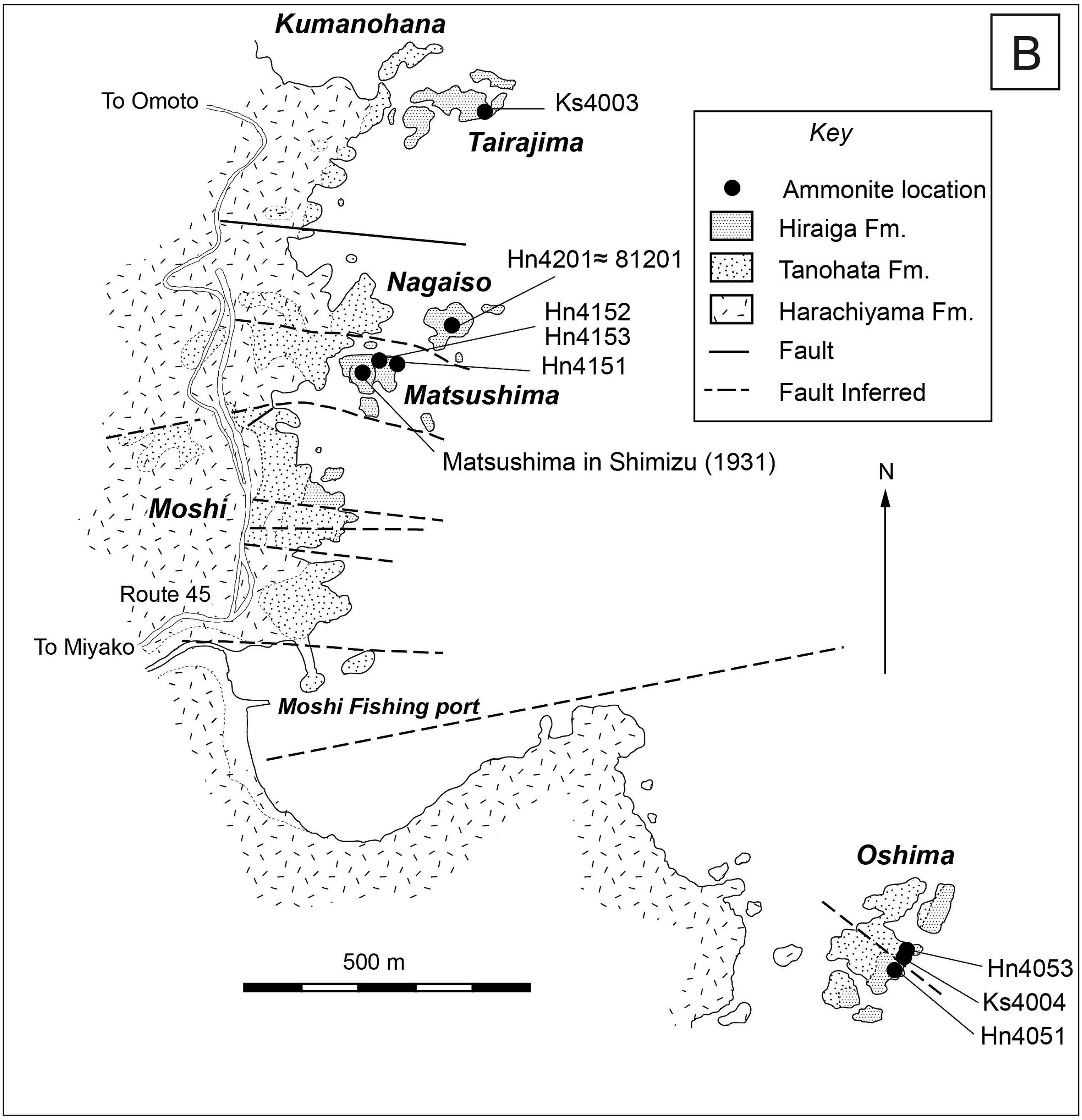

FIGURE 4. Geological map of the Miyako Group in the Moshi region. Ammonites described were collected from the Tanohata and Hiraiga formations of the Miyako Group in Moshi region in Iwaizumi Town, Iwate Prefecture. Locations of the ammonites are illustrated. Geological map based on Oishi, M. in Murai *et al*. (Ed.) (1983). After Obata & Matsukawa (2018). The B in the upper right corner indicates the location of B in Fig. 1.

sandstones and coquinoid coarse-grained sandstones. The lower part of the Hiraiga Formation, which is exposed around a small hill southwest of the Hideshima fishing port, consists of alternating beds of fine-grained calcareous sandstone and sandy siltstone. The upper part of the formation consists of dark grey, well-sorted siltstones, and is exposed at what some geologists call the Hideshima Bench, west of the Ebisudana Islet at low tide. See the general lithostratigraphic section for the Sakiyama and Hideshima formations in the Sakiyama region, where these two formations are only known to occur.

5) Miyako region

Alternating beds of conglomerate and conglomeratic sandstone are exposed discontinuously in the Miyako region, which includes Takonohama and Kuwagasaki

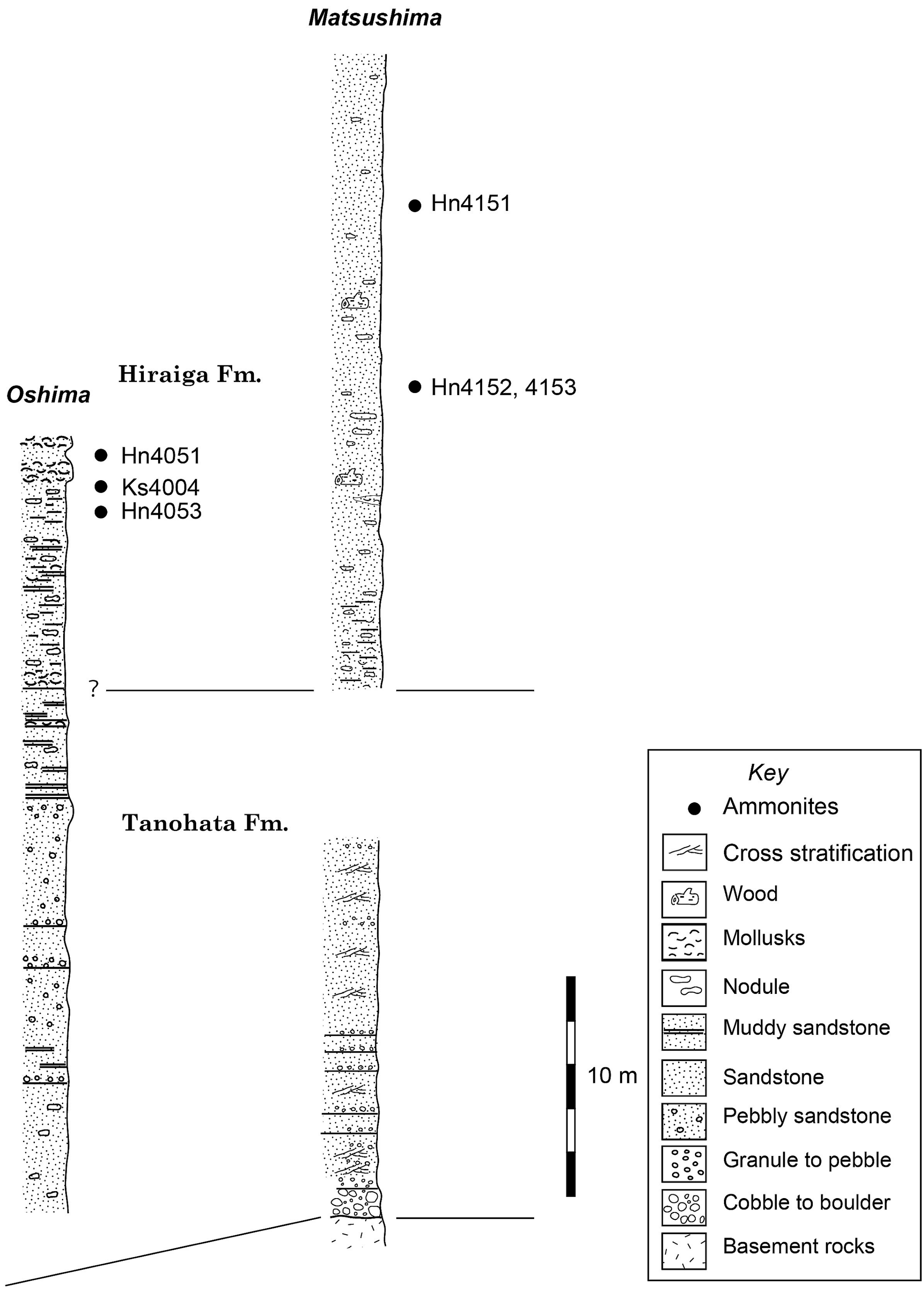

FIGURE 5. Correlation of the ammonite-bearing sections of the Miyako Group in the Moshi region in Iwaizumi Town, Iwate Prefecture. Columnar sections based on Oishi, M. in Murai *et al*. (Ed.) (1983). After Obata & Matsukawa (2018).

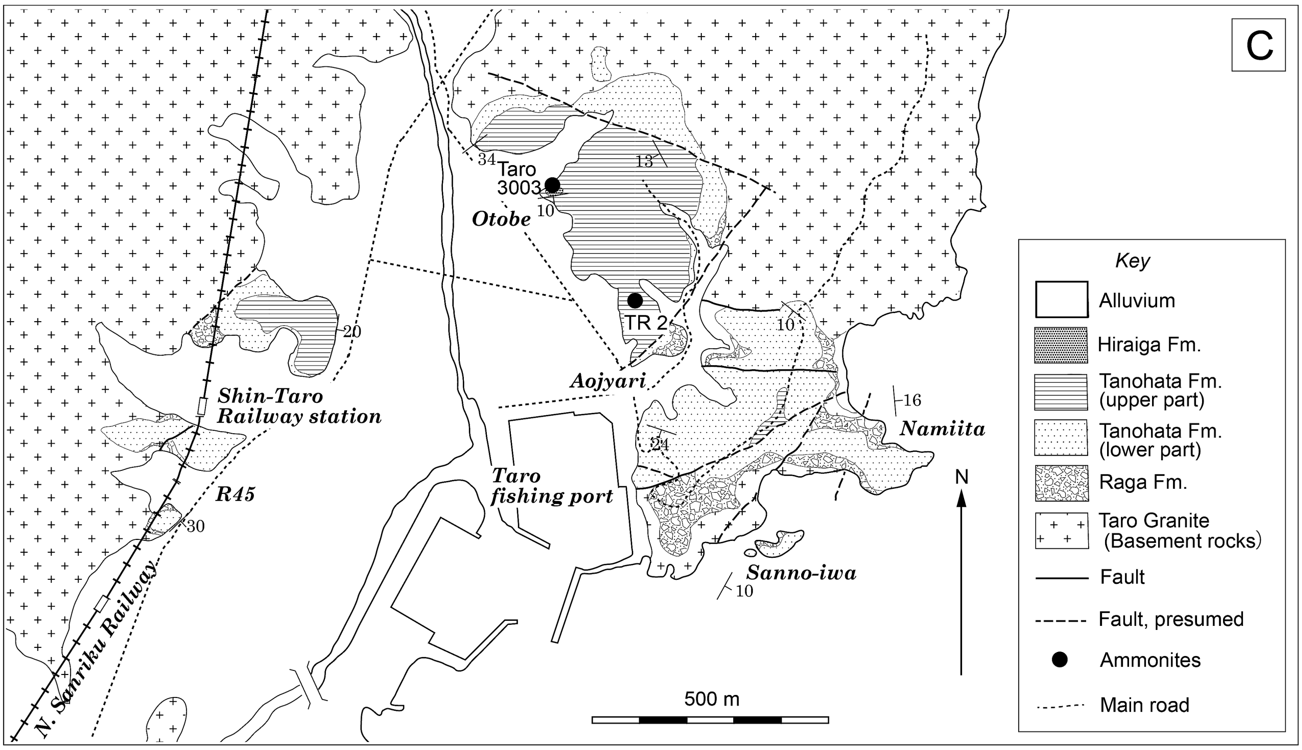

FIGURE 6. Geological map of the Miyako Group in the Taro region. Ammonites described were collected from the Tanohata and Hiraiga formations of the Miyako Group in Taro region in Miyako City, Iwate Prefecture. Locality of the ammonites is illustrated. Geological map based on Oji (1983). After Matsukawa & Oji (2022). The C in the upper right corner indicates the location of C in Fig. 1.

districts and within the town of Miyako City, Iwate Prefecture. They were regarded as the Raga Formation by Kase (1984) and Yoshida & Katada (1984), although some researchers, such as Yabe & Yehara (1913), Hanai *et al*. (1968), and Obata & Matsukawa (2013), suspected the correlation with the Raga Formation. The Raga Formation unconformably overlies mudstones of the Omoto Formation, rhyolites of the Harachiyama Formation of the Rikuchu Group, and granodiorite of the Early Cretaceous Miyako Granite (Yoshida & Katada, 1984). The uppermost part of the formation includes reddish siltstones and overlying medium-grained conglomeratic sandstones, which are about 1 m to 5 m thick, respectively (Hanai *et al*., 1968).

Lithostratigraphic correlation of the Miyako Group

Hanai *et al*. (1968) divided the Miyako Group into the Raga, Tanohata, Hiraiga, and Aketo formations in ascending stratigraphic order, based on sedimentary cycles found in the successions in the Tanohata region, each of which is characterized largely by fining-upward trends. Because the characteristics in the grain-size changes are also identified throughout the five regions, the inter-regional stratigraphic correlation has been attempted (Hanai *et al*., 1968; Shimazu *et al*., 1970; Matsukawa & Shibata, 2023). The scheme of lithostratigraphic correlation of the Miyako Group is shown in Fig. 10.

Shimazu *et al*. (1970) correlated the Hiraiga and Sakiyama formations in the Sakiyama region to the lower and upper cycles of the Hiraiga Formation of Hanai *et al*. (1968) in the Tanohata region. This correlation was on the basis of two cycles of the lower-order fining-upward trends identified in the Hiraiga Formation at Hiraiga in the Tanohata region. However, the two cycles of fining-upward trends are indistinct in the *Orbitolina* facies of the Hiraiga Formation at Raga in the Tanohata region. Therefore, the lower-order fining-upward trends are not regarded as being useful for a lithostratigraphic correlation. Thus, Matsukawa & Shibata (2023) represented an alternative correlation scheme that the Hiraiga and Sakiyama formations in the Sakiyama region correspond to the Hiraiga and Aketo formations in the Tanohata region, lithostratigraphically (Fig. 10).

Palaeontology

A total of 909 ammonite specimens, including the Komori ammonite collection, from the Miyako Group across the whole outcrop area were used for the paleontological systematics of this study. Of the 909 specimens, 217 specimens have been paleontologically described

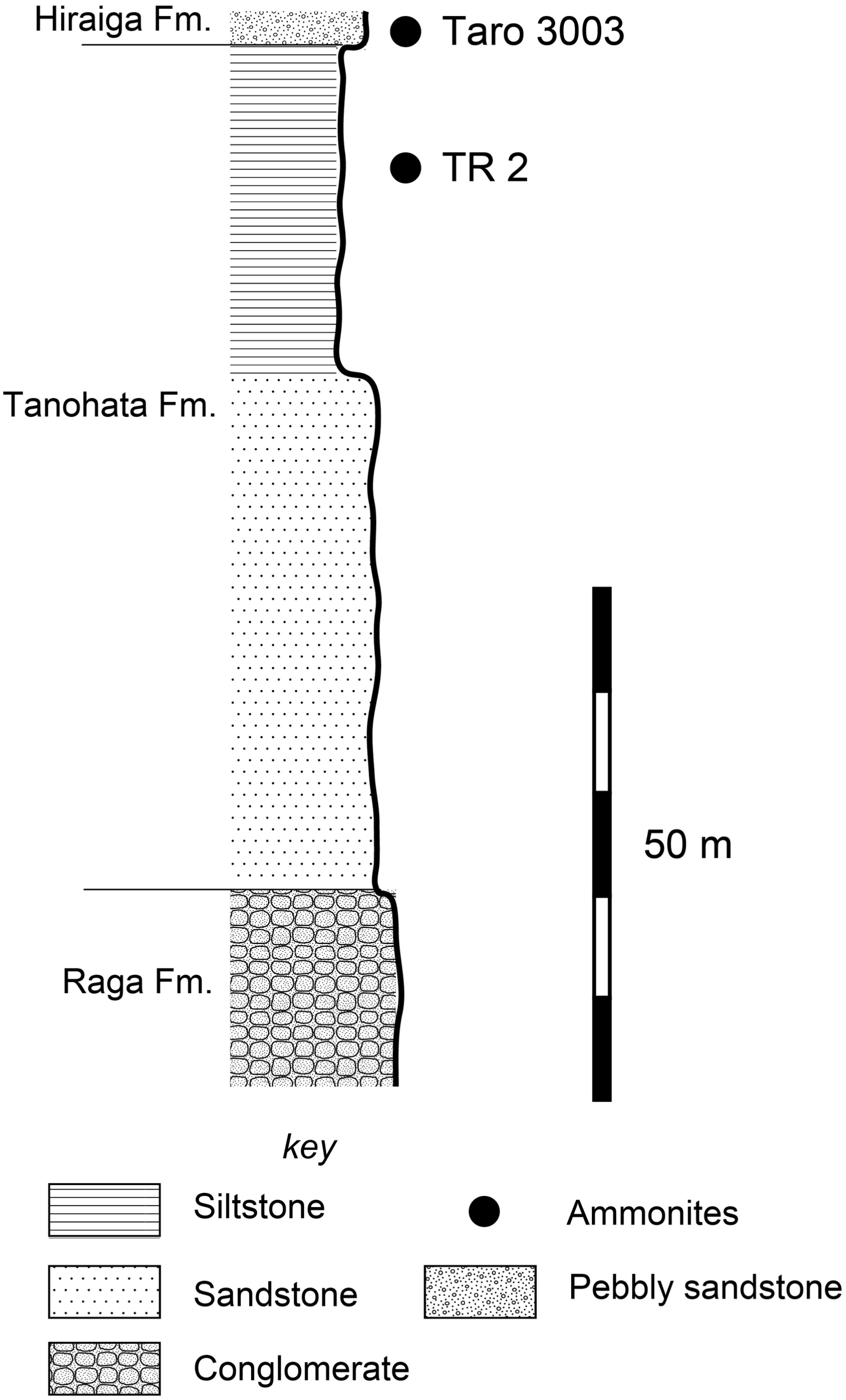

FIGURE 7. Generalized columnar section of the Miyako Group in Taro region, Miyako City, Iwate Prefecture. After Matsukawa & Oji (2022).

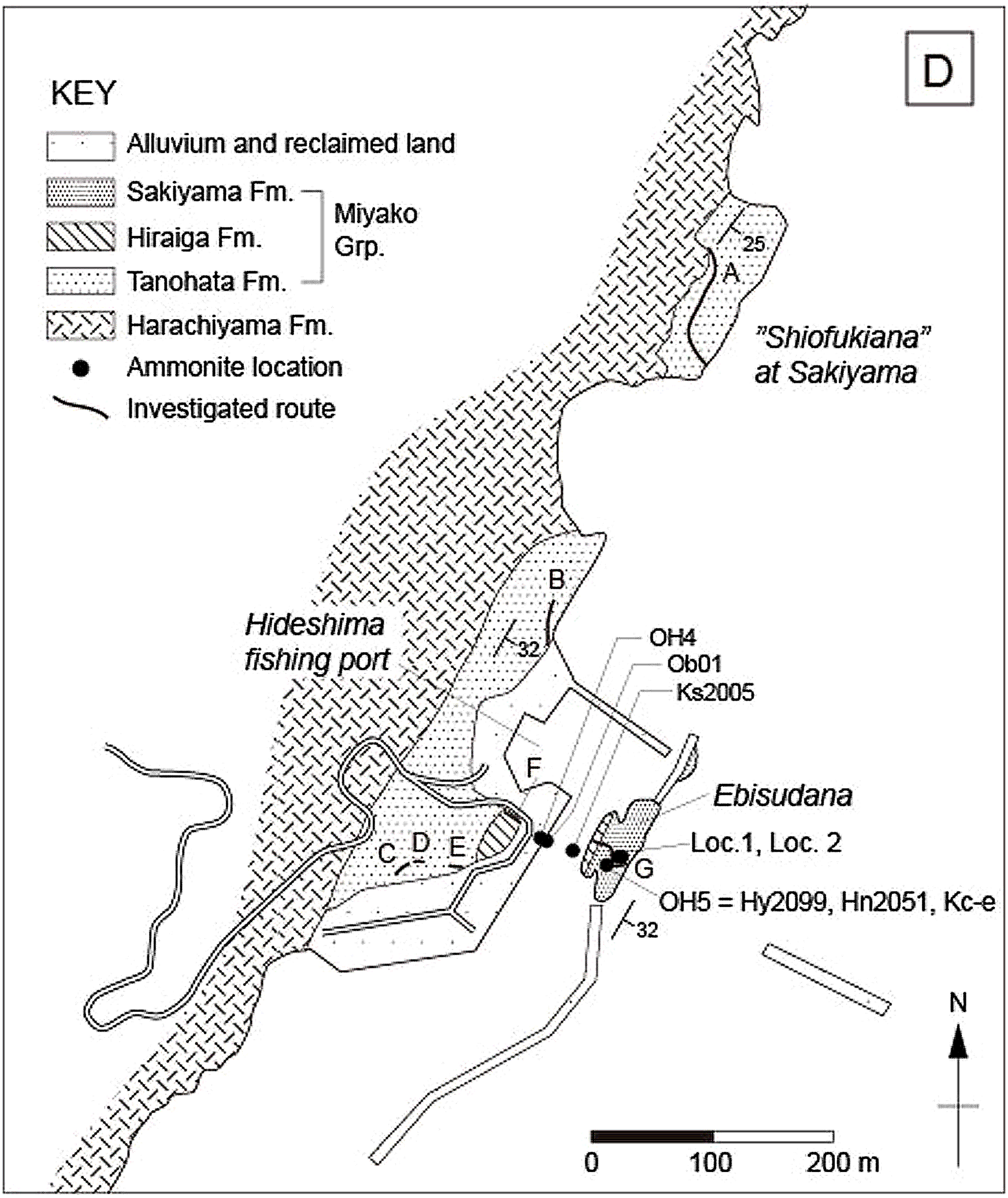

FIGURE 8. Geological map of the Miyako Group in the Sakiyama region. Ammonites described were collected from the Hiraiga and Sakiyama formations of the Miyako Group in Sakiyama region, Miyako City, Iwate Prefecture. Locations of the ammonites are illustrated. After Matsukawa & Shibata (2023). The D in the upper right corner indicates the location of D in Fig. 1.

previously in sixteen papers, of which 106 specimens were used by Obata & Matsukawa (2018). Species listed in some papers, such as Toshimitsu & Hirano (2000), are excluded from this study as they lack appropriate paleontological descriptions and photographs. The Komori ammonite collection (below) significantly improved our knowledge of the Miyako Group fauna.

The Komori Ammonite Collection

Ammonite specimens were collected by Mr. Kazuo

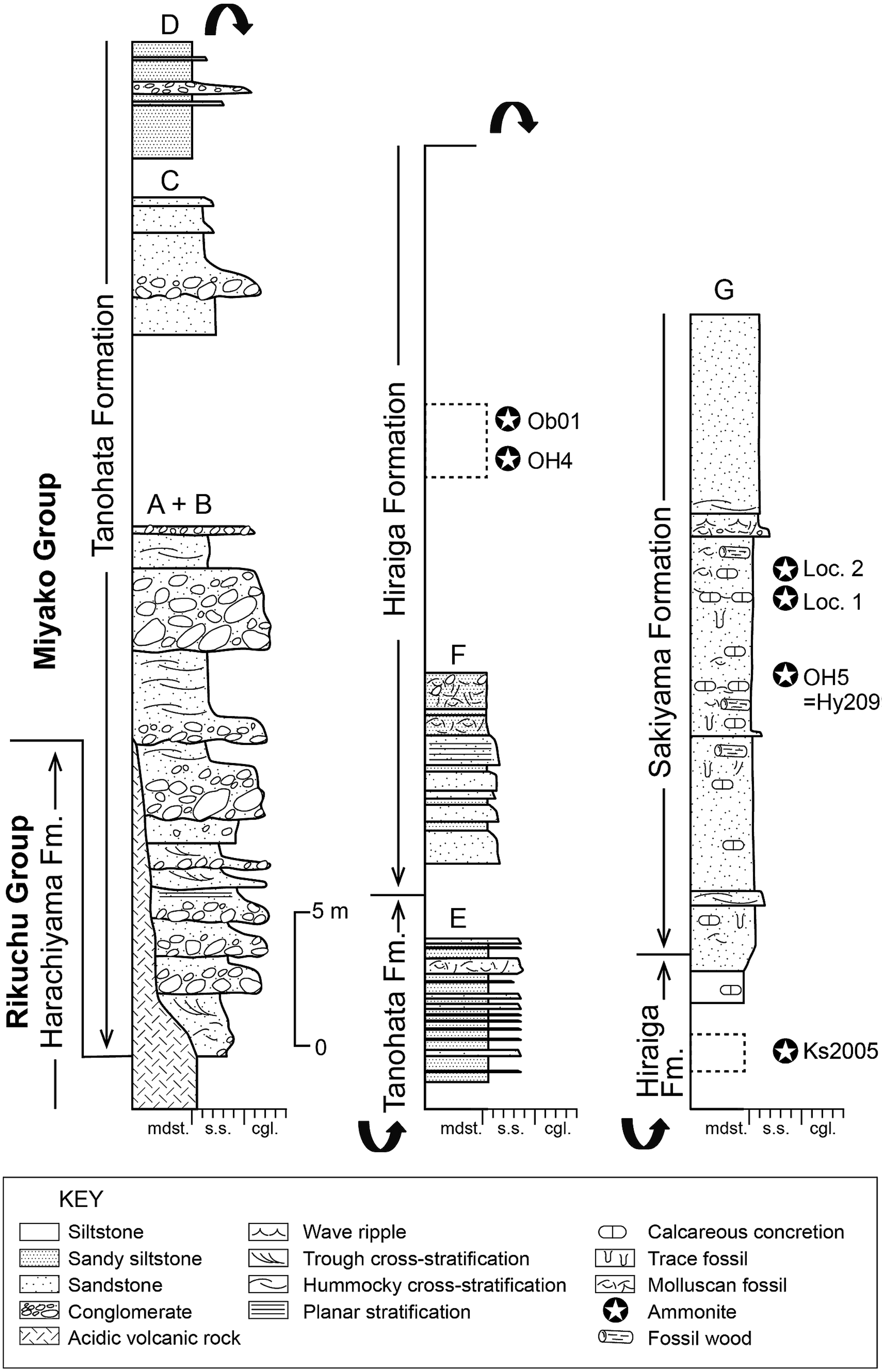

FIGURE 9. Generalized columnar section of the Miyako Group in Sakiyama region in Miyako City, Iwate Prefecture. **A** to **G** indicates investigated routes in Fig. 8. After Matsukawa & Shibata (2023).

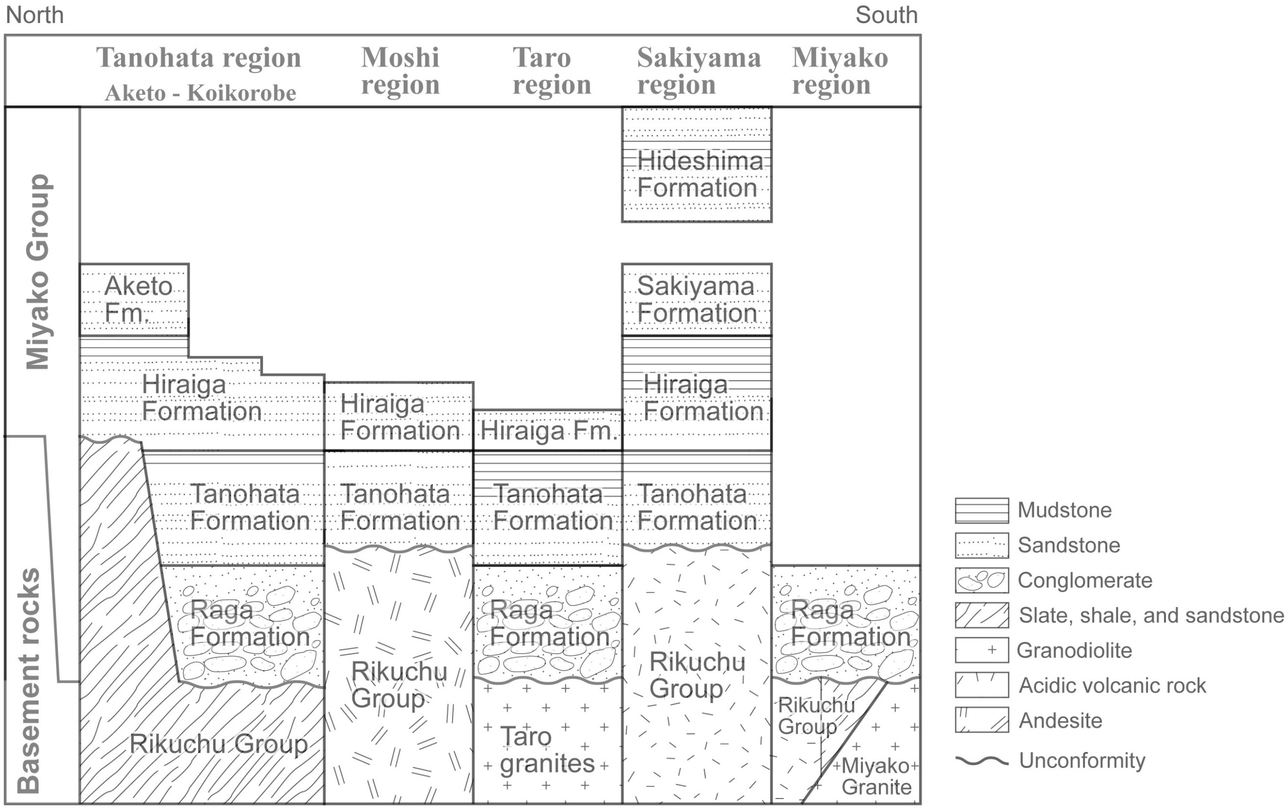

FIGURE 10. Lithostratigraphic correlation of the Miyako Group distributed in five regions. Schematic lithological features of the Miyako Group and basement rocks are also shown.

Komori, a science teacher at junior high school in Iwate Prefecture, from blasted rocks from 1985 to 1995 during the expansion work of Prefectural Highway No. 44 between Raga and Aketo hamlets of Tanohata Village, Iwate Prefecture. The blasted rocks containing ammonites were excavated from the mudstone beds at the top of the Hiraiga Formation and were piled up in a vacant lot next to the excavation site or were dropped under a cliff.

The mudstone beds of the top of the Hiraiga Formation containing the Komori ammonite collection are located at location KK in the northern part of the Miyako Group in the Tanohata region (Fig. 2). In total 251 specimens are utilized for this study. The collection is housed in the Iwate Prefectural Museum in Morioka.

Repository of specimens

The specimens described in this paper are kept in the following institutions. We examined some specimens at these following institutions by courtesy of the authorities there.

IGPS: The Tohoku University Museum, Sendai

IPMM: The Iwate Prefectural Museum, Morioka

NSM and NMNS: The National Museum of Nature and Science, Tsukuba

SKM: The Sakiyama Kaizuka Jyomon Museum, Miyako

TGUSE: Tokyo Gakugei University, Tokyo, Department of Environmental Sciences, Tokyo

UMUT: The University Museum, University of Tokyo, Tokyo

Conventions

Higher systematic nomenclature follows Wright *et al*. (1996), except for the systematic nomenclature of the order Ammonitida, which follows that of Hoffmann *et al*. (2022); for the family Phylloceratidae we follow Murphy & Rodda (2006). The use of the superfamily suffux "oidea" follows the ICZN. Morphological terms used are defined in Arkell *et al*. (1957) and descriptive terms (*e.g*., very small, very large, fairly narrow, and others) are those of Matsumoto *et al*. (1988). The following symbols for measurements are used; D = the total diameter, U = the diameter of umbilicus; U/D = the umbilicus/total diameter ratio; H = the whorl-height; W = the whorl-width; W/H = the width/height ratio; Dx = maximum diameter of loose spire; Dn = minimum diameter of loose spire; Ux = maximum umbilical gap; Un = minimum umbilical gap. L = the maximum length of shaft; B = the maximum breadth of contiguous shafts; T = maximum thickness of contiguous shafts; w_1 = the width of earlier shaft; h_1 = the height of earlier shaft; w_2 = the width of later shaft; h_2 =

the height of later shaft; w_1/h_1 = earlier shaft width/ height ratio; w_2/h_2 = later shaft width/height of later shaft ratio.

Systematic palaeontology

Order Ammonoidea Zittel, 1884
Suborder Phylloceratina Arkell, 1950
Superfamily Phylloceratoidea von Zittel, 1884
Family Phylloceratidae von Zittel, 1884
Subfamily Phylloceratinae von Zittel, 1884
Genus *Euphylloceras* Drushchits, 1956

***Euphylloceras californicum* (Anderson, 1938)**
(Fig. 11A–D, F–P)

1938 *Phylloceras californicum* Anderson, p. 143, pl. 12, fig. 7.
1960 *Hypophylloceras* cf. *californicum*, Imlay, p. 98, pl. 11, fig. 29.
1972 *Hypophylloceras* aff. *californicum*, McLearn, p. 22, pl. 1, figs 1A, B, 2A, B.
2006 *Euphylloceras californicum*, Murphy & Rodda, p. 34, pl. 1, figs 3, 9–17; pl. 2, figs 2–4, 6–11, pl. 3, figs 1, 3, 5, 7 (= Anderson, 1938, pl. 12, fig. 7), 8, text-figs. 12–16.
2007 *Euphylloceras californicum*, Kawabe, p. 116-117, figs 5:1–4; 6:1, 2.

Material. Nine specimens, IPMM 62934, 62935, 62936, 62937, 62938, 62939, 62640, 62941 (collected by K. Komori), shell, from location KK, and TGUSE-MM 6575 (collected by I. Obata), shell, from location Hn 4151.

Locality and horizon. The present species is reported from the upper Aptian (wintunium Zone) to the lower Albian (hulense Zone) of northern California (Murphy & Rodda, 2006) and the Miyako Group, Japan (this paper).

Measurements (in mm except for U/D and W/H**)**.

Specimen	D	U	U/D	H	W	W/H
IPMM 62934	88.7	6.3	0.07	51.0	32.6	0.64
IPMM 62935	57.5	3.4	0.06	38.3	22*	0.57
IPMM 62936	38.1	3.3	0.09	21.7	14.5	0.67
IPMM 62937	30.9	3.2	0.10	16.4	11.4	0.70
IPMM 62938	30.7	2.6	0.08	17.9	12.6	0.70
IPMM 62939	51.0	-	-	-	21*	-
IPMM 62940	50.2	4.5	0.09	28.3	15.2	0.54
IPMM 62941	42.5	3.2	0.08	25.3	14.5	0.57
TGUSE-MM 6575	11.4	1.6	0.14	5.8	3.8	0.66

* approximate

Remarks. Because of its very involute whorl with narrow umbilicus, numerous fine rectiradiate lirae, feeble rectiradiate constrictions, and frilled suture with polyphyllic saddle (IPMM62936 in Fig. 12), the present specimens are identified as *Euphylloceras californicum* (Murphy & Rodda, 2006, p. 34–39, pl. 1, figs 10, 11, 16; p. 2, figs 2–4, 6, 7, 9; figs 1, 3, 5, 7, 8) from the upper Chickabally Member of the Budden Canyon Formation, at east branch of the Hulen Creek, Ono district in northern California.

***Euphylloceras* sp.**
(Figs 11E, 15H)

Material. Four specimens. IPMM 63787, 63788 and 63789 (collected by K. Komori) are partial shells that are broken and come from the Hiraiga Formation at location KK. TGUSE-MM 6464 (collected by I. Obata) is a partial outer shell and comes from the Tanohata Formation at location Hn 0220.

Measurements (in mm except for U/D and W/H**)**.

Specimen	D	U	U/D	H	W	W/H
IPMM 63787	110+	15.8	0.14*	67+	47.7	0.71
IPMM 63788	52.6	5.1	0.10	29.0	18.5	0.64
IPMM 63789	-	-	-	68+	32*	0.47*

* approximate

Remarks. The specimens are similar to the specimens described as *E. californicum* above, but the constrictions of the specimens are not confirmed on their outer whorl. Thus, we postpone the species level assignment, so the specimens are identified as *Euphylloceras* sp.

Genus *Goretophylloceras* Collignon, 1948

***Goretophylloceras* cf. *fortunei* (Honnorat-Bastide, 1892)**
(Fig. 13I–K)

Material. A single imperfect specimen, IPMM 62942 (collected by K. Komori), its outer part of later whorl is lost, and the surface of shell is worn. The specimen comes from the Hiraiga Formation at location KK.

Locality and horizon. *Goretophylloceras fortunei* is reported from Spain, France, Romania, and Dagestan (Avram *et al*., 1990). Joly & Delamette (2008) showed that a biostratigraphic distribution of the species in southeast France ranges from middle Aptian (top of the martini Zone) to the beginning of the upper Aptian (Area in Nolani).

Measurements (in mm except for U/D and W/H**)**.

Specimen	D	U	U/D	H	W	W/H
IPMM 62942	42.6	3.7	0.09	25.3	20.6	0.81

Remarks. The specimen is a fairly small, discoidal and very involute whorl with very narrow umbilicus. The whorl forms a triangle in cross-section, with broadly convex flanks and narrow rounded venter. The umbilicus is deep; its wall is steep and rounds to the flanks. The

FIGURE 11. A–**D**, **F**–**O**, *Euphylloceras californicum*. **A**–**D**, IPMM 62934. **F** and **G**, IPMM 62935. **H** and **I**, IPMM 62939. **J**, IPMM 62936. **K** and **L**, IPMM 62941. **M**–**P**, IPMM 62940. **E**, *Euphylloceras* sp., TGUSE-MM 6464. Specimens except for TGUSE-MM 6464 were collected by K. Komori from loc. KK. TGUSE-MM 6464 was collected by I. Obata from loc. Hn 0220. Scale bars = 1 cm.

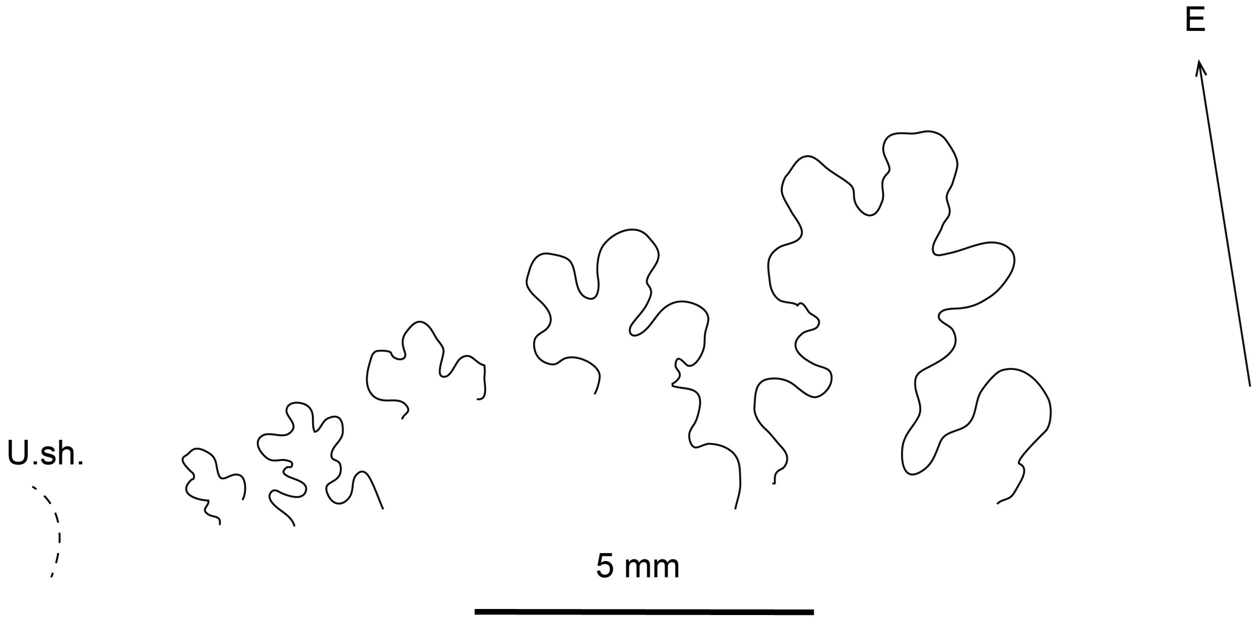

FIGURE 12. Suture of *Euphylloceras californicum*, Specimen IPMM 62936. "E" means external, which is called for ventral lobe. "U.sh." = umbilical shoulder.

flank is ornamented with very feeble lirae in a sickle-like orientation and constrictions on the early whorl. The lirae and constrictions cross the venter orthogonally. The suture shows frilled polyphyllic saddle, trifid lateral lobe, and bifid ventral lobe (Fig. 14).

Because of the triangle whorl-section, the specimen belongs to the genus *Goretophylloceras* (Murphy & Rodda, 2006). Since the specimen is small and has constrictions and sickle-shaped lirae crossing the venter, it is similar to *Goretophylloceras fortunei* (Joly, 2000, p. 145, pl. 36, figs 1a, b, 2a, b, 3a, b) from the upper Aptian in southern France. However, French specimens are smoother and finer lirae on the shell surface than that of the present specimen. So, the specimen is identified as *G.* cf. *fortunei.*

***Goretophylloceras* cf. *subalpinum* (Orbigny, 1850)**
(Fig. 13A–D)

Material. The single specimen, IPMM 62944 (collected by K. Komori), is a broken partial outer whorl with worn inner flank surface. The specimen comes from the Hiraiga Formation at location KK.

Locality and horizon. *Goretophylloceras subalpinum* (Orbigny, 1850) is reported from the middle Albian? to the upper Albian of France (Joly, 2000).

Measurements (in mm except for U/D and W/H).

Specimen	D	U	U/D	H	W	W/H
IPMM 62944	75.7*	9.1	*ca.* 0.12	47.6	27.1	0.57

* approximate

Remarks. Since the specimen is a phylloceratid with a triangular whole-section, flexuous lirae, and lacking constriction, we consider it similar to *Goretophylloceras subalpinum* (Joly, 2000, p. 146) from the Albian of southern France. As the French specimens exhibit a smoother shell surface than does the Japanese specimen, we therefore assign it to *G.* cf. *subalpinum.*

***Goretophylloceras* sp.**
(Fig. 13E–H)

Material. A single specimen, IPMM 62943 (collected by K. Komori) is a broken partial outer whorl. The specimen comes from the Hiraiga Formation at location KK.

Measurements (in mm except for W/H).

Specimen	D	U	U/D	H	W	W/H
IPMM 62943	-	6.7	-	25.9	22.0	0.84

Remarks. Because the whorl-section of the specimen is triangular, the specimen is identified as the genus *Goretophylloceras* (Murphy & Rodda, 2006). The specimen has slightly grooved constrictions and fine ribs, but the inner flanks are unknown due to poor preservation. Since the form of the ribs cannot be observed, the specimen is identified as *Goretophylloceras* sp.

Subfamily Calliphylloceratinae Spath, 1927
Genus *Holcophylloceras* Spath, 1927

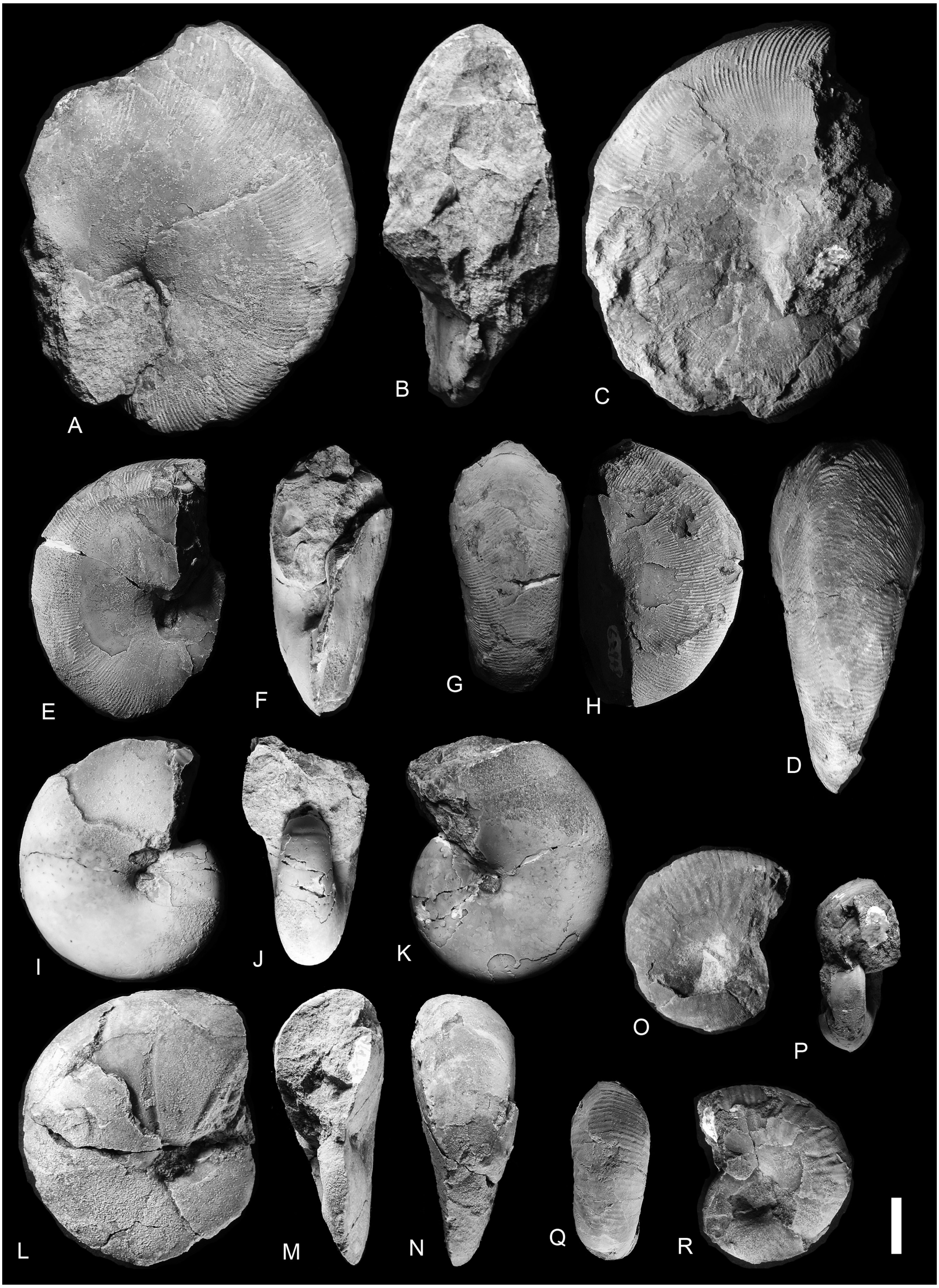

FIGURE 13. A–**D**, *Goretophylloceras* cf. *subalpinum*; IPMM 62944. **E**–**H**, *Goretophylloceras* sp., IPMM 62943. **I**–**K**, *Goretophylloceras* cf. *fortune*; IPMM 62942. **L**–**N**, *Holcophylloceras caucasicum*; IPMM 63776. **O**–**R**, *Phyllopachyceras iwatense*, IPMM 62945. All specimens are shell and were collected by K. Komori from loc. KK. Scale bars = 1 cm.

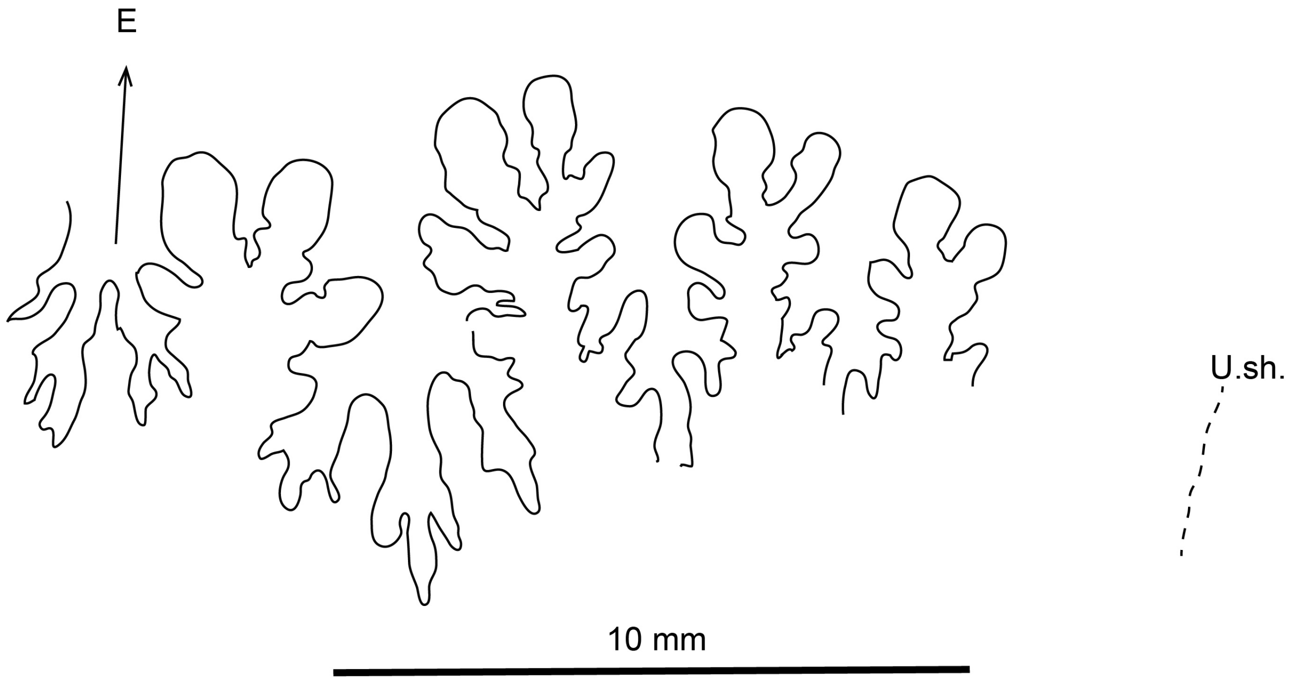

FIGURE 14. Suture of *Goretophylloceras* sp., specimen IPMM 62942.

Holcophylloceras caucasicum **(Sayn, 1920)**
(Fig. 13L–N)

1899 *Phylloceras Guettardi*, Anthula, p. 97, pl. 5, fig. 5a, b, c.
1920 *Phylloceras Guettardi* var *Caucasica*, Sayn, pl. 1, fig. 7, 7a.
1931 *Salfeldiella caucasica*, Shimizu, p. 20–21, pl. 3, figs 15–17, 28.
2018 *Holcophylloceras caucasicum*, Obata & Matsukawa, p. 232, fig. 10R–T.

Material. Two specimens. IPMM 63776 (collected by K. Komori) comes from the upper part of the Hiraiga Formation at location KK. TGUSE-MM 6498 (collected by I. Obata) comes from the lower part of the Hiraiga Formation at location Hn1902.

Locality and horizon. This species is reported from the Aptian of the Caucasus (Anthula, 1899) and the Miyako Group (Obata & Matsukawa, 2018).

Measurements (in mm except for U/D and W/H)**.**

Specimen	D	U	U/D	H	W	W/H
IPMM 63776	51.7	4.8*	0.09*	29.6	19.1	0.65

* approximate

Remarks. The specimen is similar to the specimens of *Holcophylloceras caucasicum* (Obata & Matsukawa, 2018, p. 232, fig. 10R–T) from the lower part of the Hiraiga Formation of the Miyako Group at Matsushima, Iwaizumi Town, Iwate Prefecture in having smooth surface with four distinct constrictions.

Subfamily Phyllopachyceratinae Collignon, 1937
Genus *Phyllopachyceras* Spath, 1927

Phyllopachyceras iwatense **sp. nov.**
(Fig. 13O–R)

Material. A single specimen, IPMM 62945 (collected by K. Komori), holotype, consists of a complete shell and its plaster mould, IPMM 062996. The specimen is deformed obliquely. The specimen comes from the upper part of the Hiraiga Formation at location KK.

Etymology. *Phyllopachyceras* from Iwate Prefecture, Japan.

Diagnosis. *Phyllopachyceras* with dense lirae and feeble plications on outer flank of inner whorl, with lirae becoming dense distinct plications or ribs on outer whorl. The distinct plications consist of primaries arising on the umbilical slope and intercalaries arising on the mid-flank, sandwiched between the primaries.

Locality and horizon. The species is only reported from the upper Aptian Miyako Group in Japan.

Description. The shell is very small, very involute, with a fairly compressed whorl with very narrow umbilicus. The whorl-section is broadly elliptical with inflated flank and rounded venter and is slightly higher than wide (W/H = 0.94). The widest part of the whorl is at middle flank. The umbilicus is funnel-like with rounded wall. The surface of lower flank is smooth while the upper flank is ornamented with numerous fine lirae and feeble plications on inner whorl; lirae become dense distinct plications or ribs on outer whorl. The distinct plications consist of primaries arising on the umbilical slope and intercalaries arising on the mid-flank, sandwiched between the primaries. The lirae and plications are slightly prorsiradiate and cross the venter orthogonally. The suture line is unknown.

Measurements (in mm except for U/D and W/H)**.**

Specimen	D	U	U/D	H	W	W/H
IPMM 62945 (holotype)	32.9	7.0	0.03	15.2	14.3	0.94

Remarks. Because of its strong plications on the outer whorl and lack of constrictions, the specimen belongs the family Phyllopachyceratinae and genus *Phyllopachyceras* (Arkell *et al*., 1957). The present specimen is similar to the illustrated specimen of *Phyllopachyceras occidentale* (Murphy & Rodda, 2006, p. 59–61, pl. 7, figs 9, 17, pl. 8, figs 7–9, 12, 13) from the Hauterivian to upper Aptian of California in having a broadly elliptical whorl-section, slightly higher than wide, a very narrow and deep funnel-like umbilicus, and surface ornamented with numerous lirae and plications. However, the plications of the present specimen are denser than those of the Californian specimens, and consist of dense primaries and intercalaries, whereas those of the California specimens are only primaries and coarse. The present specimen differs from the illustrated specimen of *Partschiceras eichwaldi occidentale* (Wiedmann, 1963, p. 237–239, pl. 16, figs 5a, b, text-figs. 55, 56) from the Barremian of Castellane, southern France, in that the ribs of the present specimen are denser than those of the French specimen. The present specimen is different from the specimen of *Phyllopachyceras sanchuense* (Matsukawa *et al*., 2007, p. 78-81, fig. 3a–h) from the Ishido Formation of the Sanchu Cretaceous in Japan, in that the specimen of *Phyllopachyceras sanchuense* has umbilical bullae, periodic alternating primary and secondary ribs, and no lirae on the shell surface.

Suborder Lytoceratina Hyatt, 1889
Superfamily Lytoceratoidea Neumayr, 1875
Family Lytoceratidae Neumayr, 1875
Subfamily Lytoceratinae Neumayr, 1875
Genus *Ammonoceratites* Bowdich, 1822
Subgenus *Ammonoceratites* Bowdich, 1822

***Ammonoceratites* (*Ammonoceratites*) *crenocostatus* (Whiteaves, 1876)**

Remarks. Obata & Futakami (1992, p. 89–91, p. 4, fig. 2; fig. 10) described the specimen from the Aketo Formation as *Ammonoceratites* (*Ammonoceratites*) *crenocostatus* (Whiteaves, 1876). Afterward, Klein *et al*. (2009) considered it as a synonym for *Ammonoceratites* (*A*.) *mahadeve* (Stoliczka, 1865) from India. We follow Obata & Futakami's (1992) identification, because the specimen identified as *A*. (*A*.) *crenocostatus* is characterized by a circular whorl cross-section, small contact area between inner and outer whorls, a shell surface ornamented with narrow and distinct ribs, and distinct constrictions on the inner whorl. Those are the same as the distinct characteristics of the holotype of *Ammonites crenocostatus* (Whiteaves, 1876, p. 45, pl. 9, fig. 2), which was redescribed as *Ammonoceratites crenocostatus* by McLearn (1972, p. 22, pl. 1, fig. 5A, 5B, 5C (= specimen Whiteaves, 1884, pl. 9, fig. 2), pl. 2, figs 1, 2A, 2B, 3), from the Haida Formation of British Columbia, Canada. Obata & Futakami (1992) disagreed with Kennedy & Klinger (1979) that *A. crenocostatus* (Whiteaves, 1876) should be regarded as a synonym for *A*. *mohadeva* (Stoliczka, 1865), because they considered the morphological characteristics of the two formes to be sufficiently distinct. Indeed, constrictions on the inner whorl of the holotype of *A*. *crenocostatus* (Whiteaves) are distinct than that of *A*. *mohadeva* (Stoliczka, 1865), and

the crenulate costae or lirae of the Canadian species are more evenly spaced through inner to outer whorl than are those of the Indian species. Thus, we agree with the opinion of Obata & Futakami (1992) that the Canadian and Indian species are separate species, as earlier mentioned by McLearn (1972).

Genus *Pictetia* Uhlig, 1883

***Pictetia astieriana* Orbigny, 1842**
(Fig. 16T–AA)

1842 *Crioceras Astierianus* Orbigny, p. 468, pl. 115, figs 3–5.
1850a *Crioceras Astierianus*, Orbigny, p. 125, nº64.
1871 *Crioceras Astierianus*, Eichwald, p. 37, pl. 3, figs 9, 10.
1875b *Hamites* (*Crioceras*) *Astierianus*, Neumayr, p. 896.
1883 *Pictetia Astieri*, Uhlig, p. 202.
1897 *Pictetia astieriana*, Parona & Bonarelli, p. 103.
1907 *Pictetia* (*Crioceras*) *Astierianum*, Jacob, p. 287.
1921 *Pictetia Astieriana*, Petković, p. 52.
1923a *Pictetia astieriana*, Spath, p. 29, pl. 1, fig. 7a, b, text-fig. 7 (= specimen Orbigny, 1842, pl. 115, figs 3–5).
1938 *Pictetia Astierianus*, Roman, p. 37, pl. 4, figs 31, 31a, text-fig. 31 on legend pl. 4 (= Orbigny, 1842, pl. 115, figs 3–5).
1949 *Pictetia Astieri*, Collignon, p. 47, pl. 8, fig. 2a, b.
1952b *Pictetia astieri*, Basse, p. 603, pl. 3, figs. 4, 4a (= Orbigny, 1842, pl. 115, figs 3, 4), text-fig. 49: 5 (= Orbigny, 1842, pl. 115, fig. 5).
1957 *Pictetia astieriana*, Arkell *et al*., p. L196, figs 225: 4a, b, c (= Orbigny, 1842, pl. 115, figs 3–5).
1963 *Pictetia Astieri*, Collignon, p. 7, pl. 243, fig. 1044.
1978 *Pictetia astieriana*, Kennedy & Klinger, p. 324, fig. 49A, B, C (= specimen Orbigny, 1842, pl. 115, figs 3–5).
1983 *Pictetia* cf. *astieriana*, Krishna, p. 57.

1989 *Pictetia astieriana*, Föllmi, p. 116, figs 4a, b, 5a, b, c, 6a, b, 7a, b, 8a, b.

1992 *Pictetia astieriana*, Rodda & Murphy, p. 436, figs 3.1, 3.2, 3.3, 3.6.

1993 *Pictetia astieriana*, Ivanov, p. 49, pl. 11, fig. 7.

1996 *Pictetia astieriana*, Wright *et al*., p. 2.

2006 *Pictetia astieriana*, Kennedy in Fischer & Gauthier *et al*., p. 130, pl. 40, fig. 5a,

b, c (= specimen Orbigny, 1842, pl. 115, figs 3–5).

2007 *Pictetia astieriana*, Clouter, p. 14, fig. on p. 8, 14.

2007 *Pictetia* sp., Kawabe, p. 119, figs 7: 4–11.

2009 *Pictetia astieriana*, Hoffmann *et al*., p. 524-527, figs 1A–E, 2A–P, 3A, C, E.

2013 *Pictetia astieriana*, Hoffmann *et al*., p. 520, figs 2, 3, 4.

Material. 27 specimens, IPMM 62949-62975 (all collected by K. Komori), from the upper part of the Hiraiga Formation at location KK.

Locality and horizon. The genus is reported from the lower and middle Albian of western Europe, Transcaspia, India, Madagascar, and Zululand in South Africa (Kennedy & Klinger, 1978). Collignon (1962) has recorded two species from the upper Aptian of Madagascar. The genus is reported from the Albian of Bulgaria (Ivanov, 1993), Japan (Obata, 1967a) and California (Rodda & Murphy, 1992). The genus has also been listed from western North America at Haida Gwaii (Haggart, 1986), and from western South America (Riccardi & Medina, 2002).

Measurements (in mm except for U/D and W/H**).**

Specimen	D	U	U/D	H	W	W/H
IPMM 62950	30.3	11.1	0.37	13.6	14.4	1.06
IPMM 62951	16.4	10.3	0.62	6.3	7.4	1.17
-1/2 phi	9.3	5.1	0.54	3.4	3.5	1.03
IPMM 62955	23.7	8.5	0.36	9.9	-	-
-1/2 phi	14.0	6.4	0.46	3.4	3.8	1.12
IPMM 62956	33.6	11.3	0.34	15.0	17.3	1.15
IPMM 62957	22.6	8.5	0.38	10.2	10.9	1.07
IPMM 62958	21.0*	7.4	0.35*	7.7*	9.3	1.20
IPMM 62960	17, 8	6.5	0.37	8.1	9.9	1.22
IPMM 62962	19.4	7.3	0.38	9.1	11.2	1.23

* approximate

Remarks. The specimens are characterized by a very small and a loosely coiled whorl with rapid expansion, circular whorl-section which is narrow in its early growth stage and then widens in its later growth stage, weak dorsal depression, and an umbilicus which is fairly wide in early stage and moderate wide in later. Surface is ornamented with dense, fine ribs which are annular, slightly rursiradiate on the flank, and cross the venter orthogonally, weaken on the dorsum, and strengthen on the flank and venter. Some ribs bifurcate on the lower flank and arise at middle flank. Because of these characteristics, the specimens are identified as *Pictetia astieriana* (Hoffmann *et al*., 2013).

Genus *Protetragonites* Hyatt, 1900

***Protetragonites eichwaldi* (Karakasch, 1907)**
(Fig. 15A–G)

1907 *Lytoceras eichwaldi* Karakasch, p. 50, pl. 5, fig. 8; pl. 24, fig. 5.

1955 *Lytoceras eichwaldi*, Eristavi, p. 52, text-fig. 8.

1956 *Protetragonites eichwaldi*, Drushchits, p. 95, pl. 4, figs 24a, 24б, text-fig. 41a, 41б, 41б

2007 *Protetragonites* sp., Kawabe, fig. 7:1, 2.

2018 *Lytoceras* sp., Obata & Matsukawa, p. 237, fig. 10P, Q.

Material. Four specimens, IPMM 062946, 062947, 062948 and 63802F (collected by K. Komori), from the upper part of the Hiraiga Formation at location KK.

Locality and horizon. This species is reported from the Caucasus (Karakasch, 1907).

Measurements (in mm except for U/D and W/H**).**

Specimen	D	U	U/D	H	W	W/H
IPMM 062946	28.0	13.0	0.46	9.0	8.0	0.89
IPMM 062948	23.8	11.6	0.49	8.6	7.5	0.87
IPMM 63802F	10.7	4.9	0.46	3.0	1.9	0.63

Remarks. Because of their circular whorl-sections and a few straight constrictions, the present specimens belong to the genus *Protetragonites* (Arkell *et al*., 1957). The whorl is discoidal, polygyral, evolute, and subcircular in cross-section. Ribs are feeble, coarse, and slightly prorsiradiate, straight or broadly parabolic. They arise at the umbilical seam, trend straight on the flank, and cross the venter broadly forward. The constrictions are shallow, broad, and number two or three in last whorl. They arise at the umbilical seam, trend straight radially on the flank, cross the venter orthogonally, and are parallel to the ribs.

The present specimens are similar to the illustrated specimen of *Protetragonites crebrisulcatus* (Drushchits, 1956, p. 95, pl. 5, fig. 16a, b, text-fig. 40b, c) from the Caucasus in having a subcircular whorl-section, coarse and feeble ribs. The Caucasus specimen is identified as a synonym of *P. eichwaldi* (Karakasch, 1907) by Klein *et al*. (2009). The present specimens differ from the illustrated specimen of *Lytoceras crebrisulcatus* Uhlig (1883, p. 191, figs 5–8, 8c, d, e, 9) from Silesia, in that the space of ribs in the present specimens are coarser than those of the Silesia specimens.

Superfamily Tetragonitoidea Hyatt, 1900
Family Gaudryceratidae Spath, 1927

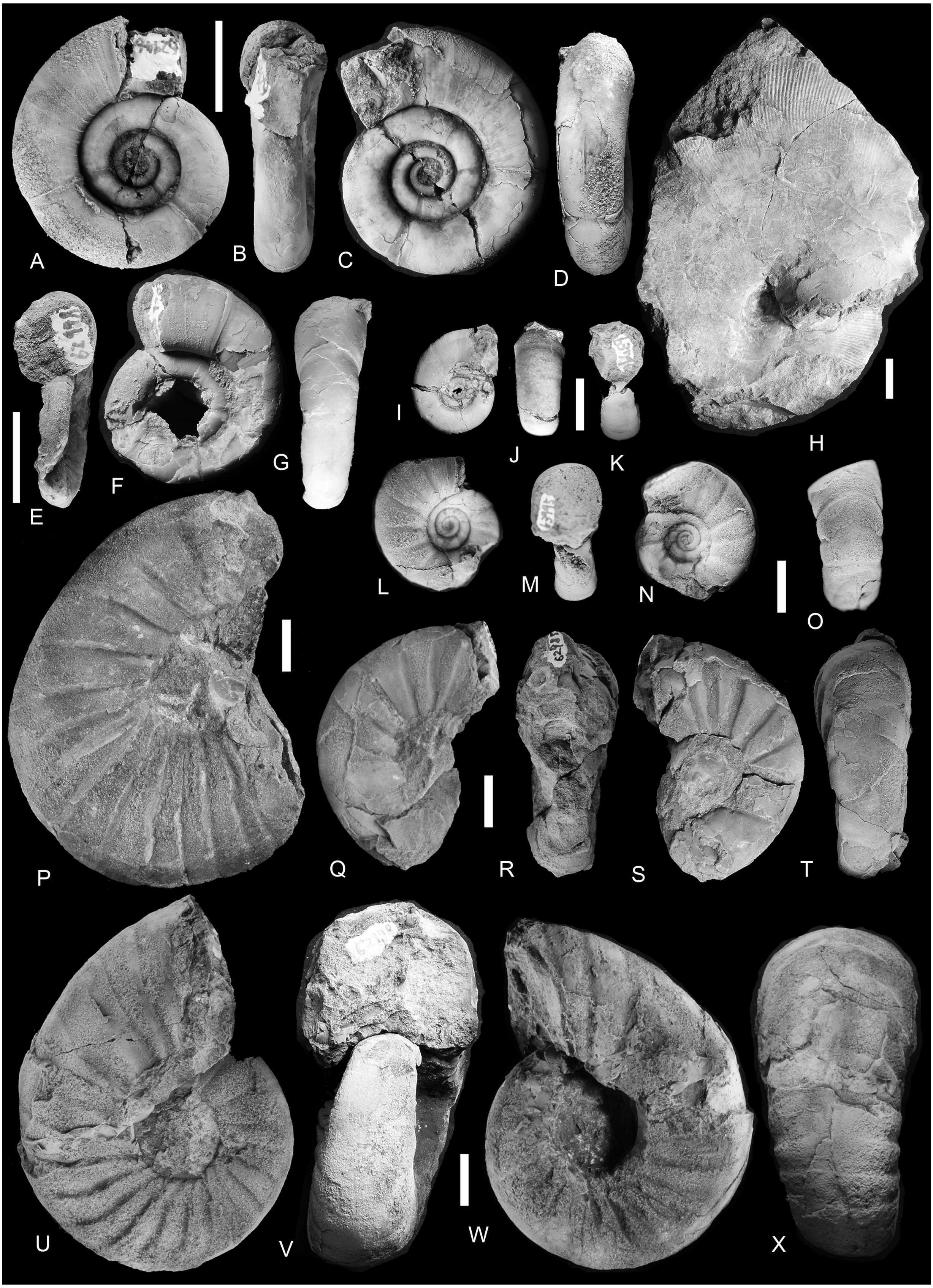

FIGURE 15. **A**–**G**, *Protetragonites eichwaldi*; **A**–**D**, IPMM 62946, and **E**–**G**, IPMM 62948. **H**, *Euphylloceras californicum*; IPMM 63787. **I**–**X**, *Eogaudryceras* (*Eotetragonites*) *gainesi*; **I**–**K**, IPMM 63799, **L**–**O**, IPMM 63795, **P**, IPMM 62979, **Q**–**T**, IPMM 62985A, and **U**–**X**, IPMM 62978. All specimens are shell and were collected by K. Komori from loc. KK. Scale bars = 1 cm.

Genus *Eogaudryceras* Spath, 1927a
Subgenus *Eotetragonites* Breistroffer, 1947

***Eogaudryceras* (*Eotetragonites*) *gainesi* (Anderson, 1938)**
(Fig. 15I–X)

1902 *Lytoceras* rel. *duvalianum* Orbigny, Anderson, p. 81, pl. 6, figs 140, 141, 142, 143.
1938 *Lytoceras angulatum* Anderson, p. 150, pl. 35, fig. 2.
1938 *Lytoceras* (*Kossmatella*) *gainesi*, Anderson, p. 153, pl. 20, figs 3, 4, 5.
1967c *Eotetragonites gainesi*, Murphy, p. 23, pl. 4, figs. 1 (=Anderson, 1902, pl. 6, figs 143), 2, 3, 4, 5.
1979 *Eogaudryceras* (*Eotetragonites*) *gainesi*, Kennedy & Klinger, p. 126.
1992 *Eotetragonites aketoensi*s Obata & Futakami, p. 87–89, pl. 6, figs 8, 9.
1993 *Eogaudryceras* (*Eotetragonites*) *gainesi*, Ivanov, p. 55, pl. 2, fig. 3.
2018 *Eotetragonites* aff. *aketoensi*s, Obata & Matsukawa, p. 230, figs 12I, T–W, X-AA, AB-Ae; 14A–D.

Material. Slightly deformed seventeen specimens, IPMM 62978, 62979, 62980, 62983A, 62985A, 62985B, 63795, 63796, 63797, 63798, 63799, 63785A-F (all collected by K. Komori). The specimens come from the upper part of the Hiraiga Formation al location KK. Three specimens (collected by I. Obata) come from the Aketo Formation, TGUSE-MM 6521 and 6583 from location Hiraname-dana, and TGUSE-MM 6149 from location C7p.

Locality and horizon. The species is reported from the lower Albian of Bulgaria (Ivanov, 1993), and the Albian of northern California (Anderson, 1938) and Japan (this paper).

Measurements (in mm except for U/D and W/H)**.**

Specimen	D	U	U/D	H	W	W/H
IPMM 62978	68.4	19.3	0.28	28.9	33.4	1.16
IPMM 62979	deformed			30.7		
IPMM 62980	54.2	16.9	0.31	22.6	25.0	1.11
IPMM 62783A	76.1	20.8	0.27	36.1	26.2	0.73
IPMM 62785A	47.8	14.7	0.31	20.0	19.2	0.96
IPMM 63785B	18.6	7.4	0.40	7.3	6.3	1.08
IPMM 63795	27.3	9.4	0.34	10.9	11.6	1.06
IPMM 63796	13.1	5.5	0.42	4.1	-	-
IPMM 63797	9.5	3.5	0.37	3.6	4.5	1.25
IPMM 63798	20.9	8.6	0.41	8.2	9.3	1.13
IPMM 63799	18.2	6.9	0.38	7.5	8.1	1.08

Remarks. The specimens are characterized by moderate shell size, square whorl-section with flat flank and arced venter, a moderate umbilicus with steep wall, a smooth shell surface and distinct prorsiradiate constrictions numbering around 20 per whorl.

The present specimens are similar to the specimens of *Lytoceras* (*Kossmatella*) *gainesi* (Anderson, 1938, p. 153, pl. 20, figs 3, 4, 5) from the Albian Horsetown Group of California, in that the whorl-section of both the Japanese and Californian specimens change from trapezoidal to square from the inner to the outer whorl, and the increasing number of constrictions from the inner to the outer whorl. The ratio of W/H of the Japanese specimen is slightly greater than that of the Californian specimens; this probably reflects a morphological variation of the whorl. Therefore, we judge that both forms should be identified as the same species.

Obata & Matsukawa (2018) described five specimens, TGUSE-MM 6172, 6183, 6186, 6227, and 6184, from the Aketo Formation as *Eotetragonites* aff. *aketoensi*s, but their ratios of umbilicus to shell diameter and shell width to shell height are within the range in *Eotetragonites gainesi*, and we therefore, regard those specimens as synonym of *E*. *gainesi*.

Genus *Anagaudryceras* Shimizu, 1931

***Anagaudryceras* sp.**
(Fig. 16M–S)

2022 *Anagaudryceras* sp., Matsukawa & Oji, p. 146, fig 4F–I.

Material. Three specimens, IPMM 63782, 63783A, and 63783B (collected by K. Komori), are casts of phragmocones, and come from the upper part of the Hiraiga Formation at location KK.

Locality and horizon. This is one of the oldest records of the genus *Anagaudryceras* from the uppermost Aptian.

Description. The specimens are characterized by a fairly small, fairly compressed and very evolute whorl that is elliptical in cross-section with rounded flanks and narrow venter, and a fairly narrow umbilicus. The whorl exhibits a rapid expansion. The umbilicus is shallow and its wall rounds to the flank. The ventral shoulder is sub-angulate and becomes rounded with growth, while the venter itself is flattened on the earlier stages and also becomes rounded with growth. The flank surface is ornamented with smooth striae, weak ribs, and constrictions with ornamented collar adapically. The ribs are undulating very weak and arise at the umbilical shoulder; they are slightly sinuous and prorsiradiate, and cross the venter with a slight forward bend. The constrictions are very shallow and narrow with a distinct collar adapically. They start at the umbilical seam, trend slightly flexuous forward across the flank and cross the venter with a

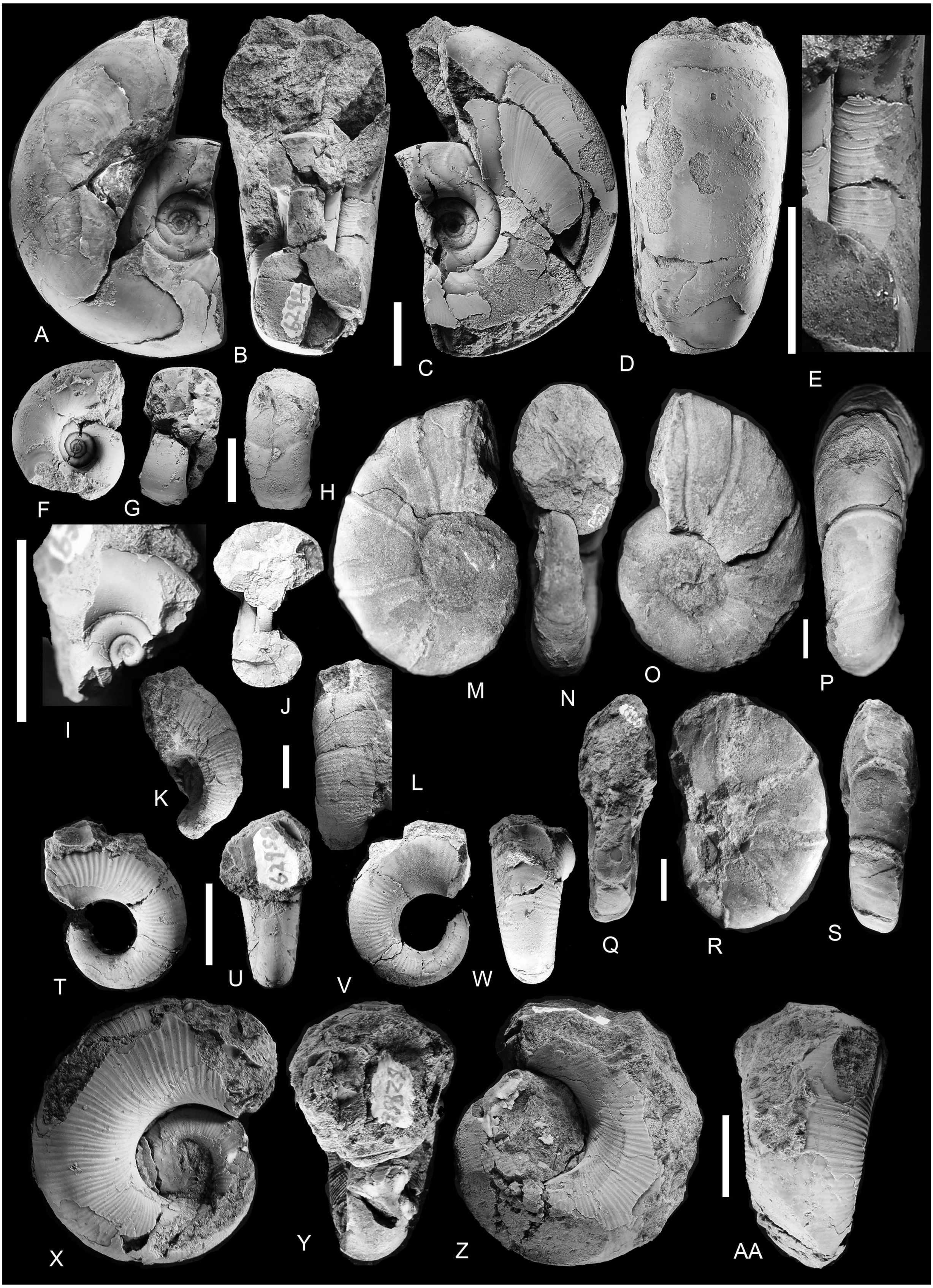

FIGURE 16. **A**–**H**, *Tetragonites hulenensis*; **A**–**E**, IPMM 62976, **E**, enlarged dorsum of outer whorl, **F**–**H**, IPMM 62977. **I** and **J**, *Gabbioceras* sp. B, IPMM 63802G. **K** and **L**; *Gabbioceras* sp. A, TGUSE-MM 6228, shell, collected by I. Obata from loc. Hiraname-dana. **M**–**S**, *Anagaudryceras* sp.; **M**–**P**, IPMM 63783B, and **Q**–**S**, IPMM 63783A. T-AA, *Pictetia astieriana*; **T**–**W**, IPMM 62958, and X-AA, IPMM 62956 (Specimen = Fig. 2A in Hoffmann *et al*., 2013). All specimens except for TGUSE-MM 6228 are shell and were collected by K. Komori from loc. KK. Scale bars = 1 cm.

slightly forward orientation. They are parallel to the ribs, and number seven to eight per volution.

Measurements (in mm except for U/D and W/H)**.** C is number of constrictions per whorl.

Specimen	D	U	U/D	H	W	W/H	C
IPMM 63782	36.6*	8.0	0.22*	18.0	11.6	0.64	7+
IPMM 63783A	58.3*	-	22.9	16.5	0.72	7	
IPMM 63783B	73.1	21.8	0.30	37.6	26.7	0.71	8+

* approximate

Remarks. Because of its very evolute whorl and constrictions with collar adapically, the specimens belong to the genus *Anagaudryceras* (Wright *et al*., 1996). In many species of the genus *Anagaudryceras*, the surface ornamentation changes remarkable at the boundary between the phragmocone and the body chamber exhibiting strong primary ribs. In the present specimen, the body chamber is not preserved, and the surface ornamentation is unknown. Therefore, the specimen is identified as *Anagaudryceras* sp. The specimen of *Anagaudryceras* sp. (NSMNS PM35972; Matsukawa & Oji, 2022, p. 146, fig. 4F–I) from the Hiraiga Formation in the Taro area is assigned to the present species in having striae and seven very shallow constrictions with collar adapically. However, the whorl-section of the former specimen is trapezoidal, whereas the latter specimen is elliptical. This is thought to reflect the characteristics of the younger-growth stage in the former and the later-growth stage in the latter, respectively.

Family Tetragonitidae Hyatt, 1900
Subfamily Tetragonitinae Hyatt, 1900
Genus *Tetragonites* Kossmat, 1895

***Tetragonites hulenensis* Murphy, 1967a**
(Fig. 16A–H)

1967a *Tetragonites hulenensis* Murphy, p. 54–57, pl. 6, figs 16–19; pl. 7, figs 3, 6, 7, 9, 10.
2007 *Tetragonites hulenensis*, Kawabe, p. 119–120, fig. 7:13–15.

Material. Eight specimens, IPMM 62976, 62977, 63790, 63791, 63792, 63783C–E (collected by K. Komori). IPMM 62976 lacks almost half of its outer shell, 62977 is a partial outer shell, and 63791 is obliquely deformed. They come from the uppermost part of the Hiraiga Formation at location KK.

Locality and horizon. The species is also reported from the upper *Leconteites lecontei* Zone and the *Brewericeras hulense* Zone in northern California and is assigned to the lower Albian (Murphy, 1967a).

Measurements (in mm except for U/D, W/H, H/D and W/D)**.**

Specimen	D	U	U/D	H	W	W/H	H/D	W/D
IPMM 62976	53.9	20.1	0.37	22.7	25.8	1.14	0.42	0.49
IPMM 62977	20.7	7.0	0.34	8.4	10.2	1.21	0.41	0.41
IPMM 63790	55.0	18.7	0.34	21.8	20.9	0.96	0.40	0.38
IPMM 63792	19.0	6.9*	0.36*	8.3	10.0	1.20	0.43	0.52

* approximate

Remarks. The whorl is fairly small, subrectangular in its cross-section, slightly wider than heigh, fairly depressed, very evolute, slightly wider than high, with broadly rounded flanks and venter. The umbilicus is moderate, rather shallow, with vertical wall, and rounded at its margin. The surface of the flank and venter is ornamented with feeble lirae, strongly prorsiradiate and bending backward at the ventro-lateral shoulder and crossing the venter concavely. The constrictions are feeble, strongly prorsiradiate, and bend backward at the ventrolateral shoulder, cross the venter concavely, and parallel the lirae. They number four per half whorl. Because of the moderate size of the umbilicus (U/D ranges from 0.34 to 0.40), the strongly prorsiradiate constrictions on the flank becoming concave on the venter, numering four per half volution, the specimens are identified as *Tetragonites hulenensis* (Murphy, 1967a, p. 54–57, pl. 6, figs 16–19; pl. 7, figs 3, 6, 7, 9, 10) from the Albian of northern California.

Subfamily Gabbioceratinae Breistroffer, 1953
Genus *Gabbioceras* Hyatt, 1900

***Gabbioceras* sp. A**
(Fig.16K, L)

2018 *Gabbioceras* sp., Obata & Matsukawa, p. 239–241, fig. 13Q–S.
2022 *Gabbioceras* sp., Matsukawa & Oji, p. 146–147, fig. 4E.

Material. Three specimens (collected by I. Obata). TGUSE-MM 6228 is an obliquely deformed whorl fragment from the Aketo Formation at location Hiraname-dana; TGUSE-MM 6251 is a small shell and comes from the Aketo Formation at location Hn6201 (≈ Hiraname-dana); TGUSE-MM 6230 is a fragment of a whorl, is obliquely deformed, and comes from the Hiraiga Formation at location Tokuzo.

Locality and horizon. The Hiraiga and Aketo formations.

Measurements (in mm except for U/D and W/H).

	D	U	U/D	H	W	W/H
TGUSE-MM 6228	-	-	-	11.8	15.6	1.32
TGUSE-MM 6251	17.0	-	-	7.0	8.2	1.17
TGUSE-MM 6230	-	-	-	12.2	23.4	1.92

Remarks. The specimens are characterized by small cadicone shell with sharp ventrolateral angle, broad arched venter, wide and deep umbilicus with steep wall, numerous fine ribs which are rectiradiate and cross the venter, and shallow and narrow constrictions which are parallel to the ribs. Because of the sharp ventrolateral angle, the specimens can be identified as the genus *Gabbioceras* (Wright *et al*., 1996). The specimens differ from the specimen of *Lytoceras* (*Gabbioceras*) *angulatum* (Anderson, 1938, p. 150, pl. 15, fig. 3) from northern California, because the whorl of the Japanese specimens is more depressed than in the California specimen: W/H of the Japanese specimens ranges from 1.17 to 1.92, but W/H of Californian species is 0.80.

The Japanese specimens may be a new species, but we hesitate to give them a new species name due to their poor preservation.

***Gabbioceras* sp. B**
(Fig. 16I, J)

Material. IPMM 63802G (collected by K. Komori) is a small specimen of four and one-half volutions and has lost about half of the shell. The specimen comes from the uppermost Hiraiga Formation at location KK.

Locality and horizon. *Gabbioceras* sp. B is one of the oldest records for the genus. The genus is reported from California (Anderson, 1938), the middle Albian of France (Orbigny, 1850) and the Gargasian of France (Breistroffer, 1947 in Murphy, 1967b), the upper Aptian of Hungary (Szives *et al*., 2007), the Aptian of Caucasus and Crimea (Luppov & Drushchits, 1958), the *Mantelliceras martimpreyi* Zone, Cenomanian, of Madagascar (Collignon, 1964 in Murphy, 1967b), and the lower Albian of Japan (Obata & Matsukawa, 2018).

Measurements (in mm except for U/D and W/H).

Specimen	D	U	U/D	H	W	W/H
IPMM 63802G	9.5	2.9	0.31	4.3	6.6	1.53

Remarks. The specimen is characterized by a very small whorl with moderate umbilicus with sloping wall. The whorl is cadicone, very evolute, much depressed, and becomes angular on the fourth volution. The whorl-section is ellipsoid, with umbilical shoulder at the apex of the ellipse. The venter is broad and arched, the flank is slightly convex and converging gradually to the venter. The shell surface is smooth. Because of its cadicone shape with sharp ventrolateral angle and smooth shell surface, the specimen belongs to the genus *Gabbioceras* (Wright *et al*., 1996). The constrictions are not confirmed because the specimen is of too small size. A specimen (TGUSE-MM 6108) described as *Gabbioceras* sp. by Obata & Matsukawa (2018, p. 239–240, fig. 12Q–S) from the Aketo Formation of the Miyako Group is larger than the present specimen, and is characterized by an ellipsoidal whorl-section, very similar the present specimen. However, the ratio of the umbilicus and shell diameter (U/D) of both specimens differs (the present specimen is 0.31, TGUSE-MM 6108 is 0.41), we consider the as different species; we assign the specimens TGUSE-MM 6108 to *Gabbioceras* sp. A and the present specimen as *Gabbioceras* sp. B.

The present specimen differs from the illustrated specimens of *Lytoceras* (*Gabbioceras*) *angulatum* (Anderson, 1902, p. 6, fig. 139; p. 150, pl. 15, figs 3, 4; Murphy, 1967b, p. 597–600, pl. 64, figs 1, 2, 8, 9), from the upper Aptian of northern California, because the angulation of the flank of the Californian specimens is sharper than that of the present specimen. The whorl-section of the present specimen is ellipsoid and much depressed, whereas those of the Californian specimens are circular and more compressed. The whorl of the illustrated specimen of *Gabbioceras jacobi* (Murphy, 1967b, p. fig. 11) from the Albian of Madagascar is more depressed than that of the present specimen, thus it is different from the present specimen; this specimen is probably a new species, but is only small specimen that is missing part of the shell, so, it is identified as *Gabbioceras* sp. B.

Suborder Ammonitina Hyatt, 1889
Superfamily Desmoceratoidea von Zittel, 1895
Family Desmoceratidae von Zittel, 1895
Subfamily Puzosiinae Spath, 1922
Genus *Valdedorsella* Breistroffer, 1947

***Valdedorsella akuschaensis* (Anthula, 1899)**
(Fig. 17A–L)

1899 *Desmoceras akuschaense* Anthula, p. 104, pl. 8, fig. 3a–c.
1905 *Desmoceras akuschaensis*, Jacob, p. 402, pl. 12, fig. 1.
1933 *Latidorsella akuschaensis*, Rouchadze, p. 184, pl. 2, fig. 7.
1957 *Valdedorsella akuschaensis*, Arkell *et al*., p. L363, figs 476: 1a, b, c (= Anthula, 1899, pl. 8, fig. 3a–c).
1962 *Valdedorsella akuschaensis*, Collignon, p. 33, fig. 979.
1967a *Valdedorsella akuschaensis*, Obata, p. 65–67, pl. 8, figs 1, 4; text-fig. 1
1980 *Valdedorsella akuschaensis*, Thomel, p. 121, fig. 241.
1981 *Valdedorsella* ex gr. *akuschaensis*, Drushchits *et al*., p. 101, pl. 1, fig. 7.
1987 *Desmoceras akuschaensis*, Leshchukh, p. 359, pl. 14, fig. 3.
1990 *Valdedorsella akuschaensis*, Ivanov & Stoykova, p. 60, pl. 1, fig. 7.

1996 *Valdedorsella akuschaensis*, Wright *et al*., p. 72, fig. 52: 1a, b, c (= Anthula, 1899, pl. 8, fig. 3a–c).

2004 *Valdedorsella* ex gr. *akuschaensis*, Bogdanova & Hoedemaeker, p. 220, pl. 28, fig. 6a, b, c.

2005 *Valdedorsella akuschaensis*, Dutour, p. 134, pl. 13, figs 6a, b, 7, 8.

2008 *Valdedorsella akuschaensis*, Joly & Delamette, fig. 7B.

2008 *Valdedorsella akuschaensis*, Abu-Zied, p. 606, figs 2K, 5R, 5S, 5T.

2022 *Valdedorsella akuschaensis*, Matsukawa & Oji, p. 147, fig. 4J, K, R–U.

Material. Eleven specimens in total. IPMM 63761, 63764, 63766B, and 63767 (collected by K. Komori), are shell and come from the uppermost of the Hiraiga Formation at location KK. TGUSE-MM 6509 (collected by I. Obata) is a partial shell and comes from the Aketo Formation at location OH6. TGUSE-MM 6447D (collected by I. Obata) comes from the Aketo Formation at location B2. TGUSE-MM 6519B (collected by I. Obata) comes from the Aketo Formation at location Hn 6201. TGUSE-MM 6517A (collected by I. Obata) and TGUSE-MM 6486 (collected by I. Obata) come from the Hiraiga Formation at location Tokuzo. TGUSE-MM 6548A (collected by I. Obata) comes from the Aketo Formation at location C6p. TGUSE-MM 6127 (K. Tanaka collector) come from the Aketo Formation at location TR138.

Locality and horizon. The genus is reported from the lower Barremian to upper Aptian of southeastern Europe, the Caucasus, central Asia (transcaspian area), northern Africa, Madagascar, Japan, Alaska, Colombia, and Argentina (Bogdanova & Hoedemaker, 2004).

Measurements (in mm except for U/D and W/H).

Specimen	D	U	U/D	H	W	W/H
IPMM 63761	34.5	10.6	0,31	14.5	13.4	0.92
IPMM 63767	9.9	3.5	0.35	4.4	5.9	1.34

Remarks. The specimens are very small and have an involute whorl, coronate whorl-section with rounded venter and moderate umbilicus (ratio to diameter ranges from 0.31 to 0.35). Surface is ornamented with dense, parabolic ribs and distinct constrictions. Some ribs are fine and start from the umbilical edge and bifurcate into two at a little below the mid-flank, while others are intercalatory. The constrictions start from the umbilical seam, trend straight or are weakly flexuous across the flank, and cross the venter widely projected. They number five per whorl and run parallel to the ribs. These characteristics indicate the specimens can be identified as *Valdedorsella akuschaensis* (Obata, 1967a, p. 65–67, pl. 8, figs 1, 4; text-fig. 1; NSM-PM 6068) from the Tanohata and Hiraiga formations of the Miyako Group, Japan.

***Valdedorsella getulina* (Coquand, 1880)**
(Fig. 17M–T)

1880 *Ammonites Getulinus* Coquand, p. 18.

1907 *Puzosia Getulina*, Pervinquière, p. 151, pl. 6, fig. 16.

1912 *Puzosia Getulina*, Joleaud, p. 120, pl. 1bis, figs 15–17.

1920 *Puzosia Getulina*, Fallot, p. 45–46, pl. 2, figs 7–10.

1957 *Desmoceras getulinum*, Almela & José De La Revilla, p. 25, pl. 6, figs 3, 3a.

1960 *Puzosia getulina*, Waitzman, p. 36, pl. 2, fig. 6a, b.

1962 *Valdedorsella getulina*, Collignon, p. 33, fig. 977.

1966 *Valdedorsella getulina*, Schindewolf, fig. 378a, b, c, d, e, f.

1967a *Valdedorsella getulina,* Obata, p. 67–69, pl. 8, fig. 2, text-fig. 2.

1968 *Valdedorsella getulina*, Wiedmann & Dieni, p. 108.

1971 *Desmoceras* (?) *getulina*, Kvantaliani, p. 103, p. 16, figs 1a, б; text-fig. 61a, б.

1975 *Valdedorsella getulina*, Lillo Beviá, p. 683, pl. 2, figs 1–5.

1976 *Valdedorsella getulina*, Fülöp, pl. 1, figs 1–5.

1982 *Valdedorsella getulina*, Renz, p. 22, pl. 2, fig. 19a–c; text-fig. 10a, b.

1996 *Valdedorsella getulina*, Szives, p. 30, pl. 2, fig. 2.

1999 *Valdedorsella getulina*, Szives, p. 404, pl. 1, fig. 2.

2004 *Valdedorsella* ex gr. *getulina*, Bogdanova & Hoedemaeker, p. 219, p. 28, figs 4a, b, 5a, b.

2005 *Desmoceras getulina*, Kvantaliani in Kotetishvili *et al*., p. 322, pl. 60, figs 5a, 6, B (= Kvantaliani, 1971, pl. 16, figs 1a, v6, B).

2007 *Valdedorsella getulina*, Szives *et al*., p. 51, pl. 1, figs 15a, b, 16a, b, 17, pl. 3, fig. 24a, b.

Material. Fourteen specimens; IPMM 63758, 63759, 63760, 63762, 63763, 63765A, 63765B, 63766A, 63766C, 63768A, 63768B, 63768C, 63768D, and 63771 (collected by K. Komori). All from the uppermost Hiraiga Formation at location KK.

Locality and horizon. The specimens from the Miyako Group are reported from Hn 4151 (the lower part of the Hiraiga Formation) and 0650 (the upper part of the Tanohata Formation) (Obata, 1967a).

Measurements (in mm except for U/D and W/H).

Specimen	D	U	U/D	H	W	W/H
IPMM 63758	17.6	4.0	0.23	8.2	11.6	1.41
IPMM 63759	19.7	4.8	0.24	9.7	11.6	1.20

Remarks. The material represents very small shells with a strongly depressed whorl with broadly rounded venter, deep and narrow umbilicus, and whorl surface with lirae and strong constrictions which are prorsiradiate on the flanks and cross the venter bending aperturally. Based on this, the specimens are identified as *Valdedorsella getulina* (Obata, 1967a, p. 67–69, pl.

8, fig. 2, text-fig. 2; NSM-PM 6070, from the Tanohata and Hiraiga formations of the Miyako Group). The suture is simple, with deep, narrow and symmetric external lobe and saddle. The first saddle is bifid and basically symmetric. The first lateral lobe is deep, trifid, and basically symmetric. The suture of the specimen IPMM 63760 is similar to that of the specimen NSM-PM 6070 from the Tanohata Formation at location Hn 4152, Matsushima, in Moshi, Iwate Prefecture (Fig. 18).

Valdedorsella kasei **Obata & Matsukawa, 2018**

2018 *Valdedorsella kasei* Obata & Matsukawa, p. 241, fig. 15A–T.
2023 *Valdedorsella kasei*, Matsukawa & Shibata, p. 14, fig. 5T–AA.

Material. Three specimens (collected by I. Obata). TGUSE-MM 6232 comes from the Hiraiga Formation at location Tokuzo. Both TGUSE-MM 6573 and 6574 are partial shells and come from the Aketo Formation at location Hiraname-dana.

Measurements (in mm except for U/D and W/H**).**

Specimen	D	U	U/D	H	W	W/H
TGUSE-MM 6232	28.0	8.2	0.29	13.5	14.3	1.06
TGUSE-MM 6573	-	-	-	8.6	10.6	1.23
TGUSE-MM 6574	-	-	-	-	9.6 +	-

Remarks. Based on its small shell, depressed and inflated whorl with broad and rounded venter, and convex constrictions, the specimens are identified as *Valdedorsella kasei* (Obata & Matsukawa, 2018, p. 241, fig. 15A–T).

Genus *Pseudohaploceras* Hyatt, 1900

Pseudohaploceras nipponicum **Shimizu, 1931**
(Fig. 17U–X)

1931 *Pseudohaploceras nipponicum* Shimizu, p. 27–28, pl. 1, figs 17–19.
1991 *Pseudohaploceras nipponicum*, Obata & Futakami, pl. 31, figs 6–8.
2018 *Pseudohaploceras nipponicum* Shimizu; Obata & Matsukawa, p. 243, fig. 14I–J, K–M, S–U, V–W; 17A–Q

Material. Seventeen specimens (collected by I. Obata) come from the Hiraiga Formation. TGUSE-MM 6505 (a partial external mould) from location Hn1902, TGUSE-MM 6592A and 6592B (both are partial external moulds) from location Tokuzo; TGUSE-MM 6557 (external mould), 6558 (shell), 6561 (shell), 6104A (shell), 6160B (partial shell), 6104C (a partial shell), 6564A, 6564B, 6564C, and 6564D (external mould) from location Hn 0220; TGUSE-MM 6202 is a tiny shell, and comes from location Hn4051; TGUSE-MM 6462 and 6463 are partial shells, and come from location Hn4053; TGUSE-MM 6555 comes from location Matsushima.

Locality and horizon. Hiraiga Formation.

Measurements (in mm except for U/D and W/H**).**

	D	U	U/D	H	W	W/H
TGUSE-MM 6202	16.7	-	-	-	-	-
1/4 earlier vol.	12.5	2.8	0.22	6.2	4.5	0.73

Remarks. Because of their compressed whorl (W/H = 0.73), fairly narrow umbilicus (U/D = 0.22), flat flank, and constrictions, the specimens can be identified as *Pseudohaploceras nipponicum* Shimizu, 1931. Ribs of the TGUSE-MM 6202 are very feeble in this size of the species.

***Pseudohaploceras*? sp.**
(Fig. 17Y–AA)

Material. TGUSE-MM 6175 (collected by I. Obata), a fragmentary specimen, external cast, from sandstone bed of the lower part of the Hiraiga Formation at location Hn0010.

Locality and horizon. Hiraiga Formation.

Measurements (in mm except for U/D and W/H**).**

	D	U	U/D	H	W	W/H
TGUSE-MM 6175	-	-	-	-	7.4	-

Remarks. Based on its compressed whorl with trapezoidal cross-section, narrowly acute venter, flat flank, fine and numerous flexuous ribs, and shallow constrictions, the specimen is similar to the specimens of *Pseudohaploceras nipponicum* (Obata & Matsukawa, 2018, p. 241, figs 14I–J, K–M, S–U, V–W, 17A–Q) from the Miyako Group. However, the disappearance of both ribs and constrictions on the venter of the present specimen differs from that of the specimens of *Pseudohaploceras nipponicum*. The genus *Pseudohaploceras* is defined based on the presence of ribs crossing the venter (Wright *et al*., 1996), so the specimen might represent a new genus; as only a single specimen shows this character, however, we identify it as *Pseudohaploceras*? sp.

Genus *Melchiorites* Spath, 1923a

Remarks. According to Wright *et al*. (1996), the genus *Melchiorites* is defined by a lack of ribs, but with radial or oblique constrictions which are projected on the venter on the early whorls: on the later whorl's ribs are rather feeble on the outer part of the flanks and venter. Wright *et al*. (1996) differentiated the genus *Melchiorites* from the genus *Puzosia* in that the constrictions of the latter genus

FIGURE 17. **A**–**L**, *Valdedorsella akuschaensis*; **A**–**D**, IPMM 63767 (collected by K. Komori), shell, from loc. KK, **E**–**H**, NSM-PM 6068 (collected by I. Obata), shell, from loc. Hn 0018, **I**–**L**, IPMM 63761 (collected by K. Komori), shell, from loc. KK. **M**–**T**, *Valdedorsella getulina*; **M**–**P**, IPMM 63758 (collected by I. Obata), shell, from loc. KK, **Q**–**T**, NSM-PM 6070 (collected by I. Obata), shell, from loc. Hn 4151. **U**–**X**, *Pseudohaploceras* sp.; TGUSE-MM 6202 (T. Kase collector), shell, from, loc. Hn 4051. **Y**–**AA**, *Pseudohaploceras*? sp.; TGUSE-MM 6175 (collected by I. Obata), internal mould, from loc. Hn 0010. Scale bars = 1 cm.

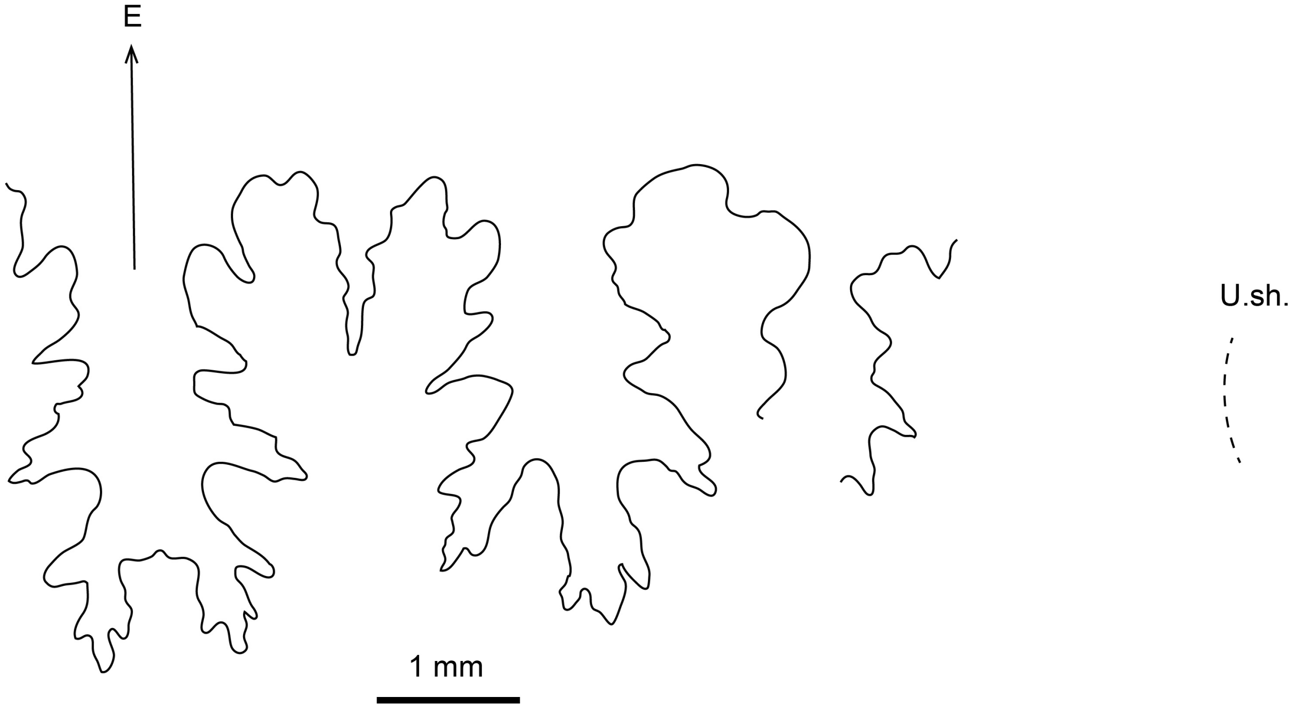

FIGURE 18. Suture of *Valdedorsella getulina*, specimen IPMM 63760.

form more linguiform projections on the venter than do those of the genus *Melchiorites*. We follow the definition of Wright *et al*. (1996).

Melchiorites yabei **(Shimizu, 1931)**
(Fig. 19A–C, J–K, Q–R, S–V)

1931 *Puzosia*? *yabei* Shimizu, p. 24–25, pl. 3, figs 18–21, 27.
2012 *Melchiorites* sp., Obata & Matsukawa, p. 22–35, fig. 1F–H.
2018 *Puzosia yabei*, Obata & Matsukawa, p. 243–245, fig. 19A–H, M–AF, AJ–AQ.

Additional material. Eleven specimens in total, including eight specimens collected by I. Obata: TGUSE-MM 6440 and 6496 come from the upper part of the Tanohata Formation at location Hn 0220, Hiraiga north; TGUSE-MM 6532 comes from the Hiraiga Formation at location Hn 4153, Matsushima; TGUSE-MM 6579 comes from the Hiraiga Formation al location Hn 4151; TGUSE-MM 6471 comes from the upper part of the Hiraiga Formation at location Hn 0320, Funaare; TGUSE-MM 6472 and 6504 come from the Hiraiga Formation at location Hn 1902, Haipe south; TGUSE-MM 6493 comes from the Hiraiga Formation at location Tokuzo, Hiraiga south, Hiraiga Formation. Additionally, three specimens (IPMM 63779, 63780; and 63781; collected by K. Komori) come from the upper part of the Hiraiga Formation at location KK. Finally, SKM-SS 060-010 and SKM-SS 063-005 (both internal moulds collected by F. Sasaki), come from the Hiraiga Formation at location Ks2005.

Locality and horizon. The genus *Melchiorites* is reported from the Barremian of Morocco (Company *et al*., 2008), Austria and Poland (Uhlig, 1883), Romania and former Yugoslavia (Vašiček, 1972), Bulgaria (Dimitrova, 1967), Italy (Lukeneder & Aspmair, 2006), and Colombia (Bogdanova and Hoedemaeker, 2004), the Aptian of France, Georgia and Tunisia (Vašiček, 1972), Italy (Wiedmann & Dieni, 1968), Slovakia, Spain, and Sardinia (Vašiček & Rakús, 1995), California (Anderson, 1938), and Colombia (Etayo-Serna, 1979), and from the Albian of Madagascar (Collignon, 1963).

Description (additional specimens)**.** The specimens are very small, fairly compressed, and exhibit a very evolute whorl with narrow umbilicus. The whorls are rectangular in cross-section, somewhat convex flanks and broadly rounded venter. Surfaces of the internal mould are smooth. Lirae are observable on outer one-fourth of flank and venter. Strong pedioric constrictions are prorsiradiate and weakly parabolic and cross the venter orthogonally or arching. A partial suture line is preserved in IPMM 63779 (Fig. 20); its ventral lobe (E) is deep, the first lateral saddle is subsymmetrically divided by a shallow lobule on the top, and the lateral lobe (L) is deep.

Measurements (in mm except for U/D and W/H)**.**

Specimen	D	U	U/D	H	W	W/H
TGUSE-MM 6440	15.8*	5.1*	0.32*	6.0*	-	-
IPMM 63779	14.9	-	-	6.3	5.9	0.94
IPMM 63780	16.3	4.6*	0.28*	6.9	5.6	0.81
IPMM 63781	11.5*	3.2*	0.28*	4.8*	4.4*	0.92*

* approximate.

Remarks. Although the holotype of the species (IGPS 36506) and the nine specimens, TGUSE-MM 6119, 6120, 6217, 6218, 6220, 6221, 6224,–and 6264, were once described as *Puzosia*? *yabei* or/and *Puzosia yabei*, respectively. These specimens are all characterized by radial or obliquely parabolic periodic constrictions and enable these specimens to be identified as *Melchiorites yabei* (Shimizu, 1931).

Genus *Puzosia* Bayle, 1878

Remarks. Wright *et al*. (1996) defined the genus based on a rounded to compressed whorl, with fine ribs and constrictions which are generally present and parallel to the ribs. In general, its whorl is more evolute than that of the genus *Melchiorites*, with more linguiform projection of constrictions on the venter and a more complex suture with more strongly retracted suspensive lobes.

Subgenus *Puzosia* Bayle, 1878

Locality and horizon. *Puzosia* (*Puzosia*) is reported from the Aptian of the western Caucasus (Egoian, 1969) and Japan (this paper), the Albian of England (Spath, 1923a), France (Breistroffer, 1947), Switzerland (Renz, 1968), Italy (Wiedmann & Dieni, 1968), India (Matsumoto *et al*., 1988), Japan (Matsumoto *et al*., 1988), British Columbia in Canada (McLearn, 1972), California (Anderson, 1938; Murphy, 1956), Brazil (Maury, 1936), Argentina (Leanza, 1970), Madagascar (Collignon, 1963), Angola (Haas, 1942), Australia (Whitehouse, 1926), and New Zealand (Henderson, 1973); from the Cenomanian of England (Wright & Kennedy, 1980), Switzerland (Renz, 1968), Japan (Matsumoto *et al*., 1988), California (Murphy & Rodda, 1960), and Madagascar (Collignon, 1964); from the Turonian of northern Mexico (Kennedy & Cobban, 1988), and Angola? (Choffat, 1888); and from the Coniacian of Madagascar (Collignon, 1961).

Remarks. The subgenus is characterized in both macro- and micro-conchs by ribs that are distinct only on the outer part of flank (Wright *et al*., 1996).

***Puzosia* (*P.*) *shimizui* sp. nov.**
(Fig. 19D–F, G–I, M–P)

2018 *Puzosia* aff. *yabei*, Obata & Matsukawa, p. 245, figs 14E–H, 19I–L, AG–AI.

Material. The following four specimens were described as *Puzosia* aff. *yabei* by Obata & Matsukawa (2018, p. 245, figs 14E–H, 19I–J, AG–AI): TGUSE-MM 6121 (holotype), 6122, and 6123 (collected by I. Obata), from the Hiraiga Formation at location Hn 1902, Koikorobe, south of Haipe coast; and TGUSE-MM 6158 (collected by I. Obata) from the Aketo Formation at location B2. Five additionally specimens are added here: TGUSE-MM 6219 (collected by I. Obata) from the Hiraiga Formation at location Hn 0016; TGUSE-MM 6158 (collected by I. Obata) from the Aketo Formation at location B2; TGUSE-MM 6665 (collected by I. Obata) from the Hiraiga Formation at location Hn 4151, and SKM-SS 062-004 and 34-#32 (collected by F. Sasaki), from the Hiraiga Formation at location Ks 2005, Hideshima fishing port, Sakiyama, Miyako city.

Etymology. After late Dr. Saburo Shimizu of Tohoku Imperial University, Sendai, and Shanghai Science Institute, China, who contributed much as a pioneer to the study of the Japanese Lower Cretaceous ammonites.

Diagnosis. *Puzosia* with collars located both forward and behind constrictions.

Description. The shells are fairly small, reaching about 75 mm in diameter. The umbilicus is fairly narrow to moderate in its width and is shallow. The umbilical wall is vertical, and rounds to flank abruptly. The whorl is fairly evolute with a flat flank and rounded venter. The whorl-section is rectangle with rounded umbilical and ventrolateral shoulders. There are seven or eight constrictions in one volution; they are strongly flexuous and show a sigmoid curvature in the lateral view and cross the venter forming a linguiform projection. A collar is found both forward and behind the constrictions and these strengthen with growth. Numerous narrow ribs arise at the mid-flank and are only developed on the outer flank, with inner flank smooth. The ribs are nearly parallel with constrictions.

Measurements (in mm except for U/D and W/H**)**.

Specimen	D	U	U/D	H	W	W/H
TGUSE-MM 6121 (holotype)	-	-	-	8.7	6.8	0.78
-phi	15.1	5.2	0.34	4.7	3.1	0.66
TGUSE-MM 6158	30.8	7.7	0.25	12.9	10.3	0.80
TGUSE-MM 6123	-	-	-	9.1*	7.0*	0.77*
SKM-SS 062-004	74.5	28.1	0.38	24.8	-	-
SKM-SS 34-#32	24.3	7.8	0.32	10.1	-	-

* approximate.

Remarks. The present specimens are similar to the holotype of *Puzosia subcorbarica* (Matsumoto, 1954, p. 73–74, pl. 9, fig. 1a, b; pl. 12, fig. 1) from the Lower Ammonite Beds of Yezo (main part of the Middle Yezo Group in Matsumoto's revision (1954)) along Ikushumbets gorge, present Albian mudstone of the Ikushumbets (Mikasa) (Matsumoto *et al*., 1988), Mikasa

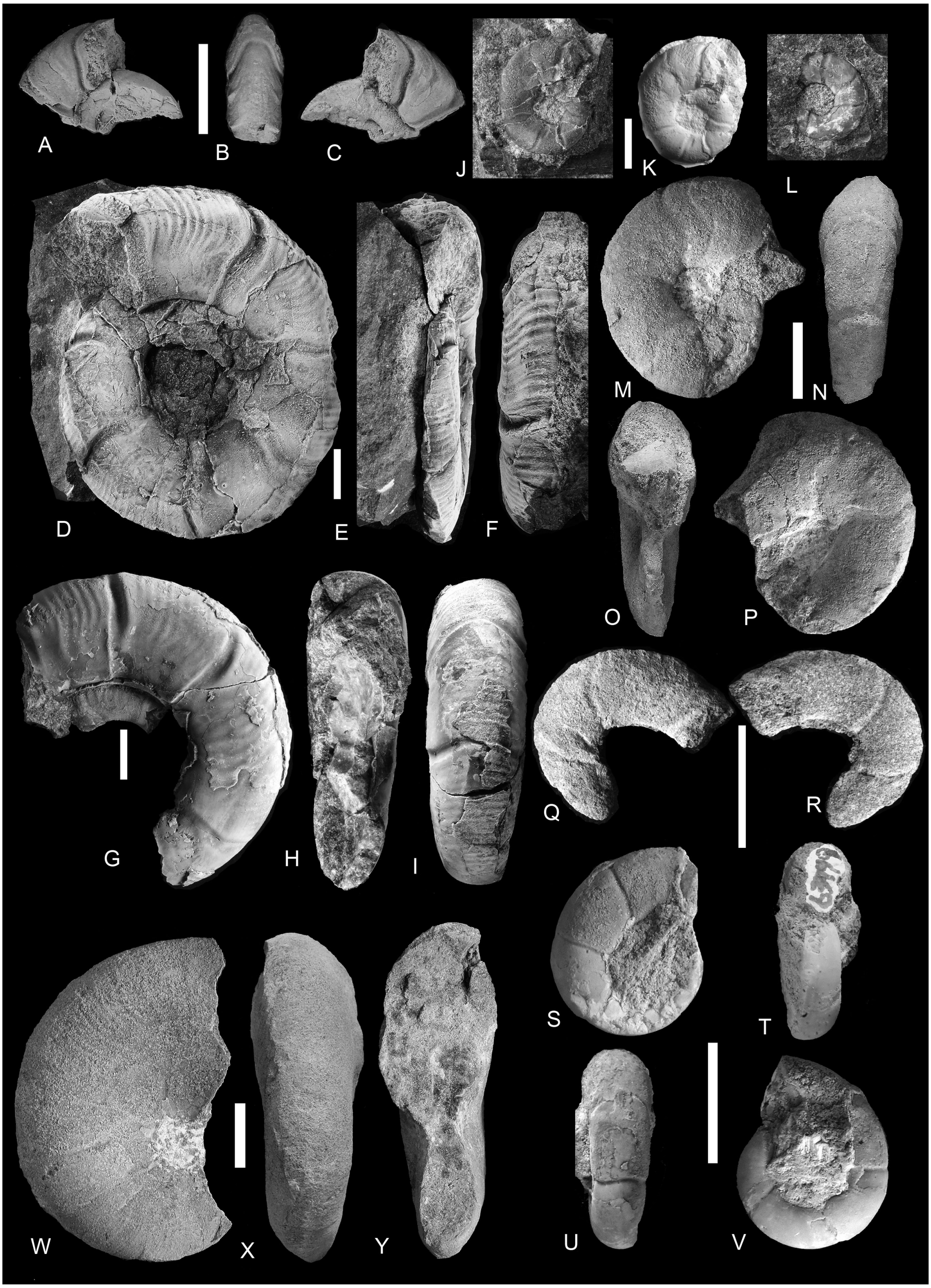

FIGURE 19. A–C, **J–K**, **L**, **Q–R**, **S–V**, *Melchiorites yabei*. **A–C**, TGUSE-MM 6122 (collected by I. Obata), shell, from loc. Hn 1902. **J** and **K**, **J**, SKM-SS 060-010 (F. Sasaki collector), internal mould, and **K**, its plaster cast, from Ks2005. **L**, SKM-SS 063-005 (F. Sasaki collector), internal mould, from Ks2005. **Q** and **R**, TGUSE-MM 6440 (collected by I. Obata), internal mould, from Hn 0220. **S–V**, IPMM 63779 (collected by K. Komori), internal mould, from KK. **D–I**, **G–I**, **M–P**, *Puzosia* (*P.*) *shimizui*; **D–F**, SKM-SS 062-004 (F. Sasaki collector), shell, from Ks2005, **G–I**, SKM-SS 34-#32, FS0079, internal mould with a part of shell, from Ks2005, **M–P**, TGUSE-MM 6158 (collected by I. Obata), internal mould, from B2. (specimen = Fig. 14 E–H in Obata & Matsukawa, 2018). **W–Y**, *Beudanticeras*? sp.; TGUSE-MM 6209, internal mould, from Cp7. Scale bars = 1 cm.

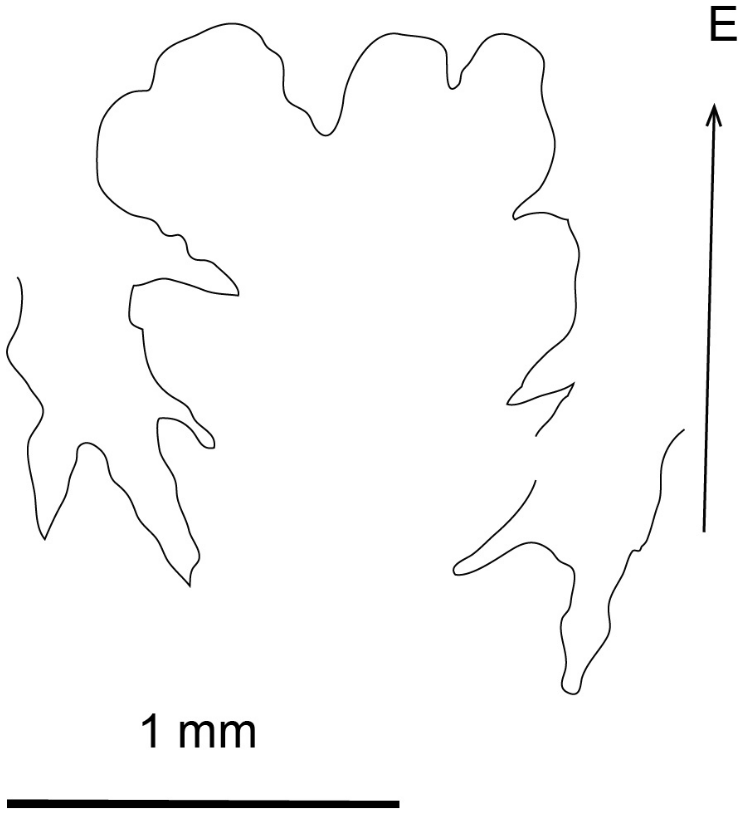

FIGURE 20. Suture of *Melchiorites yabei*, specimen IPMM 63779.

region in Hokkaido, in general shell form and surface ornamentation. However, the present specimens differ from the holotype of *P. subcorbarica* in having distinct collars both forward of and behind constrictions. The number of constrictions on the present specimens is seven to eight in one volution whereas on the specimen of *P. subcorbarica* (Matsumoto, 1954, p. 73) it is four to six.

The present specimens are also similar to the lectotype of *Puzosia hoffmannii* (Murphy & Rodda, 1977, p. 79, figs 1–5) from the upper Horsetown Group (Anderson, 1938) in Shasta County, California, in having the same ratio of umbilicus and diameter, and collars being both forward of and behind flexuous and sigmoid constrictions. They differ, however, in that the ribs of the present specimens are only developed on the outer flank, leaving a smooth inner flank, which those of the California specimens are distinct on the entire flank.

Subfamily Beudanticeratinae Breistroffer, 1953
Genus *Beudanticeras* Hitzel, 1902

***Beudanticeras*? sp.**
(Fig. 19W–Y)

2018 *Beudanticeras* (?) sp., Obata & Matsukawa, p. 249, Fig. 25U–X.

Material. TGUSE-MM 6150 and 6209 (collected by I. Obata) are from the Aketo Formation at locations Hn 6201 and Cp7, respectively; They are internal moulds and slightly deformed.

Locality and horizon. The genus is reported from the lower Albian of Spain (Lillo Beviá, 1975), England (Casey, 1961b), France (Matrion, 2010), Italy (Wiedmann & Dieni, 1968), Poland (Marcinowski & Wiedmann, 1990), Romania (Avram *et al*., 1990), Georgia (Kotetishvili, 1977), Iran (Seyed-Emami & Immel, 1995), Japan (Obata & Matsukawa, 2018), Korjak-Kamchatka, NE Russia (Alabushev, 1995), British Columbia in Canada (Whiteaves, 1900), California, (Anderson. 1938), Arizona, (Stoyanow, 1949), Texas, (Scott, 1939), Mexico (Humphrey, 1949), Colombia (Hass, 1942), Argentina

(Riccardi & Medina, 2002), Australia (Whitehouse, 1926), Madagascar (Collignon, 1963), and Tunisia (Latil, 2011).

Measurements (in mm except for U/D and W/H)**.**

	D	U	U/D	H	W	W/H
TGUSE-MM 6209	55.5	7.0	0.13	29.1	17.0	0.59

Remarks. The specimens are characterized by a fairly small, discoidal, much compressed and involute whorl, with narrow umbilicus having gently sloping umbilical wall, narrowly arched venter, faint and fine flexuous ribs, and shallow biconcave constrictions. These characteristics suggest the specimen may possibly be identified as belonging to the genus *Beudanticera*s (Wright *et al*., 1996). The sloping umbilical wall of this present specimen suggests that it may belong to the genus *B*. (*Grantziceras*). The specimen is a little thicker than the specimen of *Beudanticeras* (?) sp. (TGUSE-MM 6181) described by Obata & Matsukawa (2018): the W/H of the present specimen is 0.59, but that of the specimen described by Obata & Matsukawa (2018) is 0.47. The W/H of specimens of *Beudanticeras haydenii* (Gabb, 1864) from northern Californian is almost the same as that of the Japanese specimens: UCMP 14973 (holotype of *Beudanticeras haydenii*) is 0.46 and CASG 66450.07 is 0.56.

Subfamily Desmoceratinae von Zittel, 1895
Genus *Desmoceras* von Zittel, 1885
Subgenus *Pseudouhligella* Matsumoto, 1938

Locality and horizon. *Desmoceras* (*Pseudouhligella*) is reported from the Aptian of Japan (Obata & Matsukawa, 2018; Yoshinaga *et al*., 2024), the Albian of Japan (Matsukawa & Obata, 2015), British Columbia (Canada) (Whiteaves, 1900; McLearn, 1972), Oregon (USA) (Jones, 1960), California (USA) (Anderson, 1938; Murphy & Rodda, 1959), and the Cenomanian of Romania (Lupu, 1965), Japan (Yabe, 1904; Matsumoto, 1954), Alaska (Matsumoto, 1959), Oregon (USA) (Jones, 1960), and Texas (USA) (Young, 1958).

***Desmoceras* (*Pseudouhligella*) *sanrikucum* sp. nov.**
(Fig. 21A–L)

2018 *Desmoceras* (*Pseudouhligella*) aff. *poronaicum*, Obata & Matsukawa, p. 249–251, fig. 25A–L, Q–T.

non 2018 *Desmoceras* (*Pseudouhligella*) aff. *poronaicum*, Obata & Matsukawa, p. 249–251, figs M–P.

Material. Fifteen specimens in total. Five specimens, IPMM 63772 (holotype), 63773 (paratype), 63774 (paratype), 63775, and 63783F (all collected by K. Komori), come from the uppermost Hiraiga Formation at location KK. Ten specimens (collected by I. Obata), TGUDSE-MM 6117 from C3p, TGUSE-MM 6128, 6567A, 6567B, 6567C, and 6567D, come from location at C5p, TGUSE-MM 6519C comes from location Hn 6201, and TGUSE-MM 6456, 6565 and 6566 come from location Hiraname-dana. These locations are all in the Aketo Formation.

Etymology. *Desmoceras* (*Pseudouhligella*) from the Sanriku area, the old geographic name for the northeast part of Honshu Island facing to the Pacific Ocean.

Diagnosis. *Desmoceras* (*Pseudouhligella*) with rounded venter, compressed whorl, weakly biconcave curvature of constrictions and variable size ratio of shell diameter and umbilicus diameter.

Locality and horizon. The species is only reported from the Hiraiga and Aketo formations of the Miyako Group. This species seems endemic and is the earliest species of the genus *Desmoceras* (*Pseudouhligella*).

Description. The shell attains a diameter greater than 60 mm (IPMM 63773). The whorl is discoidal, very involute, compressed with somewhat convergent and gently convex flanks, with its maximum width in the lower flank and a broadly rounded venter. The umbilicus is fairly narrow, and rounds to the flank. The shell surface is smooth with faint striae and feeble ribs. Constrictions on the internal mould that do not appear on the external shell. They are distinct, biconcave, around number about five to six per volution, and sometimes show a shallow furrow with weak collar adapically, the constrictions run parallel to striae and cross the venter forwardly u-shaped. Suture is unknown.

Measurements (in mm except for U/D and W/H)**.**

Specimen	D	U	U/D	H	W	W/H
IPMM 63772 (holotype)	51.7	13.3	0.26	25.0	24.2	0.97
IPMM 63773 (paratype)	58.2	12.7	0.22	26.4	20.9	0.79
IPMM 64774 (paratype)	39.4	7.6	0.19	16.5	12.3	0.75

Remarks. The ratio of diameter and umbilicus (U/D) of the present specimens from the Hiraiga Formation ranges from *ca.* 0.19 to 0.26, whereas that of the specimens from the Aketo Formation ranges from 0.12 to 0.16; thus, the ratio may have decreased stratigraphically in the species. This is similar to becoming narrower in ontogenetic growth in the example of *Desmoceras* (*Pseudouhligella*) *poronaicum* figured by Kawabe & Haggart (2003); the U/D value of their specimens decreases from *ca*. 0.36 to *ca*. 0.15 as the shell diameter grows from *ca.* 15 mm to *ca.* 40 mm. Additionally, this concurs that since the

FIGURE 21. **A**–**L**, *Desmoceras* (*Pseudouhligella*) *sanrikucum*. **A**–**D**, IPMM 63774 (collected by K. Komori) (paratype), shell, from KK. **E**–**G**, IPMM 62772 (collected by K. Komori) (holotype), shell, from KK. **H**–**J**, IPMM 63779, shell, from KK. **K** and **L**, TGUSE-MM 6456 (collected by I. Obata), internal mould with a part of shell, from loc. Hiraname-dana. Scale bars = 1 cm.

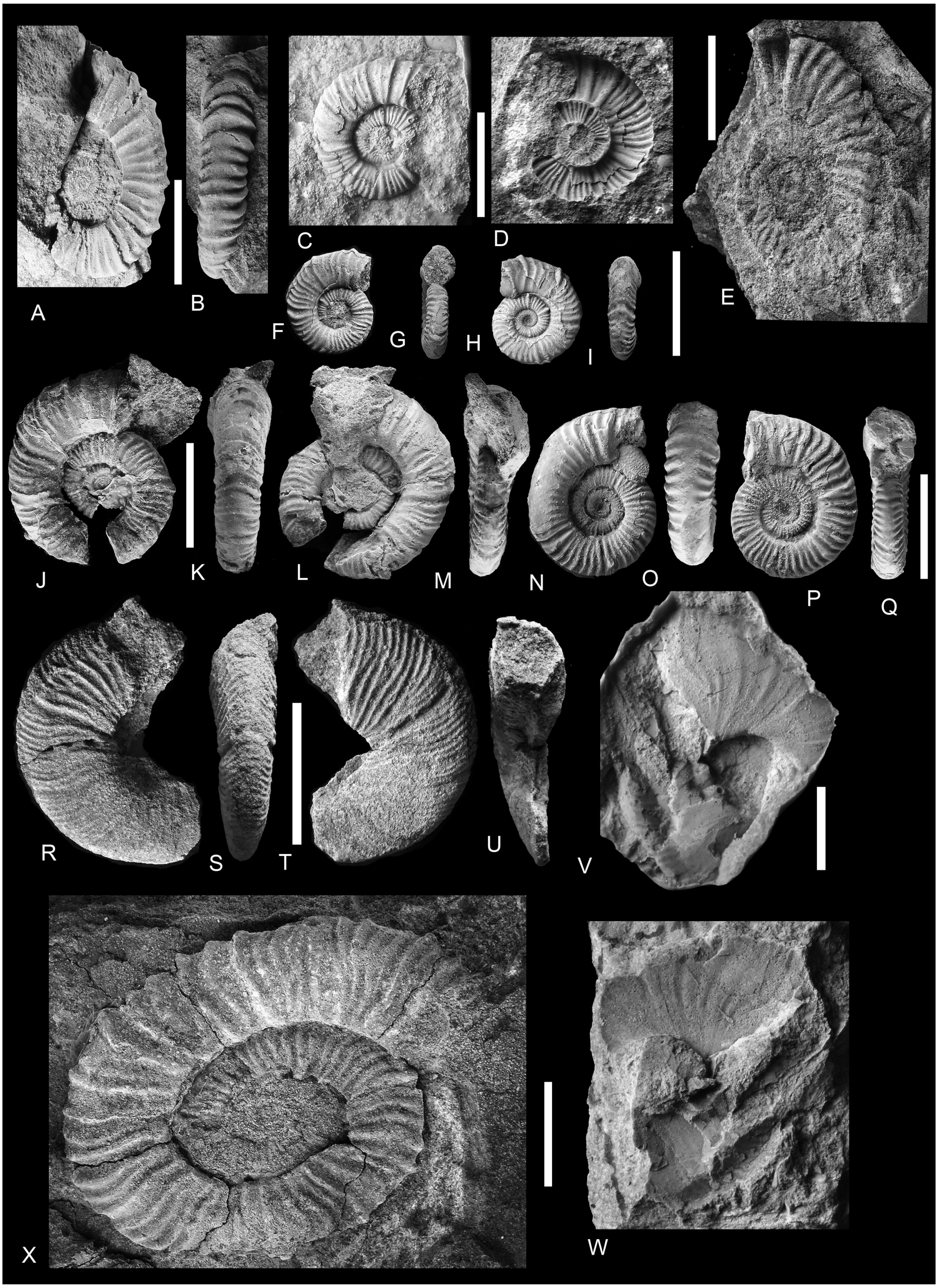

FIGURE 22. **A**–**M**, **X**, *Miyakoceras tanohatense*. **A**–**B**, IPMM 63757 (collected by K. Komori), internal mould, from loc. KK. **C**–**D**, TGUSE-MM 6241 (collected by I. Obata); **C**, its rubber pull, from loc. C6p, **D**, external mould. **E**, TGUSE-MM 6459 (collected by I. Obata), internal mould, from loc. Hn 0220. **F**–**I**, TGUSE-MM 6088 (collected by I. Obata), shell, from loc. 0010. **J**–**M**, NSM-PM 6119 (collected by I. Obata) (holotype), shell, from loc. Hn 1902, (= specimen Pl. 11, fig. 3a–d in Obata, 1967). **N**–**Q**, *Miyakoceras hayamii*; NSM-PM 6123 (collected by I. Obata) (holotype), shell, from loc. Hn 0010, (= specimen pl. 11, fig. 6a–c in Obata, 1967b). **R**–**U**, *Marshallites miyakoensis*, TGUSE-MM 6455, internal mould, from loc. Hiraname-dana. **V**–**W**, *Anadesmoceras* sp. B, TGUSE-MM 6458 (collected by I. Obata), shell, from loc. C6p; **W**, external mould, **V**, its rubber pull. **X**, NSM-PM 6118 (collected by I. Obata) (paratype), internal mould, from loc. Hn 0220, (= specimen pl. 11, fig. 1 in Obata, 1967). Scale bars = 1 cm.

values of *Desmoceras* (*Pseudouhligella*) *poronaicum* from the upper Albian Fujikawa Formation and the upper Albian and Cenomanian Yezo Group ranges 0.11 to 0.19 (Matsukawa & Obata, 2015; Matsumoto, 1954), it is considered to be also a stratigraphical narrowing in the species.

The present species differs from *Desmoceras* (*Pseudouhligella*) *poronaicum* (Matsumoto, 1954, p. 259–260, pl. 2, figs 5–7; pl. 3, fig. 7) from Japan in having a larger size of the adult shell, a more evenly rounded venter and a less compressed whorl. The size of shell of the present species attains 60 mm, whereas that of the *Desmoceras* (*Pseudouhligella*) *poronaicum* attains 34 mm (Matsumoto, 1954) and less than *ca.* 40 mm (Kawabe & Haggart, 2003). Its holotype is 25 mm (Matsumoto, 1954).

In two specimens, IPMM 63773 and 63774, the constrictions are accompanied with a prominent ridge on the venter and outer flank. Although these characteristics support that these specimens possibly belonging to *D.* (*P.*) *japonicum* (Yabe, 1904, p. 35, pl. 5, figs 3, 4) from the Cenomanian of Japan, we judge that the characteristics of somewhat convergent and gently convex flank of these specimens indicate they are better identified as the new species. *D.* (*P.*) *japonicum* (Yabe, 1904, p. 35, pl. 5, figs 3, 4), from the Cenomanian of Japan, the type species of the subgenus *Pseudouhligella*, has nearly flat and parallel flanks and angular umbilical shoulder.

Regarding a comparison with other specimens, we follow Obata & Matsukawa (2018, p. 251).

Family Silesitidae Hyatt, 1900
Genus *Miyakoceras* Obata, 1967b

***Miyakoceras tanohatense* Obata, 1967b**
(Fig. 22A–M, X)

1967b *Miyakoceras tanohatense*, Obata, p. 133, pl. 11, figs 1–4, text-fig. 1.
2012 *Miyakoceras tanohatense*, Matsukawa *et al*., p. 265–266, fig. 2H–J.
2017 *Miyakoceras tanohatense*, Matsukawa, p. 206, fig. 5A–C.
2021 *Miyakoceras tanohatense*, Matsukawa, p. 6–7, fig. 3H, I.
2022 *Miyakoceras tanohatense*, Matsukawa & Oji, p. 149–150, fig. 6D, E, I.

Material. IPMM 63757 (collected by K. Komori), missing the middle part of shell, comes from the uppermost Hiraiga Formation at location KK. Six specimens (collected by I. Obata) come from the upper part of the Tanohata Formation at location Hn 0220 (TGUSE-MM 6459 and 6556), from the Hiraiga Formation at location Hn 1902 (TGUSE-MM 6155, 6502 and 6503), and from the lower part of the Hiraiga Formation at location Hn 0010 (TGUSE-MM 6088).

Locality and horizon. The species is reported from the upper Aptian of Philippines (Matsukawa *et al*., 2012), the Miyako Group (Obata, 1967b) and the Todai Formation (Matsukawa, 2021). *Miyakoceras* sp. (ex gr. *tanohatense* Obata, 1967b) is also reported from the middle/upper Aptian of Colombia (Bogdanova & Hoedemaker, 2004)

Measurements (in mm except for U/D and W/H)**.**

Specimen	D	U	U/D	H	W	W/H
IPMM 63757	22.7	8.9	0.39	7.3	5.8	0.79

Remarks. The specimens are characterized by very small shell, polygyral, evolute, and compressed whorl with flat flank and rounded venter. Umbilicus is moderate, shallow, its wall is low and its shoulder is round. Surface is ornamented with distinct ribs and constrictions. The ribs are dense and rectiradiate or slightly flexuous or prorsiradiate on the flank, and cross the venter with slight forward projecting. They are primary and single but rarely inserted or bifurcated. The constrictions are distinct, concave on the flank, and parallel to the ribs.

The specimens are similar to the type specimens of *Miyakoceras tanohatense* (Obata, 1967b, p. 133, pl. 11, figs 1–4, text-fig. 1; NSM-PM 6119 and 6118) from the Tanohata and lower part of the Hiraiga formations in having small polygyral whorl with dense ribs and distinct constrictions. The specimens differ from the type specimen of *Miyakoceras hayamii* (Obata, 1967b, p. 134–135, pl. 11, fig. 6a–c; text-fig. 3; NSM-PM 6123), in that the type specimen of *Miyakoceras hayamii* has some tubercles and bifurcate ribs.

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Family Kossmaticeratidae Spath, 1922
Subfamily Marshallitinae Matsumoto, 1955
Genus *Hulenites* Matsumoto, 1955

***Hulenites kitamurai* Matsukawa, 2021**
(Fig. 23N–U)

2021 *Hulenites kitamurai* Matsukawa, p. 7, fig. 3L–T.

Material. Seven specimens, IPMM63717, 63725, 63726, 63727, 63728, 63730, and 63732 (collected by K. Komori), from the uppermost Hiraiga Formation at location KK. Specimen TGUSE-MM 6441 (collected by I. Obata) comes from the Aketo Formation at location C6p.

Locality and horizon. The genus is reported from the upper Aptian of the Todai Formation (Matsukawa, 2021), the Albian of Alaska (Imlay, 1960), and the Aptian to Albian of California (Matsumoto, 1955).

Measurements (in mm except for U/D and W/H).

Specimen	D	U	U/D	H	W	W/H
IPMM 63717	35.8	-	-	16.1	9.2	0.57
IPMM 63725	40.4	10.6	0.28	17.2	11.5	0.67
IPMM 63726	31.0	7.6	0.25	13.8	-	-
IPMM 63728	28.3	5.7	0.20	12.6	6.6	0.52

Remarks. The specimens are small discoidal shells, involute and compressed whorl with moderate umbilicus. The whorl-section is rectangular with flat flank and narrowly flattened venter. The umbilicus is shallow, and its vertical wall rounds to the flank. The surface is ornamented with dense, fine, prorsiradiate ribs and numerous periodic constrictions. The ribs are slightly prorsiradiate and generally arise at the umbilical margin with occasional branching into two on the lower and mid-flanks; some arise on mid-flanks, and cross the venter arcing slightly bent forward. The constrictions are wide, deep, concave and prorsiradiate, and cross the venter slightly forward. They number eight to nine in a volution and some truncate into fine ribs on the flank.

Because of its constrictions and truncating into fine ribs, the specimens are identified as *Hulenites kitamurai* (Matsukawa, 2021, p. 7, fig. 3L–T) from the upper Aptian of the Upper Member of the Todai Formation.

***Hulenites* sp.**
(Fig. 23V–W)

Material. IPMM 63719 (collected by K. Komori) comes from the uppermost Hiraiga Formation at location KK.

Measurements (in mm except for U/D and W/H).

Specimen	D	U	U/D	H	W	W/H
IPMM 63719	41.9	16.4	0.39	14.2	-	-

Remarks. The specimen is characterized by a small discoidal, involute and compressed whorl with flat flank and rounded venter, wide umbilicus, dense ribs, and distinct constrictions. Ribs arise at the umbilical margin, are sinuous and slightly prorsiradiate, crossing the flank, and occasionally branch on the outer flank, crossing the venter orthogonally. The suture is rather deep, with bifid saddle and trifid lateral lobe (Fig. 24). Based on its constrictions and truncated ribs, the specimen is assigned to the genus *Hulenites*. The specimen differs from the specimens described above as *Hulenites kitamurai* in that it has single ribs whereas the latter specimens have branched ribs. Also, the umbilicus of the present specimen is wider than that of the latter specimens. The specimen is probably a new species, but as it is the only one available, it is identified as *Hulenites* sp.

Genus *Marshallites* Matsumoto, 1955

***Marshallites miyakoensis* Obata & Futakami, 1991**
(Figs 23A–M; 22R–U)

1991 *Marshallites miyakoensis* Obata & Futakami, p. 123–128, pl. 31, figs 1–5.

2012 *Marshallites miyakoensis*, Matsukawa & Obata in Matsukawa *et al*., p. 267, fig. 2X.

2013 *Pseudohaploceras* sp., Inose *et al*., fig. 6a, b.

2018. *Marshallites miyakoensis*, Obata & Matsukawa, fig. 35, E–I.

2023 *Marshallites miyakoensis*, Matsukawa & Shibata, p. 14–15, fig. 8A, B, G–I.

Material. 22 specimens in total. Twelve specimens, IPMM 63714, 63715, 63718, 63720, 63721, 63722, 63723, 63724, 63729, 63731, 63733, and 63735 (all collected by K. Komori), come from the upper part of the Hiraiga Formation at location KK, Raga north. Ten specimens (collected by I. Obata); TGUSE-MM 6182 from the upper of the Aketo Formation at location OH6, TGUSE-MM 6189 from the upper part of the Hiraiga Formation at location Hn 6203, TGUSE-MM 6246 and 6252 come from the Aketo Formation at location Hn 6201, TGUSE-MM 6268, 6526, 6455, and 6528A from the Aketo Formation at location Hiraname-dana.

Locality and horizon. The species is reported from the upper Aptian Yop Formation in Philippines (Matsukawa *et al*., 2012) and the Miyako Group (Obata & Futakami, 1991). The genus is also reported from the upper Aptian Tomochi Formation (Matsumoto & Murakami, 1991), the Albian to Cenomanian Yezo Group, (Matsumoto *et al*., 1991), the upper Albian to lower Cenomanian strata of the Korjak-Kamchatka region of northeast Russia (Alabushev, 1995), the Albian to Cenomanian strata of the upper Chitina Valley, southern Alaska (Matsumoto, 1959), the upper Albian Haida Formation of British Columbia (Canada) (McLearn, 1972) and the upper Aptian to uppermost Albian of the upper Chickabally Member of the Budden Canyon Formation in northern California (Murphy *et al*., 1964).

Measurements (in mm except for U/D and W/H).

Specimen	D	U	U/D	H	W	W/H
IPMM 63715	37.9	10.5	0.28	16.6	10.8	0.65
IPMM 63721	39.0	12.7	0.33	16.6	9.2*	0.55*
IPMM 63722	21.3	6.3	0.30	8.9	5.5+	0.61+
TGUSE-MM 6252	-	-	-	8.3	5.3	-
TGUSE-MM 6268	24.0	7.8	-	10.3	-	-

* approximate

Remarks. Because of its fairly small and compressed whorl with narrow umbilicus, flexuous ribs,

FIGURE 23. **A**–**M**, *Marshallites miyakoensis*. **A**–**D**, IPMM 63715 (collected by K. Komori), shell, from loc. KK. **E**–**F**, TGUSE-MM 6252 (collected by I. Obata), internal mould, from loc. Hn 6201. **G**–**I**, IPMM 63721 (collected by K. Komori), internal mould, from loc. KK. **J**–**M**, TGUSE-MM 6189 (collected by I. Obata), internal mould, from loc. Hn 6203. **N**-–**U**, *Hulenites kitamurai*; **N**, IPMM 63726 (collected by K. Komori), internal mould, from loc. KK. **O**–**R**, IPMM 63725, internal mould, from loc. KK. **S**, IPMM 63717 (collected by K. Komori), shell, from loc. KK. **T**–**U**, TGUSE-MM 6441 (collected by I. Obata), **T**, external mould, **U**, its rubber pull, from loc. C6p. **V**–**W**, *Hulenites* sp., IPMM 63719 (collected by K. Komori). Scale bars = 1 cm.

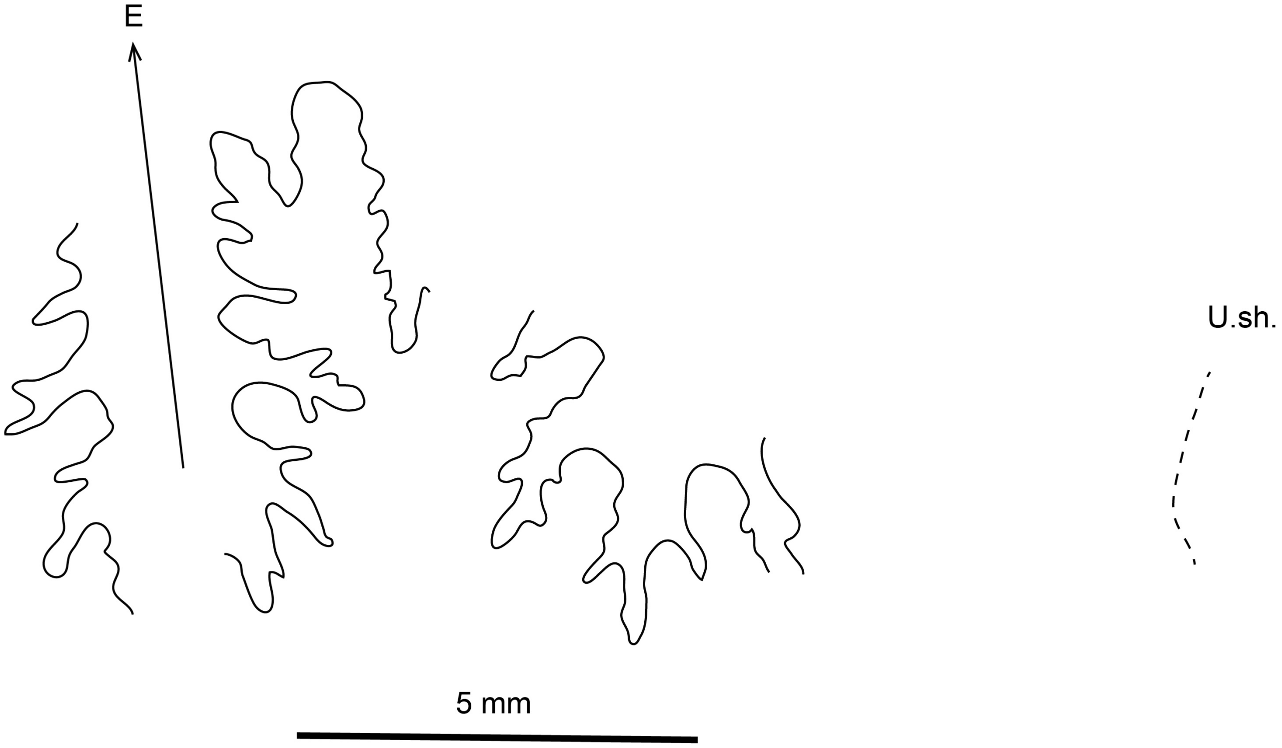

FIGURE 24. Suture of *Hulenites* sp., specimen IPMM 63719.

some of which are bundled two or three at the umbilical bullae or branch on mid-flanks, and its narrow and deep constrictions which row parallel with ribs, the specimen is identified as *Marshallites miyakoensis* (Obata & Futakami, 1991, p. 123–128, pl. 31, figs 1–5) from the lower part of the Miyako Group.

Family Cleoniceratidae Whitehouse, 1926
Genus *Anadesmoceras* Casey, 1954

Locality and horizon. The genus is reported from the lower Albian of England (Casey, 1966), Mangyshlak (Kazakhstan) (Saveliev, 1973), Colombia (Etayo-Serna, 1979), and Japan (this paper).

Remarks. Although Wright *et al*. (1996) and Klein & Vašíček (2011) regarded the genus *Carloscaceresiceras* as a junior synonym of *Anadesmoceras* (Casey, 1954), Bogdanova & Hoedemaeker (2004) noted that *Carloscaceresiceras* is distinguishable from *Anadesmoceras* because it is characterized by a much thicker whorl ornamented with striae instead of ribs on the flank, and bundles of ribs are absent on the inner lateral area (Etayo-Serna, 1979). However, since Etayo-Serna (1979) describes that the striae bundles are found in specimens of *Carloscaceresiceras caceresi* up to 26 mm diameter, we follow the criteria of the genus of Wright *et al*. (1996) because our materials are over 26 mm.

***Anadesmoceras* sp. A**
(Fig. 25V–Z)

2013 Desmoceratidae gen. et sp. indet., Inose *et al*., fig. 4a, b.
2023 *Anagaudryceras* sp., Matsukawa & Shibata, p. 15, fig. 5P–S.

Material. Two specimens, IPMM 63755A and 63785G (collected by K. Komori). The right side of the whorl of IPMM 63785G is obliquely deformed. Both specimens come from the uppermost Hiraiga Formation at location KK.

Description. Shells are very small, discoidal with smooth surface, and have a fairly narrow umbilicus. The whorl is fairly involute, much compressed, with broadly rounded flank and rounded venter. The whorl-section is oval. The umbilicus is shallow, with steep wall nearly perpendicular to the flank and rounded at the rim. Flank surface is ornamented with broadly sigmoid striae arising at the umbilical seam, some of which are bundled leaving slight bands or rib-like impression at the umbilical margin. The striae trend slightly forward on the lower flank, then trend straight radially, and bent slightly backward on the middle flank, and trend forward again on the outer flank crossing the venter convexly. Constrictions are distinct and comparatively deep; they arise at the umbilical seam and are parallel to the striae. The suture is rather simple (Fig. 26): the ventral lobe is almost the same depth as the first lateral lobe, the lateral saddles are symmetrical

FIGURE 25. **A**–**I**, **N**–**U**, *Anadesmoceras* sp. B. **A**–**E**, IPMM 63777, **E**, enlarged flank of shell. **F**–**I**, IPMM 63755B. **N**–**Q**, IPMM 63756A. **R**–**U**, IPMM 63778. **J**–**M**, *Anadesmoceras*? sp., IPMM 63802H. **V**–**Z**, *Anadesmoceras* sp. A, IPMM 63755A, **Z**, enlarged flank of shell. All specimens are shell and come from loc. KK. Scale bars = 1 cm.

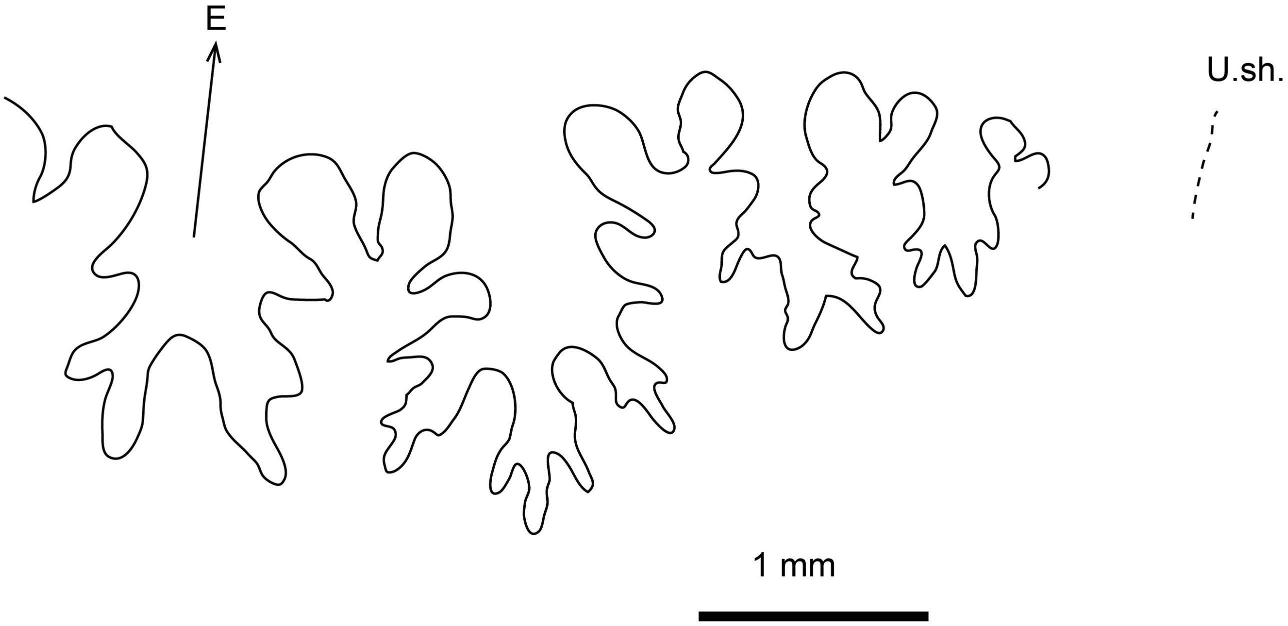

FIGURE 26. Suture of *Anadesmoceras* sp. A., specimen IPMM 63755A.

bifid, and the lateral lobes are asymmetrical trifid with protrusion.

Measurements (in mm except for U/D and W/H).

Specimen	D	U	U/D	H	W	W/H
IPMM 63755A	13.5	3.3	0.24	7.5	4.8	0.64
IPMM 63785G	15.6	3.9	0.25	7.4	-	-

Remarks. Because of its ornamentation of striae, some bundled, the specimens can be assigned to the genus *Anadesmoceras* (Casey, 1954). The present specimens are similar to the illustrated specimen of *Carloscaceresiceras caceresi* (Etayo-Serna, 1979, p. 25, pl. 10, fig. 1; text-figs 4A, B, 10) from the lower Albian Capotes Member of Colombia, because the inner shell surface of the Colombian specimen is also characterized by a fairly narrow umbilicus, its shell surface is ornamented with flexuous striae that are bundled, distinct constrictions running parallel to the striae, and suture consists of symmetrical bifid saddles and asymmetrical trifid lateral lobes with protrusion. In the Colombian specimen, distinct constrictions become developed on the later whorls. However, these are not confirmed in the present specimen because the later whorl of the shell is lost. Since the genus *Carloscaceresiceras* (Etayo-Serna, 1979) has been regarded as a junior synonym of the genus *Anadesmoceras* (Wright *et al*., 1996), *Carloscaceresiceras caceresi* should be identified as *Anadesmoceras caceresi* (Etayo-Serna, 1979).

The venter of *Anadesmoceras strangulatum* (Casey, 1954, p. 107; Casey, 1966, p. 576–577, pl. 96, figs 3a, b, 4a, b; pl. 97, figs 2, 4, 5; text-fig. 218b, f), which is the type species of the genus, from the lower Albian of England, is sublanceolate on its inner whorls and narrowly arched venter on its outer whorls; the venter of the present specimens are rather arched. An ontogenetic change in the form of the venter is also observed in two species, *A. subbaylei* (Casey, 1966, p. 577–578, pl. 97, fig. 6q, b; text-fig. 218c) and *A. costatum* (Casey, 1966, p. 578–579, pl. 96, figs 1, 2a, b; text-fig. 218a), from England. The genus *Anadesmoceras* is not defined the basis of the form of the venter (Casey, 1966, p. 575), so the Miyako specimens provide important characteristic of the genus.

***Anadesmoceras* sp. B**
(Figs 22V, W; 25A–I, N–U)

2018 *Cleoniceras* (*C.*) cf. *cleon*, Obata & Matsukawa, p. 254, figs F–I.

Material. Ten specimens. IPMM 63755B, 63756A, 63756B, 63777, 63778, and 63802B-E (collected by K. Komori) come from the uppermost Hiraiga Formation at location KK, TGUSE-MM 6458 (collected by I. Obata) comes from the Aketo Formation at location C6p.

Measurements (in mm except for U/D and W/H).

Specimen	D	U	U/D	H	W	W/H
IPMM 63755B	10.3	2.5	0.24	5.3	4.1	0.77
IPMM 63756A	26.1	4.2	0.16	11.8	9.7	0.82
IPMM 63756B	21.8	4.8*	0.22*	10.6*	-	-
IPMM 63777	27.3	4.4	0.16	13.0	10.3	0.79
IPMM 63778	25.2	5.4	0.21	12.5	9.2	0.74

IPMM 63802B	28.1	4.6	0.16	15.1	-	-
IPMM 63802C	23.1+	3.6	0.16	10.5	8.0	0.76
IPMM 63802D	19.6	3.7	0.19	10.7	9.2	0.85
IPMM 63802E	18.3	-	-	10.1	7.7	0.76

* approximate

Remarks. The specimens are characterized by a very small, very involute, and fairly compressed whorl with fairly narrow umbilicus. The umbilical wall is steep, nearly perpendicular to the flank, and round at the rim. The flank surface is ornamented with sigmoidal striae which arises at the umbilical seam, some of which are bundled, leaving slight bands or rib-like impressions at the umbilical margin, and trend flexuously across the flank and cross the venter in a forward. Constrictions are shallow, and some with a collar behind them, and run parallel to the striae. The present specimens differ from the specimen of *Anadesmoceras* sp. A described above, because the whorl of the present specimens is thicker that of *Anadesmoceras* sp. A.

***Anadesmoceras*? sp.**
(Fig. 25 J–M)

2018 *Cleoniceras* (*C.*) cf. *cleon*, Obata & Matsukawa, p. 251, fig. 26J–M.

Material. Three specimens. IPMM 63802A (collected by K. Komori) is slightly deformed, and comes from the uppermost Hiraiga Formation at location KK. TGUSE-MM 6102 and 6588 (collected by I. Obata) comes from the Hiraiga Formation at locations Hn 4053 and Hn 4051, respectively.

Measurements (in mm except for U/D and W/H).

Specimen	D	U	U/D	H	W	W/H
IPMM 63802A	27.3	6.6	0.24	12.7	7.3	0.57

Remarks. The whorl is small, very involute, much compressed, much higher than wide, and rectangular in cross-section, with subangular ventrolateral shoulder. The flanks are slightly convex in these lower parts, nearly flat in the upper part, and round suddenly into a rounded flat venter. The umbilicus is fairly narrow, its wall is low and vertical, and its rim is angular. The inner flank surface is smooth while the outer flank is covered by feebly falcoid crescentic striae and weak constrictions. The specimens are similar to the illustrated specimen of *Carloscaceresiceras monteroi* (Etayo-Serna, 1979, p. 26–27, pl. 10, fig. 5) from the lower Albian Capotes Member of Colombia, which is characterized by an angular ventral shoulder. However, the Colombian specimen is larger than the present specimen, and the venter of the Colombian species is not illustrated, for comparing with the present specimen. We thus identify the present specimen as *Anadesmoceras*? sp.

Suborder Ancyloceratina Wiedmann, 1966
Superfamily Ancyloceratoidea Gill, 1871
Family Ancyloceratidae Gill, 1871
Subfamily Ancyloceratinae Gill, 1871
Genus *Pseudolithancylus* nov.

Type species. *Pseudolithancylus tohokuense* **sp. nov.**

Etymology. Pseudo-*Lithancylus*.

Diagnosis. Long and slender shaft, crozier, and hook, as in the genus *Hamites*, with dense, fine, oblique ribbing on the shaft and coarse, radiate ribbing on the crozier and hook. No tubercles, but a pair of very small tubercles are present on the ribs of the venter on the later hook.

Remarks. The ribbing of the present genus is similar to that of the genus *Lithancylus* (Wright *et al*., 1996), but the ribs of crozier and hook are smooth and ventral tubercles on hook, whereas those of the genus *Lithancylus* have tritubercles on the ribs of the crozier and hook. The genus differs from the genus *Tonohamites* (Wright *et al*., 1996), because *Tonohamites* is characterized by major and minor ribs with tubercles on the major ribs.

***Pseudolithancylus tohokuense* sp. nov.**
(Fig. 27L–X)

Material. Four specimens. TGUSE-MM 6445 (collected by I. Obata), holotype, comes from the upper part of the Hiraiga Formation at location Hn 6203. TGUSE-MM 6229 (collected by I. Obata), paratype, and TGUSE-MM 6446 (collected by I. Obata) external moulds, from the Hiraiga Formation at location Tokuzo, while TGUSE-MM 6449 (collected by I. Obata) comes from the Aketo Formation at location Hiraname-dana. These specimens include part of the shaft, crozier, and hook.

Etymology. Tohoku is a name of the area of northeast Honshu Island, Japan.

Locality and horizon. The species is only known from the Miyako Group.

Description. All specimens are over 30 mm in length. Shaft, crozier, and terminal hook are ornamented with dense and oblique ribs on the shaft and coarse and radiate ribs on the crozier and the hook. The cross-section of the shaft, the crozier, and the hook are elliptical. The ribs are annular; on the dorsum they are fine and crowded, prorsiradiate and convex on the flank, and cross the venter orthogonally. Some of the ribs branch into two at the dorsal shoulder. The spacing between ribs widens from shaft to hook, and the width of the ribs broaden. A pair of very small tubercles are present on the ribs on the venter of the hook; these may be enlarged in the later stage of the hook.

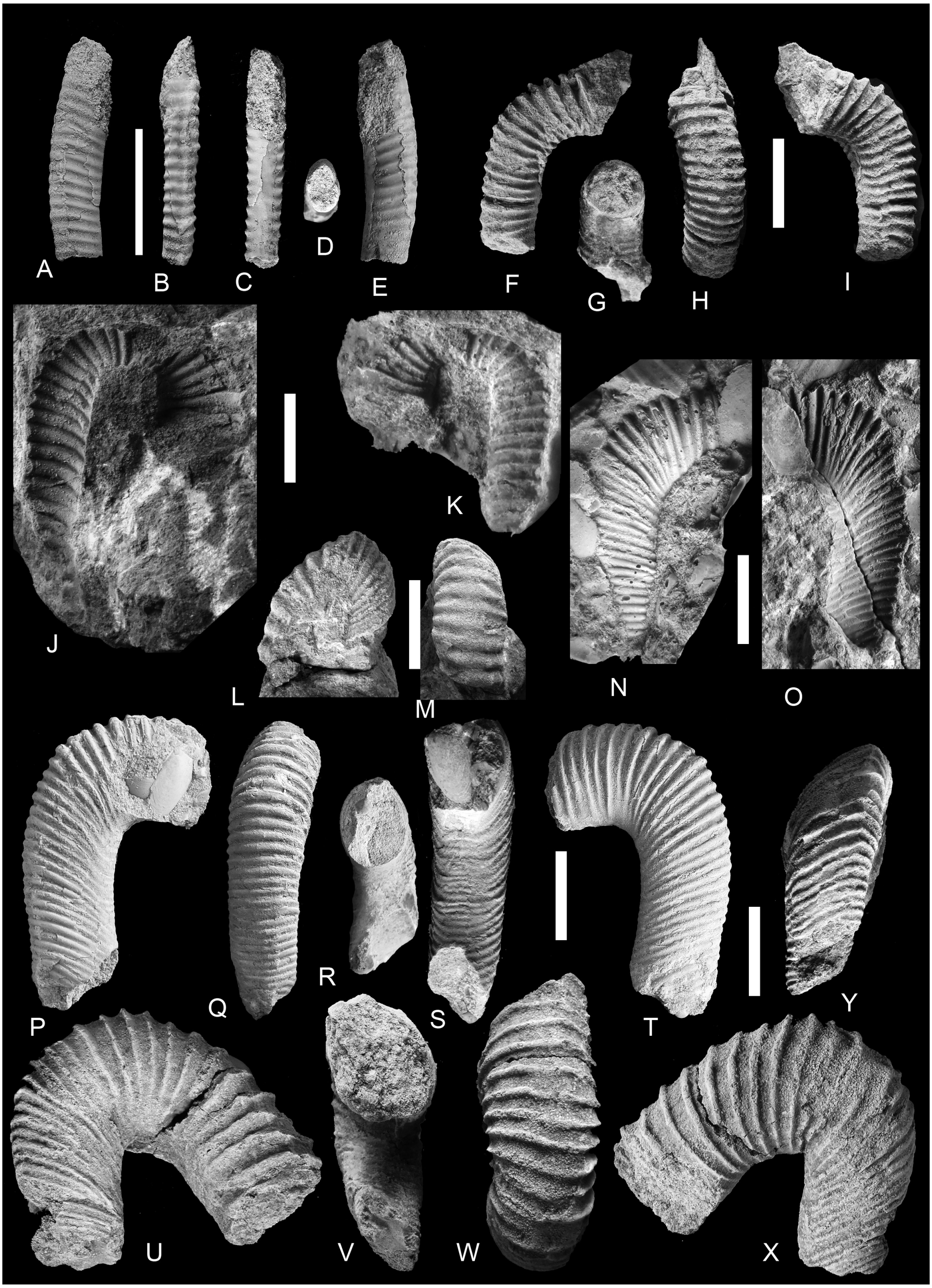

FIGURE 27. A–**E**, *Hamites* (*H.*) cf. *intermedius*, IGPS 36859 (S. Shimizu collector), shell, loc. Matsushima. **F**–**I**, *Hamites* (*H.*) sp. B, TGUSE-MM 6447A (collected by I. Obata), internal mould, from loc. B2. **J**–**K**, *Hamites* (*H.*) sp. C, TGUSE-MM 6448 (collected by I. Obata), external mould (**J**), its rubber pull (**K**), from Hiraname coast. **L**–**X**, *Pseudolithancylus tohokuense*. **L**–**M**, TGUSE-MM 6449 (collected by I. Obata), internal mould, from Hiraname-dana. **N**–**O**, TGUSE-MM 6446, external mould (**O**), its rubber pull (**N**), from Tokuzo. **P**–**T**, TGUSE-MM 6229 (collected by I. Obata), internal mould, from Tokuzo. **U**–**X**, TGUSE-MM 6445 (collected by I. Obata), internal mould, from Hn 6203. Scale bars = 1 cm.

FIGURE 28. A–O, *Ptychoceras* cf. *emericianum*. **A–E**, IPMM 63603A. **F–J**, IPMM 63611A. **K–O**, IPMM 63606. **P–T**, *Diptychoceras iwatense*, IPMM 63601A. **U–V**, *Diptychoceras* cf. *renngarteni*; IPMM 63600. All specimens are shell and come from loc. KK. Scale bars = 1 cm.

Measurements (in mm)**.**

Specimen	L	B	T	h_1	h_2
TGUSE-MM 6229 (paratype)	33.5	-	9.9	10.7	-
TGUSE-MM 6445 (holotype)	30.0	30.5*	13.7	11.5	14.9
TGUSE-MM 6446	32.4	-	-	-	-
TGUSE-MM 6449	19.6	14.5	10.1	4.4*	4.6*

* approximate

Remarks. The pattern of rib changes of the present specimens is similar to the illustrated specimen of *Lithancylus tirolensis* (Casey, 1965, p. 74, text-fig. 29) from the upper Barremian, Puez Alp, near Corvara (Tyrol) in Italy, but the present specimens have a pair of very small ventral tubercles on the ribs of the later hook, whereas the Tyrolean specimen has trituberculate ribs on the hook, and the curvature of the crozier of the present specimens is more pronounced than that of the Tyrol specimen. Therefore, the present specimens of the species differ from the illustrated specimen of *Lithancylus tirolensis*.

Subfamily Helicancylinae Hyatt, 1894?
Genus *Tonohamites* Spath, 1924

Locality and horizon. The genus *Tonohamites* is reported from the lower Aptian of England (Casey, 1960, 1961a), the Aptian of Germany (Koenen, 1902), the upper Aptian–lower Albian of Hungary (Szives & Monk, 2002), the upper Aptian of Zululand in South Africa (Klinger & Kennedy, 1977), and the upper Aptian of Madagascar (Collignon, 1962),

***Tonohamites*? sp.**
(Fig. 34K, L, M)

Material. A single specimen, TGUSE-MM 6522 (collected by I. Obata), is a partial shaft of the internal mould, and comes from the Aketo Formation at location Hiraname-dana. The shaft is obliquely deformed.

Measurements (in mm)**.** Maximum length of shaft is 31.7, maximum width of shaft is 6.5 and maximum height of shaft is 9.9.

Remarks. The specimen is characterized by a slightly curved compressed shaft with rounded ventral and dorsal shoulders and a flat venter, the surface ornamented with both stout and narrow ribs. Ribs are annular, but those on the dorsum are weaker than those on the flanks and venter. The stout ribs have three tubercles, two laterals and one ventral. Some narrow ribs are conspicuous on the dorsum but disappear on the flank and venter. One narrow rib is sandwiched between stout ribs and annularly covers the shaft. Because the stout ribs on the shaft have three tubercles and lack branching ribs, the specimen probably belongs to the genus *Tonohamites* (Wright *et al*., 1996). In *Tonohamites decurrens* (Casey, 1960, pl. 5, fig. 3a, b; Casey, 1961a, p. 86–87), from the upper Aptian of England, stout ribs with tubercles are dominant on the shaft at the early stage of growth, but the surface of the crozier and hook are covered by narrow ribs without tubercles. The present specimen resembles the rib characteristics of the early growth shaft of the illustrated specimen of *T. decurrens*. However, we think it is better to identify the specimen as *T*. sp., because the characteristics of crozier and hook are unknown.

Family Ptychoceratidae Gill, 1871
Genus *Ptychoceras* Orbigny, 1842

***Ptychoceras* cf. *emericianum* Orbigny, 1842**
(Fig. 28A–O)

2013 *Ptychoceras* sp., Inose *et al*., figs 5–10.
2018 *Ptychoceras* cf. *puzosianum*, Obata & Matsukawa, p. 253, figs A–D, I–M, AJ–AN, AO–AS.
2023 *Ptychoceras* cf. *puzosianum*, Matsukawa & Shibata, p. 15, fig. 8C–F.

Material. Four specimens, IPMM 63603A, 63603B, 63606, and 63611A (collected by K. Komori), are only preserved as partial shafts. They come from the uppermost Hiraiga Formation at location KK. Five specimens (collected by I. Obata) include TGUSE-MM 6469, from the Hiraiga Formation at location Hn4153, TGUSE-MM 6223 from the Hiraiga Formation at location Hn0010, TGUSE-MM 6586 from the Hiraiga Formation at location Hn0016, TGUSE-MM 6580 from the Aketo Formation at location C6p, TGUSE-MM 6157 from the Aketo Formation at location B2.

Locality and horizon. *Ptychoceras emericianum* is reported from France (Orbigny, 1842), Romania (Avram, 1970), and the northern Caucasus (Rouchadzé, 1938).

Measurements (in mm except for w_1/h_1 and w_2/h_2)**.**

Specimen	L	B	T	w_1	h_1	w_1/h_1	w_2	h_2	w_2/h_2
IPMM 63603A	22.2	6.8	4.7	2.8	2.3	1.22	4.0	2.7	1.48
IPMM 63606	27.0	9.5	6.6	3.9	3.0	1.30	7.8	6.1	1.28
IPMM 63611A	17.5	6.9	5.0	4.4	4.1	1.07	3.9	3.2	1.22

Remarks. The specimens are small for the genus. They are characterized by contiguous shafts, smooth on the surface of the early shaft, with ribs appearing on the later shaft. The ribs consist of those that arise at the dorsal seam and those which appear on the lower flank. The cross-section of the shell is circular in the early stage and becomes wider than heigh in the later stage. Those characteristics suggest that the specimens can be assignable to *Ptychoceras emericianum* (Orbigny, 1842, p. 555, pl. 137, figs 1–4.) from the Aptian of southeast France. The French specimens are, however, larger than the Japanese specimens. Since the ontogenetic characteristics of both taxa are unknown, we therefore identify the present specimen as *Ptychoceras* cf. *emericianum* Orbigny (1842).

***Ptychoceras minimum* Rouchadzé, 1933**
(Fig. 29A–H, M, N)

1933 *Ptychoceras minimum* Rouchadzé, p. 180, pl. 1, fig. 8a–d.
1960 *Ptychoceras minimum*, Drushchits, p. 265, pl. 11, fig. 5.
1969 *Ptychoceras minimum*. Egoian, p. 147, pl. 7, fig. 5a, б.
1989 *Ptychoceras minimum*. Sharikadze, text-figs 1–3.
1989 *Ptychoceras minimum*, Doguzhaeva & Mutvei, pl. 1, figs 1, 2, pl. 3, figs 1–3, pl. 4, figs 1–7, pl. 5, figs 1, 2; text-fig. 1A, 2A–C, 3A–C.
1990 *Ptychoceras minimum forma typica*. Wiedmann *et al*., p. 369, txt-fig. 1.
1990 *Ptychoceras minimum forma trifida*. Wiedmann *et al*., p. 371, text-figs 2, 3, 4A–C, 5A–G, 6, 8.
1993 *Ptychoceras minimum*, Doguzhaeva & Mutvei, p. 104, fig. 6.3: a, d, e; fig. 6.4: a–d.
2005 *Ptychoceras minimum*, Kakabadze in Kotetishvili *et al*., p. 378, pl. 90, fig. 3 (= Rouchadze, 1933, pl. 1, fig. 8d)
2018 *Ptychoceras* sp., Obata & Matsukawa, fig. 28E–H, N–O, AG–AI, AT.

Material. Thirteen specimens in total. Three specimens, IPMM 63602, 63607, and 63610 (collected by K. Komori); IPMM 63602 consists of three shafts, but its initial part is lost. Both IPMM 63607 and 63610 include two preserved shafts, but the first shafts are broken. All three specimens come from the uppermost Hiraiga Formation at location KK. Ten specimens (collected by I. Obata) include: TGUSE-MM 6096, 6488, and 6491 from the Hiraiga Formation at location Tokuzo; TGUSE-MM 6584, 6585, 6586, and 6587 from the Hiraiga Formation at location Hn 0016; TGUSE-MM 6542, and 6550 from the Aketo Formation at location C6p; and TGUSE-MM 6147 from the Aketo Formation at location Hn 0650.

Locality and horizon. The species is reported from Aptian of Georgia (Rouchadzé, 1933) and the Miyako Group (this paper).

Measurements (in mm except for w_1/h_1 and w_2/h_2)**.**

Specimen	L	B	T	w_1	h_1	w_1/h_1	w_2	h_2	w_2/h_2
IPMM 63602	28.4	3.9	3.8	3.7	3.7	1.00	4.3	3.7	1.16
IPMM 63607	46.8	7.7	4.5	-	-	-	-	-	-
IPMM 63610	23.1	4.3	2.6	1.1	1.1	1.00	-	-	-

Remarks. The specimens are characterized by small contiguous shafts, circular cross-section of shafts and completely smooth surface. Suture is simple with ventral, lateral and dorsal lobes almost of all the same depth. The lobes are bifid, and lateral saddles are bifid (Fig. 30). These characteristics, except for the suture, indicate the specimens can be assigned to *Ptychoceras minimum* Rouchadzé (1933, p. 180, pl. 1, fig. 8a–d) from the Aptian of western Georgia.

Genus *Diptychoceras* Gabb, 1869

***Diptychoceras iwatense* Obata & Matsukawa, 2018**
(Fig. 28P–T)

2018 *Diptychoceras iwatense* Obata & Matsukawa, p. 255, fig. 28P–S, Z–AF.
2022 *Diptychoceras iwatense*, Matsukawa & Oji, p. 150, figs 6F, 7A–D.

Material. Four specimens. IPMM 63601A (collected by K. Komori) comes from the uppermost Hiraiga Formation at location KK. Three specimens (collected by I. Obata) in total, from the Hiraiga Formation at location Tokuzo (TGUSE-MM 6589 and 6590) and from the Aketo Formation at location Hiraname-dana (TGUSE-MM 6527).

Locality and horizon. The present species is reported from the upper Aptian of the Miyako Group (Obata & Matsukawa, 2018) and the upper Aptian Todai Formation (Matsukawa, 2021). The genus *Diptychoceras* is reported from the Aptian strata of Dagestan (Rouchadzé, 1938), the Albian Haida Formation, British Columbia (Canada) (McLearn, 1972), northern California (Anderson, 1938) and Mexico (Bose, 1923).

Measurements (in mm except for w_1/h_1 and w_2/h_2)**.**

Specimen	L	B	T	w_1	h_1	w_1/h_1	w_2	h_2	w_2/h_2
IPMM 63601A	30.3	13.7	8.7	5.7	5.7	1.00	7.8	6.5	1.20

Remarks. Because of its contiguous two shafts ornamented with faint undulations, feeble striae, and weak and shallow constrictions, the specimens are identified as *Diptychoceras iwatense* (Obata & Matsukawa, 2018, p. 255, fig. 28P–S, Z–AF) from the Miyako Group. The characteristics of the suture of the species can be observed in the present specimen and are described as follows: suture is simple with almost equal depth of ventral, lateral, and dorsal lobes, as well as the lateral saddles (Fig. 31); The lobes and saddles are bifid. The shafts of the present specimens are circular on the 1st shaft and elliptical of the 2nd shaft. Shaft cross-section is one of the characteristics of the species, and the present specimens differ from that of *D. leave* (Gabb, 1869, p. 144, pl. 25, figs 21, 21a, b), from the Lower Cretaceous of northern California, because that species has on elliptical 1st shaft and circular 2nd shaft.

FIGURE 29. A–**H**, **M**, **N**, *Ptychoceras minimum*. **A**–**E**, IPMM 63602. **F**–**H**, IPMM 63607. **M**–**N**, IPMM 63610. **I**–**K**, *Diptychoceras* cf. *renngarteni*; IPMM 63599. All specimens are shells and come from loc. KK. Scale bars = 1 cm.

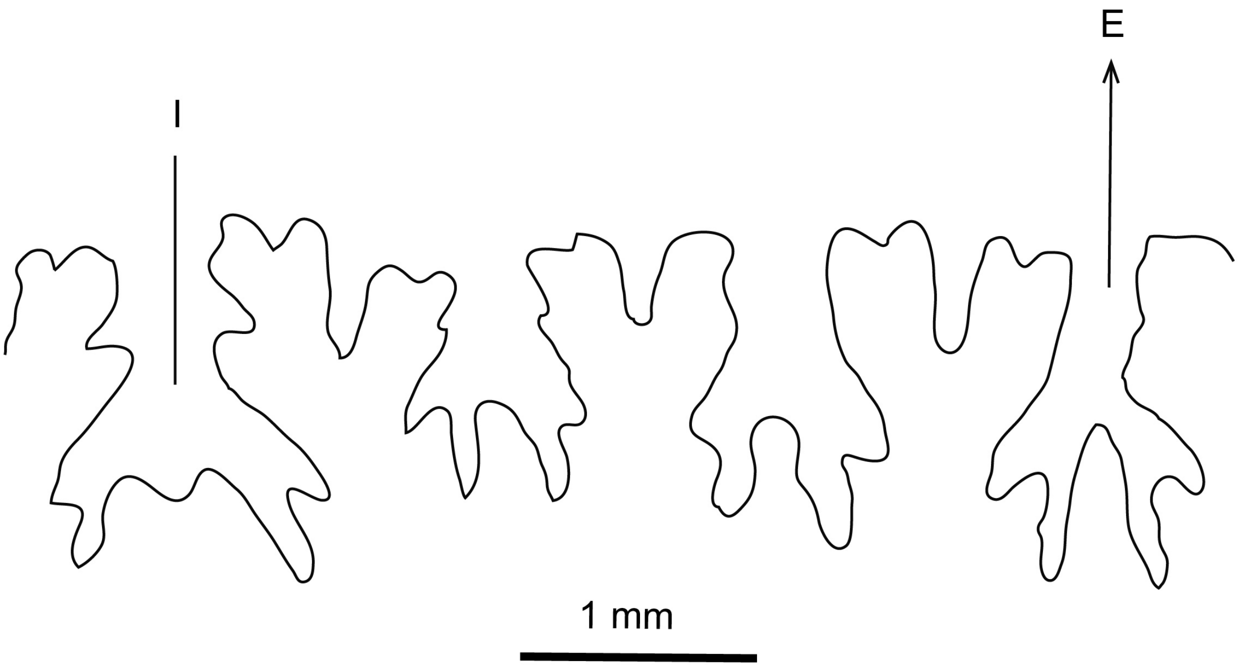

FIGURE 30. Suture of *Ptychoceras minimum*, specimen IPMM 63603.

***Diptychoceras* cf. *renngarteni* (Egoian, 1969)**
(Figs 28U, V; 29I–K)

Material. Two specimens (collected by K. Komori), IPMM 63599 and 63600. The specimens consist of the first and second shafts, but their croziers are lost. The specimens come from the uppermost Hiraiga Formation at location KK.

Locality and horizon. The species is reported from the Caucasus (Egoian, 1969) and Japan (this paper).

Measurements (in mm except for w_1/h_1 and w_2/h_2).

Specimen	L	B	T	w_1	h_1	w_1/h_1	w_2	h_2	w_2/h_2
IPMM 63599	69.4	8.1	8.8	5.0	3.1	1.6	5.0	5.0	1.0
IPMM 63600	25.4	7.2	-	-	-	-	-	-	-

Remarks. Both specimens are two contiguous shafts. The first shaft is flat in its second half, and the second shaft becomes rounded in the ventral area and flatted in the dorsal area. The expansion of the shafts is very rapid. A middle groove is present in the dorsum of the second shaft. The surface is smooth on the first shaft, with narrow and weak ribs appearing early on the second shaft and becoming smooth again on the later second shaft. Constrictions are present on the inner side of the second shaft.

Because of the constrictions on the shaft, the specimens belong to the genus *Diptychoceras* (Gabb, 1869). The specimens are similar to the illustrated specimens of *Ptychoceras renngarteni* (Egoian, 1969, p. 143–145, pl. 6, figs 1a, б, 2a, б, в, 3a, б) from the upper Aptian of western Caucasus in having a flat second half of the first shaft, a rounded outer and flat inner second shaft, a middle groove on the inner part of the second shaft, and constrictions. However, a rounded a first half of the first shaft, and a short and swollen third shaft are not confirmed in the present specimens. According to Gabb (1869), ptychoceratids with constrictions belong to the genus *Diptychoceras*, so *Ptychoceras renngarteni* (Egoian, 1969) should be identified as *Diptychoceras renngarteni* (Egoian, 1969). Therefore, the present specimens are identified as *Diptychoceras* cf. *renngarteni* (Egoian, 1969).

Superfamily Turrilitoidea Gill, 1871
Family Anisoceratidae Hyatt, 1900
Genus *Protanisoceras* Spath, 1923b

***Protanisoceras hanaii* Obata & Matsukawa, 2018**
(Figs 32A–R; 36X–AC)

2018 *Protanisoceras hanaii* Obata & Matsukawa, p. 255, fig. 30A, B.

2022 *Protanisoceras hanaii*, Matsukawa & Oji, p. 150–152, fig. 7E–G.

Material. 46 specimens (collected by K. Komori): IPMM 63629–63634, 63636–63647, 63649–63662, and 63664–63677. They are all partial shafts and come from the uppermost Hiraiga Formation at location KK.

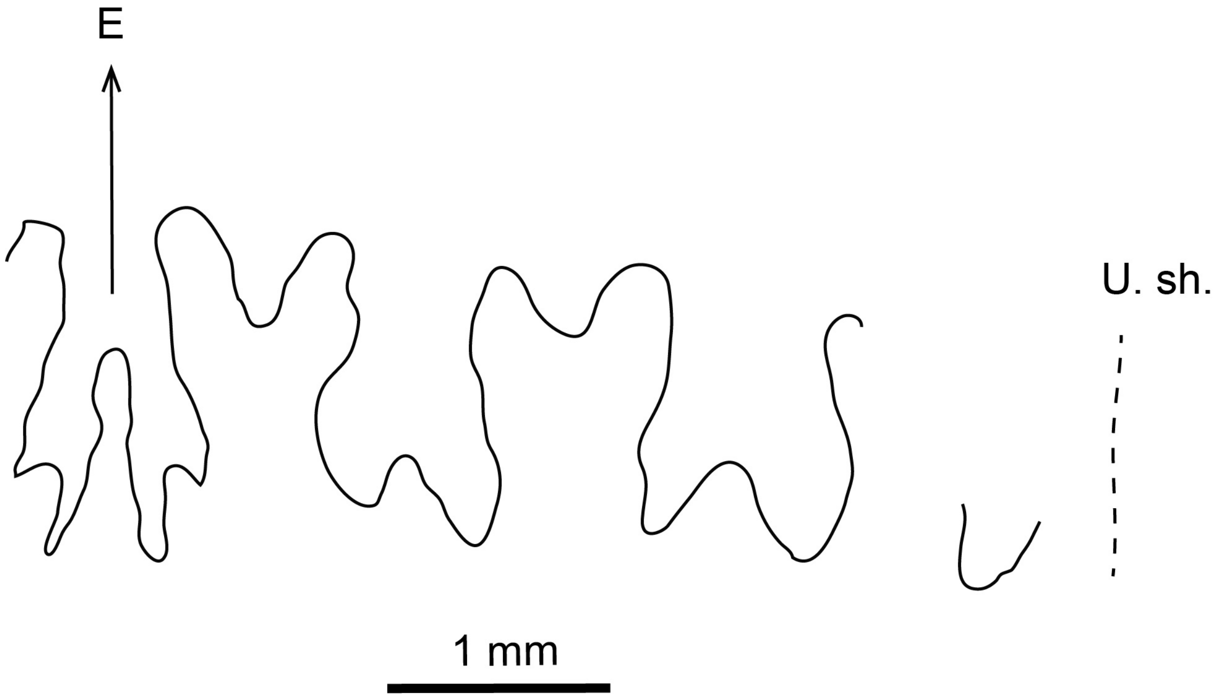

FIGURE 31. Suture of *Diptychoceras iwatense*, specimen IPMM 63786.

Locality and horizon. The genus is reported from the upper Aptian strata of Majorca, Spain (Wiedmann, 1962), Madagascar (Collignon, 1962), and the Miyako Group (Obata & Matsukawa, 2018), as well as Albian strata of England (Spath, 1938; Casey, 1961a, 1980), France (Orbigny, 1842), Switzerland (Pictet, 1854), the Caucasus (Karakasch, 1897), Madagascar (Collignon, 1963), Australia (McKenzie, 1999), Colombia (Kakabadze & Hoedemaeker, 1997), and the Miyako Group (Obata & Matsukawa, 2018).

Measurements (in mm except for w_1/h_1 and w_2/h_2).

Specimen	max L	B	h_1	w_1	w_1/h_1	h_2	w_2	w_2/h_2
IPMM 63629	105.0	57.6	11.6	12.7	1.09	17.5	18.0+	1.03
IPMM 63630	23.8	15.9	3.8	3.0	0.80	5.3	6.0	1.13
IPMM 63631	41.5	25.5	4.6	5.4	1,17	10.2	11.8	1.16
IPMM 63636	35.6	28.3	8.6	5.5	0.64	8.2	7.8	0.95
IPMM 63642	39.1	19.4	5.0	5.9	1.18	7.8	9.2	1.18
IPMM 63643	28.7	16.3	3.0	-	-	3.0	5.5	1.83
IPMM 63634	105.8	-	21.2	23.6	1.11	30.3	26.1	0.86
IPMM 63661	96.8	47.3+	-	-	-	-	-	-
IPMM 63671	80.0	-	-	-	-	-	-	-

Remarks. The specimens are small, coiled in an open spiral in one plane, vary from ancyloceratid coiling in the early growth stage, a nearly straight shaft in the middle stage, and finally hamitid coiling in the latest stage. They form an O-shaped coil. The coiling of the initial part of the whorl is uncertain because it is lost. The shaft is nearly as high as wide. The curved shaft on the early growth stage follows an almost straight shaft and terminal hook, forming as U-shape. The first U-shaped bend of the of shaft, while the second bend forms the typical U-shape. Both U-shaped bends of the holotype (UMUT-MM 32631) form a typical U-shape. The surface is ornamented with annular, coarse, and rectiradiate ribs. The ribs are narrow on the dorsum, strengthen toward the outer flank and are even stronger on the venter. A row of mid-lateral pointed nodes is discernible on each lateral rib; pointed nodes also develop on the ventrolateral shoulder. The nodes weaken on the later growth stage of large specimens. Suture is simple; lateral saddles are bifid, as are lateral lobes (Fig. 33). The suture is similar to that of *Protanisoceras raulinianum* (Spath, 1938, txt-fig. 200i). These characteristics indicate the specimens are *Protanisoceras hanaii* (Obata & Matsukawa, 2018, p. 255, fig. 30A, B) from the Hiraiga Formation of the Miyako Group. Klein (2015) lists 36 species in the genus *Protanisoceras*, most of which consist of partial specimens of shell, the overall shapes of which are unknown. However, *Protanisoceras* (*P.*) c*reutzbergi* (Kakabadze & Hoedemaeker, 1997, p. 82–83, pl. 16, figs 4–6, fig. 14) from the Albian strata of Colombia is an example forming a triangular coiling shell, which is different from the present species forming an O-shaped shell.

FIGURE 32. A–**R**, *Protanisoceras hanaii*. **A**–**D**, IPMM 63630. **E**–**F**, IPMM 63643. **G**–**J**, IPMM 63642. **K**–**L**, IPMM 63646. **M**–**O**, IPMM 63631. **P**–**R**, IPMM 63644. All specimens are shell and come from loc. KK. Scale bars = 1 cm.

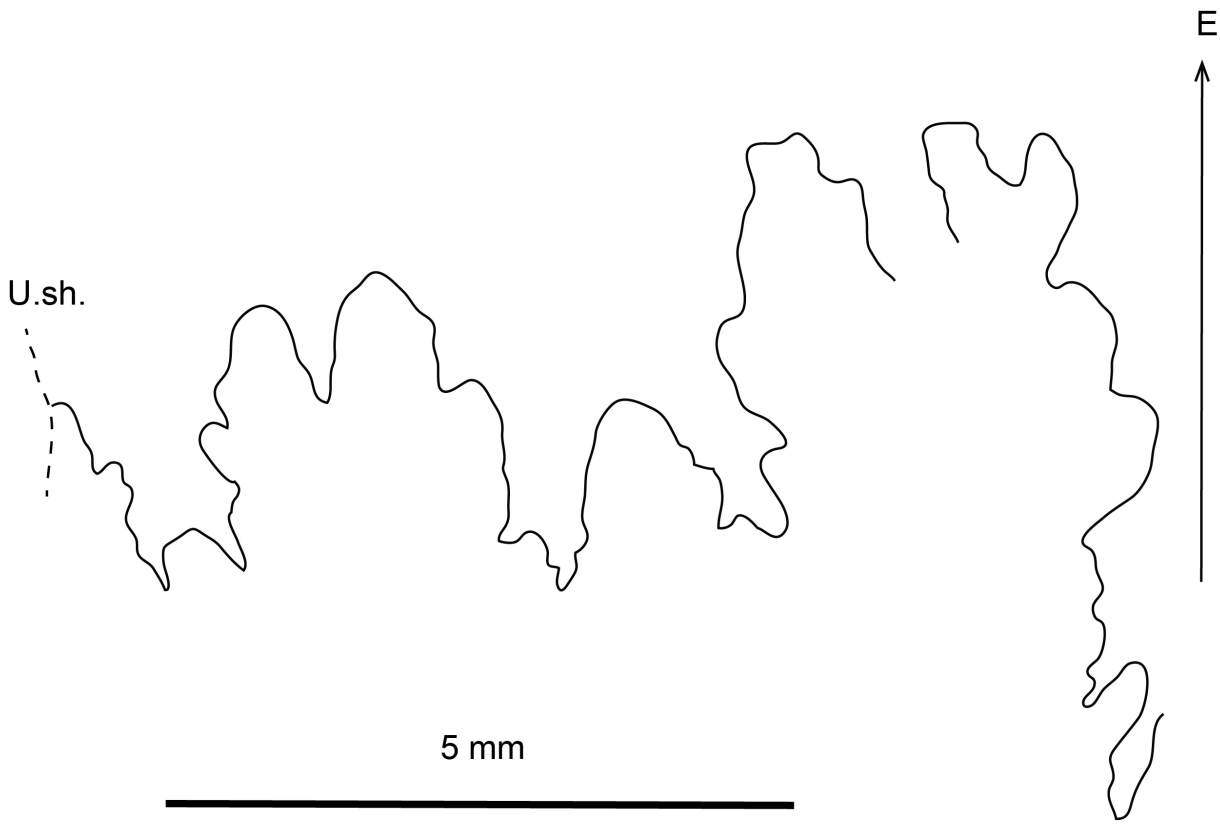

FIGURE 33. Suture of *Protanisoceras hanaii*, specimen IPMM 63631.

Genus *Ephamulina* Collignon, 1963

Type species. *Anisoceras* (?) *trituberculatum* Collignon, p. 52, pl. 8, fig. 5, text-fig. 8, by original designation by Collignon, 1963, pl. 27.

***Ephamulina monotuberculata* sp. nov.**
(Fig. 34F–J, N–AB)

2018 *Metahamites* (?) sp. indet., Obata & Matsukawa, p. 257, fig. 27A–E, K–T, U–AD.

2018 *Ephamulina* (?) sp. indet., Obata & Matsukawa, p. 257–258, fig. 27Z–AD.

Material. Eleven specimens in total. Seven specimens (collected by K. Komori), IPMM 63617 (holotype), 63618, 63622, 63624A, 63624B, 63627 (paratype), and 63663, come from the upper part of the Hiraiga Formation at location KK. Four specimens (collected by I. Obata), TGUSE-MM 6520 comes from the Aketo Formation at location B2, and TGUSE-MM 6435, 6546, and 6547A come from the Aketo Formation at location C6p. The early shell of all these specimens is not preserved.

Etymology. *Ephamulina* with a single low of tubercles on the ventral shoulder.

Diagnosis. *Ephamulina* with only one tubercle on ventrolateral shoulder.

Locality and horizon. The genus *Ephamulina* is reported from the Aptian strata of France (Kennedy, 2000), Hungary (Szives & Monk, 2002), and the Miyako Group (this paper), as well as the Albian strata of Madagascar (Collignon, 1963).

Description. The specimens are all parts of shafts. The whorl-section is subrectangular with rounded ventral and dorsal shoulders. The whorl surface is ornamented with very dense, even, fine ribs, linked periodically in groups at a single low tubercle on the ventrolateral shoulder. Three to five ribs are seen between the groups that link at tubercles. Suture line is simple: ventral lobe is rather shallow and almost same depth as the lateral lobe. Lateral saddle is bifid, lateral lobe is bifid (Fig. 35).

Measurements (in mm except for W/H).

Specimen	Mx L shaft	Height of shaft	Width of shaft	W/H
IPMM 63617 (holotype)	76.0	11.1	8.6	0.77
IPMM 63622	73.2	15.3	10.2	0.67
IPMM 63624A	47.2	11.2	8.7	0.78
IPMM 63627 (paratype)	128.3	31.7	-	-
TGUSE-MM 6435	28.7	4.9	-	-

Remarks. The present species differs from *Ephamulina* cf. *arcuata* (Kennedy, 2000, p. 684, fig. 50e, j, k) from the upper Aptian, jacobi Zone, Drôme, France, because the present species has only one tubercle on the ventrolateral shoulder, while the French species has two on the flank and ventrolateral shoulder. The present species also has three to five fine ribs between the groups that link at the tubercles, whereas the French species has eight or more. Since *Ephamulina trituberculatum* (Collignon, 1949; Kennedy, 2000, p. 684) from the Albian of Madagascar has three tubercles, the present species also differs from it. The specimen identified as *Metahamites* (?) sp. indet. (Obata & Matsukawa, 2018, p. 257, fig. 27P–T) from the Miyako Group, has five to eight minor ribs between majors, and thus also differs from the present specimens.

Genus *Idiohamites* Spath, 1925

***Idiohamites pacificum* sp. nov.**
(Fig. 34A–E)

Material. A single specimen, IPMM 63620, holotype (collected by K. Komori). Shell is preserved as a partial whorl, with early and later whorls lost. The specimen comes from the uppermost Hiraiga Formation at location KK.

Etymology. Meaning *Idiohamites* species from the Pacific Province.

Diagnosis. Coiling in a planar open spire and with radiate ribs consisting of thick main ribs with tubercles on the ventrolateral shoulder and three or four fine ribs inserted between the main ribs.

Locality and horizon. In the Miyako Group, the species is found in the uppermost part of the Hiraiga Formation within the Aptian to Albian transition. The genus is reported from the Albian strata of England (Spath, 1938), Spain (Wiedmann, 1962), Switzerland (Renz, 1968), Romania (Muţiu, 1984), Texas (U.S.A.) (Clark, 1965), Australia (Henderson, 1990), Madagascar (Collignon, 1963), South Africa (Klinger, 1976), and Angola (Cooper & Kennedy, 1979), the Cenomanian of Romania (Chiriac, 1981), Montana, Wyoming, Colorado (U.S.A.) (Kennedy & Cobban, 1990), and Madagascar (Collignon, 1931, 1965a).

Description. Whorl is small, normally coiled in a planar open spire. The whorl-section is elliptical in its early stage and becomes circular in its later stage. The venter of the whorl is narrow and the whorl increases rapidly in height. The flank is compressed in the early whorl, becoming swollen in the later whorl. The whorl surface is ornamented with dense, narrow, radiate, and annular ribs, consisting of thick main ribs with tubercles on the ventrolateral shoulder, and three or four fine ribs inserted between the main ribs. Suture is unknown.

Measurements (in mm except for Ux/Dx, w_1/h_1 and w_2/h_2).

Specimen	Dx	Ux	Ux/Dx	h_1	w_1	w_1/h_1	h_2	h_2	w_2/h_2
IPMM 63620 (holotype)	24.7	12.6	0.51	2.8	2.2	0.79	8.4	4.5+	0.53+

Remarks. Because of its coiling in a planar open spire and radiate ribs with a single pair of tubercles on the ventral shoulder, the specimen belongs to the genus *Idiohamites* (Wright *et al*., 1996).

The specimen is similar to the illustrated lectotype and the syntypes of *Idiohamites tuberculatus* (Spath, 1938, p. 582–584, pl. 64, fig. 12; pl. 65, figs 3, 4, 10; text-fig. 206a–h) from the Upper Gault, Folkestone, in England, in having coiling in a planar open spire, compressed whorl-section, and radiating ribs. However, the whorl height increases fairly rapidly in the present specimen compared with the English specimens. Additionally, the present specimen has tubercles on the ventral shoulder, whereas the English specimens have tubercles on the ventral shoulder and sometimes the suspicion of a lateral node. The present specimen is also similar to the illustrated specimens of *Idiohamites turgidus* var. *subannulata* (Spath, 1938, p. 587–589, text-fig. 209j–n) from the Upper Gault, Folkestone, England, in having a planar coil with open spire and rapidly increasing whorl height, but the ribs of the present specimen consist of thick main ribs with tubercles on the ventrolateral shoulder with two or three fine ribs between the thick ribs, whereas those of the English specimens are uniform. The present species differs from *Idiohamites spiniger* (Sowerby, 1818, in Spath, 1938, p. 584–586, pl. 64, figs 10, 11; pl. 65, fig. 12; text-figs 206i, 207) from the Upper Albian of Folkestone, Maidstone, and Burham, Kent in England, because the English species has both ventral and lateral tubercles.

According to Klein (2015), the genus *Idiohamites* comprising 39 species, often identified based on the characteristics of only a part of the whorl. Regarding species identification comes these taxa, the characteristics of the adult shells can be understood from those of the young shells. As the present specimen with coiling in a planar open spire on the young shell differs from the specimens of the three species discussed above, as well as other taxa noted by Klein (2015). Thus, we regard the specimen as a new species.

Family Hamitidae Gill, 1871
Genus *Hamites* Parkinson, 1811
Subgenus *Hamites* Parkinson, 1811

FIGURE 34. **A**–**E**, *Idiohamites pacificum*, IPMM 63620 (collected by K. Komori) (holotype), shell, from loc. KK. **F**–**J**, **N**–**AB**, *Ephamulina monotuberculata*. **F**–**G**, TGUSE-MM 6435 (collected by I. Obata), external mould (**K**), and its rubber pull (**J**), from loc. C6p. **H**–**J**, IPMM 63622 (collected by K. Komori), shell, from loc. KK. **N**–**R**, IPMM 63624B (collected by K. Komori), shell, from loc. KK. **S**–**V**, IPMM 63617 (collected by K. Komori) (holotype), enlarged venter (**T**), shell, from loc. KK. **W**–**Z**, IPMM 63624A (collected by K. Komori), shell, from loc. KK. **AA**–**AB**, IPMM 63627 (collected by K. Komori), shell, from loc. KK. **K**–**M**, *Tonohamites*? sp., TGUSE-MM 6522 (collected by I. Obata), internal mould, from loc. Hiraname-dana.

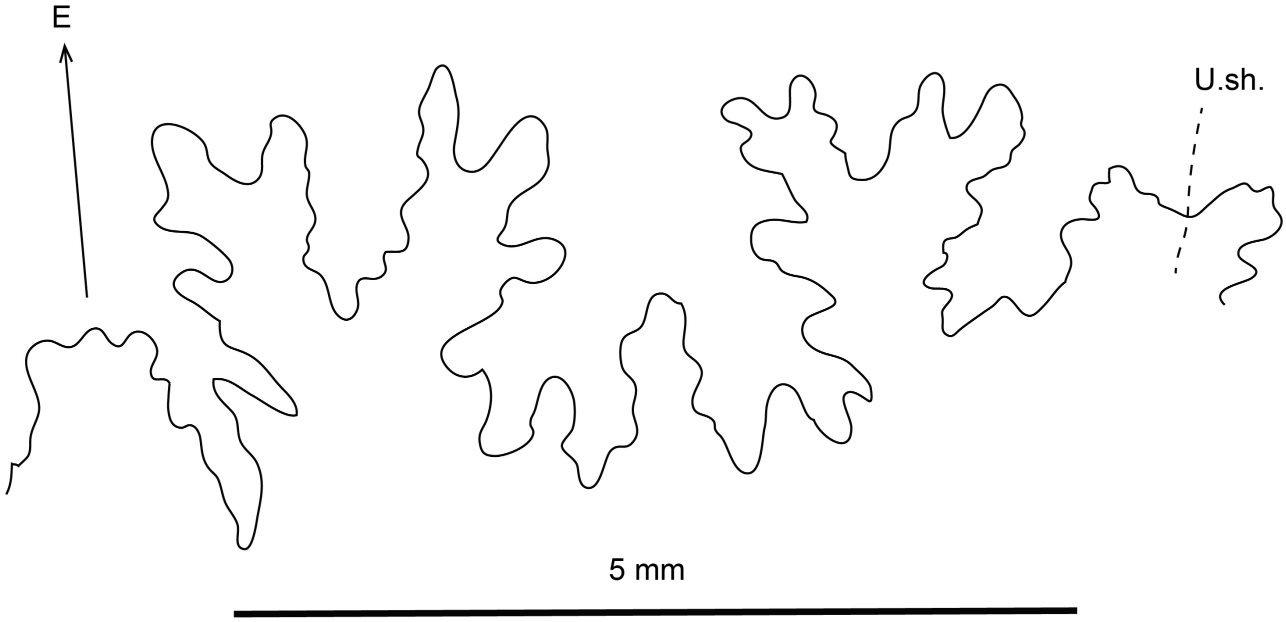

FIGURE 35. Suture of *Ephamulina monotuberculata*, specimen IPMM 63624.

Remarks. According to Wright *et al*. (1996), the genus *Hamites* is divided into three subgenera, *Hamites*, *Psilohamites*, and *Lytohamites*. The subgenus *Hamites* is defined by ribs always present. We follow the criteria of the subgenus of Wright *et al*. (1996).

***Hamites* (*Hamites*) cf. *tenuis* J. Sowerby, 1814**
(Fig. 36A–S)

Material. Nine specimens in total. Six specimens, IPMM 63619, 63625A, 63625B, 63626, 63628, and 63648 (collected by K. Komori), come from the upper part of the Hiraiga Formation at location KK, Raga north. Specimen IPMM 63619 preserves the initial coiling but not the subsequent shaft. The other five IPMM specimens are partial shafts with no preserved initial coiling. Three specimens collected by Obata included; TGUSE-MM 6436, from the lower part of the Hiraiga Formation at location Hn 4151, Matsushima; TGUSE-MM 6437, an external mould of loosely coild spire from the Aketo Formation at location C6p; and TGUSE-MM 6447C from the Aketo Formation at location B2.

Locality and horizon. We follow the synonymies of the genus *Hamites* (*H.*) listed by Klein (2015). The genus is reported from the upper Aptian / lower Albian of Hungary (Szives & Monk, 2002), the upper part of the Hiraiga Formation of the Miyako Group (this paper), the Albian strata of England (Spath, 1938; Casey, 1961a), France (Breistroffer, 1947), Switzerland (Renz, 1968), Italy (Wiedmann & Dieni, 1968), Romania (Chiriac, 1981), Texas (U.S.A.) (Clark, 1965), Mexico (Bose, 1923), and New Zealand (Henderson, 1973), the Cenomanian of Montana, Colorado, Arizona, New Mexico and Oklahoma in U.S.A. (Cobban *et al*., 1989), and the upper Albian and /or Cenomanian of the Yezo Group, Japan (Inoma, 1980) and the Albian to Cenomanian transition of Venezuela (Renz, 1982).

Measurements (in mm except for Ux/Dx and w_1/h_1).

Specimen	Dx	Ux	Ux/Dx	h_1	w_1	w_1/h_1
IPMM 63619	27.9	18.4	0.66	6.7	-	-
IPMM 63648	10.0	6.7	0.67	2.7	2.3	0.85
IPMM 63625A	-	-	-	4.7	3.9	0.83
TGUSE-MM 6437	16.3	10.9	0.67	2.5	-	-
TGUSE-MM 6436	15.7*	11.3*	0.72*	2.9	2.5	0.86

* approximate

Remarks. The specimens are characterized by ancyloceratoid coiling, compressed whorl which is elliptical in cross-section, and fine and dense ribs that are annular and slightly prorsiradiate on the flank and cross the venter orthogonally. The whorl is a loosely coiled spire with rapid expansion. The surface of the whorl is smooth initially, and the ribs appear later. The suture is simple, but incomplete; both the lateral saddle and lobe are bifid (Fig. 37).

The present specimens are similar to the illustrated specimens of *Hamites tenuis* (Spath, 1941, p. 628–630, pl. 68, fig. 14; pl. 70, figs 2, 16, 17; pl. 71, fig. 1; text-fig. 228) from the Lower Gault in England in their coiling, whorl compression, ribbing, and suture. However, the initial coiling of the present specimen forms a tight circle, while the English specimen is slightly loose. Additionally, the whorl-expansion increases faster than on the English specimen. Although these characteristics may indicate morphologic variation within the same species, since such variation is not yet well defined, we identify the specimen as *Hamites* cf. *tenuis* (J. Sowerby, 1814). The present specimens differ from the illustrated specimen of *Hamites compressus* (Spath, 1941, p. 617–619, pl. 68, figs 10–13; text-fig. 222) from the Lower Gault, *dentatus* and *lautus* zones, England, because the initial coiling of the present specimens is ancyloceratoid, whereas that of the illustrated specimen of *Hamites compressus* is crioceratoid.

***Hamites* (*H.*) cf. *intermedius* Sowerby, 1814**
(Fig. 27A–E)

1931 *Torneutoceras*? aff. *intermedium*, Shimizu, p. 23, pl. 3, figs 3, 4.

Material. A single fragmentary specimen, slightly deformed, IGPS 36859 (S. Shimizu collector), from Matsushima.

Locality and horizon. The label of the box containing the specimen states the location as "Matsushima in Taro Village". Matsushima is a small islet offshore north Moshi, Iwaizumi Town, in recent administrative divisions. Matsushima probably belonged to Omoto Village when the label was written. The Hiraiga Formation.

Measurements (in mm except for W/H).

Specimen	Maxim length of shaft	Height of shaft	Width of shaft	W/H
IGPS 36859	19.1	4.3	2.8	0.65

Remarks. The specimen has a slightly curved and compressed shaft, ellipsoidal whorl-section, and dense and blunt ribs. The ribs are prorsiradiate and cross the venter orthogonally and disappear on the dorsum. The characteristics of the ellipsoidal shell whorl-section and blunt ribs disappearing on the dorsum of the present specimen are similar to those of the illustrated specimen of *Hamites intermedius* (Spath, 1941, p. 630–634, pl. 70, figs 19, 20; pl. 71, figs 3–6, text-fig. 229a–g, m–p) from the Gault of England, although the rib irregularities (*e.g.*, intercalated short ribs or branching costae) which are often seen in *H. intermedius*, are not confirmed in the present specimen. These characteristics are not always confirmed in specimens illustrated as *H. intermedius*. We, therefore, identify the present specimen as *Hamites* (*H.*) cf. *intermedium*. Although Shimizu (1931) identified the specimen as *Torneutoceras*? aff. *intermedium* (Sowerby, 1814), and interpreted the specimen as related to that species, we cannot find supporting data for this interpretation.

***Hamites* (*H.*) sp. A**
(Fig. 36T–W)

Material. A single specimen, IPMM 63635 (collected by K. Komori), from the uppermost Hiraiga Formation at location KK.

Measurements (in mm except for W/H).

Specimen	Mx L shaft	Height of shaft	Width of shaft	W/H
IPMM 63635	46.6	6.9	8.1	1.17

Remarks. The specimen is characterized by ancyloceratoid coiling with "dogleg" bent shaft, compressed whorl-section being oval, and dense annular ribs that are radiate in early stage and slightly prorsiradiate in subsequent stages. Although the characteristics of ancyloceratoid coiling, oval whorl-section, and dense annular ribs suggest the specimen is similar to that of illustrated specimens of *H. gardneri* (Spath, 1941, p. 624–625, pl. 70, figs 3–5; text-fig. 225) from the Lower Gault, England, although the curving of the whorl of the present specimen is more pronounced than on the English specimens. The specimen is thus identified as *Hamites* (*H.*) sp. A.

***Hamites* (*H.*) sp. B**
(Fig. 27F–I)

1992 *Hamites* sp., Obata & Futakami, p. 91, pl. 4, fig. 3a–c.

Material. Two specimens of partial shafts, TGUSE-MM 6447A and 6447B (collected by I. Obata), from the Hiraiga Formation at location Tokuzo.

Measurements (in mm except for W/H).

Specimen	Maximum length of shaft	Height of shaft	Width of shaft	W/H
TGUSE-MM6447A	22.3	6.8	6.9	1.01
TGUSE-MM 6447B	20.3	7.7	6.1	0.79

Remarks. The specimens are small and partial shafts. The cross-section of the shaft is circular. The surface of the shaft is ornamented with dense and distinct annular ribs. On the dorsum these are rather fine but thicken on the flanks and venter. Ribs on the flank are radiate and cross the venter orthogonally. Because of these characteristics, the present specimen belongs to the genus *Hamites* (*Hamites*) (Wright *et al.*, 1996). The present specimens may resemble a partial shaft of the specimen described

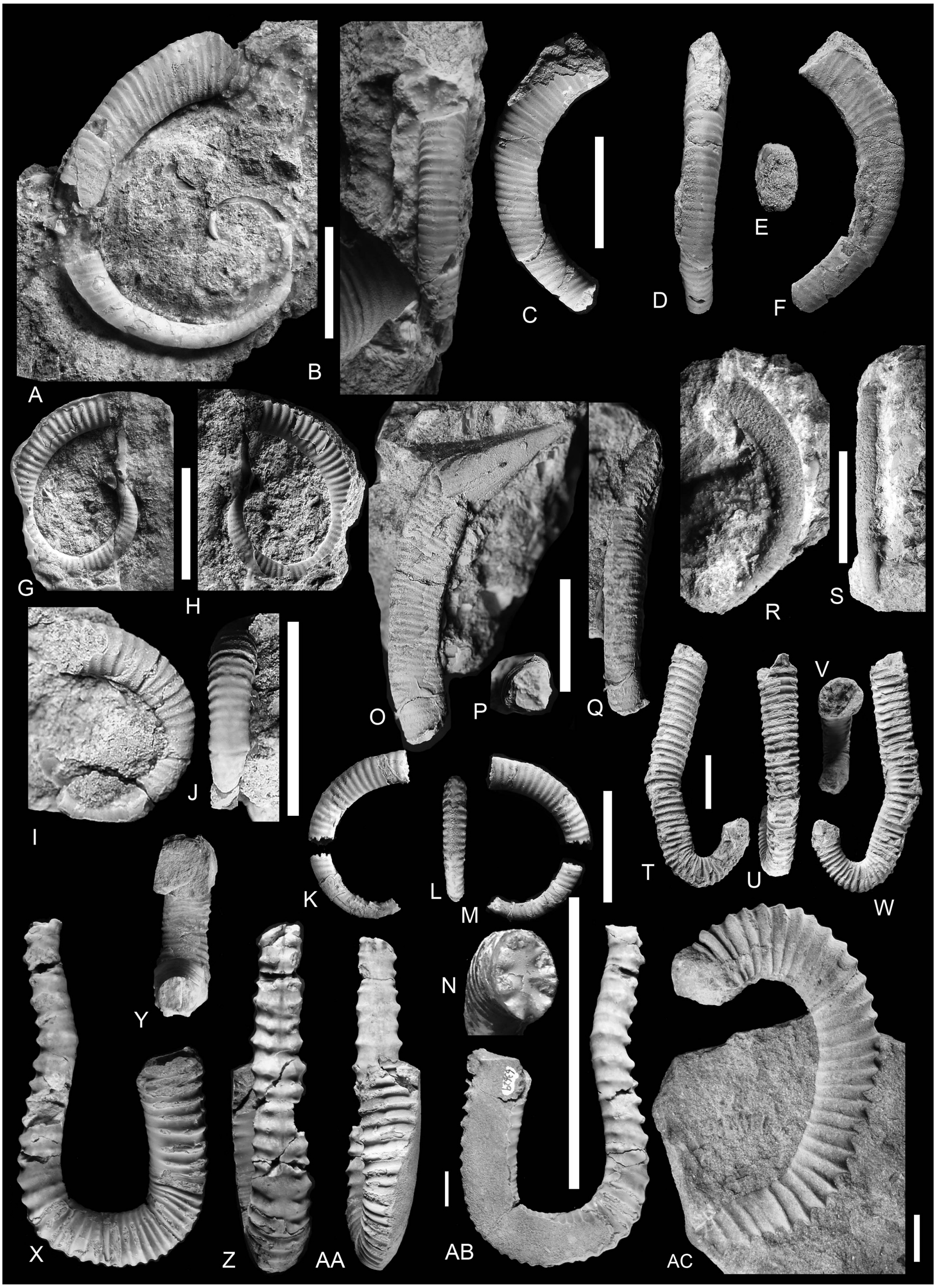

FIGURE 36. **A**–**S**, *Hamites* (*Hamites*) cf. *tenuis*. **A**–**B**, IPMM 63619 (collected by K. Komori), shell, from loc. KK. **C**–**F**, IPMM 63625A (collected by K. Komori), shell, from loc. KK. **G**–**H**, TGUSE-MM 6437 (collected by I. Obata), external mould (**H**) and its rubber pull (**G**), from C6p. **I**–**J**, IPMM 63648 (collected by K. Komori), shell, from loc. KK. **K**–**N**, TGUSE-MM 6436 (collected by I. Obata); **N**, enlarged shaft section, shell, from loc. Hn 4151. **O**–**Q**, IPMM 63625B (collected by K. Komori), shell, from loc. KK. **R**–**S**, IPMM 63628 (collected by K. Komori), internal mould, from loc. KK. **T**–**W**, *Hamites* (*H.*) sp. A; IPMM 63635 (collected by K. Komori), shell, from loc. KK. **X**–**AC**, *Protanisoceras hanaii*. **X**–**AA**, IPMM 63629 (collected by K. Komori), shell, from loc. KK. **AB**–**AC**, IPMM 63641 (collected by K. Komori), shell, from loc. KK. Scale bars = 1 cm.

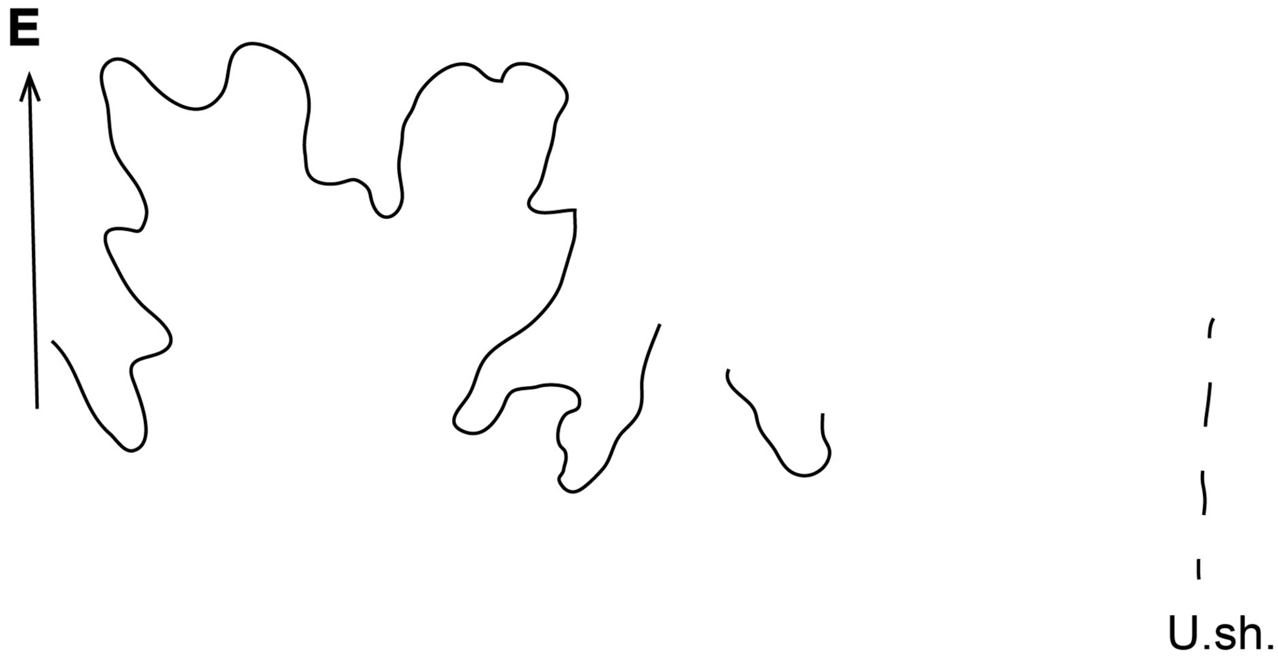

FIGURE 37. Suture of *Hamites* (*Hamites*) cf. *tenuis*, specimen IPMM 63619.

above as *H.* (*H.*) sp. A, although a "dogleg" bend of the shaft is not confirmed. Additionally, the cross-section of the shaft of the present specimen is circular whereas that of the *H.* (*H.*) sp. A is oval. We, therefore, identify the specimen as *H.* (*H.*) sp. B.

***Hamites* (*H.*) sp. C**
(Fig. 27J, K)

Material. A fragmentary specimen of a partial shaft, crozier, and hook, external mould, TGUSE-MM 6448 (collected by I. Obata), from the Aketo Formation at location Hiraname-dana.

Measurements (in mm)**.**

Specimen	Maximum length of shaft	Height of shaft	Width of shaft	W/H
TGUSE-MM 6448	*ca*. 24.1	6.8	-	-

Remarks. The specimen is characterized by rectangular shaft cross-section, crozier, and a hook with round dorsal and ventral shoulders, flat flanks, and narrow and crested ribs that are prorsiradiate on the shaft and are rectiradiate on the crozier and hook. These modes of ribbing differ from those of *H.* (*H.*) sp. and *H.* (*H.*) sp. B, thus the specimen is identified as *Hamites* (*H.*) sp. C.

Family Baculitidae Gill, 1871
Genus *Lechites* Nowak, 1908
Subgenus *Lechites* Nowak, 1908

***Lechites* (*Lechites*) *komorii* sp. nov.**
(Fig. 38A–T)

2018 *Metahamites* (?) sp., Obata & Matsukawa, p. 257, fig. 27F–J.

Material. Seven specimens in total. Five specimens (collected by K. Komori), IPMM 63594 (paratype), 63595, 63596 (holotype), 63597, and 63598, come from the uppermost Hiraiga Formation at location KK; specimens, IPMM 63594 and 63596, consist of phragmocone and body chamber. IPMM 63596 was, unfortunately, broken during preparation, and the specimen is currently divided into two. Two specimens (collected by I. Obata), TGUSE-MM 6106 and 6195, come from the Hiraiga Formation at location Tokuzo.

Etymology. Named after Mr. Kazuo Komori, a science teacher at a school in Iwate Prefecture, who has contributed much to the study of the ammonite fauna of the Miyako Group.

Diagnosis. *Lechites* with ribs that are wide and weak, and these of early shaft are annular, broad and distinct.

Locality and horizon. The genus *Lechites* is reported from the upper Albian strata of England (Spath, 1941), France (Kennedy & Latil, 2007), Hungary (Szives, 2007), Bulgaria (Ivanov, 1991), and Texas (U.S.A.) (Clark, 1965), the Albian strata of Germany (Scholz, 1971), Switzerland (Pictet & Campiche, 1861), Italy (Wiedmann & Dieni, 1968), Madagascar (Collignon, 1963), and northern Australia (Henderson, 1990), and the upper Albian to Cenomanian Romania (Chiriac, 1981, 1988), Venezuela (Renz, 1982). *L.* (*L.*) *komorii* **sp. nov.** from the Upper Aptian Miyako Group is one of the earliest records for genus.

Description. Shell is long, slender with acute angle, slightly curved single shaft; initial whorl is unknown. Shaft is compressed, square in cross-section in early stage with round flank, venter, and dorsum, and oval in later shaft. Early shaft bends weakly towards the dorsum. Later shaft is almost straight; its expansion is slow. Surface is ornamented with dense, broad, and prorsiradiate ribs. The ribs on the early shaft are annular, broad, and distinct. The breadth of ribs is twice the interspace between them. The ribs on later shaft disappear on the dorsum and become difficult to see, and the surface may appear smooth. These arise at the dorsal shoulder and strengthen toward the outer flank and become stronger on the venter. The ribs are straight on the flank and cross the venter slightly forward. The suture is simple, with bifid ventral lobe, bifid lateral saddle, bifid lateral lobe, and trifid internal lobe (Fig. 39); lobes are rather deep. This is similar to the suture of *Baculites gaudini* (Pictet & Campiche, 1861, p. 55, fig. 6) and the suture of *Lechites gaudini* (Spath, 1941, text-fig. 242i).

Measurements (in mm except for W/H).

Specimen	Mx L shaft	Height of shaft	Width of shaft	W/H
IPMM 63594 (paratype)	79.4	6.6	6.3	0.96
IPMM 63596 (holotype)	74.5+	6.0	5.4	0.90

Remarks. Because of their slightly curved shafts, oval cross-sections, low and prorsiradiate ribs, and lack of constriction and tubercles, the specimens belong to the genus *Lechites* (*Lechites*) (Wright *et al*., 1996).

The present specimens are similar to the illustrated specimens of *Baculites gaudini* (Pictet & Campiche, 1861, p. 112–113, p. 55, figs 5–7) from Switzerland in having prorsiradiate ribs that arise at the dorsal shoulder, strengthen toward the outer flank, and disappear on the dorsum. However, the ribs of the present specimens are wider and weaker than those of Swiss specimens. Additionally, the ribs on the early shaft of the present specimens are annular, broad and distinct. The characteristics of the early shaft of the growth are only confirmed for the first time in the present specimens. Furthermore, the present specimens are found in Aptian–Albian transition strata, but the other species described, including *L. gaudini*, are reported from Albian to Cenomanian (Cooper & Kennedy, 1977). In the future, there is the possibility that specimens with similar characteristics of the early shaft will be found for previously described, but at this time, those characteristics can be only confirmed in the present species.

Superfamily Douvilleiceratoidea Parona & Bonarelli, 1897

Family Douvilleiceratidae Parona & Bonarelli, 1897

Subfamily Douvilleiceratinae Parona & Bonarelli, 1897

Genus *Epicheloniceras* Casey, 1954

***Epicheloniceras* sp.**

(Fig. 40O–Q)

2023 *Epicheloniceras* sp., Matsukawa & Shibata, p. 17, fig. 8M–O.

Material. Three specimens. TGUSE-MM 6664 (collected by T. Kase) is an inner mould of a partial outer whorl and comes from the Hiraiga Formation at location Hn 4051, Oshima, TGUSE-MM 6578 (collected by I. Obata) is from the Hiraiga Formation at location Hn 4151, Matsushima, and TGUSE-MM 6554 (collected by I. Obata) comes from the Hiraiga Formation at location Hn 4053, Oshima.

Locality and horizon. The genus *Epicheloniceras* is reported from England (Casey, 1962), France (Jacob, 1905), Switzerland (Jacob & Tobler, 1906), Italy (Tavani, 1949), Bulgaria (Dimitrova, 1967), middle Volga (Wassiliewski, 1909), the Caucasus (Sinzow, 1907), Georgia (Eristavi, 1955), Dagestan (Rouchadzé, 1938), California (Gabb, 1869), Mexico (Humphrey, 1949), Colombia (Etayo-Serna, 1979), Madagascar (Collignon, 1962), and Mozambique (Förster, 1975) and Japan (Matsukawa & Obata, 2015).

Measurements (in mm except for U/D and W/H).

Specimen	D	U	U/D	H	W	W/H
TGUSE-MM 6664	-	-	-	30.7	53.1	1.73
TGUSE-MM 6554	-	-	-	-	46.7+	-

Remarks. The specimen, TGUSE-MM 6664, is characterized by a fairly small, evolute, and much depressed whorl which is subquadrate in cross-section with a flat venter. Whorl surface is ornamented with coarse, radiate ribs, numbering five observed. One of ribs arises at very a small umbilical tubercle, trends straight across the lower flank, branches into two at a small lateral tubercle, with the two ribs trending straight on the flank and crossing the venter orthogonally. There appears to be a rise in ventral tubercles, although this is difficult to judge due to preservation. The remaining four ribs arise at the umbilical shoulder, trend straight across the flank and cross the venter orthogonally. Because of the presence of one rib branching into two, and faint umbilical and lateral tubercles and possible ventral tubercles, the specimen is identified as the genus *Epicheloniceras* (Wright *et al*., 1996). The ventral tubercles of the genus *Epicheloniceras* disappear with growth. The presence or absence of raised

FIGURE 38. A–**T**, *Lechites* (*Lechites*) *komorii*. **A**–**E**, IPMM 63594. **F**–**K**, IPMM 63596. **L**–**P**, IPMM 63595. **Q** and **R**, IPMM 63595. **S** and **T**, IPMM 63598. **L**=**R** are the same individual. Large and small individuals are arranged as suggestive successive growth stages. All specimens are collected by K. Komori, are shell, and come from loc. KK. Scale bars = 1 cm.

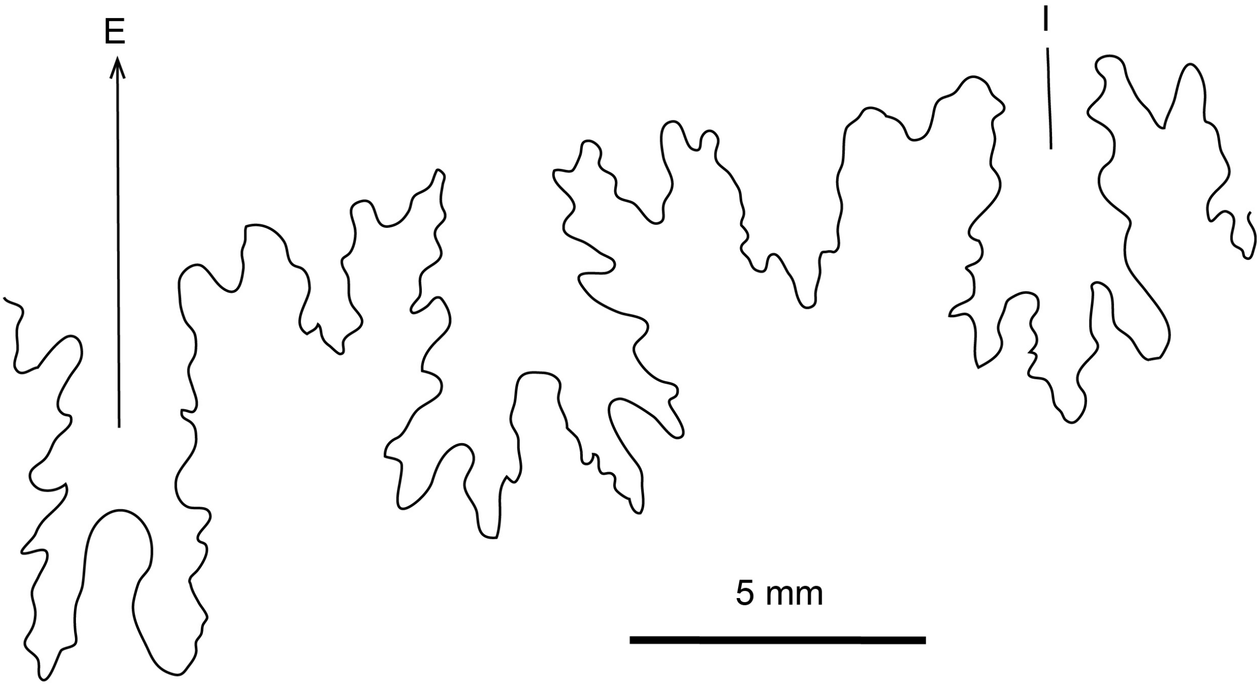

FIGURE 39. Suture of *Lechites* (*Lechites*) *komorii*, specimen IPMM 63596.

ventral tubercles in the present specimen is considered to be a characteristic of the adult shell of the genus.

The four unbranched ribs line up next to the bifurcated rib. This indicates that at least four ribs are sandwiched between the bifurcated ribs. This characteristic is similar to the illustrated specimens of the adult shell of *Epicheloniceras tschernyschewi* (Casey, 1962, p. 236–239, pl. 38, fig. 6a, b; pl. 39, figs 6a, b, 7; text-fig. 82) from the upper Aptian Kysil-Kaspak, Mangyshlak, Kazakhstan, and *Epicheloniceras gracile* (Casey, 1962, p. 250–251, pl. 38, fig. 2a, b; pl. 39, fig. 1a, b; text-fig. 86a) from the upper Aptian Lower Greensand of southern England. However, the ribs of specimens of these two species are finer and denser than those of the present specimen. Additionally, the whorl-section of the Kazakhstan specimens is more rounded than that of the present specimen.

Although the present specimen may be recognized as a new species, it is identified as *E*. sp. because it is partial whorl.

Genus *Paracheloniceras* Collignon, 1962b

Paracheloniceras guenoti Collignon, 1965c
(Fig. 41E–H)

1965c *Paracheloniceras guenoti* Collignon, p. 47–48, pl. 1, figs 1, 1a, 1b, 2, 2a, b.

2000 *Paracheloniceras guenoti,* Kennedy, fig. 58de, e = Collignon, 1965c, pl. 1, figs 2, 2a, 2b.

2023 *Paracheloniceras guenoti*, Matsukawa & Shibata, p. 17, fig. 8J–L.

Material. A single specimen, IPMM 63693 (collected by K. Komori), comes from the uppermost Hiraiga Formation at location KK.

Locality and horizon. The present species is reported from the Aptian of Madagascar and Japan (Matsukawa & Shibata, 2023).

Description. The specimen is small, reaching about 33 mm in diameter. The umbilicus is fairly narrow and deep. The umbilical wall is vertical, and rounds to flank abruptly. The whorl is fairly evolute and compressed. The whorl-section is subquadrate with angular ventral shoulder. The surface of whorl is ornamented with dense, stout, rectiradiate and flat-topped ribs that arise at umbilical seam, widen, form a torch-like shape, trend across the flank and cross the venter orthogonally. There are four tubercles consisting of small umbilical bullae, inner and outer lateral tubercle and large earlike clavi. Suture is unknown.

Measurements (in mm except for U/D and W/H**).**

	D	U	U/D	H	W	W/H
IPMM 63693	32.8	9.9	0.30	13.1	13.8	1.05

Remarks. These characteristics suggest the specimen is assigned to *Paracheloniceras guenoti* (Collignon, 1965c, pl. 1, figs 1, 1a, 1b, 2, 2a, b) from the Aptian of Madagascar. In the Madagascar specimen, the ribs become thinner and the tubercles smaller in later growth stages, but these characteristics cannot be confirmed in this specimen.

***Paracheloniceras regina* (Obata & Matsukawa, 2018)**
(Fig. 42A–L)

2018 *Hypacanthoplites regina* Obata & Matsukawa, p. 261–263, fig. 35A–D.

Material. Four specimens: 1) TGUSE-MM 6438 (collected by I. Obata) is an external mould and comes from the Tanohata Formation at location Hn 0220; 2) TGUSE-MM 6192 (collected by I. Obata) comes from the Tanohata Formation at location Hn 0220; this specimen is slightly deformed, but the last one-fourth volution preserves the original whorl form; 3) TGUSE-MM 6485 (collected by I. Obata) is an external mould and comes from the Hiraiga Formation at location Tokuzo; 4) TGUSE-MM 6211 (collected by A. Shimonosono) comes from the Tanohata Formation at location C21, Shimanokoshi Port.

Locality and horizon. The present species is only reported from the Miyako Group.

Description. The specimens are characterized by very to fairly small and have fairly narrow umbilicus with compressed and very evolute whorl. The whorl is roughly hexagonal or rectangular in cross-section with a flat venter and angular shoulders. Umbilicus is shallow and has a steep wall which rounds into the flanks. Flank surface is ornamented with ribs consisting of primaries and rarely secondaries. The primary ribs are flat-topped, forming narrow torch-shape, straight or flexuous, and have umbilical bullae, lateral tubercles and large earlike ventrolateral clavi, but on the later whorl, the flat-topped ribs change to narrow crested ribs, and the lateral tubercles on the outer flank and the earlike ventrolateral clavi disappear. The secondary ribs are inserted between the primaries on only the later whorls. The ribs cross the venter orthogonally, but those on the early whorl weaken on the venter.

Additional description using by the type specimen of the species. In the type specimen of *Paracheloniceras regina*, NMNS-PM 7542 (collected by I. Hayami and I. Obata) comes from the Hiraiga Formation at near location Hn 0016 and 0018, the ribs on the venter weak in the younger to later whorls are weak and cross the venter orthogonally. However, these of the latest whorl are narrow and crest-topped ribs instead of flat-topped, broad and stout, are not weak and cross the venter orthogonally.

Measurements (in mm except for U/D and W/H)**.**

	D	U	U/D	H	W	W/H
TGUSE-MM 6438	34.0	9.5	0.28	14.9	-	-
TGUSE-MM 6192	36.1	8.8	0.24	16.3	14.1	0.86
TGUSE-MM 6211	-	-	-	11.2	10.5	0.94

Remarks. Flat-topped ribs and large earlike ventrolateral clavi suggest that the specimens are assigned to the genus *Paracheloniceras* (Wright *et al*., 1996). The specimens are similar to the illustrated specimens of *Paracheloniceras guenoti* (Collignon, 1965c, pp. 47–48, pl. 1, figs 1a, b, 2a, b), from the Aptian of Madagascar in having depressed whorl and surface ornamented with stout ribs with earlike ventrolateral clavi. However, a number of lateral tubercles is one for the present specimens whereas two for the Madagascar specimens.

***Paracheloniceras kazuoi* sp. nov.**
(Fig. 41A–D, X, Y, AD, AE)

1975 *Diadochoceras* (?) sp. aff. *nodosocostatiforme*, Obata, 1975, p. 2–5, pl. 1, fig. 2

2021 *Diadochoceras nodosocostatiforme*, Matsukawa, p. 10–11, fig. 7N, O.

Material. Three specimens. IPMM 63690 (collected by K. Komori), holotype, and 63706 (collected by K. Komori), paratype, comes from come from the uppermost Hiraiga Formation at location KK. NSM-PM 7546 (collected by T. Hanai, I. Hayami and I. Obata) comes from the Hiraiga Formation at location Hn 4151.

Etymology. Named after Mr. Kazuo Komori, a science teacher at a school in Iwate Prefecture, who has contributed much to the study of the ammonite fauna of the Miyako Group.

Diagnosis. Ribs consisting of two or three secondaries between primaries, the primary ribs consisting of crest-topped and flat-topped at the distal end. There are three tubercles, one of which is large and long ventrolateral clavi.

Locality and horizon. The present species is reported from the upper Aptian Todai Formation (Matsukawa, 2021) and the Hiraiga Formation of the Miyako Group (present study).

Description. The shell is very small, reaching about 40 mm in diameter. The umbilicus is moderate and shallow, and its wall rounds to flank. The whorl is fairly evolute, and its compression is as high as broad. The whorl-section is subquadrate with round umbilical and ventral shoulders. The surface of whorl is ornamented with dense and rectiradiate ribs consisting of primaries and secondaries. They arise at umbilical seam, trend across flank and cross the venter orthogonally. The ribs are crest-topped and become flat-topped at its distal end. Two or three secondary ribs are sandwiched between primary ribs in the younger whorl, whereas only one is sandwiched in the later whorl and then disappears. There are three tubercles consisting of small umbilical bullae, lateral spine and large an elongated clavi. The suture is simple, having a deep ventral lobe, shallow lateral saddle, and rather wide lateral lobe (Fig. 43).

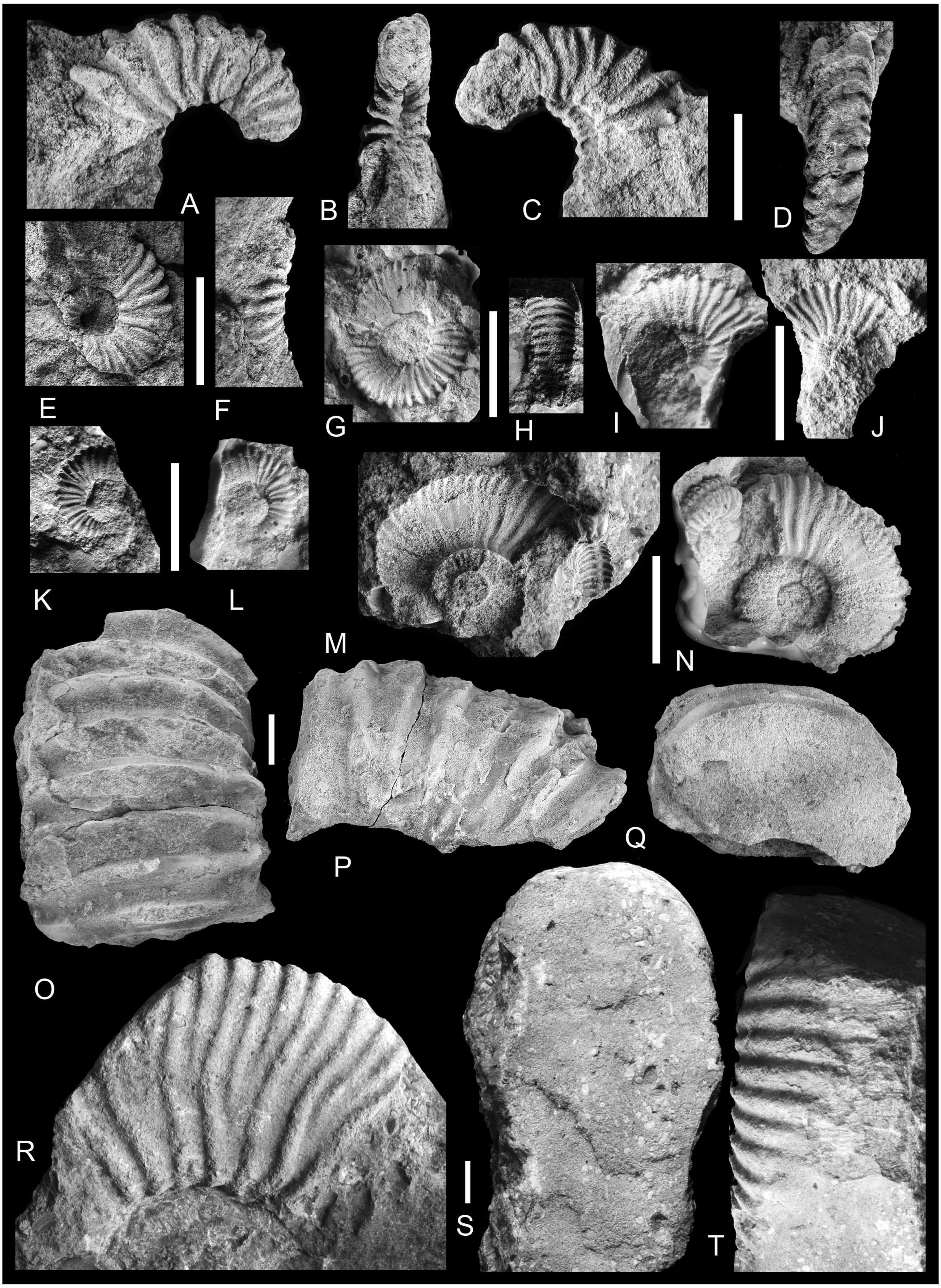

FIGURE 40. **A**–**F**, *Pseudoleymeriella hiranamensis*. **A**–**D**, TGUSE-MM 6432 (S. Ogino collector), internal mould, from loc. Hiraname-dana. **E**, **F**, TGUSE-MM 6433 (S. Ogino collector), internal mould, from loc. Hiraname-dana. **G**–**N**, *Pseudoleymeriella hataii*; **G**, TGUSE-MM 6442 (collected by I. Obata), rubber pull of external mould, from loc. C6p. **H**, TGUSE-MM 6444A (collected by I. Obata), internal mould, from loc. C6p. **I** and **J**, IGPS36513 (S. Shimizu collector), external mould (**J**) and its rubber pull (**I**), from Aketo. **K** and **L**, TGUSE-MM 6460A (collected by I. Obata), external mould (**K**) and its rubber pull (**L**), from loc. Hn 0679. **M** and **N**, TGUSE-MM 6179A (collected by I. Obata), external mould (M) and its rubber pull (**N**), from loc. C6p. **O**–**Q**, *Epicheloniceras* sp.; TGUSE-MM 6664, internal mould, from loc. Hn 4051. **R**–**T**, *Colombiceras yaegashii*.; TGUSE-MM 6272, internal mould, from loc. Tokuzo. Scale bars = 1 cm.

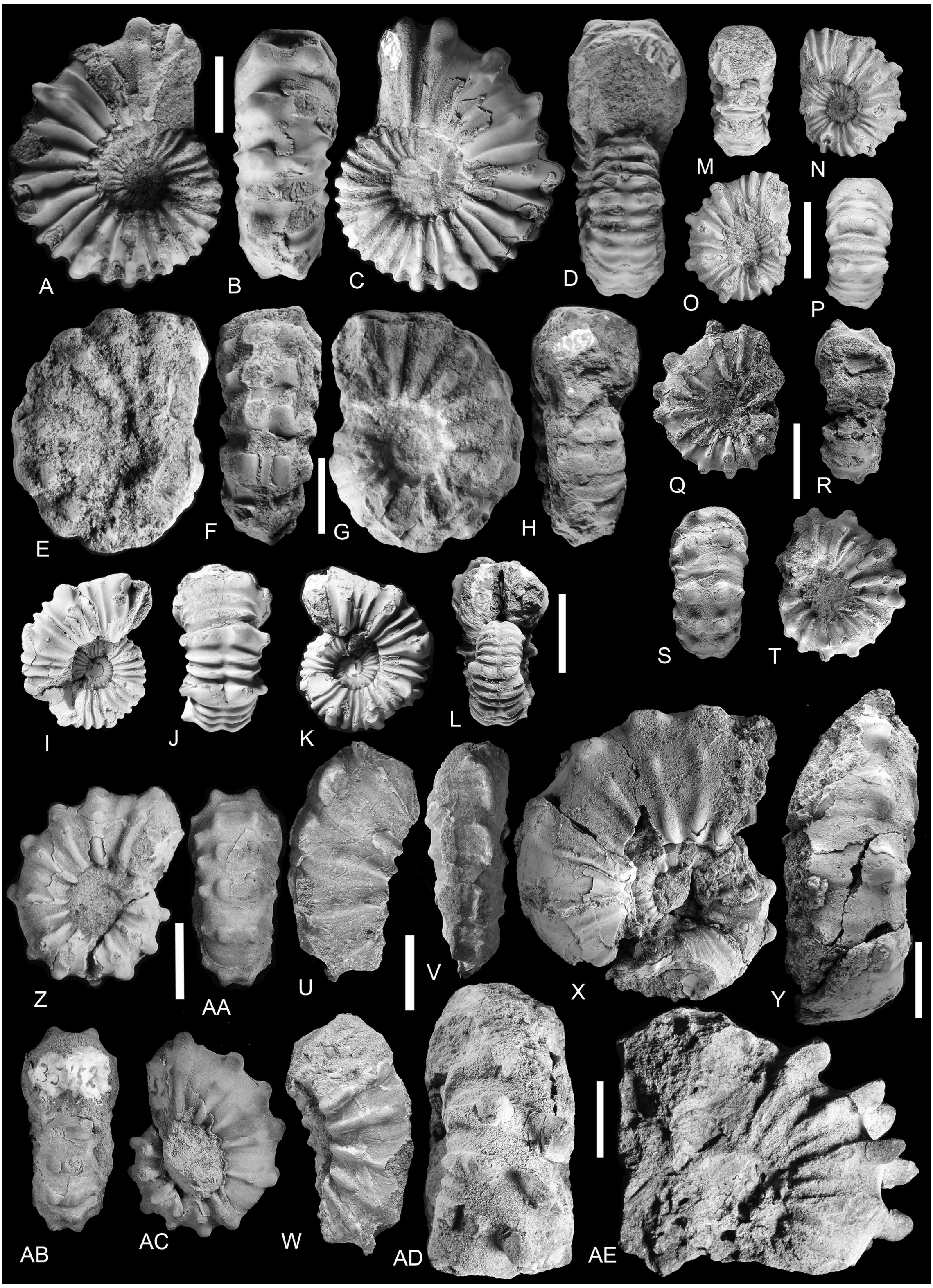

FIGURE 41. **A**–**D**, *Parancheloniceras kazuoi*, IPMM 63690 (collected by K. Komori), shell, from loc. KK. **E**–**H**, *Parancheloniceras guenoti*, IPMM 63693 (collected by K. Komori), shell, from loc. KK. **I**–**L**, IPMM 63701 (collected by K. Komori), shell, from loc. KK. **M**–**P**, TGUSE-MM 6244 (T. Kase collector), shell, from loc. Ks4004. **Q**–**T**, NSM-PM 7545 (collected by I. Obata), shell, from loc. Hn 4151 (specimen = Obata, 1975, pl. 1, fig. 3). **U**–**W**, *Parancheloniceras regina*, TGUSE-MM 6211 (collected by I. Obata), shell, from loc. SMK. **X** and **Y**, *Parancheloniceras kazuoi*, NSM-PM 7546 (collected by I. Obata), shell, from loc. Hn 4151 (specimen = Obata, 1975, pl. 1, fig. 2). **Z**–**AC**, IGPS 35152 (S. Shimizu collector) (holotype), shell, from Matsushima (specimen = Shimizu, 1931, p. 1, figs 6, 7; Obata and Matsukawa, 2018, fig. 35 M–P). **AD** and **AE**, *Parancheloniceras kazuoi*, IPMM 63706 (collected by K. Komori), shell, from loc. KK. Scale bars = 1 cm.

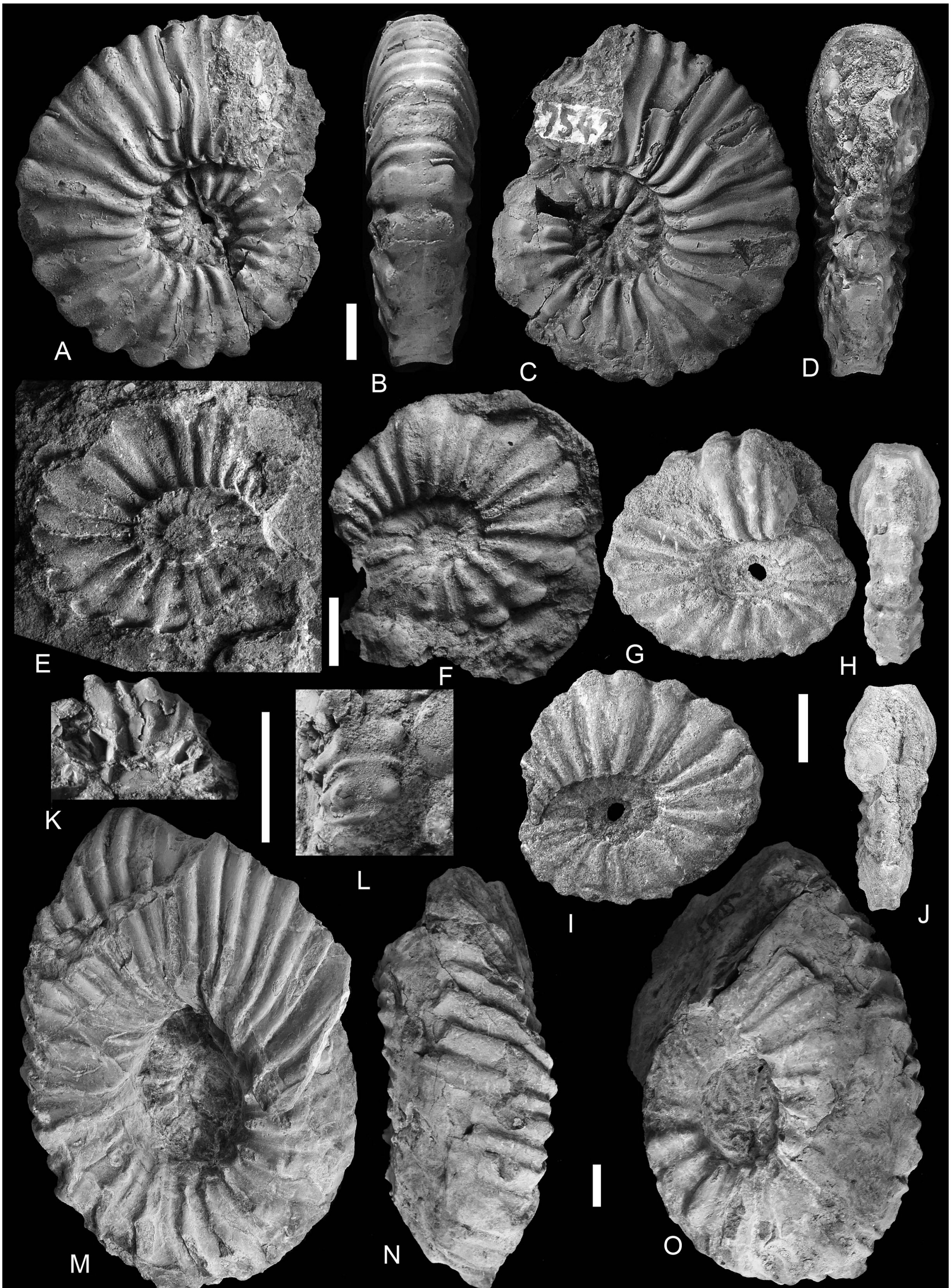

FIGURE 42. **A**–**L**, *Paracheloniceras regina*. **A**–**D**, NMNS-PM 7542 (I. Hayami and collected by I. Obata) (holotype), shell, from loc. Tokuzo (specimen = Obata & Matsukawa, 2018, fig. 35A–D). **E** and **F**, TGUSE-MM 6438 (collected by I. Obata), external mould (**E**) and its rubber pull (**F**), from loc. Hn 0220. **G**–**I**, TGUSE-MM 6192 (collected by I. Obata), internal mould, from loc. Hn 0220. **K** and **L**, TGUSE-MM 6485 (collected by I. Obata), shell, from loc. Tokuzo. **M**–**O**, *Hypacanthoplites subcornuerianus*, TGUSE-MM 6236, shell, from loc. C21. Scale bars = 1 cm.

Measurements (in mm except for U/D and W/H).

	D	U	U/D	H	W	W/H
IPMM 63690 holotype	33.6	11.3	0.34	13.8	14.1	1.02
IPMM 63706 paratype	-	-	-	14.5	15.5	1.04
NSM-PM 7546	38.5	12.3	0.32	17.6	-	-

Remarks. *Paracheloniceras kazuoi* differs from *P. guenoti* (Collignon, 1965c, p. 47–48, pl. 1, figs 1, 1a, 1b, 2, 2a, b), because the former species is characterized by the ribs consisting of two or three secondaries between primaries, the primary ribs consisting of crest-topped and flat-topped at its distal end, and large and long ventrolateral clavi, whereas these of the latter species are much primaries and rare secondaries, flat-topped primaries and large earlike ventrolateral clavi. Additionally, a number of tubercles of the former species is three, whereas that of the letter is four.

Genus *Diadochoceras* Hyatt, 1900

***Diadochoceras nodosocostatiforme* (Shimizu, 1931)**
(Figs 41I–T, Z–AC)

1931 *Douvilleiceras nodosocostatiforme* Shimizu, p. 35, pl. 1, figs 6, 7.
1968 *Diadochoceras nodosocostatiforme*, Hanai *et al*., pl. 2, fig. 7.
1968 *Diadochoceras* cf. *nodosocostatiforme*, Matsumoto, p. 141–143, pl. 2, fig. 1.
1975 *Diadochoceras nodosocostatiforme*, Obata, p. 2–5, pl. 1, figs 3–5, text-figs 1, 2.
1979 *Diadochoceras nodosocostatiforme*, Kitamura *et al*., pl. 7, figs 1, 4.
2018 *Diadochoceras nodosocostatiforme*, Obata & Matsukawa, figs M–P.
2021 *Diadochoceras nodosocostatiforme*, Matsukawa, p. 10, figs 7N–R.
2023 *Diadochoceras nodosocostatiforme*, Matsukawa & Shibata, p. 17–18, fig. 8P–R.

Material. 25 specimens in total. 20 specimens, IPMM 63691, 63692, 63694–63705, 63707–63712 (collected by K. Komori), come from the uppermost Hiraiga Formation at location KK. Four specimens also come from the Hiraiga Formation; TGUSE-MM 6581 and 6466 (collected by I. Obata) come from location Hn 4151, TGUSE-MM 6169, 6244 (collected by T. Kase) come from location Ks 4004, Oshima.

Locality and horizon. The genus is reported from France (Orbigny, 1841), Hungary (Szives, 2007), Georgia (Kvantaliani, 1972), the northern Caucasus (Mikhailova, 1963), the western Caucasus (Egoian, 1965), Madagascar (Collignon, 1962), Venezuela (Renz, 1982) and Japan (Obata, 1975).

Measurements (in mm except for U/D and W/H)**.**

Specimen	D	U	U/D	H	W	W/H
IPMM 63701	19.2	8.3	0.43	9.3	13.2	1.43
TGUSE-MM 6244	18.1	6.9	0.38	7.6	9.2	1.21

Remarks. The specimens are characterized by a small, very evolute, and highly depressed whorl, with surface ornamented with strongly radiating primary ribs with small umbilical bullae, large ventro-lateral and ventral tubercles, and two narrow minor ribs between the primaries.

Subfamily Douvilleiceratinae Parona & Bonarelli, 1897

Genus *Eodouvilleiceras* Casey, 1962

Remarks. Latil (2011) claimed that the genus *Eodouvilleiceras* is regarded as a junior synonym of the genus *Douvilleiceras*. On the other hand, Matsukawa & Shibata (2023) disagreed with Latil's (2011) opinion because of peculiar characteristics of *Eodouvilleiceras* shown in *E. matsumotoi*. In this paper, we follow the opinion of Matsukawa & Shibata (2023), and rank *Eodouvilleiceras* as an independent genus.

***Eodouvilleiceras matsumotoi* Obata, 1969**
(Fig. 44A–AA)

1969 *Eodouvilleiceras matsumotoi* Obata, p. 166–169, p. 18, figs 2, 3, 5; pl. 19, fig. 2; text-fig. 1.
2018 *Douvilleiceras matsumotoi*, Obata & Matsukawa, p. 259.
2023 *Eodouvilleiceras matsumotoi*, Matsukawa & Shibata, p. 19, fig. 9A–J.

Material. TGUSE-MM 6529A, 6529B, and 6530 (collected by I. Obata) are all from the Hiraiga Formation at location 81201, Tairajima. TGUSE-MM 6185A and 6185B (collected by I. Obata) are from the Hiraiga Formation at location Hn 4053, while TGUSE-MM 6465 (collected by I. Obata) comes from the formation at location Hn 4151. These six specimens are all preserved as partial whorls.

Locality and horizon. This genus is reported from France (Jacob, 1905), Turkmenistan (Urmanova, 1962), Caucasus (Egoian, 1969), Georgia (Eristavi, 1955), Japan (Matsumoto *et al*., 1968; Obata, 1969), Texas in USA (Scott, 1939), and Colombia (Riedel, 1938).

Remarks. Obata (1969) described *Eodouvilleiceras matsumotoi* as a new species, and also *Eodouvilleiceras* aff. *matsumotoi*, based on seven and six specimens,

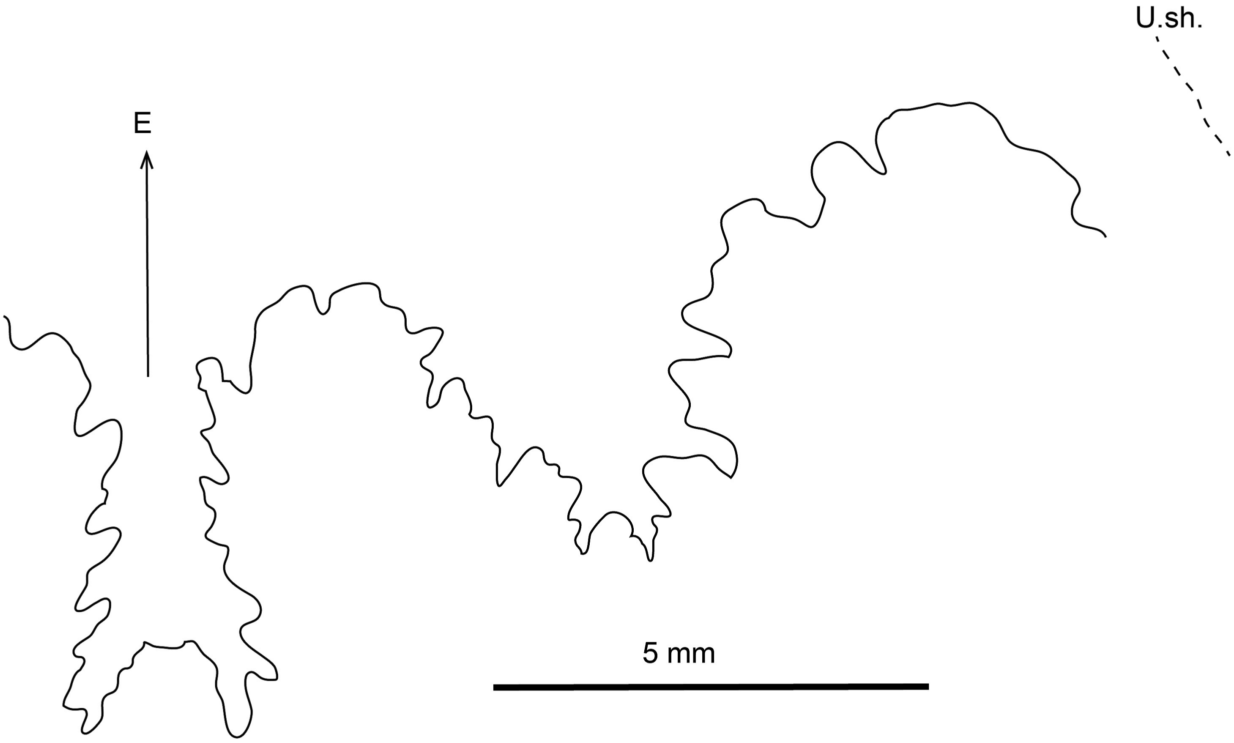

FIGURE 43. Suture of *Parachéloniceras kazuoi*, specimen IPMM 63690.

respectively, from the Hiraiga Formation. Both taxa are characterized by a strongly depressed and coronate whorl, radiating ribs which are stout and have three tubercles. The ventral tubercles are mammillate, but unlike *Douvilleiceras*, they are neither divided nor increasing in number in early stage. These characteristics suggest that they belong to the genus *Eodouvilleiceras* (Wright *et al*., 1996). In addition, the thin minor ribs are sandwiched between the main stout major ribs with three tubercles; this characteristic is shared with *Eodouvilleiceras horridum*, a representative species of the genus *Eodouvilleiceras* (Riedel, 1938).

According to Obata (1969) (fig. 19), *Eodouvilleiceras matsumotoi* is characterized by a strongly depressed whorl (W/H ranges from 1.51 to 2.07), a moderately wide umbilicus (U/D ranges from 0.38 to 0.45) with a subangular top slightly above the umbilical shoulder, simple ribbing, mammilliform tubercles but undivided ventral tubercles, and applicable distance between the two ventral tubercles. In contrast, *Eodouvilleiceras* aff. *matsumotoi* is characterized by a fairly depressed whorl (W/H ranges from 1.29 to 1.58), a fairly narrow umbilicus (U/D ranges 0.25 to 0.35), coarse and less numerous ribs, nodes, and a short distance between the two ventral tubercles. In addition, we, here, add the characteristics of the two juvenile shells; ribs of both species are simple and rectiradiate, and the distance between the ribs of *E. matsumotoi* is greater than that on *E*. aff *matsumotoi*. The minor ribs of *E*. *matsumotoi* are very weak and few in number (0 to 2), while those of *E*. aff. *matsumotoi* are distinct and numerous (2 to 4).

Obata (1969) mentioned that the specimens identified as *E*. aff. *matsumotoi* may be a new species, but he hesitated to establish the new species until more specimens could be obtained. With regard to *E*. *matsumotoi*, however, the specimen described here has the characteristic that one minor rib is sandwiched between the major ribs and can be classified as *E*. *matsumotoi*. Since this specimen is larger than the type specimens, it shows a characteristic of the adult shell of this species. The conclusion is still pending on *E*. aff. *matsumotoi*.

Casey (1962, p. 261) established the genus *Eodouvilleiceras* based on the specimen of *Douvilleiceras horridum* (Riedel, 1938, p. 29–31, pl. 6, figs 1, 2) from the lower Albian at Utica in Colombia as type species for the genus. Regarding, its age and location, Casey (1962, text-fig. 90) described as "from Upper Aptian, near Bogota, Colombia". The specimen identified as *Eodouvilleiceras horridum* (Riedel, 1938) is characterized by simple radiating ribs that alternate with major ribs showing umbilical, lateral, and ventral tubercles, and minor ribs. The ventral tubercles are mammillate and divide into two on later whorls but are undivided on the early whorls. These characteristics are similar to those of the specimens of *Eodouvilleiceras matsumotoi* (Obata, 1969, p. 166–

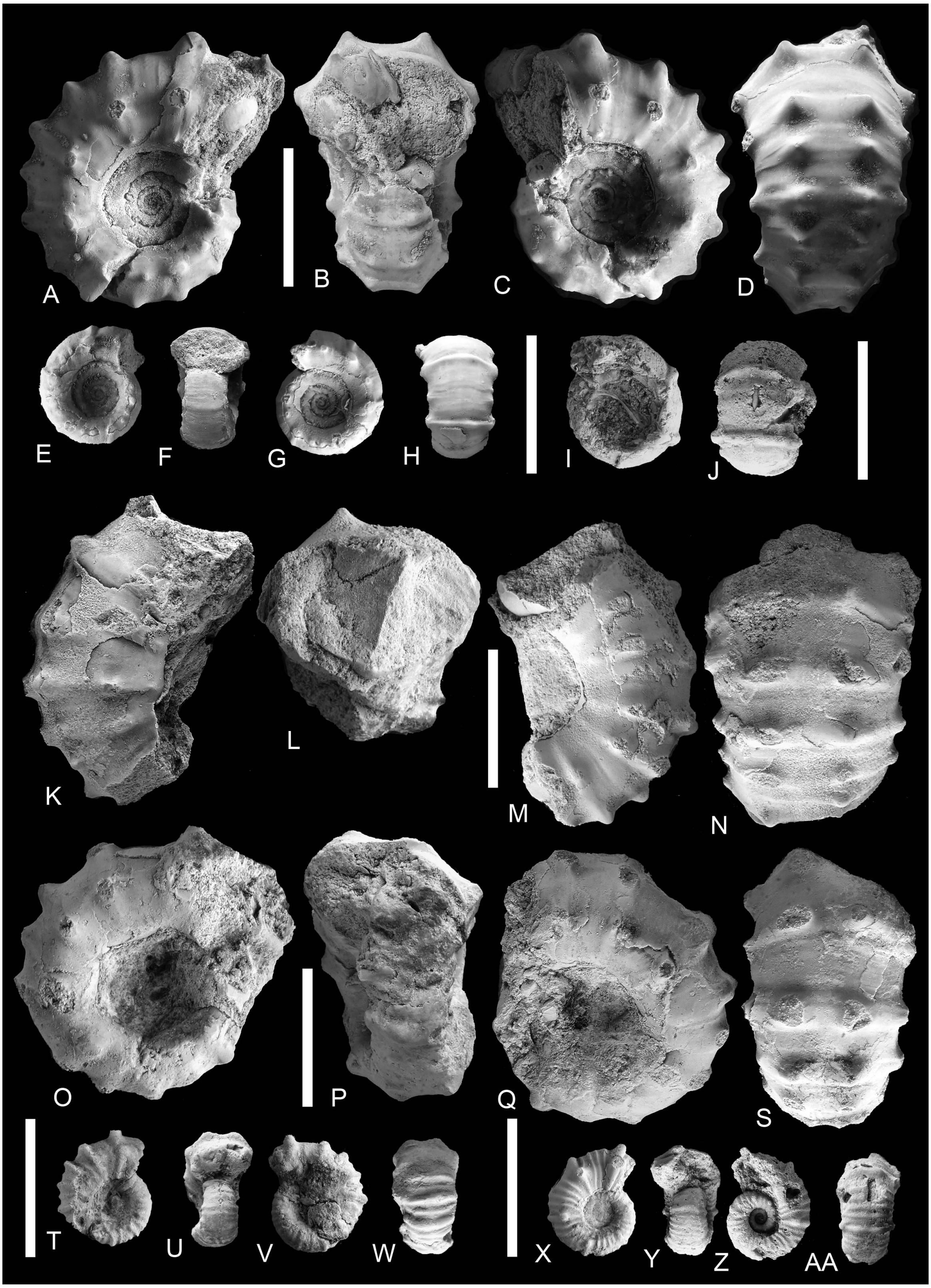

FIGURE 44. A–**J**, *Eodouvilleiceras matsumotoi*. **A**–**D**, NSM-PM 7272 (collected by I. Obata) (holotype), shell, from loc. Hn 4201 (specimen = Obata, 1969, pl. 18, fig. 5a–d in Obata, 1969). **E**–**H**, NSM-PM 7264 (collected by I. Obata) (paratype), shell, from loc. Hn 4151 (specimen = Obata, 1969, pl. 18, fig. 2a–c). **I** and **J**, NSM-PM 7268 (collected by I. Obata) (paratype), shell, from Hn 4152 (specimen = Obata, 1969, pl. 18, fig. 3a, b). **K**–**AA**, *Eodouvilleiceras* aff. *matsumotoi*. **K**–**N**, NSM-PM 7262 (collected by I. Obata), shall, from Hn 4151 (specimen = Obata, 1969, pl. 18, fig. 4a–c). **O**–**S**, NSM-PM 7261 (collected by I. Obata), shell, from Hn 4151 (= Obata, 1969, pl. 18, fig. 6a–c). **T**–**W**, NSM-PM 7265 (collected by I. Obata), shell, from Hn 4151. **X**–**AA**, MSM-PM 7267 (collected by I. Obata), shell, from Hn 4151 (specimen = Obata, 1969, pl. 19, fig. 1a–d). Scale bars = 1 cm.

169, p. 18, figs 2, 3, 5; pl. 19, fig. 2; text-fig. 1). As shown herein, the later growth whorls of *E. matsumotoi* exhibit ventral tubercles which are divided into three, which is different from that of *E. horridum*.

The major ribs of specimens identified as *Eodouvilleiceras matsumotoi* and *E.* aff. *matsumotoi* are not bifurcated. This indicates that the genus *Eodouvilleiceras* does not have the principal characteristics of the genus *Epicheloniceras* having bifurcate ribs. Therefore, it does not support the interpretation of Latil (2011) that the genus *Eodouvilleiceras* is ontogenetically a juvenile of the genus *Douvilleiceras* and is derived from the genus *Epicheloniceras*.

Genus *Douvilleiceras* Grossouvre, 1894

***Douvilleiceras spiniferum* (Whiteaves, 1900)**
(Fig. 45E, F)

1876 *Ammonites Stoliczkanus* variety *spiniferum* Whiteaves, p. 24, pl. 3, fig. 1, text-fig. 2.
1900 *Acanthoceras spiniferum*, Whiteaves, p. 273, pl. 35, figs 2, 3, 3a.
1938 *Douvilleiceras restitutum* Anderson, p. 175, pl. 54, fig. 2.
1970 *Douvilleiceras spiniferum*, Jeletzky, pl. 25, figs 1a, b, 4a, b, c.
1972 *Douvilleiceras spiniferum*, McLearn, p. 62, pl. 10, figs 1a, b, c, 2a, b, c 3a, b, c; pl. 11, fig. 1A, B, C (= specimen Whiteaves, 1876, pl. 3, fig. 1), fig. 2A, B, C (= Jeletzky, 1970, pl. 25, fig. 4a, b, c), pl. 28, fig. 1A, B, C.
2018 *Douvilleiceras spiniferum*, Futakami & Haggart, p. 288, fig. 11.

Material. A single specimen, TGUSE-MM 6171 (collected by I. Obata) is an internal mould and comes from fine sandstone beds of the Aketo Formation at location Hiraname-dana.

Locality and horizon. The species is reported from British Columbia in Canada (Whiteaves, 1876) and California in USA (Futakami & Haggart, 2018). This is the first record of the species from Japan.

Measurements (in mm except for U/D and W/H).

	D	U	U/D	H	W	W/H
TGUSE-MM 6171	51.5*	23.4	0.45*	17.4	18.5*	1.06*

* approximate

Remarks. The specimen is characterized by a fairly small, fairly depressed and evolute whorl, almost quadrangular with rather narrow flat venter, round ventral shoulder, fairly wide umbilicus, deep and vertical umbilical wall, and coarse and thick, slightly rursiradiate ribs with tubercles. Ribs arise at umbilical tubercles, trend straight and slightly radiately across the flank, and cross the venter orthogonally. There are six tubercles on ribs on the flanks and venter and a very shallow and wide ventral sulcus. These tubercles correspond to three ventro-lateral tubercles (set 1) and three tubercles, umbilical, inner lateral, and lateral tubercles (set 2) of Futakami & Haggart (2018). Tubercles of set 2 are prominent, with spines. According to Futakami & Haggart (2018), species of the genus *Douvilleiceras* can be differentiated based on the number of tubercles in two sets (set 1 and set 2). Since *D. spiniferum* (Whiteaves) is characterized by three or four in set 1 and three in set 2 (Futakami & Haggart, 2018), the present specimen can be identified as *D. spiniferum* (Whiteaves). Prominent tubercles on set 2 of the present specimen also support this identification.

***Douvilleiceras bifurcatum* sp. nov.**
(Figs 45A–D; 46A–J)

1969 *Douvilleiceras mammillatum*, Obata, p. 172–174, pl. 19, figs 3, 5.

Material. Nine specimens, IPMM 63678–63682, 63684, 63685 (holotype) , 63687 (paratype), and 63689 (collected by K. Komori) come the uppermost Hiraiga Formation at location KK. The other three specimens (collected by I. Obata), NSM-PM 7242 and 7276 from the Aketo Formation at location Hn 6200, and NSM-PM 7275 from the uppermost Hiraiga Formation at location Hn 6203, were once described as *Douvilleiceras mammillatum* (Obata, 1969, p. 172–174, pl. 19, figs 3, 5).

Etymology. *Douvilleiceras* with bifurcated ribs.

Diagnosis. Shell is moderate in size. Whorl is evolute, fairly depressed and coronate in cross-section. Umbilicus is moderately wide. Surface is ornamented with stout and rectiradiate ribs with tubercles. The ribs are coarse and stout in the early growth stage and become dense and weaken in later growth stages. On the early growth shall, some ribs branch into two at lateral tubercles that number three, being umbilical, lateral and mammilliform ventro-lateral, becoming five (umbilical, lateral and three ventro-lateral) in the later growth stage. Tubercles of ventro-lateral rows divide into two on the early shell or three on the later shell. The median ventral sulcus is rather wide.

Locality and horizon. The genus is reported from Albian of England (Spath, 1923a; Casey, 1962), Spain (Martinez *et al*., 1994), France (Orbigny, 1850; Matrion, 2010), Germany (Stahlecker, 1935), Slovakia (Rukús *et al*., 1995), Hungary (Szives, 2007), Romania (Chiriac, 1981), Bulgaria (Dimitrova, 1967; Ivanov, 1991), Georgia (Sharikadze & Kotetishvili in Kotetishvili *et al*., 2005), Turkmenistan (Mirazoyev, 1967), Kazakhstan

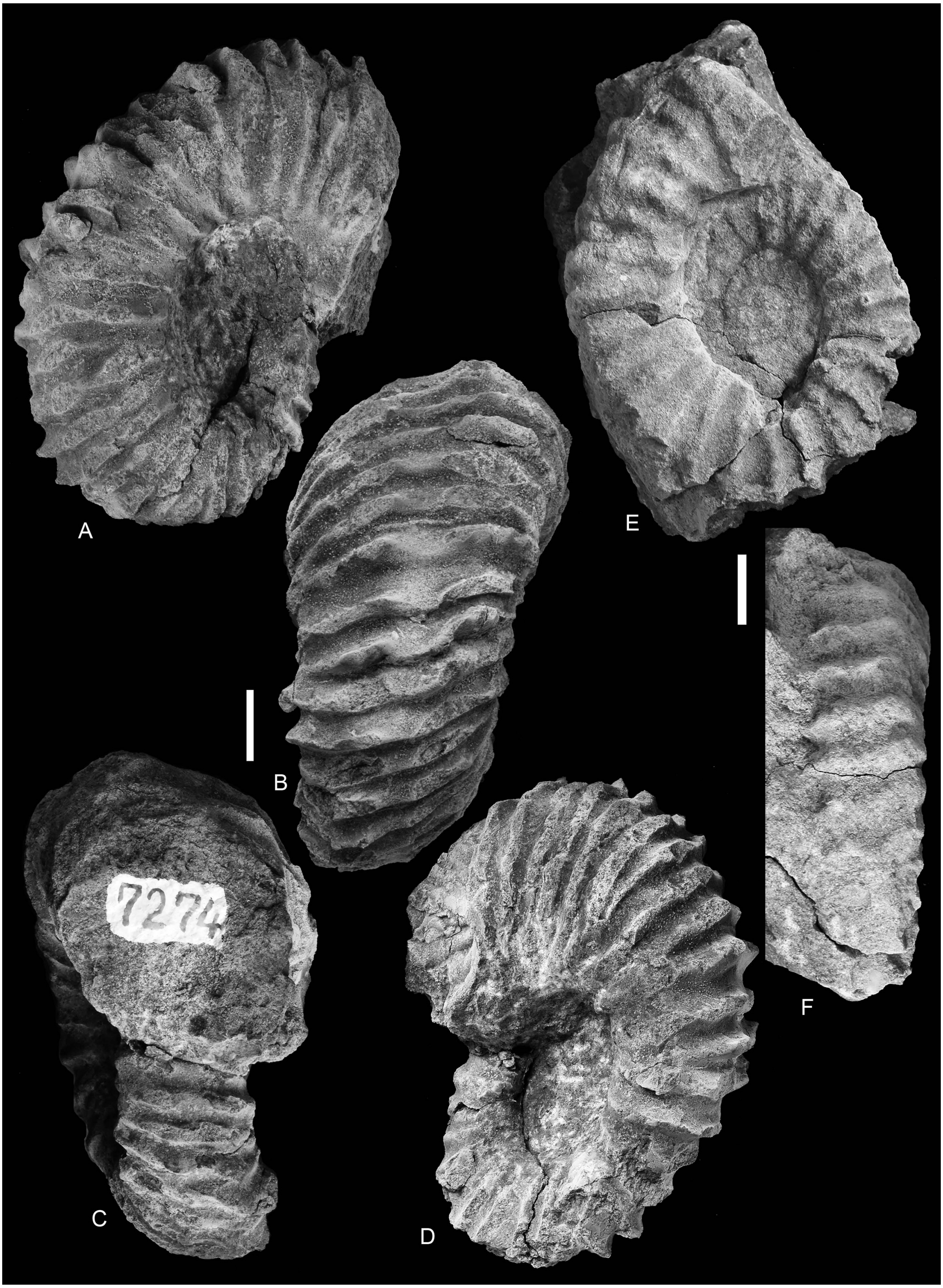

FIGURE 45. A–D, *Douvilleiceras bifurcatum*, NSM-PM 7274 (collected by I. Obata), internal mould, from loc. Hn 6200 (specimen = Obata, 1969, pl. 19, fig. 3a-d). **E** and **F**, *Douvilleiceras spiniferum*; TGUSE-MM 6171 (collected by I. Obata), internal mould, from loc. Hiraname-dana. Scale bars = 1 cm.

(Saveliev, 1992), Iran (Seyed-Emani & Immel, 1995), British Columbia (Canada) (McLearn, 1972), California (U.S.A.) (Anderson, 1938), Arizona (Stoyanow, 1949), New Mexico (Lucas, 2000), Texas (U.S.A.) and Mexico (Young, 1974), Dominican Republic (Myczyński & Iturralde-Vinent, 2005), Colombia (Etayo-Serna, 1979), Peru (Robert, 2002), Brazil (Maury, 1936), Tunisia (Latil, 2008), Madagascar (Collignon, 1963), Somalia (Tavani, 1949), Angola (Cooper, 1982) and Japan (Obata, 1969; Futakami & Haggart, 2018).

Description. (1) IPMM 63678. Shell diameter is 46.8 mm. The shell is very small, strongly depressed, with moderately wide umbilicus. Whorl is very evolute with coronate cross-section. The maximum width of the whorl is some distance below the mid-flanks. The umbilicus is deep, with steep wall which rounds to flanks. Surface is ornamented with radiate and stout ribs with three tubercles. Ventro-lateral tubercles are mammillate in form and divide into two on the tops. The median ventral sulcus is wide.

In the inner, earlier whorl, the ribs arise at the umbilical seam, trend straight with stout lateral tubercle across the flanks and with stout mammilliform ventro-lateral tubercles on the ventro-lateral shoulder and cross the venter orthogonally. On the later whorls, the ribs subsequently change, arising at small tubercle on the umbilical margin, then trending straight along the flanks and crossing the venter orthogonally. There are three tubercles, in the umbilical, lateral and ventro-lateral positions. The lateral is stoutest, the ventro-lateral is medium strongly and the umbilical is very small. Some ribs branch into two at the lateral tubercles. Ribs lacking tubercules are sometimes intercalated.

On the outer whorl, the ribs arise at small tubercles on the umbilical shoulder, trend straight across the flanks and cross the venter orthogonally. Some ribs bifurcate two at the lateral tubercle. Three tubercles, umbilical, lateral, and ventro-lateral, increase strength from umbilical to ventro-lateral through lateral positions. The ventro-lateral tubercles are mammillate and divide into two on their tops.

(2) IPMM 63685. Shell diameter is *ca.* 114 mm. The left half of the shell and its inner part are lost. Whorl is moderately depressed and evolute, and its cross-section is coronate. The maximum width of the whorl is at some distance below the mid-flank. Umbilicus is rather shallow and round to flanks. Surface is ornamented with dense radiate ribs which arise at the umbilical seam, trend straight, and cross the venter orthogonally. Some ribs branch into two at the lateral tubercle. There are small umbilical tubercles, large and stout lateral tubercles and four ventro-lateral tubercles. The four ventro-lateral tubercles become larger from the umbilical side to the ventral side. Among the ventro-lateral tubercles, the top of the tubercles on the central side of the venter is divided into three. Of the two, the centrecentre side of the venter is smaller than the outside. Ventral sulcus is wide.

Redescription of the specimen NSM-PM 7274, identified as Douvilleiceras mammillatum (Obata, 1969)

Obata (1969, p. 172–174, pl. 19, figs 3, 5) described three specimens as *Douvilleiceras mammillatum*, NSM-PM 7274, 7275, and 7276. These specimens were collected by I. Obata from location Hn 6200 (NSM-PM 7274 and 7276), and location Hn 6203 (NSM-PM 7275). The specimen NSM-PM 7274 is slightly deformed, but it retains characteristics for species identification. The specimens are characterized by a moderate size shell (D = 77.7 in Obata, 1969), moderately wide umbilicus (U= 29.3 and U/D = 0.39 in Obata, 1969), a much depressed whorl, polygonal or coronate whorl section, and dense, radial ribs with tree strong tubercles and ventral tubercles which are mammillate in the early whorl and divided into three on the later whorl. The umbilicus is deep, its wall is vertical and passes into a roundly umbilical shoulder. The ribs arise at the umbilical seam, trend straight across the flank and cross the venter orthogonally. Some ribs bifurcate at lateral tubercle on the outer whorl. Tubercles consist of umbilical, lateral, and ventral. The tubercles have small umbilical and lateral and become larger in the order of ventral position. The ventral tubercles are mammillate on the early whorl and become trifurcate on later whorls. The ventral tubercles are divided into three with the largest on the ventral side and become smaller toward the outside. The median ventral sulcus is wide and shallow.

Measurements (in mm except for U/D and W/H)**.**

Specimen	D	U	U/D	H	W	W/H
IPMM 63678	46.8	17.4	0.37	19.0	-	
-1/4 phi (paratype)	38.5	12.9	0.34	15.2	23.0	1.51
IPMM 63679	59.5	19.3	0.32	23.8	31.8	1.34
IPMM 63680	29.3	10.5*	0.36*	-	-	
IPMM 63681	-	-	-	13.6	16.7	1.23
IPMM 63682	-	-	-	-	12.4*	-
IPMM 63684	38.7	-	-	15.7	22.3	1.42
IPMM 63685 (holotype)	114*	-	-	37.1	-	-
IPMM 63687	-	-	-	18.4	-	-
IPMM 63689	66.4+	-	-	-	-	-

* approximate

Remarks. The specimens are characterized by (1) dense and stout ribs with multiple tubercles, (2) mammilliform ventro-lateral tubercles which divide into two on their top, and (3) some ribs which bifurcate into two at the lateral tubercle. Characteristics (1) and (2) indicate that the specimens belong to the genus *Douvilleiceras* (Wright *et al*., 1996). The bifurcation of ribs at the lateral tubercles indicates that the specimens are phylogenetically related with the genus *Epicheloniceras*. Since Casey (1962) designated the genus *Douvilleiceras* as forms the ribs do not bifurcate from the lateral tubercle, it is better to consider that the bifurcated ribs of the present specimens are characteristic of the species. The bifurcated rib at the lateral tubercle of the species is a unique characteristic among the genus *Douvilleiceras*. The characteristic is not confirmed in, for examples, *Douvilleiceras mammillatum* (Casey, 1962, p. 265–271, pl. 40, fig. 4; pl. 41, fig. 4a, b; pl. 42, figs 6, 9a, b; text-fig. 102a, b) from England and *D. spiniferum* (Futakami & Haggart, 2016, p. 47–51, figs 4–9) from British Columbia, Canada.

Douvilleiceras leightonense (Casey, 1962, p. 274–277, pl. 41, fig. 1a, b; pl. 42, fig. 3; text-figs 96, 97, 102i, 103e–h) from England is characterized by ribs which tend to unite in pairs at large flat umbilical spine-bases. Bundled ribs characteristic of *D. leightonense* are similar to *D. bifurcatum*. Since the position where the ribs are bundled is the umbilical margin in *D. leightonense,* whereas it is at the lateral tubercle in *D. bifurcatum*, it is reasonable to judge that they are different species.

***Douvilleiceras* sp.**
(Fig. 47A, B)

Material. A single specimen, SKM-SS 062-006 (collected by F. Sasaki), shows the ontogenetic shell-growth, although the shell is obliquely deformed. The specimen is an internal mould and comes from the Hiraiga Formation at location Ks2005.

Locality and horizon. The species occurs with *Hypacanthoplites subcornuerianus* and *Diadochoceras nodosocostatiforme*. These species suggest that the lithostratigraphic horizon is the upper Aptian, thus, *D*. sp. is the oldest occurrence record of the genus *Douvilleiceras*.

Measurements (in mm except for U/D and W/H)**.**

Specimen	D	U	U/D	H	W	W/H
SKM-SS 062-006	67.3*	11.0	0.16*	28*	28*	1.0*

* approximate

Description. The specimen is characterized by broad and low, thick, depressed whorl with narrow and deep umbilicus, and dense and thick, radial primary ribs and thin secondary ribs. The primary ribs arise at the umbilical seam, trend across the flank, and cross the venter orthogonally. The primary ribs are coarse on the inner whorl and become crowded on the outer whorl. The ribs have umbilical bullae, lateral tubercles and a mammillate ventral tubercle which splits into three. On the early whorls, the umbilical bullae and lateral tubercles are not prominent, and the ventral tubercles are prominent but not divided. Where the ventral-tubercles divide into three, the largest is in the mid-venter position and the smallest is at the outside. The ventral sulcus is shallow and narrow. Secondary ribs lacking tubercles are only found on the middle growth-stage of whorl and are inserted between the primaries. Using the *Douvilleiceras* tubercles expression presented by Futakami & Haggart (2018), the specimen can be expressed as the Set 1 consisting of 2 (ventrolateral) tubercles, and the Set 2 consisting of two (lateral and umbilical) tubercles.

Remarks. The surface features of this specimen, including three branched mammillate ventrolateral ribs, umbilical bullae, lateral tubercles, and three branched ventrolateral ribs on the surface of the late spiral rings, suggest that this specimen can be classified as the genus *Douvilleiceras*. The secondary ribs inserted between the primaries of the middle growth-stage of whorl, and the tubercles expression of Set 1 and the Set 2 of 3 and 2, respectively, suggest the specimen may be a new species. Other species of *Douvilleiceras* with the tubercle expression of the species of *Douvilleiceras* with the similar to the present specimen (Futakami & Haggart, 2018), *e.g*., the Set 1 of *Douvilleiceras spiniferum* is 3 and/or rarely 4, while the Set 2 is 3, include *D. leightonense* (Set 1, 2 are 4 and 3, respectively), and *D. solitae* (3 and 3, respectively), while that of *D. mammillatum* is 5 and/or 7 and 3, respectively. Based on the characteristics of the coarse primary ribs with distinct ventral tubercles in the inner whorl, and the inserted secondary ribs in the middle whorl of the present specimen, we suggest that the present species may be related to the genus *Eodouvilleiceras.*

Family Trochleiceratidae Breistroffer, 1951
Genus *Pseudoleymeriella* Casey, 1957

***Pseudoleymeriella hataii* Obata, 1973**
(Figs 40G–N; 48A–N)

1931 *Hoplites* aff. *dentatus*, Shimizu, p. 28–29, pl. 4, figs 10, 11.
1973 *Pseudoleymeriella hataii* Obata, p. 309–312, pl. 34, figs 1, 2, 4, 5, 7, 8; text-figs 1, 2.
2013 *Pseudoleymeriella hataii*, Inose *et al*., fig. 5-2a, b.
2023 *Pseudoleymeriella hataii*, Matsukawa & Shibata, p. 20–21, fig. 9K–M.

Material. 40 specimens in total. IGPS36513 (collected by S. Shimizu) comes from Hiraname-dana. Three specimens, IPMM 63740, 63743, and 63744 (collected by K. Komori), come from the uppermost Hiraiga Formation at location KK. 36 specimens (collected by I. Obata) come from the Aketo Formation; TGUSE-MM 6131,

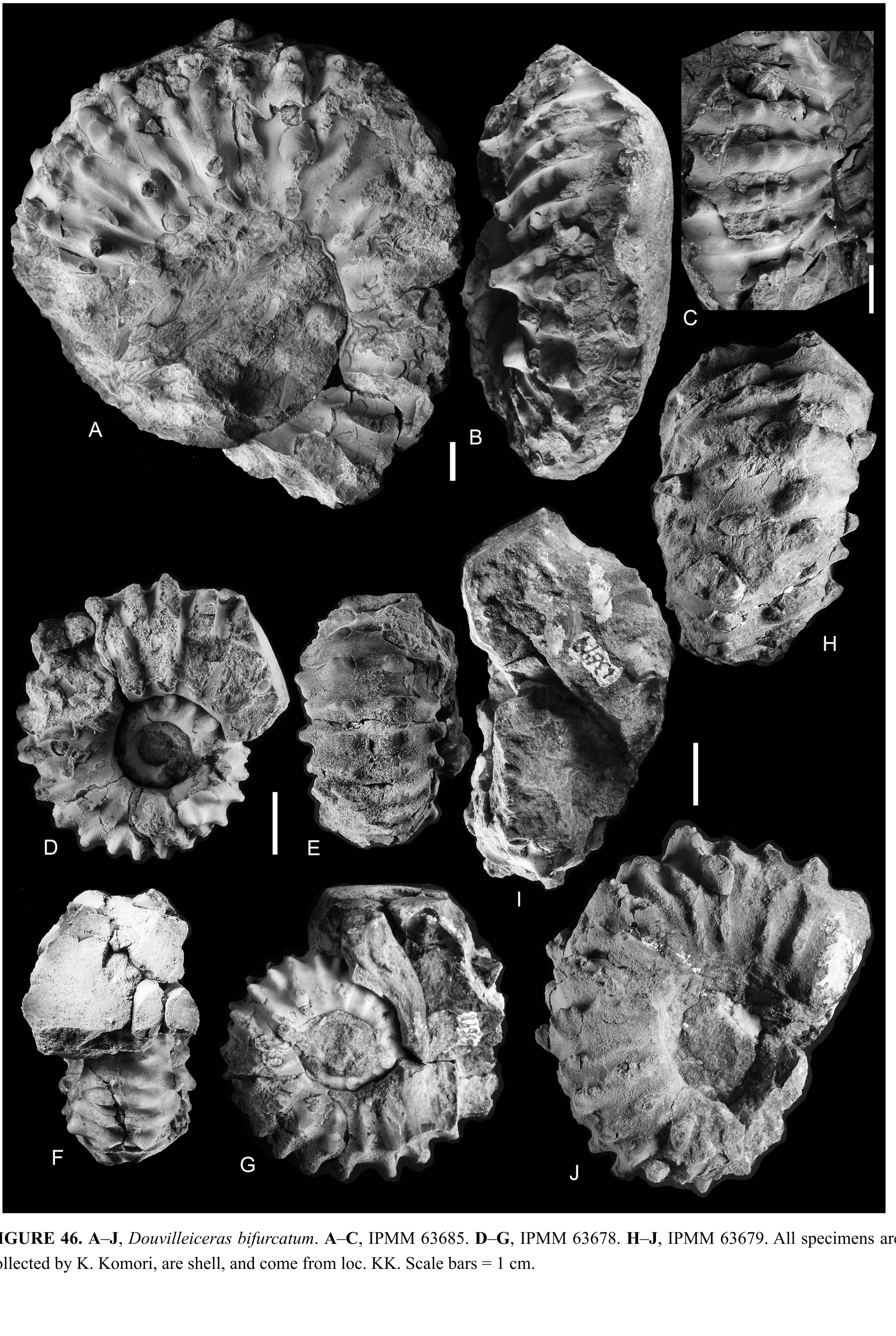

FIGURE 46. A–**J**, *Douvilleiceras bifurcatum*. **A**–**C**, IPMM 63685. **D**–**G**, IPMM 63678. **H**–**J**, IPMM 63679. All specimens are collected by K. Komori, are shell, and come from loc. KK. Scale bars = 1 cm.

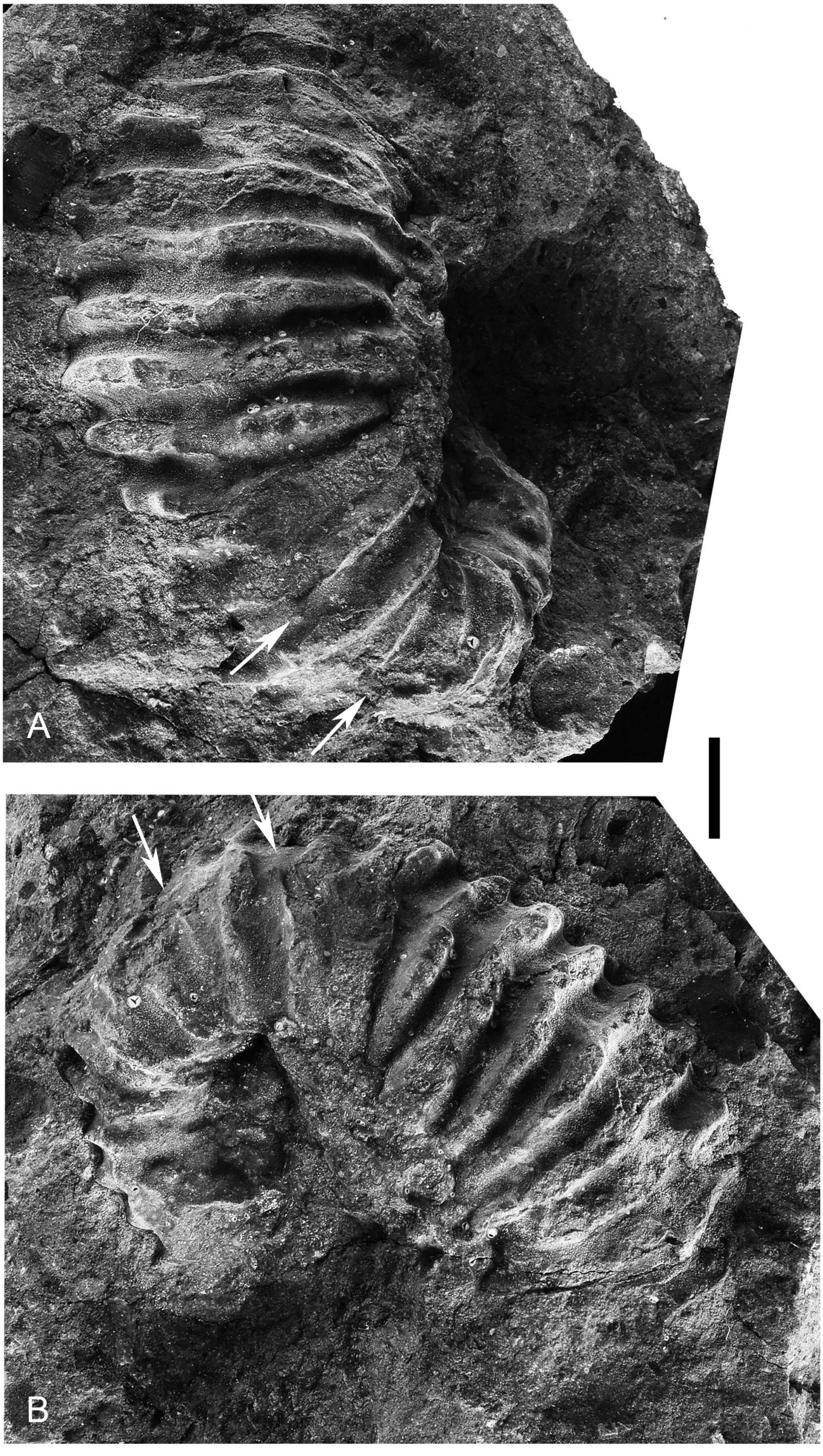

FIGURE 47. A, **B**, *Douvilleiceras* sp., SKM-SS 062-006 (collected by F. Sasaki), internal mould, from Ks2005. Arrows show minor rib. Scale bar = 1 cm.

6132, 6133, 6134, and 6138–6146 come from location at Hn 0650; TGUSE-MM 6179A, 6179B, 6180A, 6442, 6444A, 6534, 6535, 6536, 6538, 6539, 6541, 6543, 6547B, 6548B, 6549, 6551, and 6552 come from location C6p; TGUSE-MM 6525 comes from location Hiraname-dana; TGUSE-MM 6460A, 6460B, 6460C, and 6460D come from location Hn0679; and TGUSE-MM 6569 comes from location C5p.

Locality and horizon. The genus is reported from the Aptian of Spain (Wiedmann, 1966), British Columbia (Canada) (Whiteaves, 1893), and Japan (Obata, 1973).

Measurements (in mm except for U/D and W/H).

Specimen	D	U	U/D	H	W	W/H
IPMM 63740	15.8	7.3		5.9	-	-
IPMM 63743	15.5	5.0*	0.33*	5.5	4.3	0.79
IPMM 63744	22.6	5.6	0.25	9.6	9.8	1.02
TGUSE-MM 6179A	15.9	5.3	0.33	6.5	-	-
TGUSE-MM 6442	14.3	5.2	0.36	4.6	-	-

* approximate

Remarks. The specimens are characterized by a very small, fairly depressed, and moderately involute whorl, with surface ornamented with dense radial ribs interrupted on the venter, ribbing consists of primaries and inserted secondaries. The ribs have ventral tubercles.

These characteristics suggest that the specimens can be identified as *Pseudoleymeriella hataii* (Obata, 1973, p. 309–312, pl. 34, figs 1, 2, 4, 5, 7, 8; text-figs 1, 2) from the upper part of the Hiraiga Formation and the lower part of the Aketo Formation at Raga in Tanohata Village, Iwate Prefecture. With respect to the specimen (IGPS) described as *Hoplites* aff. *dentatus* (Shimizu, 1931, p. 28–29, pl. 4, figs 10, 11) from the Aketo Sandstone (= Aketo Formation) at Aketo (Hiraname-dana), it was confirmed that only the external mould of the specimen is currently kept at the Tohoku University Museum (confirmed on February 20, 2023, by MM). The specimen is a partial whorl, and is characterized by very small, fairly depressed whorl and surface ornamented with dense radiate ribs consisting of primaries and inserted secondaries. Although the ribs are interrupted on the venter, and the ventral tubercles are not able to be confirmed due to lost of the shell, these characteristics are similar to those of other specimens identified as the *P. hataii* and are sufficient for identification with this species.

Pseudoleymeriella hiranamensis **Obata, 1973**
(Figs 40A–F; 48P–AC)

1973 *Pseudoleymeriella hiranamensis* Obata, p. 312–315, pl. 34, figs 3, 6.

Material. Seven specimens in total. Three specimens, IPMM 64741, 64742A, and 63745 (collected by K. Komori), come from the Hiraiga Formation at location KK. The other four specimens come from the Aketo Formation and include TGUSE-MM 6432 and 6433 (S. Ogino collector), from the location Hiraname-dana, Hiraname, and TGUSE-MM 6443 and 6533 (collected by I. Obata), from the location C6p.

Locality and horizon. Type specimens, NSM-PM 7284 (holotype) and NSM-PM 7286 (paratype), described by Obata (1973), are from the Aketo Formation at locations Hn 0650 and Hn 6201, respectively.

Measurements (in mm except for U/D and W/H).

Specimen	D	U	U/D	H	W	W/H
IPMM 63741	11.8	4.3	0.36	4.2	4.9	1.17
IPMM 63742A	9.2	-	-	2.3	3.4	1.48
IPMM 63745	15.9	-	-	5.2	5.4	1.04
TGUSE-MM 6433	12.6	3.8	0.30	-	6.1	-

Remarks. Because they show characteristics of the genus *Pseudoleymeriella*, and also exhibit lateral tubercles, the specimens are identified as *Pseudoleymeriella hiranamensis* (Obata, 1973, p. 312–315, pl. 34, figs 3, 6), the type of which comes from the upper part of the Hiraiga Formation to the lower part of the Aketo Formation at Raga in Tanohata Village, Iwate Prefecture. The present specimens are more depressed than the type specimens of the present species

Pseudoleymeriella obatai **Matsukawa & Oji, 2021**
(Fig. 48O)

2021 *Pseudoleymeriella obatai* Matsukawa & Oji, p. 153–154, figs 6J–L, 7L–O.

Material. A single specimen, IPMM 63713 (collected by K. Komori), only preserves the ventral part of the shell. The specimen comes from the uppermost Hiraiga Formation at location KK.

Locality and horizon. The species is only reported from the Miyako Group.

Measurements (in mm except for U/D and W/H).

Specimen	D	U	U/D	H	W	W/H
IPMM 63713	-	-	-	-	10.5*	-

* approximate

Remarks. Because it is a *Pseudoleymeriella* with broad whorl, and with primary ribs interrupted on the venter and bifurcating at lateral tubercles on the later whorl, the specimen is identified as *Pseudoleymeriella*

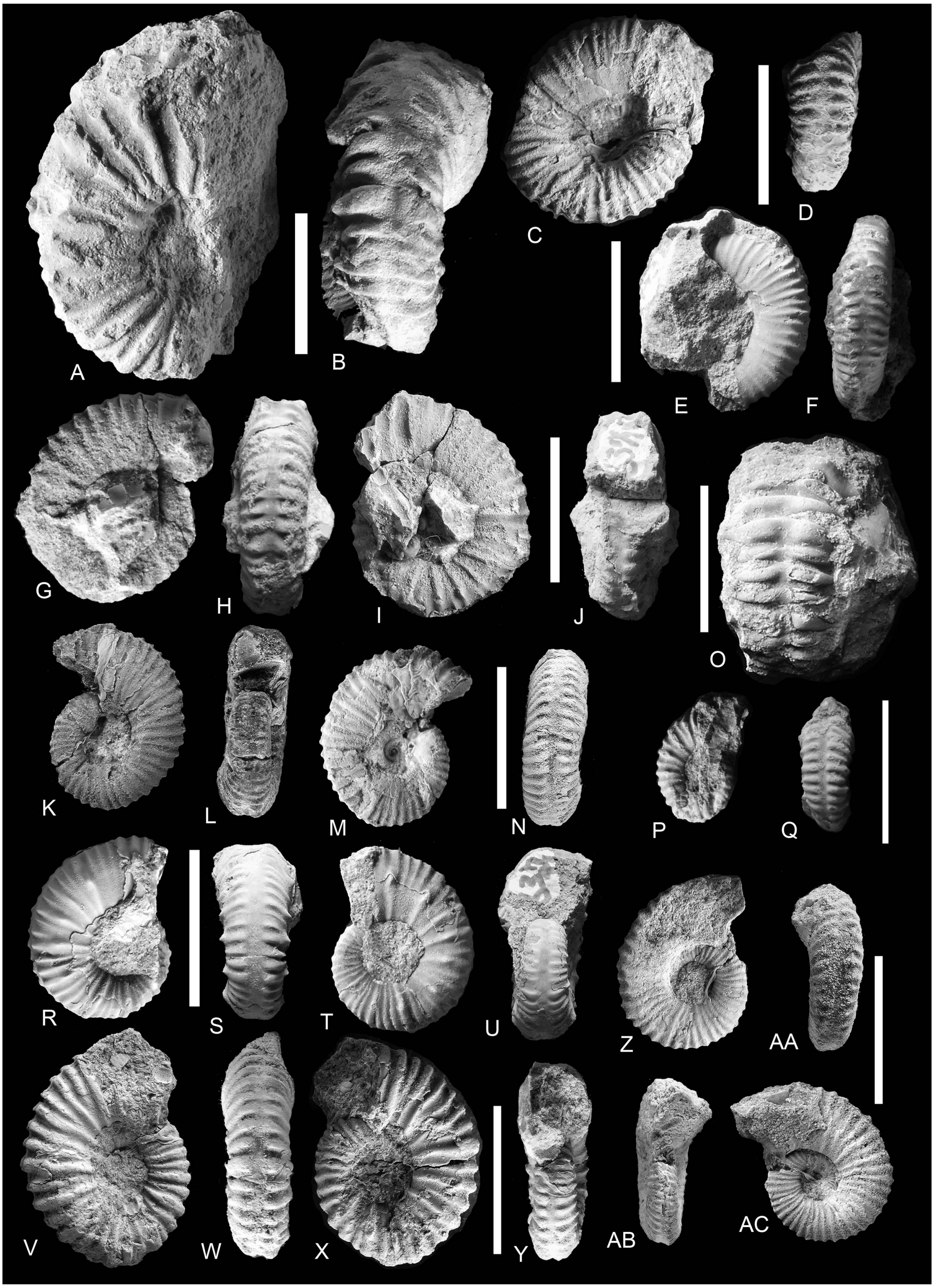

FIGURE 48. **A**–**N**, *Pseudoleymeriella hataii*. **A**–**B**, IPMM 63744 (collected by K. Komori), internal mould, from loc. KK. **C**–**D**, TGUSE-MM 6131 (collected by I. Obata), internal mould, from loc. Hn 0650. **E**–**F**, IPMM 63743 (collected by K. Komori), shell, from loc. KK. **G**–**J**, IPMM 63745 (collected by K. Komori), internal mould, from loc. KK. **K**–**N**, NSM-PM 7282 (collected by I. Obata) (holotype), internal mould, from loc. Hn 0650 (specimen = Obata, 1973, pl. 34, fig. 1a–d). **O**, *Pseudoleymeriella obatai*; IPMM 63719 (collected by K. Komori), shell, from loc. KK. **P**–**AC**, *Pseudoleymeriella hiranamensis*; **P**–**Q**, IPMM 63742 (collected by K. Komori), shell, from loc. KK. **R**–**U**, IPMM 63741 (collected by K. Komori), shell, from loc. KK. **V**–**Y**, NSM-PM 7284 (collected by I. Obata) (holotype), shell, from loc. Hn 0650 (specimen = Obata, 1973, pl. 34, fig. 6a–d). **Z**–**AC**, NSM-PM 7286 (collected by I. Obata) (paratype), shell, from loc. Hn 6201 (specimen = Obata, 1973, pl. 34, fig. 3a–c). Scale bars = 1 cm.

obatai (Matsukawa & Oji, 2021, p. 153–154, figs 6J–L, 7L–O), from the Hiraiga Formation of the Miyako Group in Taro, Iwate Prefecture.

Family Parahoplitidae Spath, 1922
Subfamily Acanthohoplitinae Stoyanow, 1949
Genus *Colombiceras* Spath, 1923a

***Colombiceras yaegashii* (Shimizu, 1931)**
(Fig. 40R–T)

1931 *Parahoplites yaegashii* Shimizu, p. 30–32, pl. 2, figs 1–3; pl. 3, figs 1, 2.
1992 *Nolaniceras yaegashii*, Obata & Futakami, p. 34–35.
2018 *Nolaniceras* (?) *yaegashii*, Obata & Matsukawa, p. 259–261, figs 33A–D, 35K–L.

Material. Three specimens. (1) IGPS 36509; the specimen has been described as *Parahoplites yaegashii* by Shimizu (1931), *Nolaniceras yaegashii* by Obata & Futakami (1992) and *Nolaniceras* (?) *yaegashii* by Obata & Matsukawa (2018). The specimen comes from the upper part of the Hiraiga Formation at location near OH5. (2) TGUSE-MM 6271; the specimen has been described as *Nolaniceras* (?) *yaegashii* by Obata & Matsukawa (2018). The location is C21, although it was once described as loc. SMK. (3) TGUSE-MM 6272 (collected by I. Obata); a part of a whorl of the internal mould and comes from the Hiraiga Formation at location Tokuzo.

Description. (1) IGPS 36509, see Shimizu (1931, p. 30–32), Obata & Futakami (1992, p. 84–85) and Obata & Matsukawa (2018, p. 259–261); (2) TGUSE-MM 6271, see Obata & Matsukawa (2018, p. 259–261); (3) TGUSE-MM 6372; The specimen is characterized by a fairly large and compressed whorl, the cross-section of which is almost rectangular, with flat flanks or slightly swollen at mid-flank, rounded ventral shoulder and wide and almost flat venter, and dense and strong sinuous ribs. The umbilicus is shallow, moderately its width and has a vertical wall. The ribs consist of primaries and secondaries inserted. The primary ribs arise at the umbilical seam and form a slightly dog-leg bend radially across the flank. The secondary ribs arise at one-third of the distance from the umbilical margin on the flank and/or of mid-flank. One or two secondary ribs are inserted between the primaries. Both primary and secondary ribs cross the venter orthogonally.

Locality and horizon. The genus is reported from the Aptian of France (Orbigny, 1841), Switzerland (Jacob in Jacob & Tobler, 1906), Italy (Wiedmann & Dieni, 1968), Bulgaria (Dimitrova, 1967), northern Caucasus and Dagestan (Bogdanova & Mikhailova, 2016), Iran (Lehmann *et al*., 2019), India (Spath, 1930), Japan (Matsukawa, 2021), Arizona, U. S. A. (Stoyanow. 1949), Mexico (Cantu Chapa, 1963), Colombia (Sharikadze *et al*., 2004), and Madagascar (Collignon, 1962).

Measurements (in mm except for U/D and W/H**).**

	D	U	U/D	H	W	W/H
TGUSE-MM 6272	-	-	-	58.9	-	-

Remarks. The specimens are represented by later outer whorls but lack preserved inner whorls due to poor preservation. They are characterized by a compressed whorl with flattened flank or slightly swollen at mid-flank, and dense sinuous ribs that cross the venter orthogonally. Those characteristics suggest that the specimens can be assigned to the genera *Acanthoplites*, *Colombiceras*, or *Parahoplites*. The whorl compression character suggests that the specimens do not belong to the genus *Parahoplites*. In addition, the ribs which cross the venter in the genus *Parahoplites* are projected forward, while these of the genera *Acanthoplites* and *Colombiceras* are orthogonal. Additionally, the width of the umbilicus of specimens of the genus *Parahoplites* is narrower than that of the present specimens, similar to that of the genera *Acanthoplites* or *Colombiceras*. The ribs of the genus *Colombiceras* are flat-topped in early stages and rounded in later, while those of the genus *Acanthoplites* are crest like-topped throughout the different growth stages. The genus *Acanthohoplites* is characterized by having tubercles in its early growth stage while disappear in its later stages. With respect to tubercles, the genus *Colombiceras* (*C.*) lacks them throughout early to late growth stages. Considering whether the specimens belong to the genus *Acanthohoplites* or the genus *Colombiceras* (*C.*) based on the presence or absence of tubercles, the genus *Colombiceras* (*C.*) is more likely because it lacks tubercles throughout its growth. In addition, the compression of whorl in the present specimens is similar to that of the later whorl of the specimens of the genus *Colombiceras* (*C.*) than it is to the genus *Acanthohoplites*. Since the present specimens have more characteristics of the genus *Colombiceras* (*C.*) than they do of genus *Acanthohoplites,* it is more acceptable to assign the specimens to the genus *Colombiceras* (*C.*).

The specimens differ from the illustrated specimen of *Colombiceras tobleri* (Casey, 1965, text-fig. 154) from the upper Aptian of the Caucasus, in that their ribs are denser than those of the Caucasian specimens. According to Bogdanova and Mikhailova (2016, p. 863–865, pl. 16, figs 1, 2; pl. 17, figs 1, 2), who examined specimens from the middle Aptian of northern Caucasus and Dagestan, the ribs of *Colombiceras tobleri* are crest like-topped and weakly flat-topped on the venter.

Genus *Hypacanthoplites* Spath, 1923a

***Hypacanthoplites subcornuerianus* (Shimizu, 1931)**
(Figs 42M–O; 49A–C, G–N)

1931 *Acanthoplites subcornuerianus*, Shimizu, p. 32–33, pl. 1, figs 8, 9.
1968 *Hypacanthoplites subcornuerianus*, Hanai *et al*., pl. 2, fig. 6a–c.
1979 *Hypacanthoplites subcornuerianus*, Kitamura *et al*., pl. 7, fig. 5.
1980 *Hypacanthoplites subcornuerianus*, Obata & Matsukawa, p. 185–211, pls 23, 24.
2018 *Hypacanthoplites subcornuerianus*, Obata & Matsukawa, p. 14, figs 8Q, R, 9G-K.
2023 *Hypacanthoplites subcornuerianus,* Matsukawa & Shibata, p. 22, fig. 10S–X.

Material. 160 specimens in total. 16 specimens (collected by K. Komori); IPMM 63686, 63734, 63736–63739, 63746–63754, and 63800 come from the upper part of the Hiraiga Formation at location KK. 144 specimens were collected by I. Obata: TGUSE-MM 6559 and 6560 come from the Tanohata Formation at location Hn 0220; TGUSE-MM 6537 comes from the Hiraiga Formation at location Hn 0010; TGUSE-MM 6198, 6199, 6231A–D, 6233, 6515, 6518, 6563A–C, 6599A–C, 6601, 6602, 6603A–C, 6604, 6605, 6606, 6608, 6609A, 6610A–C, 6611A, B, 6612A–D, 6613A–D, and 6614 come from the Hiraiga Formation at location Hn0016; TGUSE-MM 6475–6478 and 6479 come from the Hiraiga Formation at location Hn 0017; TGUSE-MM 6480–6484, 6487A–E, 6490, 6494, TGUSE-MM 6510A–H, 6511A–J, 6512A–E, 6513, 6514A–E, 6515, 6516A–E, 6507A, 6591A–C, 6952A, B, 6597A–D, 6859A and B come from the Hiraiga Formation at location Tokuzo; TGUSE-MM 6499A–C, 6500A, B, 6501, 6506A, B, 6507A–J, 6508A, and B come from the Hiraiga Formation at location Hn 1902; TGUSE-MM 6474A–I comes from the Hiraiga Formation at location Hn 1904. TGUSE-MM 6236 is a large specimen which is obliquely deformed and comes from the Hiraiga Formation at location C21; TGUSE-MM 6434 comes from the Hiraiga Formation at location OH4.

Locality and horizon. The species is reported from the Tanohata and Hiraiga formations of the Miyako Group and the Todai Formation (Obata & Matsukawa, 2018; Matsukawa, 2021). The genus is reported from the Aptian and Albian strata of England (Casey, 1965), France (Orbigny, 1841), Germany (Kemper, 1975), Switzerland (Pictet & Campiche, 1860), Austria (Föllmi, 1989), Hungary (Szives, 2007), Romania (Chiriac, 1981), Bulgaria (Stoykova & Ivanov, 1988), Georgia (Eristavi, 1961), Caucasus (Egoian, 1969), Kazakhstan (Glazunova, 1953), Tajikistan (Luppov, 1961), Iran (Raisossadat, 2006), Somalia (Tavani, 1949), Tibet (Liu, 1988), Texas, U.S.A. (Young, 1974), Mexico (Humphrey, 1949), Colombia (Etayo-Serna, 1979), Madagascar (Collignon, 1962), Egypt (Aly *et al*., 2001), Ethiopia (Zeiss, 1975), Morocco (Witam, 1998), Algeria (Sornay, 1955), and Tunisia (Latil, 2011).

Measurements (in mm except for U/D and W/H)**.**

Specimen	D	U	U/D	H	W	W/H
TGUSE-MM 6198	12.4	3.7	0.30	5.1	6.1	1.20
TGUSE-MM 6199	-	-	-	4.1	4.5	1.10
TGUSE-MM 6236	112.0	38.3	0.34	48.5	-	-
TGUSE-MM 6429	24.3	6.8	0.28	9.2	-	-
IPMM 63737	44.1	14.0	0.32	16.5	15.9+	0.96+
IPMM 63747	24.6	7.5	0.30	9.5	9.4	0.99
IPMM 63750	30.6	9.3	0.30	11.8	10.6	0.90

Remarks. The specimens are characterized by fairly small shell, discoidal, evolute, and compressed whorl with moderate umbilicus, whorl-section is hexagonal, and shell surface ornamented with flexuous stout major and fine minor ribs. The whorl height and width are almost equal. The umbilicus is shallow and is surrounded by a vertical wall. The ribs are dense and radiating. The major ribs arise at the umbilical seam, pass along flank and cross the venter orthogonally. Ribs have umbilical bullae, lateral tubercles at mid-flank, and ventro-lateral clavi. Some ribs branch into two at the lateral tubercles on mid-flank. The minor ribs arise at the umbilical margin, mid-flank, or on the outer flank. The lateral tubercles start to disappear on later whorls. Two or three minor ribs are inserted between major ribs on the early whorls, and the minor ribs begin to alternate with major ribs on the later whorls. Ribs are dense and some branch into two at umbilical bullae on large sized later whorls (TGUSE-MM 6236). These characteristics suggest that the specimens can be identified as *H. subcornuerianus* (Shimizu, 1931) from the Miyako Group (Shimizu, 1931; Obata & Matsukawa, 1980, 2018). The present specimens differ from the type specimens of *H. kawakamii* (Obata & Futakami, 1992, p. 80–82, pls 1–3, figs 1–3) from the Hiraiga Formation of the Miyako Group in having smaller shells and short and thick whorls. The characteristics of weakening ribs and decreasing numbers of tubercles with growth are commonly confirmed in both species. The later whorl of *H. kawakamii* is slender, whereas that of *H. subcornuerianus* is short and thick. However, the ontogenetic changes of both species have not yet been compared.

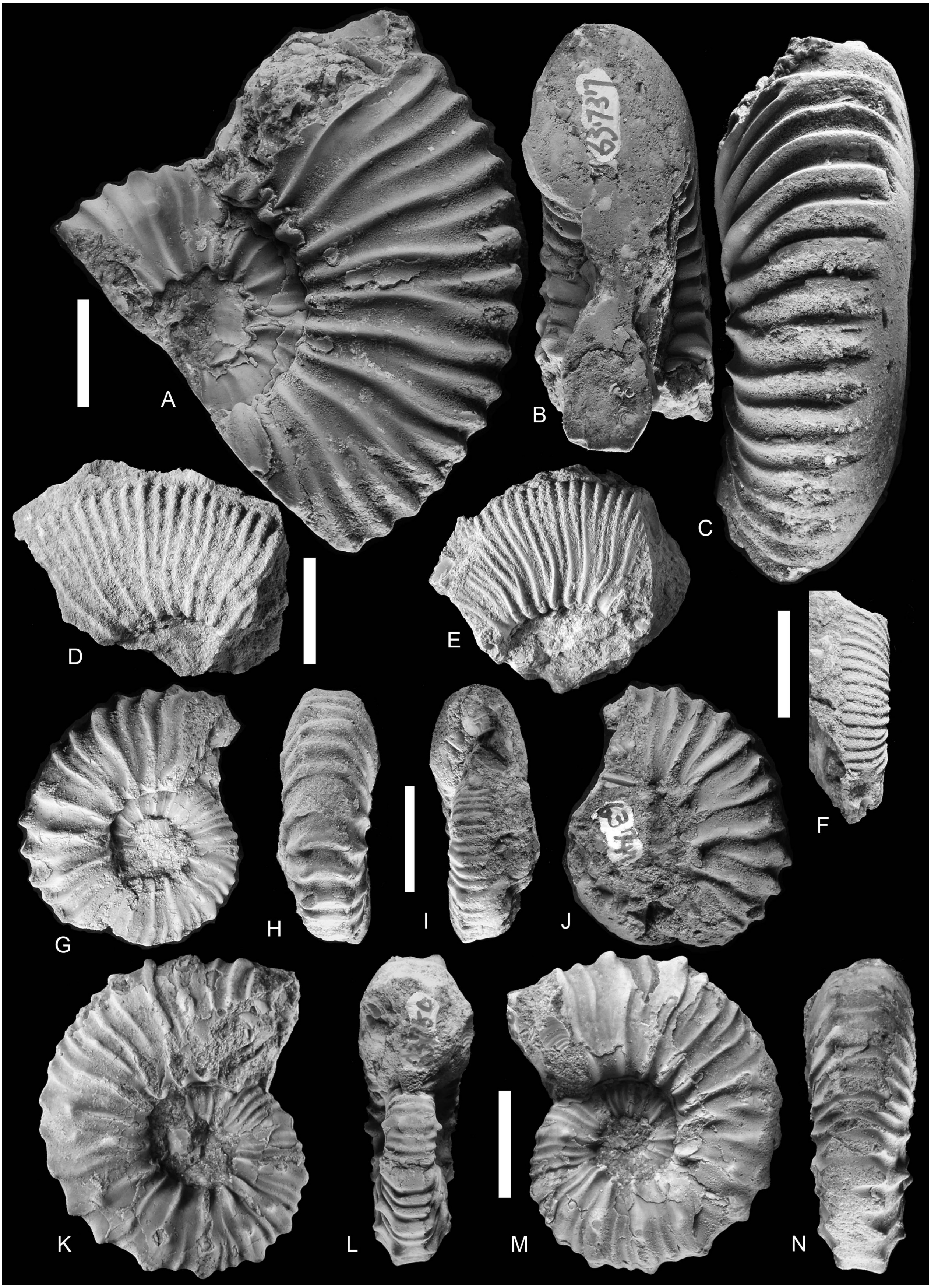

FIGURE 49. A–**C**, **G**–**N**, *Hypacanthoplites subcornuerianus*. **A**–**C**, IPMM 63737. **G**–**J**, IPMM 93747. **K**–**N**, IPMM 63750. All specimens are shells, collected by K. Komori from loc. KK. **D-F**, *Hypacanthoplites* cf. *elegans*. **D**, TGUSE-MM 6607B. **E** and **F**, TGUSE-MM 6607A, (both collected by I. Obata), internal moulds, from loc. Hn 0016. Scale bars = 1 cm.

***Hypacanthoplites* cf. *elegans* (Fritel, 1906)**
(Fig. 49D–F)

2023 *Hypacanthoplites* cf. *elegans*, Matsukawa & Shibata, p. 23, fig. 10L–O.

Material. Two specimens (collected by I. Obata), TGUSE-MM 6607A and B, are partial internal moulds, and come from the Hiraiga Formation at location Hn 0016.

Locality and horizon. *H. elegans* is reported from England (Casey, 1965), Germany (Kemper, 1982), France (Kennedy, 2000), Hungary (Szives, 2007), Bulgaria (Stoykova & Ivanov, 1988), Tajikistan (Luppov, 1961), Iran (Raisossadat, 2006), and Morocco (Peybernès *et al*., 2013).

Measurements (in mm except for U/D and W/H)**.**

Specimen	D	U	U/D	H	W	W/H
TGUSE-MM 6607A	-	-	-	11.9	-	-
TGUSE-MM 6607B	-	-	-	12.7	-	-

Remarks. The specimens are characterized by a compressed, subrectangular whorl with flat flanks that converge at one third of the outer flank to a narrow, rounded venter, a fairly narrow umbilicus, and dense and narrow ribs bending slightly on lower flank and becoming rectiradiate on the middle and outer flank. The comma-shaped ribs arise at umbilical bullae and / or at the lower, middle, or upper flank. They are bifurcate or single, trend almost straight across the flank, and cross the venter orthogonally. The specimens are similar to the illustrated specimens of *Hypacanthoplites elegans* (Casey, 1965, p. 439–441, pl. 71, fig. 1a, b; pl. 72, fig. 3; pl. 74, fig. 10a, b; text-fig. 163a, b, c) from the upper Aptian of Germany and England in various points described above. The European specimens have lateral tubercles represented by microscopic pimples on the first few volutions, whereas these are not confirmed on the present specimens because the first volution of the whorl lacking. We, therefore, identify the specimens as *H*. cf. *elegans.*

Genus *Oshimaceras* Obata & Futakami, 1992

Remarks. Obata & Futakami (1992) assigned the genus *Oshimaceras* to the Subfamily *Parahoplitinae* Spath, 1922.

***Oshimaceras kanazawai* Obata & Futakami, 1992**
(Fig. 50A–D)

Material. A single specimen, IPMM 8698 (unknown collector). It is told that the original specimen was discovered at Oshima islet in about 1925, and the original specimen is housed at Kazuo Kanazawa's home in Moshi hamlet. The replica of its specimen, IPMM 8698 (unknown collector), is housed in the Iwate Prefectural Museum. The specimen come from the Hiraiga Formation at location Ks 4004, Oshima islet.

Locality and horizon. The endemic species is reported only from the Hiraiga Formation.

Remarks. The specimen is previously described as *Oshimaceras kanazawai* by Obata & Futakami (1992, p. 85–87, pl. 5, figs 6, 7). Based on Obata & Futakami (1992), shell dimensions are presented; diameter is 190.0 mm, height is 88.7 mm, breadth is 62.1 mm, and umbilical diameter is 53.2 mm, breadth/height ratio is 0.70, and umbilicus/diameter ratio is 0.28. The specimen is characterized by a fairly large shell with fairly narrow umbilicus, much compressed whorl, oval whorl-cross section with round venter, radial ribs which cross the venter orthogonally, and bullae-like small projections on the umbilical margin. The ribs are coarse on the earlier whorls and dense on later whorls. The ribs consist of primaries and secondaries. The primary ribs arise at the umbilical seam and trend straight across the flank, and some of them bifurcate at the middle flank of the middle whorl. The secondary ribs arise at the middle flank, and a few are inserted between the primaries. These characteristics suggest that the specimen can be assigned to the genus *Acanthoplites*, *Colombiceras* or *Parahoplites*. However, we agree with Obata & Futakami (1992) the characteristics of compressed whorl and complicated suture merit the designation of this specimen as the new genus *Oshimaceras*. This also suggests that the specimen can possibly be identified as the genera *Colombiceras* or *Acanthohoplites*. This is characterized by lateral tubercles on the inner whorls which disappear on later whorls, but the presence of lateral tubercles on the outer whorl of the present specimen is not confirmed because it not seen. It is thus better to identify this specimen as *Oshimaceras kanazawai* until additional specimens with these characteristics are found.

Discussion

Ammonite-bearing lithostratigraphic horizons of the Miyako Group

A total of 909 ammonite specimens from the Miyako Group were used for the study, all were collected by previous workers (Shimizu, 1931; Obata, 1967a, b, 1969, 1973, 1975; Obata & Matsukawa, 1980, 2012, 2018; Obata & Futakami, 1991, 1992; Obata *et al*., 2010; Kawabe, 2007, Hoffmann *et al*., 2013; Matsukawa & Oji, 2022; Matsukawa & Shibata, 2023). The 909 specimens are divided into 92 species of 49 genera, and these have been described systematically above. The specimens came from 54 locations in the Tanohata,

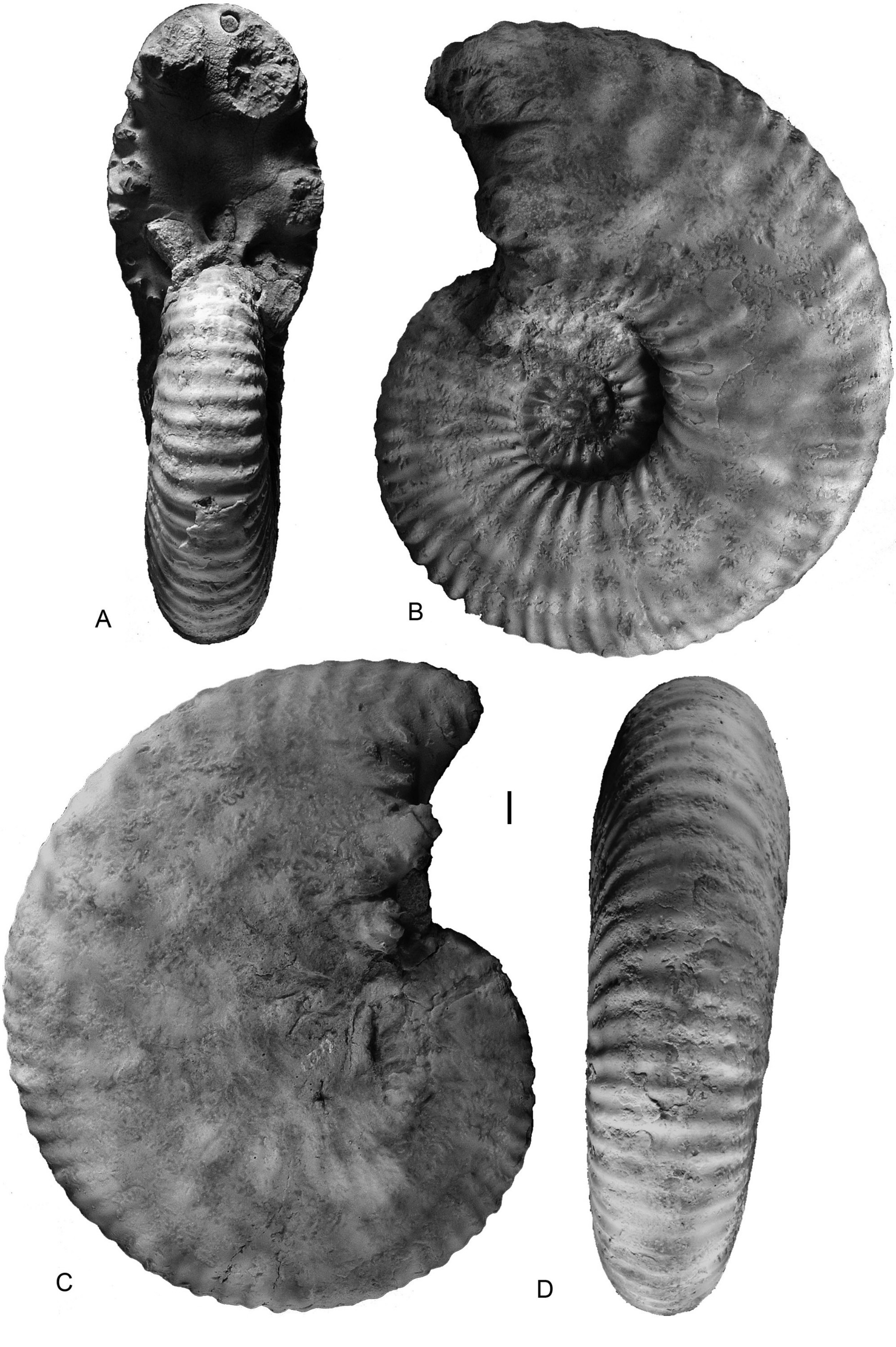

FIGURE 50. A–D, *Oshimaceras kanazawai* Obata & Futakami. IPMM 8698 (unknown collector), FRP replica, from loc. Ks 4004. Scale bars = 1 cm.

Hiraiga, Aketo and Sakiyama formations, and represent 30 lithostratigraphic horizons, consisting of four horizons in the Tanohata Formation, 20 in the Hiraiga Formation, three from the Sakiyama Formation, and three from the Aketo Formation. For the discussion of the ammonite biostratigraphy and ammonite fauna of the Miyako Group, we use the systematically described specimens above, and further limited specimens whose occurrences can be clearly determined on topographic maps (Fig. 51). Based on these, we will consider the ammonite biostratigraphy of the Miyako Group.

Ammonite biostratigraphy

The stratigraphic distribution of the ammonite assemblages of the Miyako Group can be divided into 1) a combination of multiple teilzones as the biozone consisting of taxon-range, interval, and assemblage zones, and 2) a single occurrence of characteristic species as the biostratigraphic horizon. Following the first option, we evaluate ammonite biostratigraphic occurrences in the Miyako Group in each of five regions distributed discontinuously, then establish an ammonite biostratigraphy of the Group for each region. Based on the lithostratigraphic correlation, we combine the biostratigraphy of each region into a single ammonite biostratigraphy for the Miyako Group. Finally, we subdivide the biostratigraphy into biozones.

Tanohata region

Seventy-six species of 41 genera are identified, based on 757 specimens from the 17 lithostratigraphic horizons within the Tanohata, Hiraiga and Aketo formations. Thirty-eight of the total 76 species occur in multiple lithostratigraphic horizons. In the Tanohata region, *Hypacanthoplites subcornuerianus* and *Douvilleiceras bifurcatum* are found in seven and three lithostratigraphic horizons, respectively. These stratigraphic occurrences can be confirmed as the *Hypacanthoplites subcornuerianus* Taxon-range Zone and overlying *Douvilleiceras bifurcatum* Interval Zone (Fig. 52). The ranges of following taxa are somewhat overlapped, and the co-occurrence of several species observed at the location KK.

1) *Hypacanthoplites subcornuerianus* Taxon-range Zone. This zone lies between the lithostratigraphic horizon of location Hn 0220 as the FAD (first appearance datums) and the lithostratigraphic horizons of locations KK as the LAD (last appearance datums). The zone is characterized by the dominant occurrence of *Pseudohaploceras nipponicum*, *Miyakoceras tanohatense*, *Lechites komorii*, *Diadochoceras nodosocostatiforme*, and *Colombiceras yaegashii* in the Tanohata and lower Hiraiga formations.

2) *Douvilleiceras bifurcatum* Interval Zone. This zone lies between the lithostratigraphic horizon of location Hn 6203 and the lithostratigraphic horizons of locations Hn 6200. The zone is characterized by the dominance of *Eogaudryceras* (*Eotetragonites*) *gainesi*, *Desmoceras* (*Pseudouhligella*) *sanrikucum*, *Hulenites kitamurai*, *Marshallites miyakoensis*, *Anagaudryceras* sp. B, *Hamites* (*H.*) cf. *tenuis*, *Pseudoleymeriella hataii*, and *P. hiranamensis* in the upper part of the Hiraiga and Aketo formations.

Moshi region

Twenty species of 17 genera based on 76 specimens are identified from ten locations in the Hiraiga Formation in this region. These locations occur on four islets; three locations, Hn4051, Hn4053 and Ks4004, are on Oshima Islet; four locations, Hn4151, Hn4152, Hn4153 and Matsushima in Shimizu (1931), are on Matsushima Islet; one location, Hn4201, is on Nagaiso Islet; and two locations, Ks4003 and 81201, are on Tairajima Islet. Based on the lithostratigraphy of the Hiraiga Formation in this region (Murai *et al*., 1983), and the geographical relationship among the four islets (see geological map in fig. 4), the stratigraphic order of the ten locations is from lowest to highest Hn4053, Ks2004, Hn4051 and Hn4152 and the equivalent horizons of Hn4153 and Matsushima, and Hn4151 and its equivalent horizons of Ks4003, 81201, and Hn4201. With in these locations, five biostratigraphic horizons can be recognized (Fig. 53).

Pseudohaploceras nipponicum comes from four locations, and *Epicheloniceras* sp. comes from three locations. Since the FAD of *Epicheloniceras* sp. is earlier than that of *Diadochoceras nodosocostatiforme,* we chose *Epicheloniceras* sp. as the zonal index (taxon-range zone) for the succession from Hn4053 to Hn4151, Hn4201 (Obata, 1975), Ks4003, and 81201 of the Hiraiga Formation. *Epicheloniceras* sp. can thus be divided into the Miyako Group as *Epicheloniceras* sp. Taxon-range Zone.

The upper Aptian in the Lower Cretaceous ammonite zonal distribution of the ammonite standard zonation of the Aptian Stage of the western Mediterranean province of the Tethyan realm (Szives *et al*., 2024) is divided into four bio-zones, and the *Epicheloniceras martini* Zone is earlier than the *Diadochoceras nodosocostatum* Zone. This concurs with the occurrence of *Epicheloniceras* sp. being lower than that of *Diadochoceras nodosocostatiforme* in the Miyako Group in the Moshi region. This indicates that the Hiraiga Formation may be correlated with the *Epicheloniceras martini* Zone, which is the lowest zone of four zones of the upper Aptian of the Lower Cretaceous ammonite zonal distribution (Szives *et al*., 2024).

Taro region

According to Matsukawa & Oji (2022), 17 species of 15 genera have been found here based on 28 specimens from two lithostratigraphic horizons of the Tanohata and Hiraiga formations. Ammonites on only found in these

	Taxa	Number of specimens: Komori collection	Number of specimens: newcomer specimens	Shimizu, 1931	Obata 1967a	Obata, 1967b	Obata, 1969	Obata, 1973	Obata, 1975	Obata & Matsukawa, 1980	Obata & Futakami, 1991	Obata & Futakami, 1992	Kawabe, 2007	Obata et al., 2010	Obata and Matsukawa, 2012	Hoffmann et al., 2013	Obata and Matsukawa, 2018	Matsukawa and Oji, 2022	Matsukawa and Shibata, 2022	Total number of specimens	Original source for numbers in brackets
Phylloceratidae	*Euphylloceras californicum* (Anderson, 1938)	8 (4)	1										4				(4)			9	4 specimens = Kawabe 2007, fig. 5:1-4.
	E. sp.	3	1																	4	
	E. ? sp.																2			2	
	Goretophylloceras cf. *fortunei* (Honnorat-Bastide, 1892)	1(1)											1							1	1 specinen = Kawabe, 2007, fig. 5:8, 9.
	G. cf. *subalpinum* (Orbigny, 1850)	1 (1)											1							1	1 specimens = Kawabe, 2007, figs. 5:5,6 ; 6:3, 4.
	G. sp.	1																		1	
	G. ? sp.																3			3	
	Hypophylloceras sp.																4			4	
	Holcophylloceras caucasicum (Sayn, 1920)	1	1	2													(2)	1		5	2 specimens = Shimizu, 1931, pl. 3, figs. 15-17, 28
	Phyllopachyceras iwatense sp. nov.	1 (1)											1							1	1 specimen = Kawabe, 2007, fig. 5:10.
	P. aff. *infundibulum* (Orbigny, 1841)																3			3	
	Phylloceratidae gen. et sp. indet.																4			4	
Lytoceratidae	*Ammonoceratites* (*A*.) *crenocostatus* (Whiteaves, 1876)											1								1	
	A. giganteus Obata, Matsukawa and Tsuda, 2010													1						1	
	Pictetia astieriana Orbigny, 1842	27 (6)											6			29 (6)				27	6 specimens = Kawabe, 2007, fig. 7:4-12. 27 specimens = Hoffmann et al., 2013, p. 520, figs. 2A-H.
	P. aff. *astieriana* Orbigny, 1842																3			3	
	P. sp.																		1	1	Inose et al. (2013) listed
	Protetragonites eichwaldi (Karakasch, 1907)	4 (1)											1				1			5	1 specimen = Kawabe, 2007, figs. 7:1, 2,
	P. sp.																1	3		4	
Gaudryceratidae	*Eogaudryceras* (*Eotetragonites*) *gainesi* (Anderson, 1938)	17	3									1					5			26	
	E. (*E.*) sp.																		1	1	
	Anagudryceras sp.	3																1		4	
Tetragonitidae	*Tetragonites hulenensis* Murphy, 1967	8 (1)											1							8	1 specimen = Kawabe, 2007, figs. 7:13-15.
	Gabbioceras sp. A		3															1		4	
	G. sp. B	1																		1	
	Tetragonitidae gen. et sp. indet.																	1		1	
Oppeliidae	*Aconeceras* aff. *nisoudes* (Sarasin, 1893)																1		(1)	1	1 specimen = Inose et al., 2013, fig. 5-1a, b
	A. (*A*.) sp.																	2		2	
	Sanmartinoceras bifurcatum Matsukawa and Shibata, 2022																		1	1	
Desmoceraidae	*Valdedorsella akuschaensis* Anthula, 1899	4	7		3													2		16	
	V. getulina Coquand, 1880	14			2															16	
	V. kasei Obata and Matsukawa, 2018		3														6		2	11	1 specimen = Inose et al., 2013, fig.5-3
	V. sp.				1															1	
	Pseudohaploceras nipponicum Shimizu, 1931		17	1											2		9 (1)			26	1 specimen = Shimizu, 1931, pl. 1, figs. 17-19.
	P. ? sp.		1																	1	
	Melchiorites yabei (Shimizu, 1931)	3	8	1													10 (1)			21	1 specimen = Shimizu, 1931, pl. 3, figs. 18-20, 27.
	Puzosia (*P*.) *shimizui* sp. nov.		5														4			9	
	Uhligella matsushimaensis Shimizu, 1931			1													15 (1)	1	1	17	1 specimen = Shimizu, 1931, pl. 1, figs. 10-13; pl. 3, fig. 26.
	U. aff. *matsushimaensis* Shimizu, 1931																1			1	
	Beudanticeras? sp.		2														1			3	
	Desmoceras (*Pseudouhiligella*) *sanrikucum* sp. nov.	5	10														5	1		21	
Silesitidae	*Miyakocersa tanohatense* Obata, 1967	1	6			4									1			2		13	
	M. aff. *tanohatense* Obata, 1967					1														1	
	M. hayamii Obata, 1967					1														1	
Kossmaticeratidae	*Hulenites kitamurai* Matsukawa, 2021	7	1																	8	
	H. sp.	1																		1	
	Marshallites miyakoensis Obata and Futakami, 1991	12	8								5								3	28	1 specimen = Inose et al., 2013, fig. 5-6.
Cleoniceratidae	*Anadesmoceras* sp. A	2																	1	3	
	A. sp. B	9	1														1			11	
	A. ? sp.	1															2			3	
	Cleonicreas (*C*.) cf. *cleon* (Orbigny, 1850)																5			5	
Hoplitidae	*Anahoplites*? sp. indet.																1			1	
Ancyloceratidae	*Pseudolithancylus tohokuense* sp. nov.		4																	4	
	Tonohamites? sp.		1																	1	
Ptychoceratidae	*Ptychoceras* cf. *emericianum* Orbigny, 1842	4	5														8		1	18	
	P. minimum Rouchadzé, 1933	3	10																	13	
	P. sp.																4			4	
	Diptychoceras iwatense Obata and Matsukawa, 2018	1	3														3	2		9	
	D. cf. renngarteni (Egoian, 1969)	2																		2	
Anisoceratidae	*Protanisoceras hanaii* Obata and Matsukawa, 2018	46															1	1		48	
	P. aff. *hanaii* Obata and Matsukawa, 2018																	1		1	
	P. ? sp.																8			8	
	Ephamulina monotuberculata sp. nov.	7	4														5			16	
	Idiohamites pacificum sp. nov.	1																		1	
Hamitidae	*Hamites* (*H*.) cf. *tenuis* Sowerby, 1814	6	3																	9	
	H. (*H.*) cf. *intermedius* Soweby, 1814			1																1	
	H. (*H*.) sp. A	1																		1	
	H. (*H.*) sp. B		2																	2	
	H. (*H*.) sp. C		1																	1	
Baculitidae	*Lechites* (*L*) *komorii* sp. nov.	5	2																	7	
Douvilleiceratidae	*Epicheloniceras* sp.		3																2	5	
	*Parachelonicera*s *guenoti* Collignon, 1965	1																	1	2	
	P. *regina* (Obata and Matsukawa, 2018)		4														1			5	
	P. *kazuoi* sp. nov.	2							1											3	
	Diadochoceras nodosocostatiforme (Shimizu, 1931)	20	4	1					4						4				2	31	
	Sonoraceras? sp.																	1	1	2	
	Eodouvilleiceras matsumotoi Obata, 1969		6				7												3	16	2 specimens = Inose et al., 2013, fig. 5-6,7.
	E. sp. nov.? aff. *matsumotoi* Obata, 1969						7													7	
	Douvilleiceras spiniferum (Whiteaves, 1900)		1																	1	
	D. bifurcatum sp. nov.	9					3								1					12	
	D. sp.		1																	1	
Trochleiceratidae	*Pseudoleymeriella hataii* Obata, 1973	3	36	1				8											1	49	1 specimen = Inose et al., 2013, figs. 5-2a, b
	P. hiranamensis Obata, 1973	3	4					2												9	
	P. obatai Matsukawa and Oji, 2021	1																3		4	
Parahoplitidae	*Colombiceras yaegashii* (Shimizu, 1931)		2	1								(1)					(1)			3	1 specimen = Shimizu, 1931, pl. 2, figs. 1-3; pl. 3, figs. 1, 2.
	Hyacanthoplites subcornuerianus (Shimizu, 1931)	16	135	1						92		(1)			3				13	257	1 specimen = Obata and Futakami, pl.4, fig/ 1; figs.4, 5.
	H. kawakamii Obata and Futakami, 1992											2								2	
	H. cf. *anglicus* Casey, 1965																		3	3	
	H. cf. *elegans* (Fritel, 1906)		2																1	3	
	H. sp.																		1	1	
	Parahoplites aff. *vectensis?* Casey, 1965														1		1			1	
	P. cf. *laticostatus* (Sinzow, 1907)																		1	1	
	Oshimaceras kanazawai Obata and Futakami, 1992											1								1	
	Total of specimens	251	311	10	6	6	17	10	5	92	5	5	15	1	(12)	(29)	113	23	39	909	

FIGURE 51. List of Aptian–Albian ammonite species and the number of specimens from the Miyako Group, which have been systematically described in previous works and in the present study. Unknown provenances of all specimens in Obata & Matsukawa (2012) and a specimen, IPMM8725, of *Hyacanthoplites cornuerianus* in Obata & Futakami (1992) are not included. The numbers in parentheses indicate the numbers of specimen counted in previous works. The previous works are listed in the notes.

Family	Taxa	Hn0006	Hn0220	SMK C21	Hn0010	Hn1904 Hn1902	Hn0016	Tokuzo Hn0017	Hn0018	TR137 Hn0320 Hn0319	KK	TR139 Hn0650 Hn6203	C2p C2	C4	Hn6202	B2 Hiraname-dana Hn0679 Hn6201	TR138 C7p C6p C3p OH7' OH7	a cliff of Hiraname-dana OH6 C5p Hn6200
	Stage	Aptian									Albian							
	Zonation	*Epicheloniceras* sp. Taxon-range Zone			*Hypacanthoplites subcornueruanus* Taxon-range Zone							*Douvilleicras bifurcatum* Interval Zone						
	Lithostratigraphic unit	Tanohata Formation			Hiraiga Formation											Aketo Formatiopn		
Phylloceratidae	*Euphylloceras californicum* (Anderson, 1938)										●							
	E. sp.		●								●							
	E. ? sp.							●									●	
	Goretophylloceras cf. *fortunei* (Honnorat-Bastide, 1892)										●							
	G. cf. *subalpinum* (Orbigny, 1850)										●							
	G. sp.										●							
	G. ? sp.						●						●			●		
	Hypophylloceras sp.							●				●	●		●			
	Holcophylloceras caucasicum (Sayn, 1920)					●					●							
	Phyllopachyceras iwatense sp. nov.										●							
	P. aff. *infundibulum* (Orbigny, 1841)															●		
	Phyllopachyceratidae gen. et sp. indet.						●								●	●		
Lytoceratidae	*Ammonoceratites* (*A.*) *crenocostatus* (Whiteaves, 1876)															●		
	A. giganteus Obata, Matsukawa and Tsuda, 2010															●		
Lytoceratidae	*Pictetia astieriana* Orbigny, 1842										●							
	P. aff. *astieriana* Orbigny, 1842																●	●
	Protetragonites eichwaldi (Karakasch, 1907)										●			●				
	P. sp.	●																
Gaudryceratidae	*Eogaudryceras* (*Eotetragonites*) *gainesi* (Anderson, 1938)										●					●	●	
	Anagudryceras sp.										●							
Tetragonitidae	*Tetragonites hulenensis* Murphy, 1967										●							
	Gabbioceras sp. A							●								●		
	G. sp. B										●							
Desmoceraidae	*Valdedorsella akuschaensis* Anthula, 1899		●					●	●		●					●	●	●
	V. getulina Coquand, 1880										●	●						
	V. kasei Obata and Matsukawa, 2018							●								●		
	V. sp.						●											
	Pseudohaploceras nipponicum Shimizu, 1931		●			●		●										
	P. ? sp.				●													
	Melchiorites yabei (Shimizu, 1931)				●	●	●	●		●	●					●		
	Puzosia (*P.*) *shimizui* sp. nov.					●										●		
	Uhligella matsushimaensis Shimizu, 1931						●											
	U. aff. *matsushimaensis* Shimizu, 1931																●	
	Beudanticeras ? sp.															●	●	●
	Desmoceras (*Pseudouhiligella*) *sanrikucum* sp. nov.										●					●	●	●
Silesitidae	*Miyakoceras tanohatense* Obata, 1967		●		●	●	●				●							
	M. aff. *tanohatense* Obata, 1967						●											
	M. hayamii Obata, 1967				●													
Kossmaticeratidae	*Hulenites kitamurai* Matsukawa, 2021										●						●	
	H. sp.										●							
	Marshallites miyakoensis Obata and Futakami, 1991										●	●	●			●		●
Cleoniceratidae	*Anadesmoceras* sp. A										●							
	A. sp. B										●						●	
	A. ? sp.										●					●	●	
	Cleoniceras (*C.*) cf. *cleon* (Orbigny, 1850)															●		
Hoplitidae	*Anahoplites* ? sp. indet.																●	
Ancyloceratidae	*Pseudolithancylus tohokuense* sp. nov.							●				●				●		
	Tonohamites ? sp.															●		
Ptychoceratidae	*Ptychoceras* cf. *emericianum* Orbigny, 1842				●		●	●			●					●	●	
	P. minimum Rouchadze, 1933						●	●			●	●					●	
	P. sp.							●								●		
Diptychoceratidae	*Diptychoceras iwatense* Obata and Matsukawa, 2018							●			●					●		
	D. cf. renngarteni (Egoian, 1969)										●							
Anisoceratidae	*Protanisoceras hanaii* Obata and Matsukawa, 2018										●							
	P. ? sp.													●		●	●	
	Ephamulina monotuberculata sp. nov.										●			●		●	●	
	Idiohamites pacificum sp. nov.										●							
Hamitidae	*Hamites* (*H.*) cf. *tenuis* J. Sowerby, 1814										●					●	●	
	H. (*H.*) sp. A										●							
	H. (H.) sp. B							●								●		
	H. (*H.*) sp. C															●		
Baculitidae	*Lechites (L) komorii* sp. nov.							●			●							
Douvilleiceratidae	*Parachelonoceras guenoti* Collignon, 1965										●							
	P. regina (Obata and Matsukawa, 2018)		●	●				●										
	P. kazuoi sp. nov.										●							
	Diadochoceras nodosocostatiforme (Shimizu, 1931)										●							
	Douvilleiceras spiniferum (Whiteaves, 1900)															●		
	D. bifurcatum sp. nov.										●	●						●
Trochleiceratidae	*Pseudoleymeriella hataii* Obata, 1973										●	●				●	●	●
	P. hiranamensis Obata, 1973										●	●				●	●	
	P. obatai Matsukawa and Oji, 2021										●							
Parahoplitidae	*Colombiceras yaegashii* (Shimizu, 1931)			●				●										
	Hyacanthoplites subcornuerianus (Shimizu, 1931)		●	●	●	●	●	●			●							
	H. kawakamii Obata and Futakami, 1992			●														
	H. cf. *elegans* (Fritel, 1906)						●											
	Parahoplites aff. *vectensis?* Casey, 1965			●														

FIGURE 52. Biostratigraphic distribution of ammonites in the three formations of the Miyako Group in the Tanohata region. Solid circles show ammonite occurrences. Black lines show biostratigraphic ranges of ammonite species.

two horizons, and *Protetragonites* sp. and *Diptychoceras iwatense* occur from both levels. It does not establish an ammonite biozone. A small and partial shell of a specimen identified as *Sonoraceras*? sp. *Sonoraceras tepachensis*, which is allied to *Sonoraceras*? sp., is found in the *Immunitoceras immunitum* Zone of northwestern Mexico, which is uppermost Aptian (Samaniego-Pesqueira *et al*., 2021). The two ammonite assemblages from the Tanohata and Hiraiga formations are regarded as uppermost Aptian. Matsukawa & Oji (2022) regarded that ammonite assemblage from location TR2 belong to the *Hypacanthoplites subcornuerianus* Taxon-range Zone or immediately beneath it. However, this view is revised here because the assemblage does not contain any zone-indexing ammonite species which positively indicate the zone (Fig. 54).

Sakiyama region

Subsequent to the work of Matsukawa & Shibata (2023), two specimens of *Puzosia* (*P.*) *shimizui* and a single specimen of *Douvilleiceras* sp. from the Ks2005 have been identified in the Sakiyama region. Accordingly, 22 species from 19 genera are identified here, based on 51 specimens from six lithostratigraphic horizons of the Hiraiga and Sakiyama formations of the Miyako Group. Four species, *Valdedorsella kasei*, *Marshallites miyakoensis*, *Eodouvilleiceras matsumotoi* and *Hypacanthoplites subcornuerianus*, are found in multiple lithostratigraphic horizons.

The lithostratigraphic horizon at location OH4 yields *Marshallites miyakoensis*, *Epicheloniceras* sp., *Paracheloniceras guenoti*, *Sonoraceras*? sp., *Hypacanthoplites subcornuerianus*, *H.* cf. *anglicus*, *H.* cf. *elegans*, and *H.* sp. The lithostratigraphic horizon OH4 is therefore assigned to the *Epicheloniceras* sp. Taxon-range Zone.

Based on the occurrences of *Hypacanthoplites subcornuerianus* from lithostratigraphic horizons at locations, Ob01 and Ks2005, these levels of the Hiraiga Formation can be assigned to the *Hypacanthoplites subcornuerianus* Taxon-range Zone. Since the lithostratigraphic horizon at location Loc. 2 of the Sakiyama Formation yields *Pseudoleymeriella hataii*, which is characteristic of the *Douvilleiceras bifurcatum* Interval Zone in the Tanohata region, the lithostratigraphic horizon in the Sakiyama region is assigned to the *D. bifurcatum* Interval Zone equivalent biozone.

Marshallites miyakoensis occurs in three lithostratigraphic horizons in the Hiraiga and Sakiyama formations. These occurrences are shown as a teilzone, but the lower two occurrences are included in the *Epicheloniceras* sp. Taxon-range Zone and *H. subcornuerianus* Taxon-range Zone. Both horizons at these locations yield *Hypacanthoplites subcornuerianus* and *Marshallites miyakoensis*, the same as the lithostratigraphic horizon at location KK in the uppermost part of the Hiraiga Formation in the Tanohata region that yields both species. Since the lithostratigraphic horizon KK is assigned to the *Hypacanthoplites subcornuerianus* Taxon-range Zone, three lithostratigraphic horizons of the Hiraiga Formation that yield both species can be assigned to the *Hypacanthoplites subcornuerianus* Taxon-range Zone. Therefore, the lithostratigraphic horizon at location Loc. 1 yielding only *Marshallites miyakoensis* can be assigned to the *D. bifurcatum* Interval Zone equivalent biozone.

At lithostratigraphic horizon at location OH5, only two species occur, and the location is assigned to the *Colombiceras yaegashii* Biostratigraphic horizon (Fig. 55), and it seems to be assigned within the *Hypacanthoplites subcornuerianus* Taxon-range Zone.

Ammonite zones within the Miyako Group and their biostratigraphic correlations

Figure 56 shows the ammonite biostratigraphic zones throughout all five regions where the Miyako Group is found. The Miyako Group in the Taro and Miyako regions does not yield ammonite species for recognizing biozones, and thus no ammonite biostratigraphic zones.

The Miyako Group is divided into three ammonite biozones, the *Epicheloniceras* sp. and *Hypacanthoplites subcornuerianus* Taxon-range zones, and the *Douvilleiceras bifurcatum* Interval Zone, in ascending biostratigraphic order. The *Epicheloniceras* sp. Taxon-range Zone appears earlier than the *Hypacanthoplites subcornuerianus* Taxon-range Zone, because *Epicheloniceras* sp. occurs in the lowest lithostratigraphic horizon of the *Hypacanthoplites subcornuerianus* Taxon-range Zone in Sakiyama region.

The ammonite zonation of the Miyako Group is defined as follows:

1) *Epicheloniceras* sp. Taxon-range Zone. This zone is defined by the FAD and the LAD of *Epicheloniceras* sp. from the lithostratigraphic horizons at locations Hn4053 to Hn4151, Hn4201, Ks4003, and 81201 of the Hiraiga Formation in Moshi region, and OH4 of the Hiraiga Formation in Sakiyama region. *Epicheloniceras* sp. Biostratigraphic horizon at the horizon OH4 in the Hiraiga Formation in the Sakiyama region is included in this zone.

2) *Hypacanthoplites subcornuerianus* Taxon-range Zone. This zone is defined by the FAD and the LAD of *Hypacanthoplites subcornuerianus* between lithographic horizons at locations Hn0020 and at location KK of the Hiraiga Formation in the Tanohata region, and between lithographic horizons at location Ob01 and Ks2005 in the Hiraiga Formation in Sakiyama region. *Colombiceras yaegashii* Biostratigraphic horizon corresponds to the lithostratigraphic horizon OH5 in the Hiraiga Formation in the Sakiyama region and is included in this zone.

Stage		Aptian				
Zonation		*Epicheloniceras* sp. Taxon-range Zone				
Lithostratigraphic unit		Hiraiga Fm.				
Lithostratigraphic horizon / Taxa		Hn 4053	Ks 4004	Hn 4051	Matsushima Hn 4153 Hn 4152	Hn 4201 81201 Ks 4003 Hn 4151
Phylloceratidae	*Euphylloceras californicum* (Anderson, 1938)					●
	Holcophylloceras caucasicum (Sayn, 1920)				●	
	Phylopachyceras aff. *infundibulum* (Orbigny, 1841)					●
	Phylloceratidae gen. et sp. indet.					●
Desmoceratidae	*Valdedorsella getulina* Coquand, 1880					●
	*Pseudohaploceras nipponicum S*himizu, 1931	●	—	●	●	●
	Melchiorites yabei (Shimizu, 1931)				●	●
	Puzosia (*P*.) *shimizui* sp. nov.				●	●
	Uhligella matsushimaensis Shimizu, 1931				●	●
Cleoniceratidae	*Anadesmoceras*? sp.	●	—	●		
Ptychoceratidae	*Ptychoceras* cf. *emericianum* Orbigny, 1842				●	
Hamitidae	*Hamites* (*H*.) cf. *tenuis* J. Sowerby, 1814					●
	H. (*H.*) cf. *intermedius Soweby, 1814*				●	
Douvilleiceratidae	*Epicheloniceras* sp.	●	—	●	—	●
	Paracheloniceras kazuoi sp. nov.					●
	Diadochoceras nodosocostatiforme (Shimizu, 1931)		●	—	●	●
	D. aff. *nodosocostatiforme* (Shimizu, 1931)					●
	Eodouvilleiceras matsumotoi Obata, 1969	●	—	—	●	●
	E. sp. nov.? aff. *matsumotoi* Obata, 1969					●
Parahoplitidae	*Oshimaceras kanazawai* Obata and Futakami, 1992		●			

FIGURE 53. Biostratigraphic distribution of ammonites in the Hiraiga Formations of the Miyako Group in the Moshi region. Solid circles show ammonites. Black line shows biostratigraphic range of ammonite species.

Stage		Aptian	
Taxa		Tanohata Fm. TR2	Hiraiga Fm. Taro 3003
Phylloceratidae	*Holcophylloceras caucasicum* (Sayn, 1920)		●
Lytoceratidae	*Protetragonites* sp.	●	●
Gaudryceratidae	*Anagaudryceras* sp.		●
Tetragonitidae	*Gabbioceras* sp.		●
	Tetragonitidae gen. et sp. indet.	●	
Oppeliidae	*Aconeceras* (*A*.) sp.	●	
Desmoceratidae	*Valdedorsella akuschaensis* (Anthula, 1899)		●
	V. kaseki Obata and Matsukawa 2018		●
	Uhligella matsushimaensis (Shimizu, 1931)		●
	Desmoceras (*Pseudouhligella*) aff. *poronaicum*? Yabe, 1904		●
Silesitidae	*Miyakoceras tanohatense* Obata, 1967	●	
Ptychoceratidae	*Ptychoceras* cf. *puzosianum* Orbigny, 1842		●
	Diptychoceras iwatense Obata and Matsukawa, 2018	●	●
Anisoceratidae	*Protanisoceras hanaii* Obata and Matsukawa, 2018		●
	P. aff. *hanaii* Obata and Matsukawa, 2018		●
Trochileiceratidae	*Sonoraceras*? sp.		●
Douvilleiceratidae	*Pseudoleymeriella obatai* Matsukawa and Oji, 2022		●

FIGURE 54. Biostratigraphic distribution of ammonites in the Tanohata and Hiraiga formations of the Miyako Group in the Taro region. Solid circles show ammonites. Black line shows biostratigraphic range of ammonite species.

3) *Douvilleiceras bifurcatum* Interval Zone. This zone is defined by the occurrence of *Douvilleiceras bifurcatum* without *Hypacanthoplites subcornuerianus* from the upper part of the Hiraiga Formation to the Aketo Formation in the Tanohata region, and between lithostratigraphic horizons at location Loc. 1 and at Location 2 in the Sakiyama Formation in the Sakiyama region.

Shimizu (1931) established six ammonite zones in the Miyako Group consisting of the Zone of *Acanthohoplites subcornuerianus*, the Zone of *Parahoplites yaegashii*, the Zone of *Saynella matsushimaensis*, the Zone of *Salfeldiella caucasica*, the Zone of *Douvilleiceras nodosocostatiforme*, and the Zone of *Hoplites* aff. *dentatus*, in ascending stratigraphic order. However, since he did not show the exact biostratigraphic distributions, his biozones are regarded as insufficient to characterize as biostratigraphic horizons or even biozones. Some of species that Shimizu (1931) used as zone species are regarded as synonyms of others, such as *Hoplites* aff. *dentatus*, which is a zone species of the Zone of *Hoplites* aff. *dentatus* and is herein identified as *Pseudoleymeriella hataii*. The biozones defined by Shimizu (1931) thus differ from those presented here. Although Obata & Matsukawa (2018) did not describe biostratigraphic correlations among four discontinuous regions, their ammonite zonation is fundamentally the same as in this study, except that we now regard the biostratigraphic distribution of *Diadochoceras nodosocostatiforme* as insufficient to establish a biozone and so is not adopted.

Biostratigraphic correlation with the Barremian–Albian ammonite zonation of the west Mediterranean Province

Based on the ammonite standard zonation of the Barremian–Albian stages for the west Mediterranean Province (Reboulet *et al*., 2018), the upper Aptian is subdivided into four zones, the *Epicheloniceras martini*, *Parahoplites melchioris*, *Acanthohoplites nolani*, and *Hypacanthoplites jacobi* zones, in ascending biostratigraphic order. The succession from the *Epicheloniceras* sp. to *Hypacanthoplites subcornuerianus* Taxon-range zones of the Miyako Group correlates with the four European ammonite standard zones. There is difference in the species level, however, biostratigraphic

	Stage	Aptian					Albian	
	Zonation	*Epicheloniceras* sp. Taxon-range Zone		*Hypacanthoplites subcornuerianus* Taxon-range Zone			*Douvilleiceras bifurcatum* Interval Zone equivalent biozone	
			Epicheloniceras sp. Biostratigraphic horizon			*Colombiceras yaegashii* Biostratigarphic horizon		
	Lithostratigraphic unit	Tanohata Fm.	Hiraiga Fm.			Sakiyama Fm.		
	Lithostratigraphic horizon						Inose et al. (2013)	
Taxa			OH4	Ob01	Ks2005	OH5 = Hy2099	Loc. 1	Loc. 2
Lytoceratidae	*Pictetia.* sp.							●
Gaudryceratidae	*Eogaudryceras (Eotetragonites)* sp.							●
Oppeliidae	*Aconecras* aff. *nisoudes* (Sarasin, 1893)						●	
	Sanmartinoceras bifurcatum sp. nov.			●				
Desmoceratidae	*Valdedorsella kasei* Obata and Matsukawa, 2018				●	●	—	●
	Puzosia (*P*.) *shimizui* sp. nov.				●			
Kossmaticeratidae	*Marshallites miyakoensis* Obata and Futakami, 1991		●	●	—	—	●	
Cleoniceratidae	*Anadesmoceras* sp. A							●
Ptychoceratidae	*Ptychoceras* cf. *emericianum* Orbigny, 1842							●
Douvilleiceratidae	*Epicheloniceras* sp.		●					
	Paracheloniceras guenoti Colligno, 1965		●					
Douvilleiceratidae	*Diadochoceras nodosocostatiforme* (Shimizu, 1931)				●			
	Sonoraceras ? sp.		●					
	Eodouvilleiceras matsumotoi Obata, 1969				●	—	—	●
	Douvilleiceras sp.				●			
Trochleiceratidae	*Pseudoleymeriella hataii* Obata, 1973							●
Parahoplitidae	*Colombiceras yaegashii* (Shimizu, 1931)					●		
	Hyacanthoplites subcornuerianus (Shimizu, 1931)		●	●	●			
	H. cf. *anglicus* Casey, 1965		●					
	H. cf. *elegans* (Fritel, 1906)		●					
	H. sp.		●					
	Parahoplites cf. *laticostatus* (Sinzow, 1907)				●			

FIGURE 55. Stratigraphic distribution of ammonites in the Hiraiga and Sakiyama formations of the Miyako Group in the Sakiyama region. Solid circles show ammonites. Black line shows biostratigraphic range of ammonite species.

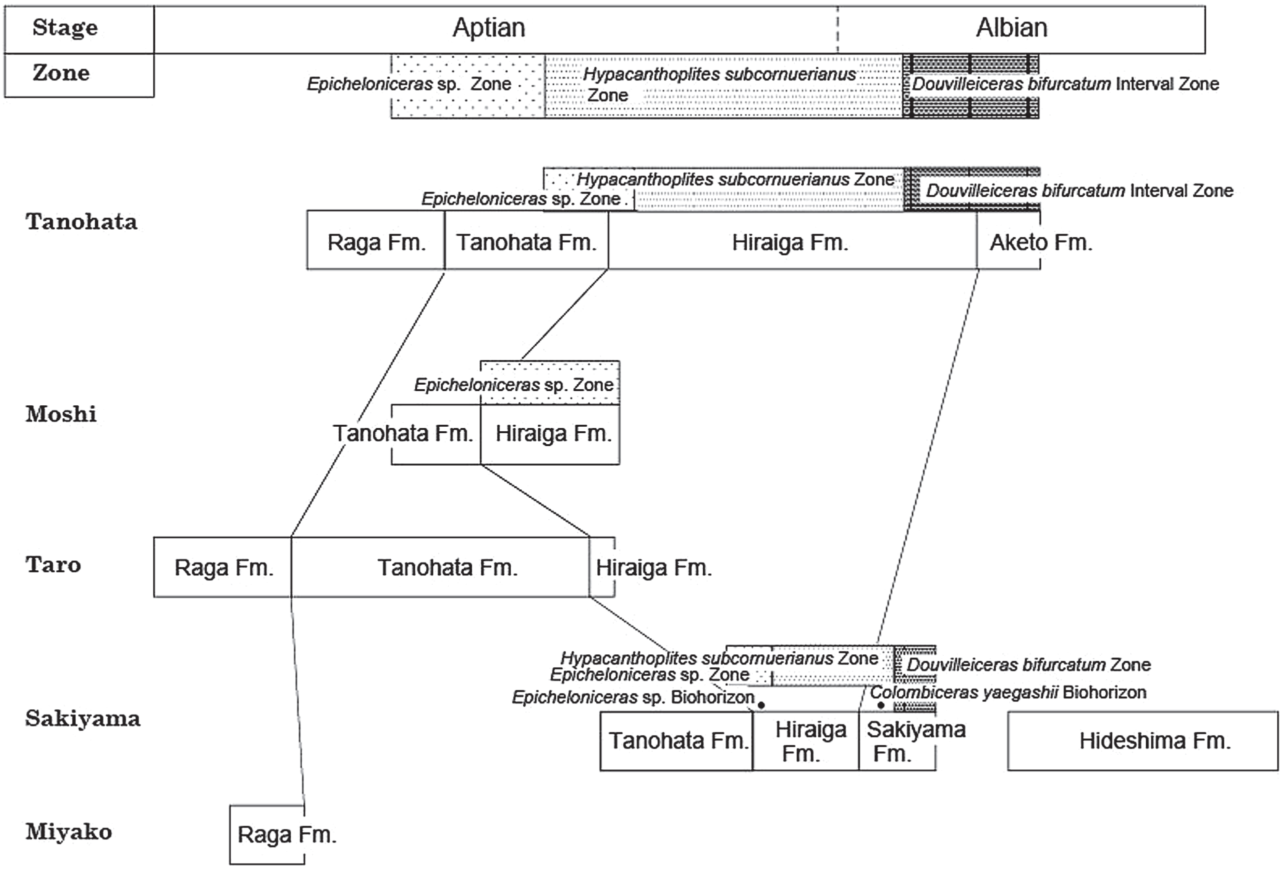

FIGURE 56. Lithostratigraphic correlation among five regions where the Miyako Group is distributed discontinuously, with ammonite zones.

order in genus level is essentially similar between both regions. Recently, the ammonite standard zonation of the Barremian–Albian stages for the west Mediterranean Province was revied by Szives *et al*. (2024), in which the *Acanthohoplites nolani* Zone was changed to the *Diadochoceras nodosocostatum* Zone and was not adopted as a zonal species. The *Epicheloniceras martini* Zone is earlier than the *Diadochoceras nodosocostatum* Zone in west Mediterranean Province. This concurs with the occurrence of *Epicheloniceras* sp. is earlier than that of *D. nodosocostatiforme* in the Miyako Group in Sakiyama area. This indicates that the lowermost part of the Hiraiga Formation may be correlated with the *E. martini* Zone, which is the lowest zone of four zones of the upper Aptian of the ammonite standard zonation of the Barremian–Albian stages for the west Mediterranean Province (Szives *et al*., 2024) (Fig. 57).

The lower Albian of the ammonite standard zonation is divided into the *Leymeriella tardefurcata* Zone and overlying *Douvilleiceras mammillatum* Zone, and the *Leymeriella tardefurcata* overlies the uppermost Aptian *Hypacanthoplites jacobi* Zone (Reboulet *et al*., 2018). In the Miyako Group, *Douvilleiceras bifurcatum* Interval Zone overlies the *Hypacanthoplites subcornuerianus* Taxon-range Zone, thus the *Douvilleiceras bifurcatum* Interval Zone is correlated with the *Leymeriella tardefurcata* Zone in the western Europe. Although the *Leymeriella tardefurcata* Zone has been agreed as the ammonite zone representing the base of the Albian in the standard zonation (Reboulet *et al*., 2018), the Aptian–Albian boundary lies within the *Hypacanthoplites plesiotypicus* Zone, which is regarded as the equivalent to the *H. jacobi* Zone at the GSSP of the Albian in north of Barrême, southern France (Kennedy *et al*., 2017).

Biostratigraphic occurrences of *Hypacanthoplites subcornuerianus* and *Douvilleiceras bifurcatum* in the Miyako Group are similar to those of ammonite species at the Aptian–Albian boundary of the Lower Cretaceous, including at the Albian GSSP (Global Boundary Stratotype Section and Point) north of Barrême, southern France (Fig. 58).

In the GSSP section, the FAD of *Leymeriella* (*L.*) *tardefurcata* was taken as the base of the Albian Stage (Kennedy, 2000). Subsequently, the Aptian–Albian boundary was redefined by the first appearance of the planktonic foraminifera *Microhedbergella renilaevis*

(Kennedy *et al*., 2017). The lithostratigraphic horizon employed for the definition is the base of a black fissile shale bed with a thickness of 1 m called the Niveau Kilian, which does not bear any ammonites. Lying below the Niveau Kiklian, a 1.5 m thickness of laminated organic-rich shale called the Niveau Jacob has yielded abundant ammonites, including *Hypacanthoplites elegans* and rare *H. clavatus* and *H. plesiotypicus*. A lithostratigraphic horizon about 10 m above the Niveau Kilian has yielded *Hypacanthoplites* of the *elegans* group (Kennedy *et al*., 2000).

The Aptian–Albian boundary thus lies between the strata that bears these ammonite species and is situated within an ammonite biostratigraphic zone named as *Hypacanthoplites plesiotypicus* Zone.

In the Tanohata region, the ranges of *Hypacanthoplites subcornuerianus* and *Douvilleiceras bifurcatum* are somewhat overlapped, and the co-occurrence of several species is observed at the location KK. This overlap occurrence is the same as *H. trivialis*, *H. anglicus*, *H. clavatus,* and *H. milletioides*, and *Douvilleiceras leightonense* in the Niveau Paquier of the Albian stratotype section, southern France. The biostratigraphic horizon showing overlap in France is situated within the Albian Stage. The boundary in France lies between lithostratigraphic horizons bearing *H. elegans* and *D. leightonense*, respectively. The lithostratigraphic horizon location KK in the Miyako Group is probably situated within the Albian Stage, and the Aptian–Albian boundary is interpreted to lie in the upper part of the *Hypacanthoplites subcornuerianus* Taxon-range Zone. The boundary probably lies between lithostratigraphic horizons bearing *H*. cf. *elegans* and *D. bifurcatum,* respectively, that is, the lithostratigraphic horizons of locations Hn 0016 and KK. The FAD of most *Douvilleiceras* species is not descending stratigraphically to the upper Aptian, thus the Aptian–Albian transition is supported to exists in the *Hypacanthoplites subcornuerianus* Taxon-range Zone in the Hiraiga Formation of the Miyako Group.

The *Leymeriella tardefurcata* Zone has not been identified in the Miyako Group, an absence also noted in California (Murphy, 1956) in the northern Pacific Province. This may be caused by two possibilities: 1) the biogeographic distribution of *Leymeriella tardefurcata* did not extend to the circum-northern Pacific Realm, and / or 2) physical and biogeographic connections between both circum northern Pacific Realm and the Tethyan Realm were closed during the Aptian–Albian interval (Matsukawa & Shibata, 2023). In Tunisia and Algeria where lay on the Tethyan margin, Latil (2011) proposed a regional ammonite biozonation for the early Albian, there, but the Aptian–Albian boundary was not defined due to a lack of paleontological data. A continuous record from the base of the Albian is confirmed in the Hameima Formation in Tunisia and Algeria, and the record from the upper part of the Hiraiga to Aketo formations can be correlated with the Hameima Formation.

In the Sangenh and Aitiamir formations in northern Iran, which was in the eastern part of the Tethyan province, Lehmann *et al*. (2019) identified the Aptian–Albian boundary in the biostratigraphic distribution of *Hypacanthoplites elegans*. The occurrences of *Hypacanthoplites elegans* are known to straddle the Aptian–Albian boundary in northern Germany (Mutterlose *et al*., 2003). In New Mexico, U.S.A., the Aptian–Albian boundary should be also present in the U-bar Formation bearing *Hypacanthoplites immunitus* and *Douvilleiceras mammillatum*, but the exact boundary is not yet confirmed there (Lucas & Estep, 2000).

Successive change of ammonite whorl-form and characteristics of Miyako Group ammonite assemblages

In order to understand the characteristics of the ammonite faunas of the Miyako Group, we have divided the ammonite faunas into three distinct assemblages based on their biostratigraphic occurrences their composition, comparisons, and temporal changes (Fig. 59).

The assemblage in the lowest *Epicheloniceras* sp. Taxon-range Zone consists of 34 species of 25 genera belonging to 10 families, dominated by the Desmoceratidae Douvilleiceratidae, and Parahoplitidae. The assemblage in the overlying *Hypacanthoplites subcornuerianus* Taxon-range Zone consists of 70 species of 43 genera belonging to 17 families, dominated by Parahoplitidae. Finally, that of the *Douvilleiceras bifurcatum* Interval Zone consists of 44 species of 32 genera belong to 15 families, dominated by Trochleiceratidae and Desmoceratidae. The fauna of the *E*. sp. Taxon-range Zone is the least diverse, as defined by species numbers. The subsequent fauna in the *Hypacanthoplites subcornuerianus* Taxon-range Zone fauna is the most diverse, while in the fauna in the *Douvilleiceras bifurcatum* Interval Zone fauna is intermediate in diversity. The ammonite species and genus diversity thus increased twofold during the initial of basin development. In contrast, the *D. bifurcatum* Interval Zone, which has 44 species of 32 genera, reflects a reduction in diversity in the later history of the basin. The ammonites in these assemblages are morphologically represented by 1) smooth or weakly ornate planispiral forms, 2) ornate planispiral forms, and 3) heteromorph forms. The stratigraphic distribution of morphotypes found in the three ammonite assemblages is as follows: The assemblage of the lowest *E*. sp. Taxon-range Zone includes the group: 1) smooth or weakly ornate planispiral forms representing 11 genera (five species of four genera of Phylloceratidae, one species of one genus of Lytoceratidae, six species of five genera of Desmoceratidae, and one species of one genus of Cleoniceratidae); 2) ornate planispiral forms consisting

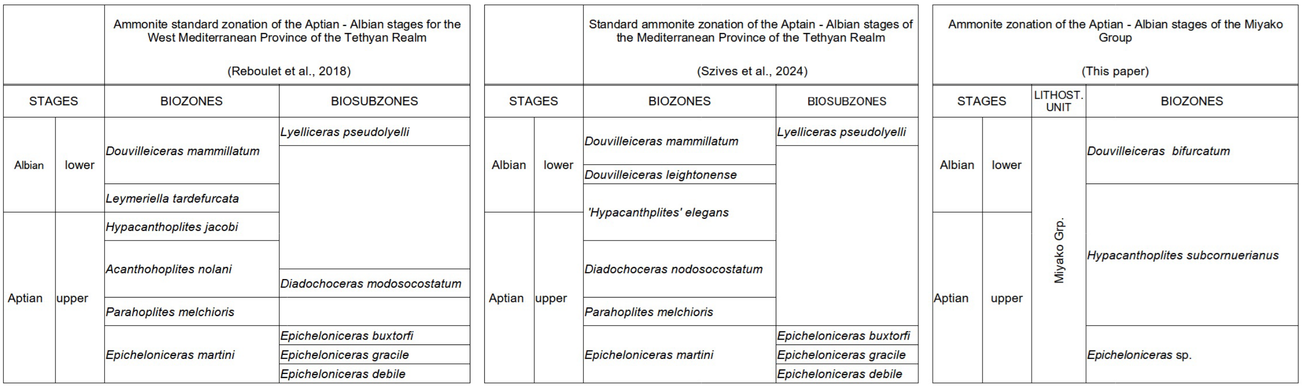

FIGURE 57. Comparison of the ammonite standard zonation of the upper Aptian and the lower Albian stages of the Mediterranean Province of the Tethyan Realm and that of the Miyako Group.

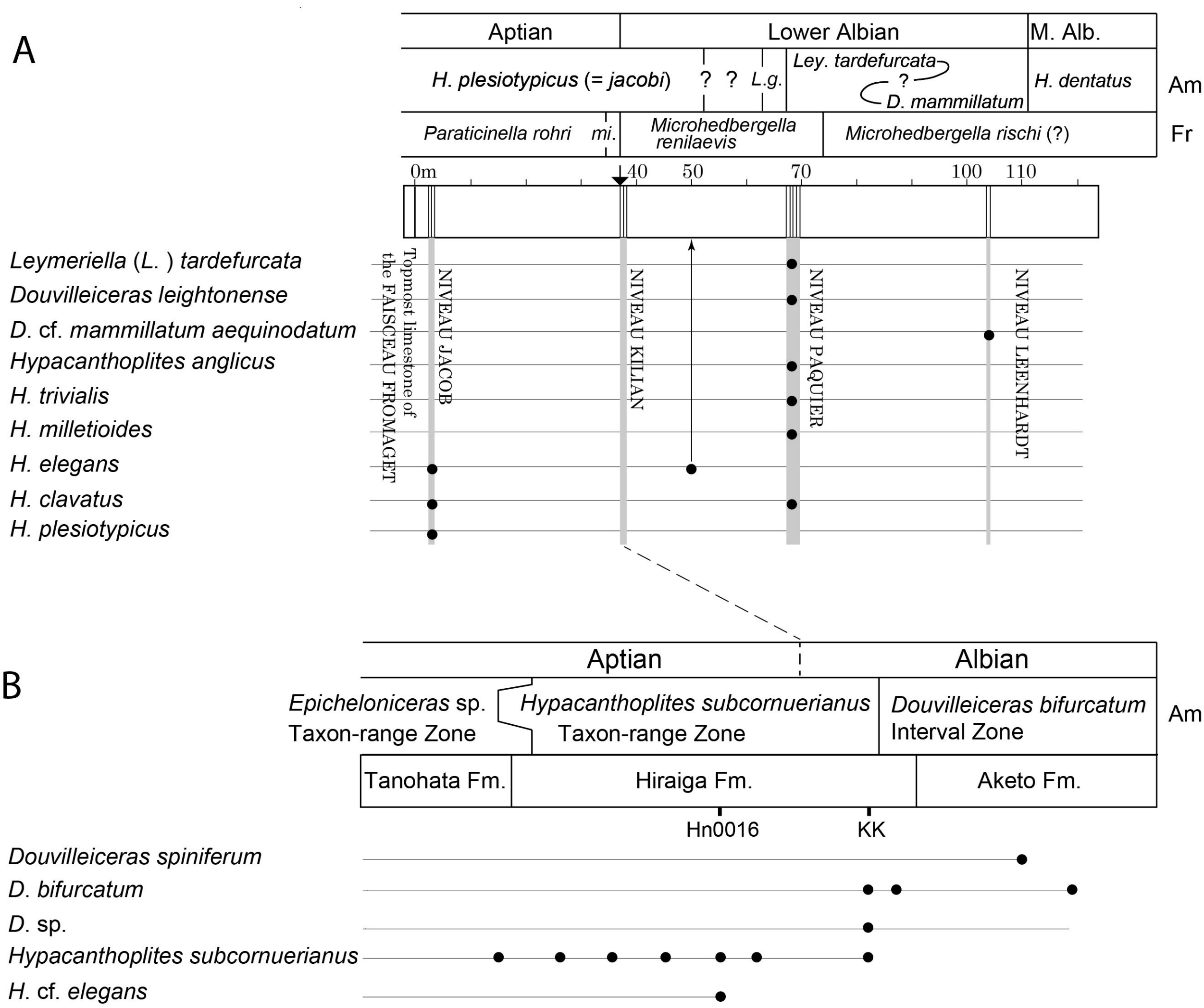

FIGURE 58. Comparison of the Aptian–Albian transition of the stratotype section of the base of the Albian stage (GSSP) (**A**) and the Miyako Group (**B**). Line with arrow shows the Aptian–Albian boundary. The date of the GSSP is cited from Kennedy *et al.* (2000, 2017).

of 11 genera (one species of one genus of Silesitidae, one species of one genus of Kossmaticeratidae, eight species of five genera of Douvilleiceratidae, and eight species of four genera of Parahoplitidae); and 3) heteromorph forms consisting of three species of two genera of Hamitidae. The assemblage of the middle *Hypacanthoplites subcornuerianus* Taxon-range Zone includes: 1) smooth or weakly ornate planispiral forms consisting of 22 genera (11 species of six genera of Phylloceratidae, three species of two genera of Lytoceratidae, two species of two genera of Gaudryceratidae, four species of three genera of Tetragonitidae, two species of two genera of Oppeliidae, and 10 species of seven genera of Desmoceratidae); 2) ornate planispiral forms consisting of 12 genera (three species of one genus of Silesitidae, three species of two genera of Kossmaticeratidae, eight species of five genera of Douvilleiceratidae, three species of one genus of Trochleiceratidae, and five species of three genera of Parahoplitidae); and 3) heteromorph forms consisting of eight genera (one species of one genus of Ancyloceratidae, five species of two genera of Ptychoceratidae, four species of three genera of Anisoceratidae, two species of one genus of Hamitidae, and one species of one genus of Baculitidae). The assemblage of the uppermost *Douvilleiceras bifurcatum* Interval Zone assemblage include: 1) smooth or weakly ornate planispiral forms consisting of 19 genera (five species of five genera of Phylloceratidae, five species of three genera of Lytoceratidae, two species of one genus of Gaudryceratidae, one species of one genus of Tetragonitidae, one species of one genus of Oppeliidae, eight species of six genera of Desmoceratidae, three species of two genera of Cleoniceratidae); 2) ornate planispiral forms consisting of seven genera (two species of two genera of Kossmaticeratidae, one species of one genus of Hoplitidae, three species of two genera of Douvilleiceratidae, and three species two genera of Trochleiceratidae); and 3) heteromorph forms consisting of seven genera (two species of two genera of Ancyloceratidae, four species of two genera of Ptychoceratidae, two species of two genera of Anisoceratidae, and three species of one genus of Hamitidae).

The group (2), ornate planispiral forms, predominates throughout the Miyako Group. The number of heteromorphy species of the group (3) increased explosively in the middle assemblage of the *Hypacanthoplites subcornuerianus*

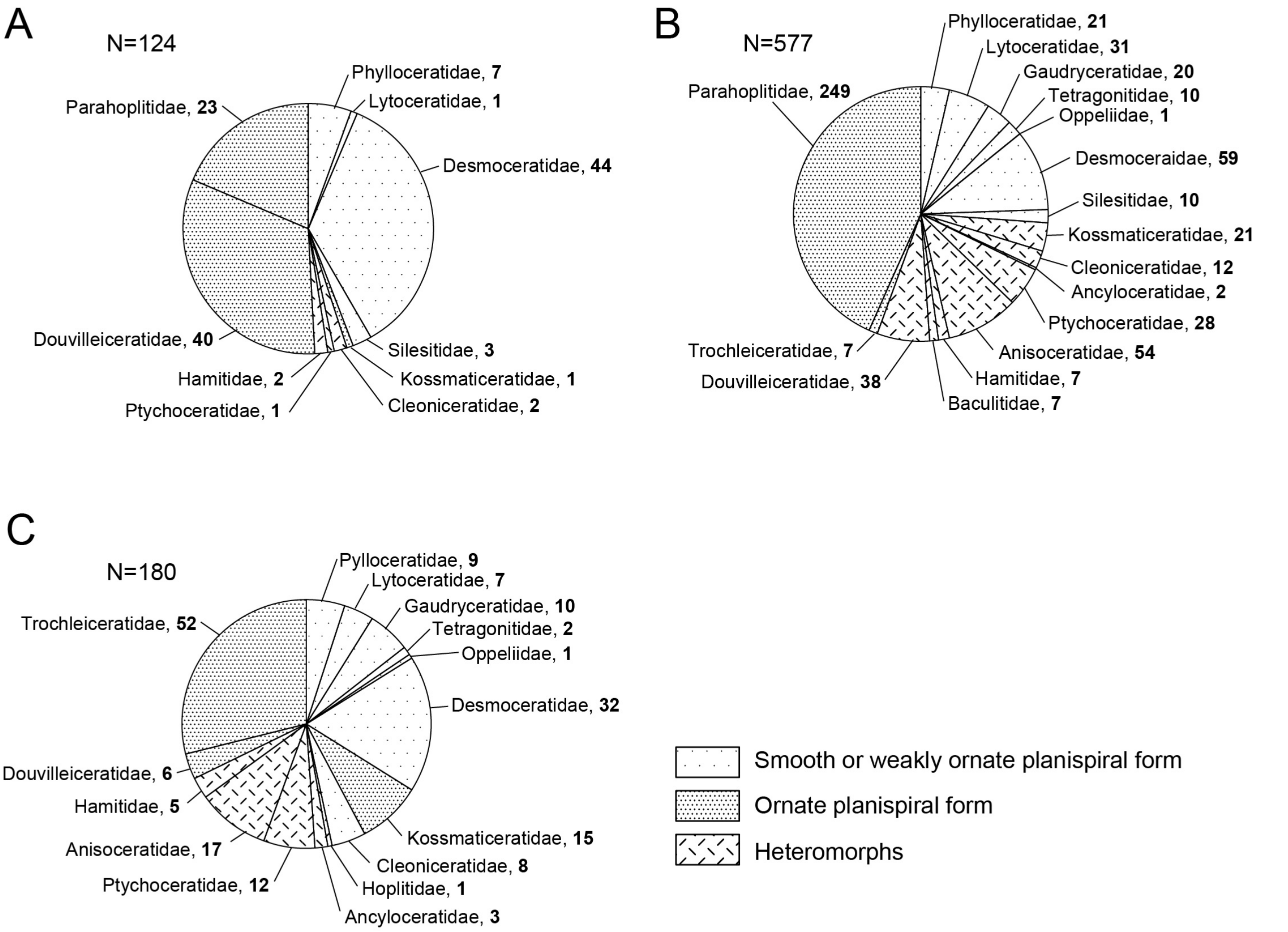

FIGURE 59. Diagrams displaying the specimens of ammonite families of the Miyako Group. **A**, Ammonite association of *Epicheloniceras* sp. Zone. **B**, Ammonites association of *Hypacanthoplites subcornuerianus* Zone. **C**, Ammonites association of *Douvilleiceras bifurcatum* Zone.

Taxon-range Zone and maintained its dominance in the highest assemblage of the *Douvilleiceras bifurcatum* Interval Zone. The group (1), smooth or weakly ornate planispiral forms, dominates in the lowest assemblage of the *Epicheloniceras* sp. Taxon-range Zone, but decrease significantly in the middle assemblage of the *H. subcornuerianus* Taxon-range Zone, then increase slightly in the uppermost assemblage of the *D. bifurcatum* Zone.

Both ornate planispiral and smooth or weakly ornate planispiral forms, inhabited the Miyako area initially, and the number of ammonite species and their abundance increased, and their shell morphology diversified, during the geological history of the three assemblages. These changes occurred during a transgressive episode when the habitat for ammonites expanded. Both ornate planispiral and smooth or weakly ornate planispiral forms appeared first, followed by the heteromorph expansion. Since species of ornate planispiral newly described here are principally endemic, whereas those of smooth or weakly ornate planispiral forms share common species with North America and the Tethyan area. The ornate planispiral forms presumably speciated near the Miyako area and, with smooth or weakly ornate planispiral forms, migrated, elsewhere expanding biogeographically during the transgressive episode.

Evolution of early douvilleiceratids

Since the Miyako Group yields specimens of five species of the genera *Eodouvilleiceras* and *Douvilleiceras*, we propose an evolutionary model of the early douvilleiceratids in the northern Pacific Province based on these five species (Fig. 60). The biostratigraphic occurrences of these species are summarized as follows: 1) *E*. aff. *matsumotoi* is found in the *Epicheloniceras* sp. Taxon-range Zone in the Hiraiga Formation; 2) *Eodouvilleiceras matsumotoi* is found in the *Epicheloniceras* sp. Taxon-range Zone in the Hiraiga Formation and the *Douvilleiceras bifurcatum* equivalent zone in the Sakiyama Formation; 3) *Douvilleiceras* sp. is found in the *Hypacanthoplites subcornuerianus* Taxon-range Zone in the Hiraiga Formation; 4) *Douvilleiceras bifurcatum* is found in the three biostratigraphic horizons of the *Douvilleiceras bifurcatum* Interval Zone in the Aketo Formation; 5) *D. spiniferum* is found in the *Douvilleiceras bifurcatum* Interval Zone in the Aketo Formation; 6) the FAD of *E. matsumotoi* is earlier than the occurrence of *Douvilleiceras* sp.; 7) *D*. sp. is the earliest appearance among three species of *Douvilleiceras*; and 8) the FAD of *D. bifurcatum* is earlier than that of *D. spiniferum*.

We can examine and compare characteristics of ribbing and tubercle expression for genera *Eodouvilleiceras* and *Douvilleiceras* to suggest some phylogenetic relationships. Futakami & Haggart (2018) proposed a tubercle expression formula where in the Set 1 is the number of ventrolateral tubercles and Set 2 is the number of lateral and umbilical tubercles. This expression formula also applies to the genus *Eodouvilleiceras*. The Set 1 and the Set 2 expression of both *Eodouvilleiceras matsumotoi* and *E*. aff. *matsumotoi* are 1 and 2, that of *Douvilleiceras* sp. is 3 and 2, that of *D. bifurcatum* is 4 and 2, while that of *D. spiniferum* is 3 and/or 4 and 3. With respect to ribbing variability, *Eodouvilleiceras matsumotoi*, *E*. aff. *matsumotoi*, and *Douvilleiceras spiniferum* all have a single rib, while *D*. sp. has single ribs consisting of primaries and secondaries, and *D. bifurcatum* has bifid ribs.

Based on the number of tubercles and the features of the ribs, the relative relationships of the five species can be interpreted as follows. With respect to tubercles, the number of tubercles increases in the biostratigraphic order of both *E. matsumotoi* and *E*. aff. *matsumotoi*, as well as *D*. sp., *D. bifurcatum*, and *D. spiniferum*. The increasing number of tubercles thus indicates the order of appearance of the five species. The co-occurrences of *E. matsumotoi* and *E*. aff. *matsumotoi* supports this interpretation, because they both have the same number of tubercles. Then, regarding ribbing, both *Eodouvilleiceras matsumotoi* and *E*. aff. *matsumotoi, Douvilleiceras* sp. and *D. spiniferum* have single ribs, whereas *D. bifurcatum* has bifid ribs. The features of the ribs show no regularity in change related to the biostratigraphic order of species appearance.

The lithostratigraphic horizon of *Douvilleiceras* sp. at location Ks2005 is assigned to the upper Aptian, because it occurs with *Hypacanthoplites subcornuerianus* and *Diadochoceras nodosocostatiforme*. Since this is the earliest occurrence record of the genus *Douvilleiceras*, it can be interpreted that the genus originated in the Miyako area and /or its adjacent area in the northern Pacific Province. In the Miyako Group, *D. bifurcatum* and *D. spiniferum* appeared in that biostratigraphic order. Since *D. bifurcatum* occurs only in the lowermost Albian of the Miyako Group, it is probable that it was derived from *D*. sp. The Set 1 and Set 2 of *D*. sp. is 3 and 2, and that of *D. bifurcatum* is 4 and 2, which concurs with the trend that younger species tend to have greater numbers of tubercles. *D. spiniferum* has been reported from British Columbia in Canada and also California, but because the accuracy of geological time resolution is low, it is not possible to determine the biostratigraphic order of appearance of douvilleiceratids in these areas. Therefore, it can only be interpreted that the douvilleiceratid species originated in some area of the northern Pacific Province, and the expanded elsewhere across the province. *Douvilleiceras mammillatum* from the Albian Yezo Group, Japan (Futakami & Haggart, 2018) is similar because it is reported from all over the world.

Latil (2011) regarded the genus *Eodouvilleiceras* (Casey, 1962) as a synonym of the genus *Douvilleiceras* de Grossouvre (1894) based on the ontogeny of some juvenile, primitive members of the *Douvilleiceras* presented by Jacob (1905). Latil (2011) suggested that the genus *Eodouvilleiceras* has transitional morphologies from *Epicheloniceras* to *Douvilleiceras* and could represent an ontogenetic stage of early members of the genus *Douvilleiceras*. The genus *Epicheloniceras* is characterized by rib bifurcation at the lateral tubercles (Wright *et al*., 1996). Ribs of both *Eodouvilleiceras matsumotoi* and *Eodouvilleiceras* aff. *matsumotoi*, are, however, not branched throughout their ontogeny. This does not support the interpretation of Latil (2011). In the Pacific Province, following two early douvilleiceratid species in which ribs are not bifid are reported. First, *Eodouvilleiceras kumaense* (Matsumoto & Tamura, 1982) occurs from the uppermost Aptian of the Tomochi Formation. Secondary, *Eodouvilleiceras horridum* (Riedel, 1938) occurs from the lower Albian strata of Colombia (although Casey (1962) stated it came from the upper Aptian) with ribs which also are not bifid. *Douvilleiceras bifurcatum* has bifid ribs. Based on the characteristic of ribs branching at the lateral tubercle, it is thus possible to interpret that *D. bifurcatum* evol v ed from a species of *Epicheloniceras*, supporting Latil's (2011) interpretation. However, since *D. spiniferum* does not have bifid ribs throughout its growth stages (Futakami & Haggart, 2016), it can be interpreted that *D. spiniferum* did not come from an *Epicheloniceras* ancestor. In the Miyako Group, *Eodouvilleiceras matsumotoi* occurs in the *Epicheloniceras* sp. Taxon-range Zone before the appearance of *Douvilleiceras* sp., indicating that the genus *Eodouvilleiceras* appeared before the genus *Douvilleiceras*. It is possible that *D*. sp. was derived from *E*. *matsumotoi*, because the early whorl of *D*. sp. has the inserted minor ribs that are seen on *E*. *matsumotoi*. This interpretation also gives support for Latil's (2011) ideas, but for a different reason. According considerings all of this evidence, it is perhaps reasonable to conclude that the genus *Douvilleiceras* was a polyphyletic group, with evolutionary relationships with multiple ancestors.

The accuracy of geologic time resolution is low for the time of *Eodouvilleiceras*, and it is thus not yet possible to use this group for establishing an age of the

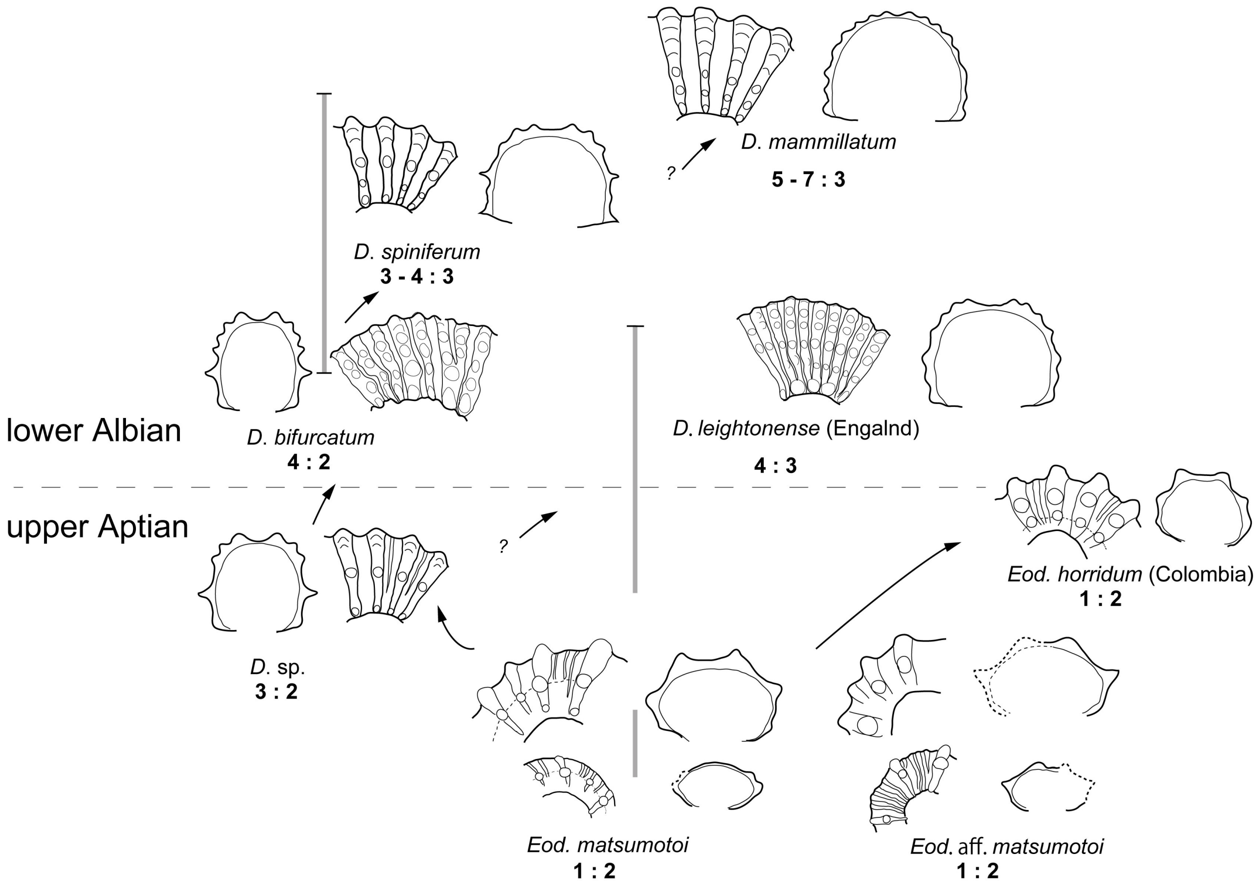

FIGURE 60. Diagrams displaying an evolutionary model of the early douvilleiceratids in the western side of the north Pacific Province. Grey bars show the biostratigraphic range of *Eodouvilleiceras matsumotoi* and *Douvilleiceras bifurcatum*. Solid numbers show the genus *Douvilleiceras* tubercles expression presented by Futakami & Haggart (2018): set 1 (forward) is the number of ventrolateral tubercles and set 2 (hind) is the number of lateral and umbilical tubercles.

Miyako Group. This genus is reported from France, the Caucasus, Georgia, Turkmenistan, Texas, and Colombia. *E. horridum* from Colombia is considered as a descendant of *E. matsumotoi* because it came from the lower Albian (Riedel, 1938), although Casey (1962) regarded it of upper Aptian age.

Conclusion

1) The Miyako Group across the whole of its distributed area is divided lithostratigraphically into the Raga, Tanohata, Hiraiga, and Aketo and its equivalents, the Sakiyama and Hideshima formations, in ascending stratigraphic order.

2) The Miyako Group has yielded a rich ammonite fauna from the Tanohata, Hiraiga, Aketo, and Sakiyama formations totalling 92 species of 49 genera including one new genera (*Pseudolithancylus*) and nine new species (*Phyllopachyceras iwatense*, *Puzosia* (*P.*) *shimizui*, *Desmoceras* (*Pseudouhligella*) *sanrikucum*, *Pseudolithancylus tohokuense*, *Ephamulina monotuberculata*, *Idiohamites pacificum*, *Lechites* (*L.*) *komorii*, *Paracheloniceras kazuoi*, and *Douvilleiceras bifurcatum*), which are described systematically.

3) These ammonite assemblages can be divided into three ammonite biostratigraphic zones, the *Epicheloniceras* sp. Taxon-range Zone, the *Hypacanthoplites subcornuerianus* Taxon-range Zone, and the *Douvilleiceras bifurcatum* Interval Zone. These zones are identified in the Tanohata to Sakiyama formations, and two ammonite biostratigraphic horizons (*Epicheloniceras* sp. Biostratigraphic horizon and *Colombiceras yaegashii* Biostratigraphic horizon) can be recognized in the Hiraiga Formation of the Sakiyama region. The three zones (*Epicheloniceras* sp. Taxon-range Zone, *Hypacanthoplites subcornuerianus* Taxon-range Zone, *Douvilleiceras bifurcatum* Interval Zone) can be correlated with the ammonite standard zonation of the Barremian–Albian stages of the West Mediterranean Province of the Tethyan Realm. The *Epicheloniceras* sp. to *Hypacanthoplites subcornuerianus* Taxon-range zones of the Miyako Group correlate with the *Epicheloniceras martini*, *Parahoplites melchioris*, and *Diadochoceras nodosocostatum* to '*Hypacanthoplites elegans*' zones of the ammonite standard zonation and are thus assigned to the upper Aptian and the Aptian–Albian transition. The *Douvilleiceras bifurcatum* Interval Zone can be correlated with the *Douvilleiceras leightonense* Zone of the ammonite standard zonation.

4) The Aptian–Albian transition in the Miyako Group exhibits within the *Hypacanthoplites subcornuerianus* Taxon-range Zone because this zone can be correlated to the *H. plesiotypicus* Zone, which is the equivalent of the *H. jacobi* Zone of the ammonite standard zonation, including at the GSSP of the Albian Stage in France. In the Miyako Group, this boundary is found between lithostratigraphic horizons of locations Hn 0016 and KK in the upper part of the Hiraiga Formation in the Tanohata region.

5) The *Hypacanthoplites subcornuerianus* Taxon-range Zone of the Hiraiga Formation has the highest diversity ammonite assemblage in the Miyako Group and the *Douvilleiceras bifurcatum* Interval Zone in the Aketo Formation has the second highest, followed by the *Epicheloniceras* sp. Taxon-range Zone of the lower part of the Hiraiga and Tanohata formations. Morphological characteristics of ornate planispiral forms and smooth or weakly ornate planispiral forms are abundant in the *Epicheloniceras* sp. Taxon-range Zone. This is followed by abundant ornate planispiral forms, and common smooth or weakly ornate planispiral forms and heteromorph forms in the *Hypacanthoplites subcornuerianus* Taxon-range Zone, and, finally, equally common proportions of all three morphotypes in *Douvilleiceras bifurcatum* Interval Zone. These changes appear to be related to transgression. In the expansion of the ammonite habitat accompanying transgression, both the ornate planispiral and smooth or weakly ornate planispiral forms appear first, followed by the heteromorph forms. The new species of ornate planispiral forms described above are endemic to the Miyako Group, but smooth or weakly ornate planispiral forms share common species with North America and the Tethyan area. Thus, the ornate planispiral forms are interpreted to have speciated in the Miyako area during the transgressive episode, while the smooth or weakly ornate planispiral forms migrated and expanded their biogeographical range.

6) Since the Miyako Group yields some specimens identified as five species of the genera *Eodouvilleiceras* and *Douvilleiceras*, we propose an evolutionary model of the early douvilleiceratids in the northern Pacific Province. In these species, the number of tubercles increases in the biostratigraphic order of the species' appearance, but the features of the ribs show no such regularity in appearance. *Douvilleiceras* sp. is found in association with Aptian ammonite species, and its occurrence in the Miyako Group is the earliest record of the genus *Douvilleiceras*. It can be interpreted that *D.* sp. appeared initially in the Miyako area and /or adjacent areas of the northern Pacific Province and gave rise subsequently to *D. bifurcatum*. Unfortunately, it is not possible to determine the biostratigraphic level of *D. spiniferum* in these areas, because the chronological resolution is low in these areas. Since any ribs of both *Eodouvilleiceras matsumotoi* and *Eodouvilleiceras* aff. *matsumotoi* are not branch in their growth stages from juvenile to adult, the interpretation that the genus *Douvilleiceras* was derived from the genus *Eodouvilleiceras* is not supported based on this example.

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Appendix

Locality Guide

The localities of the ammonite specimens described by Obata (1967a, b, 1969, 1973, 1975), Obata & Futakami (1991, 1992), Obata & Matsukawa (1980, 2018), Obata *et al*. (2010) and the present paper are listed from north to south, as shown Figs 2–9, Hanai's locations are indicated by prefix Hn, Obata's by B, C and OH, Tanaka's by TR, Hayami's by Hy, and Kase's location by Ks. The ammonite specimen numbers studied are given by location. The 6000s number prefix is omitted, but it is TGUSE-MM.

(1) Tanohata region of Tanohata Village, Iwate Prefecture (Fig. 2)

Hn0650

Location: southern extremity of the Aketo coast.

Lithology: Concretion in calcareous sandstone containing *Orbitolina* sp.

Stratigraphic position: upper part of the *Orbitolina* sandstone in the Hiraiga Formation.

Ammonite species: *Valdedorsella getulina* Coquand, 1880 (NSM-PM 6073 in Obata, 1967a), *Ptychoceras minimum* Rouchadzé, 1933 (6147), *Pseudoleymeriella hataii* Obata, 1973 (all NSM-PM 7282, 7283, 7287, 7288, 7289, 7290, 7291 in Obata, 1973; 6131, 6132, 6133, 6134 and 6138-6146), *P. hiranamensis* Obata, 1973 (NSM-PM 7284 in Obata, 1975).

Collector: I. Obata.

C2 (≈ C2p)

Location: Road-cut south of Aketo.

Lithology: Pebbly sandstone containing *Orbitolina* sp.

Stratigraphic position: Hiraiga Formation.

Ammonite species: *Goretophylloceras*? sp. (6194 in Obata & Matsukawa, 2018), *Hypophylloceras* sp. (6196 in Obata & Matsukawa, 2018), *Marshallites miyakoensis* Obata & Futakami, 1991 (6105).

Collector: I. Obata.

C4

Location: Road-cut south of Aketo.

Stratigraphic position: Hiraiga Formation.

Ammonite species: *Protetragonites eichwaldi* (6269 in Obata & Matsukawa, 2018, described as *Lytoceras* sp.), *Protanisoceras*? sp. (6260 in Obata & Matsukawa, 2018), *Ephamulina monotuberculata* **sp. nov.** (6240 in Obata & Matsukawa, 2018, described as *Metahamites*? sp. indet.).

Collector: I. Obata.

Hn0679

Location: Aketo coast.

Lithology: Greenish grey fine-grained sandstone.

Stratigraphic position: lower part of the Aketo Formation.

Ammonite species: *Marshallites miyakoensis* Obata & Futakami, 1991 (NSM-PM 7695 and 7696 in Obata & Futakami, 1991), *Protanisoceras*? sp. (6160 in Obata & Matsukawa, 2018), *Pseudoleymeriella hataii* Obata, 1973 (NSM-PM 7289; 6460A, 6460B, 6460C and 6460D).

Collector: I. Obata.

OH7 (≈ C3p, C6p, C7p, OH7', TR138)

Location: Road-cut north of Raga.

Lithology: Massive medium- to fine-grained sandstone, either calcareous or muddy, partly abounding in fossils.

Stratigraphic position: Aketo Formation.

Ammonite species: *Euphylloceras*? sp. (6197 in Obata & Matsukawa, 2018), *Pictetia* cf. *astieriana* Orbigny, 1842 (6225, 6226, 6193 in Obata & Matsukawa, 2018), *Eogaudryceras* (*Eotetragonites*) *gainesi* (Anderson, 1938) (6149), *Valdedorsella akuschaensis* Anthula, 1899 (6548A, 6127), *Uhligella* aff. *matsushimaensis*, Shimizu, 1931 (6165 in Obata & Matsukawa, 2018), *Beudanticeras*? sp. (6209), *Desmoceras* (*Pseudouhligella*) *sanrikucum* **sp. nov.** (6117), *Hulenites kitamurai* (6441), *Anadesmoceras* sp. B (6458), *A*.? sp. (6279 in Obata & Matsukawa, 2018, described as *Cleoniceras* (*C.*) cf. *cleon*), *Anahoplites*? sp. indet. (6159 in Obata & Matsukawa, 2018), *Ptychoceras* cf. *emericianum* Orbigny, 1842 (6093, 6094, 6095, 6580), *Ptychoceras minimum* Rouchadzé, 1933 (6542, 6550), *Protanisoceras*? sp. (6153, 6154 in Obata & Matsukawa, 2018). *Ephamulina monotuberculata* **sp. nov.** (6435, 6546, 6547A; 6107, 6111 and 6112 in Obata & Matsukawa, 2018, described as *Metahamulina*? sp. indet.), *Hamites* (*H.*) cf. *tenuis* J. Sowerby, 1814 (6437), *Pseudoleymeriella hataii* Obata, 1973 (6179A, 6179B, 6180A, 6442, 6534, 6535, 6536, 6538, 6539, 6541, 6543, 6544A, 6547B, 6548B, 6549, 6551 and 6552), *P. hiranamensis* Obata, 1973 (6443, 6533).

Collectors: K. Tanaka, S. Ogino and I. Obata.

A cliff of Hiraname coast (≈ OH6)

Location: Hiraname coast.

Lithology: Silty sandstone.

Stratigraphic position: Aketo Formation.

Ammonite species: *Valdedorsella akuschaensis* Anthula, 1899 (6509), *Marshallites miyakoensis* Obata & Futakami, 1991 (6182).

Collector: I. Obata.

Hn6200 (≈ C5p, Hiraname coast in Obata *et al*., 2010)

Location: road-cut north of Raga.

Lithology: Muddy, calcareous fine-grained sandstone.

Stratigraphic position: upper part of the Aketo Formation.

Ammonite species: *Pictetia* cf. *astieriana* Orbigny, 1842 (6193 in Obata & Matsukawa, 2018), *Beudanticeras*? sp. (6181 in Obata & Matsukawa, 2018), *Desmoceras* (*Pseudouhligella*) *sanrikucum* **sp. nov.** (6118, 6125, 6130, 6216 in Obata & Matsukawa, 2018; 6128, 6567A–D), *Marshallites miyakoensis* Obata & Futakami, 1991 (6568), *Douvilleiceras bifurcatum* **sp. nov.** (NSM-PM 7274 and 7276 in Obata, 1969, described as *Douvilleiceras mammillatum*), *Pseudoleymeriella hataii* Obata, 1973 (6569).

Collector: Kaneko, H. Tsuda and I. Obata.

Hn6201 (≈ B2, Hiraname-dana)

Location: Road-cut of Hiraname, northeast part of Raga.

Lithology: Greenish grey fine-grained calcareous sandstone.

Stratigraphic position: lower part of Aketo Formation.

Ammonite species: *Goretophylloceras*? sp. (6237 in Obata & Matsukawa, 2018), *Phyllopachyceras* aff. *infundibulum* (6178 in Obata & Matsukawa, 2018), Phylloceratidae **gen. et sp.** indet. (UMUT 32621 in Obata & Matsukawa, 2018), *Ammonoceratites* (*A.*) *crenocostatus* (Whiteaves, 1876) (IPMM 20804 in Obata & Futakami, 1992), *A. gigas* (Obata *et al*., 2010) (6004, Obata *et al*., 2010), *Eogaudryceras* (*Eotetragonites*) *gainesi* (Anderson, 1938) (IPMM 8743 in Obata & Futakami, 1992; all 6184, 6172, 6183, 6186, 6227, 6521, 6583 in Obata & Matsukawa, 2018), *Gabbioceras* sp. (6228, 6251), *Valdedorsella akuschaensis* Anthula, 1899 (6447D, 6519B), *Valdedorsella kasei* Obata & Matsukawa, 2018 (6573, 6574), *Melchiorites yabei* (Shimizu, 1931) (6217, 6218 in Obata & Matsukawa, 2018, described as *Puzosia yabei*), *Puzosia* (*P.*) *shimizui* **sp. nov.** (6158), *Beudanticeras*? sp. (6150), *Desmoceras* (*Pseudouhligella*) *sanrikucum*, **sp. nov.** (6519C, 6565, 6456, 6566; UMUT32628), *Marshallites miyakoensis* Obata & Futakami, 1991 (6268, 6455, 6526, 6528A, 6246, 6252; all NSM-PM 7692, 7693, 7694 in Obata & Futakami, 1991), *Cleoniceras* (*Cleoniceras*) cf. *cleon* (Orbigny, 1850) (6275, 6276, 6277, 6278, 6281), *Pseudolithancylus tohokuense* **sp. nov.** (6449), *Tonohamites*? sp. (6522), *Ptychoceras* cf. *emericianum* Orbigny, 1842 (6157), *Ptychoceras* sp. (6245), *Diptychoceras iwatense* Obata & Matsukawa, 2018 (6097 in Obata & Matsukawa, 2018, 6527), *Protanisoceras*? sp. (6151, 6152, 6261, 6263 in Obata & Matsukawa, 2018), *Ephamulina monotuberculata*, **sp. nov.** (6520; 6109 in Obata & Matsukawa, 2018, described as *Ephamulina*? sp.

indet.), *Hamites* (*H.*) cf. *tenuis* Sowerby, 1814 (6447C), *Hamites* (*H.*) sp. B (6447A), *H.* (*H.*) sp. C (6448), *Pseudoleymeriella hataii* Obata, 1973 (6525; NMS-PM 7285, 7290, 7291 in Obata, 1973; IGPS36513 in Shimizu, 1931), *P. hiranamensis* Obata, 1973 (6432, 6433: NSM-PM 7286 in Obata, 1973), *Douvilleiceras spiniferum* (Whiteaves, 1900) (6171).
Collector: K. Tanaka, I. Hayami, H. Tsuda and I. Obata.

Hn6202
Location: Road-cut of Hiraname, northeast part of Raga.
Stratigraphic position: uppermost part of the "*Orbitolina* sandstone" in the Hiraiga Formation.
Ammonite species: *Hypophylloceras* sp. (6201 in Obata & Matsukawa, 2018), Phyllopachyceratidae **gen. et sp.** indet. (UMUT-MM 32622 in Obata & Matsukawa, 2018).
Collectors: T. Hanai, I. Hayami and I. Obata.

Hn6203 (≈ TR139)
Location: Road-cut north of Raga.
Lithology: Alternating beds of fine-grained muddy sandstone and sandy mudstone. Ammonites occur in sandy mudstone.
Stratigraphic position: Hiraiga Formation.
Ammonite species: *Hypophylloceras* sp. (6176 in Obata & Matsukawa, 2018), *Marshallites miyakoensis* Obata & Futakami, 1991 (6189), *Pseudolithancylus tohokuense* **sp. nov.** (6445), *Douvilleiceras bifurcatum* **sp. nov.** (NSM-PM 7275 in Obata, 1969, described as *Douvilleiceras mammillatum*).
Collectors: K. Tanaka and I. Obata.

KK
Location: Raga north.
Lithology: Mudstone.
Stratigraphic position: uppermost part of the Hiraiga Formation.
Ammonite species: *Euphylloceras californicum* (Anderson, 1938) (all IPMM 62934, 62935, 62936, 62937, 62938, 62939, 62640, 62941), *E.* sp. (all IPMM 63787, 63788, 63789), *Goretophylloceras* cf. *fortunei* (Honnorat-Bastide, 1892) (IPMM 62942), *Goretophylloceras* cf. *subalpinum* (Orbigny, 1850) (IPMM 62944), *G.* sp. (IPMM 62943), *Holcophylloceras caucasicum* (Sayn, 1920) (IPMM 63776), *Phyllopachyceras iwatense* **sp. nov.** (IPMM 62945), *Pictetia astieriana* Orbigny, 1842 (IPMM 62949-62975), *Protetragonites eichwaldi* (Karakasch, 1907) (IPMM 062946, 062947, 062948 and 63802F), *Eogaudryceras* (*Eotetragonites*) *gainesi* (Anderson, 1938) (all IPMM 62978, 62979, 62980, 62983A, 62985A, 62985B, 63795, 63796, 63797, 63798, 63799, 63785A–F), *Anagaudryceras* sp. (all IPMM 63782, 63783A, 63783B), *Tetragonites hulenensis* Murphy, 1967a (all IPMM 62976, 62977, 63790, 63791, 63792, 63783C-E), *Gabbioceras* sp. B (IPMM 63802H), *Valdedorsella akuschaensis* Anthula, 1899 (all IPMM 63761, 63764, 63766B, 63767), *V. getulina* Coquand, 1880 (IPMM 63758, 63759, 63760, 63762, 63763, 63765A, 63765B, 63766A, 63766C, 63768A, 63768B, 63768C, 63768D, 63771), *Melchiorites yabei* (Shimizu, 1931) (all IPMM 63779, 63780, 63781), *Desmoceras* (*Pseudouhligella*) *sanrikucum* **sp. nov.** (all IPMM 63772, 63773, 63774, 63775, 63783F), *Miyakoceras tanohatense* Obata, 1967b (IPMM 63757), *Hulenites kitamurai* Matsukawa, 2021 (all IPMM 63717, 63725, 63726, 63727, 63728, 63730, 63732), *Hulenites* sp. (IPMM 63719), *Marshallites miyakoensis* Obata & Futakami, 1991 (all IPMM 63714, 63715, 63718, 63720, 63721, 63722, 63723, 63724, 63729, 63731, 63733, 63735), *Anadesmoceras* sp. A (IPMM 63755A, 63785G), *Anadesmoceras* sp. B (all IPMM 63755B, 63756A, 63756B, 63777, 63778, 63802B–E), *Anadesmoceras*? sp. (IPMM 63802A), *Ptychoceras* cf. *emericianum* Orbigny, 1842 (all IPMM 63603A, 63603B, 63606, 63611A), *Ptychoceras minimum* Rouchadzé, 1933 (all IPMM 63602, 63607, 63610), *Diptychoceras iwatense* Obata & Matsukawa, 2018 (IPMM 63601A), *Diptychoceras* cf. *renngarteni* (Egoian, 1969) (all IPMM 63599, 63600), *Protanisoceras hanaii* Obata & Matsukawa, 2018 (all IPMM 63629–63634, 63636–63647, 63649–63662, 63664–63677), *Ephamulina monotuberculata* **sp. nov.** (all IPMM 63617, 63618, 63622, 63624A, 63624B, 63627, 63663), *Idiohamites pacificum* **sp. nov.** (IPMM 63620), *Hamites* (*Hamites*) cf. *tenuis* Sowerby, 1814 (all IPMM 63619, 63625A, 63625B, 63626, 63628, 63648), *Hamites* (*H.*) sp. A (IPMM 63635), *Lechites* (*Lechites*) *komorii* **sp. nov.** (all IPMM 63594, 63595, 63596, 63597, 63598), *Parachelonicerasguenoti* Collignon, 1965c (IPMM 63693), *P. kazuoi* **sp. nov.** (IPMM63690, 63706), *Diadochoceras nodosocostatiforme* (Shimizu, 1931) (all IPMM 63691–63692, 63694–63705, 63707–63712), *Douvilleiceras bifurcatum* **sp. nov.** (all IPMM 63678-63682, 63684, 63685, 63687, 63689), *Pseudoleymeriella hataii* Obata, 1973 (all IPMM 63740, 63743, 63744), *Pseudoleymeriella hiranamensis* Obata, 1973 (all IPMM 64741, 64742A, 63745), *Pseudoleymeriella obatai* Matsukawa & Oji, 2021 (IPMM 63713), *Hypacanthoplites subcornuerianus* (Shimizu, 1931) (all IPMM 63686, 63734, 63736–63739, 63746–63754, 63800).
Collector. K. Komori.

Hn0320 (≈ 0319, TR137)
Location: Funaare, sea off of north Hiraiga.
Lithology: Coarse-grained sandstone with frequent sandy siltstone interbeds.
Stratigraphic position: upper part of the Hiraiga Formation.
Ammonite species: *Melchiorites yabei* (Shimizu, 1931) (6471).
Collector: I. Obata.

Hn0220
Location: Kofunare, northern sea-cliff of Hiraiga.
Lithology: Dark grey, fine sandy mudstone.
Stratigraphic position: uppermost part of the Tanohata Formation.
Ammonite species: *Euphylloceras* sp. (6464), *Valdedorsella akuschaensis* Anthula, 1899 (NSM-PM 6069 in Obata, 1967a), *Melchiorites yabei* Shimizu, 1931 (6440, 6496), *Pseudohaploceras nipponicum* (Shimizu, 1931) (6557, 6558, 6561, 6104A, 6160B, 6104C, 6564A, 6564B, 6564C, 6564D), *Miyakoceras tanohatense* Obata, 1967 (NSM-PM 6118 in Obata, 1967b; 6459 and 6556), *Hypacanthoplites subcornuerianus* (Shimizu, 1931) (6559, 6560), *Parachelonicerasregina* (Obata & Matsukawa, 2018) (6438, 6192).
Collector: I. Obata.

Hn0006
Location: West of Tokuzo, southern cost of Hiraiga inlet.
Lithology: Sandy mudstone.
Stratigraphic position: lower part of the Tanohata Formation.
Ammonite species: *Protetragonites* sp. (UMUT 32624 in Obata & Matsukawa, 2018).
Collector: T. Hanai.

Hn0010
Location: Tokuzo, southern coast of Hiraiga inlet.
Lithology: Pebble of calcareous sandstone.
Stratigraphic position: The lower part of the Hiraiga Formation.
Ammonite species: *Pseudohaploceras*? sp. (6175), *Melchiorites yabei* (Shimizu, 1931) (6224 in Obata & Matsukawa, 2018 described as *Puzosia yabei*), *Miyakoceras tanohatense* Obata, 1967b (6088), *Miyakoceras hayamii* Obata, 1967b (NSM-PM 6123 in Obata, 1967b), *Ptychoceras* cf. *emericianum* Orbigny, 1842 (6223), *Hypacanthoplites subcornuerianus* (Shimizu, 1931) (6537).
Collector: I. Hayami and I. Obata.

Hn0016
Location: Tokuzo, southern cost of Hiraiga inlet.
Lithology: Silty fine-grained calcareous sandstone.
Stratigraphic position: lower part of the Hiraiga Formation.

Ammonite species: *Goretophylloceras*? sp. (UMUT 32618 in Obata & Matsukawa, 2018), Phylloceratidae **gen. et sp.** indet. (6187 in Obata & Matsukawa, 2018), *Valdedorsella* sp. (NSM-PM 6071 in Obata, 1967a), *Melchiorites yabei* (Shimizu, 1931) (all 6120, 6220 and 6221 in Obata & Matsukawa, 2018 described as *Puzosia yabei*), *Puzosia* (*P.*) *shimizui* (6219 in Obata & Matsukawa, 2018 described as *Puzosia yabei*), *Uhligella matsushimaensis*, Shimizu, 1931 (6285 and 6286) in Obata & Matsukawa, 2018, *Miyakoceras tanohatense* Obata, 1967b (NSM-PM 6121 in Obata, 1967b), *Miyakoceras* aff. *tanohatense* Obata, 1967 (NSM-PM 6122 in Obata, 1967b), *Ptychoceras* cf. *emericianum* Orbigny, 1842 (6586), *P. minimum* Rouchadzé, 1933 (6584, 6585, 6586, 6587) , *Hypacanthoplites subcornuerianus* (Shimizu, 1931) (6198, 6199, 6231A–D, 6233, 6515, 6518, 6563A–C, 6599A–C, 6601, 6602, 6603A–C, 6604, 6605, 6606, 6608, 6609A, 6610A–C, 6611A, B, 6612A–D, 6613A–D and 6614, and many specimens registered as TGUSE), *H.* cf. *elegans* (Fritel, 1906) (6607A, B).
Collectors: T. Hanai, H. Hayami and I. Obata.

Hn0017
Location: Tokuzo, southern cost of Hiraiga inlet.
Lithology: Silty, fine-grained calcareous sandstone.
Stratigraphic position: lower part of the Hiraiga Formation.
Ammonite species: *Ptychoceras* cf. *emericianum* Orbigny, 1842 (6090 and 6092 in Obata & Matsukawa, 2018, described as *Ptychoceras* cf. *puzosianus*), *Ptychoceras* sp. (6114-6116 in Obata & Matsukawa, 2018), and *Hypacanthoplites subcornuerianus* (Shimizu, 1931) (6475–6479, and many specimens registered as TGUSE).
Collector: I. Hayami, I. Obata.

Hn0018
Location: Tokuzo, southern cliff of Hiraiga.
Lithology: Silty, fine-grained calcareous sandstone.
Stratigraphic position: lower part of the Hiraiga Formation.
Ammonite species: *Valdedorsella akuschaensis* (Anthula) (NSM-PM 6068 in Obata, 1967a)
Collector: I. Obata.

Tokuzo
Location: Tokuzo, southern cliff of Hiraiga.
Lithology: Silty, fine-grained calcareous sandstone.
Stratigraphic position: lower part of the Hiraiga Formation.
Ammonite species: *Euphylloceras*? sp. (6234 in Obata & Matsukawa, 2018), *Hypophylloceras* sp. (6231 in Obata & Matsukawa, 2018), Phyllopachiceratidae gen. et sp. indet. (6187), *Gabbioceras* sp. (6230), *Valdedorsella akuschaensis* Anthula, 1899 (6517A, 6486), *V. kasei* Obata & Matsukawa, 2018 (6232), *Pseudohaploceras nipponicum* Shimizu, 1931 (6592A, 6592B), *Melchiorites yabei* (Shimizu, 1931) (6493), *Pseudolithancylus tohokuense* **sp. nov.** (6229, 6446), *Ptychoceras* cf. *emericianum* Orbigny, 1871 (6090, 6092 in Obata & Matsukawa, 2018 as *P.* cf. *puzosianus* Orbigny, 1842), *Ptychoceras minimum* Rouchadzé, 1933 (6096, 6488, 6491), *Diptychoceras iwatense* Obata & Matsukawa, 2018 (6099 and 6091 in Obata & Matsukawa; 2018 6589, 6590), *Hamites* (*H.*) sp. B (6447A, B), *Ephamulina monotuberculata* **sp. nov.** (6262 in Obata & Matsukawa, 2018, described as *Metahamites*? sp. indet.), *Lechites* (*L.*) *komorii* **sp. nov.** (6106, 6195), *Colombiceras yaegashii* (Shimizu, 1931) (6272), *Hypacanthoplites subcornuerianus* (Shimizu, 1931) (6480–6484, 6487A–E, 6490, 6494, TGUSE-MM 6510A–H, 6511A–J, 6512A–E, 6513, 6514A–E, 6515, 6516A–E, 6517A, 6591A–C, 6952A, B, 6597A–D, 6859A and B, and many specimens registered as NSM-PM; many specimens registered as TGUSE), *Paracheloniceras regina* (Obata & Matsukawa, 2018) (NMNS-PM 7542 in Obata & Matsukawa, 2018, described as *Hypacanthoplites regina*: 6485).
Collectors: I. Hayami and I. Obata.

Hn1902 (≈ 1904)
Location: Koikorobe, southern Haipe, south of Hiraiga.
Lithology: Calcareous sandstone in sandstone.
Stratigraphic position: lower part of the Hiraiga Formation.
Ammonite species: *Holcophylloceras caucasicum* (6498), *Pseudohaploceras nipponicum* Shimizu, 1931 (6273 in Obata & Matsukawa, 2018; 6505), *Melchiorites yabei* (Shimizu, 1931) (6472, 6504), *Puzosia* (*P.*) *shimizui* **sp. nov.** (6121, 6122, 6123), *Miyakoceras tanohatense*, Obata, 1967b (6155, 6502, 6503; NSM-PM 6119 and 6120 in Obata, 1967b), *Hypacanthoplites subcornuerianus* (Shimizu, 1931) (6474A–I, 6499A–C, 6500A, B, 6501, 6506A, B, 6507A–J, 6508A and B).
Collector: T. Hanai, I. Hayami and I. Obata.

C21
Location: Block dredged from the sea bottom of the fishing port of Shimanokoshi.
Lithology: muddy fine-grained sandstone to sandy siltstone.
Stratigraphic position: upper part of the Tanohata Formation.
Ammonite species: *Paracheloniceras regina* (Obata & Matsukawa, 2018) (6211), *Colombiceras yaegashii* (Shimizu, 1931) (6271), *Hypacanthoplites subcornuerianus* (Shimizu, 1931) (6236).
Collector: Unknown.

SMK
Location: A block at about 15 m west of Shimanokoshi coast.
Stratigraphic position: Hiraiga Formation.
Ammonite species: *H. kawakamii* Obata & Futakami, 1992 (IPMM 8696 and 8697 in Obata & Futakami, 1992), *Parahoplites* aff. *vectensis* Casey, 1965 (6282 in Obata & Matsukawa, 2018).
Collector: F. Sasaki and A. Shimonosono.

(2) Moshi region in Iwaizumi Town, and Miyako City, Iwate Prefecture (Fig. 4)

81201
Location: Tairajima where is a small islet offshore north of Moshi, Iwaizumi Town.
Lithology: Unknown.
Stratigraphic position: Hiraiga Formation.
Ammonite species: *Phyllopachyceras* aff. *infundibulum* (all UMUT-MM 32619, 32620) (Obata & Matsukawa, 2018), *Uhligella matsushimaensis* (Shimizu, 1931) (6283 and 6284 in Obata & Matsukawa, 2018), *Eodouvilleiceras matsumotoi* Obata, 1969 (6529A, 6529B and 6530).
Collector: I Obata.

Ks4003
Location: Tairajima, where there is a small islet off Kumanohana, Omoto, Iwaizumi Town.
Stratigraphic position: lower part of the Hiraiga Formation.
Ammonite species: *Pseudohaploceras nipponicum* Shimizu, 1931 (all NMNS PM 35078, 35079, 35080, 35081, 35082 in Obata& Matsukawa, 2018).
Collector: T. Kase.

Hn4201
Location: Nagaiso, where there is a small islet off Moshi, Iwaizumi Town.
Lithology: A calcareous concretion in the sandstone.
Stratigraphic position: lower part of the Hiraiga Formation.
Ammonite species: *Diadochoceras nodosocostatiforme* (Shimizu, 1931) (NSM-PM 7280 and 7543 in Obata, 1967a), *Eodouvilleiceras matsumotoi* Obata, 1969 (all NSM-PM 7269, 7272, 7281 in Obata, 1969) and *E.* aff. *matsumotoi* Obata, 1969 (7270 in Obata, 1969).
Collectors: T. Hanai, I. Hayami and I. Obata.

Hn4151
Location: Matsushima, where there is small islet off north Moshi coast, Iwaizumi Town.
Lithology: calcareous concretion in the upper fossiliferous sandstone.
Stratigraphic position: lower part of the Hiraiga Formation.
Ammonite species: *Euphylloceras californicum* (6575), Phylloceratidae gen. et sp. indet. (UMUT-MM 32623 in Obata & Matsukawa, 2018), *Valdedorsella getulina* Coquand, 1880 (NSM-PM 6070 in Obata, 1967a), *Melchiorites yabei* (Shimizu, 1931) (6264 in Obata & Matsukawa, 2018, described as *Puzosia yabei*; 6579,), *Puzosia* (*P.*) *shimizui* **sp. nov.** (6665), *Hamites* (*Hamites*) cf. *tenuis* J. Sowerby, 1814 (6436), *Epicheloniceras* sp. (6578), *Paracheloniceras kazuoi* **sp. nov.** ((NSM-PM 7546 in Obata, 1975), *Diadochoceras nodosocostatiforme* (Shimizu, 1931) (6581, 6466; NSM-PM 7544 and 7545 in Obata, 1975), *Eodouvilleiceras matsumotoi* Obata, 1969 (NSM-PM 7263, 7264 and 7268 in Obata, 1969; 6465) and *E*. aff. *matsumotoi* Obata, 1969 (all NSM-PM 7261, 7262, 7265, 7266, 7267, 7278 in Obata, 1969).
Collectors: T. Hanai, I. Hayami and I. Obata.

Hn4152
Location: Matsushima, where there is small islet off coast north of Moshi coast, Iwaizumi Town.
Lithology: a calcareous concretion in the middle fossiliferous bed at Matsushima.
Stratigraphic position: upper portion of the lower part of the Hiraiga Formation.
Ammonite species: *Melchiorites yabei* (Shimizu, 1931) (6119 in Obata and& Matsukawa described as *Puzosia yabei*), *Uhligella matsushimaensis* Shimizu, 1931 (6100, 6161, 6162 in Obata & Matsukawa, 2018), *Eodouvilleiceras matsumotoi* Obata, 1969 (IGPS 87145 in Obata, 1969).
Collectors: S. Yehara, T. Hanai and I. Obata.

Hn4153
Location: Matsushima, where there is small islet off coast north of Moshi coast, Iwaizumi Town.
Lithology: a calcareous concretion.
Stratigraphic position: Hiraiga Formation.
Ammonite species: *Melchiorites yabei* (Shimizu, 1931) (6532), *Uhligella matsushimaensis* Shimizu, 1931 (UMUT-MM 32627 and 6163 in Obata & Matsukawa, 2018), *Ptychoceras* cf. *emericianum* Orbigny, 1842 (6469).
Collectors: T. Hanai and I. Obata.

Hn4053
Location: Oshima of Miyako City, where there is a small islet off north of Moshi coast, Iwaizumi Town.
Lithology: Medium calcareous sandstone.
Stratigraphic position: Hiraiga Formation.
Ammonite species: *Pseudohaploceras nipponicum* Shimizu, 1931 (6462, 6463), *Uhligella matsushimaensis* Shimizu, 1931 (6163 in Obata & Matsukawa, 2018), *Anadesmoceras*? sp. (6102), *Epicheloniceras* sp. (6554), *Eodouvilleiceras matsumotoi* Obata (1969) (6185A, B).
Collector: I. Obata.

Ks4004
Location: the east coast of the Oshima, belongs to Miyako City, where there is a small islet off north of Moshi coast.
Lithology: Calcareous sandstone.
Stratigraphic position: upper part of the Hiraiga Formation.
Ammonite species: *Oshimaceras kanazawai* Obata & Futakami, 1992 (IPMM 8698 in Obata & Futakami, 1992) and *Diadochoceras nodosocostatiforme* (Shimizu, 1931) (6169, 6244).
Collector: K. Kanazawa who collected the specimen in about 1925, T. Kase.

Hn4051
Location: Oshima of Miyako City, where is a small islet off north of Moshi coast, Iwaizumi Town.
Lithology: Calcareous sandstone.
Stratigraphic position: Hiraiga Formation.
Ammonite species: *Pseudohaploceras nipponicum* Shimizu, 1931 (6202), *Anadesmoceras*? sp. (6588), *Epicheloniceras* sp. (TGUSE-MM 6664).
Collector: T. Kase.

Matsushima in Shimizu (1931)
Location: Matsushima where is a small islet offshore north of Moshi, Iwaizumi Town.
Lithology: Unknown.
Stratigraphic position: Hiraiga Formation.
Ammonite species: *Holcophylloceras caucasicum* (all IGPS 36508a, b), *Pseudohaploceras nipponicum* Shimizu, 1931 (IGPS 36514, UMUT-MM 32625 and 32626 in Obata & Matsukawa, 2018; 6555), *Melchiorites yabei* (Shimizu, 1931) (IGPS 36506 in Obata & Matsukawa 2018 described as *Puzosia yabei*), *Puzosia* (*P.*) *shimizui* **sp. nov.** (6555), *Uhligella matsushimaensis* (Shimizu, 1931) (IGPS 36507a-f in Obata & Matsukawa, 2018), *Hamites* (*H.*) cf. *intermedius* Sowerby, 1814 (IGPS 36859), *Hamites* (?) sp. and *Diadochoceras nodosocostatiforme* (Shimizu, 1931) (IGPS 35152 in Shimizu, 1931, described as *Douvilleiceras nodosocostatiforme*).
Collectors: T. Nagao, S. Oishi, S. Shimizu and T. Hanai.

(3) Taro region, Miyako City, Iwate Prefecture (Fig. 6)
Taro (≈ Ks3001, Taro 3003)
Location: Taro.
Lithology: Siltstone containing coaly drifts.
Stratigraphic position: Hiraiga Formation.
Ammonite species: *Ptychoceras* cf. *emericianum* Orbigny, 1842 (UMUT-MM 32629 and 32630 in Obata & Matsukawa, *Protanisoceras* (*Protanisoceras*) *hanaii* Obata & Matsukawa 2018 (UMUT-MM 32631 in Obata & Matsukawa, 2018).
Collectors: H. Hanai.

Ks3001 (≈ Taro, Taro 3003)
Location: Taro.
Lithology: Siltstone containing numerous shell fragments and coaly woods.
Stratigraphic position: Basal part of the Hiraiga Formation.
Ammonite species: *Valdedorsella kasei* Obata & Matsukawa, 2018 (NMNS-PM 35076, 35077 in Obata & Matsukawa, 2018).
Collector: T. Kase.

Taro 3003 (≈ Ks3001, Taro)
Location: Otobe, Taro.
Lithology: Siltstone containing numerous shell fragments and coaly woods.
Stratigraphic position: Basal part of the Hiraiga Formation.
Ammonite species: *Holcophylloceras caucasicum* (NMNS PM 35970 in Matsukawa & Oji, 2022), *Protetragonites* sp. (NMNS PM35967 and 35969, and 6412 in Matsukawa & Oji, 2022), *Anagaudryceras* sp. (NMNS PM 35972 in Matsukawa & Oji, 2022), *Gabbioceras* sp. A (NMNS PM 35968 in Matsukawa & Oji, 2022), *Valdedorsella akuschaensis* Anthula, 1899 (NMNS PM 35958 and 35959), *Uhligella matsushimaensis*, Shimizu, 1931 (NMNS PM 35960 in Matsukawa & Oji, 2022), *Desmoceras* (*Pseudouhligella*) *sanrikucum* **sp. nov.** (NMNS PM 35961 in Matsukawa & Oji, 2022, described as *Desmoceras* (*Pseudouhligella*) aff. *poronaicum*?), *Diptychoceras iwatense* Obata & Matsukawa, 2018 (NMNS PM 35965 in Matsukawa & Oji, 2022), *Protanisoceras hanai*i Obata & Matsukawa, 2018 (NMNS PM 35966 in Matsukawa & Oji, 2022), *Protanisoceras* aff. *hanai*i Obata & Matsukawa, 2018 (NMNS PM 35964 in Matsukawa & Oji, 2022),

Sonoraceras? sp. (NMNS-PM 35962), *Pseudoleymeriella obatai* (NMNS PM 35963, 35971and 35973 in Matsukawa & Oji, 2022).
Collector: T. Oji, H. Maeda, T. Kamiya.

TR 2
Location: Aojyari, Taro.
Lithology: siltstone.
Stratigraphic position: Uppermost of the Tanohata Formation.
Ammonite species: Tetragonitidae gen. et sp. indet. (6276 in Matsukawa & Oji, 2022), *Aconeceras* (*A*.) sp. (6277, 6278 in Matsukawa & Oji, 2022), *Miyakoceras tanohatense* Obata, 1967 (6279 and 6280 in Matsukawa & Oji, 2022), *Diptychoceras iwatense* Obata & Matsukawa, 2018 (6282 in Matsukawa & Oji, 2022).
Collector: K. Tanaka.

(4) Sakiyama region, Miyako City, Iwate prefecture
Hn2051 (≈ Hy2099, Kc-e)
Location: Ebisudana, off the Hideshima coast.
Lithology: Calcareous fine sandstone.
Stratigraphic position: Sakiyama Formation.
Ammonite species: *Valdedorsella kasei* Obata & Matsukawa, 2018 (NMNS PM 35073, 35074, 35075 in Obata & Matsukawa, 2018).
Collector: S. Ogino, T. Kase.

Ks2005
Location: Hideshima coast.
Lithology: Massive dark grey sandy mudstone.
Stratigraphic position: uppermost Hiraiga Formation.
Ammonite species: *Valdedorsella kasei* Obata & Matsukawa, 2018 (NMNS PM 35072 in Obata & Matsukawa, 2018), *Melchiorites yabei* (Shimizu, 1931) (SKM-SS 060-010, SKM-SS 063-005), *Puzosia* (*P.*) *shimizui* **sp. nov.** (SKM-SS 062-004, SKM-SS 34-#32), *Diadochoceras nodosocostatiforme* (Shimizu, 1931) (all IPMM 31210 and 6421 in Matsukawa & Shibata, 2023), *Eodouvilleiceras matsumotoi* Obata, 1969 (6174 in Matsukawa & Shibata, 2023), *Douvilleiceras* sp. (SKM-SS 062-006), *Hypacanthoplites subcornuerianus* (Shimizu, 1931) (6450, 6451 and 6452 in Matsukawa & Shibata, 2023), *Parahoplites* cf. *laticostatus* (Sinzow, 1907) (IPMM 30427 in Matsukawa & Shibata, 2023).
Collector: F. Sasaki, S. Inomata, T. Kase.

Ob01
Location: Hideshima Fishing port, Hideshima coast, Sakiyama.
Lithology: dark grey to muddy black sandstone with a piece of wood and mud flakes.
Stratigraphic position: Hiraiga Formation.
Ammonite species: *Sanmartinoceras bifurcatum* (6101 in Matsukawa & Shibata, 2023), *Marshallites miyakoensis* Obata & Futakami, 1991 (6419 in Matsukawa & Shibata, 2023), *Hypacanthoplites subcornuerianus* (Shimizu, 1931) (6420 in Matsukawa & Shibata, 2023).
Collector: H. Yaegashi, K. Tanaka.

OH4
Location: Hideshima Fishing port, Hideshima coast, Sakiyama.
Lithology: dark grey to black muddy sandstone with piece of wood and mud flakes.
Stratigraphic position: Hiraiga Formation.
Ammonite species: *Marshallites miyakoensis* Obata & Futakami, 1991 (6212 in Matsukawa & Shibata, 2023), *Epicheloniceras* sp. (6416 and 6431 in Matsukawa & Shibata, 2023), *Paracheloniceras guenoti* Collignon, 1965c (IGPS 36512B in Matsukawa & Shibata, 2023), *Sonoraceras*? sp. (6428 in Matsukawa & Shibata, 2023), *Hypacanthoplites subcornuerianus* (Shimizu, 1931) (IGPS 36512 in (Shimizu, 1931, described as *Acanthoplites subcornuerianus*); 6415, 6417, 6418, 6422, 6423, 6427, 6434, 6453, 6454 in Matsukawa & Shibata, 2023), H. cf. *anglicus* Casey, 1965 (6424, 6425, 6426 in Matsukawa & Shibata, 2023), *H*. cf. *elegans* (Fritel, 1906) (6429 in Matsukawa & Shibata, 2023; 6607A, B), *H*. sp. (6430 in Matsukawa & Shibata, 2023).
Collector: S. Shimizu, S. Nagashima, I, Obata.

OH5
Location: Hideshima Fishing port, Hideshima coast, Sakiyama.
Lithology: brownish dark grey muddy sandstone.
Stratigraphic position: Sakiyama Formation.
Ammonite species: *Valdedorsella kasei* Obata & Matsukawa, 2018 (6413 in Matsukawa & Shibata, 2023), *Colombiceras yaegashii* (Shimizu, 1931) (IGPS 36509 in Shimizu, 1931, described as *Parahoplites yaegashii*).
Collector: H. Yaegashi, I. Obata.

Loc. 1
Location: Ebisudana islet, Hideshima coast, Sakiyama.
Lithology: dark grey, massive, and well-sorted sandy mudstone including intercalated very thin, fine-grained sandstone layers.
Stratigraphic position: Sakiyama Formation.
Ammonite species: *Aconeceras* aff. *nisoides* (Sarasin, 1893) (MNMS 23790 in Matsukawa & Oji, 2022), *Marshallites miyakoensis* Obata & Futakami, 1991 (NMNS-PM 23795 in in Matsukawa & Shibata, 2023).
Collector: Inose *et al*.

Loc. 2
Location: Ebisudana Islet, Hideshima coast, Miyako City.
Lithology: dark grey, massive, and well-sorted sandy mudstone including intercalated very thin, fine-grained sandstone layers.
Stratigraphic position: Sakiyama Formation.
Ammonite species: *Pictetia* sp. (NMNS PM 23798 in Matsukawa & Shibata, 2023), *Eogaudryceras* (*Eotetragonites*) sp., (NMNS PM 23794 in Matsukawa & Shibata, 2023), *Valdedorsella kasei* Obata & Matsukawa, 2018 (NMNS PM 23792 in Matsukawa & Shibata, 2023), *Anadesmoceras* sp. A. (NMNS PM 23793 in Matsukawa & Shibata, 2023), *Ptychoceras* cf. *emericianum* Orbigny, 1842 (NMNS-PM 23799 in Matsukawa & Shibata, 2023), *Eodouvilleiceras matsumotoi* Obata, 1969 (NMNS PM 23796 and 23797 in Matsukawa & Shibata, 2023), *Pseudoleymeriella hataii* Obata, 1973 (NMNS PM 23791 in Matsukawa & Shibata, 2023).
Collector: Inose *et al*.