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A new species of *Gabbioceras* (Ammonitida, Tetragonitidae) from the Albian (Lower Cretaceous) of Hokkaido, Japan

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Abstract. **Ammonoid *Gabbioceras orientale* sp. nov., which represents the first record of the genus in the Northwest Pacific region, is described from the lower Albian in the Mikasa area, Hokkaido, northern Japan. The adult phragmocone of the new taxon is characterized by a fairly wide, funnel-shaped umbilicus with a subangular umbilical shoulder. Its adult body chamber is characterized by rounded umbilical shoulders and rounded, fold-like ribs on the distal part. The stratigraphic distribution of *Gabbioceras* in Hokkaido suggests that the genus migrated from the Mediterranean area or Madagascar to the Northwest Pacific region during early Albian time, and then became extinct during middle Albian time, similar to *Gabbioceras* from other areas.**

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Keywords: Albian, ammonoid, Cretaceous, *Gabbioceras*, Hokkaido

Introduction

The genus *Gabbioceras* Hyatt, 1900, belonging to the subfamily Gabbioceratinae Breistroffer, 1953 of the family Tetragonitidae Hyatt, 1900, is considered to be one of the derivatives of *Eogaudryceras* Spath, 1927 (Hoffmann, 2015). Its comprehensive generic diagnosis is summarized as follows: 1) depressed shell with rounded venter, 2) moderately wide, funnel-shaped umbilicus with angular umbilical shoulder at the pre-adult growth stage, 3) ornamentation with growth lines, fine ribs and forward projected constrictions on the venter, and 4) gaudryceratid-type suture line with $ELU_2U_1I_s$ and lateral angulation located in the middle of U_2 (Murphy, 1967a; Shigeta *et al.*, 2012; Hoffmann, 2015).

Gabbioceras flourished in the Mediterranean area, California and Madagascar during the late Aptian to early Albian, and gave rise to *Jauberticeras* Jacob, 1907 in the late Aptian, *Tanabeceras* Shigeta *et al.*, 2012 in the early Albian and probably also *Obataceras* Shigeta *et al.*, 2012 in the early Albian (Shigeta *et al.*, 2012) before eventually disappearing from the areas (Murphy, 1967a; Shigeta *et al.*, 2012). Shigeta (1996) described two species from the lower Cenomanian of Hokkaido as *Gabbioceras*, but these were later reassigned to *Tanabeceras* (Shigeta *et al.*, 2012). More recently, Obata and Matsukawa (2018) and Matsukawa and Oji (2022) documented two small-sized specimens as *Gabbioceras* sp. from the upper Aptian and lower Albian of the Miyako Group in Northeast Japan.

The huge "Kawashita Collection" of Cretaceous ammonoids from Hokkaido, which was amassed by the late Mr. Yoshitaro Kawashita (1934–2000) and donated to the National Museum of Nature and Science (NMNS, Tsukuba, Ibaraki) by his family in 2001 (Shigeta, 2001), contains one specimen referable to *Gabbioceras* from the lower Albian of the Mikasa area, central Hokkaido. Furthermore, two specimens referable to *Gabbioceras* collected from the Mikasa area by Masataka Izukura were recently donated to the NMNS.

These Mikasa area specimens are described in this paper as a new species of *Gabbioceras* and the taxon's evolution during Albian is discussed.

Notes on stratigraphy

The Albian fossiliferous strata of the Yezo Group, which crop out along the Pombetsu River in the Mikasa area (e.g. Futakami, 1996; Figure 1), are subdivided into the Shuparogawa and Hikagenosawa formations, in ascending order (Futakami *et al.*, 2008).

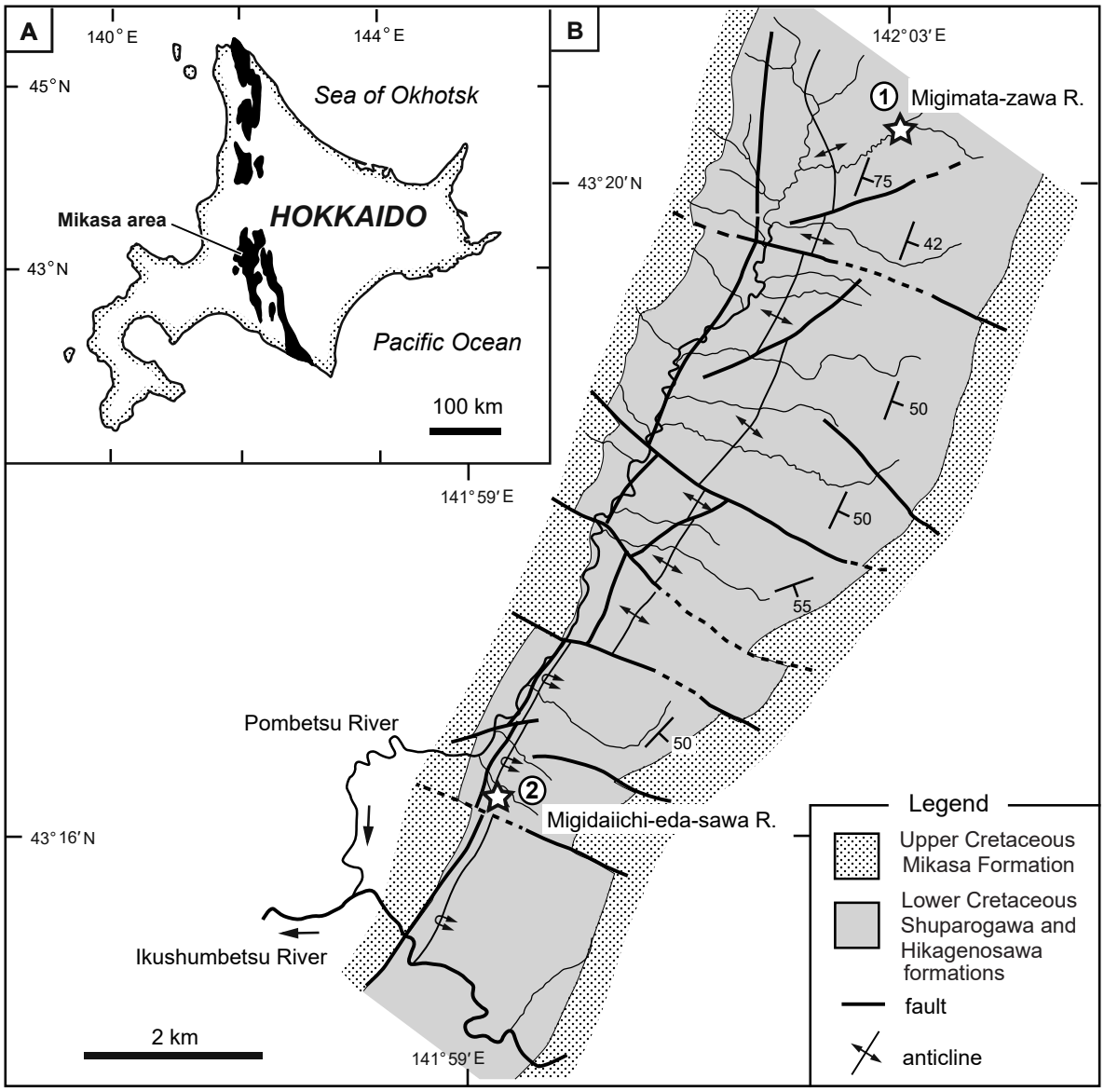

Figure 1. Index map showing distribution of exposures of the Cretaceous Yezo Group (black areas) in Hokkaido (**A**), and geological map (modified from Futakami and Haggart, 2018) showing collection localities of *Gabbioceras orientale* sp. nov. specimens described herein (indicated by stars) along the Pombetsu River in the Mikasa area (**B**).

The 980 m thick Shuparogawa Formation consists mainly of laminated mudstone in the lower part and alternating beds of turbiditic sandstone and mudstone in the middle to upper parts (Futakami and Haggart, 2018). Early Albian ammonoids, i.e., *Leconteites lecontei* (Anderson, 1902) and *Douvilleiceras mammillatum* (Schlotheim, 1813) as well as several other species of *Douvilleiceras*, occur in the lower part (Futakami, 1996, 2003; Futakami and Haggart, 2018). *Ammonoceratites ezoense* (Yabe, 1903) and *Hyperpuzosia tammon* Matsumoto *et al.* in Matsumoto, 1988 also occur (Futakami, 1996) in this interval. The formation is conformably overlain by the Hikagenosawa Formation.

The 420 m thick Hikagenosawa Formation, composed mainly of laminated mudstone with thick, medium-grained sandstone beds, contains middle to late Albian ammonoids, i.e., *Lyelliceras* cf. *lyelli* (d'Orbigny, 1841), *Diploceras cristatum* (Brongniart, 1822), *Oxtropidoceras* sp., *Falloticeras proteus* (d'Orbigny, 1842), and *Stoliczkaia* sp. (Futakami, 1996; Futakami *et al.*, 1998). The formation is conformably overlain by the Upper Cretaceous Mikasa Formation.

Material and methods

Material

Specimens (NMNS PM 17368, 45648, 45649), upon which we based our new species of *Gabbioceras*, were collected from float calcareous concretions probably derived from the lower part of the Shuparogawa Formation along tributaries of the Pombetsu River, i.e., NMNS PM 17368 from the Migimata-zawa River (Loc. 1 in Figure 1B) and NMNS PM 45648 and 45649 from the Migidaiichi-eda-sawa River (Loc. 2 in Figure 1B). A specimen referable to *Douvilleiceras mammillatum* (e.g. NMNS PM 17376, Futakami and Haggart, 2018, fig. 7) was also collected from the vicinity of the Migimata-zawa River. Specimens referable to *Douvilleiceras* (e.g. HMG-2205) and *Ammonoceratites ezoense* (e.g. HMG-2199), which were also collected from the Migidaiichi-eda-sawa River, are housed in the Hobetsu Museum (HMG, Mukawa, Hokkaido).

Methods

All specimens were examined for biometric analysis of conch morphology. They were scanned using X-ray computed tomography (inspeXio SMX-225CT FPD HR, Shimadzu) at the National Museum of Nature and Science, Tsukuba with settings of 0.05–0.10 mm resolution, 225 kV and 70 μA. Four classic geometric parameters of the shell, i.e., shell diameter (*D*), umbilical diameter (*U*), whorl height (*H*) and whorl width (*W*), were measured every half whorl using an X-ray CT image of the cross section and then three ratios, relative umbilical size (*U*/*D*) and relative whorl thickness (*W*/*H*) and whorl expansion rate ($WER = [D/D']^2$; *D'*, diameter before half whorl; see Klug *et al.*, 2015), were calculated and scatter diagrams of *U*/*D* versus *D* and *W*/*H* versus *D* were made.

Paleontological description

Systematic descriptions basically follow the classification of the Lytoceratoidea established by Hoffmann (2015) and Hoffmann *et al.* (2022). Morphological terms in the systematic description are those used by Arkell (1957) for Mesozoic Ammonoida. Quantifiers used to describe the shape of ammonoid shell replicate those proposed by Matsumoto (1954, p. 246) and modified by Haggart (1989, table 8.1).

Abbreviations for shell dimensions.—See Methods section.

Institution abbreviations.—NMNS, National Museum of Nature and Science, Tsukuba.

Superorder Ammonoida Haeckel, 1866
Order Ammonitida Haeckel, 1866
Suborder Lytoceratina Hyatt, 1889
Superfamily Lytoceratoidea Neumayr, 1875
Family Tetragonitidae Hyatt, 1900
Subfamily Gabbioceratinae Breistroffer, 1953
Genus ***Gabbioceras*** Hyatt, 1900

Type species.—*Ammonites batesi* Gabb, 1869 (*non* Trask, 1855) = *Lytoceras* (*Gabbioceras*) *angulatum* Anderson, 1902.

Gabbioceras orientale sp. nov.

Figures 2–5

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Type specimens.—Holotype, NMNS PM 17368 (Figure 2), measuring about 69.0 mm in shell diameter, from a float calcareous concretion found in the Migimata-zawa River, a tributary on the left bank of the Pombetsu River in the Mikasa area (Loc. 1 in Figure 1B). Specimen consists of the phragmocone and body chamber, which begins at a diameter of about 42.0 mm and occupies nearly five-sixths of the outer whorl.

Paratypes, two specimens, NMNS PM 45648 (Figure 3A–C) and 45649 (Figure 3D–F) were extracted from a float calcareous concretion found in the Migidaiichi-eda-sawa River, a tributary on the left bank of the Pombetsu River (Loc. 2 in Figure 1B). Each specimen has a shell diameter of about 72.0 mm and consists of the phragmocone and body chamber, which begins at about 43.0 mm in shell diameter and occupies nearly five-sixths of the outer whorl.

Diagnosis.—*Gabbioceras* with phragmocone characterized by fairly wide, funnel-shaped umbilicus with subangular umbilical shoulder, and body chamber characterized by rounded umbilical shoulders and rounded, fold-like ribs on the distal part.

Etymology.—Because this species is only found in the Northwest Pacific region, its species name refers to the Latin word *orientalis*, meaning eastern.

Description.—Early to middle whorls (up to 30 mm in diameter): Fairly evolute, very depressed shell (*W*/*H* = 1.51–1.89) characterized by a modelately whorl expansion rate (*WER* = 1.62–1.98) and a sub-trapezoidal whorl section with a gently convex umbilical wall, subangular umbilical shoulder, and broadly arched venter. Maximum whorl width occurs on umbilical shoulders at two-third of whorl height. Umbilicus fairly wide (*U*/*D* = 0.36–0.42) and funnel-shaped. Ornamentation consists only of fine, prorsiradiate lirae, which arise at umbilical seam, curve backwards on umbilical shoulder, and cross venter in a broad, slightly convex arch.

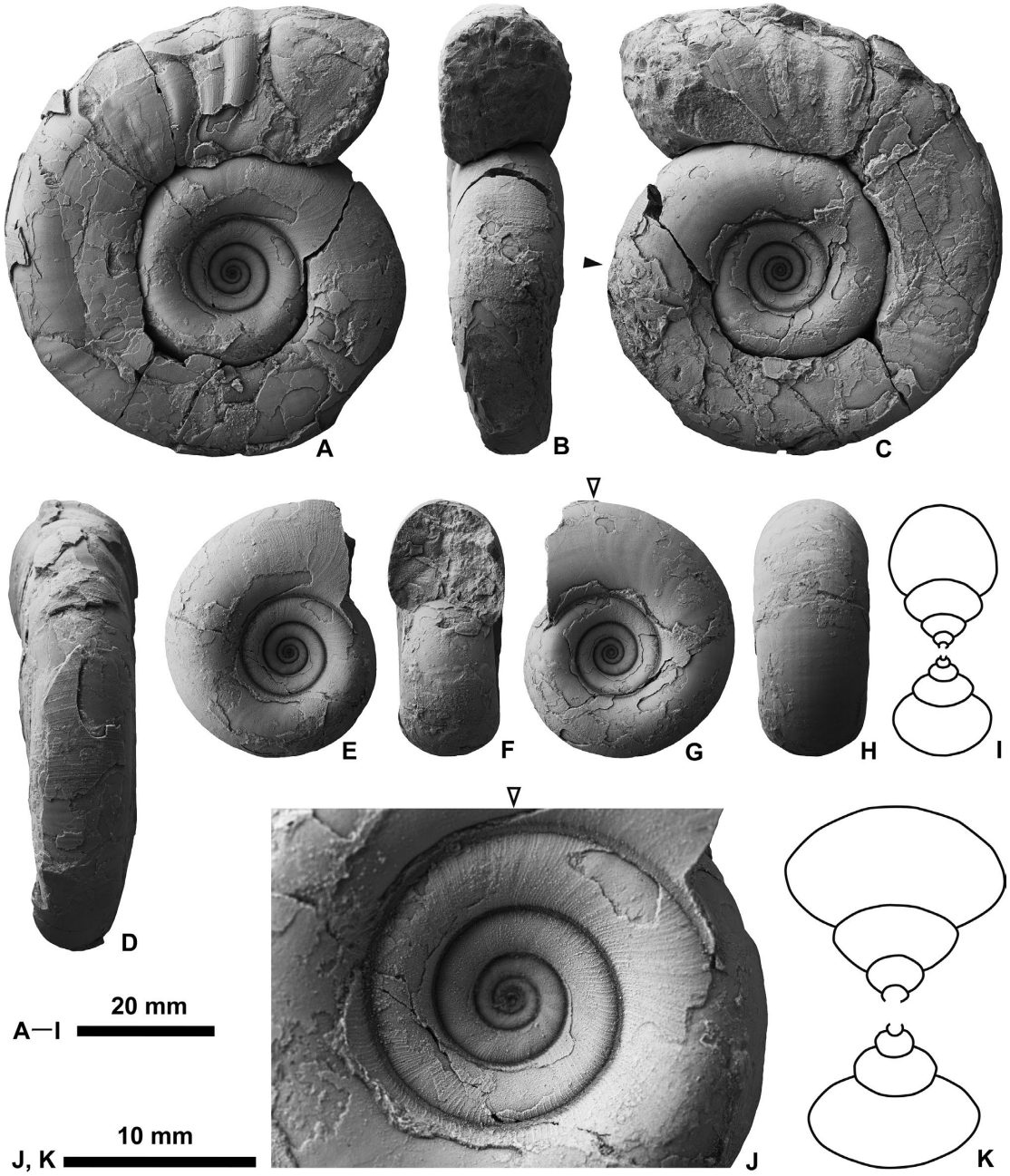

Figure 2. *Gabbioceras orientale* sp. nov., NMNS PM 17368 (holotype), from the Mikasa area, Hokkaido (Loc. 1 in Figure 1B). **A,** left lateral view; **B,** apertural view; **C,** right lateral view; **D,** ventral view; **E–H,** inner whorls after removal of parts of phragmocone and body chamber; E, left lateral view; F, apertural view; G, right lateral view; H, ventral view; **I,** whorl cross section drawn from X-ray CT image at position indicated by white arrow in G; **J,** enlarged photo showing umbilical area; **K,** whorl cross section drawn from X-ray CT image at position indicated by white arrow in J. Black arrow indicates position of last septum.

Later whorls (over 30 mm in diameter): As shell grows (Figure 4), whorl cross-section becomes more compressed (W/H = 1.18–1.38) and circular with arched venter, while relative umbilical size (U/D =0.39–0.42) and whorl expansion rate (WER = 1.86–2.00) are almost constant. Maximum whorl width occurs on umbilical shoulders at one-third to one-fourth of whorl height. Distal part of body chamber, larger than 65–70 mm in diameter, has two to three rounded, fold-like ribs. Suture consists of early gaudryceratid-type characters with bipartite lateral

Figure 3. *Gabbioceras orientale* sp. nov. from the Mikasa area, Hokkaido (Loc. 2 in Figure 1B). **A–C,** NMNS PM 45648 (paratype); **D–F,** NMNS PM 45649 (paratype). A, D, left lateral views; B, E, apertural views; C, F, right lateral views. Black arrows indicate position of last septum.

saddles (Figure 5). Umbilical shoulder located in middle of second umbilical lobe (U_2).

Measurements.—See Table 1.

Comparison.—*Gabbioceras orientale* sp. nov. is distinguished from *G. lamberti* (Breistroffer, 1937), *G. angulatum* (Anderson, 1902) and *G. jacobi* Murphy, 1967a by its wider umbilicus and from *G. lanternoi* (Wiedmann, 1962) by its much more compressed whorl (Figure 4). Although the ornamentation on the body chamber of the above four species is well known only for *G. angulatum*, the rounded, fold-like ribs seen in the distal part of the body chamber of the new species are not known in *G. angulatum* (Wiedmann, 1962; Murphy, 1967b).

Occurrence.—The holotype and paratypes, which

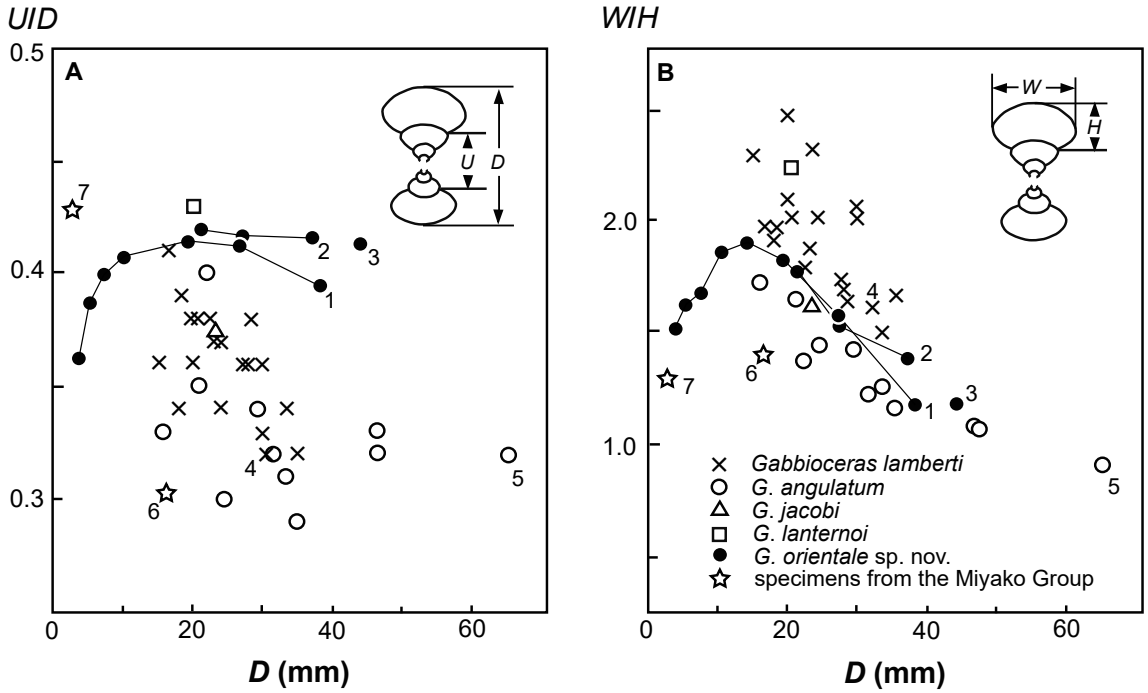

Figure 4. Scatter diagrams of umbilical diameter/shell diameter (*U*/*D*) versus shell diameter (**A**) and whorl width/whorl height (*W*/*H*) versus shell diameter (**B**) for three specimens of *Gabbioceras orientale* sp. nov. (1, NMNS PM 17368, holotype; 2, NMNS PM 45648, paratype; 3, NMNS PM 45649, paratype), 18 specimens of *G. lamberti* by Murphy (1967a, table 2) and holotype (4) by Wiedmann (1962, table 1), 10 specimens of *G. angulatum* by Murphy (1967a, table 1) and holotype (5) by Wiedmann (1962, table 1), holotype of *G. jacobi* measured from photos of Collignon (1963, pl. 251, fig. 1079), holotype of *G. lanternoi* by Wiedmann (1962, table 29), and two specimens assigned to *Gabbioceras* sp. (6, TGUSE-MM 6108; 7, NMNS PM 35968) by Obata and Matsukawa (2018, p. 239, fig. 12Q–S) and Matsukawa and Oji (2022, p. 146, fig. 4E), which probably should be attributed to *Eogaudryceras* (see Discussion section and Figure 6).

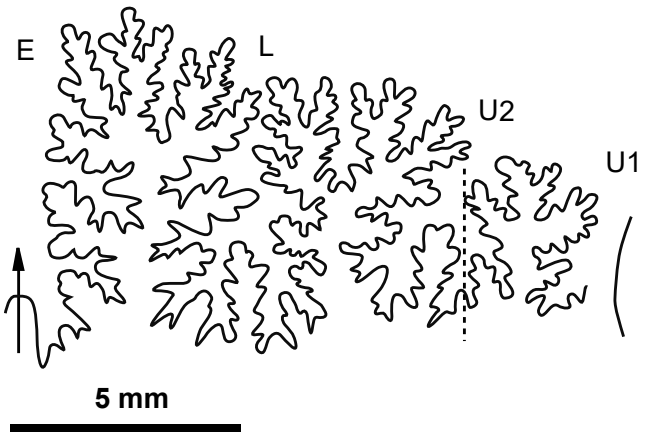

Figure 5. Suture line of *Gabbioceras orientale* sp. nov., NMNS PM 17368 (holotype), from the Mikasa area, Hokkaido, at D = 31 mm. Arrow indicates position of the siphuncle. Solid line and dotted line indicate position of umbilical seam and umbilical shoulder. E, external lobe; L, lateral lobe; U_1, first umbilical lobe; U_2, second umbilical lobe.

are early Albian, were collected from float calcareous concretions probably derived from the lower part of the Shuparogawa Formation along tributaries of the Pombetsu River in the Mikasa area.

Discussion

Two small-sized specimens identified as *Gabbioceras* were reported from the upper Aptian and lower Albian of the Miyako Group in northeastern Japan (Obata and Matsukawa, 2018; Matsukawa and Oji, 2022). Specimen NMNS PM 35968 from the upper Aptian Hiraiga Formation is 4.9 mm in diameter and was assigned to *Gabbioceras* sp. by Matsukawa and Oji (2022). Specimen TGUSE (Tokyo Gakugei University, Department of Environmental Sciences)-MM 6108 from the lower Albian Aketo Formation is about 30 mm in diameter and was likewise assigned to *Gabbioceras* sp. by Obata and Matsukawa (2018). Both specimens were described as a depressed cadicone with a sloping umbilical wall and a sharp ventro-lateral shoulder (Obata and Matsukawa, 2018, p. 241; Matsukawa and Oji, 2022, p. 146). However, upon

Table 1. Measurements (in mm) of herein studied specimens of *Gabbioceras orientale* sp. nov. *D*, shell diameter; *D'*, diameter before half whorl; *U*, umbilical diameter; *H*, whorl height; *W*, whorl width; *U*/*D*, relative umbilical size; *W*/*H*, relative whorl thickness; *WER*, whorl expansion rate = $(D/D')^2$; <H>, holotype; <P>, paratype.

register number	*D* (mm)	*D'* (mm)	*U* (mm)	*H* (mm)	*W* (mm)	*U*/*D*	*W*/*H*	*WER*
NMNS PM 17368 <H>	3.86	—	1.40	1.40	2.11	0.36	1.51	—
	5.44	3.86	2.11	1.84	2.98	0.39	1.62	1.98
	7.54	5.44	2.98	2.63	4.39	0.40	1.67	1.92
	10.35	7.54	4.21	3.51	6.49	0.41	1.85	1.88
	14.12	10.35	5.79	4.91	9.30	0.41	1.89	1.86
	19.47	14.12	8.07	6.49	11.75	0.41	1.81	1.89
	27.02	19.47	11.14	9.47	14.91	0.41	1.57	1.92
	38.24	27.02	15.09	13.86	16.32	0.39	1.18	2.00
NMNS PM 45648 <P>	21.38	—	8.97	6.89	12.07	0.42	1.75	—
	27.24	21.38	11.37	8.62	13.10	0.42	1.52	1.62
	37.24	27.24	15.52	12.76	17.59	0.42	1.38	1.86
NMNS PM 45649 <P>	44.00	—	18.18	15.27	18.18	0.41	1.19	—

examination of their whorl cross sections using X-ray CT imaging, the present authors have concluded that their rounded whorl cross sections, without umbilical shoulder angulation, do not exhibit the features of *Gabbioceras*, and instead, probably should be attributed to *Eogaudryceras* (Figure 6). Their ornamentation, consisting of prorsiradiate, shallow, weak constrictions, is somewhat similar to *Eogaudryceras wintunius* (Anderson, 1938) from the upper Aptian of California (Murphy, 1967b) as Obata and Matsukawa (2022, p. 241) have already pointed out. Therefore, *G. orientale* sp. nov. described from the lower Albian of Hokkaido in this study represents the first report of *Gabbioceras* in the Northwest Pacific region.

It is plausibly assumed that the oldest member of *Gabbioceras*, i.e., *G. lamberti*, evolved from *Eogaudryceras numidum* (Coquand, 1880) in the Mediterranean area during the early late Aptian (Wiedmann, 1962; Murphy, 1967a; Kennedy and Klinger, 1977) and then became widely distributed in the Mediterranean area during the late Aptian. Its possible descendant, *G. angulatum*, flourished in California (Wiedmann, 1962; Murphy, 1967a; Figure 7) during the late Aptian, but by early Albian time, *Gabbioceras* had completely disappeared from California. At the same time, *Gabbioceras* expanded its distribution to Madagascar (Murphy, 1967a) and the Northwest Pacific region, where *G. jacobi* and *G. orientale* sp. nov. evolved, respectively (Figure 7). In the Mediterranean area, *G. lanternoi* eventually evolved from *G. lamberti* (Wiedmann, 1962).

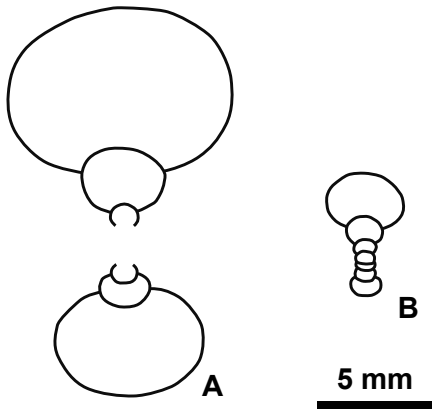

Figure 6. Whorl cross sections of two ammonoid specimens from the Miyako Group, northeastern Japan, which were drawn from X-ray CT images taken under 0.01–0.03 mm resolution, 225 kV and 70 μA setting at the National Museum of Nature and Science, Tsukuba. **A,** TGUSE-MM 6108 from the lower Albian of the Aketo Formation described by Obata and Matsukawa (2018, p. 239, fig. 12Q–S); **B,** NMNS PM 35968 from the upper Aptian Hiraiga Formation described by Matsukawa and Oji (2022, p. 146, fig. 4E). Both specimens were assigned to *Gabbioceras* sp., but probably should be attributed to *Eogaudryceras* (see Discussion section).

Outcrops of Albian strata are widely exposed along the Pombetsu River in the Mikasa area and in the Manji

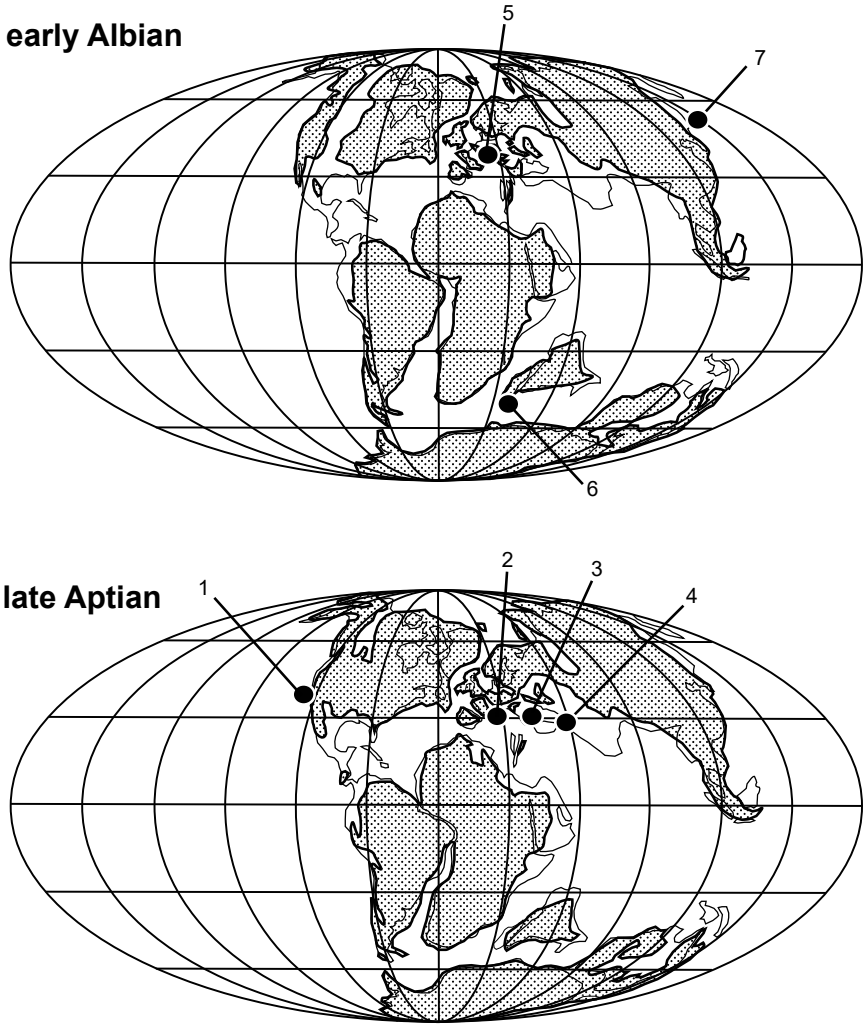

Figure 7. Paleogeographical distribution of *Gabbioceras* during late Aptian and early Albian time. Paleomap from Smith *et al.* (1994). 1, *Gabbioceras angulatum*, Anderson (1902); 2, *G. lamberti*, Breistroffer (1937); 3, *G. lamberti*, Szives *et al*. (2007); 4, *G. lamberti*, Drushchits (1960); 5, *G. lanternoi*, Wiedmann (1962); 6, *G. jacobi*, Murphy (1967a); 7, *G. orientale* sp. nov., this study.

area, just south of the Mikasa area. Two members of the Gabbioceratinae subfamily, i.e., *Tanabeceras pombetsuense* Shigeta *et al.*, 2012 and *Obataceras manjiense* Shigeta *et al.*, 2012, have been described from the upper Albian in these two areas, respectively. Although many other Albian ammonoids occur in these two areas (Obata and Futakami, 1975; Futakami, 1996), *Gabbioceras* has only been found in the lower Albian as described herein. This evidence suggests that *Gabbioceras* was extinct by middle Albian time in the Northwest Pacific region. *Gabbioceras* is also known to have gone extinct in the middle Albian in the Mediterranean area and Madagascar. The cause of the extinction of *Gabbioceras* in the Mediterranean area and Madagascar is unknown. According to a database of Japanese Cretaceous ammonoids by Toshimitsu and Hirano (2000), ammonoid species diversity declined sharply between early and middle Albian time. It is also known that the "cooling" episode occurred during this interval (Iba and Sano, 2007, 2008; Iba, 2009). Although detailed studies of paleoclimate during Albian time have not been conducted, the "cooling" episode may be related to the extinction of *Gabbioceras* as well as the decline of species diversity. The changing pattern of geographical distribution of *Gabbioceras* may provide an important key for understanding the global environmental change that occurred during late Aptian to early Albian.

Acknowledgments

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Author contributions

M. I. collected fossils and contributed to the geological aspect of the study. Y. S. conducted the taxonomic study. Both authors contributed to the writing of the paper.