むかわ町穂別博物館研究報告第 39 号（2024 年 3 月）15-27 頁
The Bulletin of the Hobetsu Museum, no.39 (Mar., 2024), p.15–27

Original Article

The early Cenomanian (Late Cretaceous) ammonoid *Parajaubertella* from the Hobetsu area, Hokkaido

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Abstract. *Parajaubertella* specimens ranging in diameter from 10 to 50 mm from the lower Cenomanian *Mantelliceras saxbii* Zone in the Hobetsu area, south-central Hokkaido have a slightly narrower umbilicus and a slightly more depressed whorl section than *Parajaubertella kawakitana* specimens of comparable size from the lowest Cenomanian *Graysonites wooldridgei* and *Stoliczkaia japonica* Assemblage zones in the Horokanai area, north-central Hokkaido. Because their ontogenetic development of ornamentation and whorl geometry are identical and shells larger than 50 mm in diameter appear very similar to each other, we conclude that these differences can be attributed to phyletic transition within a lineage; therefor, the Hobetsu specimens are assigned to *P. kawakitana*. As same as the Horokanai specimens, microconchs and macroconchs are observed in the Hobetsu specimens. This evidence increases support for the hypothesis of dimorphism in *P. kawakitana*.

Key words: ammonoid, Cenomanian, Cretaceous, dimorphism, Hobetsu, Hokkaido, *Parajaubertella*
(Recieved 26 October 2023)

Introduction

The Hobetsu area in south-central Hokkaido, northern Japan, is one of the areas in Hokkaido, where early Cenomanian ammonoids are abundant and include various taxa of the *Mantelliceras saxbii* Zone, the third highest zone of the lower Cenomanian ammonoid zones (Matsumoto et al., 2003, 2004). *Mariella lewesiensis* (Spath, 1926), *Takahashiceras eureka* (Matsumoto, 1984) and *Tanabeceras yezoense* (Shigeta, 1996) have been reported from the zone (Matsumoto and Kijima, 2000; Shigeta et al., 2010; Shigeta and Izukura, 2013, 2017; Shigeta, 2021), and *Mosirites mirabilis*, a large heteromorph ammonoid was recently described by Shigeta et al. (2024).

In 2017, co-author M. Izukura donated his huge collection of Cretaceous ammonoids from Hokkaido to the Hobetsu Museum, Mukawa, Hokkaido (Nishimura, 2018). The collection includes many early Cenomanian specimens from the Hobetsu area, and in particular, the "Izukura Collection" contains eight specimens referable to *Parajaubertella* Matsumoto, 1943 from the Hobetsu area.

Parajaubertella, a genus belonging to the family Tetragonitidae Hyatt, 1900 (Hoffmann, 2015), is one of the most common early Cenomanian ammonoid genera in the Northwest Pacific region (e.g. Matsumoto, 1995). Although two species, i.e., the typically large shell-sized *P. kawakitana* Matsumoto, 1943 and the small-sized *P. zizoh* Matsumoto et al., 1997, have been described from the lower Cenomanian of Hokkaido and Sakhalin (Russian Far East), Shigeta et al. (2023) recently compared the ontogenetic development of ornamentation and whorl geometry of the two taxa and subsequently concluded that they are dimorphs, i.e., microconch and macroconch of a single species.

Shigeta et al. (2023) examined the dimorphism of *Parajaubertella* in specimens from the lower Cenomanian *Graysonites wooldridgei* Zone, whose zonal index *G. wooldridgei* was synonymized with

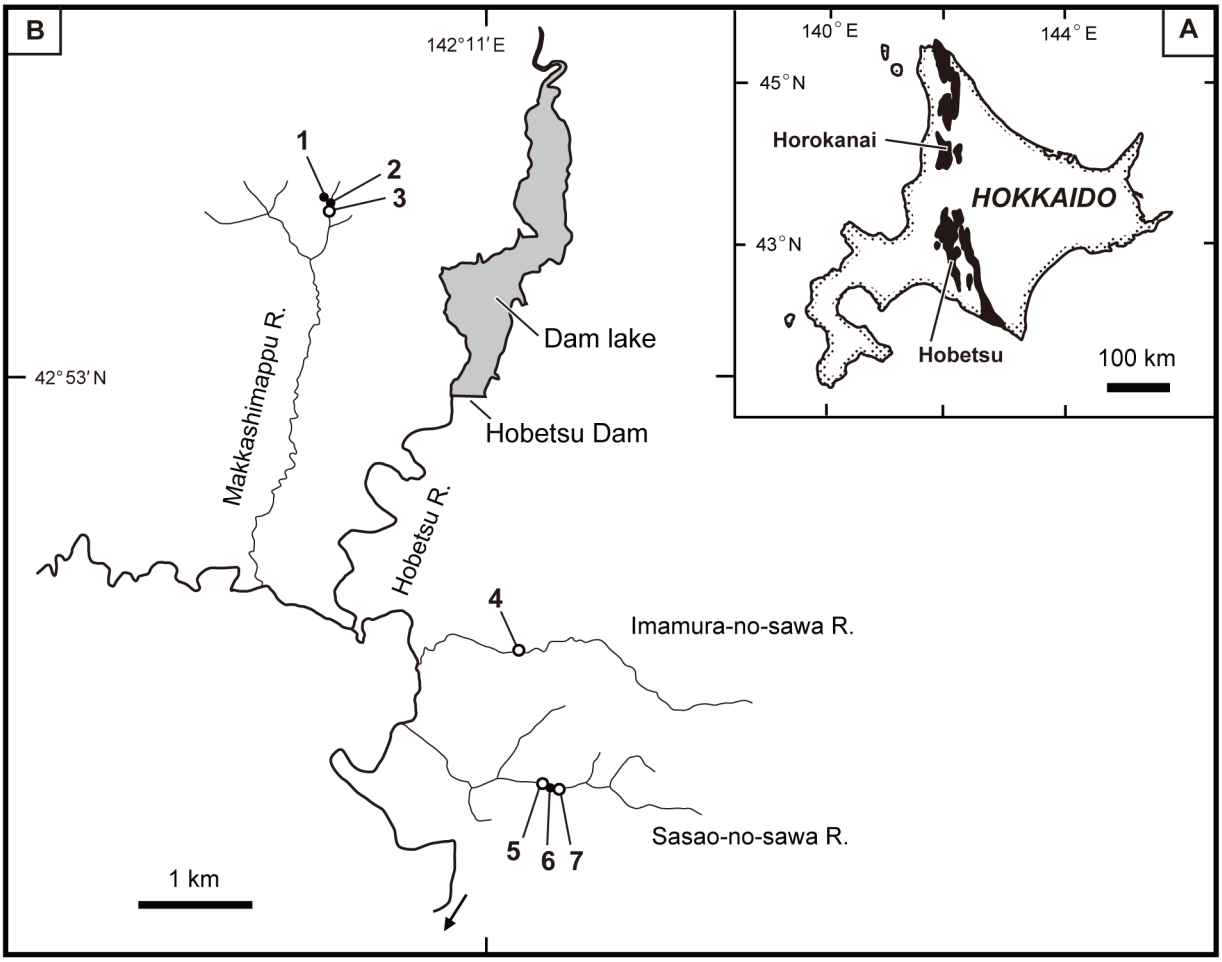

Figure 1. Index map showing distribution of the Yezo Group (black areas) in Hokkaido (**A**) and collection localities (black circles, *in-situ* concretions; white circles, float concreations) of *Parajaubertella* specimens in the Hobetsu area (**B**).

G. wacoensis (Böse, 1928) by Kennedy et al. (2005) and *Stoliczkaia japonica* Assemblage Zone, which comprise the lowest two Cenomanian ammonoid zones (Matsumoto et al., 2003, 2004) in the Horokanai area, north-central Hokkaido. In this paper, we report on specimens referable to *Parajaubertella* from the Hobetsu area that are housed in the Hobetsu Museum and discuss their species assignment and dimorphism.

Notes on stratigraphy

The Hikagenosawa Formation, which is widely distributed in central Hokkaido, consists of dark grey, weakly laminated mudstone with sandstone-bed intercalation, and contains late Albian to Cenomanian-aged ammonoids, inoceramids and foraminiferes (Takashima et al., 2004). It is distributed in a narrow band running in a north-south direction from the east side of the Hobetsu River to the west side of the Hobetsu Dam (Takahashi et al., 2002). Many early Cenomanian ammonoid specimens have been collected from float calcareous concretions, which most likely came from the *Mantelliceras saxbii* Zone in the mudstone portion of the formation, in this area (Shigeta et al., 2024).

Material and methods

Material

The Hobetsu Museum has 8 specimens in its collection from the Hobetsu area, which are assignable to *Parajaubertella*, i.e., HMG-2146, 2147, 2152a, 2376, 2377 and 2428–2430 (Figures 2–7). These specimens as listed below were collected from

outcrops or float calcareous concretions in the lower Cenomanian *Mantelliceras saxbii* Zone along the Makkashimappu, Imamura-no-sawa and Sasao-no-sawa rivers in the Hobetsu area (Figure 1).

HMG-2152a (Figure 2A–D), measuring about 65 mm in diameter, was collected from a float calcareous concretion, which contains *Eogunnarites tanakai* Hayakawa, 1997, *Desmoceras* sp. and *Mariella* sp., in the Sasao-no-sawa River (Loc. 7 in Figure 1). This specimen consists of the phragmocone and most of the body chamber, which begins at a diameter of about 34 mm and occupies nearly five-eighths of the outer whorl.

HMG-2428 (Figure 2E, F) was extracted from a float calcareous concretion in the Sasao-no-sawa River (Loc. 5 in Figure 1). This specimen consists of the phragmocone and most of the body chamber which begins at a diameter of about 25 mm. However, it is unclear exactly how much of the outer whorl the body chamber occupies due to secondary deformation.

HMG-2146 (Figures 2G, 3) was collected from an *in-situ* calcareous concretion in the Makkashimappu River (Loc. 1 in Figure 1). This specimen consists of the phragmocone and part of the body chamber, which begins at a diameter of about 147 mm and occupies nearly three-eighth of the outer whorl.

HMG-2376 (Figures 4A–C, 7B) was extracted from a float calcareous concretion in the Makkashimappu River (Loc. 3 in Figure 1). This specimen consists of the phragmocone and part of the body chamber, which begins at a diameter of about 59 mm and occupies nearly three-eighth of the outer whorl.

HMG-2147 (Figures 4D, 5D, 7E) was collected from an *in-situ* calcareous concretion in the Makkashimappu River (Loc. 2 in Figure 1). The last part of the phragmocone and the first part of the body chamber of this specimen are missing, but the body chamber probably begins at a diameter of about 112 mm and occupies nearly five-eighth of the outer whorl.

HMG-2377 (Figures 5A–C, 7D) was extracted from a float calcareous concretion in the Sasao-no-sawa River (Loc. 5 in Figure 1). Although the body chamber is crushed due to compaction, this specimen consists of the phragmocone and part of the body chamber, which begins at a diameter of about 48 mm and occupies about half of the outer whorl.

HMG-2429 (Figures 6A–D, 7C) was extracted from a float calcareous concretion in the Imamura-no-sawa River (Loc. 4 in Figure 1). This specimen consists of the phragmocone and most of the body chamber, which begins at a diameter of about 63 mm.

HMG-2430 (Figures 6E–H, 7A), measuring about 34 mm in diameter and consisting of only the phragmocone, was collected from an *in-situ* calcareous concretion in the Sasao-no-sawa River (Loc. 6 in Figure 1).

Methods

All specimens were examined for biometric analysis of shell morphology. Five of the specimens (HMG-2147, 2376, 2377, 2429, 2430) 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 0.01–0.05 mm resolution, 200–225 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 two ratios, i.e., relative umbilical size (*U/D*) and relative whorl thickness (*W/H*), were calculated.

Results

Shell surface ornamentation

The ribbing style on all specimens is seem to change with growth. All specimens up to 40 mm in diameter are ornamented only with fine growth lines and slightly flexuous lirae. Specimens HMG-2152a and 2428 exhibit rounded fold-like ribs separated by narrow interspaces on the body chamber beginning at a diameter of 40 mm (Figure 2A–F). In contrast, specimens HMG-2146, 2377, 2376 and 2429 (Figures 3–6) at diameters between 40 and 150 mm exhibit periodic segments with a set of 3 to 5 narrow grooves followed by flexuous narrow ribs. Each segment extends for 30–40 degrees in spiral length, while the interval without ribs and grooves extends between 50 and 70 degrees. At diameters greater than 150 mm,

Figure 2. *Parajaubertella* from the Hobetsu area. **A**–**F**, microconchs of *P. kawakitana* Matsumoto, 1943; A–D, HMG-2152a; E, F, HMG-2428; **G**, macroconch of *P. kawakitana*, HMG-2146. Black arrows indicate position of last septum.

Figure 3. Macroconch of *Parajaubertella kawakitana* Matsumoto, 1943 from the Hobetsu area, HMG-2146. Black arrow indicates position of last septum.

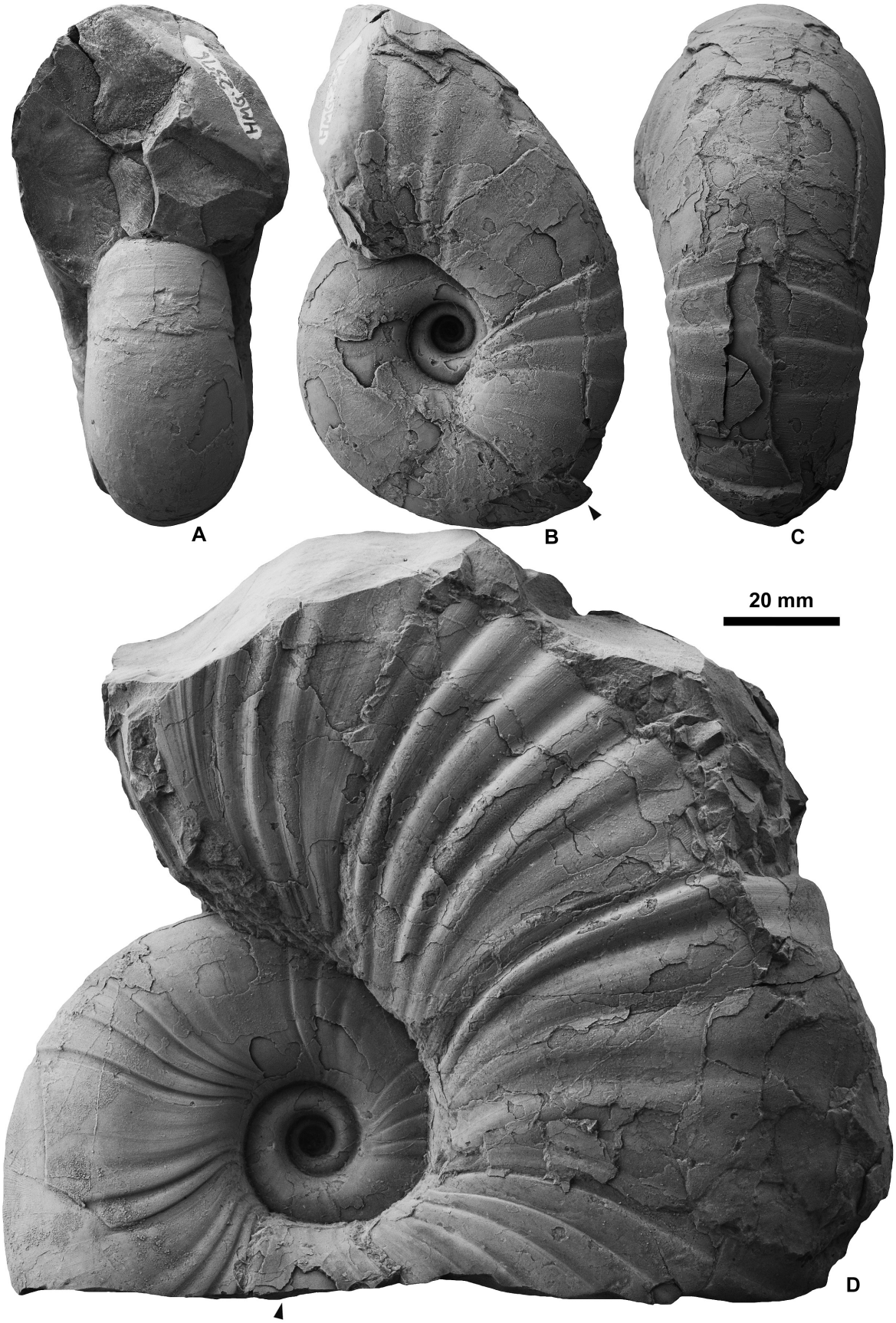

Figure 4. Macroconchs of *Parajaubertella kawakitana* Matsumoto, 1943 from the Hobetsu area. **A**–**C**, HMG-2376; **D**, HMG-2147. Black arrows indicate position of last septum.

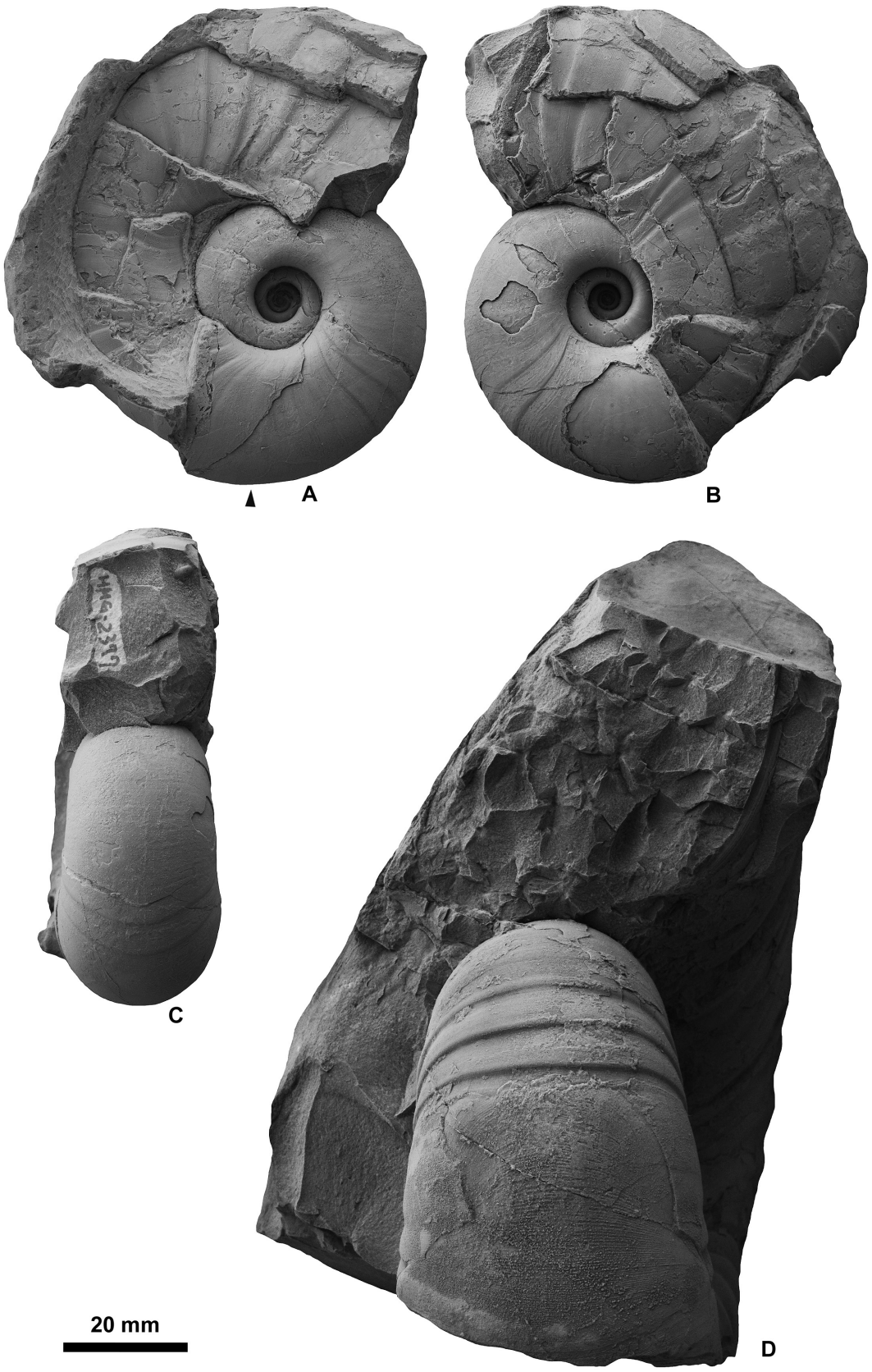

Figure 5. Macroconchs of *Parajaubertella kawakitana* Matsumoto, 1943 from the Hobetsu area. **A**–**C**, HMG-2377; **D**, HMG-2147. Black arrows indicate position of last septum.

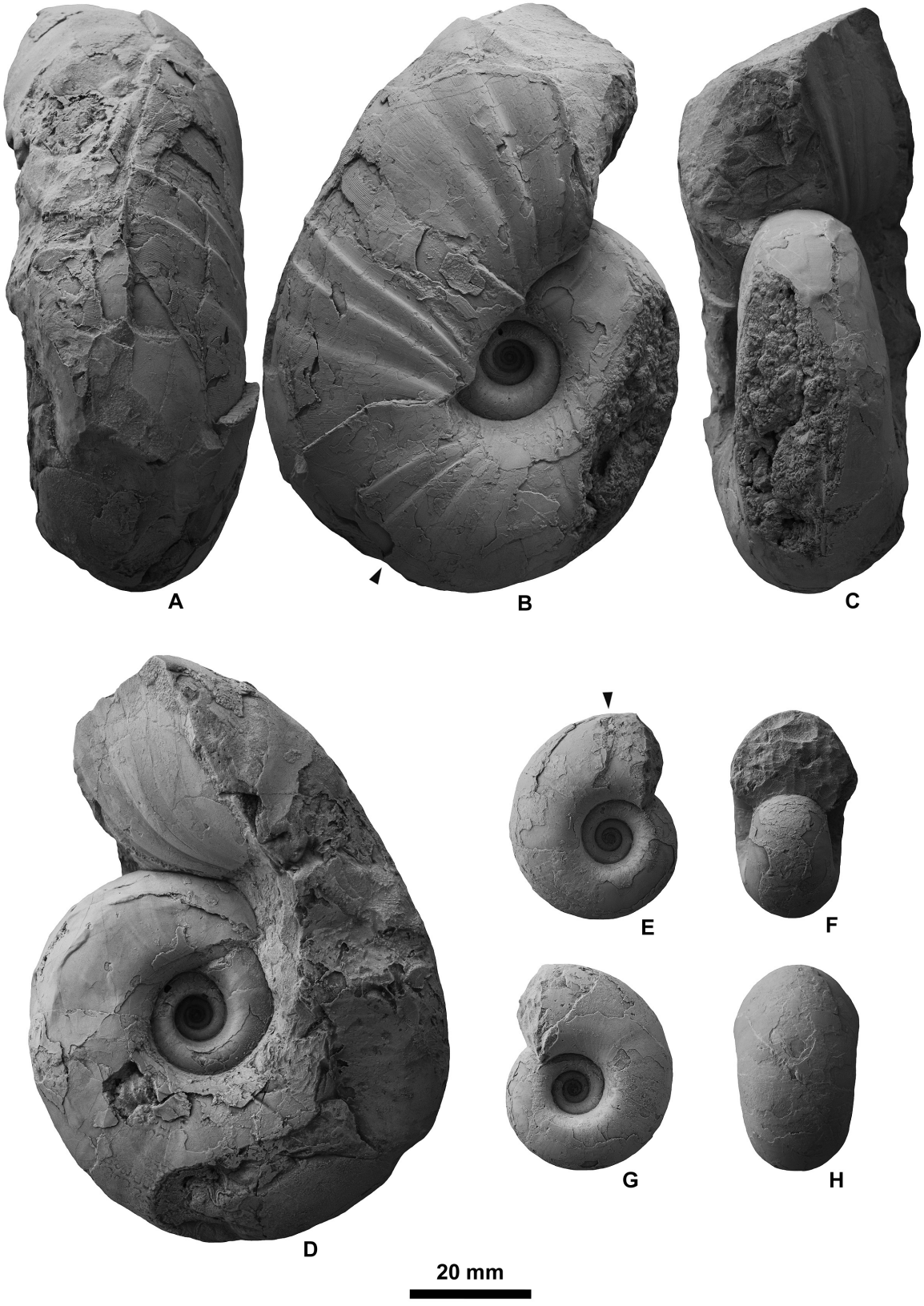

Figure 6. *Parajaubertella* from the Hobetsu area. **A**–**D**, macroconch of *P. kawakitana* Matsumoto, 1943, HMG-2429; **E**–**H**, juvenile of *P. kawakitana*, HMG-2430. Black arrows indicate position of last septum.

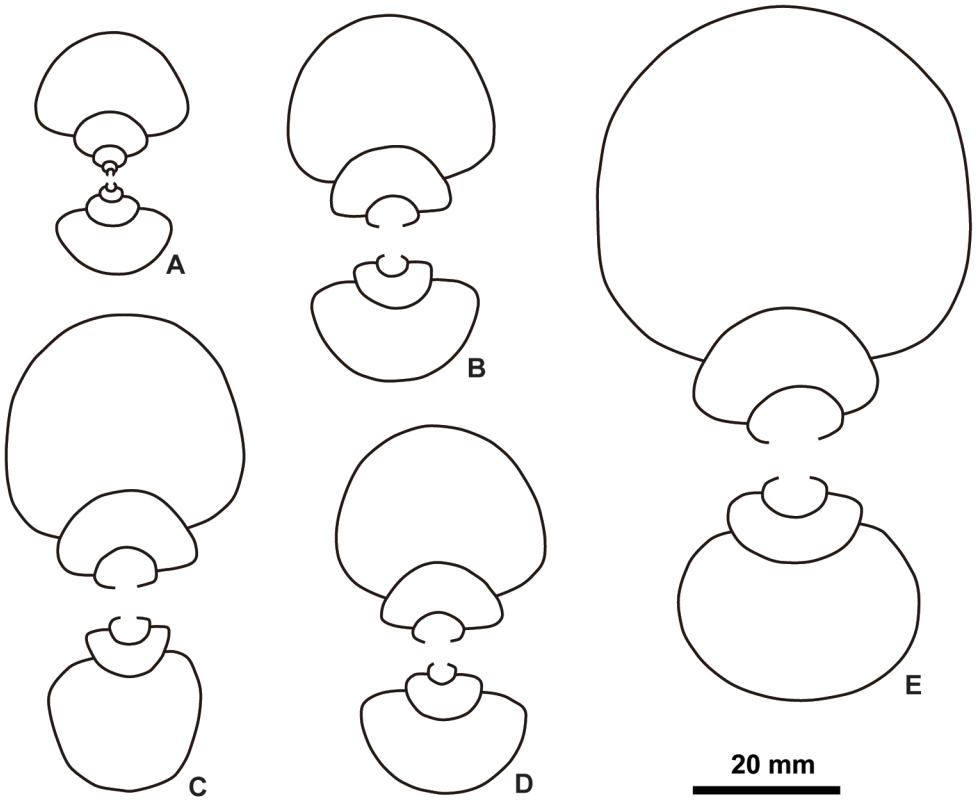

Figure 7. Whorl cross sections drawn from X-ray CT images of *Parajaubertella kawakitana* Matsumoto, 1943 from the Hobetsu area. **A**, HMG-2430; **B**, HMG-2376; **C**, HMG-2429; **D**, HMG-2377; **E**, HMG-2147.

specimens HMG-2146 and 2147 exhibit rounded fold-like ribs separated by narrow interspaces on the body chamber (Figures 3, 4).

Adult features

It is a well-known fact that fold-like or flat-topped ribs appear only on the later part of the phragmocone and/or adult body chamber in *Anagaudryceras* (e.g. Kennedy and Klinger, 1979; Matsumoto, 1995). The presence of fold-like ribs similar to *Anagaudryceras* on the body chambers of HMG-2152a, 2428, 2146 and 2147 suggests that these shells are adults or sub-adults (Figures 2–4). The adult shell diameters of HMG-2152a and 2428 are 50–60 mm, but those of HMG-2146 and 2147 are 200–250 mm.

Whorl geometry

The whorl geometries of the examined specimens change with growth and these changes are nearly identical (Figure 8, Appendix). At a diameter of ~3mm, HMG-2430 exhibits a fairly depressed whorl (*W/H* = 1.23) and a moderately wide umbilicus (*U/D* = 0.41). As the shell grows, *U/D* becomes progressively smaller and the whorl section becomes more depressed (*W/H* = 1.72–1.82) up to ~20 mm in diameter. Shells with diameters greater than 20 mm gradually become more compressed. HMG-2146, with a diameter larger than 140 mm, exhibits a whorl section that is as high as broad (*W/H* = 0.96) and a fairly narrow umbilicus (*U/D* = 0.25). The umbilical wall of the examined specimens, up to 20 mm, is vertical with a narrowly rounded shoulder, but it becomes oblique with a broadly rounded shoulder as the shell grows (Figure 7).

Discussion

Those *Parajaubertella* specimens, with diameters ranging from 10 to 50 mm from the *Mantelliceras saxbii* Zone in the Hobetsu area, have a slightly narrower umbilicus and slightly more depressed whorl section than *Parajaubertella kawakitana* specimens

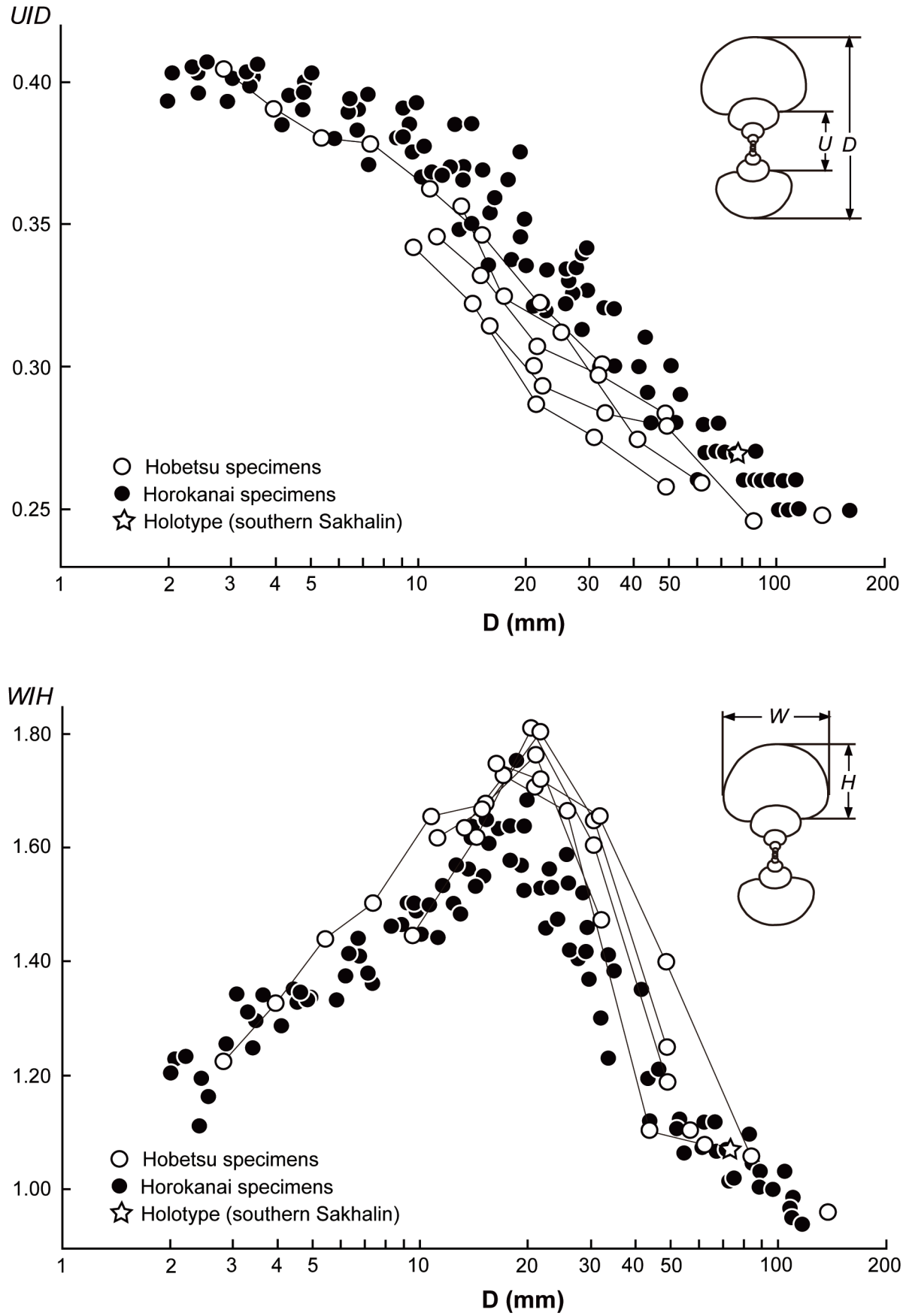

Figure 8. Scatter diagrams showing ontogenetic variation in umbilical diameter/shell diameter (*U/D*) versus shell diameter (*D*) and whorl width/whorl height (*W/H*) versus shell diameter for *Parajaubertella kawakitana* Matsumoto, 1943 from the Hobetsu (white circles) and Horokanai (black circles) areas and the holotype UMUT MM 19698 from southern Sakhalin (white star), based on data from Shigeta et al. (2023).

of comparable size from the *Graysonites wooldridgei* and *Stoliczkaia japonica* Assemblage zones in the Horokanai area (Figure 8). Because their ontogenetic development of ornamentation and whorl geometry are identical and shells larger than 50 mm in diameter appear very similar to each other, these differences should be attributed to phyletic transition within a lineage. Therefore, the Hobetsu specimens are assigned to *P. kawakitana.*

Dimorphism in *Parajaubertella* was examined in detailed by Shigeta et al. (2023) based on specimens from the lower Cenomanian *Graysonites wooldridgei* and *Stoliczkaia japonica* Assemblage zones in the Horokanai area. An investigation of the ontogenetic shell development (ornamentation and whorl geometry) and suture line revealed that *Parajaubertella kawakitana* and *P. zizoh* differ in adult morphology, but have identical early ontogenies. That is, the sizes of their adult shells are distinctly bimodal (187 to 284 mm for *P. kawakitana*, 34 to 51 mm for *P. zizoh*), and their immature stages share similar ornamentation and shell morphology at comparable sizes. Their stratigraphic ranges are restricted to the lower Cenomanian, and their geographic distribution is limited to the Northwest Pacific region. Additionally, they sometimes co-occur in the same concretion (figure 7P-R in Shigeta et al., 2023). Based on this evidence, Shigeta et al. (2023) considered the two species to be dimorphs, microconch and macroconch, of a single species *P. kawakitana*.

Specimens HMG-2152a (Figure 2A–D) and 2428 (Figure 2E, F) are characterized by their small adult sizes (50–60 mm in diameter), and their shell morphology and ornamentation are very similar to the microconch of *Parajaubertella kawakitana*. In contrast, the shell morphology and ornamentation of HMG-2146(Figures 2G, 3) and 2147 (Figures 4D, 5D), which are over 200 mm in diameter, are very similar to the macroconch of *P. kawakitana*, and the shell morphology and ornamentation of HMG-2376 (Figure 4A–C), 2377 (Figure 5A–C) and 2429 (Figure 6A–D) are very similar to the middle growth stage of the macroconch of *P. kawakitana*. The fact that a dimorphic pair was observed in the *Mantelliceras saxbii* Zone increases support for the hypothesis of dimorphism in *P. kawakitana* proposed by Shigeta et al. (2023).

Acknowledgments

We are deeply indebted to the Hobetsu Musem (Mukawa) for kindly providing the opportunity to examine the specimens. We thank G. Shinohara, S. Nomura, T. Kutsuna and T. Mikami for their support with scanning the studied specimens at the National Museum of Nature and Science (Tsukuba), and to Jim Jenks (West Jordan, Utah) for his helpful suggestions and improvement of the English text.

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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. All authors contributed to the writing of the paper.

Yasunari Shigeta and Masataka Izukura, 2024, The early Cenomanian (Late Cretaceous) ammonoid *Parajaubertella* from the Hobetsu area, Hokkaido. *The Bulletin of the Hobetsu Museum*, **39**, 15—27.
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（要　旨）

穂別地域の下部セノマニアン階 *Mantelliceras saxbii* 帯から産出する *Parajaubertella* は，直径 10 ～ 50 ｍｍの大きさの時、幌加内地域の最下部セノマニアン階 *Graysonites wooldridgei* 帯や *Stoliczkaia japonica* 群集帯から産出する同サイズの *Parajaubertella kawakitana* よりも若干狭いヘソと若干太い螺管断面を持つ．これらの表面装飾や殻形態の個体成長様式は同じであることや直径 50 mm より大きな殻はお互いに似ていることから，これら違いは系統内での変化と考えられ、穂別標本は *P. kawakitana* に帰属される．幌加内標本と同様に，穂別標本にもマクロコンクとミクロコンクが観察される．このことは，*P. kawakitana* の二型性仮説の支持を高める．

Appendix. Measurements (in mm) of herein studied specimens of *Parajaubertella kawakitana* Matsumoto, 1943 from the Hobetsu area. M, macroconch; m, microconch; *D*, shell diameter; *U*, umbilical diameter; *H*, whorl height; *W*, whorl width.

register number	M or m	*D* (mm)	*U* (mm)	*H* (mm)	*W* (mm)	*U*/*D*	*W*/*H*
HMG-2146	M	140.50	35.00	69.00	66.00	0.25	0.96
HMG-2147	M	16.52	5.22	96.96	12.17	0.32	1.75
		22.17	6.52	9.56	16.52	0.29	1.72
		32.17	9.13	13.91	23.04	0.28	1.66
		49.56	13.91	21.74	30.43	0.28	1.40
		87.83	21.74	44.35	46.96	0.25	1.06
HMG-2152a	m	65.00	—	—	—	—	—
HMG-2376	M	9.76	3.33	4.29	6.19	0.34	1.44
		14.76	4.76	6.19	10.00	0.32	1.62
		21.43	6.19	9.29	16.90	0.29	1.82
		30.95	8.56	13.81	22.14	0.28	1.60
		49.52	12.86	23.33	27.62	0.26	1.18
HMG-2377	M	11.06	3.83	4.47	7.23	0.35	1.62
		15.32	5.11	6.38	10.64	0.33	1.67
		21.70	6.60	8.94	16.17	0.30	1.81
		31.49	9.36	13.40	22.13	0.30	1.65
		49.36	14.04	22.13	27.66	0.28	1.25
HMG-2429	M	13.02	4.65	5.12	8.37	0.36	1.63
		17.67	6.05	6.74	11.63	0.34	1.73
		25.12	7.91	11.16	18.60	0.31	1.67
		40.47	11.16	18.60	20.47	0.28	1.10
		64.19	16.74	29.76	32.09	0.26	1.08
HMG-2430	?	2.86	1.16	1.03	1.27	0.41	1.23
		3.97	1.56	1.43	1.90	0.39	1.33
		5.40	2.06	1.98	2.86	0.38	1.44
		7.54	2.86	2.85	4.29	0.38	1.50
		10.71	3.89	4.13	6.83	0.36	1.65
		15.08	5.24	5.87	9.84	0.35	1.68
		21.45	7.06	8.73	15.40	0.33	1.76
		32.54	9.84	13.81	20.32	0.30	1.47
HMG-2428	m	21.26	6.42	9.26	15.79	0.30	1.71