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Notes on *Pachydiscus* from Hokkaido
(Studies on the Cretaceous Ammonites from
Hokkaido and Saghalien-XXXIX)

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Abstract

In this paper four new species are established for the genus *Pachydiscus* based on the specimens from Hokkaido. The first one, which certainly belongs to the subgroup of *P. neubergicus*-*P. gollevillensis*, occurs in K6a (Campanian). Other three are from K6b (approximately Maastrichtian). The second new species, characterized by flexuous ribs, is diagnostic of K6b2. Some specimens which were referred to *P. (P.) subcompressus* should be transferred to this second new species. The third new species of *P. (P.)* was found solitarily from K6b of the Urakawa area. The fourth new species from K6b2 is referred to *P. (Neodesmoceras)* and is distinct from *P. (N.) japonicus* from K6b1.

In conclusion, these *Pachydiscus* species from Hokkaido are discussed in connexion with the problem of faunal provincialism and a difficulty in precise inter-regional correlation is explained.

Introduction

The purpose of this paper is to report the result of our study on several species of the genus *Pachydiscus* from the Hetonaian (K6, approximately Campanian and Maastrichtian) of Hokkaido.

Previously two species of *Pachydiscus* were established on the basis of the specimens from the Upper Hetonaian (K6b, approximately Maastrichtian of current usage) of Hokkaido and Saghalien [Sakhalin]. They are *P. (Neodesmoceras) japonicus* MATSUMOTO, 1947 (see also MATSUMOTO and SAITO, 1954 for full description), from the lower part of K6b, and *P. (P.) subcompressus* MATSUMOTO, 1954, from the upper part of K6b. These two species, together with associated inoceramid species, *Inceramus (Endocostea) shikotanensis* NAGAO and MATSUMOTO and *I. (Sphenoceras) ? hetonaianus* MATSUMOTO respectively, have been selected as indices of Substages K6b1 and K6b2 (MATSUMOTO, 1959a, 1977; also 1980 in press).

Meanwhile, we continued our field works to establish more clearly the sequence of strata and to collect more specimens. As a result, we have noticed that there

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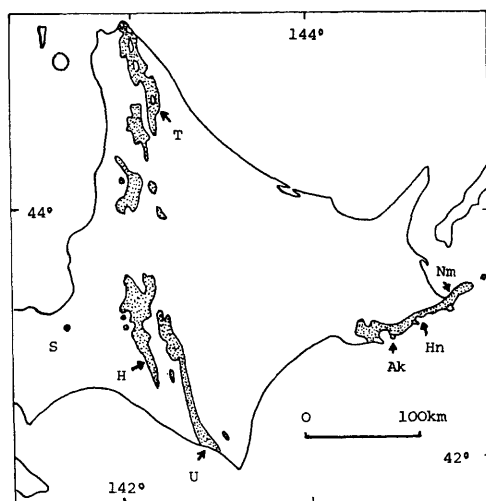


Fig. 1. Map of Hokkaido showing locations of the areas where the described species of *Pachydiscus* occurred. T: Tombetsu Valley, H: Hobetsu Valley, U: Urakawa area, Nm: Nemuro, Hn: Hamanaka, Ak: Akkeshi. Dotted area: Post-Aptian Cretaceous outcrops. S: Sapporo.

are additional new species of *Pachydiscus* and that the previously described species should be revised.

The basic material for this study comes from the following four areas in Hokkaido (Fig. 1), where strata of the Hetonaian (K6) are well exposed:

(1) Tombetsu Valley, northern central Hokkaido.—The Upper Cretaceous stratigraphy in this area is concisely described in a separate paper (MATSUMOTO et al. in press), indicating ammonite localities on five maps. The specimens were obtained by Dr. S. IGI of the Geological Survey of Japan (GSJ) and Dr. A INOMA, Messrs. H. KIDO and S. KATO under the leadership of Dr. K. KINOSHITA of the Japan Petroleum Exploitation Co. (JPE), with whom H. OKADA and one of us (T. M.) cooperated. These specimens are now kept in the Type Collections of the Department of Geology, Kyushu University (GK). Some of the specimens stored at the University Museum, University of Tokyo (UMUT) and at the Department of Geology & Mineralogy, Hokkaido University (GH) are from this and adjacent areas.

(2) Hobetsu Valley, central Hokkaido.—The Hobetsu and the adjacent Tomiuchi (formerly called Hetonai) areas include the type localities of the Hetonaian and its subdivisions. The stratigraphy of the Hetonai area, previously described by MATSUMOTO (1942, 1954), is generally applicable to that of the Hobetsu area. Although more precise investigations are being continued, a geological map for the whole area of the Hobetsu Valley has not been published. In this paper, the locations of the described *Pachydiscus* are indicated on two local maps (Figs. 3 and 7).

One of the described specimens was collected by Dr. H. SHIMOGAWARA, former Director of the Geological Survey, Hokkaido Colliery & Steamship Co., who

donated it to Kyushu University through T. MATSUMOTO; others were collected by one of us (T. M.), with assistance of Mr. T. MURAMOTO. These Hobetsu specimens are kept in the Type Collection, Kyushu University.

(3) Urakawa area, southern central Hokkaido.—The stratigraphy of this area was described by MATSUMOTO (1942) and then by Y. KANIE (1966), who still continues his field work together with some micropalaeontologists. The result of this revisory work has not fully been described yet, but preliminary reports of its progress appeared in technical newsletters for domestic circulation. A local map showing the location of the described *Pachydiscus* is included in this paper (Fig. 9). That ammonite was collected by one of us (Y. K.) and is now kept at the Yokosuka City Museum (YCM).

(4) Nemuro-Hamanaka-Akkeshi area, eastern Hokkaido.—A series of rocks from the Campanian to Palaeocene in this area is called the Nemuro Group. MATSUMOTO and YOSHIDA (1979) have recently given a concise account of the Nemuro Group, summarizing a number of previous works including their own. The ammonite localities of the Hamanaka area are shown in that paper, and those of another area near Nemuro in Fig. 10 of this paper. The specimens are kept in Yamagata University (YU.) and Kyushu University (GK.).

In this paper the palaeontological descriptions are given in three parts under different authorships as follows:

- Part I Some New Species of *Pachydiscus* from the Tombetsu and the Hobetsu Valleys T. MATSUMOTO
- Part II A New Species of *Pachydiscus* from the Urakawa Area
..... T. MATSUMOTO and Y. KANIE
- Part III Two Species of *Pachydiscus* from the Nemuro-Hamanaka Area ...
..... T. MATSUMOTO and S. YOSHIDA

In the concluding remarks, after the descriptions in these three parts, a summary of taxonomic and stratigraphic results will be shown and discussions will be given on some relevant problems.

Acknowledgements.—Before going further we thank all the persons (whose names recorded above) who have helped us in various ways, including the offer of their valuable specimens. Dr. K. TANABE and Miss Kazuko HARA have kindly assisted us in preparing the manuscript.

This is a part of a cooperative work on interregional correlation of the Cretaceous System which was financially supported by the Science Research Fund (No. 334043) of the Ministry of Education, Science and Culture (*Monbusho*), Japan. It is also a contribution to the Working Group of the Coniacian-Maastrichtian Stages (Leader: Professor F. SCHMID) of the IUGS Subcommittee on Cretaceous Stratigraphy (Chairman: Professor Tove BIRKELUND).

Palaeontological Descriptions

Part I

Some New species of *Pachydiscus* from the Tombetsu
and the Hobetsu Valleys

(Tatsuro MATSUMOTO)

Family Pachydiscidae SPATH, 1922

Genus *Pachydiscus* ZITTEL, 1884

Type-species.—*Ammonites neubergicus* HAUER, 1858 (subsequent designation by DE GROSSOUVRE, 1894, p. 177).

Diagnosis.—See WRIGHT in MOORE (ed.), 1957, p. L 380.

Remarks.—As has been mentioned by MATSUMOTO (1959b, p. 41), three subgroups may be recognized in this genus. The typical subgroup, represented by *P. neubergicus*, *P. egertoni* (FORBES) and *P. gollevillensis* (D'ORBIGNY), is "compressed and high-whorled, with oval or flat-sided section," and has the ribs which "tend to differentiate into short umbilical and separate ventrolateral ribs" (citation from WRIGHT, *op. cit.*).

The second subgroup represented by *P. japonicus* MATSUMOTO (type-species), *P. catarinae* (ANDERSON and HANNA) and *N. mokotibense* COLLIGNON, has been treated as the subgenus *Neodesmoceras* MATSUMOTO, 1947, which is characterized by almost smooth shell, with remarkable weakening or disappearance of ribs and umbilical bullae at earlier growth stage. Because of its very intimate relation with the first subgroup, it is better to be kept as a subgenus of *Pachydiscus*.

The third subgroup, represented by *P. colligatus* (BINCKHORST) and other allied species, have the whorl which is higher than broad but more inflated than the typical subgroup and the tendency to differentiate umbilical and ventrolateral ribs is not distinctly shown.

There are, however, several species which show intermediate features in shell-form and/or ribbing between the two subgroups. Also some species of the third subgroup could lead to some species of *Neodesmoceras* by reducing the ornament. Therefore, I hesitate to establish a new subgenus for the third subgroup, which is currently assigned to *Pachydiscus* (s.s.). Certain species of the third subgroup, e.g. *P. colligatus* itself, is fairly similar to some species of *Anapachydiscus* at the immature stage.

Distribution.—World-wide in the Campanian and the Maastrichtian.

Subgenus *Pachydiscus* ZITTEL

Pachydiscus (*Pachydiscus*) *excelsus* MATSUMOTO, n. sp.

Pl. 8, Fig. 1; Text-fig. 2

Holotype.—GK. H5895, from the sandstone of the Hakobuchi Group, middle course of the creek Sanushube, a tributary of the River Hobetsu, Yufutsu-gun

(Iburi province), Hokkaido, collected by H. SHIMOGAWARA, Geological Survey of the Hokkaido Colliery & Steamship Co., in August 1955 and donated to Kyushu University through T. MATSUMOTO in 1956.

Diagnosis.—Large shell, with fairly narrow umbilicus, consisting of rapidly enlarging high whorls with narrowly elliptical to ovoid sections; ornamentation consists of moderately distant, blunt, elongated umbilical ribs and numerous, fairly dense, regular, projected ventrolateral ones: the latter being 3 to 3.5 times as numerous as the former. A few of the umbilical ribs extend to the ventrolateral ones, showing a gently sigmoid curvature, but many others are much weakened or disappear at some distance from the middle of the flank. Sutures as complicated as in *P. gollevillensis*.

Remarks.—As the rock matrix is calcareous sandstone, the specimen is little deformed and the shell layers are partly preserved. The last septum is at the diameter of about 360 mm and the body-chamber is only partly preserved. Assuming that the body-chamber is about a half whorl, as suggested by the trace of its umbilical seam, the restored entire shell would be about 560 mm in diameter.

Fig. 2 shows the whorl-section at each $\pi/2$ of the septate shell. The section of the inner whorl is compressed elliptical and that of the outer whorl is narrowly ovoid, broadest at about one third of the whorl-height from the umbilical margin. The umbilicus is narrowing as the shell grows, with U./D. about 0.27 at D.=50 mm to about 0.18 at D.=300 mm (see *Measurements*). Distinct tubercles never appear at the umbilical shoulder, but the ribs are bluntly thickened around the umbilicus and gradually weakened to extend beyond the mid-flank. In a half of the outer whorl, there are 12 umbilical ribs and about 40 ventrolateral ones. The ribs cross the venter with a forward curve and with some weakening on the siphonal zone. The umbilical shoulder is subrounded and the ribs are remarkably rursiradiate on the umbilical wall, forming a sinus (probably ocular sinus) at the shoulder. The very apertural margin is not preserved.

Measurements (in mm).—

Stage	Diameter	Umbilicus	Height	Breadth	B./H.
	51.0	14.0(.27)	23.0	16.5	.71
0.5 π later	79.5	21.0(.26)	38.0	24.7	.65
1.5 π "	117.0	29.0(.25)	52.8	32.2	.61
Ca 2 π "	179.0	40.3(.22)	92.0	54.8	.59
2.5 π "	281.0	51.5(.18)	141.0	80.5	.57
Still 30° "	300.0	55.0(.18)	151.0	86.0	.57

Comparison.—This species closely resembles *P. (P.) gollevillensis*, from the Maastrichtian of Europe (D'ORBIGNY, 1841; GROSSOUVRE, 1894, 1908; NOWAK, 1913 under *P. egertoni*), Crimea (MOSKVIN, ed., 1959), Armenia (ATABEKYAN and AKOPYANA, 1969; AKOPYANA, 1974), India (KOSSMAT, 1898), Madagascar (COLLIGNON, 1971) etc., and certainly belongs to the subgroup of *P. gollevillensis-neubergicus*. *P. (P.) gollevillensis* has tubercles at the umbilical shoulder at wide intervals and the umbilical ribs extend from the tubercles for a short distance, whereas the present species has much more numerous and distinctly longer umbilical ribs which have no tubercles but are only bluntly thickened. Hitherto

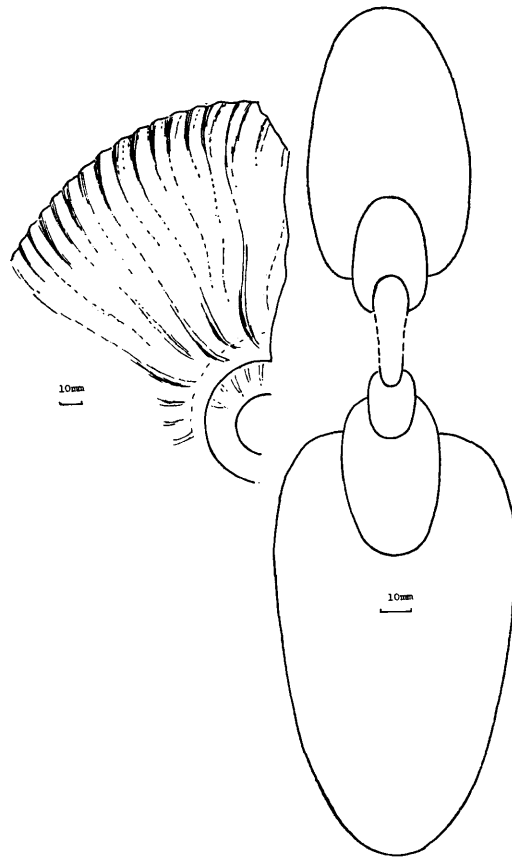


Fig. 2. *Pachydiscus (Pachydiscus) excelsus* MATSUMOTO, n. sp.
Whorl-section and a part of the lateral view of the holotype,
GK. H5395. (T.M. delin.)

illustrated specimens of *P. (P.) gollevillensis* are rather small. For instance, a specimen figured by GROSSOUVRE (1894, pl. 31, fig. 9) is about 95 mm in diameter at the last septum and another example from Armenia (AKOPYANA (ed.) 1974, pl. 143, fig. 1) is about 90 mm at the last septum and 125 mm at the end of the body-chamber. The holotype of the present species is evidently much larger. Incidentally, a form from the Upper Maastrichtian of Armenia, represented by that example, was called *P. gollevillensis armenicus* ATABEKYAN and NASOBJAN, but I think it biologically unreasonable to separate the contemporary two forms from the same province as distinct subspecies. In some examples from Armenia the umbilical ribs are somewhat more numerous than in the typical ones from Europe, but are not so numerous nor so much elongated as in the species from Hokkaido; they are elevated at the umbilical shoulder to form tubercles.

The holotype of *P. (P.) subcompressus* MATSUMOTO, 1954 (p. 287, pl. 10 [26], fig. 4) [UMUT. MM 6821=GT. I-2815], and other examples (e.g. UMUT. MM 6825, 6827) from the same formation (Rdy1 of the Ryugase Group, MATSUMOTO, 1942=Shimaiwa Shale of KAWADA, 1929) of the Naibuchi area, southern Sakhalin,

are unfortunately secondarily deformed. Although that species had originally a compressed high whorl, the precise comparison in shell form is difficult. It has tubercles at the umbilical shoulder from which ribs extend usually for a short distance. In this respect, it is more allied to *P. (P.) gollevillensis* than to *P. (P.) excelsus*, but some of its umbilical ribs extend to the ventrolateral ones, and also some of the ventral ribs extend downward, thus forming a prosiradiate orientation, without such a flexuosity as in the latter. The holotype of *P. (P.) subcompressus*, which has an incomplete body-chamber, is about 150 mm in diameter, but there are much larger paratypes. For example, UMUT. MM6825, from loc. N457 e7, Bed Rdy1, is still septate at 105 mm in whorl-height. The whorl of the late growth-stage has more numerous and less distant umbilical ribs than the inner whorl, although the ribs are rather irregular in strength. Anyhow, the mode of ribbing is dissimilar from that of the present species. The umbilicus is somewhat wider in *P. (P.) subcompressus* than in *P. (P.) excelsus* at corresponding shell diameters.

From the above observations, it could be possible to treat *P. (P.) subcompressus* as a geographical subspecies of *P. (P.) gollevillensis*, but the present species [*P. (P.) excelsus*] is evidently distinct from them.

Occurrence.—According to the reliable information of Dr. SHIMOGAWARA, the described specimen (holotype) was collected at a point (marked by a solid circle in Text-fig. 3) in the middle reaches of the Sanushube, a tributary of the River Hobetsu, from a bed of sandy siltstone in the lower part of the Hakobuchi Group, about 50 m above its base. It is, accordingly, from the middle part of the Campanian. The locality is within a tectonic klippe of an overthrust sheet, which was called the Sanushube Nappe by the late Dr. K. OTATUME (1941). The record of *Pachydiscus*, together with the fineness of the host rock, seems to be in harmony with OTATUME's interpretation that the Sanushube Nappe may have been tectonically brought from the east, if not for a long distance. In every member of the Hakobuchi Group the offshore facies gradually becomes predominant to the southeast.

Pachydiscus (Pachydiscus) flexuosus MATSUMOTO, n. sp.

Pl. 9, Figs. 1-3; Pl. 10, Fig. 4; Pl. 12, Fig. 1; Text-fig. 4

Material.—Holotype, GK. H5877, from loc. Kd 525, about 2250 m northwest of Utsunai, unit D2, Tombetsu Valley, northern Hokkaido, found by H. KIDO of JPE and donated to Kyushu University through T. MATSUMOTO.

Paratypes, GK. H5879, from loc. P238 (Pinneshiri quadrangle) obtained by Y. IGI of GSJ and donated to Kyushu University through T. MATSUMOTO; GK. H5897, from loc. K57 (coll. T. MATSUMOTO), all in the Tombetsu Valley.

Some of the specimens (e.g. MATSUMOTO, 1954, pl. 12 [28], fig. 1) which were described under *P. subcompressus* is transferred to this species.

Some other atypical specimens which are mentioned in Remarks (e.g. GK. H5882 and GH. 9460) are also to be included here.

Diagnosis.—Shell fairly large, with fairly narrow umbilicus. Whorls higher than broad, suboval in section, broadest at some distance below the mid-flank,

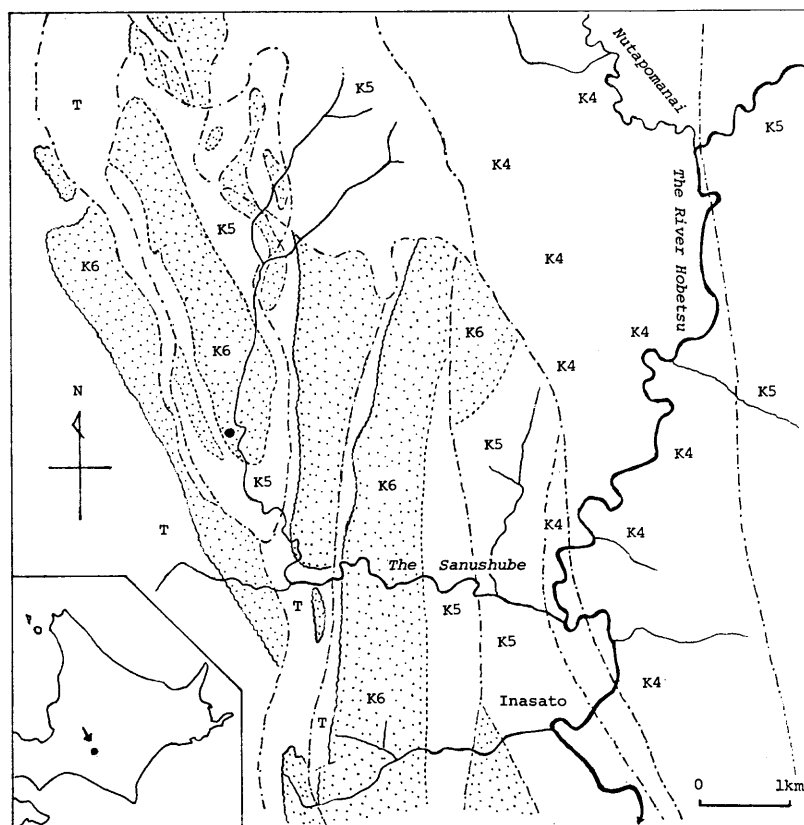


Fig. 3. Geological outline map of the Hobetsu Valley (Naka-Hobetsu area), showing the type-locality of *Pachydiscus (Pachydiscus) excelsus* MATSUMOTO, n. sp. with a solid circle. K4: Cenomanian and Turonian (Middle Yezo Group), K5: Coniacian and Santonian (Upper Yezo Group), K6: Campanian and Maastrichtian (Hakobuchi Group) (dotted), T: Palaeogene (Poronai Group). [Adapted from OTATUME 1941 and Geol. Surv. Hokkaido Colliery & Steamship Co.] (eastern half much modified by T. MATSUMOTO)

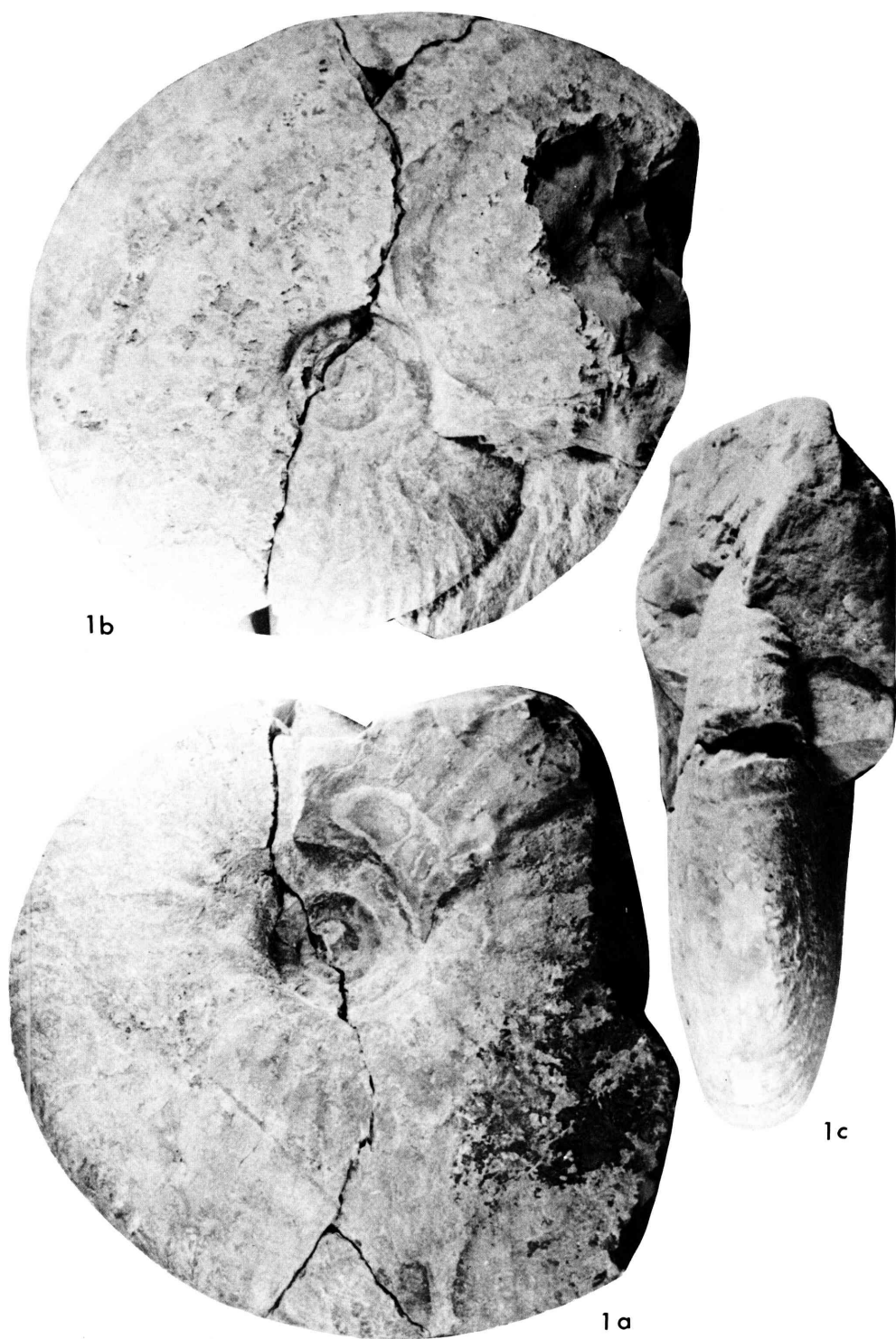
having moderately arched venter, gently convex flanks, subangular to subrounded umbilical shoulders and nearly vertical umbilical walls.

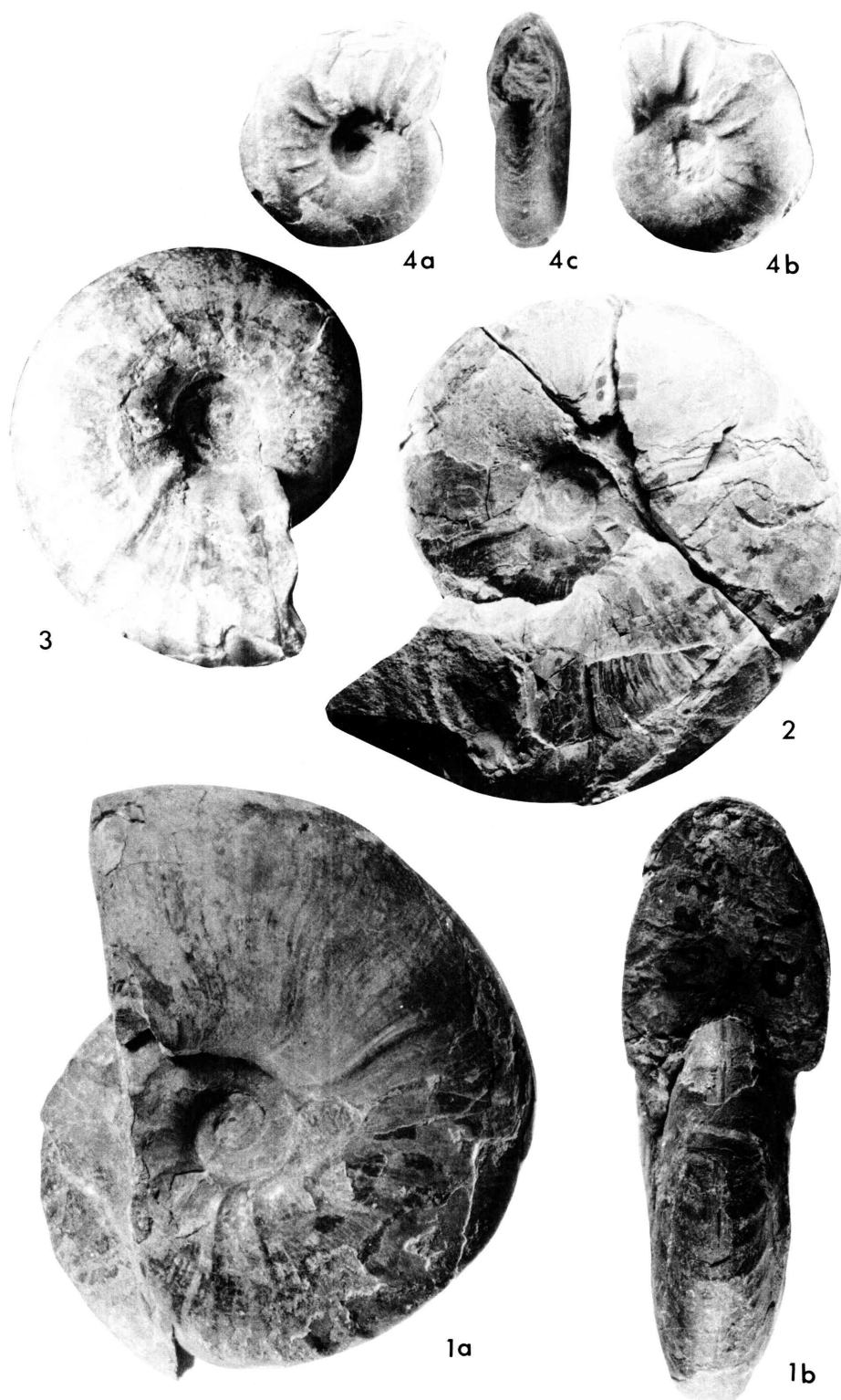
Ribs rather weak and narrow, but variable and often irregular in strength, length and distance, becoming very faint on some parts where lirae are discernible.

Explanation of Plate 8

Fig. 1. *Pachydiscus (Pachydiscus) excelsus* MATSUMOTO, n. sp.Page 50
Holotype, GK. H5895, from the Sanushube, Unit IVa, lower part of Hakobuchi Group, Hobetsu Valley (coll. H. SHIMOGAWARA).
Right (a) and left (b) lateral and frontal (c) views, much reduced, about $\times 9/25$ (≈ 0.36)

Kyushu University (K. TANABE) photos, without whitening.





The costae and the lirae rursiradiate around the umbilical margin, forming a gentle sinus above the umbilical shoulder, gently flexuous on the main part of the flank and moderately projected on the ventrolateral part, crossing the siphonal zone almost vertically.

Umbilical ribs occur at moderate interval in the typical form and elevated above (i.e. immediately outside) the shoulder to form a bulla. Some of them are stronger and longer than others and continue to the ventrolateral ribs; others are weak and almost disappear at variable distance from the umbilical margin.

In a more or less limited part of the middle growth-stage the ventrolateral ribs are typically distinct but not very strong, being separated regularly by broader interspaces. They cross the siphonal zone with some weakening. Some of them extend inward so as to be intercalated between the longer ones. They are 1.5 to twice as numerous as the umbilical ribs.

On the whorl of the stage earlier than the above mentioned, the bullate umbilical ribs alone are developed, without ventrolateral ones. On the flank of the later part of the whorl and the body-whorl, weak ribs occur at irregular interval, without notable umbilical bulla, and the ventrolateral ribs are much weakened or almost imperceptible, whereas gently sigmoidal lirae are characteristic. At this stage a very shallow but broad constriction or constriction like depression occurs, although very infrequently (only one per whorl).

Sutures deeply and finely incised, leaving very narrow stems of the elements as in *P. (P.) gollevillensis*.

Remarks.—The above diagnosis is based primarily on the holotype, other specimens from the type-locality and also GK. H5879 and GK. H5897 from other localities which are referable to the same stratigraphic unit as the holotype.

The holotype is about 130 mm in diameter at the end of the septate shell. Its body-chamber, slightly over a half whorl, is secondarily compressed and the shell is about 200 mm in diameter at its preserved end.

The stage at which the umbilical and the ventrolateral ribs are both clearly developed terminates at the diameter of about 85 mm in the holotype but at that

Explanation of Plate 9

Figs. 1–3. *Pachydiscus (Pachydiscus) flexuosus* MATSUMOTO, n. sp. . . . Page 53

1. Septate shell of holotype, GK. H5877, from loc. Kd525, Unit D2, Tombetsu Valley (coll. H. KIDO).

Lateral (a) and frontal (b) views, $\times 3/4$ ($=0.75$)

2. Entire shell of holotype, with somewhat deformed body-chamber, GK. H5877. Left lateral view, $\times 2/5$ ($=0.4$)

4. Paratype, GK. H5879, immature shell, from loc. P. 238, Unit D [=H3 of GSJ.], Tombetsu Valley (coll. S. IGI).

Right lateral view, $\times 5/6$. (see also Pl. 12, fig. 1.)

Fig. 4. *Pachydiscus (Pachydiscus) aff. flexuosus* MATSUMOTO, n. sp. . . . Page 59

GK. H5880, small probably immature shell, from loc. IA-215, Unit D, Tombetsu Valley (coll. A. INOMA).

Left (a) and right (b) lateral and frontal (c) views, $\times 1.2$.

The preserved last part (body-chamber) is somewhat deformed.

Kyushu University (K. TANABE) photos, without whitening.

of 120 mm in GK. H5879. It persists for about a half whorl or slightly more in the former but for a full whorl in the latter. In both specimens the shell is nearly smooth up to the diameter of 40 mm.

Besides the typical form there is an atypical form in which ribs are still more weakened and occur irregularly. It is represented by GK. H5882, from loc. Kt 296 of a higher stratigraphic unit. In this specimen, which is somewhat secondarily flattened, the ribs are weaker and more numerous than in the holotype and the umbilical bullae are very faint. Its umbilicus is narrower (16% of diameter as compared with 22% in the holotype), but this may be an effect of the secondary compression of the whorl. Even in some specimens from the type-locality, e.g. GK. 5878, there is a tendency towards weakening ribs, showing, thus, a transitional feature. Therefore, this kind of atypical form is provisionally included in the present species as an extreme variety.

UMUT. MM6998 [=GT. I-2830], in an old collection of the University of Tokyo, from "Tenmaku-zawa, Onnenai" (where the *Pachydiscus* bearing formation is probably extended southward from the area of the Tombetsu Valley), has also occasionally appearing [i.e. irregularly remaining] weak ribs (umbilical bullae and their extensions) which show a gently flexuous curvature. Unlike the weakly ribbed variety of *P. (P.) subcompressus* MATSUMOTO (as represented by UMUT. MM6830 [=GT. I-2827] from the Naibuchi area, South Saghalien), it has no perceptible ventrolateral ribs on the inner whorl, except for the corresponding lirae. It has also a slightly narrower umbilicus (19–20% of diameter at D.=75–83 mm) than the typical form.

Incidentally, the subspecies *P. (P.) subcompressus obsoletus* MATSUMOTO, 1954, with the holotype UMUT. MM6830 mentioned above, is inadequate, because it occurs in the same member (Rdy) of the same area as the typical form *P. (P.) subcompressus* (s. str.) (with the holotype UMUT. MM6821 [=GT. I-2815]). It should be called a weakly ribbed variety of *P. (P.) subcompressus*. Similarly the atypical form remarked here should be called a weakly ribbed variety of *P. (P.) flexuosus*, unless it had proved to occur always in a higher stratigraphic unit than the typical form.

GH. No. 9460, without reliable locality record, which I previously illustrated under *P. subcompressus obsoletus* MATSUMOTO (1954, pl. 27 [11], fig. 1), is a good example of the weakly ribbed variety of *P. (P.) flexuosus*, because it has gently flexuous weak ribs remaining on some parts and because it has no perceptible ventrolateral ribs. Its umbilicus is fairly narrow, showing the same percentage (22–23%) as that of the holotype of *P. (P.) flexuosus*. Sutures are well exposed on this specimen.

Another specimen of GH (Hokkaido University), again without reliable locality record, but "Kitami province", that probably means the area of the Tombetsu Valley, was previously described under *P. subcompressus* MATSUMOTO (1954, pl. 28 [12], fig. 1), but is here transferred to *P. (P.) flexuosus*, because of its gently flexuous ribs and the absence of distinct ventrolateral ribs.

Measurements (in mm).—

Specimen	Diameter	Umbilicus	Height	Breadth	B./H.
GK. H5877 (septate part)	118.0(1)	25.6(.22)	55.4	44.0	.72
" (—170°)	81.0	19.0(.23)	39.0	28.0	.72
GK. H5879 (inner wh.)	73.7	16.4(.22)	34.5	25.3	.73
TM. 1954, pl. 12, fig. 1	152.5	36.3(.23)	67.6	~50.3	.73
GH. No. 9460 (—180°)	129.5	29.0(.22)	58.5	39.5	.67
" (—360°)	86.7	20.2(.23)	40.8	29.2	.71
CT. I-2830 (inner wh.)	74.7	14.5(.19)	37.2	25.5	.68
GK. H5882	92.4	15.0(.16)	55.0	27.7	.5 ^(sec. compr.)

Comparison.—This species resembles *P. (P.) gollevillensis* and *P. (P.) excelsus* (established above) in its high-whorled shell, but the proportion of B./H. on an average is not so small as in the latter two. It is, however, more compressed and has a more narrowly arched venter than *P. (P.) egertoni* (FORBES, 1846) (see also STOLICZKA, 1865; KOSSMAT, 1898).

One of its most diagnostic characters is the gentle flexuosity of its ribs and lirae. Also in this species, *Pachydiscus* ornament, consisting of the distant bullae around the umbilicus and numerous, short ventrolateral ribs, occurs only in a limited part of the middle growth stage and the umbilical ribs are elongated and frequently extended on to the ventrolateral part. In these respects this species is distinct from *P. (P.) subcompressus* MATSUMOTO, 1954. In the typical examples (holotype, UMUT. MM6821 [=GT. I-2815], here re-illustrated in Fig. 5, and other specimens from the same formation, i.e. Rdy1 of MATSUMOTO, 1942) of *P. (P.) subcompressus* the ribs and lirae are nearly stratightly prorsiradiate with little or no flexuosity on the main part of the flank and the ornament consisting of distant umbilical bullae and numerous ventrolateral ribs persists for a much longer period of growth. On these criteria some of the specimens other than the holotype and closely related ones should be transferred to *P. (P.) flexuosus*. Likewise, an example from Penzhina (Far East USSR), illustrated by VERECHAGIN et al. (1965, pl. 67, fig. 1) under *P. aff. gollevillensis*, may be referred to *P. (P.) flexuosus*, although I defer the final conclusion until I look at the actual specimen.

P. (P.) flexuosus is somewhat similar to *P. (P.) kamishakensis* JONES, 1963 in the general aspects of shell-form and rather weak ribbing, but has on the average a narrower umbilicus, a smaller proportion of breadth to height (B./H.) and more distinctly flexuous ribs and lirae. The differentiation of the umbilical and ventrolateral ribs are less distinct in the latter. The latter is an index of a zone in the upper part of Member 3 of the Matanuska Formation of southern Alaska, which is referred to the uppermost Campanian or near the Campanian-Maastrichtian boundary (JONES, 1963).

Joaquinites fascicostatus ANDERSON, 1958, from the probable correlatives of the Maastrichtian and the uppermost Campanian of California, was once (MATSUMOTO, 1959b, p. 46) considered as possibly identical with *P. (P.) subcompressus obsoletus*. Its flexuous ribs starting from the umbilical margin are somewhat similar to those of *P. (P.) flexuosus*, but no ventrolateral ribs are recorded and the fasciculate mode of ribbing is emphasized by ANDERSON for that species.

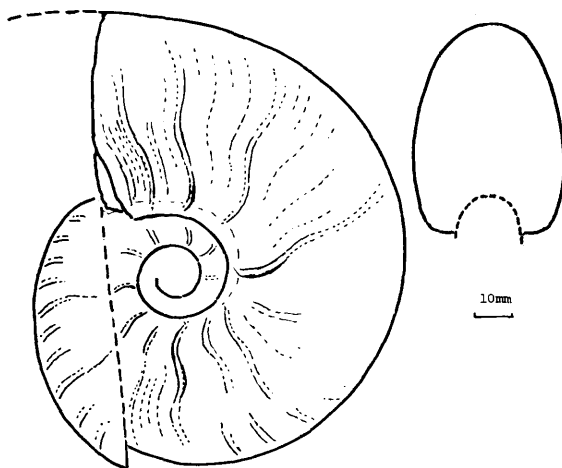


Fig. 4. *Pachydiscus (Pachydiscus) flexuosus* MATSUMOTO n. sp.
Diagrammatic sketch of the lateral view and whorl-section
of the holotype, GK, H5877 (living chamber excluded).
(T.M. delin.)

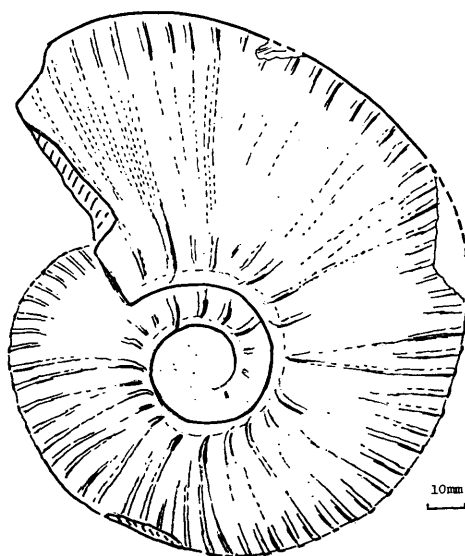


Fig. 5. *Pachydiscus (Pachydiscus) subcompressus* [MATSUMOTO.
Diagrammatic sketch of the lateral view of the holotype,
UMUT. MM6821. (T.M. delin.)

Although the similarity between it and the weakly ribbed variety of *P. (P.) flexuosus* is noted, I hesitate to conclude the identity. More careful study is needed for that California species.

The appearance of a shallow and broad constriction on the outer whorl, although infrequent, is unusual for *Pachydiscus* (s.s.). This can be reckoned as one of the characteristics of *P. (P.) flexuosus*, since it is shown by all the three specimens from the type-locality.

Occurrence.—The holotype and other typical examples are from Unit D2 of JPE., i.e. Member H3b of GSJ, in the Upper Cretaceous sequences of the Tombetsu Valley, northern Hokkaido. This unit is made up of claystone and assigned to the Zone of *Inoceramus hetonaianus*, i.e. the upper substage of K6b. An example of the weakly ribbed variety is from Unit E2 of JPE., the highest ammonite bearing bed in the sequence of the Tombetsu Valley. Other examples of the same variety are not precisely allocated stratigraphically, although some of them are presumably Unit D2.

It should be noted that *P. (P.) flexuosus* occur in finer and probably more off-shore sediments (claystone) than *P. (P.) subcompressus* (in fine-sandy siltstone).

Pachydiscus (Pachydiscus) aff. flexuosus MATSUMOTO

Pl. 9, Fig. 4

Material.—GK. H5880, from loc. IA-215, obtained by A. INOMA and donated to Kyushu University through T. MATSUMOTO.

Descriptive remarks.—This is a small, probably immature specimen, but the last 60° is a crushed living chamber. The undeformed septate part is measured as follows: Diam.=26.6 (1), Umb.=7.0 (.26), Height=12.2, Breadth=10.3, B./H.=.84. Thus, the shell is somewhat less compressed and less narrowly umbilicate than the inner whorl of *P. (P.) flexuosus* described above. The whorl-section is subelliptical, having a moderately arched venter and gently convex flanks. The maximum breadth is at about the mid-flank, and not in the lower part unlike that of *P. (P.) flexuosus*.

At first the shell is nearly smooth; at the stage of 22 mm in diameter onward occur the umbilical ribs, which are moderately strong but disappear on the flank before they reach the ventrolateral part. They are rursiradiate around the umbilicus, bent forward at about the umbilical shoulder, where they form a bulla. On the main part of the flank some of them are nearly rectiradiate and some others show a gentle convexity. The growth-lines on the venter are slightly projected. Accordingly a gently sigmoidal curvature may be followed by tracing the ribs and the growth-lines. The ventral ribs begin to appear at the stage of about 30 mm in diameter.

In this specimen, thus, the ribs begin to appear earlier and more distinctly than in the typical examples of *P. (P.) flexuosus*. The tendency towards a flexuous curvature shown by some ribs and also the compressed whorl suggest an affinity with *P. (P.) flexuosus*.

This specimen differs from any immature specimen of the hitherto known species, such as *Pachydiscus ganesa* (FORBES) (see KOSSMAT, 1898, pl. 21 [15], fig. 2), *P. suciaensis* (MEEK) (see USHER, 1952, pl. 9, figs. 1–8), *P. jacquoti* SEUNES (see SEUNES, 1890, pl. 2, fig. 3) and *P. hazzardi* JONES (1963, pl. 16, figs. 1–6), in its more compressed whorl and radial ribs which tend to be flexuous.

I presume that the present specimen could represent a new species of *Pachydiscus*, which is allied to but distinct from *P. (P.) flexuosus*. Until the characters of the later growth-stages be known, I provisionally call it *P. (P.) aff. flexuosus*.

without proposing a new specific name.

Occurrence.—Loc. IA-215, a floated calcareous nodule in the upper reaches of the stream called the Junanasen-zawa, a tributary of the River Tombetsu. It is probably derived from Unit D, and accordingly its age is not much different from that of typical examples of *P. (P.) flexuosus*.

Subgenus *Neodesmoceras* MATSUMOTO, 1947

Remarks.—This was represented in Hokkaido by *P. (N.) japonicus* MATSUMOTO, 1947 (MATSUMOTO and SAITO, 1954). Its well preserved holotype and paratypes were from Member IVb (Lower Sandy Siltstone) of the Hakobuchi Group in the Hobetsu-Hetonai area. There were some more specimens of incomplete preservations from Members IVb and also IVd (Upper Sandy Siltstone). Accordingly *N. (P.) japonicus* was recorded as occurring in both the Zone of *Inoceramus shikotanensis* (K6b1) and that of *Inoceramus hetonaianus* (K6b2) (see MATSUMOTO, 1959a, p. 76).

This was, however, incorrect. In the subsequent collections, examples of *P. (N.) japonicus* are only from K6b1, of which the most excellent is the large specimen in the private collection of Mrs. Keiko NIHONGI at Chitose, obtained from IVb in the Sososhi-zawa, a tributary of the River Hobetsu. Well preserved specimens from Members IVc and IVd of K6b2 represent another species described below.

Pachydiscus (Neodesmoceras) gracilis MATSUMOTO, n. sp.

Pl. 10, Figs. 1–3; Pl. 11, Fig. 1; Pl. 12, Fig. 2; Text-fig. 6

Material.—Holotype, GK. H5885, from loc. H311a, Kiusu, Hobetsu area, Member IVc5 (upper part of the Fukaushi Formation), Hakobuchi Group (coll. T. MATSUMOTO).

Paratypes, GK. H5846, H5887 and H5888, from loc. H311a, GK. H5889, from loc. H336b; GK. H5896 and H5898, from loc. H335; all of these in member IVc5

Explanation of Plate 10

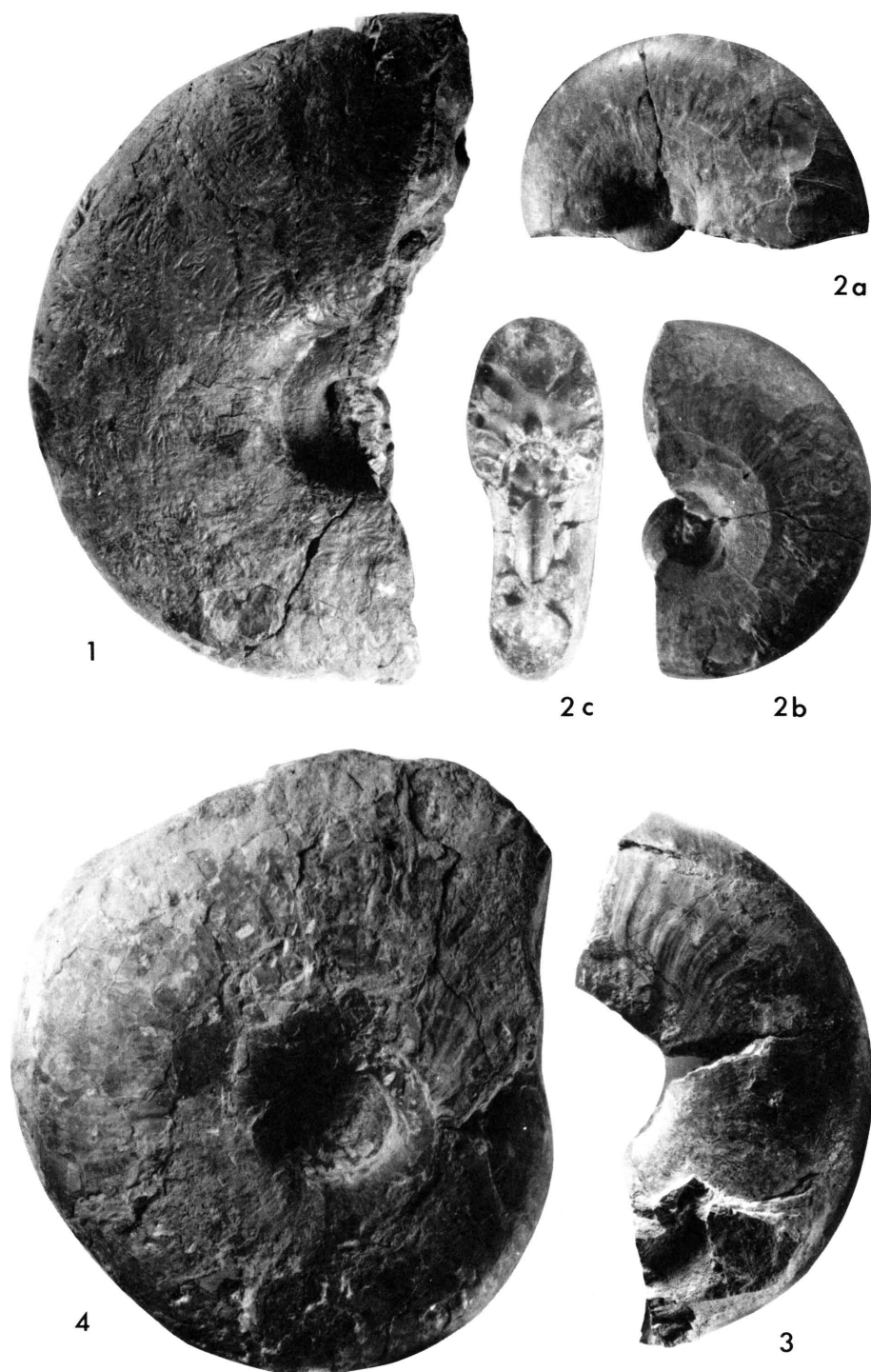
Figs. 1–3. *Pachydiscus (Neodesmoceras) gracilis* MATSUMOTO, n. sp. . . Page 60

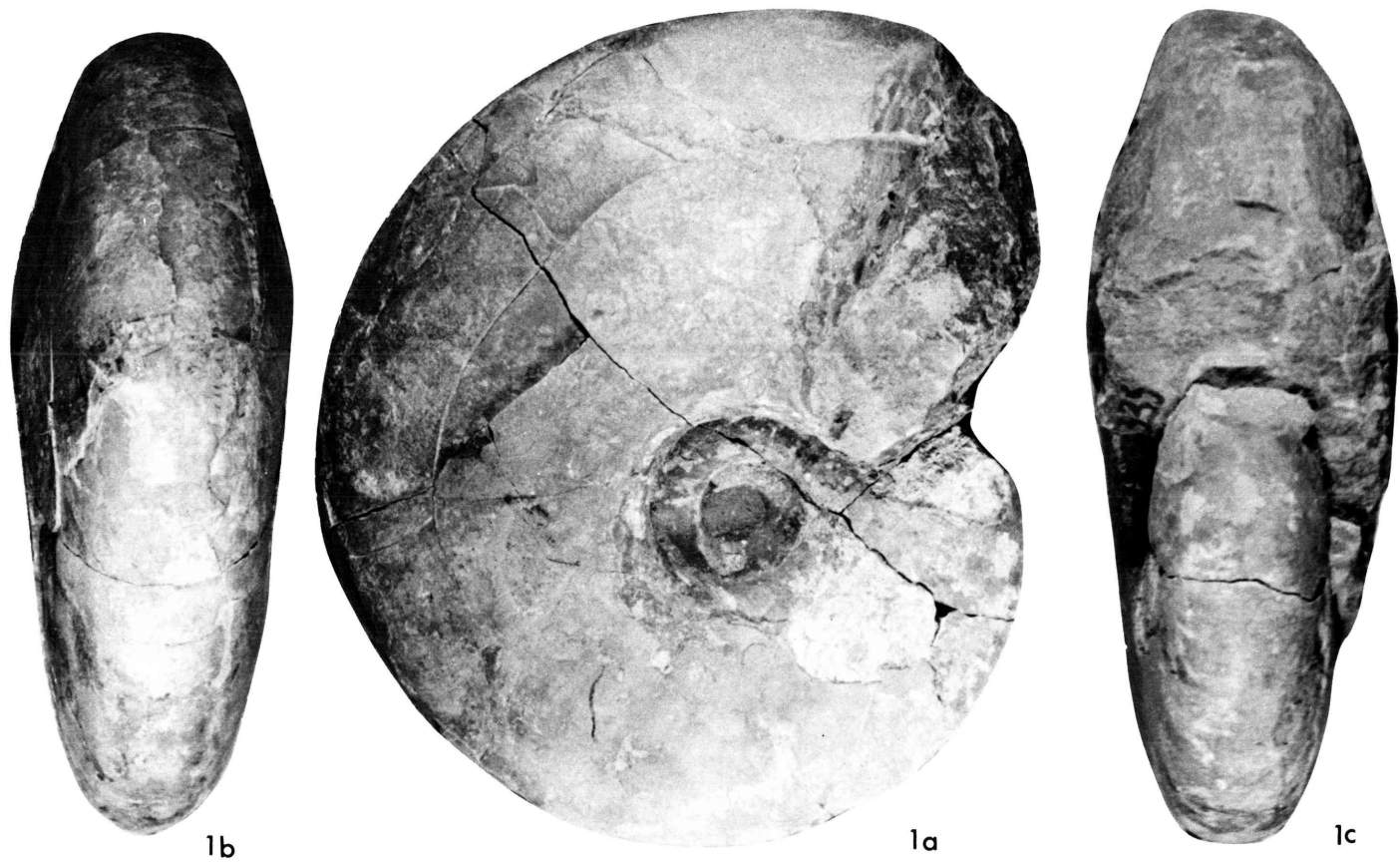
1. Holotype, GK. H5885, from loc. H311a, Kiusu, Unit IVc5, Hakobuchi Group, Hobetsu Valley (coll. T. MATSUMOTO). Lateral view, $\times 0.65$. (See also Pl. 12, Fig. 2)
2. Paratype, GK. H5881, from loc. P220, Unit D (=H3b of GSJ.), Tombetsu Valley (coll. S. IGI). Left (a) and right (b) lateral views and natural section (c) of immature shell, about $\times 1.3$.
3. GK. H5881, part of next outer whorl of the same individual as Fig. 2. Right lateral view, $\times 1.1$ (slightly enlarged). Note reminiscent ribs and lirae on a part of the whorl.

Fig. 4. *Pachydiscus (Pachydiscus) flexuosus* MATSUMOTO, n. sp. Page 53

GK. H5882, representing a weakly ornamented variety, from loc. Kt 296, Unit E2, Tombetsu Valley (coll. S. KATO). Left lateral view, $\times 0.9$.

Kyushu University (K. TANABE) photos, without whitening.





of the Hobetsu area (coll. T. MATSUMOTO). Also GK. H5881 from loc. P-220, Unit D [=Member H3b] (coll. Y. IGI) and GK. H5883, from loc. IA-149, Heitaro-zawa, Unit D (coll. A. INOMA), Tombetsu Valley.

Diagnosis.—Shell large, with a fairly narrow umbilicus. Whorls higher than broad, compressed subelliptical to suboval in section, broadest in the lower part, especially remarkably so at late growth-stage, with gently convex flanks, more or less narrowly arched venter, subrounded or subangular umbilical shoulders and steep to nearly vertical umbilical walls. The large outer whorl, as represented by the late part of GK. H5885 (holotype) and by GK. H5896, is more inflated on the lower part of the flank at some distance from the umbilical shoulder, with trigonally suboval section. It has nearly vertical umbilical walls.

Shell almost smooth, but for faint, reduced ribs which may remain on a limited part of the whorl and numerous lirae which are discernible on the surface of its outer layer. These ribs and lirae are rursiradiate around the umbilicus and very gently flexiradiate on the main part of the flank, forming a sinus at a short distance from the umbilical shoulder, and gently or moderately projected on the ventrolateral part. The umbilical bullae and the ventrolateral short ribs are absent or imperceptible.

Sutures are deeply and finely incised as in *P. (P.) gollevillensis*.

Remarks.—Aside from the very early stage, the inner whorl is compressed and narrowly subelliptical in section. The outer whorl has more inflated flanks and a subtrigonally oval section, as shown by the large example, GK. H5896. The holotype seems to show a gradual change with growth, although its body-chamber was destroyed away.

The lirae show a more gentle projection on the ventrolateral part and accordingly weaker sigmoidality on the flank in the Hobetsu specimens than in the two Tombetsu specimens. The latter has a slightly larger proportion of B./H. at the corresponding size.

Measurements (in mm).—

Specimen	Diameter	Umbilicus	Height	Breadth	B./H.
GK. H5885	147.0	32.0(.22)	68.0	49.0	.72
" (−180°)	102.0	19.8(.19)	49.0	33.0	.67
GK. H5896	272.0	54.5(.20)	130.0	95.0	.76
GK. H5886	100.0	21.0(.21)	45.5	31.6	.69
GK. H5881	65.3	14.4(.22)	~32.5	23.4	.72
" (−270°)	38.6	8.4(.22)	18.6	14.2	.76

Comparison.—This species resembles *P. (N.) japonicus* MATSUMOTO (1947; see also MATSUMOTO and SAITO, 1954), from the Lower Sandy Siltstone (Member

Explanation of Plate 11

Fig. 1. *Pachydiscus (Neodesmoceras) gracilis* MATSUMOTO, n. sp.Page 60
Paratype, GK. H5896, from loc. H335, Kiusu, Unit IVc5, Hakobuchi
Group, Hobetsu Valley (coll. T. MATSUMOTO). Left lateral (a), back (b)
and frontal (c) views, $\times 0.45$ [=9/20].

Kyushu University (K. TANABE) photos, without whitening.

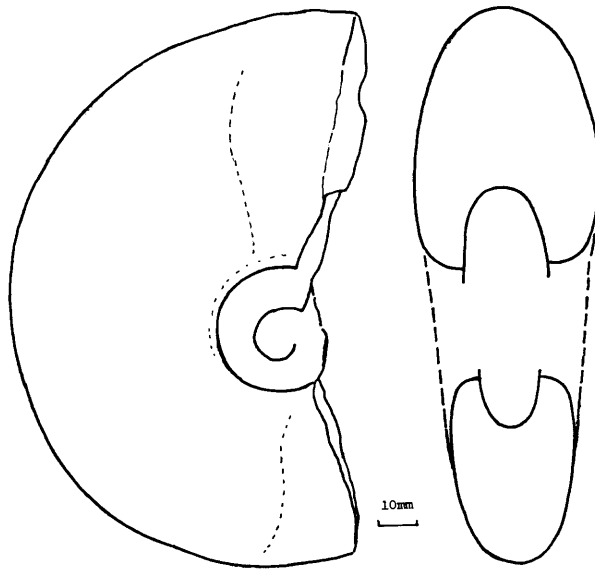


Fig. 6. *Pachydiscus (Neodemoceras) gracilis* MATSUMOTO n. sp.
Diagrammatic sketch of the septate part of the holotype,
GK, H5885. Lateral view and whorl-section. (T.M. delin.)

IVb) of the Hobetsu-Hetonai [now called Tomiuchi] area, in the shell-form of the inner whorl and the reduced ornament. The distinction is in that the outer whorl is trigonally suboval in the former but subelliptical and somewhat broader and more inflated in the latter. The remnant subcostae are more numerous and show stronger ventral projection in the latter (see MATSUMOTO and SAITO, 1954, pl. 10 fig. 1b).

P. (N.) gracilis is similar to *P. (N.) obsoletiformis* JONES (1963), from the Zone of *Pachydiscus kamishakensis* of southern Alaska, but that Alaskan species has a wider umbilicus ($U./D.=0.24-0.28$) and more flattened flank. The curvature of the subcostae or growth-lines is described as "slightly flexiradiate" in the JONES' species, but as it is not well shown in his illustration, the precise comparison is difficult, although I expect some difference. The stem of the first lateral saddle is much narrower in the present species than in that Alaskan species.

The close affinity of *P. (N.) gracilis* with *P. (P.) flexuosus* is suggested by the two specimens (GK. H5879 and H5881) by the same curvature of the lirae, as well as the similarity in shell form. It might be questioned whether or not the Tombetsu specimens are of identical species with the Hetonai specimens, the latter of which include the holotype. The difference is, in my opinion, too little to separate the two subgroups as distinct species. It is noted that the specimens from Tombetsu occur in more fine-grained sediment than those from Hobetsu. More specimens from the former area, especially the larger ones, are needed to lead a reasonable and natural conclusion.

Some examples of the present species were incorrectly called *P. (P.) subcompressus obsoletus* MATSUMOTO. The holotype of *P. subcompressus obsoletus*, GT.

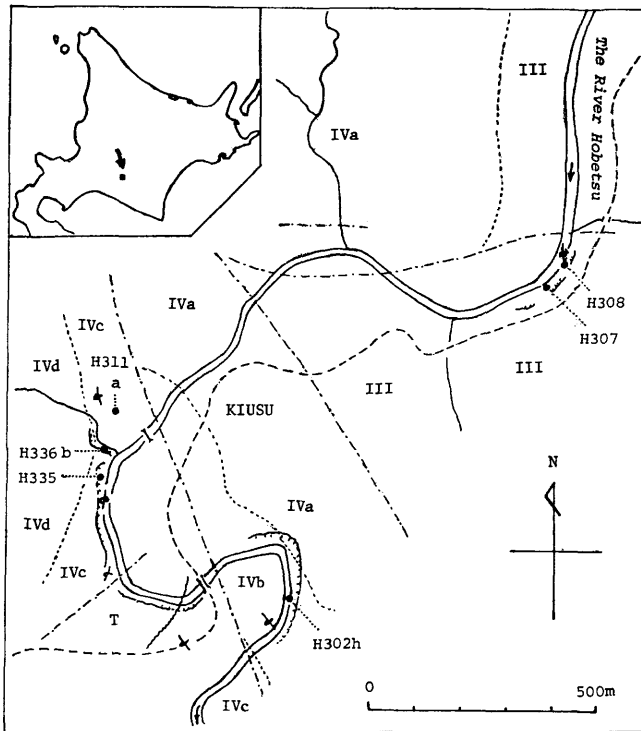


Fig. 7. Map showing ammonite localities (solid circle) near Kiusu of the Hobetsu Valley. III: Upper Yezo Group (mainly Santonian), IV: Hakobuchi Group (Campanian and Maastrichtian), IVa: Lower Hakobuchi, IVb: Lower Sandy Siltstone (Zone of *Inoceramus shikotanensis*), IVc: Fukaushi Sandstone (Zone of *Inoceramus hetonaianus*), IVd: Upper Sandy Siltstone, T. Palaeogene. Chain: fault, broken line: highway.

I-2827 [=UMUT. MM6830], has numerous ventrolateral ribs and reduced umbilical bullae and can well be connected with the typical form of *P. (P.) subcompressus*. As it occurs in the same member (Rdy of the Ryugase Group, MATSUMOTO, 1942) of the same province (i.e. Naibuchi area of South Sakhalin), the subspecific name is unnecessary. It is a weakly ribbed variety of *P. (P.) subcompressus*.

The specimen, GH. No. 9460, from an uncertain locality, illustrated by MATSUMOTO (1954, pl. 11 [27], fig. 1) under *P. subcompressus obsoletus*, is better transferred to *P. (N.) gracilis*, although a few gently flexuous, faint ribs remain on limited portions of the whorl. Its shell-form is quite similar to that of the holotype of *P. (N.) gracilis*. The gentle flexuosity of the reduced ribs in this specimen is rather similar to that shown in the Tombetsu specimen mentioned above.

Occurrence.—The holotype and 6 other specimens were obtained from the same bed of silty fine sandstone (or in part fine sandy siltstone), exposed at locs. H311a, H335, and H336b, of Member IVc5, upper part of the Fukaushi Formation

of the Hakobuchi Group in the Hobetsu area (see Fig. 7). *Inoceramus* (*Sphenoceras* ?) *hetonaianus* MATSUMOTO occurs in the same member and other parts of the Fukaushi Formation (IVc). Unit IVc and the overlying IVd (Upper Sandy Siltstone) represent Substage K6b2 (upper part of Upper Hetonaian).

Other two specimens came from Unit D of JPE, i.e. Member H3b of GSJ, in the Tombetsu Valley. This is also within K6b2, but whether it is exactly of the same stratigraphic level as IVc5 of the sequence in the Hobetsu area or somewhat older or younger is hardly determined, because the two areas are separated for about 200 km.

Part II

A New Species of *Pachydiscus* from the Urakawa Area

(Tatsuro MATSUMOTO and Yasumitsu KANIE)

Pachydiscus (*Pachydiscus*) *hidakaensis*

MATSUMOTO and KANIE, n. sp.

Pl. 13, Fig. 1; Text-fig. 8

Material.—Holotype, YCM. Ur133001, from loc. U133, Unit H2, Shiroizumi, Urakawa, District of Hidaka, southern central Hokkaido (coll. Y. KANIE).

Description.—The holotype is about 130 mm in diameter at the last septum and only a portion of the body-chamber remains. On the assumption that the body-chamber is about a half whorl, as suggested by the trace of the umbilical seam, the entire shell diameter would be about 200 mm. This is fairly large for the Ammonoidea in general (see definition of size adopted by MATSUMOTO, 1954, p. 246), but moderate for the Pachydiscidae.

Whorl is higher than broad, with the proportion of B./H. about 0.70 at the late stage and 0.75 at an earlier stage, subelliptical in section, slightly broader in the lower part, with a moderately arched venter, gently convex flanks, abruptly rounded umbilical shoulders and steep umbilical walls; umbilicus fairly narrow.

For about a whorl at the middle growth-stage, up to about 100 mm in diameter, the ribs are of moderate intensity, rursiradiate around the umbilicus and gently concave forward on the main part of the flank, with little or no flexuosity. They consist of longer and shorter ones; the longer ones are tuberculate or bullate at the umbilical shoulder and moderately distant, numbering 16 or so in a whorl; the shorter ones are as a rule alternated with the longer ones and extended for a variable length beyond the mid-flank toward the umbilicus; on the ventrolateral part all the ribs are rather narrow and of nearly equal intensity; they are weakened on crossing the venter.

On the whorl of the later growth stages, larger than 100 mm in diameter, the ribs are weakened, narrowed but more crowded, without umbilical bullae, rursiradiate around the umbilicus and prorsiradiate or gently concave on the main part of the flank. Consequently there is a sinus on the lower part of the flank but no or little flexuosity on the main part. Lirae may be associated with the ribs.

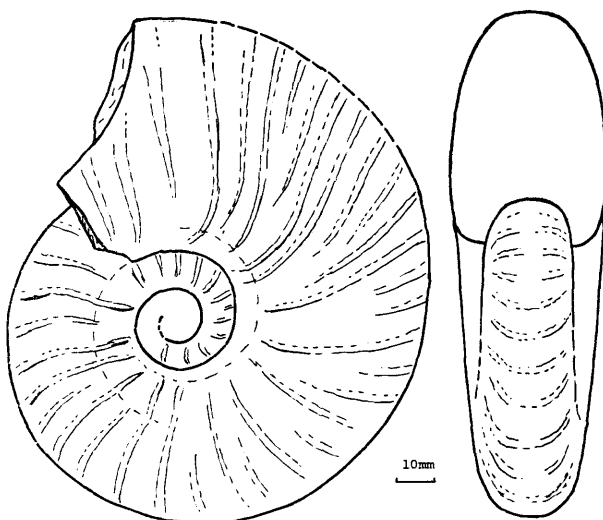


Fig. 8. *Pachydiscus* (*Pachydiscus*) *hidakaensis* MATSUMOTO and KANIE, n. sp. Diagrammatic sketch of the holotype, YCM. Ur133001, partly restored. Lateral and frontal views. (T.M. *delin.*)

Partly exposed suture is as finely and as deeply incised as in other species of *Pachydiscus* (s.s.).

Measurements (in mm).—

Position	Diameter	Umbilicus	Height	Breadth	B./H.
Preserved end	134.0	31.0(.23)	62.5	44.0	.70
—90°	112.0	24.0(.21)	53.0	38.5	.74

Comparison.—This species resembles *P. (P.) flexuosus* MATSUMOTO, n. sp. (described in Part 1) in its shell-form and weak and rather narrow ribs on the outer whorl, but is distinguished in the gently concave, instead of the gently sigmoidal, curvature of the ribs on the main part of the flank. The ribbing on the whorl of the middle growth-stage is coarser and more regular in this species and the shorter ribs are less numerous and longer than in that species. Although only a single specimen is available at present, it is certainly outside the observed variation of *P. (P.) flexuosus*, representing a distinct species.

The holotype of *P. hidakaensis* is somewhat similar to that of *P. (P.) crishna* (FORBES) (1846, p. 103, pl. 9, fig. 2), BM. C. 51041, in the whorl-section and concave curvature of ribs, but the former has a more rapidly growing whorl and a narrower umbilicus and the latter shows more distinctly the differentiation of numerous ventrolateral ribs and distant umbilical bullae.

This species is somewhat similar to "*Pachydiscus* cf. *jacquoti* SEUNES" of USHER (1952, p. 72, pl. 11, fig. 1–3), from the Nanaimo Group of Sucia-Island in its shell-form and distant ribbing of the middle growth-stage, but has a more compressed whorl and more curved ribs. The differentiation of the umbilical and the ventrolateral ribs is more distinct in *P. cf. jacquoti*, which could possibly be

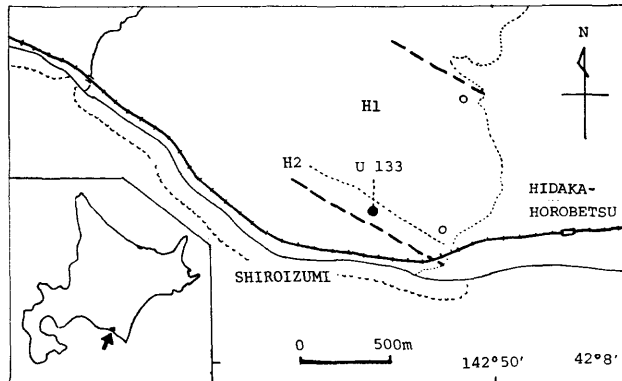


Fig. 9. Map showing fossil localities near Shiroizumi of the Ura-kawa area. Solid circle: *P. (P.) hidakaensis*, open circle: *Inoceramus (Endocostea) shikotanensis*; broken line: fault, dotted line: formational boundary.

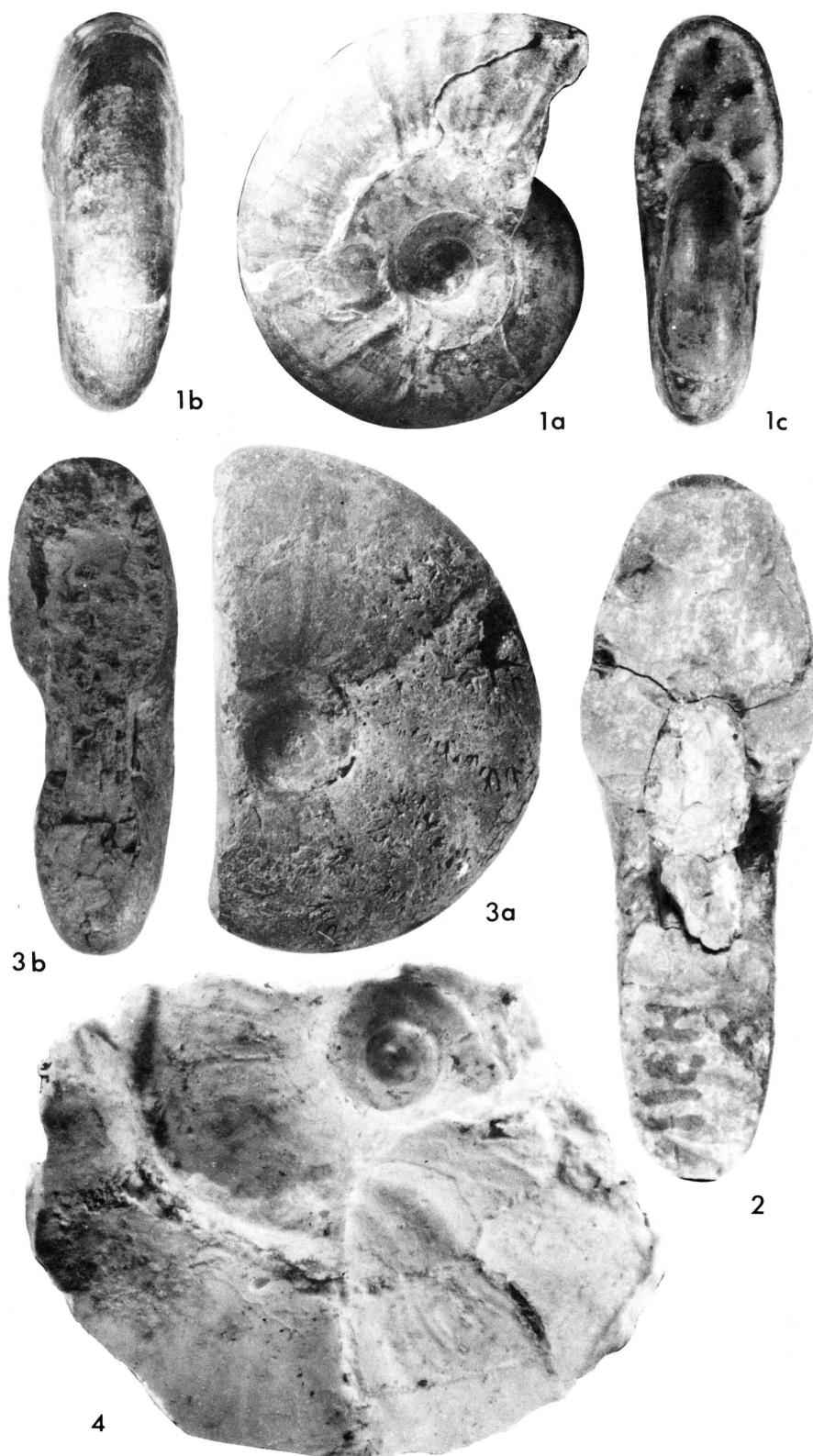
referred to *P. egertoni* (FORBES), as one of us (MATSUMOTO, 1959b, p. 42) has already mentioned.

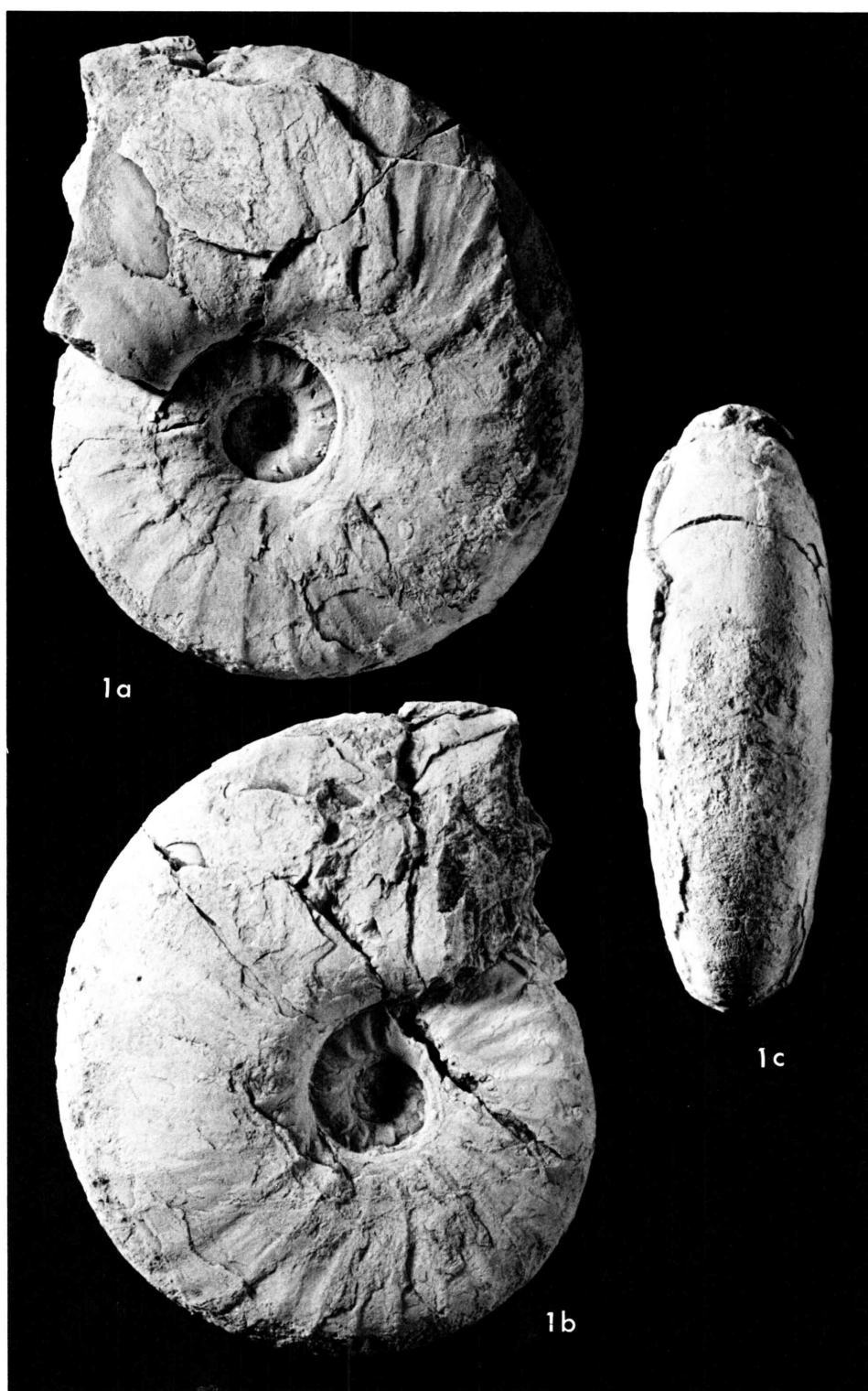
P. (P.) hidakaensis resembles *P. (P.) kamishakensis* JONES, from southern Alaska, especially in the shell-form and ribbing of the middle growth-stage (see JONES, 1963, p. 35, pl. 17, figs. 1-6), but the ribs in the former are less numerous and more remarkably projected on the ventrolateral part. At the succeeding growth-stage the ribs are more numerous, narrower and again more remarkably prorsiradiate in the former.

The described specimen was preliminarily listed by one of us (KANIE, 1966, p. 323) as *Pachydiscus* aff. *subcompressus*, but *P. (P.) subcompressus* shows more distinct differentiation of the umbilical and ventrolateral ribs, in which the latter are normally shorter and more numerous, with only occasional extension to the umbilical ones.

Explanation of Plate 12

- Fig. 1. *Pachydiscus (Pachydiscus) flexuosus* MATSUMOTO, n. sp.Page 53
Paratype, GK. H5879, immature shell, from loc. P238, Unit D2 [=H3b of GSJ.], Tombetsu Valley (coll. S. IGI).
Left lateral (a), back (b) and frontal (c) views, $\times 5/6$. (See also Pl. 9, Fig. 3.)
- Fig. 2. *Pachydiscus (Neodesmoceras) gracilis* MATSUMOTO, n. sp.Page 60
Holotype, GK. H5885, from loc. H311a, Kiusu, Unit IVc5, Hakobuchi Group, Hobetsu Valley (coll. T. MATSUMOTO).
Natural whorl-section, $\times 2/3$. (See also Pl. 10, Fig. 1.)
- Figs. 3-4. *Pachydiscus (Pachydiscus) flexuosus* MATSUMOTOPage 67
3. YU. C7623, from Esashito, Member At2, Nemuro Group, Hamanaka area (coll. S. YOSHIDA). Right lateral view (a) and natural section (b), $\times 1$.
 4. Rubber cast from the external mould of the same individual as Fig. 3, with additional outer whorl. Lateral view, $\times 0.9$.
Kyushu University (K. TANABE) photos, without whitening.





Occurrence.—Loc. U133, Shiroizumi, Urakawa area, silty sandstone of Unit H2, the observable uppermost member of the Cretaceous sequence of the Urakawa area, which was previously indicated as unit Ur7 (KANIE, 1966). The precise location is indicated in Fig. 9.

Part III

Two Species of *Pachydiscus* from the Nemuro-Hamanaka Area

(Tatsuro MATSUMOTO and Saburo YOSHIDA)

Pachydiscus (Pachydiscus) flexuosus MATSUMOTO

Pl. 12, Figs. 3–4

Material.—YU. No. C7623, from Esashito, east of Hamanaka, S. YOSHIDA Coll. 58080308.

Descriptive remarks.—The specimen consists of the internal mould of inner whorls and that of a part of the secondarily compressed living chamber. There is also an external mould on which the faint ribbing is well impressed. The shell would be about 160 mm or more in diameter, when the missing part is restored. This is not much different from the size of *P. (P.) flexuosus* from the Tombetsu area. Measurements of the inner whorl are as follows:

Diameter	Umbilicus	Height	Breadth	B./H.
76.5	17.0(.22)	25.0	24.5	.70

These are similar to those of the inner whorl of GK. H5879, a paratype of *P. (P.) flexuosus* described in Part I, although the whorl of the Esashito specimen is somewhat more compressed ($B/H=0.70$ as compared with 0.73 of GK. H5879). This minor difference can be regarded as being within the extent of variation.

Weak umbilical bullae are discernible at irregular intervals on the internal mould of the septate whorls and also on that of the living chamber. On the external mould they extend outward, showing a gently sigmoidal curvature on the flank. There are also numerous, faint subcostae or lirae on the intervals of the longer ribs. They show also a gentle flexuosity. The venter looks almost smooth, but weak ventral ribs of moderate distance are impressed on the external mould of the next inner (i.e. septate) whorl. They are somewhat projected on the ventro-lateral part. On the living chamber the ventral part is almost smooth.

The above ornamentation is essentially the same as that of *P. (P.) flexuosus*

Explanation of Plate 13

Fig. 1. *Pachydiscus (Pachydiscus) hidakaensis* MATSUMOTO and KANIE, n. sp.
.....Page 64
Holotype, YCM. Ur 133001, from loc. U133, Unit H2, Shiroizumi, Urakawa (coll. Y. KANIE). Right (a) and left lateral (b) and ventral (c) views, $\times 5/7$.

Yokosuka City Museum (Y. KANIE) photos, with whitening.

established in Part 1, but the umbilical bullae or ribs and the ventrolateral ribs are weaker and occur less frequently than in the typical form of that species. In this respect it is closer to the weakly ribbed variety of *P. (P.) flexuosus* as described in Part 1.

A shallow and broad constriction is developed on the living chamber. This is quite similar to that in the holotype and some other examples of *P. (P.) flexuosus*.

The suture is of typical pattern of *Pachydiscus*, showing deeply and finely incised elements and their narrowed stems.

To sum up, this specimen is identified with *P. (P.) flexuosus* MATSUMOTO, although it is an atypical, weakly ribbed variety of that species.

This specimen was preliminarily listed by NAGAO et al. (1966, p. 12) as *Pachydiscus subcompressus obsoletus* MATSUMOTO, because it looks similar to certain specimens (not holotype) figured under that name by MATSUMOTO (1954, pl. 27 [11], fig. 1), but those specimens have now turned to be examples of *P. (P.) flexuosus*, as has been mentioned in Part 1.

Occurrence.—The specimen was obtained from a locality at Esashito indicated as C in another paper (MATSUMOTO and YOSHIDA, 1979, text-fig. 1). It is on the eastern extension of Member At2 of NAGAO et al. (1966) (middle part of the Akkeshi Formation) at Ponporoto (locs. A and B) of the Hamanaka area, where *Gaudryceras hamanakense* MATSUMOTO and YOSHIDA, 1979 occurs commonly. The Member At2 is the highest ammonite bearing unit in the Cretaceous sequences of the Hamanaka area.

Pachydiscus (Neodesmoceras) cf. gracilis MATSUMOTO

Material.—GK. H5899 and GK. H5900, from loc. Nm 370 and GK. H5901, from loc. Nm 162 (Coll. T. MATSUMOTO).

Descriptive remarks.—GK. H5899 is an internal mould of a small septate shell and GK. H5900 is a fragmentary outer whorl, both embedded in a claystone (and not in calcareous nodules) and secondarily compressed. The former is about 48 mm in diameter and its umbilicus 8.8 mm (18%) is somewhat narrowed by secondary deformation but it is not much different from that of *P. (N.) gracilis*. It is rather smooth, without perceptible ribs, and shows deeply and finely incised sutures.

The latter, measuring about 42 mm in height, has gentle sigmoidal growth-lines and striae, showing a distinct sinus outside of the umbilical shoulder and another shallower one on the ventrolateral part; otherwise the surface is almost smooth. The curvature is quite similar to that of *P. (N.) gracilis*.

GK. H5901 is a fragmentary specimen in a calcareous nodule. It bears fine lirae or growth-lines, which show the same curvature as that of *P. (N.) gracilis*. At the same locality (loc. Nm 216), one of us (T. M.) saw during the field work a specimen embedded in a claystone, which is comparable with *P. (N.) gracilis*, but this was unfortunately crushed into pieces.

To sum up, these poorly preserved specimens are named provisionally as *Pachydiscus (Neodesmoceras) cf. gracilis* MATSUMOTO to stimulate further hunting for better specimens.

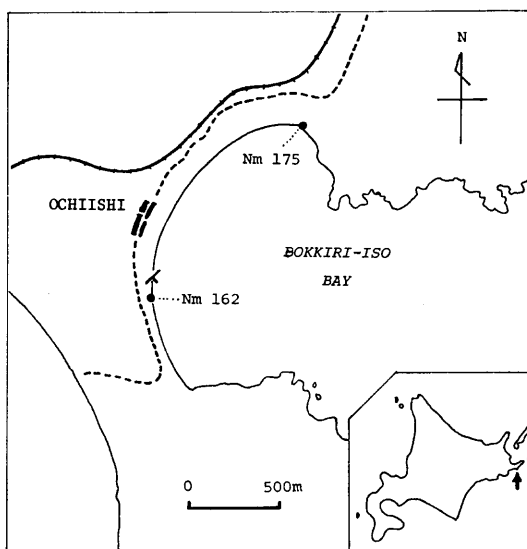


Fig. 10. Map showing ammonite localities (with solid circle) on the coast of Bokkiri-iso bay, Ochiishi, southwest of Nemuro.

Occurrence.—Loc. Nm 370, north of Senposhi, in a claystone belonging to the upper part of the Senposhi Formation. This is probably assigned to the lower part of Unit N4 (see KIMINAMI, 1978 and also MATSUMOTO and YOSHIDA, 1979). Another locality Nm 162 is near Ochiishi, a cliff on the western coast of Bokkiri-iso bay (Text-fig. 10), in a claystone within a formation locally called the Choboshi Formation. This part is interpreted by KIMINAMI (1978, fig. 5) as the upper part of his Akkeshi Formation. This would place the fossil somewhere in the middle part of Unit N4 of MATSUMOTO (1970). There are, however, debatable points as to the biostratigraphy of the Bokkiri-iso outcrops (see MATSUMOTO and YOSHIDA, 1979). At locality Nm 175, from a calcareous concretion in a claystone, on the northeastern extension of Nm 162, one of us (T. M.) found an immature shell of an undescribed species of *Anagaudryceras*.

Concluding Remarks

1. *Taxonomic and stratigraphic results.*—The following species from Hokkaido are described in Parts I–III of this paper and their occurrences are also summarized below:

- (1) *Pachydiscus* (*Pachydiscus*) *excelsus* MATSUMOTO, n. sp.: IVa of the Hako-buchi Group of the Hobetsu Valley (K6a, probably K6a2)
- (2) *Pachydiscus* (*Pachydiscus*) *flexuosus* MATSUMOTO, n. sp.: Unit D2 and Unit E2 of the Tombetsu Valley; also Member At2 of the Hamanaka area (K6b2)
- (3) *Pachydiscus* (*Pachydiscus*) aff. *flexuosus* MATSUMOTO, n. sp.: Unit D of the Tombetsu Valley (K6b2)
- (4) *Pachydiscus* (*Pachydiscus*) *hidakaensis* MATSUMOTO and KANIE, n. sp.: Unit H2 of the Urakawa area (K6b, probably K6b2)

- (5) *Pachydiscus* (*Neodesmoceras*) *gracilis* MATSUMOTO, n. sp.: Member IVc5 of the Hakobuchi Group of the Hobetsu Valley; Unit D of the Tombetsu Valley (K6b2); comparable specimens occur in the lower and possibly also in the middle part of Unit N4 of the Nemuro Group, Nemuro-Akkeshi area (K6b2). In addition to these species, there are two others, as have been described in previous papers:
- (6) *Pachydiscus* (*Neodesmoceras*) *japonicus* MATSUMOTO: Member IVb of the Hakobuchi Group in the Hobetsu-Hetonai [=Tomiuchi] area: K6b1
- (7) *Pachydiscus* (*Pachydiscus*) *subcompressus* MATSUMOTO, emended in this paper. This has not been confirmed yet in Hokkaido. It was originally reported from Member Rdy1 of the Ryugase Group in South Saghalien (K6b2) and a comparable specimen was found in the Shimonada Sandy Shale of the Awaji Group of Southwest Japan (MATSUMOTO and MAEDA, 1951).

There are records of two other undescribed specimens. One is *Pachydiscus* (*Pachydiscus*) aff. *egertoni* from K6b of the Hobetsu-Hetonai area. It was represented by a fairly well preserved specimen, which was collected by the late Dr. K. OTATUME (see MATSUMOTO, 1947, p. 43; 1959b, p. 46) but is now unfortunately missing. The other is a fragmentary cast from the Monshizu Sandstone (N2) of the Nemuro Group and is also somewhat allied to *P. (P.) egertoni*.

2. *Problem of faunal provincialism.*—As is suggested in Part I (p. 53), *P. (P.) subcompressus* of K6b2, which is based on the secondarily compressed shells, could be treated as a geographical subspecies of *P. (P.) gollevillensis* (D'ORBIGNY). *P. (Neodesmoceras) japonicus* of K6b1 is allied to *P. (N.) catarinae* (ANDERSON and HANNA) described from Baja California and *P. (N.) mokotibensis* COLLIGNON from the Lower Maastrichtian of Madagascar. Whether the distinctions are truly specific or merely subspecific is a problem to be worked out. Anyhow, these two species are useful to some extent for inter-regional correlation.

The four new species from Hokkaido described in this paper are distinct from any of the previously known one. This may give an idea of faunal provincialism.

It should be taken into consideration that some dissimilarity in facies and/or in age between the ammonite bearing rock units may have given an apparent dissimilarity of the faunas in those rock units under consideration. For example, *P. (P.) subcompressus* and *P. (P.) flexuosus* are contemporary (K6b2) and are from the same biogeographic province. They probably had their own respective habitats, characterized by depth conditions of the sea-water or the way of locomotion, as suggested by some dissimilarity of facies and also by distinct morphological characters. On the other hand, *P. (N.) japonicus* and *P. (P.) gracilis* occur in rock-units of similar facies in the same area of the same province, but their ages are different: the former is K6b1 and the latter K6b2. *P. (N.) gracilis* from Hokkaido, is allied to but distinct from *P. (N.) obsoletiforme*, from the Pacific Coast of Alaska. The latter is from the uppermost Campanian or from near the boundary of Campanian-Maastrichtian (JONES, 1963), whereas the former is distinctly from the Maastrichtian (i.e. the upper part of the correlative of the Maastrichtian). In this case, therefore, the occurrence of different species in Hokkaido and Alaska does not necessary imply the provincialism. It may be

due to the difference in age of the *Pachydiscus* bearing rock units in respective provinces.

3. *Difficulty in precise correlation.*—The above mentioned fact that the species which have been found in Hokkaido and adjoining areas are mostly distinct from those found in other provinces, including the type areas in Northwest Europe, makes it difficult to correlate precisely our sequences with those in the type sequences. Aside from the species of *Pachydiscus*, the cephalopod species which characterize the Maastrichtian Stage in Northwest Europe, such as *Sphenodiscus binckhorsti*, *Scaphite* (*Hoploscaphites*) *constrictus*, *Belemnella lanceolata*, *B. occidentalis*, *Belemnitella junior*, *Belemnella kazimiroviensis*, have never been found in Hokkaido and other provinces around the northern Pacific Ocean. This is certainly due to the difference in biogeographical province. We have endeavoured to search for other marine fossils, but have not been successful in finding useful species from the Upper Hetonaian (K6b).

Under these circumstances, the inter-regional correlation of the Hetonaian and its subdivisions in our province with the international stages and substages is indirect and accordingly approximate. *Pachydiscus* (*Pachydiscus*) *subcompressus* from K6b2 of South Saghalien and Southwset Japan and *P. (Neodesmoceras) japonicus* from K6b1 of Hokkaido, among others, are useful for this indirect correlation.

It should be noted, however, that the occurrence of *P. (P.) excelsus* from K6a of Hokkaido has made the range of the subgroup of *P. (P.) gollevillensis* longer than the previous concept. The subgroup appeared already in the Campanian (in Hokkaido) and flourished in the Maastrichtian giving rise to its world-wide distribution and diverse speciation.

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