The Cretaceous System in the Makarov Area, Southern Sakhalin, Russian Far East, edited by Y. Shigeta and H. Maeda, National Science Museum Monographs, 31: 121–136, 2005

Maastrichtian Ammonoid Fauna from the Pugachevo Area, Southern Sakhalin, Russian Far East

Haruyoshi Maeda[1] and Yasunari Shigeta[2]

[1] Department of Geology and Mineralogy, Graduate School of Science, Kyoto University, Kitashirakawa-Oiwake-cho, Sakyou-ku, Kyoto 606–8502, Japan
E-mail: maeda@kueps.kyoto-u.ac.jp
[2] Department of Geology and Paleontology, National Science Museum, 3–23–1Hyakunin-cho, Shinjuku-ku, Tokyo 169–0073, Japan
E-mail: shigeta@kahaku.go.jp

Abstract The stratigraphy and paleontology of the Cretaceous Yezo Group in the Pugachevo area has been investigated. The group is divided into the Bykov and Krasnoyarka formations in ascending order, and its exposures in the area range in age from Middle Campanian to Maastrichtian. *Canadoceras kossmati* and *Sphenoceramus schmidti*, of Middle Campanian age, characterize the Bykov Formation, while the middle and upper parts of the Krasnoyarka Formation are characterized by the presence of *Pachydiscus flexuosus* and *Gaudryceras makarovense*, which are Late Maastrichtian in age. A typical occurrence of this widespread Upper Maastrichtian ammonoid assemblage is confirmed in a new section located between the Naiba and Makarov areas.

Preservation of the Upper Maastrichtian ammonoids ranks among the best in the world and is probably unmatched in any other locality in southern Sakhalin. Specimens of *P. flexuosus* and *G. makarovense* preserved in the large calcareous nodules mainly exhibit aragonite preservation. Their phragmocones are usually free from compactional damage although the last two or three camerae are sometimes slightly crushed similar to the body chambers. As a matter of interest, it seems peculiar that juvenile and immature specimens of *P. flexuosus* and *G. makarovense* less than 5 cm in diameter are absent in both the calcareous nodules and the surrounding muddy sandstone. The scarcity of immature specimens can not be explained simply by either hydrodynamic sorting by waves or currents, or by selective dissolution of shells during diagenesis. This peculiarity may be a key to reconstructing the depositional environment and paleoecology as well as the taphonomic processes of ammonoid preservation.

Key words: ammonoids, aragonite preservation, Pugachevo, Sakhalin, Upper Cretaceous

Introduction

Since the discovery of its remarkably well preserved and abundant Maastrichtian ammonoid fauna by previous authors, the Pugachevo area has been recognized as one of the best reference sections for the Upper Cretaceous in southern Sakhalin (Yazikova, 1994). Despite the taxonomic work of Zonova *et al*. (1993) and Yazikova (1994), the exact localities, stratigraphic positions, and modes of fossil occurrence remained very poorly known. Japanese paleontologists were unaware of the Pugachevo area until Masahiro Sato, an amateur paleontologist in Osaka, informed the authors of the excellent preservation of fossils in the area.

The Pugachevo area is located in southern Sakhalin about 150 km north of Yuzhno-Sakhalinsk, along the eastern side of the West

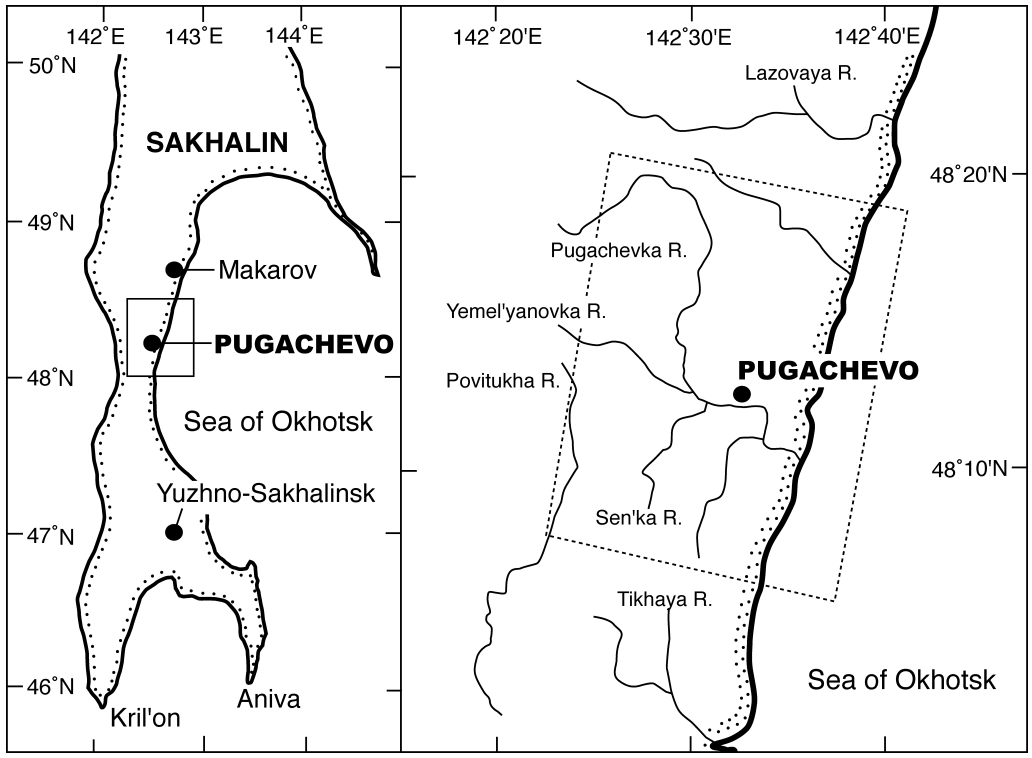

Fig. 1. Map showing the study area in the Pugachevo area, southern Sakhalin.

Sakhalin Mountains. Exposures of the Upper Cretaceous System occur at several localities along the Pugachevka River and its tributaries. Ammonoid preservation in these sediments ranks among the best in the world and is probably unmatched in any other locality in southern Sakhalin.

To ensure precise stratigraphic distribution of the Maastrichtian ammonoid fauna, topographic and geologic assessment by satellite photography was introduced. After reviewing the topographic features of the region and pinpointing promising areas for fossil exploration, field expeditions were carried out by the authors in 1993, 1994 and 1997 along the Pugachevka River and a tributary, the Sen'ka River (Figs. 1–3).

The purpose of this paper is to describe the Cretaceous stratigraphy of the Pugachevo area, and discuss from a taphonomic perspective, the manner of occurrence and preservation of the Maastrichtian ammonoids, which is somewhat different from those in the Bykov Formation.

Repository of specimens: The following abbreviations are used to indicate fossil repositories: NSM, National Science Museum, Tokyo; DGMKU, Department of Geology and Mineralogy, Kyoto University, Kyoto.

All fossils and samples utilized herein were collected during the field expeditions and were transported from Russia to Japan with permission from the Russian Government, the State Government of Sakhalin, and other concerned authorities. Locs. PC1001 and 1002 are now protected by the Russian Government as a Paleontological Monument of Nature.

Stratigraphy

The Cretaceous Yezo Group consists of marine clastics that were deposited in a forearc

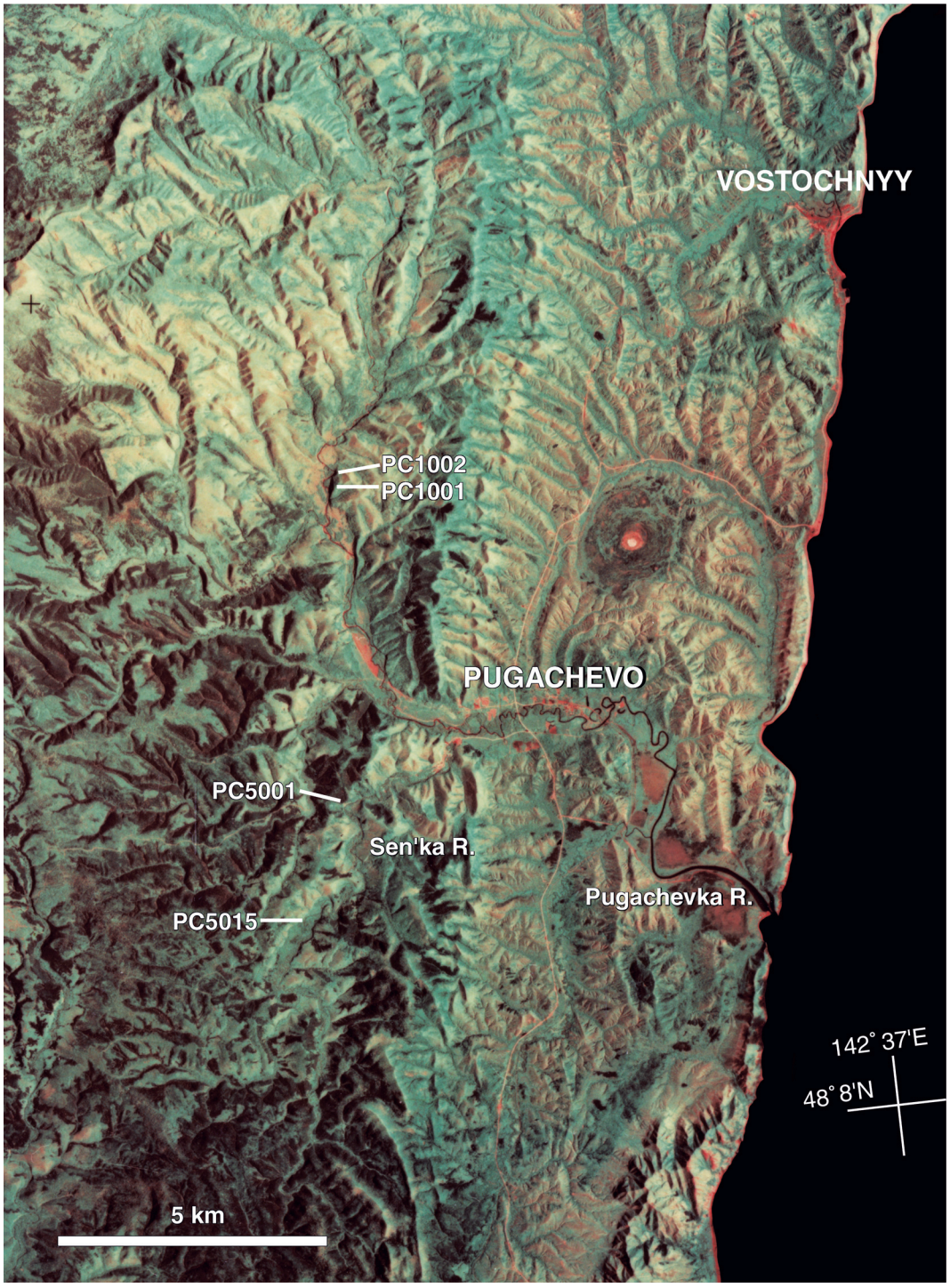

Fig. 2. Satellite photograph of the Pugachevo area, southern Sakhalin.

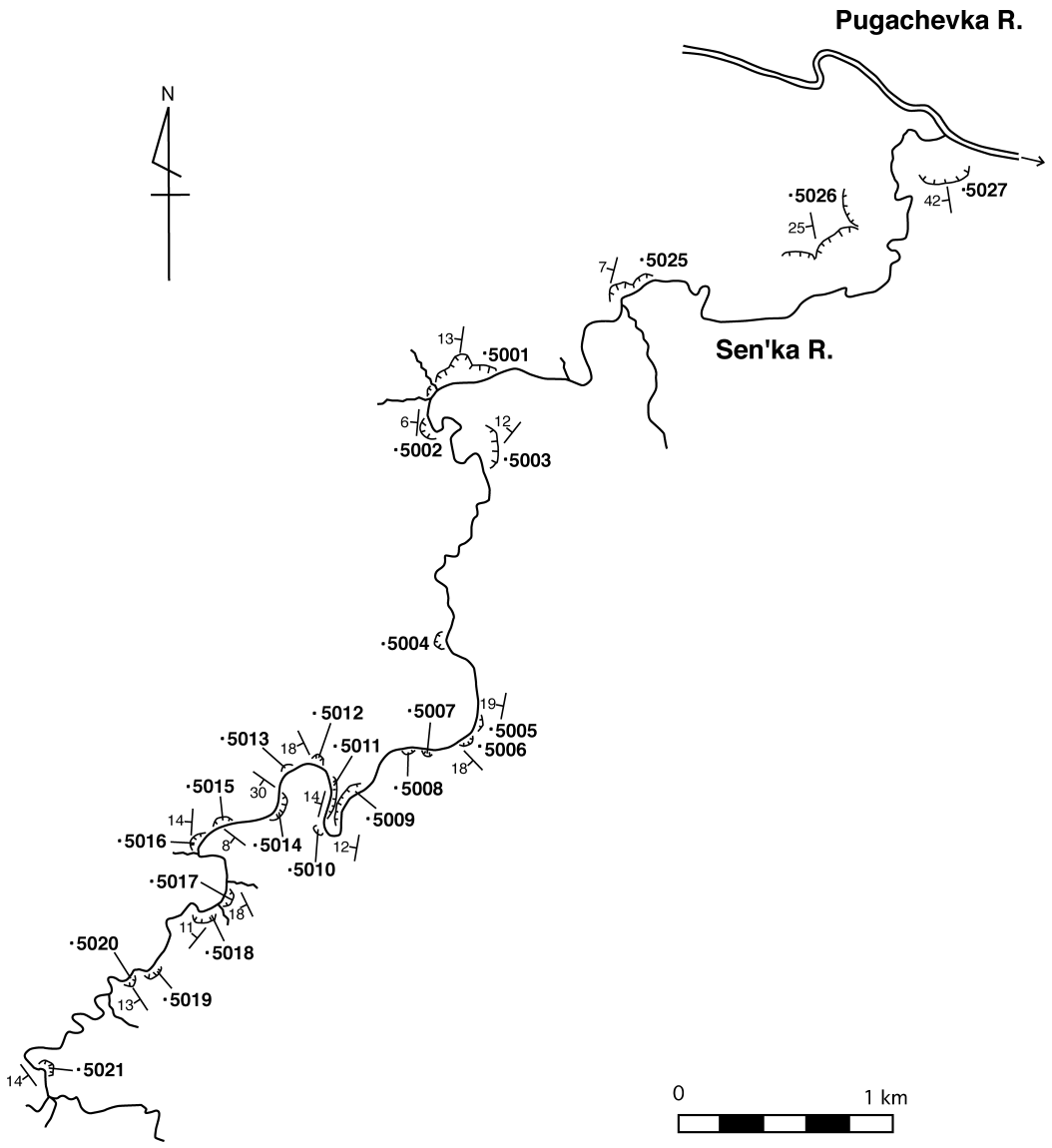

Fig. 3. Locality map along the Sen'ka River.

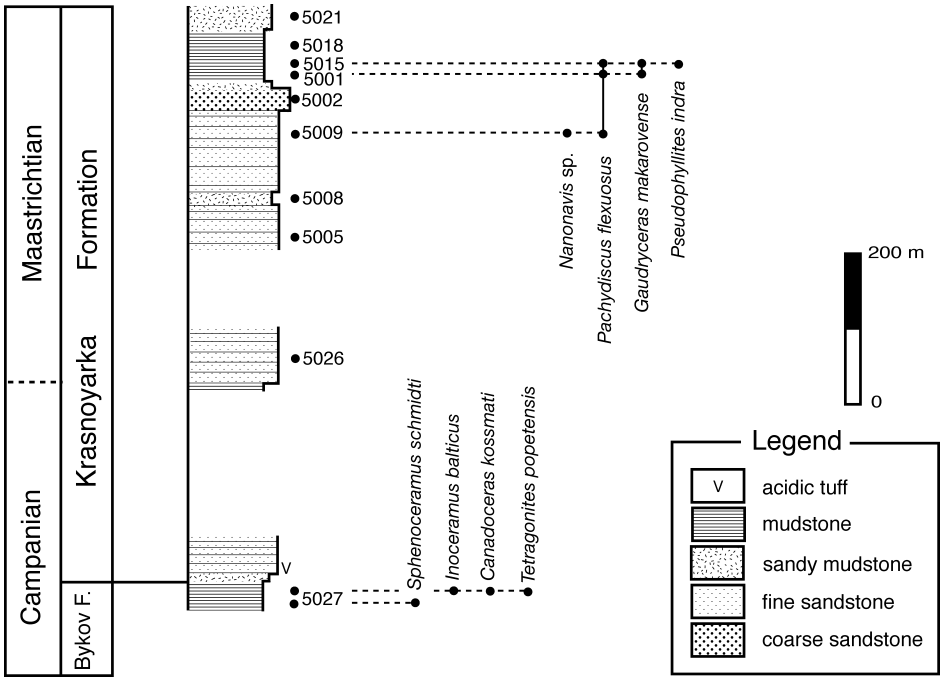

Fig. 4. Lithology and faunal succession of the Cretaceous deposits along the Sen'ka River.

basin on the northwestern Pacific margin (Okada, 1979, 1983). These deposits are widely distributed in central Hokkaido and western Sakhalin, and are composed of a thick, continuous sequence of Aptian–Maastrichtian marine sediments with abundant mega- and microfossils (Matsumoto, 1954; Vereshchagin, 1977).

The Yezo Group is widely exposed along the middle course of the Pugachevka River and the Sen'ka River, one of its tributaries. In general, the strata strike in a N–S direction, and the dip varies from 5 to 30° westward. In this particular area, the Yezo Group is divided into two units, the Bykov and Krasnoyarka formations in ascending order (Fig. 4), as defined by Vereshchagin (1961) along the Naiba River.

Due to gentle dip of the strata in the Pugachevo area, outcrops representing the entire stratigraphic range of the Yezo Group are restricted, and exposures are not as continuous. However, the Maastrichtian outcrops are fresh, and most ammonoid fossils exhibit "aragonite preservation" (Figs. 5–9).

Bykov Formation (Vereshchagin, 1961)

Stratotype: Naiba River, southern Sakhalin.

Locality: Lower course of the Sen'ka River (Loc. PC5027).

Thickness: Greater than 40 m.

Lithology: Only the uppermost part is exposed. It mainly consists of dark gray, intensely bioturbated mudstone interbedded with white vitric tuff layers ranging from 5 to 10 cm in thickness. Lenticular or spherical calcareous nodules, 30–60 cm in diameter, are commonly embedded in the mudstone.

Fossils: *Sphenoceramus schmidti* (Michael) is abundant and occurs in both the calcareous nodules and the lower and middle parts of the host rock. *Canadoceras kossmati* Matsumoto, *Tetragonites popetensis* Yabe, and *Inoceramus balticus* Böhm occur in calcareous nodules in the upper part of the formation.

Krasnoyarka Formation (Vereshchagin, 1961)

The Krasnoyarka Formation consists mainly of sandstone and sandy mudstone, and it conformably overlies the Bykov Formation. The top part is not exposed in the study area.

Stratotype: Krasnoyarka River, a tributary of the Naiba River, southern Sakhalin.

Localities: Middle course of the Pugachevka River (Locs. PC1001, 1002); the Sen'ka River (Locs. PC5001–5026).

Thickness: 770 m.

Lithology: The basal part of the formation consists of greenish gray, poorly-sorted muddy sandstone. Then it changes to bedded, fine to course grained sandstone and muddy sandstone in the middle part and to dark, greenish gray, intensely bioturbated sandy mudstone and muddy sandstone in the upper part. The sandy mudstone in the upper part often contains spherical calcareous nodules, about 30–100 cm in diameter, some of which are fossiliferous.

Fossils: *Pachydiscus flexuosus* Matsumoto and *Nanonavis* sp. were found in the fine-grained sandstone of the middle part of the formation at Loc. PC5009. The sandy mudstone in the upper part is fossiliferous, and the following very well preserved ammonoids were found in calcareous nodules: *Pachydiscus flexuosus*, *Pseudophyllites indra* (Forbes), and *Gaudryceras makarovense* Shigeta and Maeda (Figs. 5–8).

Correlation

Ammonoids in the Pugachevo area are restricted to the Bykov Formation and the middle and upper parts of the Krasnoyarka Formation. The ammonoid and inoceramid zonation applied in this area is based on the studies of Matsumoto (1942, 1954, 1959, 1984), Zonova *et al*. (1993), Zonova and Yazykova (1994), Yazikova (1994), and Toshimitsu *et al*. (1995).

The presence of *Sphenoceramus schmidti* and *Canadoceras kossmati* in the Bykov Formation suggests the upper Lower Campanian stage. Similar faunas have been recognized in the upper part of the Bykov Formation in the Makarov area and the lower part of the Krasnoyarka Formation in the Naiba, Sinegorsk, Vladimirovka, Gorbusha, and Kura areas in southern Sakhalin (Matsumoto, 1942; Vershchagin, 1970, 1977; Poyarkova, 1987; Shigeta *et al*., 1999; Kodama *et al*., 2000, 2002). This fauna is also similar to that of the Yezo Group in Hokkaido (Matsumoto, 1954).

Pachydiscus flexuosus, of the Upper Maastrichtian stage, characterizes the middle and upper parts of the Krasnoyarka Formation. The Upper Maastrichtian fauna in the Pugachevo area, which consists of *Pachydiscus flexuosus*, *Pseudophyllites indra*, and *Gaudryceras makarovense*, is similar to that of the Makarov and Manui areas in southern Sakhalin (Yazikova, 1994).

Mode of Maastrichtian ammonoid occurrence and preservation

The typical mode of Maastrichtian ammonoid occurrence can be observed at Locs. PC1001 and 1002 (Figs. 2, 5), where dark gray, moderately bioturbated, bedded muddy sandstone is exposed. These beds dip westward very gently and yield numerous large spherical or ellipsoidal calcareous nodules, 30–100 cm in diameter (Fig. 5).

Features of nodules: The nodules are tightly cemented, which causes considerable difficulty in extracting fossils, and sometimes, small burrows such as *Phycosiphon*, cover the nodule surface. Sediments in the nodules are almost massive, and neither sedimentary structures nor trace fossils are discernible. Pieces of wood, 5–30 cm long, are occasionally found in the nodules, but smaller plant fragments are few and shell debris is very rare. Besides the spherical nodules, nearly flattened or ellipsoidal calcareous concretions are also common, but they are usually barren. Unlike the Bykov Formation or the Elk Butte Member of

Fig. 5. 1, An outcrop of Upper Maastrichtian sandy mudstone of the Krasnoyarka Formation at Loc. PC1002 along the Pugachevka River. Many calcareous nodules are embedded in the sandy mudstone. 2, Vertical section of a large ellipsoidal calcareous nodule excavated from the outcrop. Note that a specimen of *Pachydiscus flexuosus* Matsumoto is horizontally embedded in the nodule. 3, *P. flexuosus* just recovered after about 70 million years. Note that the shell exhibits aragonite preservation. Lens cap is 5.2 cm in diameter.

Fig. 6. *Gaudryceras makarovense* Shigeta and Maeda, NSM PM17304 from the Upper Maastrichtian muddy sandstone of the Krasnoyarka Formation at Loc. PC1001 along the Pugachevka River. Scale bar=5 cm.

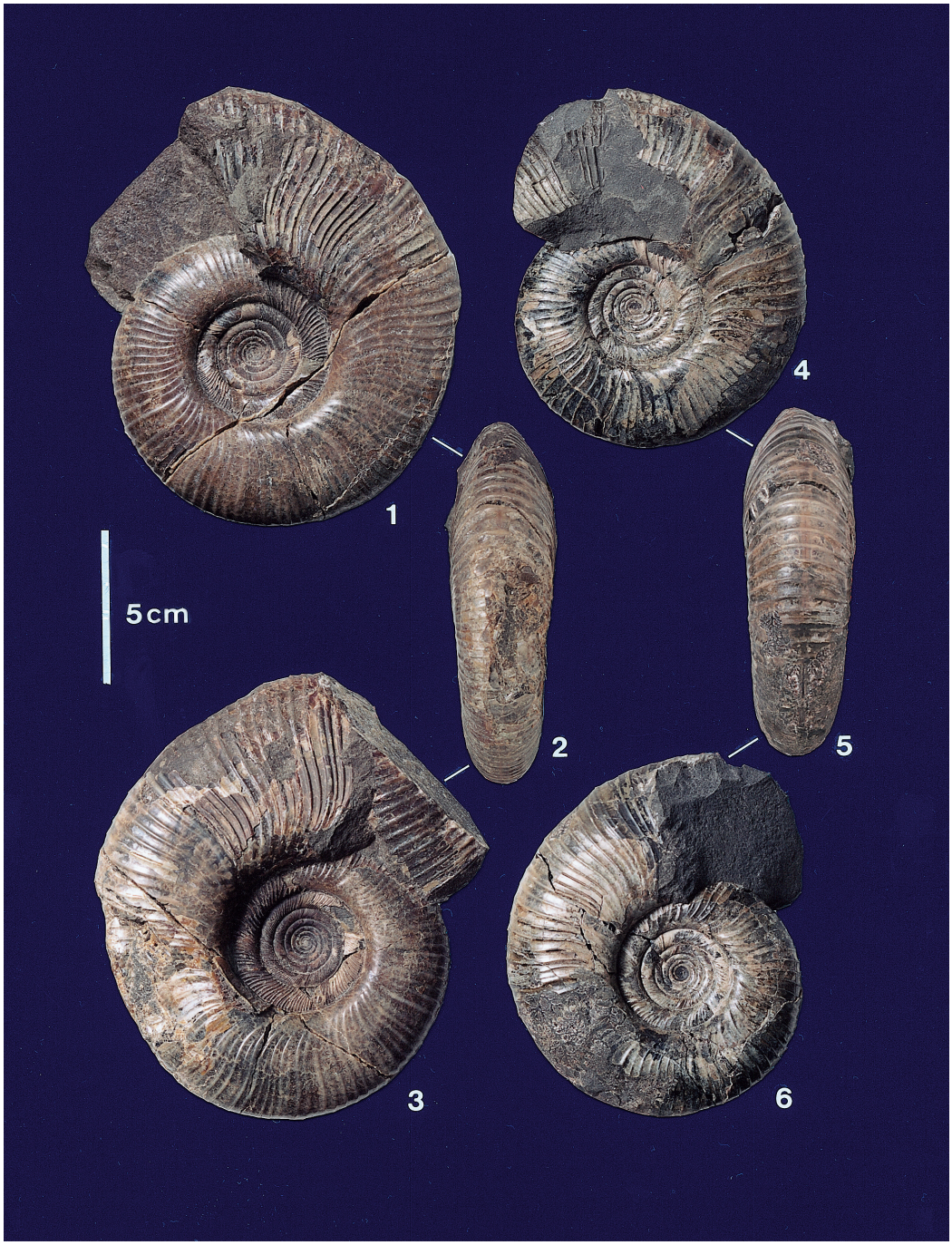

Fig. 7. *Gaudryceras makarovense* Shigeta and Maeda from the Upper Maastrichtian muddy sandstone of the Krasnoyarka Formation at Loc. PC1001 along the Pugachevka River. 1–3, NSM PM17305. 4–6, NSM PM17306. Scale bar＝5 cm.

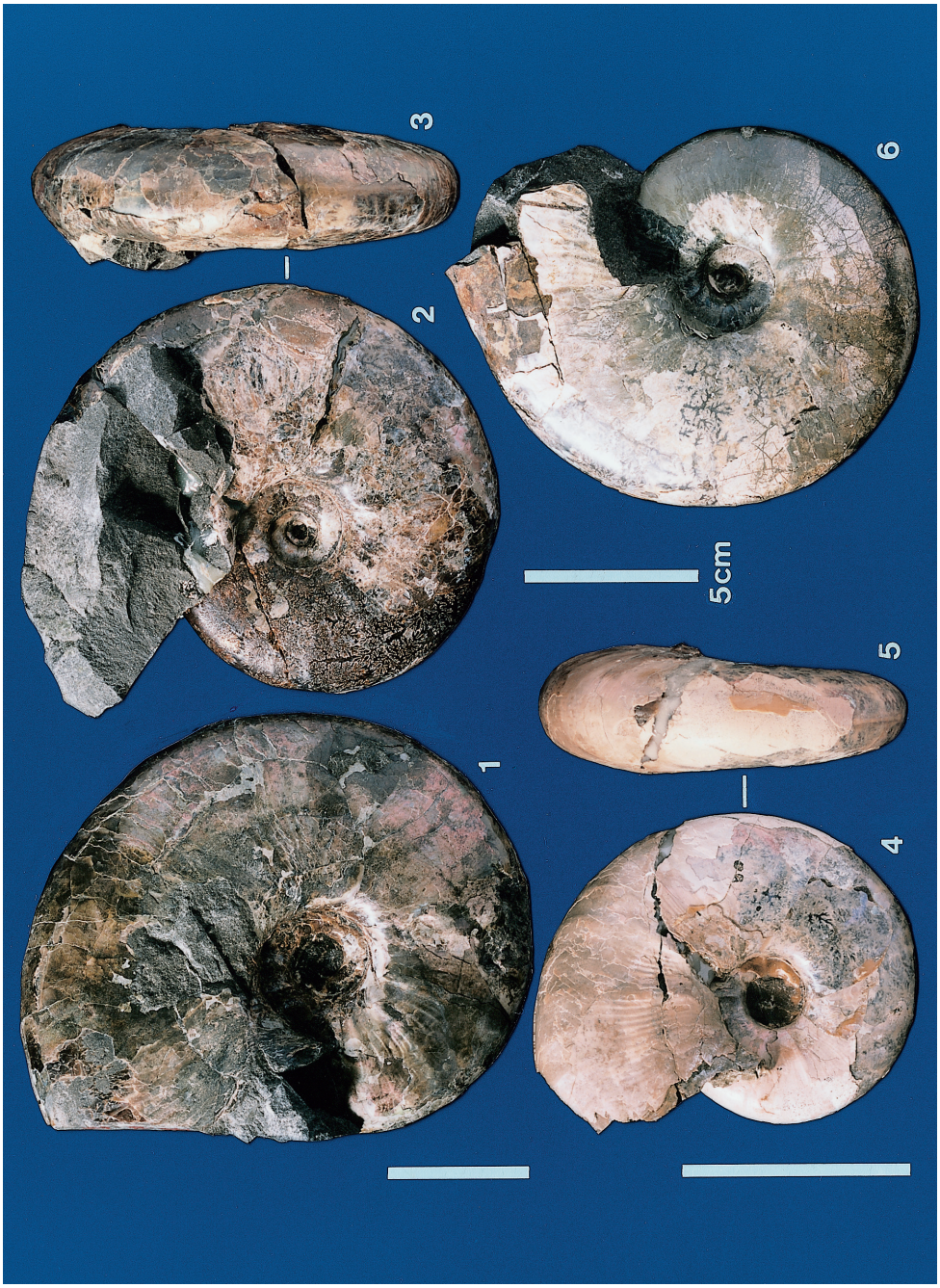

Fig. 8. Upper Maastrichtian *Pachydiscus flexuosus* Matsumoto from the Krasnoyarka Formation at Loc. PC1002 along the Pugachevka River. 1, NSM PM17307. 2–3, NSM PM17308. 4–5, NSM PM17309. 6, NSM PM17310. Each scale bar=5 cm. Upper left scale bar–1; Lower left bar–4 and 5; Central bar–2, 3 and 6.

the Pierre Shale in South Dakota, sideritic concretions are never found in the Krasnoyarka Formation (Hayakawa, 2001; Landman & Waage, 1993).

Ammonoid occurrence: Near-adult specimens of *Pachydiscus flexuosus* and *Gaudryceras makarovense* are horizontally embedded in the center of the large spherical nodules (Fig. 5). *Pachydiscus flexuosus* specimens, 20–30 cm in diameter, are most common, but it seems peculiar that immature forms less than 5 cm in diameter and juveniles are never found. Unlike the fossiliferous nodules in the Bykov Formation, each nodule contains just a single ammonoid (Fig. 5). Nodules containing plural ammonoids are rare. Generally, the nodules are two or three-times larger than the contained ammonoid. For example, a *P. flexuosus* specimen 20 cm in diameter is usually found inside a nodule exceeding 50 cm or more in diameter. In an extreme case, an immature *P. flexuosus* specimen 6 cm in diameter was found in the center of a huge nodule 70 cm in diameter. Benthic fossils such as bivalves, gastropods, and echinoids, which are common in the Bykov Formation, are very rare in the Krasnoyarka Formation.

Ammonoid preservation: Ammonoids from the Pugachevo area are exceptionally well-preserved (Figs. 5–9), and a nacreous luster is preserved on the shell tests of nearly all specimens. The degree of such aragonite preservation varies from one specimen to another; e.g., the color of the shell test ranges from pearly white to reddish brown with a rainbow luster (Fig. 8). In addition, an examination of these specimens from a taphonomic perspective reveals several distinctive preservational features that are discussed below in some detail.

Generally, the body chambers of *P. flexuosus* are only partly preserved, and on average, only a quarter of the body chamber remains. The apertural margin is usually damaged severely due to biogenic or biostratinomic factors (Fig. 8.6). Specimens preserved with a complete body-chamber and a perfect apertural margin have not yet been found. All body chambers are crushed very slightly by compaction, even in the calcareous nodules, but they are never flattened (Fig. 8.1).

Usually, the phragmocone is preserved with its original geometry, however, only the outer two or three whorls are preserved, and the central part of the umbilicus is mostly dissolved (Maeda, 1987; Maeda & Seilacher, 1996). "Half-ammonoid preservation" is not found (Seilacher *et al*., 1976; Maeda, 1987, 2001; Maeda & Seilacher, 1996).

The camerae are preserved with the septal walls and the siphuncular tube intact, and are usually filled with drusy calcite formed during diagenesis. However, the calcite infill is imperfect, and about half the volume of the camera remains hollow. Camerae with sediment infill are rare. The phragmocone is mostly free from compactional damage although the last two or three camerae are sometimes crushed slightly similar to the body chambers. Therefore, cementation of the calcareous nodules may have started just after the onset of shell-wall compaction (Maeda & Seilacher, 1996). However, crushed drusy calcite in such damaged camerae suggests that the drusy-calcite growth occurred prior to compaction of the shell.

Discussion

The significance of the Upper Maastrichtian ammonoid assemblage, consisting of *Pachydiscus flexuosus* and *Gaudryceras makarovense*, in the Pugachevo area is summarized as follows:

1) A typical occurrence of this widespread Upper Maastrichtian ammonoid assemblage is confirmed in a new section located between the Naiba and Makarov areas.

2) Exceptionally well-preserved specimens displaying aragonite preservation are newly obtained.

3) Its taphonomic features are remarkably different from those of ammonoid occurrences

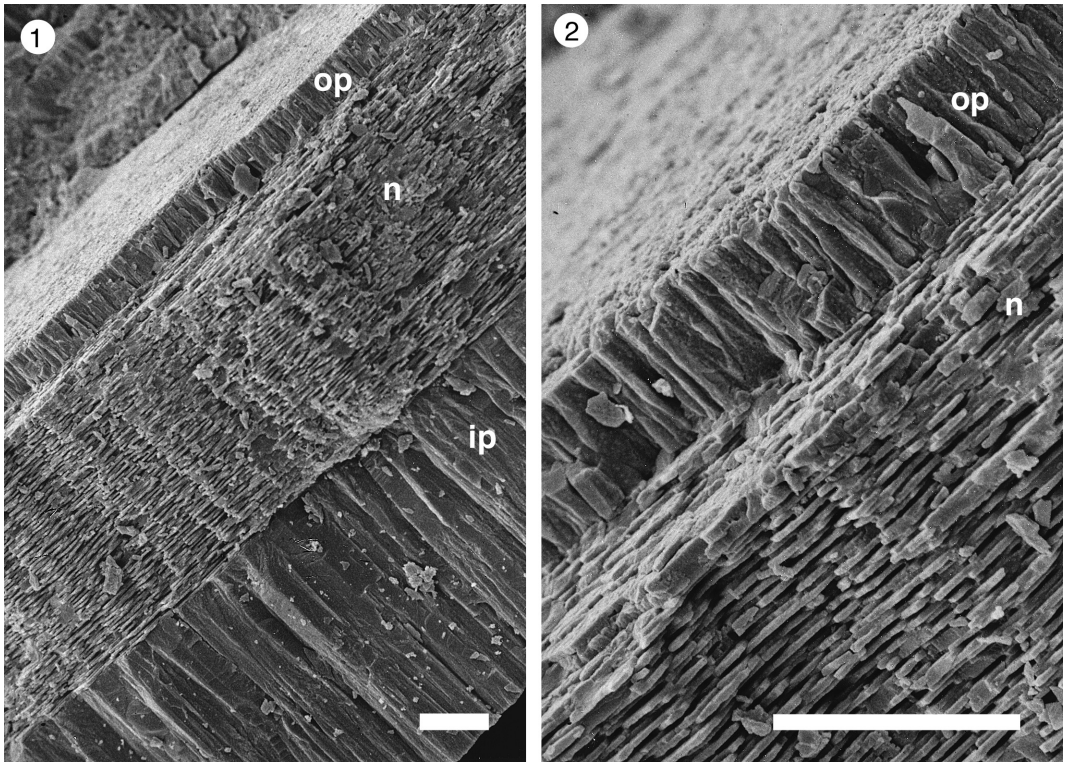

Fig. 9. Scanning electron micrographs of the shell wall of *Pachydiscus flexuosus* Matsumoto, NSM PM17311 collected from the Krasnoyarka Formation at Loc. PC1002 along the Pugachevka River. Scale bar＝10 μm. 1, Ventral wall at about 10 mm in shell diameter, consisting of the three layers: outer prismatic layer (op), nacreous layer (n) and inner prismatic layer (ip). 2, Close-up of outer prismatic layer and nacreous layer. Note that the original shell microstructure is well preserved.

in the Bykov Formation.

Upper Maastrichtian assemblage: Due to an increasing influx of coarse grained deposits, the Maastrichtian marine fossil record becomes much more intermittent in Hokkaido, Japan. Even in the Naiba section, the *P. flexuosus-G. makarovense* Assemblage is obscure (Kodama *et al*., 2002). In contrast, an alternative good Maastrichtian succession has been discovered in the northern part of southern Sakhalin, e.g., the Makarov section (Maeda *et al*., 2005; this volume).

The abundant occurrence of *P. flexuosus* from the Pugachevo area has revealed a wide range of morphological variation in the species. This variation becomes particularly apparent when studying shell ornamentation, whereby various morphotypes ranging from almost smooth (Fig. 8.6) to umbilically bullate (Fig. 8.2) exist in a population sample. At the extreme end, a strongly ribbed morphotype is occasionally found (Maeda *et al*., 2005; Fig. 14.2, 14.5). The inner whorls of such strongly ribbed morphotypes superficially resemble *Canadoceras*, and thus, they could be mistakenly identified (Matsumoto & Morozumi, 1980, p. 7, pl. 2, fig. 1).

Detailed field observations reveal that the *P. flexuosus-G. makarovense* Assemblage is widespread in various areas in southern Sakhalin and Hokkaido. The discovery of an abundant occurrence of this fossil assemblage in the Pugachevo area seems to suggest the existence of a wide distribution of this Upper Maastrichtian assemblage in the North Pacific Realm. Fragmentary fossil records of the

Maastrichtian in Hokkaido can now be stratigraphically reinterpreted by comparing them with the succession in the Pugachevo area.

In contrast to the abundant occurrence of *P. flexuosus*, which is widespread in the North Pacific Realm, neither *P. subcompressus* Matsumoto nor *Zelandites varuna* (Forbes) are found in the Maastrichtian sequence in the Pugachevo area. This lack of representatives from the Indian province in the typical North Pacific assemblage is also confirmed in the Makarov area in another paper (Maeda *et al*., 2005: this volume).

Aragonite preservation: Preservation of the Upper Maastrichtian ammonoids in the Pugachevo area ranks among the best in the world (Fig. 9) and is probably unmatched in any other locality in southern Sakhalin or Hokkaido. In the Naiba area, *P. subcompressus* rarely exhibits aragonite preservation (Kodama *et al*., 2002, p. 378, fig. 8G).

Fossiliferous layers containing the *P. flexuosus*-*G. makarovense* Assemblage are also traceable in the Makarov area. However, preservation in the Pugachevo area forms a striking contrast with that in the Makarov area, in which *P. flexuosus* and *G. makarovense* never display aragonite preservation (Maeda *et al*., 2005, Fig. 15).

The reason(s) for the excellent ammonoid preservation in the Pugachevo area is still obscure. In the near future, well-preserved shell material from Upper Maastrichtian ammonoid specimens will be subjected to oxygen and carbon-isotopic analyses.

Taphonomic features: The taphonomic aspects of the Upper Maastrichtian ammonoids from the Pugachevo area largely remain to be exploited. It seems rather odd that juvenile and immature ammonoids less than 5 cm in diameter are absent, in both the calcareous nodules and the surrounding muddy sandstone. This scarcity of immature forms raises valid questions that may be explained by taphonomic analyses.

Juvenile and immature ammonoids usually outnumber adults and near-adults in the Bykov Formation, particularly in the fossiliferous calcareous nodules (Tanabe *et al*., 1977; Maeda, 1987, 1993). In the Bykov Formation, the size-distributional pattern of ammonoids is usually bimodal. Generally, the first mode consists of immature ammonoids less than 10 cm in diameter, and the second mode includes large adults more than 30 cm in diameter. Ammonoids within the first mode usually occur in calcareous nodules, while those within the second mode are solitarily embedded in the host rock (Maeda, l987). Ammonoids in the mid-range of 20–30 cm in diameter are relatively few in number.

The original size-distributional patterns of ammonoids may be biassed by taphonomic processes, i.e., hydrodynamic sorting by currents and/or selective shell dissolution after burial (Maeda, 1991). However, there are no signs of strong currents or wave actions in surrounding deposits, and ammonoids from Locs. PC1001 and 1002 appear not to have been accumulated as shell-lags, or reworked. Likewise, their exceptionally well preserved shell tests prevent us from concluding that strong chemical dissolution has selectively eliminated the thin-shelled juveniles during diagenesis.

The scarcity of immature forms is one of the unusual taphonomic features of certain uppermost Cretaceous ammonoids, e.g., *Pachydiscus flexuosus*. Upper Maastrichtian ammonoids from the Pugachevo area provide an excellent opportunity for us to investigate this phenomenon through the reconstruction of the depositional environment and the examination of ammonoid paleoecology as well as the taphonomic processes of their preservation.

Conclusions

A typical occurrence of the widespread Upper Maastrichtian ammonoid assemblage, represented by *Pachydiscus flexuosus* and *Gaudryceras makarovense* is confirmed in a new section located between the Naiba and

Makarov areas. Preservation of the Upper Maastrichtian ammonoids ranks among the best in the world and is probably unmatched in any other locality in southern Sakhalin or Hokkaido. Aragonite preservation of the shell tests and the scarcity of immature ammonoids are suggested as distinctive characteristics of this Upper Maastrichtian Fauna. These features will be exploited in the near future from a taphonomic perspective.

Acknowledgments

We are very much grateful to K. F. Sergeev, Director of the Institute of Marine Geology and Geophysics, Yuzhno-Sakhalinsk, and G. S. Steinberg, Director of the Institute of Volcanology and Geodynamics, Yuzhno-Sakhalinsk, for their supervision of this research program. We also thank the various staff personnel of these Institutes for their kind help and cooperation throughout the field survey. A. V. Solov'yov (Institute of Volcanology and Geodynamics) and members of the Joint-Research Program, T. Kase and K. Uemura (National Science Museum, Tokyo), K. Kodama (Kochi University), T. Okamoto (Ehime University), T. Hasegawa (Kanazawa University), M. Futakami (Kawamura Women's University), and T. Takeuchi (Anjo Gakuen High School) gave us kind advice and help in various ways during the course of this study. Thanks are also extended to the Mayor and other area authorities, as well as the citizens of Makarov, and the State Government of Sakhalin for their assistance during the work.

This study was financially supported by the Japanese Government's Ministry of Education, Science, Culture, and Sports (Project Nos. 5041068, 8041113 and 9041114), and by the Fujiwara Natural History Foundation's support of H.M. (Project No. 12-3) and Y.S. (Project No. 7-21).

References

Hayakawa, H., 2001. Sedimentary environments and fossil preservation in the mudstone yielding siderite nodule in the Upper Yezo Group (Upper Cretaceous), Kotanbetsu, Hokkaido. *Bull. Mikasa City Mus.*, **5**: 1–17. (In Japanese with English abstract)

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

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

Landman, N. H. & K. M. Waage, 1993. Scaphitid ammonites of the Upper Cretaceous (Maastrichtian) Fox Hills Formation in South Dakota and Wyoming. *Bull. Am. Mus. Nat. Hist.*, **215**: 1–257

Maeda, H., 1987. Taphonomy of ammonites from the Cretaceous Yezo Group in the Tappu area, northwestern Hokkaido, Japan. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, **148**: 285–305.

Maeda, H., 1991. Sheltered preservation: a peculiar mode of ammonite occurrence in the Cretaceous Yezo Group, Hokkaido, north Japan. *Lethaia*, **24**: 69–82.

Maeda, H., 1993. Dimorphism of late Cretaceous falsepuzosiine ammonites, *Yokoyamaoceras* Wright and Matsumoto, 1954 and *Neopuzosia* Matsumoto, 1954. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, **169**: 97–128.

Maeda, H., 2001. Taphonomy of poorly preserved fossils: Haif-ammonoid. *Jap. Sci. Montly*, **54**: 37–40. (In Japanese)

Maeda, H. & A. Seilacher, 1996. Ammonoid taphonomy. *In* N. H. Landman, K. Tanabe & R. Davis (eds.), Ammonoid Paleobiology, pp. 543–578. Plenum Press, New York.

Maeda, H., Y. Shigeta, A. G. S. Fernando & H. Okada, 2005. Stratigraphy and fossil assemblages of the Upper Cretaceous System in the Makarov area, southern Sakhalin, Russian Far East. *In* Y. Shigeta & H. Maeda (eds.), The Cretaceous System in the Makarov area, southern Sakhalin, Russian Far East, pp. 25–120. Natn. Sci. Mus. Monographs, 31.

Matsumoto, T., 1942. Fundamentals in the Cretaceous stratigraphy of Japan, Part 1. *Mem. Fac. Sci., Kyushu Imp. Univ., Ser. D*, **1**: 129–280, pls. 5–20.

Matsumoto, T. (ed.), 1954. The Cretaceous System in the Japanese Islands. 324 pp. Japan Society for the Promotion of Science, Tokyo.

Matsumoto, T., 1959. Zonation of the Upper Cretaceous in Japan. *Mem. Fac. Sci., Kyushu Univ., Ser. D*, **9**: 55–93, pls. 6–11.

Matsumoto, T., 1984. Some ammonites from the Campanian (Upper Cretaceous) of northern Hokkaido. *Palaeont. Soc. Japan Spec. Pap.*, **27**: 1–93, pls. 1–31.

Matsumoto, T. & Y. Morozumi, 1980. Late Cretaceous ammonites from the Izumi Mountains, Southwest Japan. *Bull. Osaka Mus. Nat. Hist.*, **33**: 1–31, pls. 1–16.

Okada, H., 1979. The geology of Hokkaido and its plate tectonics. *Earth Monthly*, **1**: 869–877. (In Japanese)

Okada, H., 1983. Collision orogenesis and sedimentation in Hokkaido, Japan. *In* M. Hashimoto & S. Ueda (eds.), Accretion Tectonics in the Circum-Pacific Regions, pp. 91–105. Terra Scientific Publishing Co., Tokyo.

Poyarkova, Z. N. (ed.), 1987. Oporny razrez melovykh otlozhenij Sakhalina (Naibinskij razrez). 197 pp. Nauka Leningrad. [Reference section of Cretaceous deposits in Sakhalin (Naiba section).] (In Russian)

Seilacher, A., F. Andalib, G. Dietl & H. Gocht, 1976. Preservational history of compressed Jurassic ammonites from Southern Germany. *N. Jb. Geol. Palaont. Abh.*, **152**: 303–356.

Shigeta, Y., H. Maeda, K. Uemura & A. V. Solov'yov, 1999. Stratigraphy of the Upper Cretaceous System in the Kril'on Peninsula, South Sakhalin, Russia. *Bull. Natn. Sci. Mus., Tokyo, Ser. C*, **25** (1, 2): 1–27.

Tanabe, K., H. Hirano, T. Matsumoto & Y. Miyata, 1977. Stratigraphy of the Upper Cretaceous deposits in the Obira area, northwestern Hokkaido. *Sci. Rep. Dept. Geol. Kyushu Univ.*, **12**: 181–202. (In Japanese with English abstract)

Toshimitsu, S., T. Matsumoto, M. Noda & S. Maiya, 1995. Integration of mega-, micro-, and magnetostratigraphy of the Upper Cretaceous in Japan. *In* K. H. Chang & S. O. Park (eds.), Environmental and tectonic history of East and South Asia with emphasis on Cretaceous correlation (IGCP 350), pp. 357–370. Proccedings of 15th International Symposium of Kyungpook National University, Taegu.

Vereshchagin, V. N., 1961. Skhema stratigrafii melovykh otlozhenij Sakhalina. *In* N. B. Vassoyevich (ed.), Resheniya mezhvedomstvennogo soveshchaniya po razrabotke unifitsirovannykh stratigraficheskikh skhem dlya Sakhalina, Kamchatki, Kurilskikh i Komandorskikh ostrov. pp. 11. Gostoptekhizdat, Leningrad. [Scheme on stratigraphy of Cretaceous deposits of Sakhalin. *In* N. B. Vassoyevich (ed.), Decision of interdepartmental meeting on development of unified stratigraphical schemes for Sakhalin, Kamchatka, Kuril and Commandor Islands.] (In Russian)

Vereshchagin, V. N., 1970. Zapadno-Sakhalinckie gory. *In* V. N. Vereshchagin & Y. M. Kovtunovitch (eds.), Geologiya SSSR, t. 33 Ostrov Sakhalin, Geologicheskoe opisanie, pp. 67–87. Nedra, Moscow. [Western Sakhalin Mountain. *In* V. N. Vereshchagin & Y. M. Kovtunovitch (eds.), Geology of USSR, v. 33, Sakhalin Island.] (In Russian)

Vereshchagin, V. N., 1977. Melovaya sistema Dal'nego Vostoka. *Trudy VSEGEI, N. S.*, **245**: 1–207. [The Cretaceous System of Far East.] (In Russian)

Yazikova (Yazykova), E. A., 1994. Maastrichtian ammonites and biostratigraphy of the Sakhalin and the Shikotan Islands, Far Eastern Russia. *Acta Geol. Polon.*, **44** (3, 4): 277–303, pls. 1–20.

Zonova, T. D., L. I. Kazintsova & E. A. Yazykova, 1993. Atlas rukovodyashchikh grup melovoj fauny Sakhalina. 327 pp. Nedra, S.-Petersburg. [Atlas of index fossils in the Cretaceous fauna of Sakhalin.] (In Russian)

Zonova, T. D. & E. A. Yazykova, 1994. Zonalnoe raschlenenie maastrikhta Tikhookeanskogo poyasa v predelakh Rossii. *In* A. N. Olenikov (ed.), Zonalnye podrazdeleniya i mezhregionalnaya korrelyatsiya paleozoiskikh i mezozoiskikh otlozhenij Rossii i sopredelnykh territorij, 2. Mezozoi, pp. 158–185. Izdatelstwo VSEGEI, S.-Petersburg. [Zonal division of Maastrichtian in Russian Pacific coast. *In* A. N. Olenikov (ed.), Zonal subdivisions and interregional correlation of Paleozoic and Mesozoic sequences of the Russia and adjacent areas, 2, Mesozoic.] (In Russian)

ロシア極東・サハリン南部・プガチェボ地域のマストリヒチアン階アンモノイド化石群：プガチェボ地域の白亜系蝦夷層群について，層序学的研究と古生物学的研究を行った．本層群は，下位からブイコフ層とクラスノヤルカ層に区分され，カンパニアン期中期からマストリヒチアン期の地層が露出する．ブイコフ層はカンパニアン期中期の *Canadoceras kossmati* や *Sphenoceramus schmidti* で特徴づけられる．一方，クラスノヤルカ層中部と上部はマストリヒチアン期後期の *Pachydiscus flexuosus* と *Gaudryceras makarovense* で特徴づけられる．ナイバ地域とマカロフ地域の間に位置する本セクションから，マストリヒチアン期後期を特徴づけるアンモノイド化石群が典型的に産出することが確認された．マストリヒチアン期後期のアンモノイド化石の保存状態は，世界的に見ても最良の部類に属し，他の南部サハリン各地における化石の保存状態を凌駕している．大型の石灰質ノジュール中から産する *P. flexuosus* と *G. makarovense* の殻は，多くの場合アラレ石保存を示す．最後の 2~3 の気室は，住房部と同様にわずかに圧密を受けているが，それ以外の気房部は圧密の影響を全く受けていない．また，殻の直径が 5 cm 未満の *P. flexuosus* と *G. makarovense* の幼年殻が，石灰質ノジュール中にも母岩の泥質砂岩中にも見られないことは注目に値する．この幼年殻の少なさは，単なる波浪や水流による淘汰，あるいは続成の過程における選択的な殻の溶解では説明できない．このような特異な現象は，化石化作用の解明と同様に，堆積環境やアンモノイドの古生態を復元する上で，重要な鍵となると考えられる．

前田晴良・重田康成
