

## Early Permian ammonoids from the Takakurayama area, Abukuma Mountains, northeast Japan

Masayuki FUJIKAWA\* and Chisato SUZUKI\*\*

### Abstract

Four ammonoid species, *Thalassoceras?* sp., *Artinskia* sp., *Agathiceras* sp., and *Paragastrioceras?* sp., are described from the lower part of the Takakurayama Formation in the Takakurayama area, Abukuma Mountains, northeast Japan. This fauna indicates an Early Permian (Sakmarian-Artinskian) age. Three of these species except for *Agathiceras* sp. are described from the Takakurayama Formation for the first time.

*Key words:* Abukuma Mountains, ammonoid, Early Permian, Takakurayama.

### Introduction

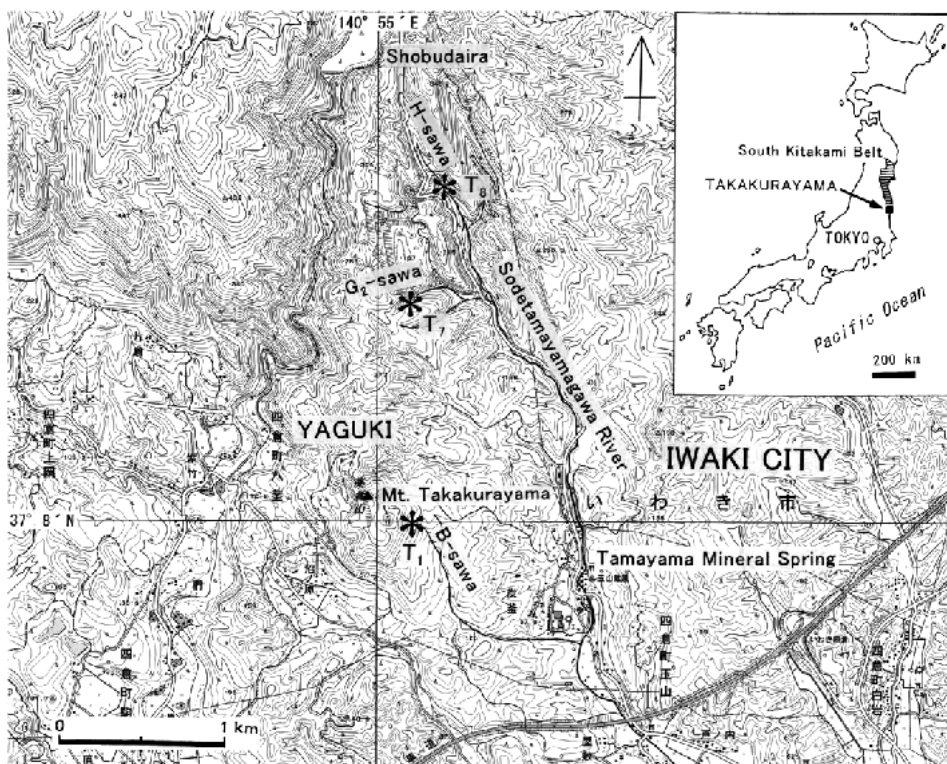
The Permian Takakurayama Formation (Onuki, 1966) is widely distributed in the Takakurayama area, Abukuma Mountains, South Kitakami Belt, northeast Japan (Fig. 1). The formation is exposed on the northeastern slope of Mt. Takakurayama, where it generally strikes NNE-SSW and dips at 30-45° to the west. It consists mainly of black shale with subordinate sandstone and conglomerate, and is more than 805 m in total thickness (Fig. 2). The formation is subdivided into three members: the Iriishikura, Motomura, and Kashiwadaira members, in ascending order (Onuki, 1966). These members are equivalent to the Iriishikura, Motomura, and Kashiwadaira formations proposed by Yanagisawa and Nemoto (1961). Here, we adopt Onuki's scheme, and refer to the lower part of the Takakurayama beds as the Iriishikura Member. This paper describes ammonoid specimens

---

\* Akiyoshi-dai Museum of Natural History, Mine, Yamaguchi 754-0511, Japan

\*\* Yotsukura-machi, Aza Nishi 2-6-3, Iwaki, Fukushima 979-0201, Japan

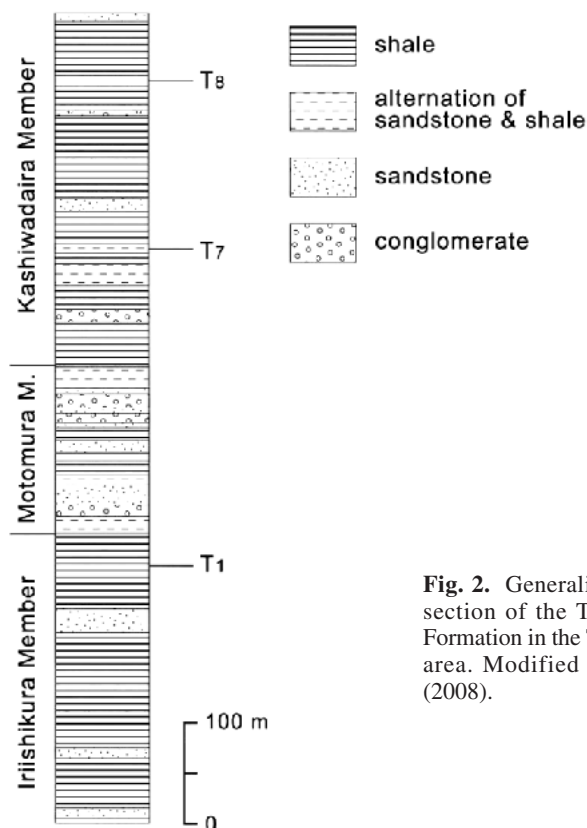
(Manuscript received 13 December, 2010; accepted 22 February, 2011)



**Fig. 1.** Index map showing the fossil locality  $T_1$  in the Takakurayama area. Using the topographical map of “Yotsukura” scale 1:25,000 published by the Geospatial Information Authority of Japan. Adapted from Tazawa (2008).

collected from locality  $T_1$  of the Iriishikura Member, which consists mainly of shale and minor sandstone beds.

Yanagisawa and Nemoto (1961) were the first to describe the ammonoid fauna from the Takakurayama Group (Formation), reporting *Medlicottia?* sp., *Paraceltites* sp., *Waagenoceras* sp., and *Agathiceras* sp. Hayasaka (1965) described eight species of Permian ammonoids collected from the Kashiwadaira Formation (Member): *Propinacoceras* spp. indet., *Medlicottidae?* gen. et sp. indet., *Paraceltites* aff. *elegans* Girty, *?Pseudogastrioceras* sp. indet., *Agathiceras* cf. *suessi* Gemmellaro, *Stacheoceras* aff. *grunwaldti* Gemmellaro, *Popanoceras* sp. indet., and *Waagenoceras* cf. *dieneri richardsoni* Miller and Furnish. Subsequently, Yanagisawa (1967) described the following Middle Permian ammonoids from localities  $T_7$  and  $T_8$  (Fig. 2) of the Kashiwadaira Member: *Agathiceras* cf. *suessi*, *Waagenoceras* cf. *dieneri* Böse, *Propinacoceras* aff. *knighti* Miller and Furnish, *Medlicottia* cf. *costellifera* Miller and Furnish, *Paraceltites* aff. *elegans*, and *P. elegans*. Tazawa et al. (2005) reported four Middle Permian (Wordian) ammonoid species from locality  $T_7$  of the Kashiwadaira Member: *Propinacoceras* sp., *Agathiceras* sp., *Mexioceras?* sp., and



**Fig. 2.** Generalized columnar section of the Takakurayama Formation in the Takakurayama area. Modified from Tazawa (2008).

*Roadoceras* sp. Finally, Ehiro (2008) described five species of Middle Permian (Wordian) ammonoids from locality T<sub>7</sub> of the Kashiwadaira Member: *Jilingites?* sp., *Waagenoceras* sp., *Popanoceras* sp., *Tauroceras* sp., and *Agathiceras* sp.

In this paper, we describe four species of Early Permian ammonoids from locality T<sub>1</sub> of the Irishikura Member. All of the ammonoid specimens described in this paper are housed in the Fukushima Museum, Japan, under the prefix 'FM-N'.

### Age of the lower Takakurayama Formation

Many types of faunas have been collected from locality T<sub>1</sub>, including anthozoans, echinoderms, brachiopods, gastropods, and cephalopods (Yanagisawa, 1967; Tazawa, 2008). Yanagisawa (1967) assigned a Middle Permian age to locality T<sub>1</sub> based on the occurrence of *Paraceltites* aff. *elegans*. Tazawa (2008) reported five brachiopod species: *Chonetinella transversa* Tazawa, *Dyoros* (*Dyoros*) sp., *Haydenella* sp., *Lamnimargus peregrinus* (Fredericks), and *Yakovlevia mammatiformis* (Fredericks) from locality T<sub>1</sub>. These brachiopod fossils were interpreted as reworked fossils, and the age of locality T<sub>1</sub> was assigned a Late Permian (Lopingian) age.

System	Series	Stage	Ammonoid
<b>PERMIAN</b>	Lopingian	<b>Changhsingian</b>	<div style="display: flex; flex-direction: column; align-items: center;"> <div style="margin-bottom: 20px;"><i>Thalassoceras</i> sp.</div> <div style="margin-bottom: 20px;"><i>Artinskia</i> sp.</div> <div style="margin-bottom: 20px;"><i>Agathiceras</i> sp.</div> <div><i>Paragastrioceras</i> sp.</div> </div>
		<b>Wuchiapingian</b>	
	Guadalupian	<b>Capitanian</b>	
		<b>Wordian</b>	
		<b>Roadian</b>	
	Cisuralian	<b>Kungurian</b>	
		<b>Artinskian</b>	
		<b>Sakmarian</b>	
		<b>Asselian</b>	

**Fig. 3.** Stratigraphical distribution of some Permian ammonoid genera found from locality T<sub>1</sub> of the Takakurayama Formation.

The four ammonoid species collected from locality T<sub>1</sub> and described in this paper provide valuable age constraints based on their stratigraphic distributions (Fig. 3), which follow the results reported by Zhou et al. (1999) and Furnish et al. (2009). The ages indicated by *Thalassoceras*, *Agathiceras*, *Paragastrioceras*, and *Artinskia* are Sakmarian-Wordian, Kasimovian-Wordian, Asselian-Kungurian, and Gzhelian-Artinskian, respectively. Therefore, the ammonoid fauna from T<sub>1</sub> indicates an Early Permian (Sakmarian-Artinskian) age. This finding differs from the Middle Permian age proposed by Yanagisawa (1967). This discrepancy may have arisen from the mis-identification of *Paraceltites* aff. *elegans* by Yanagisawa. No photograph of *P.* aff. *elegans* has been published, and there is no systematic description of the specimen at locality T<sub>1</sub>. It is therefore necessary to confirm the identification of the specimen of *P.* aff. *elegans* from this locality. If the specimen has been mis-identified, locality T<sub>1</sub> would be assigned to a strict age of Early Permian (Sakmarian-Artinskian). Meanwhile, we cannot say for certain whether these fossils are reworked or not. If the ammonoid fauna from T<sub>1</sub> were reworked, the age of locality T<sub>1</sub> might be changed to younger age than Early Permian.

**Table 1.** Measurements of Early Permian ammonoids from locality T<sub>1</sub> of the Takakurayama Formation.

Figure	Reg. No.	<i>D</i>	<i>H</i>	<i>W</i>	<i>U</i>	<i>H/D</i>	<i>W/H</i>	<i>U/D</i>
4-1	FM-N201000040	63.1	26.3	11.0	3.5	0.42	0.42	0.06
4-2	FM-N201000041	25.5	10.2	7.9	2.3	0.40	0.77	0.09
4-3	FM-N201000042	-	11.8	5.3	-	-	0.45	-
4-4	FM-N201000043	-	-	6.3	-	-	-	-
4-5	FM-N201000044	-	-	-	-	-	-	-
4-6	FM-N201000045	-	-	-	-	-	-	-
4-7	FM-N201000046	21.5	13.3	5.0	-	0.62	0.38	-
4-8	FM-N201000047	-	10.7	7.0	-	-	0.65	-
4-9	FM-N201000048	16.1	9.1	-	-	0.57	-	-
4-10	FM-N201000049	14.4	8.7	4.4	1.3	0.60	0.51	0.09
4-11	FM-N201000050	17.0	10.8	6.0	-	0.64	0.56	-
4-12	FM-N201000051	-	14.9	15.7	11.4	-	1.1	-

Values in mm where applicable. *D*: diameter of conch, *H*: height of whorl, *W*: width of conch, *U*: diameter of umbilicus.

### Systematic paleontology

Order Goniatitida Hyatt, 1884

Suborder Goniatitina Hyatt, 1884

Superfamily Thalassocerataceae Hyatt, 1900

Family Thalassoceratidae Hyatt, 1900

Genus *Thalassoceras* Gemmellaro, 1887

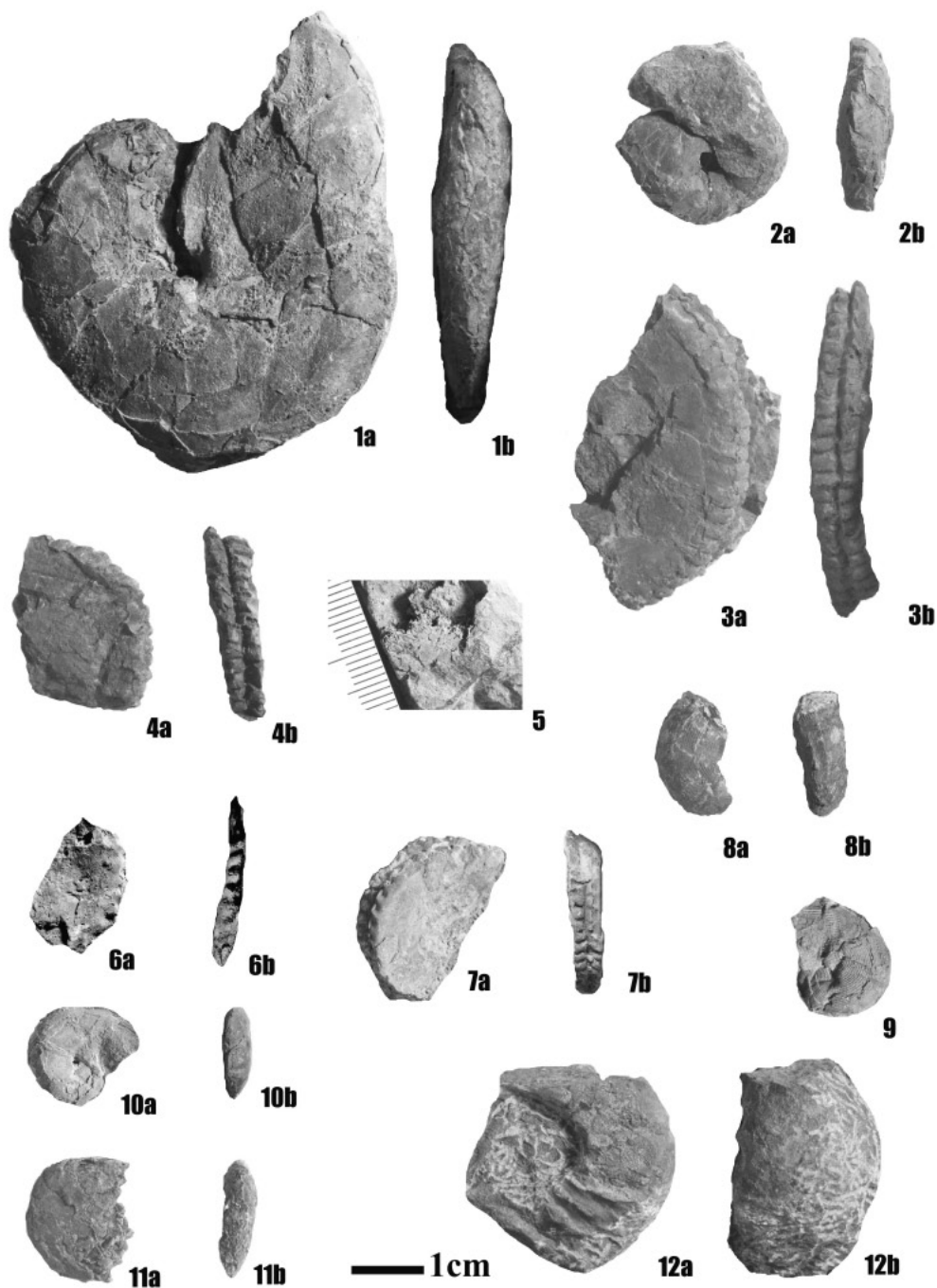
*Type species.*—*Thalassoceas mediterraneum phillipsi* Gemmellaro, 1887.

*Thalassoceras?* sp.

Figs. 4.1a-4.2b

*Material.*—Two laterally compressed and deformed specimens, FM-N201000040, FM-N201000041.

*Description.*—Shell medium to large for genus (Table 1). The lenticular conch is deformed laterally due to tectonic deformation. Moderately involute conch has very small umbilicus (The ratio of *U/D* is from 0.06 to 0.09). Whorl cross section is not precisely known by compression, but seems elliptical, higher than wide (*W/H* is from 0.42 to 0.77). Shell surface is smooth, and there is no ornamentation as ribs, tubercles or growth lamellae on lateral and ventral shell. Laterally flattened shell is broadly rounded, narrow venter rounded acutely but not angular. Ventral and umbilical shoulders are gently rounded, not ornamented or flared. The suture line is not preserved.



**Fig. 4.** 1-2. *Thalassoceras?* sp. (FM-N201000040, FM-N201000041), 3-7. *Artinskia* sp. (FM-N201000042, FM-N201000043, FM-N201000044, FM-N201000045, FM-N201000046), 8-11. *Agathiceras* sp. (FM-N201000047, FM-N201000048, FM-N201000049, FM-N201000050), 12. *Paragastrioceras?* sp. (FM-N201000051), lateral (a) and ventral (b) views. Scale bar shows 1 cm.



*Comparison.*—The Family Thalassoceratidae consists of *Gleboceras*, *Mapesites*, *Thalassoceras*, *Aristoceras*, *Aristoceratoides*, *Eothalassoceras*, *Epithalassoceras*, and *Prothalassoceras*. *Gleboceras* has wide whorl and venter gently rounded. *Mapesites* has subglobose conch and strong ribs and tubercles on surface of the shell. *Aristoceras* has deep grooves on ventrolateral shoulder. *Aristoceratoides* has wide whorl and ventrolateral grooves. *Eothalassoceras* has wide conch compare with *Thalassoceras*. *Epithalassoceras* and *Prothalassoceras* are distinguished from *Thalassoceras* by the wide umbilicus. So these specimens can be referred to *Thalassoceras*. However, it is insufficient to determine the genus name for the lack of the suture line. Therefore, we gave the genetic name questionably. The small umbilicus, broadly rounded lateral shell and lenticular conch of these specimens closely resembles to those of *Thalassoceras mediterraneum* (Leonova and Dmitriev, 1989, pl. 5, fig. 8) from the southeastern Pamirs and *T. gemmellaroi* (Ruzhencev, 1956, pl. 6, figs. 1-5) from the southern Urals. The lenticular conch of *T. wadei* (Miller, 1936, pl. 92, figs. 8-12) from the lower Ferruginous Series, western Australia, and *T. welleri* (Miller and Parizek, 1948, pl. 57, figs. 3-6) from the Hueco Formation, New Mexico, are also similar to these specimens.

*Measurements.*—See Table 1.

Suparfamily Agathicerataceae Arthaber, 1911

Family Agathiceratidae Arthaber, 1911

Genus *Agathiceras* Gemmellaro, 1887

*Type species.*—*Agathiceras suessi* Gemmellaro, 1887.

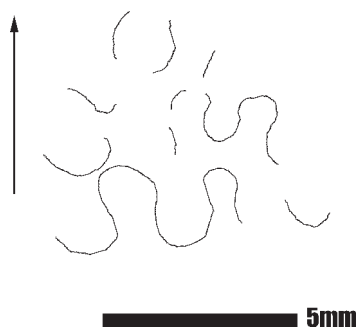
*Agathiceras* sp.

Figs. 4.8a-4.11b, 5

*Material.*—Four specimens. One fragmental body chamber, two partly compressed specimens, and one lateral mould, FM-N201000047, FM-N201000048, FM-N201000049, FM-N201000050.

*Description.*—Shell medium for genus, diameter of conch is from 16.1 mm to 17.0 mm (Table 1). The discoidal conch has fine longitudinal lirae, and three or four sinuous transverse constrictions on lateral shell. Conch strongly involute. The specimen FM-N201000049 has very small umbilicus ( $U=1.3$  mm,  $U/D=0.09$ ). Umbilicus of two of specimens (FM-N201000048, FM-N201000050) closed. Whorl cross section is gently rounded, almost ellipse shaped. There is no rib or tubercles on ventrolateral shoulder. The suture line (Fig. 5) shows the typical *Agathiceras*'s one, three broad saddles and lobes are presented. Lateral lobes and saddles broad, gently rounded, with pouched. Width of lobes and saddles seem almost same.

*Comparison.*—Family Agathiceratidae consists of *Agathiceras*, *Gaetanoceras* and ? *Pericleites*. *Gaetanoceras* and ? *Pericleites* distinguished from *Agathiceras* by lack of fine



**Fig. 5.** Suture line of *Agathiceras* sp. (FM-N201000050, Fig. 4.11).

longitudinal lirae. These specimens are identified as *Agathiceras*. However, these specimens are laterally compressed or lateral mould, so the thickness of conch is uncertain. It is insufficient to determine the species name. Therefore, we treat these specimens under the open nomenclature. The genus *Agathiceras* is one of the most famous goniatitid ammonoids and was established by Gemmellaro (1887) based on specimens from the Sosio beds of Sicily. It is an almost cosmopolitan genus, and is known to occur from the Lower Pennsylvanian to the Middle Permian. The present species of the genus *Agathiceras* might be similar particularly to the specimens from Takakurayama, Japan (Tazawa et al., 2005, fig.5, B-D), in having fine longitudinal lirae, thickly discoidal involute conch and very small umbilicus.

*Measurements.*—See Table 1.

Superfamily Gastriocerataceae Hyatt, 1884  
Family Paragastrioceratidae Ruzhencev, 1951  
Genus *Paragastrioceratas* Tchernow, 1907

*Type species.*—*Goniatites jossae* de Verneuil, 1845.

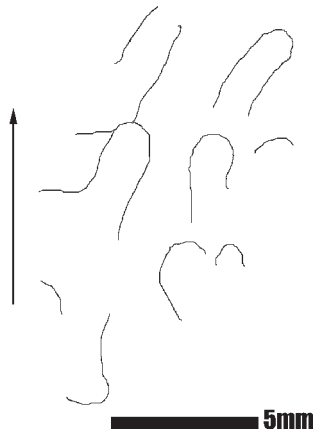
*Paragastrioceras?* sp.  
Figs. 4.12a-4.12b

*Material.*—One fragmental specimen, FM-N201000051.

*Description.*—Shell medium for genus (Table 1). The globular conch is evolute, and has wide umbilicus. U/D can be estimated 30-40%. Umbilical wall steep, umbilical shoulder rounded acutely. Whorl cross section seems almost circle, slightly wider than height ( $W/H=1.1$ ). Shell surface is smooth. Strong ribs are pronounced on umbilical shoulder, and transversely elongated. They gradually faded and fade out to ventrolateral shoulder. Venter and ventrorateral shoulder gently rounded. Growth line, reticulate sculpture and suture line is not preserved.

*Comparison.*—Five Paragastrioceratid genera, *Epijuresanites*, *Svetlanoceras*,





**Fig. 6.** Suture line of *Artinskia* sp.  
(FM-N201000044, Fig. 4.5).

*Synuraloceras*, *Tumaroceras*, and *Uraloceras*, are taxonomically close to *Paragastrioceras*. *Epijuresanites* and *Tumaroceras* have smooth shell and do not have the ornamentation. *Svetlanoceras* has numerous fine ribs on lateral shell. *Synuraloceras* has angular venter and fine growth lines. *Uraloceras* has fine longitudinal lirae and angular umbilical shoulder. Strong ribs and rounded wide whorl of this specimen might be determined as the genus *Paragastrioceras*. However, this specimen is fragment and the whole conch is uncertain. In addition, the suture line is not preserved. Therefore, we identified the genetic name with questionably. Many species of *Paragastrioceras* (Bogoslovskaya, 1976; Glenister and Furnish, 1961; Plummer and Scott, 1937; Nassichuk, 1971; Nassichuk et al., 1965; Ruzhencev, 1956; Teichert, 1942) are closely similar to this specimen on the strong ribs and evolute conch, nevertheless, it is difficult to compare some specimens (Hayasaka, 1947; Zhao and Zheng, 1977; Zhu and Sheng, 1988) with the present specimen for their poor photographs.

*Measurements.*—See Table 1.

Order Prolecanitida Miller and Furnish , 1954  
Superfamily Medlicottiaceae Karpinsky, 1889  
Family Medlicottidae Karpinsky, 1889  
Genus *Artinskia* Karpinsky, 1926

*Type species.*—*Goniatites falx* Eichwald, 1857.

*Artinskia* sp.  
Figs. 4.3a-4.7b, 6

*Material.*—Five specimens. All of them are fragmental, FM-N201000042, FM-N201000043, FM-N201000044, FM-N201000045, FM-N201000046.

*Description.*—Shell medium for genus (Table 1). The conch is involute and thinly discoidal.

Whorl cross section is rectangular, W/H is 0.45 (FM-N201000042). Umbilicus is closed. Shell surface is laterally smooth and so flat that almost parallel. The venter bears two rows of prominent nodes or short ribs toward the ventrolateral shoulder. The median groove on the venter separates those nodes. The suture line (Fig. 6) is poorly preserved in one specimen (FM-N201000044). Lateral saddles are narrow and high compare with width. The top of saddle is rounded. Ventral, ventrolateral, umbilical parts and lateral lobes are not preserved.

*Comparison.*—Genera of the Family Medlicottidae are cosmopolitan and are morphologically so close to each other. *Medlicottia*, *Eumedlicottia*, *Neogeoceras*, and *Syrdenites* are taxonomically close to *Artinskia*. *Medlicottia*, *Eumedlicottia*, and *Syrdenites* have concave venter without ventrolateral nodes. *Neogeoceras* has wide umbilicus. Therefore, these specimens are identified as *Artinskia*. However, to determine the species name, the suture line is so important in this case, therefore we should treat these specimens under the open nomenclature. *Artinskia artiensis*, *A. adkinsi*, *A. electraensis* (Plummer and Scott, 1937, pl. 4, figs. 1-4,6-21), *A. falx*, *A. hucoensis*, *A. electraensis* (Miller and Furnish, 1940, pl. 2, figs. 7, 8, pl. 3, figs. 1-3, pl. 4, figs. 3, 4), *A. adkinsi*, *A. liliana* (Miller and Youngquist, 1947, pl. 3, fig. 6-9), and other species are very similar on the thinly discoidal conch and two rows of prominent nodes on ventrolateral shoulder.

*Measurements.*—See Table 1.

### Acknowledgements

We would like to thank Jun-ichi Tazawa of Niigata City for valuable discussion during the course of this work, and Atsushi Matsuoka of the Department of Geology, Faculty of Science, Niigata University for critical reading of the manuscript.

### References

- Arthaber, G. V., 1911, Die Trias von Albanien. *Beitrage zur Paläontologie und Geologie Österreich-Ungarns und des Orients*, **24**, 169-277.
- Bogoslovskaya, M. F., 1976, Kungurian ammonoids from central Cisralia. *Paleont. Jour.*, no. 4, 417-424.
- Ehiro, M., 2008, Two genera of Popanoceratidae (Permian Ammonoidea) from the South Kitakami Belt, Northeast Japan, with a note on the age of the Takakurayama Formation in the Abukuma Massif. *Bull. Tohoku Univ. Mus.*, no. 8, 1-8.
- Eichwald, E., 1857, Beitrag zur geographischen Verbreitung der fossilen Thiere Russlands; Alte Periode. *Soc. Imp. Natur. Moscou Bull.*, **30**, 192-212.
- Furnish, W. M., Glenister, B. F., Kullman, J. and Zhou, Z., 2009, *Treatise on Invertebrate Paleontology, part L, Mollusca 4, revised, Volume 2, Carboniferous and Permian Ammonoidea (Goniatitida and Prolecanitida)*, Univ. Kansas, 1-258.
- Gemmellaro, G. G., 1887, La fauna dei calcari con Fusulina della valle del Fiume Sosio nella provincia di Palermo. *Gior. Sci. Nat. Econ.*, **19**, 1-106.
- Glenister, B. F. and Furnish, W. M., 1961, The Permian ammonoids of Australia. *Jour.*

- Paleont.*, **35**, 673-736.
- Hayasaka, I., 1947, A Permian cephalopod faunule from Chechiang Province, China. *Acta Geol. Taiwanica*, **1**, 12-38.
- Hayasaka, I., 1965, Some cephalopods in the Permian faunule of Takakura-yama, Fukushima Prefecture, Japan (with a note on the geology of the district, by I. Yanagisawa and M. Nomoto). *Trans. Proc. Palaeont. Soc. Japan, N. S.*, no. 57, 8-27.
- Hyatt, A., 1883-1884, Genera of fossil cephalopods. *Proc. Boston Soc. Natur. Hist.*, **22**, 253-338 (253-272 issued December 1883; 273-338 issued January 1884).
- Hyatt, A. 1900, Cephalopoda: in Zittel's *Text Book of Paleontology*, **1**, 502-604.
- Karpinsky, A. P., 1889, Über die Ammoneen der Artinsk-Stufe und einige mit denselben verwandte carbonische Formen. *Mém. Acad. Imp. Sci. St. Pétersbourg*, 7 *Séries*, **37**, 1-104.
- Karpinsky, A. P., 1926, On a new species of ammonoid of the family Medlicottinae; on the relationship between genera of the family, and on the ontogeny and phylogeny of Prolecanitidae: *Annuaire Soc. Pal. Russie*, **4**, 1-9.
- Leonova, T. B. and Dmitriev, V. Yu., 1989, Early Permian ammonoids of the southwestern Pamirs. *Doklady Akademii Nauk SSSR*, **235**, 1-198. (in Russian)
- Miller, A. K., 1936, A new Permian ammonoid fauna from western Australia. *Jour. Paleont.*, **10**, 684-688.
- Miller, A. K. and Furnish, W. M., 1940, Permian ammonoids of the Guadalupe Mountain region and adjacent areas. *Geol. Soc. Am., Spec. Pap.*, no. 26, 1-237.
- Miller, A. K. and Furnish, W. M., 1954, The classification of the Paleozoic ammonoids. *Jour. Paleont.*, **28**, 685-692.
- Miller, A. K. and Parizek, E. J., 1948, A Lower Permian ammonoid fauna from New Mexico. *Jour. Paleont.*, **22**, 350-358.
- Miller, A. K. and Youngquist, W., 1947, Lower Permian cephalopods from the Texas Colorado River Valley. *Univ. Kansas, Paleont. Contr., Mollusca, Article*, **1**, 1-15.
- Nassichuk, W. W., 1971, Permian ammonoids and nautiloids, southeastern Eagle Plain, Yukon Territory. *Jour. Paleont.*, **45**, 124-126.
- Nassichuk, W. W., Furnish, W. M. and Glenister, B. F., 1965, The Permian ammonoids of Arctic Canada. *Bull. Geol. Surv., Canada*, **131**, 1-56.
- Onuki, Y., 1966, Stratigraphy and structural geology of the Paleozoic Formations in the Yaguki and Takakurayama districts, Abukuma Massif, Fukushima Prefecture, Japan. *Prof. S. Matsushita Mem. Vol.*, 41-52. (in Japanese)
- Plummer, F. B. and Scott, G., 1937, The geology of Texas, Upper Paleozoic ammonites and Fusulinids. *Univ. Texas Bull.*, no. 3701, 1-516.
- Ruzhencev, V. E., 1951, Lower Permian ammonoids of the Southern Urals-1, Ammonoids of the Sakmarian Stage. *Doklady Akademii Nauk SSSR*, **33**, 1-188. (in Russian)
- Ruzhencev, V. E., 1956, Lower Permian ammonoid from southern Urals, 2. Artinskian Ammonoid Formation. *Doklady Akademii Nauk SSSR*, **60**, 1-271. (in Russian)
- Tazawa, J., 2008, Brachiopods from the Upper Permian Takakurayama Formation, Abukuma Mountains, northeast Japan. *Sci. Rep., Niigata Univ. (Geol.)*, no. 23, 13-53.
- Tazawa, J., Fujikawa, M., Zakharov, Y. D. and Hasegawa, S., 2005, Middle Permian ammonoids from the Takakurayama area, Abukuma Mountains, northeast Japan, and their stratigraphical significance. *Sci. Rep., Niigata Univ. (Geol.)*, no. 20, 15-27.
- Tchernow, A., 1907, L'étage d'Artinsk; I, Ammonoides des bassins de Jaiva, de Kosva, et de Tschousovaia. *Bull. Soc. Imp. Nat. Moscow, New Series*, **20**, 270-401.
- Teichert, C., 1942, Permian ammonoids from western Australia. *Jour. Paleont.*, **16**, 221-232.
- Verneuil, E. de., 1845, in Murchison, *Verneuil and Keyserling, Géologie de la Russie d'Europe et des Montagnes de l'Ural*, **2**, Paleontologie, 1-512.
- Yanagisawa, I., 1967, Geology and paleontology of the Takakurayama-Yaguki area,

- Yotsukura-cho, Fukushima Prefecture. *Sci. Rep., Tohoku Univ., 2nd Ser.*, **39**, 63-112.
- Yanagisawa, I. and Nemoto, M., 1961, On the Paleozoic formations of the Takakura-yama district, Abukuma Mountainland. *Jour. Geol. Soc. Japan*, **67**, 274-283. (in Japanese)
- Zhao, J. and Zheng, Z., 1977, The Permian ammonoids from Zhejiang and Jiangxi. *Acta Paleont. Sin.*, **16**, 217-254. (in Chinese)
- Zhou, Z., Glenister, B. F., Furnish, W. M. and Spinosa, C., 1999, Multi-episodal extinction and ecological differentiation of Permian ammonoids. In Rozanov, A. Y. and Shevurev, A. A., eds., *Fossil cephalopods: recent advances in their study*. Acad. Nauk. Moskva, 195-212.
- Zhu, G. and Sheng, H., 1988, Early Permian ammonoids from Hunggermiao of Abga Qi, Inner Mongolia. *Prof. Pap. Stratigr. Palaeont.*, no. 21, 65-78.