

## Middle Permian ammonoids from the Takakurayama area, Abukuma Mountains, northeast Japan, and their stratigraphical significance

Jun-ichi TAZAWA\*, Masayuki FUJIKAWA\*\*, Yuri D. ZAKHAROV\*\*\*  
and Satoshi HASEGAWA\*\*\*\*

### Abstract

Four ammonoid species, *Propinacoceras* sp., *Agathiceras* sp., *Mexicoceras?* sp. and *Roadoceras* sp., are described from the upper Takakurayama Formation in the Takakurayama area, Abukuma Mountains, northeast Japan. These ammonoids indicate a Middle Permian (Wordian) age. The Takakurayama ammonoid specimens are reworked fossils, probably derived from shallow marine continental shelf to a deep-sea basin by sediment-gravity flows in Late Permian.

*Key words:* Abukuma Mountains, ammonoid, Middle Permian, reworked fossil, Takakurayama Formation.

### Introduction

Permian rocks consisting chiefly of black shale with sandstone and conglomerate are distributed in the Takakurayama area, eastern Abukuma Mountains, i.e., Yaguki, Yotsukuramachi, Iwaki City, Fukushima Prefecture, northeast Japan (Fig. 1). The Permian section of the Takakurayama area was studied first by Iwao and Matsui in 1961 during mapping of the Taira 1: 50,000 Sheet, published by the Geological Survey of Japan. They recognized the occurrence of some Permian marine invertebrate fossils from around Mt. Takakurayama, and

---

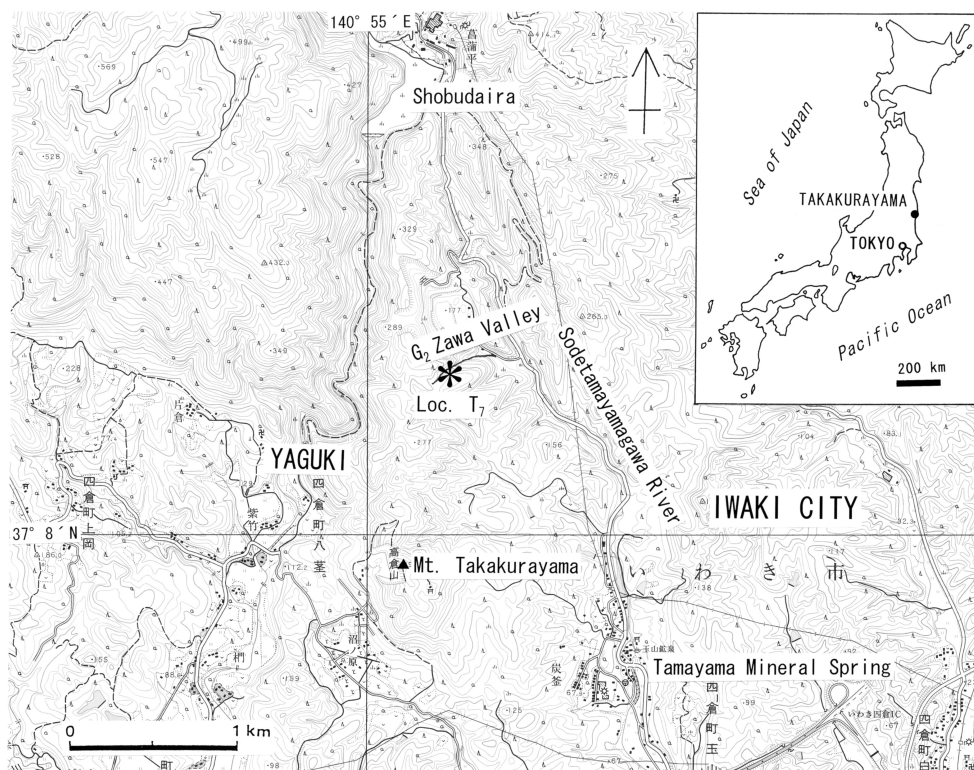
\* Department of Geology, Faculty of Science, Niigata University, Niigata 950-2181, Japan

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

\*\*\* Far Eastern Geological Institute, Russian Academy of Sciences, Vladivostok 690022, Russia

\*\*\*\* Kyushu Regional Office, Yachiyo Engineering Co., Ltd., Arato 2-1-5, Chuo-ku, Fukuoka 810-0062, Japan

(Manuscript received 20 January, 2005; accepted 14 February, 2005)



**Fig. 1.** Index map showing the fossil locality T<sub>7</sub>, in the Takakurayama area, eastern Abukuma Mountains. Using the topographical map of “Yotsukura” scale 1: 25,000 published by the Geographical Survey of Japan.

proposed the Takakurayama Series for the Permian rocks distributed in this area. In the same year but shortly later, Yanagisawa and Nemoto (1961) published their detail stratigraphical work on the Permian, in which they named the Permian as the Takakurayama Group and subdivided it into three formations, the Iriishikura, Motomura and Kashiwadaira Formations, in ascending order. Subsequently Onuki (1966) called the whole Permian rocks of the Takakurayama area as the Takakurayama Formation because of the predominance of black shale with some sandstone and conglomerate intercalations throughout the sequence. We follow the Onuki's opinion and use the term, Takakurayama Formation for the Permian sequence in the Takakurayama area.

Yanagisawa and Nemoto (1961) correlated the Takakurayama Group (=Takakurayama Formation) with the Lower to Middle Permian, lower to middle Maiya Group (Tachibana, 1952) of the Nagasaki area in the southern Kitakami Mountains. Onuki (1966) correlated the Takakurayama Formation with the Middle Permian Kanokura Formation (Onuki, 1937) of the

southern Kitakami Mountains. Yanagisawa (1967) correlated the Takakurayama Group with the Lower Permian Sakamotozawa Formation (Onuki, 1937) to the Upper Permian Toyoma Formation (Mabuti and Noda, 1934) in the southern Kitakami Mountains. Moreover, Ueno (1992) correlated the Takakurayama Group with the Middle Permian (upper Murgabian). The disagreement among the above four opinions is owing to their overlooking the nature of fossils, namely, the reworked fossils from the Takakurayama Formation.

Recently the fourth author (SH) studied the Permian section and made a 1: 10,000 scale geological map of the Takakurayama area in the course of his graduate thesis under supervision of the first author (JT). During the field survey, he collected some ammonoid specimens from sandy shale of the upper part of the Takakurayama Formation, cropped out at the locality T<sub>7</sub> (of Yanagisawa, 1967) in the G<sub>2</sub> Zawa Valley (named by Yanagisawa and Nemoto, 1961), a tributary of the Sodeyamayamagawa River in the Takakurayama area. Then the second and third authors (MF and YZ) studied the systematics of the Hasegawa's collection and another ammonoid specimen, collected from the same locality and housed in the Tohoku University, Sendai.

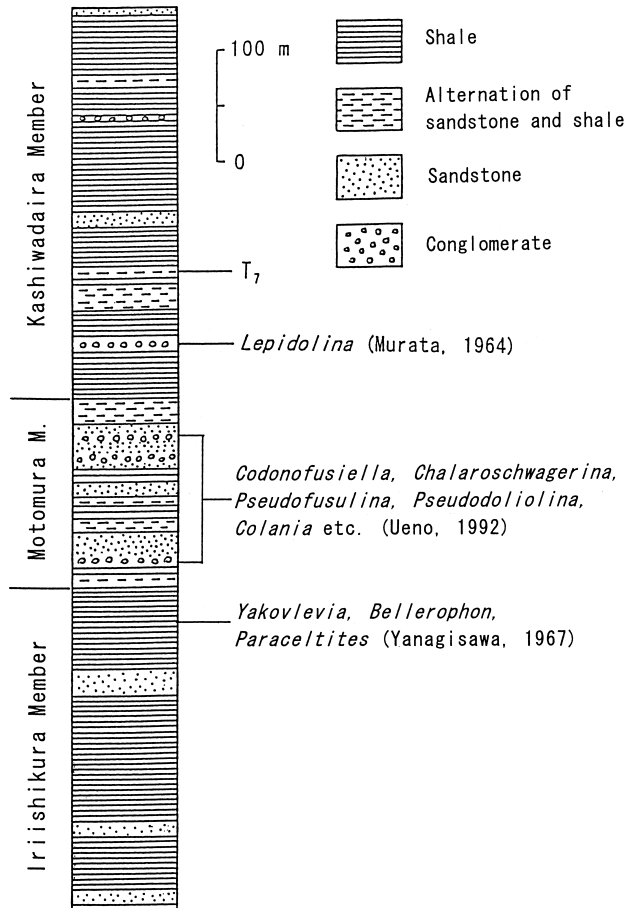
In this paper we describe four species of ammonoid from the locality T<sub>7</sub>, and discuss the ages of the ammonoid fauna and the Takakurayama Formation. The ammonoid specimens treated in this paper are reworked fossils, probably derived from shallow marine continental shelf to a deep-sea basin by sediment-gravity flows in Late Permian.

### **Stratigraphy**

(by JT and SH)

The Takakurayama Formation is exposed in the northeastern slope of Mt. Takakurayama, dipping 30-45° W and striking in a general NNE-SSW direction, and occupying the area of about 3 km<sup>2</sup>. It consists mostly of black shale with subordinate sandstone and conglomerate, more than 805 m in total thickness. This formation is subdivided into three members, 1) the Iriishikura Member, consisting mostly of shale with some sandstone beds, 290 m thick, 2) the Motomura Member, consisting mostly of sandstone and conglomerate with some shale beds, 167 m thick and 3) the Kashiwadaira Member, consisting mostly of shale with some sandstone and conglomerate beds, 348 m thick, in ascending order (Fig. 2). These three members are approximately equal to the Iriishikura, Motomura and Kashiwadaira Formations, established by Yanagisawa and Nemoto (1961), respectively. The ammonoid fossils studied herein were collected from sandy shale of the upper Takakurayama Formation (Kashiwadaira Member), about 570 m above the base of the formation at the locality T<sub>7</sub>. The Takakurayama Formation is intruded by the Cretaceous granitic rocks on the northeast, unconformably overlain by the Upper Cretaceous Futaba Group on the southeast, and contacts with fault the Lower Cretaceous intermediate volcanic rocks on the west.

It is noteworthy that the black shales of the Takakurayama Formation are quite similar in lithology to those of the Toyoma Formation (=Toyoma Series, Minato et al., 1979); and the



**Fig. 2.** Generalized columnar section of the Takakurayama Formation in the Takakurayama area.

conglomerates resemble the Usuginu-type conglomerate (Iwai and Ishizaki, 1966; Kano, 1971). Both of them are developed in the Upper Permian of the southern Kitakami Mountains, northeast Japan.

Permian marine invertebrates, such as fusulinaceans, smaller foraminifers, brachiopods, pelecypods, cephalopods and trilobites, furthermore land plants also have been described from the Takakurayama Formation, mostly from sandy shale of the upper part, the Kashiwadaira Member, at the locality T<sub>7</sub> by many authors (Hayasaka, 1957, 1965; Endo and Matsumoto, 1962; Yanagisawa, 1967; Nakazawa and Newell, 1968; Nakamura, 1972; Asama, 1974; Kobayashi and Hamada, 1984; Ueno, 1992; Tazawa, 1999).



## 2. Age and correlation of the Takakurayama Formation

Figure 2 shows the fossil horizons and their fossil contents. Yanagisawa (1967) reported the occurrence of a brachiopod *Linoproductus?* cf. *mammatus* (Keyserling) [=*Yakovlevia mammatiformis* (Fredericks) by Tazawa, 1999], a gastropod *Bellerophon* sp. and an ammonoid *Paracelites* aff. *elegans* Girty from shale of the Iriishikura Member at the locality T<sub>1</sub>, about 31 m below from the base of the Motomura Member. He correlated the Iriishikura Member with the Lower Permian Sakamotozawa Formation based on these fossils. The later two forms, however, occur also from the Kashiwadaira Member at the locality T<sub>7</sub> (Yanagisawa, 1967). Moreover, *Bellerophon* is common in the Upper Permian Toyoma Formation (Onuki, 1969, p. 68), and *Paracelites* has a stratigraphical range from the Roadian to Wuchiapingian (Zhou et al., 1999).

Ueno (1992) described 74 taxa of foraminifers including fusulinaceans, such as *Codonofusiella abukumaensis* Ueno, *Chalartoschwagerina vulgaris* (Schellwien), *Pseudofusulina fusiformis* (Schellwien), *Pseudodoliolina* cf. *ozawai* Yabe and Hanzawa and *Colania* sp., from limestone pebbles and sandy or muddy matrix of conglomerates in the Motomura Member, and correlated the conglomerates with the Middle Permian (upper Murgabian). However, the foraminifers indicating various ages from Artinskian to Wuchiapingian occur evidently as reworked fossils.

The Kashiwadaira Member, especially the sandstone-shale alternation at the locality T<sub>7</sub>, is highly fossiliferous. Hayasaka (1957, 1965) described the following 3 nautiloid and 8 ammonoid species from sandy shale at the locality T<sub>7</sub>: *Tainoceras abukumaense* Hayasaka, *Tainoceras* aff. *unklesbayeri* Miller and Youngquist, *Tylonautilus permicus* Hayasaka, *Propinacoceras* sp., Medlicottidae gen. et sp. indet., ?*Pseudogastrioceras* sp., *Agathiceras* cf. *suessi* Gemmellaro, *Stacheoceras* aff. *grünwaldti* Gemmellaro, *Popanoceras* sp. and *Waagenoceras* cf. *richthofeni* Miller and Furnish. He considered the age of the cephalopod fauna to be a Middle Permian (Sosioian). Asama (1974) described 8 species of land plants, including *Bicoemphleopteris hallei* Asama and *Gigantopteris nicotianaefolia* Schenk, from sandy shale at the locality T<sub>7</sub>, and correlated the Takakurayama flora with the Northern Cathaysian-type flora of the Upper Shihhotse Formation (upper Maokouan-Wuchiapingian) of Shanxi, north China. In this study, we confirmed the occurrence of the middle Middle Permian (Wordian) ammonoid fauna consisting of four species from the horizon T<sub>7</sub>. It is remarkable that a late Middle Permian (Capitanian) fusulinacean *Lepidolina multiseptata* (Deprat) occurs from a redeposited limestone block or limestone pebble of conglomerate in the lower Kashiwadaira Member, about 70 m below from the horizon T<sub>7</sub> (Murata, 1964) (see Fig. 2).

We, judging from the age and nature of occurrence of the above-sited fossils and the lithostratigraphy of the Takakurayama Formation, concluded that this formation is correlated with the Upper Permian Toyoma Formation in the southern Kitakami Mountains. Consequently the ammonoid specimens from the locality T<sub>7</sub>, as well as the almost all of the fossils hitherto

reported from the Takakurayama Formation, are probably reworked fossils, derived from shallow marine continental shelf to a deep-sea basin by sediment-gravity flows in the Late Permian. Concerning this conclusion, Yoshida and Machiyama (1997, 1998) suggested a similar Late Permian sedimentary environment in the South Kitakami region on the basis of their lithological and sedimentological studies on the Toyoma Formation and the Usuginu-type conglomerate.

### **Systematic palaeontology**

(by MF and YZ)

In the following descriptions, NU-CP indicates cephalopod specimens housed in the Department of Geology, Faculty of Science, Niigata University; IGPS indicates the Department of Geology and Palaeontology (now changed the name to the Department of Geoenvironmental Science), Faculty of Science, Tohoku University, Sendai.

Class Cephalopoda Cuvier, 1797  
Subclass Ammonoidea Zittel, 1884  
Order Prolecanitida Miller and Furnish, 1954  
Superfamily Medlicottioidea Karpinsky, 1889  
Family Medlicottidae Karpinsky, 1889  
Genus *Propinacoceras* Gemmellaro, 1887

*Propinacoceras* sp.

Fig. 5A

*Material*.—One ventral mould specimen, NU-CP5.

*Remarks*.—A single ventral mould specimen is available. The venter is almost flat, but bears two rows of transversely elongate nodes separated by prominent median groove. The elongate nodes and median groove of the present specimen are similar to those of *Propinacoceras* sp., described and figured by Hayasaka (1965, p. 15, pl. 2, figs. 1-2) from the upper Takakurayama Formation. The ventral nodes of Capitanian *Propinacoceras* sp., from the Ochiai Formation, southern Kitakami Mountains (Ehiro and Araki, 1997, p. 64, figs. 9.1-9.4), look lower than those of the present specimen. However, the comparison of these specimens is difficult because of their ill state of preservation.

Order Goniaticida Hyatt, 1884  
Suborder Goniaticina Hyatt, 1884  
Superfamily Goniaticaceae de Haan, 1825

## Family Agathiceratidae Arthaber, 1911

Genus *Agathiceras* Gemmellaro, 1887*Agathiceras* sp.

Figs. 5B-D

*Agathiceras* cf. *suessi* Gemmellaro: Hayasaka, 1965, p. 19, pl. 2, figs. 3-4; text-fig. 2;  
Yanagisawa, 1967, p. 100, pl. 1, fig. 16; pl. 3, fig. 4.

*Material*.—Three specimens, NU-CP3, NU-CP6, NU-CP7.

*Description*.—Shell medium in size, discoidal to subdiscoidal in outline, involute with narrow arched venter. Sides flattened. Umbilicus small, being 10 % or less of conch diameter; umbilicus border not distinct. Ornamentation represented by fine longitudinal lirae, with no marked radial constrictions. Both growth line and external suture-line absent.

*Remarks*.—*Agathiceras* is characterized by its discoidal conch, small umbilicus, fine longitudinal lirae and sinuous transverse constriction. Our specimens safely assigned to the genus *Agathiceras* in size, outline, and in having small umbilicus. These specimens are comparable with *Agathiceras* cf. *suessi* Gemmellaro, described by Hayasaka (1965) and Yanagisawa (1967) from the Kashiwadaira Member.

*Measurements*.—See Table 1.

**Table 1.** Measurements of *Agathiceras* sp., from the locality T<sub>7</sub>, upper Takakurayama Formation. Values in mm where applicable.

Register 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>
NU-CP3	8.2	4.5		0.8	0.55		0.10
NU-CP6	16.2	7.3	>2.0	1.0	0.45	>0.27	0.06
NU-CP7	18.6	9.0		2.0?	0.48		0.11?

*D*: diameter of conch, *H*: height of whorl, *W*: width of conch, *U*: diameter of umbilicus.

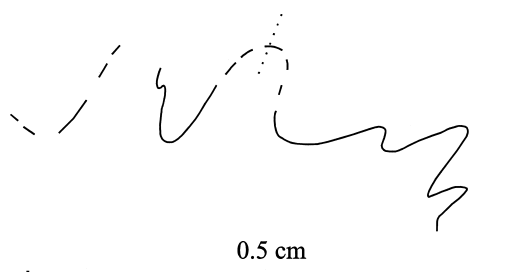
## Superfamily Cyclolobaceae Zittel, 1895

## Family Cyclolobidae Zittel, 1903

Genus *Mexioceras* Ruzhencev, 1955*Mexioceras*? sp.

Figs. 4, 5E





**Fig. 4.** Suture-line near the umbilical area of *Mexioceras?* sp., IGPS86629, from the locality T<sub>7</sub>, upper Takakurayama Formation in the Takakurayama area.

*Waagenoceras* cf. *dieneri* Böse: Yanagisawa, 1967, p. 100, pl. 3, fig. 13.

*Material.*—One specimen, IGPS86629.

*Description.*—Shell subglobular, involute. Umbilical shoulder abruptly rounded and vertical, with small umbilicus. Umbilicus being about 10% of conch diameter. Venter rounded. Concentric shallow groove on surface of shell. Both growth line and radial ornament absent. Suture-line near umbilical part consisting of series of small lobes and saddles (Fig. 4).

*Remarks.*—The present specimen was described and illustrated by Yanagisawa (1967, p. 100, pl. 3, fig. 13) as *Waagenoceras* cf. *dieneri* Böse. However, we review the morphological data and propose the specific name *Mexioceras?* sp. for this specimen. Identification with *Mexioceras* was made only in question on the basis of resemblance of the suture-line fragments from the near umbilical part of the shell, not for their characteristics as subglobular conch, fine concentric longitudinal lirae, and small umbilicus. Generally *Mexioceras* has involute, subglobular conch, therefore the conch proportion of our specimen also be close to the genus *Mexioceras*.

*Measurement.*—See Table 2.

**Table 2.** Measurement of *Mexioceras?* sp., from the locality T<sub>7</sub>, upper Takakurayama Formation. Values in mm where applicable.

Register 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>
IGPS86629	37.0	17.1		4.1	0.46		0.11

*D*: diameter of conch, *H*: height of whorl, *W*: width of conch, *U*: diameter of umbilicus.

Superfamily Gastriocerataceae Hyatt, 1884  
 Family Paragastrioceratidae Ruzhencev, 1951  
 Subfamily Pseudogastrioceratinae Furnish, 1966  
 Genus *Roadoceras* Zhou, 1985

*Roadoceras* sp.

Figs. 5F-G

*Material*.—Two specimens, NU-CP4, NU-CP13.

*Description*.—Shell discoidal, evolute, with arched venter and flattened sides. Umbilical border narrowly rounded, but distinct; umbilical wall steep and comparatively high; umbilicus reasonably wide. Ornamentation consisting of numerous strong spiral ribs. External suture-line not expressed.

*Remarks*.—The genus *Roadoceras* is characterized by its involute and discoidal shell, surface ornamentation of coarse spiral lines, and transverse ribs lacking in the early stage. Our fragment specimens are safely referred to *Roadoceras*, but the specific identification is difficult owing to their ill preservation. This genus is distributed in the Wordian and Capitanian of North America, Sicily, Far East Russia, China and Japan (Takakurayama). *Roadoceras subroadense* Zakharov and Pavlov, 1986 from the Capitanian Barabash Formation of western Primorye, Far East Russia differs from the Takakurayama species in having wider umbilicus and more flattened shell sides.

*Measurement*.—See Table 3.

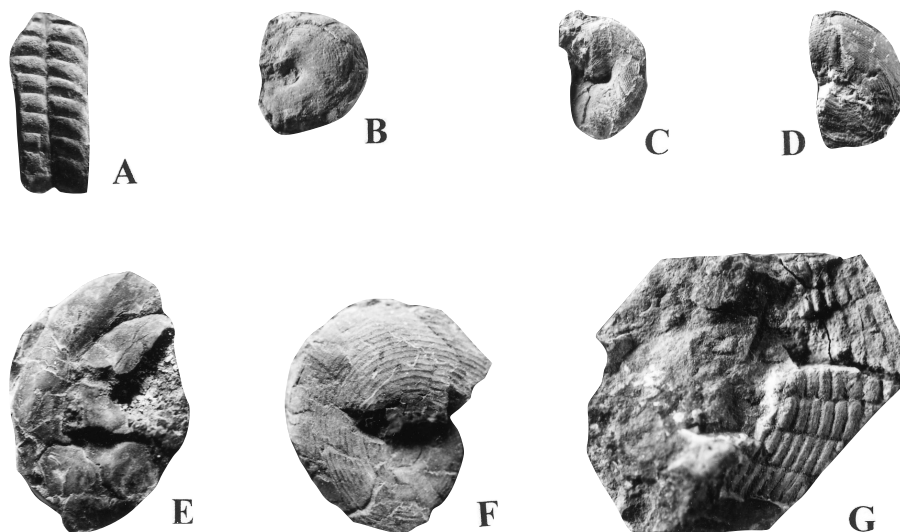
**Table 3.** Measurement of *Roadoceras* sp., from the locality T<sub>7</sub>, upper Takakurayama Formation. Values in mm where applicable.

Register 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>
NU-CP4	30.0	15.0	>8.0	8.0	0.5	>0.53	0.27

*D*: diameter of conch, *H*: height of whorl, *W*: width of conch, *U*: diameter of umbilicus.

### Acknowledgements

We are grateful to Jun Nemoto of the Department of Geoenvironmental Science, Tohoku University for loan of ammonoid specimens housed in the Tohoku University; Atsushi Matsuoka of the Department of Geology, Niigata University and Takeshi Ishibashi of Fukuoka City for critical reading of the manuscript.



**Fig. 5.** Permian ammonoids from the locality T<sub>7</sub>, upper Takakurayama Formation in the Takakurayama area. A: *Propinacoceras* sp., NU-CP5; B-D: *Agathiceras* sp., B: NU-CP3, ×2, C: NU-CP6, D: NU-CP7, E: *Mexicoceras*? sp., IGPS86629, F, G: *Roadoceras* sp., F: NU-CP4, G: NU-CP13. All figures are in natural size unless otherwise indicated.

### References

- Asama, K., 1974, Permian plants from Takakurayama, Japan. *Bull. Nat. Sci. Mus. Tokyo*, no. 3, 239-250.
- Arthaber, G.V., 1911, Die Trias von Albanien. *Beitr. Paläont. Geol., Öst-Ung. u. Orients*, **24**, 169-277.
- Cuvier, G., 1797, *Tableau Élémentaire de l'Histoire Naturelle des Animaux*. Paris, 710 p.
- Ehiro, M., 1998, Ammonoid biostratigraphy of the Middle Permian in the South Kitakami Belt, Japan and correlation with the reference sections in the Tethyan region and North America. *Proc. Roy. Soc. Vic.*, **110**, 147-156.
- Ehiro, M. and Araki, H., 1997, Permian cephalopods of Kurosawa, Kesenuma City in the southern Kitakami Massif, northeast Japan. *Paleont. Res.*, **1**, 55-66.
- Endo, R. and Matsumoto, E., 1962, Permo-Carboniferous trilobites from Japan. *Sci. Rep., Saitama Univ. Ser. B*, **4**, 149-172.
- Furnish, W.M., 1966, Ammonoids of the Upper Permian *Cyclolobus*-Zone. *N. Jb. Geol. Paläont., Abh.*, **125**, 265-296.
- 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., Furnish, W.M., Zhou, Z. and Polahan, M., 1990, Ammonoid cephalopods from the Lower Permian of Thailand. *Jour. Paleont.*, **64**, 479-480.

- Haan, G. de, 1825, *Monographie ammoniteorum et goniatiteorum*, 168 p.
- Hayasaka, I., 1957, Two Permian nautiloids from Takakura-yama near Yotsukura-machi, Fukushima Prefecture (Abukuma Plateau region), Japan. *Sci. Rep., Yokohama Nat. Univ.*, *Sec. 2*, no. 6, 21-30.
- 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 Ichiro Yanagisawa and Mamoru Nemoto). *Trans. Proc. Palaeont. Soc. Japan, N. S.*, no. 57, 8-27.
- Hyatt, A., 1884, Genera of fossil cephalopods. *Proc. Boston Soc. Nat. Hist.*, **22**, 273-338.
- Iwai, J. and Ishizaki, K., 1966, A preliminary study on the Usuginu type conglomerate —With special reference to its paleogeographical and structural significance—. *Contr., Inst. Geol. Paleont. Tohoku Univ.*, no. 62, 35-53. (in Japanese)
- Iwao, S. and Matsui, H., 1961, *Explanation text of the geological map of Japan, scale 1: 50,000, "Taira and Kawamae (incl. Ide)"*. Geol. Surv. Japan, Kawasaki, 103 p. (in Japanese)
- Kano, H., 1971, Studies on the Usuginu conglomerates in the Kitakami Mountains—Studies on the granite-bearing conglomerates in Japan, no. 22—. *Jour. Geol. Soc. Japan*, **77**, 415-440. (in Japanese)
- Karpinsky, A.P., 1889, Über die Ammoneen der Artinsk-Stufe und einige mit denselben verwandte Carbonische Formen. *Mém. Acad. Imp. Sci. St. Pétersbourg, Sér. 7*, **37**, 1-104.
- Kobayashi, T. and Hamada, T., 1984, Permian trilobites of Japan in comparison with Asian, Pacific and other faunas. *Palaeont. Soc. Japan, Spec. Pap.*, no. 26, 1-92.
- Mabuti, S. and Noda, M., 1934, On the Palaeozoic formations of the southern Kitakami Mountainland. *Jour. Geol. Soc. Japan*, **41**, 401-403. (in Japanese)
- Miller, A.K. and Furnish, W.M., 1954, The classification of the Paleozoic ammonoids. *Jour. Paleont.*, **28**, 685-692.
- Minato, M., Hunahashi, M., Watanabe, J. and Kato, M., 1979, *Variscan geohistory of northern Japan: The Abean Orogeny*. Tokai Univ. Press, Tokyo, 427 p.
- Murata, M., 1964, Geological age of the Kanokura Formation in the southern part of the Kitakami Massif, northeast Japan. *Saito Ho-on Kai Mus. Res. Bull.*, no. 33, 17-29.
- Nakamura, K., 1972, *Anidanthus* and *Megousia* (Brachiopoda) from the Permian of Japan and Cambodia. *Jour. Fac. Sci., Hokkaido Univ., Ser. 4*, **15**, 427-446.
- Nakazawa, K. and Newell, N.D., 1968, Permian bivalves of Japan. *Mem. Fac. Sci., Kyoto Univ., Ser. B*, **35**, 1-108.
- Onuki, Y., 1937, On the Palaeozoic formation near Sakamotozawa, Kitakami Mountainland. *Jour. Geol. Soc. Japan*, **44**, 168-186. (in Japanese)
- 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)
- Onuki, Y., 1969, Geology of the Kitakami Massif, northeast Japan. *Contr., Inst. Geol. Paleont. Tohoku Univ.*, no. 69, 1-239. (in Japanese)
- Ruzhencev, V.E., 1951, Nizhnepermiskie ammonoidei Yuzhnogo Urala, 1. Ammonoidei Sakmarogo yarusa. *Tr. Paleont. Inst., Acad. Sci. USSR*, **33**, 1-188. (in Russian)
- Ruzhencev, V.E., 1955, O semejstve Cyclolobidae Zittel. *Doklady, Acad. Sci., USSR*, **103**, 701-703. (in Russian)
- Tachibana, K., 1952, On the Tobigamori Group of the Nagasaka district, Kitakami Mountainland. *Jour. Geol. Soc. Japan*, **58**, 353-360, 445-455. (in Japanese)
- Tazawa, J., 1999, Boreal-type brachiopod *Yakovlevia* from the Middle Permian of Japan. *Palaeont. Res.*, **3**, 88-94.
- Ueno, K., 1992, Permian foraminifers from the Takakurayama Group of the southern Abukuma Mountains, northeast Japan. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, no. 168, 1265-1295.

- 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)
- Yoshida, K. and Machiyama, H., 1997, The sedimentary environment of the Permian Daido Formation in the South Kitakami Terrane, northeast Japan. *Commem. Vol. Prof. M. Kato*, 261-273. (in Japanese)
- Yoshida, K. and Machiyama, H., 1998, Middle Permian coarse clastics in the western marginal area of the South Kitakami Terrane. *Jour. Geol. Soc. Japan*, **104**, 71-89. (in Japanese)
- Zakharov, Yu.D. and Pavlov, A.M., 1986, Permian cephalopods of the Primorye region and the problem of Permian zonal stratification in the Tethys. In Zakharov, Yu.D. and Onoprienko, Y.I., eds, *Correlation of Permo-Triassic sediments of the East USSR*. DVNCAN SSSR, Vladivostok, 5-32. (in Russian)
- Zhou, Z., 1985, Several problems on the Early Permian ammonoids from South China. *Palaeontologia Cathayana*, no. 2, 179-209.
- 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 Shevyrev, A.A., eds., *Fossil cephalopods: recent advances in their study*. Acad. Nauk, Moskva, 195-212.
- Zittel, K.A.von, 1884, *Cephalopoda. Handbuch der Paläontologie, Abt. 1*. Oldenbourg, Minich u. Leipzig, 329-522.
- Zittel, K.A.von, 1895, *Grundzüge der Paläontologie (Paläozoologie), Ed. 1*. München, 386-435.
- Zittel, K.A.von, 1903, *Grundzüge der Paläontologie (Paläozoologie), Abt. 1, Invertebrata, Ed. 2*. München u. Berlin, 398-468.