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Middle Permian orthoconic nautiloids from the Takakurayama Formation in the Yaguki area, Fukushima Prefecture, Northeast Japan

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Abstract: Four species of orthoconic nautiloids belonging to the orders Orthocerida and Pseudorthocerida are described from the Wordian (middle Permian) Kashiwadaira Member of the Takakurayama Formation, Northeast Japan. They are *Geisonoceras*? sp., *Iwakiella ichiroi* Hatai, Kotaka and Noda, 1972, *Pseudorthoceras*? sp., and *Bitaunioceras* sp. Our observations of the newly acquired two specimens of *I. ichiroi* have resulted in addition to the generic diagnosis, especially in natures of the annulations and surface ornamentation of the adult shells and the septal characters.

Introduction

A thick sequence of the Permian clastic rocks in the Yaguki area, Fukushima Prefecture, Northeast Japan is assigned to the Takakurayama Formation (Iwao and Matsui, 1961; Onuki, 1966), in which three stratigraphic units, namely the Iriishikura, Motomura and Kashiwadaira Members in ascending order, are recognized (Yanagisawa and Nemoto, 1961; Yanagisawa, 1967). Following Ehiro (2008, 2022), that were described ammonoids and coiled nautiloids, the present study focuses on orthoconic nautiloids belonging to the orders Orthocerida and Pseudorthocerida occur in the Wordian (middle Permian) Kashiwadaira Member as the third fascicle. Detailed geologic setting and locality information of the examined specimens herein are referable in the preceding papers.

Repository.— All specimens described in this study and the holotype of *Iwakiella ichiroi* Hatai, Kotaka and Noda, 1972, are reposited in the Tohoku University Museum, Sendai (prefixed IGPS).

Systematic paleontology

Subclass Nautiloidea Agassiz, 1847
Order Orthocerida Kuhn, 1940
Family Geisonoceratidae Zhuravleva, 1959
Genus ***Geisonoceras*** Hyatt, 1884
Type species.— *Orthoceras rivale* Barrande, 1866.

Geisonoceras ? sp.
Figures 1.A, 1.B

Description.— A single external mold of fragmentary and strongly deformed specimen was available for study; it is longiconic orthocone with 38 mm in length and very gradual conch expansion; reconstructed conch diameter as circular cross section is 7 mm. Surface ornamentation consists of transverse narrow bands; adjacent bands divided by striae; subtriangular salients developed; no internal structure preserved.

Material examined.— IGPS coll. cat. no. 112740.

Occurrence.— Lower part of the Kashiwadaira Member at B-valley (T_1 locality).

Discussion.— The poorly preserved specimen is questionably placed in *Geisonoceras* on the basis of its gross conch shape and characteristic ornamentation consisting of the narrow bands and striae.

Family Sphaerorthoceratidae Ristedt, 1968
Genus ***Iwakiella*** Hatai, Kotaka and Noda, 1972
Type species.— *Iwakiella ichiroi* Hatai, Kotaka and Noda, 1972.

Emended diagnosis.— Annulated orthocone with gradual conch expansion; initial chamber spherical; annulations oblique and closely spaced in juvenile shell; spacings of annulations become slightly wider in adult shell including body chamber; interspaces of annulations nearly flat; longitudinal surface lirae restrictedly occur in juvenile shell; oblique lirae developed in interspaces of annulations; camerae relatively short.

Discussion.— Because the type and only included species, *Iwakiella ichiroi*, of the genus was monotypic, its generic diagnosis was previously based only on the holotype

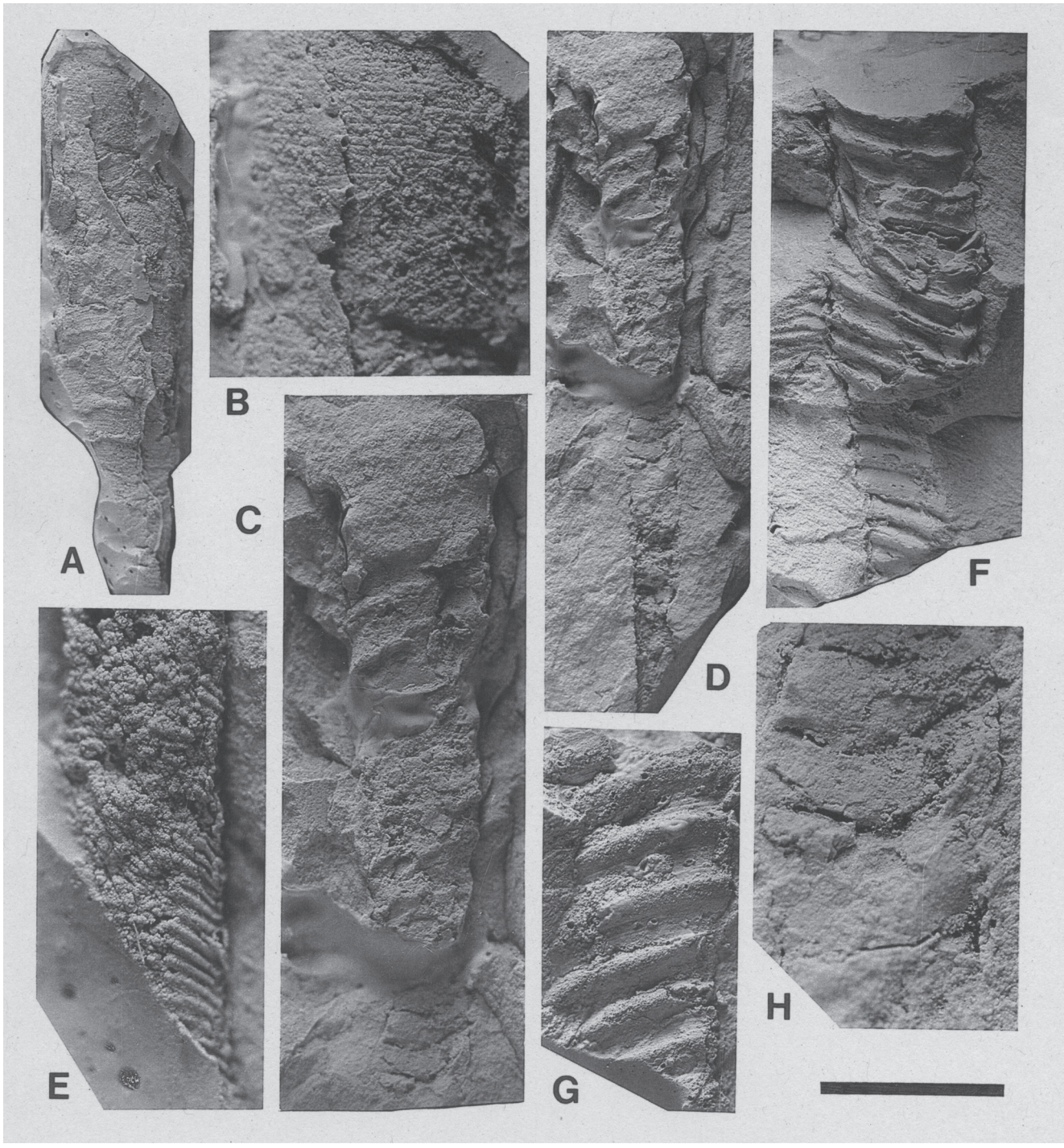

Figure 1. A, B. *Geisonoceras*? sp. IGPS coll. cat. no. 112740. A, silicone rubber cast, side view: B, partial enlargement of A to show details of surface ornamentation. **C–H.** *Iwakiella ichiroi* Hatai, Kotaka and Noda, 1972. C–E, H, IGPS coll. cat. no. 112737; C, partial enlargement of D to show details of surface ornamentation at adoral shell; D, side view; E, silicone rubber cast prepared from apical shell, showing details of annulations and surface ornamentation; H, partial enlargement of D to show details of septa: F, G. IGPS coll. cat. no. 86628; F, side view; G, silicone rubber cast prepared from apical shell, showing details of annulations and surface ornamentation. Scale bar is 12 mm in A, D, F; 3 mm in B, E, H; 7.5 mm in C; 6 mm in G.

(IGPS coll. cat. no. 86669). Furthermore, internal structure of the holotype was mostly unknown. The study has resulted in emendation for the diagnosis on the basis of knowledges derived from the following two newly acquired specimens. A specimen (IGPS coll. cat. no. 112737) reveals that the holotype is the juvenile shell and natures of the adult shell and the septa. Another specimen (IGPS coll. cat. no. 86628) provides data of the body chamber.

Similar annulations with *Iwakiella* also appear rarely in other Late Paleozoic genera, such as *Cycloceras* M'Coy (1844; type species, *C. laevigatum* M'Coy, 1844; see Histon, 1991), *Lopingoceras* Shimansky *in* Ruzhentsev *et al*. (1962; type species, *Orthoceras lopingense* Stoyanow, 1910), and *Neocycloceras* Flower and Caster (1935; type species, *N. obliquum* Flower and Caster, 1935). Although *Cycloceras* clearly differs *Iwakiella* from in its strongly concave and non-ornamented interspaces of the annulations, the generic distinctions between *Iwakiella*, *Lopingoceras* and *Neocycloceras* are undeterrable at present because of their insufficient morphological informations. Solution of the problems is beyond the purposes of this study.

Iwakiella ichiroi Hatai, Kotaka and Noda, 1972
Figures 1.C–1.H

[?] *Cycloceras* sp., Yanagisawa and Nemoto, 1961, p. 282.
Michelinoceras? sp., Yanagisawa, 1967, p. 98, pl. 4, fig. 9.
Tentaculites sp., Yanagisawa, 1967, p. 104, pl. 3, fig. 7.
Iwakiella ichiroi Hatai, Kotaka and Noda, 1972, p. 2–5, text-fig.; Niko, 2022, p. 229, 230, figs. 1.1–1.6.

Description.— Conchs are longiconic and annulated orthocones with gradual conch expansion; in examined two specimens herein, apex and adoral body chamber including peristome are not preserved; a specimen of deformed phragmocone (IGPS coll. cat. no. 112737) has 45 mm in length, 1.7 mm in reconstructed diameter as circular conch section near apical end, 4.5 mm in ditto near adoral end, and approximately 4.5° in reconstructed expansion angle; length of another specimen of distorted body chamber (IGPS coll. cat. no. 86628) is 33 mm. Annulations well-developed throughout and oblique; in apical (= juvenile) shell, they are closely spaced, 6 in conch length of 2 mm, and possess rounded crests; then, their spacings become slightly wider with 2–3 annulations in conch length 5 mm and shapes of crests shift to rounded triangular in adult shell; approximate angles of annulations per transverse plane of shell in these deformed specimens range from 20° to 30°; interspaces of annulations are nearly flat. Surface ornamentation consists of very fine longitudinal lirae, that are restricted in apical shell, and oblique ones developed in interspecies of annulations and parallel with these. Septal curvatures moderate; camerae relatively short for the family and indicate approximate form ratio (width/length) of 3; sutures, siphuncle and deposits are not observable.

Material examined.— IGPS coll. cat. nos. 86628, 112737.

Occurrence.— Middle part of the Kashiwadaira Member at G_2-valley (T_7 Locality).

Discussion.— Apical shell morphologies of a new specimen (IGPS coll. cat. no. 112737) are identical with the juvenile shell characters of the holotype, that was erroneously assigned to *Tentaculites* (see Niko, 2022). In addition, its annulation shape in the adoral shell is reasonably well with that of another specimen (IGPS coll. cat. no. 86628) representing the body chamber. The latter specimen was described by Yanagisawa (1967) as *Michelinoceras*? sp., but the presence of annulations in this specimen clearly excludes it from the genus *Michelinoceras* Foerste, 1932, whose type species, *Orthoceras michelini* Barrande, 1866, has non-annulated conch.

Cycloceras sp. in Yanagisawa and Nemoto (1961) may be conspecific with this species, but it remains undescribed.

Order Pseudorthocerida Barskov, 1963
Superfamily Pseudorthoceratoidea Flower and Caster, 1935
Family Pseudorthoceratidae Flower and Caster, 1935
Subfamily Pseudorthoceratinae Flower and Caster, 1935
Genus ***Pseudorthoceras*** Girty, 1911
Type species.— *Orthoceras knoxense* McChesney, 1859.

Pseudorthoceras? sp.
Figures 2.A–2.C

Description.— Conchs are longiconic orthocones with moderate conch expansion and relatively large; a specimen of imperfect phragmocone (IGPS coll. cat. no. 112735) attains 87 mm in length and has 9 mm in reconstructed diameter as circular cross section near apical end, 15 mm in ditto near adoral end, and approximately 5.5° in reconstructed expansion angle. Conch surface lacks distinct ornamentation. Very shallow septa form roughly transverse sutures; cameral length is short having form ratios (reconstructed width/length) of 2.4–4.7; no siphuncle preserved.

Material examined.— IGPS coll. cat. nos. 112735, 112738.

Occurrence.— Middle part of the Kashiwadaira Member at G_2-valley (T_7 Locality).

Discussion.— The smooth conch surface and short camerae of the Takakurayama species may suggest it to be *Pseudorthoceras*. Furthermore, there is a possibility that the species is conspecific with *P. ouchii* Endo and Mori (1969, p. 112, 113, fig. 1) because the holotype of the latter species was collected also from G_2-valley in the Yaguki area. The preservations of the examined two specimens, however,

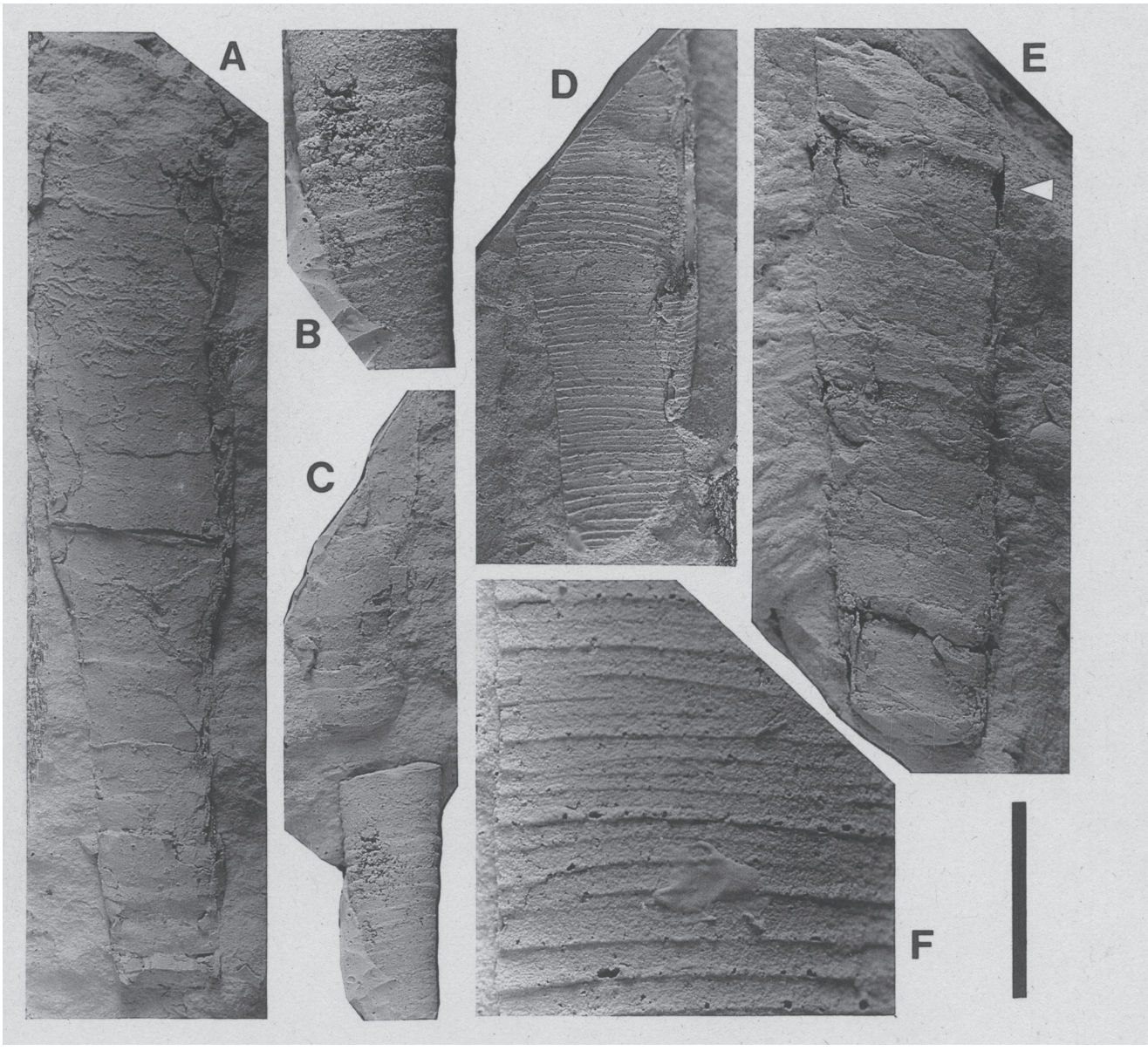

Figure 2. A–C. *Pseudorthoceras*? sp. A, IGPS coll. cat. no. 112735, silicone rubber cast, side view: B, C, IGPS coll. cat. no. 112738; B, partial enlargement of C to show details of sutures; C, silicone rubber cast, shell wall mostly peeling off, side view. **D–F.** *Bitaunioceras* sp. D, F, IGPS coll. cat. no. 112739; D, silicone rubber cast, side view; F, partial enlargement of D to show details of surface ornamentation: E, IGPS coll. cat. no. 112736, side view, arrow indicates constriction at peeled part of shell wall. Scale bar is 20 mm in A, C; 12 mm in B, D, E; 3 mm in F.

are incomplete to enough for the generic and specific identifications.

Mooreoceras sp. indet. described by Ouchi (1971, p. 135, pl. 1, figs. 1a–h) from G_2-valley is similar in its gross conch shape and cameral length to *Pseudorthoceras*? sp., from which it is separated by the presence of cancellate surface ornamentation.

Subfamily Spyroceratinae Shimizu and Obata, 1935

Genus ***Bitaunioceras*** Shimizu and Obata, 1936

Type species.— *Orthoceras bitauniense* Haniel, 1915.

Bitaunioceras sp.
Figures 2.D–2.F

Description.— Conchs are longiconic orthocones with gradual conch expansion; a fragmentary and deformed specimen (IGPS coll. cat. no. 112736) has 51 mm in length, 6 mm in reconstructed diameter as circular cross section near apical end, 8 mm in ditto near adoral end, and approximately 3° in reconstructed expansion angle. Surface ornamentation consists of transverse and slightly distant lirae that frequently form shallow salients; internal mold of conch marked by relatively deep, transverse and periodic constrictions provided by thickening of shell walls. Septum shallow; suture and siphuncle are not observable.

Material examined.— IGPS coll. cat. nos. 112736, 112739.

Occurrence.— Middle part of the Kashiwadaira Member at G_2-valley (T_7 Locality).

Discussion.— The distinctive constrictions formed by inward shell wall thickening of this species are exclusively for *Bitaunioceras*. Although 11 species of the genus have been reported from Italy (Gemmellaro, 1890), East Timor (Haniel, 1915), Mexico (Miller, 1944), the southern Urals in Russia (Shimansky, 1954), Texas (Miller and Youngquist, 1947) and Oklahoma (Niko *et al*., 2018) in North America, and Japan (Niko and Nishida, 1987), the present *B*. sp. is not complete to enough for comparisons with these previously known species.

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