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4. Late Gzhelian (Carboniferous) to early Asselian (Permian) non-ammonoid cephalopods from the Taishaku Limestone Group, Southwest Japan

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Abstract. The non-ammonoid cephalopod fauna described here was collected from the upper Gzhelian-lower Asselian (Upper Carboniferous to Lower Permian) hydrozoan-algal buildups in the Taishaku Limestone Group, Southwest Japan. The fauna consists of four orthocerids: *Michelinoceras*? sp., *Bogoslovskya miharanoroensis* sp. nov., *Geisonocerina*? sp., *Lopingoceras hayasakai* sp. nov.; two nautilids: *Parachouteauoceras bingoense* gen. et sp. nov., *Parachouteauoceras*? sp.; and a bactritid: *Bactrites* sp. *Parachouteauoceras* is most similar to *Chouteauoceras*, but unlike the latter has a lobated aperture. The occurrence of *Bogoslovskya miharanoroensis* represents one of the latest records of the genus in the world. This fauna is important because it adds some new data to a poorly known Late Carboniferous-Early Permian non-ammonoid cephalopod fauna.

Key words: Asselian, Bactritida, Gzhelian, Nautilida, Orthocerida, Taishaku Limestone Group

Introduction

The non-ammonoid cephalopods of the Taishaku Limestone Group, Southwest Japan, were first noticed by Hayasaka and Nishikawa (1963) who reported the orthocerid species *Orthoceras* cf. *adrianense* Gemmellaro in an oral presentation (Koizumi, 1975). Of the fauna, only three specimens were kept back for future examination. Recent studies, as described by Niko *et al.* (1993), show that the specimens are referable to a bactritid and represent a new species, *Aktastioceras nishikawai.* An additional seven species belonging to the Orthocerida, Nautilida and Bactritida are described and figured herein from the upper Gzhelian to lower Asselian part of the Taishaku Limestone Group. This report adds some new data to a poorly known non-ammonoid cephalopod fauna in the vicinity of the Carboniferous-Permian boundary, and will provide a basis for future biostratigraphic and paleobiogeographic studies.

All specimens used for the study are housed in the paleontological collections of the Department of Earth and Planetary Sciences, Nagoya University (ESN).

Geologic setting and occurrence

The Taishaku Limestone Group, located in the northeastern part of Hiroshima Prefecture, is a thick Carboniferous to Permian greenstone-limestone sequence occurring in the Akiyoshi Terrane in the Inner Zone of Southwest Japan. Hase *et al.* (1974) conducted a detailed facies analysis of the Taishaku Limestone Group and interpreted that it was formed as a table reef complex on the submarine volcanic mound. In Miharanoro, Hiba-gun, Hiroshima Prefecture (Figure 1), Upper Carboniferous to Lower Permian hydrozoan-algal reef complexes are well developed, forming a reef core facies in the Taishaku Limestone Group. The Upper Carboniferous to Lower Permian sequence of the Taishaku Limestone Group in Miharanoro is divided into the following six fusulinacean zones (Ozawa and Hirakawa, MS): in ascending order, these are the *Triticites ozawai-Carbonoschwagerina morikawai* Zone, *Triticites contractus* Zone, *Pseudoschwagerina muongthensis* Zone, *Pseudoschwagerina miharanoensis* Zone, *Pseudofusulina vulgaris* Zone, and *Pseudofusulina kraffti* Zone. The stratigraphic horizon of *Aktastioceras nishikawai* belongs to the *Pseudoschwagerina miharanoensis* Zone, indicating a late Asselian age. On the other hand, fossil localities of the present non-ammonoid cephalopods are in the *Triticites contractus* Zone, which coincides with the *Carbonoschwagerina minatoi-Daixina* cf. *robusta* Zone (upper Gzhelian) and the *Sphaeroschwagerina fusiformis* Zone (lower Asselian) of the Akiyoshi Limestone Group (Ozawa and Kobayashi, 1990).

The cephalopods described herein were collected by the

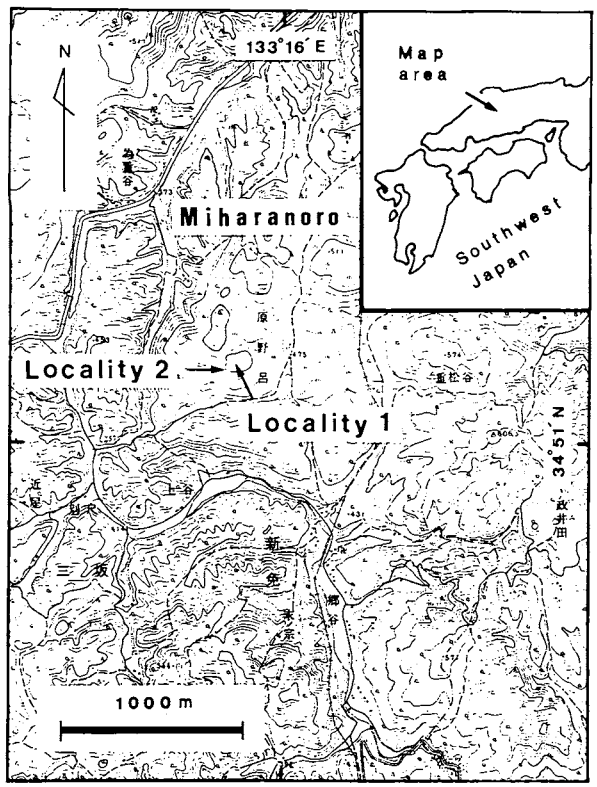


Figure 1. Part of topographic map "Tojo", 1:25,000 quadrangle of Geographical Survey Institute, showing fossil localities in Miharanoro, Hiroshima Prefecture.

junior author from bioclastic limestones in channellike depressions of the *Triticites contractus* Zone. In the channel-fill sediments, they occurred along with ammonoids, gastropods, pelecypods, brachiopods, and foraminifers.

Systematic paleontology

Class Cephalopoda Cuvier, 1797
Subclass Nautiloidea Agassiz, 1847
Order Orthocerida Kuhn, 1940
Superfamily Orthocerataceae M'Coy, 1844
Family Orthoceratidae M'Coy, 1844
Subfamily Michelinoceratinae Flower, 1945
Genus ***Michelinoceras*** Foerste, 1932

Type species.—*Orthoceras michelini* Barrande, 1866.

Michelinoceras ? sp.

Figures 2-14—16

Description.—Smooth-surfaced orthocones with gradual shell expansion, circular cross section; largest specimen (ESN 2593) of phragmocone 3.9 mm in adoral diameter; sutures straight, transverse; siphuncle central, composed of orthochoanitic necks and cylindrical connecting rings.

Discussion.—This description is based on three poorly preserved phragmocones of probably immature portions. Judging from the siphuncular structure, they may represent a species of *Michelinoceras.* However, there is no denying the possibility that the specimens are apical shells of associated *Geisonocerina* ? sp. (this report) until better material is recovered.

Material and occurrence.—ESN 2593-2595 from Locality 1.

Genus ***Bogoslovskya*** Zhuravleva, 1978

Type species.—*Bogoslovskya perspicua* Zhuravleva, 1978.

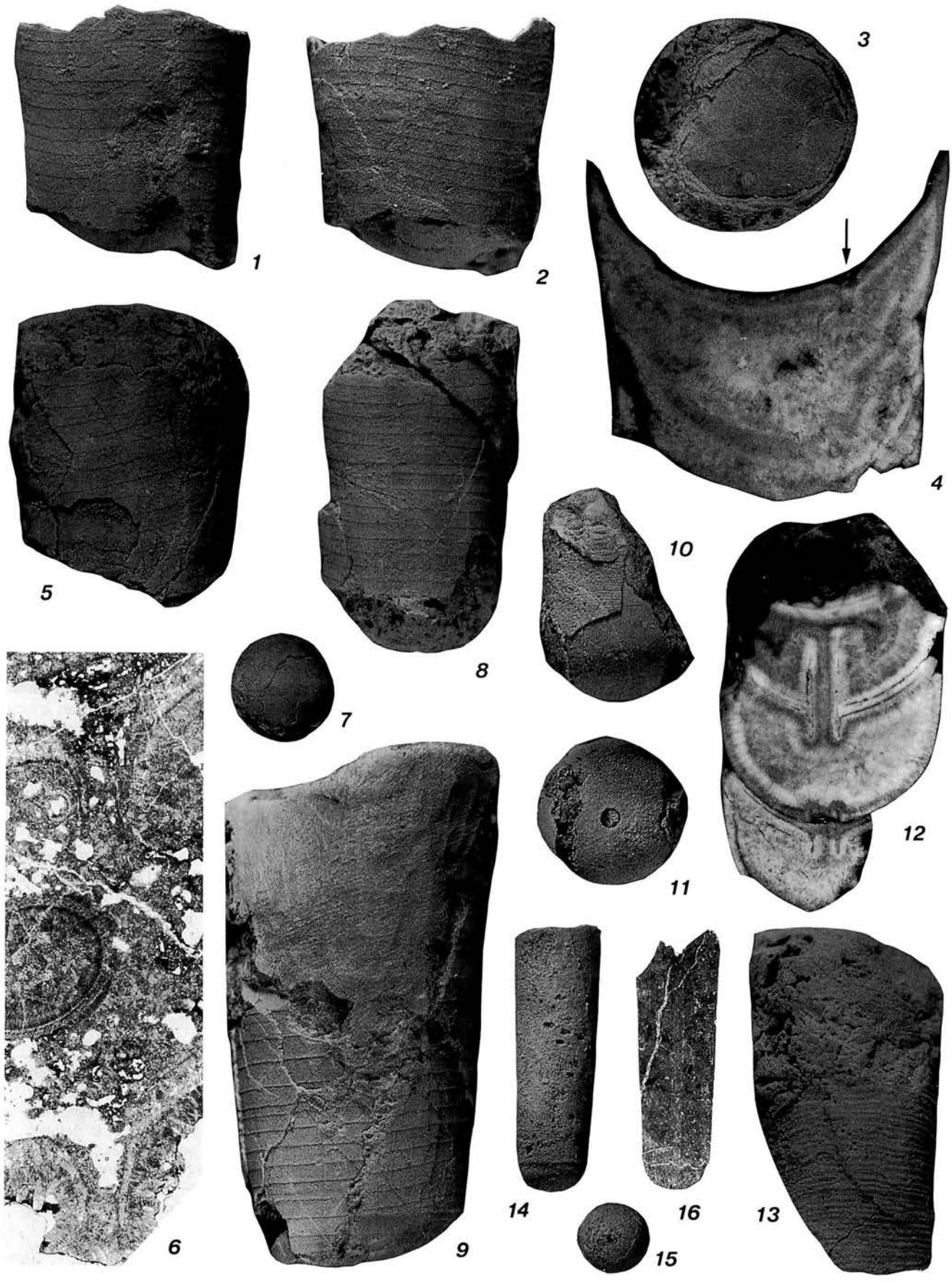
Bogoslovskya miharanoroensis sp. nov.

Figures 2-1—9

Diagnosis.—Species of relatively large *Bogoslovskya* with distant, very narrow ribs; cameral ratio approximately 3-4; siphuncular position midway between center and margin in adoral shell.

Description.—Shells relatively large for genus, orthoconic with circular cross section, largest specimen (ESN 2590) of phragmocone reaches approximately 25 mm in diameter; angle of shell expansion moderate, 4-5 degrees; surface ornamentation consists of distant, very narrow ribs, weakly sinuate, slightly toward aperture on antisiphuncular side, rib index (number of ribs per length of corresponding shell diameter) 13-17, interribs space flat, smooth; septa moderately deep forming straight, transverse sutures; cameral length short for genus, cameral ratio (diameter/length) 3.2-4.1; siphuncle very narrow, maximum external diameter of septal neck/shell diameter 0.03 in holotype, siphuncular position submarginal, but shifts midway between center and margin in adoral shell, minimum distance of siphuncular axis from shell surface per shell diameter in dorsoventral section 0.19 in immature shell (9.5 mm in diameter) of paratype (ESN 2589), increases to 0.26 adorally (20 mm in diameter); length of septal necks moderately long for genus, approximately 1.8 mm at shell diameter of 21 mm, gently tapering orthochoanitic with weak auxiliary deposits in funnel-shaped septal foramen; connecting rings not preserved; no camer-

Figure 2. 1-9. *Bogoslovskya miharanoroensis* sp. nov., 1-4: holotype, ESN 2586, 1, side view of siphuncular side, ×2, 2, lateral view, siphuncular side on right, ×2, 3, septal view of apical end, ×2, 4, dorsoventral polished section, arrow indicates siphuncular position, ×3, 5, 6: paratype, ESN 2587, 5, lateral view, siphuncular side on left, ×2, 6, dorsoventral thin section, details of siphuncular structure, note auxiliary deposits, ×10, 7: paratype, ESN 2589, septal view of apical end, ×2, 8: paratype, ESN 2591, lateral view, siphuncular side on right, ×2, 9: paratype, ESN 2590, lateral view, siphuncular side on left, ×2. **10-13.** *Geisonocerina* ? sp., 10-12: ESN 2596, 10, side view, ×2, 11, septal view, ×2, 12, longitudinal polished section, ×3, 13: ESN 2597, side view, ×2. **14-16.** *Michelinoceras* ? sp., ESN 2593, 14: side view, ×4, 15: septal view of apical end, ×4, 16: longitudinal thin section, ×4.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al deposits detected.

Discussion.—The possession of surface ribs of *Bogoslovskya miharanoroensis* sp. nov. clearly distinguishes it from all other known species of the genus. The range of *Bogoslovskya* was previously restricted to the Middle to Late Devonian of the Urals (Zhuravleva, 1978) and the Middle Carboniferous of the Akiyoshi Limestone Group (Niko *et al*., 1995). Thus, this late Gzhelian to early Asselian species represents the youngest record of the genus.

Etymology.—The specific name is derived from the type locality name Miharanoro.

Material and occurrence.—Holotype, ESN 2586, incomplete phragmocone, 22.5 mm in length; five paratypes, ESN 2587-2591, incomplete phragmocones, are surely, and a specimen, ESN 2592, is questionably, assigned to this species. All specimens from Locality 1.

Family Geisonoceratidae Zhuravleva, 1959
Genus ***Geisonocerina*** Foerste, 1935

Type species.—*Orthoceras wauwatosense* Whitfield, 1882.

Geisonocerina ? sp.

Figures 2-10—13

Description.—Orthocones with gradual shell expansion, circular cross section; surface ornamentation consists of distinct transverse lirae, adorally indicating weak sinuations; largest specimen (ESN 2597) of phragmocone reaches approximately 16 mm (reconstructed) in diameter; septa thick, deeply concave, forming straight, transverse sutures; siphuncle central; septal necks long, orthochoanitic, but slightly dilated terminally; connecting rings cylindrical.

Discussion.—This description is based on two fragmentary phragmocones. They are not sufficiently well preserved to identify more precisely, but lack of periodic thickening of the lirae suggests this species probably belongs to *Geisonocerina* rather than *Geisonoceras* Hyatt, 1884.

Material and occurrence.—ESN 2596, 2597. In addition, a specimen (ESN 2598) is questionably assigned to this species. All specimens from Locality 1.

Superfamily Pseudorthoceratacea Flower and Caster, 1935
Family Pseudorthoceratidae Flower and Caster, 1935
Subfamily Spyroceratinae Shimizu and Obata, 1935
Genus ***Lopingoceras*** Shimanskiy in Ruzhentsev, 1962

Type species.—*Orthoceras lopingense* Stoyanow, 1909.

Lopingoceras hayasakai sp. nov.

Figures 3-1—7

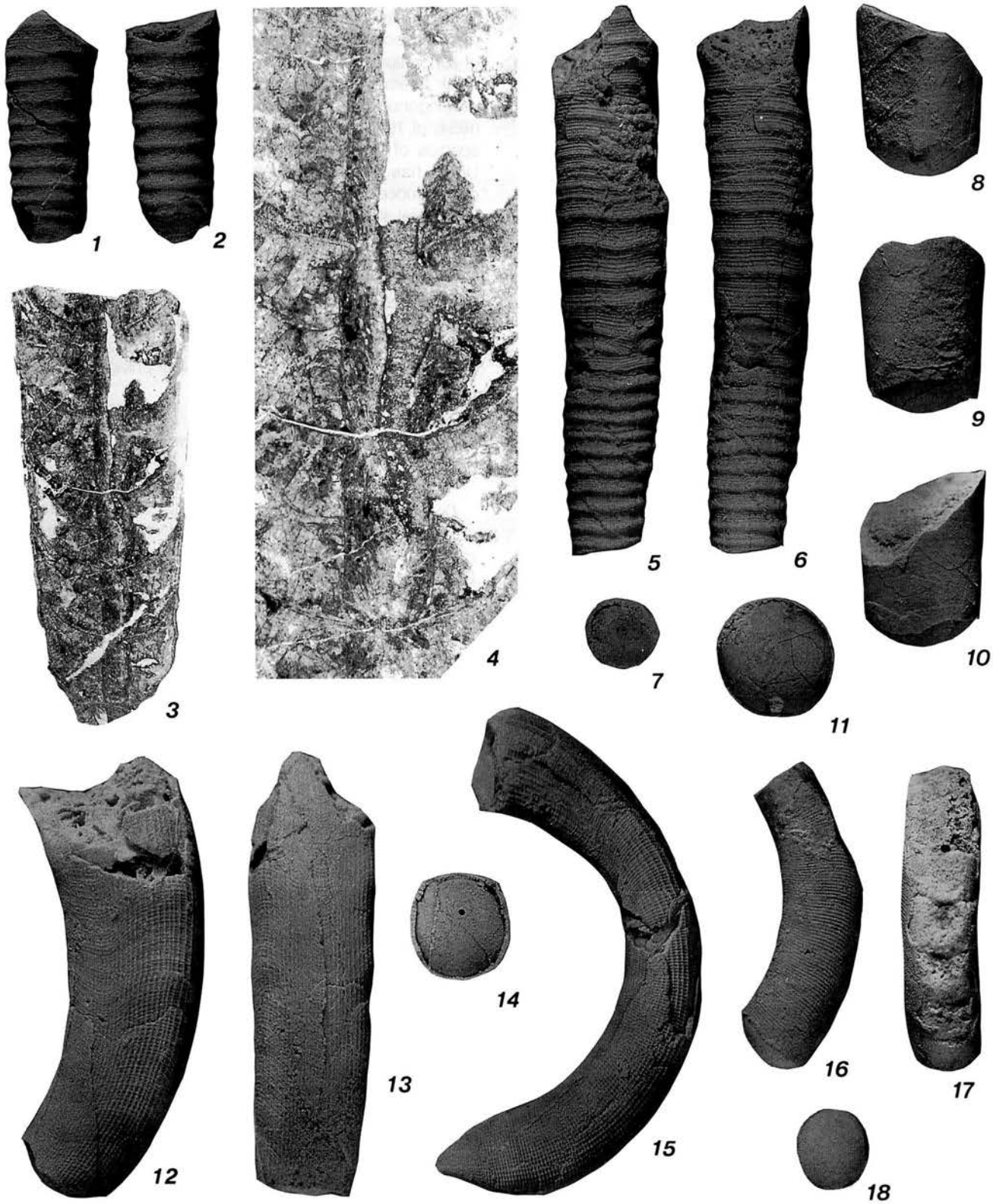
Diagnosis.—Annulated orthocones with conspicuous surface lirae, annulations have subangular profile; cameral deposits episeptal-mural, hyposeptal; endosiphuncular deposits form continuous lining.

Description.—Annulated orthocones with gradual shell expansion, angle approximately 3-4 degrees; cross section of shell circular; largest specimen (ESN 2600) of phragmocone reaches approximately 10 mm (reconstructed) in diameter; annulations relatively low, subangular profile in longitudinal section, bearing weak lateral sinus; annulations and interspaces of annulations ornamented by conspicuous lirae that run parallel with annulation, salient forms over injured portion of shell as repaired; sutures straight, transverse; septal curvature moderate, cameral ratio approximately 2.2 in holotype; there are usually two annulations in single camera; siphuncle subcentral, shifts slightly dorsally from center, septal necks short, suborthochoanitic to weakly cyrtochoanitic, 0.45 mm in length in holotype, connecting rings subcylindrical with constrictions at septal foramen and weak dorsal inflations, maximum external diameter of connecting rings/shell diameter in each segment of holotype approximately 0.2; cameral deposits episeptal-mural, hyposeptal; endosiphuncular deposits well developed, form thick continuous lining on siphuncular wall, thicker in venter than dorsum.

Discussion.—Generic assignment of the species is tentative at present. A combination of surface annulations and conspicuous lirae relates the form to *Reticycloceras* Gordon, 1960, but the possession of hyposeptal deposits in the species clearly separates them. *Lopingoceras* Shimanskiy in Ruzhentsev (1962) is based on an Upper Permian species from Dzhul'fa, of which species has an annulated orthocone. The distinguishing feature of *Lopingoceras* is angularity of outline of annulations, and the present species shears this morphology. Although the structure of deposits is unknown in the generic type species, we consider that the present species probably belongs to *Lopingoceras*.

Shimanskiy (1954, pl. 7, figs. 6a-v) referred a species from the lower Asselian of the southern Urals to *Cycloceras laevigatum* M'Coy (1844, pl. 2, fig. 3), which was described from the Lower Carboniferous of Ireland. With the exception of a somewhat larger angle of shell expansion (approximately 6 degrees), the Russian species is very likely closely related to *Lopingoceras hayasakai* sp. nov. *Cycloceras* was defined on an internal mold of a body chamber by M'Coy

Figure 3. 1-7. *Lopingoceras hayasakai* sp. nov., 1-4: holotype, ESN 2599, 1, ventral view, ×2, 2, lateral view, venter on right, ×2, 3: dorsoventral thin section, venter on left, note subangular profile of annulations, ×4, 4, details of siphuncular structure, note thick continuous lining of endosiphuncular deposits, ×10, 5-7: paratype, ESN 2600, 5, lateral view, venter on right, ×2, 6, dorsal view, ×2, 7, septal view of apical end, venter down, ×2. **8-11.** *Bactrites* sp., ESN 2607, 8: ventral view, ×2, 9: lateral view, venter on right, ×2, 10: dorsal view, ×2, 11: septal view of apical end, venter down, ×2. **12-15.** *Parachouteauoceras bingoense* gen. et sp. nov., 12-14: holotype, ESN 2601, 12, lateral view, note color markings through ammonium chloride coating, ×3, 13, ventral view, ×3, 14, septal view of apical end, venter up, ×3, 15: paratype, ESN 2602, lateral view with complete embryonic shell, ×3. **16-18.** *Parachouteauoceras* ? sp., ESN 2604, 16: lateral view, ×3, 17: ventral view, ×3, 18: septal view of apical end, venter up, ×3.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(1844), thus the diagnosis of the genus calls for nothing further than an annulated orthocone with low angles of expansion. Sweet (1964) properly stated that "no species other than the type species should be referred to *Cycloceras* until its type is better known". This problem is still unsolved.

Etymology.—The specific name refers to the late Dr. Ichiro Hayasaka, a pioneer in the study of the Paleozoic nautiloids of Japan.

Material and occurrence.—Holotype, ESN 2599, incomplete phragmocone, 20.1 mm in length; paratype, incomplete phragmocone, ESN 2600. Both from Locality 2.

Order Nautilida Agassiz, 1847
Superfamily Trigonocerataceae Hyatt, 1884
Family Trigonoceratidae Hyatt, 1884
Genus ***Parachouteauoceras*** gen. nov.

Type species.—*Parachouteauoceras bingoense* sp. nov.

Diagnosis.—Like *Chouteauoceras* but differs in possession of lobed peristome with linguiform ventral sinus, ventrolateral saddle, dorsolateral sinus, dorsal saddle.

Etymology.—The generic name is derived from the Greek *para*, meaning near, and *Chouteauoceras*.

Parachouteauoceras bingoense sp. nov.

Figures 3-12—15

Diagnosis.—As for the genus.

Description.—Loosely coiled, gyrocones losing contact; whorl section weakly compressed, width/height ratio ranges from 0.90 to 0.97 in holotype, venter and flanks slightly convex with subangular ventral shoulders, dorsum broadly rounded; adoral end of body chamber of holotype reaches 8.6 mm in height; embryonic shell weakly inflated in dorsoventral direction, with cone-shaped primary shell; most inflated portion of embryonic shell 5.3 mm in height, 4.7 mm in width, giving a ratio of 0.89; surface ornamentation consists of numerous longitudinal ridges and growth lines; growth lines nearly transverse, producing a latticework in embryonic shell; later growth lines indicate lobed peristome of deep linguiform ventral sinus, rounded ventrolateral saddle, shallow dorsolateral sinus, broadly rounded dorsal saddle; sutures transverse with broadly rounded lateral lobes, dorsal and ventral saddles; siphuncle small, subcentral, slightly shifts to venter; preserved color markings consist of 7 or 8 relatively wide bands, which run parallel with peristome, in ventral shoulder to ventrolateral position on holotype.

Discussion.—The gyroceraconic shells with a compressed whorl section, the longitudinal surface ridges, and rounded lateral lobes in the sutures of *Parachouteauoceras bingoense* gen. et sp. nov. suggest a relationship to the trigonoceratid genus *Chouteauoceras* Miller and Garner, 1953. *Chouteauoceras* is a rare genus which embraces the type species *C. americanum* (Miller and Furnish, 1938, pl. 48, figs. 4-6) from Missouri and some other species questionably assigned to the genus from North America, Belgium and Ireland. All occurrences are in the Lower Carboniferous. *Parachouteauoceras* can be distinguished from *Chouteauoceras* by its peristome shape. The growth lines of *Chouteauoceras* indicate a transverse peristome with weak lateral saddles.

Apogonoceras remotum Ruzhentsev and Shimanskiy (1954, pl. 11, figs. 8a, 8b; only known species and the type species of the genus) from the Artinskian of the southern Urals has a shell shape generally similar to *Parachouteauoceras bingoense,* but has nearly straight sutures in the adoral shell and a somewhat subtriangular whorl section. The peristome shape of *Apogonoceras* is unknown.

Etymology.—The specific name is derived from Bingo, which is the historic province name of the region in which the type locality lies.

Material and occurrence.—Holotype, ESN 2601, incomplete phragmocone with apical body chamber, 25.5 mm in length; two paratypes, ESN 2602, 2603, apical phragmocones. All specimens from Locality 2.

Parachouteauoceras ? sp.

Figures 3-16—18

Description.—Loosely coiled juvenile phragmocones losing contact; whorl section compressed, ovoid, width/height ratio 0.90; shell height reaches 4.9 mm in largest specimen ESN 2604; surface ornamentation consists of weak longitudinal ridges and growth lines indicating ventral sinus; sutures nearly transverse; siphuncle subcentral.

Discussion.—This species is represented by two fragmentary phragmocones of juvenile portion. The specimens differ from *Parachouteauoceras bingoense* gen. et sp. nov. (this report) in smaller shell size in the corresponding shell portion. The lack of adult shells of this species leaves doubt upon assignment to *Parachouteauoceras.*

Material and occurrence.—ESN 2604, 2605 from Locality 1.

Subclass Bactritoidea Shimanskiy, 1951
Order Bactritida Shimanskiy, 1951
Family Bactritidae Hyatt, 1884
Genus ***Bactrites*** Sandberger, 1843

Type species.—*Bactrites subconicus* Sandberger, 1843.

Bactrites sp.

Figures 3-8—11

Description.—Orthocones with gradual shell expansion, angle approximately 3.5 degrees, circular cross section; largest specimen (ESN 2607) of phragmocone reaches 11.5 mm in diameter; transverse lirae of surface ornamentation slightly sinuate, very fine, closely spaced; sutures straight, transverse with ventral lobe, siphuncle relatively large, ventral margin in position.

Discussion.—This species resembles most closely *Bactrites costatus* Mapes (1979, pl. 31, figs. 7-9, 13) from the upper Virgilian of Texas in having closely spaced surface lirae. *Bactrites costatus* differs from the present species in

its larger angle (5-7 degrees) of shell expansion.

Material and occurrence.—Based on two phragmocones: ESN 2606 from Locality 1, and ESN 2607 from Locality 2.

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Bingo 備後, Hiba-gun 比婆郡, Miharanoro 三原野呂, Taishaku 帝釈, Tojo 東城