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Ordovician cephalopods from the Maggol Formation of Korea

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Abstract. **A cephalopod fauna consisting of 11 species belonging to 7 genera is described from the Lower Ordovician Maggol Formation near Taebaeg City in South Korea. The fauna includes two new species, *Ormoceras weoni* and *Michelinoceras cancellatum*, and *Wutinoceras*, a primitive genus of the family Actinoceratidae first reported from South Korea. *Ormoceras cricki* from the Middle Ordovician Duwibong Formation occurs in the uppermost horizon of the Maggol Formation, and thus may be regarded as a forerunner of the ormocerids in Korea.**

The Maggolian cephalopod fauna comprising *Wutinoceras robustum, Kogenoceras nanpiaoense*, and *Manchuroceras* spp. shows closest affinities with those from the Setul Limestone of the Langkawi Islands, Malaysia and from the Beianzhuang Formation of Hwangho Basin, North China. This fauna is, therefore, assigned in age to the late Ibexian to early Whiterockian in the American Early Ordovician scale.

Key words: cephalopod fauna, lower Whiterockian, Maggol Formation, Ormoceratidae, upper Ibexian, Korea

Introduction

Kobayashi (1927) first described seven cephalopod species from the Ordovician of South Korea, including *Kotoceras grabaui* from the Middle Ordovician Maggol Formation. In a subsequent monograph (Kobayashi, 1934), the stratigraphic occurrences of these species were reassigned to the overlying Middle Ordovician Jigunsan Formation.

Cephalopod fossils seldom occur in the Maggol Formation. They are commonly found as partial phragmocones whose internal structures are difficult to recognize because of recrystallization. Despite such generally unfavorable fossil preservation, more than fifty well preserved cephalopod specimens have been recently collected from the Maggol Formation of Sanaegol, Taebaeg City, Kangweondo, Korea (Figure 1).

This paper describes the cephalopod fauna of the formation based mainly on newly collected material in addition to Kobayashi's (1927) type and figured specimens. Comparison with contemporary faunas from other regions is also given in this paper, with discussion of the biostratigraphic and paleobiogeographic implications of the Maggol fauna.

All specimens described herein are housed in the Department of Earth Science, Teachers College, Kyungpook National University (prefix KPE), Taegu, Korea.

Geological setting

The Maggol Formation was originally named by Kobayashi (1927) for a limestone formation "the Great Limestone Group" exposed near the village "Maggol", at the Sangdong Scheelite Mine, Sangdong, Yeongweol. The formation extends from east to west in the southern limb region of the Baegunsan Syncline where the Duwibong type Joseon Supergroup is widely distributed. The formation ranges from 250 m to 400 m in thickness.

The Maggol Formation conformably overlies the Dumugol Formation and is overlain by the Jigunsan Formation. Almost complete sequence of the formation is exposed along the Sanaegol Section, 7 km southwest of Hwangjidong in Taebaeg City (Figure 1). In this section, the lower part of the formation is barren of macrofossils. Cephalopod fossils were found in two stratigraphic units, the middle-upper and uppermost parts of the formation (Figure 2).

Lithologic components of the formation consist of bioturbated limestone, well bedded limestone and bioclastic limestone with frequent intercalations of dolomite and dolomitic limestone. Flat pebble conglomerates are included in the lower part of the formation, but they were not observed in the section examined. The boundary between the underlying Maggol and overlying Jigunsan Formations was observed at a small waterfall, about 1.5 km upstream along the valley from Sanaegol village. The lithic facies at this place shows an abrupt change from bioclastic grainstone consisting mostly of öolitic particles to calcareous black shale. Based on the general compostion and sedimentary structures such as desiccation cracks, ripple marks, bird's-eye structures, and bioturbation, Paik (1985, 1987, 1988) suggested tidal flats as the depositional environments of the Maggol Formation. Cephalopod fossils were collected mainly from the bioclastic

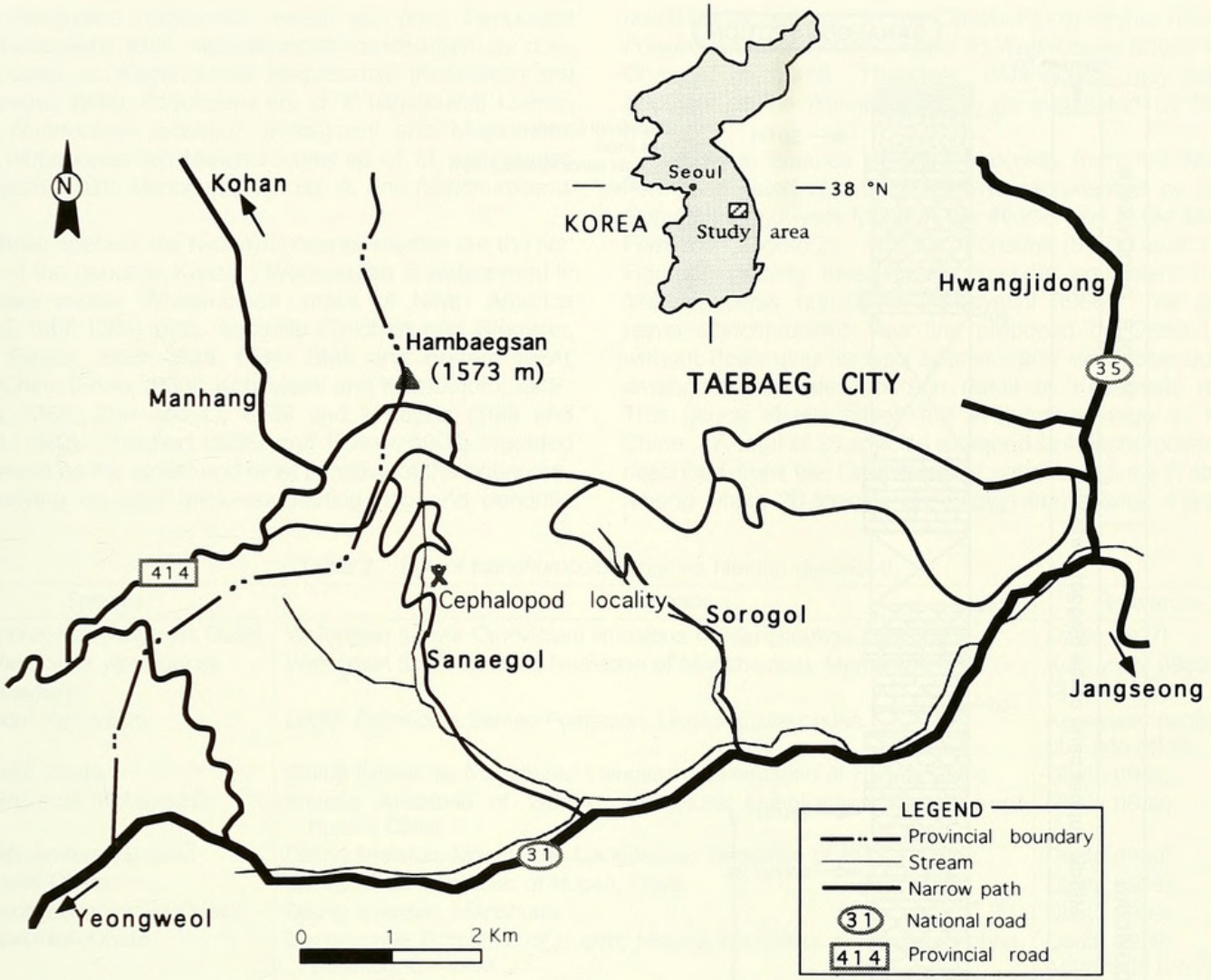


Figure 1. Index map of fossil locality on the western area of Taebaeg City, Kangweondo.

and bioturbated limestones in the two stratigraphic levels mentioned above, being especially abundant in the uppermost horizon of this formation.

Faunal characteristics and correlation

Based on a relatively limited number of cephalopod specimens, Kobayashi (1966) designated three fossil horizons in the middle and upper parts of the Maggol Formation; *Manchuroceras, Polydesmia*, and *Sigmorthoceras* horizons in ascending order (Table 1), and correlated them with upper Canadian, and lower and middle Chazyan (Whiterockian in the present usage) in North America, respectively. Kobayashi (1977) studied Takuhito Shiraki's collection and described four endoceroid species belonging to *Manchuroceras* from the Maggol Formation, without documentation of their exact localities and stratigraphic positions. Since siphuncular remains of *Manchuroceras* were not found in the overlying Jigunsan and Duwibong Formations, Kobayashi (1966) assigned the horizon of the *Manchuroceras* fauna to the middle part of the Maggol Formation.

Table 1. Lithostratigraphic and biostratigraphic division of Ordovician Duwibong type sequence of Joseon Supergroup in Korea (Complied from Kobayashi, 1966; Kim *et al.*, 1991).

Formation	Macrofossil zone
Duwibong	Actinoceroids
Jigunsan	Orthoceroids
Maggol	*Sigmorthoceras* *Polydesmia* *Manchuroceras* *Clarkella*
Dumugol	*Kayseraspis* *Protopliomerops* *Asaphellus*
Dongjeom	*Pseudokainella*

In this study, 53 cephalopod specimens from seven horizons in the Maggol Formation were collected and analyzed (Figure 2). The following 11 species belonging to 7 genera

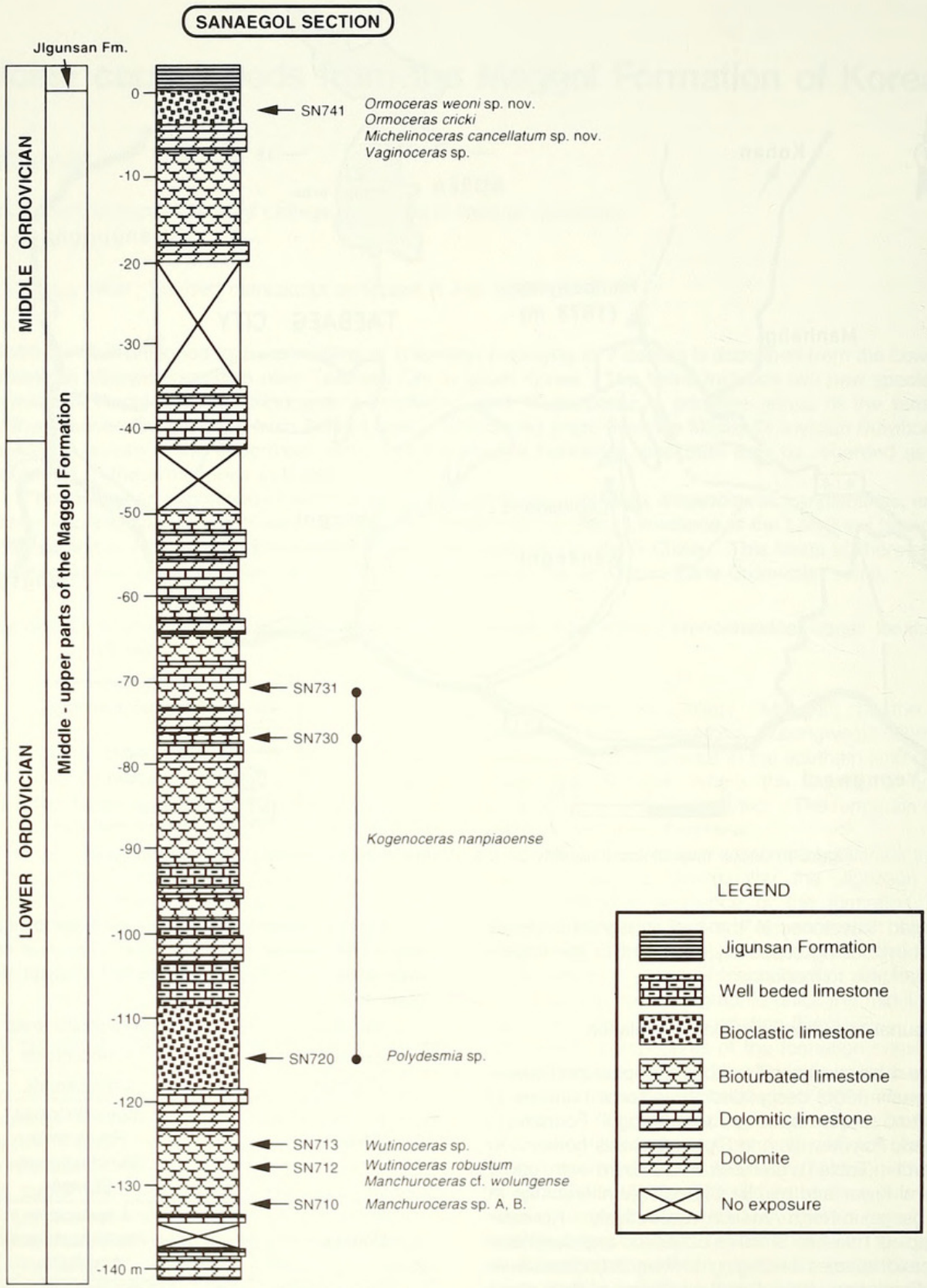


Figure 2. Geologic column of the middle to upper parts of the Maggol Formation at Sanaegol section, showing the cephalopod-bearing horizons. SN stands for the locality name, "Sanaegol".

were recognized : *Ormoceras weoni* sp. nov., *Ormoceras cricki* Kobayashi, 1934, *Michelinoceras cancellatum* sp. nov., *Vaginoceras* sp., *Kogenoceras nanpiaoense* (Kobayashi and Matsumoto, 1942), *Polydesmia* sp. cf. *P. canaliculata* Lorenz, 1906, *Wutinoceras robustum* (Kobayashi and Matsumoto, 1942), *Wutinoceras* sp., *Manchuroceras* sp. cf. *M. wolungense* (Kobayashi, 1931), *Manchuroceras* sp. A, and *Manchuroceras* sp. B.

Of these species, the two *Wutinoceras* species are the first report of the genus in Korea. *Wutinoceras* is widespread in the lower-middle Whiterockian strata of North America (Flower, 1957, 1968, 1976), Australia (Teichert and Glenister, 1953 ; Flower, 1968 ; Stait, 1984 ; Stait and Burrett, 1984), North China (Endo, 1930 ; Kobayashi and Matsumoto, 1942 ; Chang, 1965 ; Zhu and Li, 1996) and Malaysia (Stait and Burrett, 1982). Teichert (1935) and Flower (1968) regarded *Polydesmia* as the oldest and most primitive of the actinoceroids, relying on their thick connecting ring and dendritic radial canal system. In the Ordovician of China, however, *Polydesmia* does not occur prior to *Wutinoceras* (Chen, 1976 ; Chen *et al*., 1980). Therefore, *Wutinoceras* may be the ancestor of the Actinoceratidae, as suggested by Flower (1976).

The three species of *Manchuroceras* from the Maggol Formation listed above are always represented by partial siphuncles and were found in the middle part of the Maggol Formation (Figure 2). The two horizons (SN710 and 712 in Figure 2) yielding these fossils may be equivalent to the *Manchuroceras* horizon of Kobayashi (1966). The genus name *Manchuroceras* was first proposed by Ozaki (1927) without describing its type species, and was subsequently emended and redescribed in detail by Kobayashi (1935). This genus characterizes the Wolungian stage in North China. A total of 28 species assigned to *Manchuroceras* are described from the Ordovician of various regions (Table 2), among which 20 species are known from China, 4 species

Table 2. List of *Manchuroceras* species hitherto described.

Species	Occurrence	Reference
Manchuroceras nom. nud. Ozaki	Wolungian (Lower Ordovician) limestone of Manchoukou, Manchuria	Ozaki (1927)
Manchuroceras wolungense (Kobayashi)	Wolungian (L. Ordovician) limestone of Manchoukou, Manchuria	Kobayashi (1935), Obata (1939)
M. endoi Kobayashi	Lower Ordovician Santao Formation, Liaotoug, Manchuria	Kobayashi (1935) cf. Endo (1932)
M. ozakii Obata	Daling limestone, Manchuria; Liangjiashan Formation of Hupeh, China	Obata (1939)
M. compressa (Kobayashi)	Wolung limestone of Wolung, Manchuria; Liangjiashan Formation of Hupeh, China	Obata (1939)
M. platyventrum (Grabau)	Daling limeston, Manchuria; Liangjiashan Formation of Hupeh, China	Obata (1939)
M. ishidai Obata	Liangjiashan Formation of Hupeh, China	Obata (1939)
M. yenchouchengense Obata	Daling limeston, Manchuria	Obata (1939)
M. kobayashii Obata	Liangjiashan Formation of Hupeh; Maggol Formation of Yongyeon-chon, Taebaeg, S. Korea	Obata (1939), Kobayashi (1977)
M. katsunumai Obata	Liangjiashan Formation of Hupeh, China	Obata (1939)
M. steanei Teichert	L. Ordovician, Adamsfield, Tasmania	Teichert (1947)
M. excavatum Teichert	L. Ordovician, Adamsfield, Tasmania	Teichert (1947)
M. asiasticum Balashov	Early Middle Ordovician Krivolutsky Formation, Siberia Platform	Balashov (1962)
M. sp.	L. Ordovician Lower Jiacun Group of Nyalam, Xiuang, China	Chen (1975)
M. qingshuiheense Chen	L. Ordovician Liangchiashan Fm., Qingshuihe, Inner Mongolia	Chen (1976)
M. tochuanshanense Chang	Lower Ordovician, upper part of Tochuanshan limestone, Chinghai, N.W. China	Chang (1965)
M. lemonei Hook & Flower	Florida Mountains Formation, El Paso, Texas	Hook & Flower (1977)
M. cf. *platyventrum* (Grabau)	Maggol Formation of Gaesan-chon, Taebaeg City, Kangweondo, S. Korea	Kobayashi (1977)
M. tenuise Kobayashi	Maggol Formation of Guemdae-chon, Sangjangmyeon, Samcheok-gun, Kangweondo, Korea	Kobayashi (1977)
M. hanense Kobayashi	Maggol Formation of Godoo-am, Guraeri, Samgdong, Yeongweol, Kangweondo, S. Koera	Kobayashi (1977)
M. ? sp.	Maggol Formation of Godoo-am, Guraeri, Samgdong, Yeongweol, Kangweondo, S. Koera	Kobayashi (1977)
M. limatum Xu.	L. Ordovician Honghuayuan Formation of Yichang, Hupeh, Central China	Xu (1981)
M. densum Xu	L. Ordovician Honghuayuan Formation of Yichang, Hupeh, Central China	Xu (1981)
M. pachymuratum Xu	L. Ordovician Honghuayuan Formation of Yichang, Hupeh, Central China	Xu (1981)
M. yangteense Xu	L. Ordovician Honghuayuan Formation of Yichang, Hupeh, Central China	Xu (1981)
M. yazipingense Zou	L. Ordovician Liagchishan Formation of Shanxi, North China	Zou (1981)
M. minitum Zou	L. Ordovician Liagchishan Formation of Shanxi, North China	Zou (1981)
M. pianguanense Zou	L. Ordovician Liagchishan Formation of Shanxi, North China	Zou (1981)
M. platyventrum (Grabau)	L. Ordovician Liagchishan Formation of Hebei, North China	Lai *et al.* (1982)
M. nakamense Stait & Burrett	Upper Ibexian Thungsong Formation of Ron Phibum, Southern Thailand	Stait & Burrett (1984)

from South Korea, 2 species from Tasmania, 1 species from the Siberian Platform, and 1 species from Texas, U.S.A. Most of them, excluding the Russian one, are known to occur in the Lower Ordovician (upper Ibexian). The *Manchuroceras* horizon of the Maggol Formation in Korea is correlated with the Liangchiashan Formation, Hwangho Region and with the Hunghuayuan Formation, Yangtze Region (Chen *et al*., 1980). The cephalopod fauna including *Manchuroceras nakamense* from the Lower Setul Limestone of Malaysia shows some affinities with that from the Maggol Formation. The OT8 zone of the Karmberg Limestone, Tasmania, proposed by Banks and Burrett (1980) may also be correlated with the Maggol Formation.

The specialized actinoceroid *Polydesmia*, which is characterized by a vertically lamellate structure of the siphuncular filling and high obliquity of the radial canal, is only known from East Asia, including North Korea, Inner Mongolia, South Manchuria and Shandong in China. Kobayashi (1966) designated the *Polydesmia* horizon in the upper part of the Maggol Formation, based on a single specimen of this genus. Unfortunately, he did not illustrate this specimen and it is probably lost. Furthermore, all of the type specimens of the four *Polydesmia* species described by Kobayashi (1940) from China and North Korea are lost. According to Chen *et al*. (1980), *Polydesmia* is typically found in the Lower Ordovician Beianzhuang Formation of Hubei and Shandong in North China, which is conformably underlain by the *Manchuroceras*-bearing Liangchiashan Formation. The occurrence of *Polydesmia* cf. *canaliculata* in the upper part of the Maggol Formation supports the validity of the *Polydesmia* horizon established by Kobayashi (1966). This genus cooccurs with two other genera, *Wutinoceras* and *Manchuroceras* in Korea and China. Since the upper part of the Korean Maggol Formation yields *Polydesmia*, its age is assigned to the early Whiterockian in the North American scale.

Wutinoceras robustum (Kobayashi and Matsumoto, 1942) occurs in the middle part of the Maggol Formation, together with some *Manchuroceras* specimens (Figure 2). The higher horizons (locs. SN730 and 731 in Figure 2) yield the annulated orthoconic cephalopod *Kogenoceras nanpiaoense* (Kobayashi and Matsumoto, 1942). These two species have previously been recorded from strata of uncertain age within the Ordovician in Nanpiao Coalmine, Nanpiao County, Liaoning Province, and were assigned to the Toufangian in South Manchuria by Kobayashi and Matsumoto (1942). Stait and Burrett (1982) described *W. robustum* from the Lower Setul Limestone of Whiterockian age in the Langkawi Islands, Malaysia. Subsequently, Stait *et al*. (1987) described *Kogenoceras nanpiaoense* from a slightly higher horizon than the *W. robustum*-bearing strata in the same area and assigned it a Whiterockian age. These lines of evidence suggest that the cephalopod fauna of the Maggol Formation has strong affinities to the Southeast Asian and North Chinese faunas of equivalent age.

Four species belonging to 3 genera were identified among many small-sized cephalopod specimens recovered from the horizon just below the boundary of the Maggol and Jigunsan Formations (loc. SN741 in Figure 1). Of these species, *Ormoceras weoni* sp. nov and *O. cricki* occur most abundantly, making up more than 90 per cent of the cephalopod assemblage. The latter species is common in the Duwibong Formation, the uppermost Ordovician formation in Korea (Kobayashi, 1934), indicating that this species has a long range from the Maggol Formation to the Duwibong Formation. This species possibly represents the oldest type of the ormocerids in the upper Jigunsan and Duwibong Formations.

Systematic paleontology

The terminology and measurements of various shell morphological characters used in this paper are shown in Figure 3.

Subclass Endoceratoidea Teichert, 1933
Order Endocerida Teichert, 1933
Family Manchuroceratidae Kobayashi, 1935
Genus ***Manchuroceras*** Ozaki, 1927 emend. Kobayashi, 1935
Type species : Piloceras wolungense Kobayashi, 1931

Manchuroceras sp. cf. ***M. wolungense*** (Kobayashi, 1931)

Figures 4-1a, b ; 7-5a, b

Material.—Isolated partial siphuncle, KPE20073 from loc. SN712.

Description.—Partial siphuncle with apical end, 71.2 mm in length ; its dorsal side somewhat weathered and apical portion distorted by local joint and calcite vein ; apex bluntly pointed ; dorsoventral and lateral diameters nearly equal at a distance of 49.7 mm from apex, i.e., circular in cross section, 30.5 mm in diameter ; inner side of siphuncle lined with crystalline calcite, recrystallized endosiphosheaths, this lining thinnest on dorsal side, becoming thicker laterally, ventral side of siphuncle strengthened by additional deposits, forming endosiphowedge, 12.4 mm thick at a distance of 49.7 mm from apex ; endosiphocone rapidly expanding, its apical angle approximately 45 degrees, its apex continuing into endosiphotube, in which endosiphuncular segments are detected.

Remarks.—This species appears to be closely allied to *Manchuroceras wolungense* (Kobayashi) from the Wolung Limestone of South Manchuria (Kobayashi, 1931 p. 170, pl. 17, figs. 2, 3a, b, 6 ; pl. 18, figs. 2a, b ; pl. 19, fig. 1) in having a circular cross section of the siphuncle and well developed endosiphowedge. Specific identification requires additional better preserved specimens.

Occurrence.—Known from the middle part of the Maggol Formation of Sanaegol, Taebaeg City, Kangweondo, South Korea.

Manchuroceras sp. A

Figures 4-2a, b ; 7-1a—c

Material.—Isolated partial siphuncle, KPE20256 from loc. SN710.

Description.—Internal mould of siphuncle, 77.7 mm long ; straight, with its diameter expanding twice as rapidly laterally

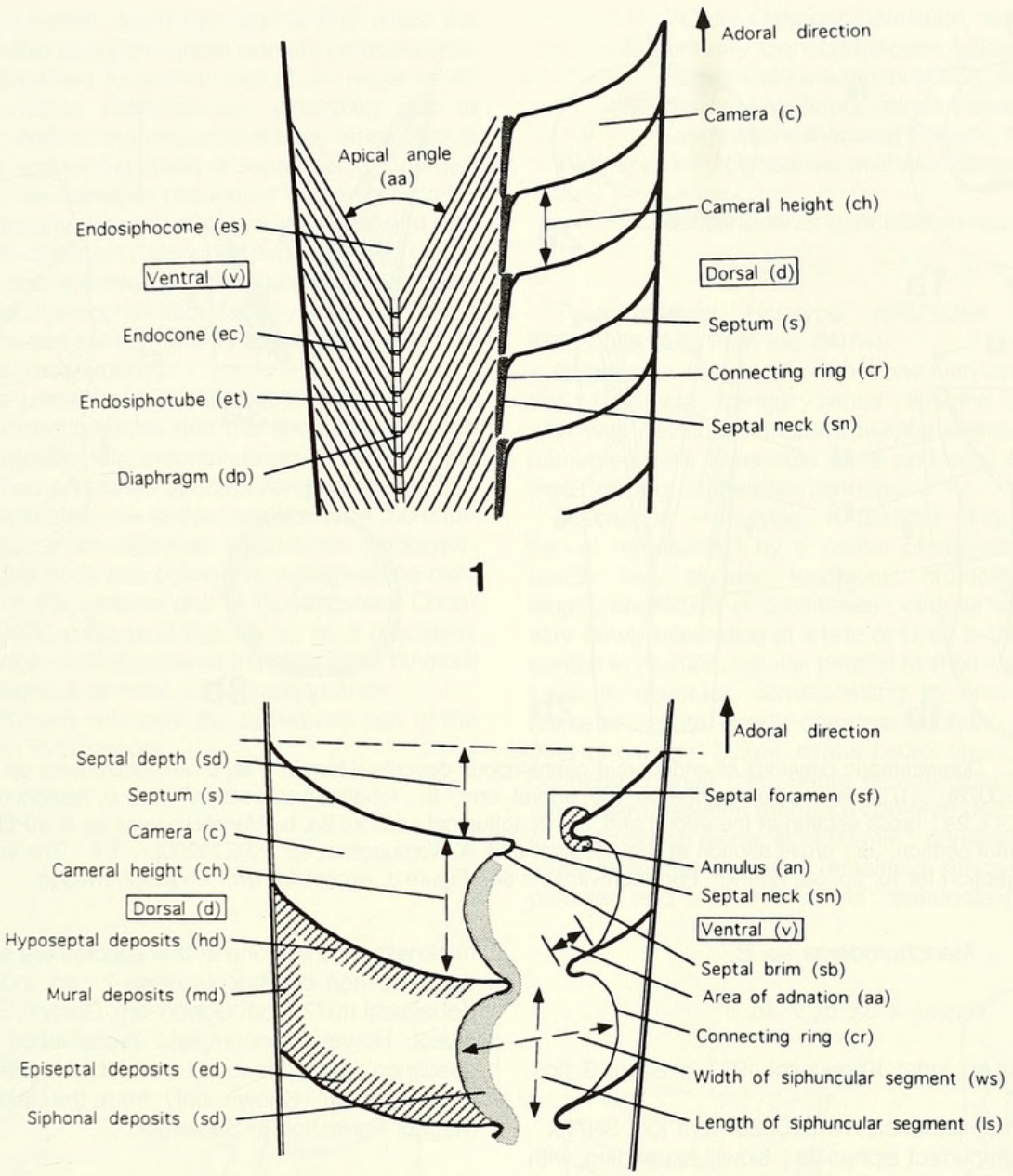


Figure 3. Terminology and measurements of internal shell structures of idealized endoceroid (1) and actinoceroid (2) cephalopods used in this paper. Abbreviations of various shell characters are written in parentheses. Compiled and modified from Teichert *et al.* (1964), Aronoff (1979), and Zhu and Li (1996).

as dorsoventrally ; its cross section circular in juvenile stage, but becomes elliptically depressed with growth, ratio of dorsoventral to lateral diameters of siphuncle at adoral end being 3 : 4 ; endosiphuncular deposits nearly uniform in thickness, not forming endosiphowedge, endocones recrystallized ; endosiphocone slender, deep, rapidly expanding with apical angle of 25 degrees, its apex acutely pointed and situated at endosiphuncular center, continuing into endosiphotube which pierces apex ; outside of siphuncle appears to be smooth.

Remarks.—This species is allied to *Manchuroceras tenuise* Kobayashi from Guemdae-chon, Taebaeg City, Kangweondo (Kobayashi, 1977) in the small apical angle of the endosiphocone and ovate cross section, but is distinguished by evenly thickened endosiphuncular linings. *Manchuroceras yenchouchengense* Obata from the Daling Limestone of Liaoning, South Manchuria (Obata, 1939, p. 103, pl. 7, figs. 4, 6 ; pl. 8, fig. 2 ; pl. 10, fig. 6) may be related to this species in the elliptical cross section, but its blunt endosiphocone and greater dorsoventral diameter serve to distinguish this species from *M. yenchouchengense*. This comparison indicates that the present species belongs to *Manchuroceras*, but well preserved additional specimens are needed for species-level assignment.

Occurrence.—Known only from the middle part of the Maggol Formation in Sanaegol.

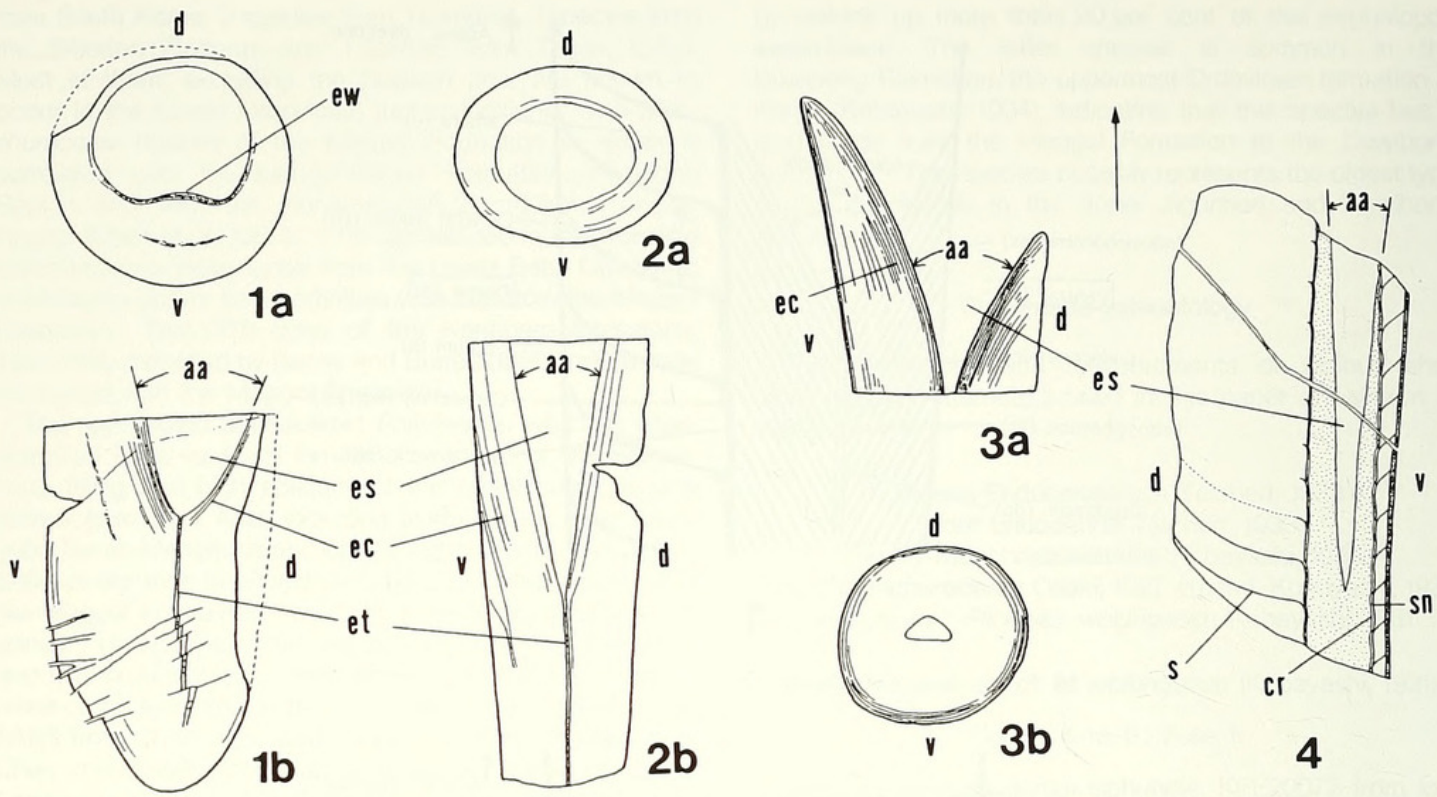


Figure 4. Diagrammatic drawings of endoceroid cephalopods described herein. **1a, b**. *Manchuroceras* sp. cf. *M. wolungense* (KPE20073), ×0.9, 1a : cross section at the adoral end, 1b : longitudinal section. **2a, b**. *Manchuroceras* sp. A (KPE20256), ×1, 2a : cross section at the adoral end, 2b : longitudinal section, **3a, b**. *Manchuroceras* sp. B (KPE20065), ×0.9, 3a : longitudinal section, 3b : cross section at the adapical end, **4**. *Vaginoceras* sp. (KPE20230), ×1.4. The arrow indicates the adoral direction for 1b, 2b, 3a, and 4. For abbreviations see Figure 3, except for ew : endosiphowedge.

Manchuroceras sp. B

Figures 4-3a, b ; 7-4a, b

Manchuroceras sp. indet. Kobayashi, 1977, p. 24, pl. 3, figs. 3a, b.

Material.—Partial siphuncle, KPE20065 from loc. SN710.

Description.—Imperfect siphuncle ; slowly expanding, with apical angle 13 degrees ; adapical end circular in cross section but endosiphocone triangular, its tip somewhat rounded, more flattened ventrally than dorsally, its basal length and height 5 mm and 2.5 mm, respectively ; apical angle of endosiphocone about 65 degrees, but abruptly decreasing toward adapical end at broadly curving point of endosipholining, attaining 15 degrees ; endocone asymmetrical, rapidly extending anteriorly and more thickened on ventral side than on dorsal side, numerous lamelliform endocones well developed ; no cameral portion detected.

Remarks.—This species is allied to *Manchuroceras tenuise* Kobayashi from Guemdae-chon, Sangjangmyeon, Samcheok, Kangweondo, Korea (Kobayashi, 1977, p. 23, pl. 4, figs. 2a, b) in its triangular endosiphocone in cross section, but differs by its centrally located and more slowly expanding endosiphocone. This species is distinguished from *Manchuroceras* sp. A described above, in the much more rapidly expanding endosiphocone.

Meanwhile, the apical angle of the endosiphocone and thickness of endocone in this species are similar to those in the specimen of *Manchuroceras* ? sp. indet. described by Kobayashi (1977) from Godoo-am, Guraeri, Sangdong, Yeongweol. However, incomplete preservation of the present specimen precludes exact specific assignment.

Occurrence.—Known only from the middle part of the Maggol Formation in Sanaegol.

Family Endoceratidae Hyatt, 1883

Genus ***Vaginoceras*** Hyatt, 1883

Type species : *Endoceras multitubulatum* Hall, 1847

Vaginoceras sp.

Figures 4-4 ; 7-2a, b

Material.—Partial phragmocone, KPE20230 from loc. SN741.

Description.—Partial phragmocone, 36 mm in length, medium-sized orthocone containing endosiphocone ; conch wall 0.6 mm thick on ventral side ; slowly expanding ; somewhat laterally compressed, ratio of dorsoventral to lateral diameter about 1.4 : 1 ; siphuncle submarginal in position, 1.5 mm distant from ventral margin, nearly circular in cross section, broad, its diameter a little less than one-third of dorsoventral conch diameter ; septa on dorsal portion mostly obliterated during fossilization, but two preserved septa at

basal part having septal depth one and a half times the cameral height, while septa on ventral side are comparatively well preserved, attached to ventral wall at an angle of 45 degrees; septal necks holochoanitic, extending just to preceding ones; connecting rings about three times thicker than septal neck, embracing inside of septal necks; cameral height 2.5 mm, six camerae distributed in a length corresponding to dorsoventral conch diameter at adoral end; no cameral deposits observed; siphonal deposits well developed, dorsally more extended in longitudinal section, long and slender endosiphocone bounded by last endocone having wedge-shaped section and its apical angle about 15 degrees; shell surface smooth.

Remarks.—The presence of a thick connecting ring and acute endosiphocone indicates that this species belongs to *Vaginoceras*. Unfortunately, incomplete preservation of the specimen examined precludes species-level assignment.

In the long endosiphocone and ectosiphuncular morphology, this species can be allied to *Vaginoceras endocylindricum* Yü from the beds just below the red limestone near Tawushu, north of the western end of Peiyangshan, Chungyanghsien (Yü, 1930, p. 33, pl. 2, figs. 5a-c; pl. 3, figs. 2a-d, 3a, b), but the former is distinguished from the latter by more closely spaced septa and more compressed conch.

Occurrence.—Known only from the uppermost part of the Maggol Formation in Sanaegol.

Order Orthoceratida 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 cancellatum sp. nov.

Figures 5-1; 7-7, 8a—c

Type material.—Holotype, KPE20254 and paratype, KPE20255 both from loc. SN741.

Diagnosis.—Longiconic orthocone with circular cross section; siphuncle central; septal spacing wide; camerae with well developed mural-episeptal deposits; surface ornamented with transverse lines and very fine longitudinal lirae, forming cancellate markings.

Description.—Holotype, KPE20254 (Figures 5-1 and 7-8a—c) represented by a partial phragmocone of juvenile conch; very slender, longiconic orthocone, 21.4 mm in length, consisting of 8 camerae; circular in cross section; very slowly expanding at a rate of 1 mm in 15 mm; siphuncle central in position, tubular, parallel to shell wall, narrow, about 1 mm in diameter, corresponding to one-sixth of conch diameter; septa gently concave adorally; its depth one-third of cameral height, septal necks short, orthochoanitic; connecting rings thin; septa broadly spaced, averaging 2 mm distant between them, 2.5 camerae occurring in a length equal to conch diameter of 6.1 mm; camerae with L-shaped mural-episeptal deposits, remaining space filled with öoid particles and inorganic matrix; siphuncle filled with some

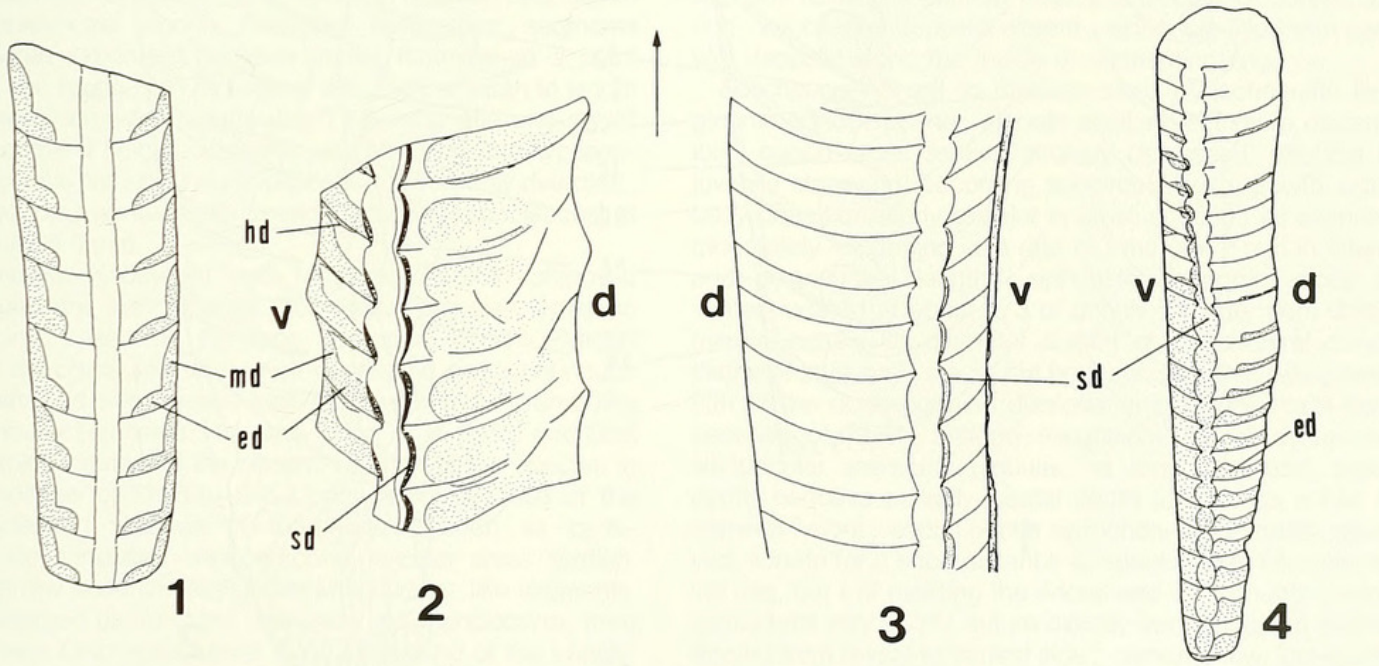


Figure 5. Diagrammatic drawings of median dorsoventral section of orthocerid (1-2) and actinocerid (3-4) cephalopods described herein. **1**. *Michelinoceras cancellatum* sp. nov. (holotype; KPE20254), ×1.5, **2**. *Kogenoceras nanpiaoense* (KPE20208), ×2, **3**. *Ormoceras weoni* sp. nov. (holotype; KPE20260), ×2, **4**. *Ormoceras cricki* (KPE20232), ×2.5. For abbreviations see Figure 3.

öoids and matrix; surface ornamented with transverse growth lines and longitudinal lirae, forming cancellate network, spaces between growth lines and between lirae 0.16 mm and 0.07 mm respectively

Paratype, KPE20255 (Figure 7-7), a partial phragmocone consisting of 9 camerae, 33.2 mm long; probably belongs to adolescent stage in view of higher camera and broader conch than those of holotype; siphuncle central, cylindrical, narrow; septal distance increasing from 3 mm to 3.5 mm during the stage observed; camera with mural-episeptal deposits.

Remarks.—In the surface ornament pattern, this species resembles *Michelinoceras reticulatum* (Kobayashi) from the Jigunsan Formation of Homyeong (Kobayashi, 1934, p. 406, pl. 16, figs. 3-5). In the former species, however, are weaker and thinner longitudinal lirae than transverse growth lines, whereas in the latter species transverse lines are more crowded than longitudinal ones. In addition, the siphuncle in the present species is central in position, not submarginal as in *M. reticulatum*.

This species is similar to *Michelinoceras shangliense* Qi from the Middle Ordovician Datianba Formation of Anhui, China (Qi, 1980, p. 251, pl. 4, fig. 1) in the expansion rate of conch and septal spacing, but the former is distinguished from the latter by its peculiar latticed ornamentation and central siphuncle. This species is also allied to *Michelinoceras paraelongatum* Chang from the Middle Ordovician of Gansu, North China (Chang, 1962, p. 517, pl. 1, figs. 5a-c) in its small-sized conch with circular cross section, but the former has more narrowly spaced septa and broader siphuncle than the latter. In its surface markings, *Michelinoceras guichiense* Ying from the Middle Ordovican Datianba Formation of Guichi, Anhui, China (Ying, 1989, p. 630, pl. 3, figs. 5, 6) exhibits an affinity to the present species, but longitudinal lirae occurring in the present species are absent in *M. guichiense*.

Occurrence.—Known only from the uppermost part of the Maggol Formation in Sanaegol.

Superfamily Pseudorthocerataceae Flower and Caster, 1935
Family Stereoplasmoceratidae Kobayashi, 1934
Genus ***Kogenoceras*** Shimizu and Obata, 1936
Type species: *Tofangoceras huroniforme* Kobayashi, 1927

Kogenoceras nanpiaoense
(Kobayashi and Matsumoto, 1942)

Figures 5-2; 7-3, 6, 9a, b

Tofangocerina nanpiaoensis Kobayashi and Matsumoto, 1942, p. 313, pl. 31, figs. 10-12; Chao *et al*., 1965, p. 96, pl. 22, fig. 11.
Kogenoceras nanpiaoense (Kobayashi and Matsumoto). Chen *et al*., 1980, p. 177, pl. 3, fig. 18; Text-fig. 10; Lai *et al*., 1982, pl. 6, figs. 12, 13; Stait, Wyatt and Burrett, 1987, p. 385, figs. 6-2—4.

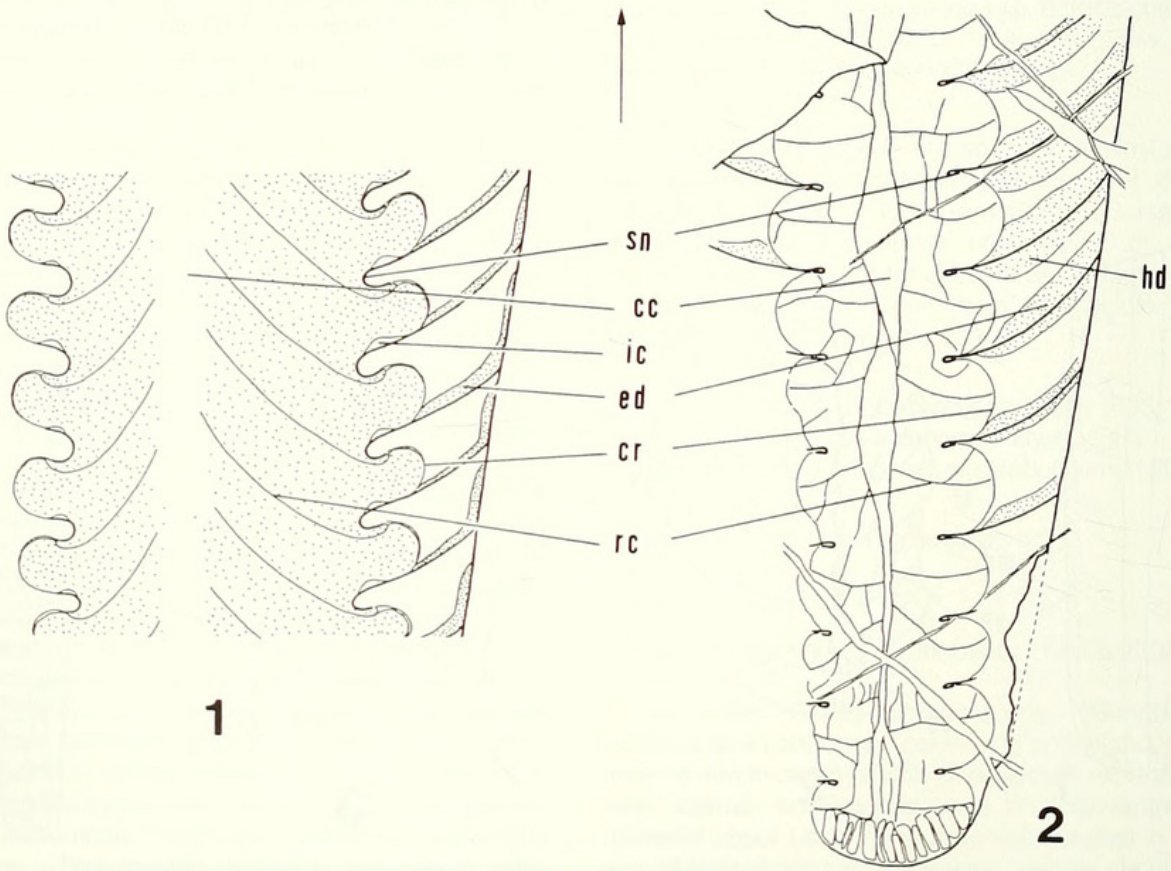


Figure 6. Diagrammatic drawings of actinoceroid cephalopods described herein. **1**. *Polydesmia* sp. cf. *P. canaliculata* (KPE20323), ×1. **2**. *Wutinoceras robustum* (KPE20206), ×1. For abbreviations see Figure 3, except for ic: interseptal cavity, cc: central canal, rc: ardial canal.

Material.—Six partial phragmocones from the upper part of the Maggol Formation at localities, SN720 (KPE20282, 20283 and 20327), SN730 (KPE20209), and SN731 (KPE20208 and 20210).

Diagnosis.—Annulated cyrtochoanitic orthocone ; cameraе with episeptal and hyposeptal deposits ; siphuncle with dorsally intermittent and ventrally connected parietal deposits.

Description.—Medium-sized annulated longiconic orthocone with eccentric siphuncle.

KPE20208 (Figures 5-2, 7-9a, b), a fragmentary phragmocone with 6 siphuncular segments, 21 mm long, very slowly enlarging, circular in cross section ; siphuncle eccentric, midway between center and venter, narrow, occupying a little more than one-sixth of dorsoventral conch diameter ; siphuncular segments *Huronia*-like in shape, greatly expanding in upper third, 2.8 mm in length and 2.3 mm in maximum diameter, contracting to 1.2 mm at septal foramen ; septa gently concave adorally, partly crushed on dorsal side, septal depth equal to half or more of the cameral height ; septal neck cyrtochoanitic, short, 0.3 mm in length ; cameral height low, about 2.8 mm at upper part, 5 camerae in a length corresponding to the dorsoventral conch diameter on the crest of annuli ; connecting rings thin, not adnate to the septa ; camera filled with both episeptal and hyposeptal deposits ; siphuncle deposits with parietal deposits consisting of longitudinal thin lamellae, dorsally occurring successively whereas ventrally intermittent ; surface ornamented with strong annulations at intervals of 7.3 mm wide, corresponding to 2.5 camerae, its height from the base of the interspace about 0.8 mm.

KPE20209 (Figure 7-3), 49 mm in length, its adapical portion not preserved ; conch nearly circular in cross section ; siphuncle close to venter, narrow, its width one-eighth of dorsoventral conch diameter ; siphuncular segments somewhat expanded between septal foramina at a point about one fourth from its anterior end, ratio of width to length 0.8 ; septa crowded, septal depth attaining one and a half times cameral height ; camerae with both epi- and hyposeptal deposits, but siphuncular deposits not distinctly detected ; surface ornamented with broadly rounded annulations at intervals of 6 mm.

Remarks.—Kobayashi and Matsumoto (1942) proposed *Tofangocerina nanpiaoensis* from the Tofangian, Nanpiao Coalmine, based on the type specimen, UMUT PM1903 which are characterized by well-developed endosiphuncular deposits and submarginal siphuncle with the *Huronia*-like siphuncular segments. However, Chen *et al*. (1980) and Stait *et al*. (1987) attributed the generic position of this species to *Kogenoceras* of Shimizu and Obata (1936) because of the characteristic features of *Kogenoceras* such as cyrtochoanitic annulated orthoceracone, circular cross section, and narrow eccentric siphuncle, with *Huronia*-like segments. The enlarged photo of the siphuncle of *K. nanpiaoense* from the Lower Ordovician Lower Setul Limestone of the Langkawi Islands, Malaysia (Stait *et al*., 1987, p. 386, fig. 6-4) shows cyrtochoanitic septal necks, though these authors mistakenly described the septal neck type as orthochoanitic.

This species is similar to *Kogenoceras huroniforme* (Kobayashi) from the Duwibong Formation of Hwarari, Kangweondo, Korea (Kobayashi, 1934, p. 435, pl. 27, figs. 9-11, 14) in the *Huronia*-like siphuncular segments and eccentric siphuncle, but is easily distinguished by the presence of the parietal deposits along the siphuncular wall.

Occurrence.—In addition to the present material, specimens assigned to this species are known from the Lower Ordovician of Nanpiao Coalmine, Nanpiao County, Liaoning Province, South Manchuria (Kobayashi and Matsumoto, 1942 ; Lai *et al*., 1982), Beianzhuang Formation of Shandong, North China (Chen *et al*., 1980) and the Lower Setul Limestone on the east coast of Pulau Langgun, Langkawi Islands, Malaysia (Stait *et al*., 1987).

Order Actinocerida Teichert, 1933
Family Ormoceratidae Saemann, 1853
Genus ***Ormoceras*** Stokes, 1840
Type species : *Ormoceras bayfieldi* Stokes, 1840

Ormoceras cricki Kobayashi, 1934

Figures 5-4 ; 8-1—8

Ormoceras cricki Kobayashi, 1934, p. 444, pl. 23, fig. 7 ; pl. 25, fig. 7.
Ormoceras sp. B., Chang, 1959, p. 266, pl. 5, fig. 5.

Material.—15 specimens, KPE20231-20245 from loc. SN741, among which 14 are partial phragmocones and one (KPE20231) is a well-preserved, almost complete adult conch.

Diagnosis.—Conch cross section elliptical in juvenile stage, but becomes subcircular in adult stage ; eccentric siphuncle with globular segments ; camera with episeptal deposits forming a pointed ridge just in front of connecting ring ; hyposeptal deposits absent ; siphuncle filled with parietal deposits along the inside of connecting ring.

Description.—Small to medium-sized cyrtochoanitic longiconic orthoceracone ; smooth shell, no sculpture discernible ; conch cross section strongly depressed, elliptical in juvenile stage, but becoming subcircular with growth, adult body chamber nearly circular in cross section ; its diameter moderately expanding at a rate of 1 mm per 8 mm in lateral and dorsoventral lengths ; siphuncle eccentric, close to venter, located at about 2/3 of conch diameter from dorsal margin, narrow, its diameter a third of dorsoventral conch diameter in juvenile stage, but becoming smaller, being one-fifth of the corresponding diameter in the adolescent shell because of nearly uniform expansion rate of siphuncle ; siphuncular segments globular, as long as broad ; septa gently concave adorally, septal depth as wide as a half of cameral height ; septal necks cyrtochoanitic, abruptly recurved, adnate for a short distance to adapical part of connecting ring, but just meeting the adoral end of connecting ring ; septal brim very short ; suture directly transverse, but slightly sloping from dorsal to ventral side ; camerae low, increasing from 1.1 mm to 1.5 mm during ontogeny, four camerae occurring in a length equal to dorsoventral conch diameter of 6.5 mm in KPE20232 (Figures 5-4 and 8-2b) ; camera with well-developed mural-episeptal deposits, in which mural deposits

vestigial dorsally but more concentrated ventrally.

The degree of development of cameral deposits changes during ontogeny (see Figure 5-4); In juvenile stage, dorsal episeptal deposits becoming thicker toward nummuli, forming a pointed ridge just in front of connecting ring and abruptly thinning out to a saucer-like shape, the apex of pointed ridge rather acute and gradually shifting to the shell wall adorally whereas it is difficult to recognize on the ventral side due to secondary recrystallization. In adolescent stage, episeptal deposits shortened dorsally, not swollen and mural-episeptal deposits still thicker ventrally. In adult stage cameral deposits seldom present.

Siphuncle filled with biogenic deposits in both juvenile and adolescent stages. The deposits more heavily developed ventrally than dorsally in adult stage, subsequently appearing to be annulosiphonate deposits ventrally.

Remarks.—This species resembles *Ormoceras woodwardsi* Kobayashi from the Jigunsan Formation of Homyeong, Jeongseon (Kobayashi, 1934, p. 445, pl. 31, fig. 5) in the globular siphuncular segments and submarginal siphuncle, but is distinguished by the absence of episeptal deposits. It is similar to *Ormoceras harioi* (Kobayashi) from the Tofango Limestone of Tofango, South Manchuria (Kobayashi, 1927, p. 196, pl. 22, fig. 12; pl. 21, fig. 9) in having episeptal deposits, but differs from the latter in the broader siphuncle in proportion to conch diameter and the more rapidly expanding conch.

In the saucer-like shape of episeptal deposits, *Paormoceras nanum* (Grabau) from the Toufango Limestone of South Manchuria (Kobayashi, 1927, p. 195, pl. 20. fig. 11; pl. 21, fig. 8; pl. 22, fig. 5) is closely related to this species, but the former is distinguished from this latter by the presence of such characters as *Huronia*-like siphuncular segments, more rapidly expanding conch and more closely spaced septa.

Occurrence.—In addition to the uppermost horizon of the Maggol Formation of Sanaegol described herein, this taxon is known from the Duwibong Formation of Hwajeolchi, Jungdong-myeon, Yeongweol area, and of Homyeong, Dongmyeon, Jeongseon area and Gaesandong, Taebaeg City, Kangweondo (Kobayashi, 1934).

Ormoceras weoni sp. nov.

Figures 5-3; 8-9—12; 9-1—3

Types.—Holotype, KPE20260, an incomplete phragmocone with an adjacent part of body chamber; 7 paratypes, KPE20261-20267, all from loc. SN741.

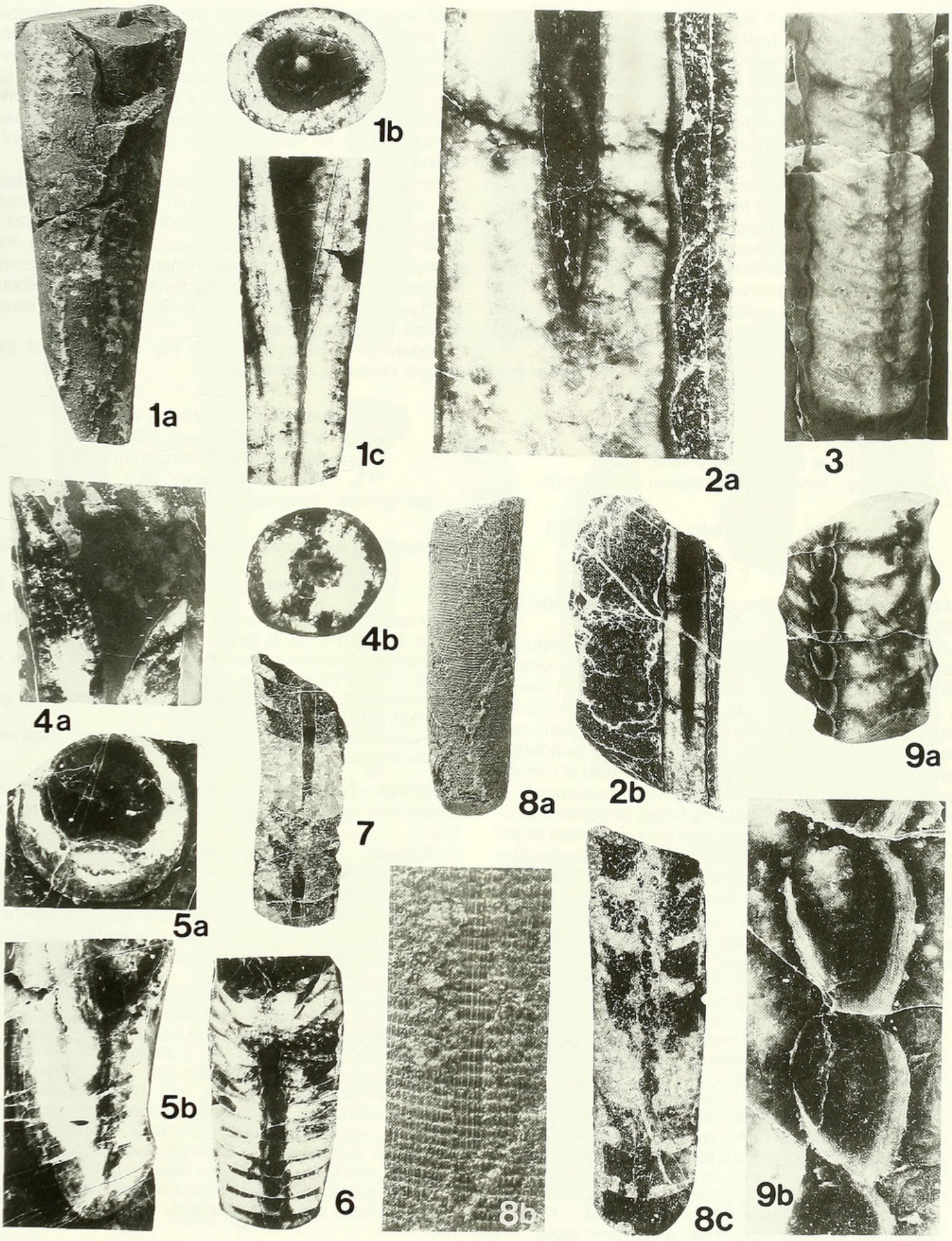
Material.—In addition to the above type specimens, seven specimens (KPE20268-20274) belong to this species. Of these, six (KPE20268-20273) were collected from the type locality, while one (KPE20330) came from the equivalent horizon of the Maggol Formation at Sesong.

Etymology.—The specific name is dedicated to Dal-Gi Weon, who collected many Paleozoic fossils from Kangweondo region and kindly provided some specimens to the author.

Diagnosis.—Longiconic or slightly curved orthocone; conch subcircular, ovately elliptical in cross section; body chamber long; siphuncle submarginal; siphuncular segments somewhat expanded; no cameral deposits detected.

Description.—Medium-sized longiconic or slightly curved orthocone; conch diameter moderately expanding at a rate of 1 mm per 6.5 mm in conch height of the holotype (Figures 8-9a—d); body chamber long; ovately elliptical in cross section, ratio between dorsoventral and lateral diameters at the apical end 4 : 5 in one of the paratypes (KPE20262; Figure 9-1b); siphuncle submarginal, narrow, occupying about one-eighth of dorsoventral conch diameter; siphuncular segments nummuloidal, more or less expanded, 1.5 mm long and 1.1 mm in maximum diameter in the upper third of the height within camerae, contracting to 0.6 mm at the septal foramen in the holotype; septa gently concave adorally, septal depth ranging from one to one and a half of cameral height, septal necks cyrtochoanitic, very short, just meeting the adoral end of connecting ring; septal spacing narrow, 7 to 8 camerae within the corresponding length of dorsoventral conch diameter; suture directly transverse in two steinkern specimens, KPE20264 (Figure 8-12) and KPE20265 (Figure 8-11); no cameral deposits detected; siphuncle filled with inorganic matrix, but in the holotype and one of the paratypes (KPE20262; Figure 5-1d), endosiphuncular deposits line siphonal surface of venter; surface smooth.

Figure 7. **1a-c.** *Manchuroceras* sp. A. partial siphuncle, KPE20256 from SN710, ×1, 1a: ventral view, 1b: cross section at the adoral potion, venter down, 1c: longitudinal section, venter on left, showing endocones and endosiphocone. **2a, b.** *Vaginoceras* sp. partial phragmocone, KPE20230 from SN741, 2a: detail of siphuncle and ventral camerae, showing very slender endosiphocone, ×5, 2b: longitudinal section, venter on right, ×1.5. **3, 6, 9a, b.** *Kogenoceras nanpiaoense* (Kobayashi and Matsumoto, 1942). 3. Partial phragmocone, KPE20209 from SN730, longitudinal section, venter on right, ×1.5, 6: Partial phragmocone, KPE20282 from SN720, longitudinal section in lateral direction, ×1, 9a, b: Partial phragmocone, KPE20208 from SN731, 9a: longitudinal section, venter on left, ×2, 9b: enlarged view of siphuncular structure, showing parietal deposits and moderately expanded siphuncular segments, ×7. **4a, b.** *Manchuroceras* sp. B. partial siphuncle, KPE20065 from SN710, ×1, 4a: longitudinal section, venter on left, showing more prolonged ventral endocone adorally, 4b: cross section at the adapical end, venter down, showing triangular endosiphocone with flattened ventral side. **5a, b.** *Manchuroceras* sp. cf. *M. wolungense* (Kobayashi, 1931), partial siphuncle, KPE20073 from SN712, ×1, 5a: cross section at the adoral end, venter down, showing circular outline and endosiphowedge, 5b: longitudinal section, venter on left, showing the blunt apical end and endosiphotube. **7, 8a-c.** *Michelinoceras cancellatum* sp. nov. 7. Partial phragmocone, paratype, KPE20255 from SN741, longitudinal section, acetate peel, ×1.5, 8a-c. Partial phragmocone, holotype, KPE20254 from SN741, 8a: side view, ×2.5, 8b: details of surface ornamentation, showing cancellate ornaments, ×12, 8c: longitudinal section, acetate peel, showing well developed mural-episeptal deposits, ×3.5.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Remarks.—This present species closely resembles *Ormoceras yokoyamai* (Kobayashi) from the Jigunsan Formation of Maggol and Homyeong (Kobayashi, 1934, p. 439, pl. 27, figs. 1-6 ; pl. 28, fig. 2) in the narrow, submarginal siphuncle with somewhat expanded segments, but differs from the latter by the presence of endosiphunuclar linings and the lack of ventral flattening in cross section.

Ormoceras cricki Kobayashi from the Duwibong Formation of Homyeong and Gaesanchon (Kobayashi, 1934, p. 444, pl. 23, fig. 7 ; pl. 25, fig. 7) and from the uppermost bed of the Maggol Formation at Sanaegol (see Figures 8-1—8 in this paper) is allied to this present species in having closely spaced septa and ectosiphuncular morphology. The former, however, can be distinguished from the latter by the presence of episeptal deposits, more depressed conch, and much smaller siphuncular diameter in relation to conch diameter.

Occurrence.—Known only from the uppermost part of the Maggol Formation in Sanaegol.

Family Polydesmiidae Kobayashi, 1940
Genus ***Polydesmia*** Lorenz, 1906
Type species : *Polydesmia canaliculata* Lorenz, 1906

Polydesmia sp. cf. ***P. canaliculata*** Lorenz, 1906

Figures 6-1 ; 9-4a, b

Material.—Fragmentary phragmocone, KPE20323 from loc. SN720.

Description.—Longiconic orthocone, 97 mm long, naturally weathered to the level of siphuncle ; outline of cross section unknown ; siphuncle large, slightly eccentric, conch diameter slowly expanding at a rate of 1 mm per 8 mm in conch height at the adapical portion ; siphuncular segments very wide and comparatively low ; septal necks cyrtochoanitic, evenly curved and long, equalling about one-third of cameral height, represented by a septal loop which corresponds to two-thirds of a circle ; septal brims broad, moderately separated from septum ; connecting rings thick, expanded largely into camerae, its posterior part forming a triangular elevation toward adoral side (ic in Figure 6-1), which was called "interseptal cavity" by Kobayashi (1940, p. 36) ; posterior area of adnation very broad ; septa moderately concave adorally, septal depth equivalent to one and a half times or less of cameral height ; camerae low, 3.2 mm high ; endosiphuncular canal system of dendritic type, central canal narrow, off-center, radial canal steeply oblique, extending adapically through about 2 siphuncular segments before entering perispatium, its terminating point located at the tip of septal brim ; annuli projected toward antero-inner side, horn-shaped in longitudinal section, internal lamellate structure obscure owing to recrystallization ; camerae with mural-episeptal deposits.

Remarks.—This species is most closely allied to *Polydesmia canaliculata* Lorenz from south of Chiang-chiawan, Liaoyang-hsien, Manchoukuo, North China (Kobayashi, 1940, p. 34, pl. 3, figs. 1-3 and pl. 4, figs. 17-19) in having the strongly oblique radial canal and triangular interseptal cavity, but incomplete preservation of the present specimen without conch outline and siphuncular position precludes exact species-level assignment.

Occurrence.—Known only from the upper part of the Maggol Formation of Sanaegol.

Family Wutinoceratidae Shimizu and Obata, 1936 emend. Flower, 1968
Genus ***Wutinoceras*** Shimizu and Obata, 1936 emend. Flower, 1957
Type species : *Nybyoceras foerstei* Endo, 1930

Wutinoceras robustum (Kobayashi and Matsumoto, 1942)

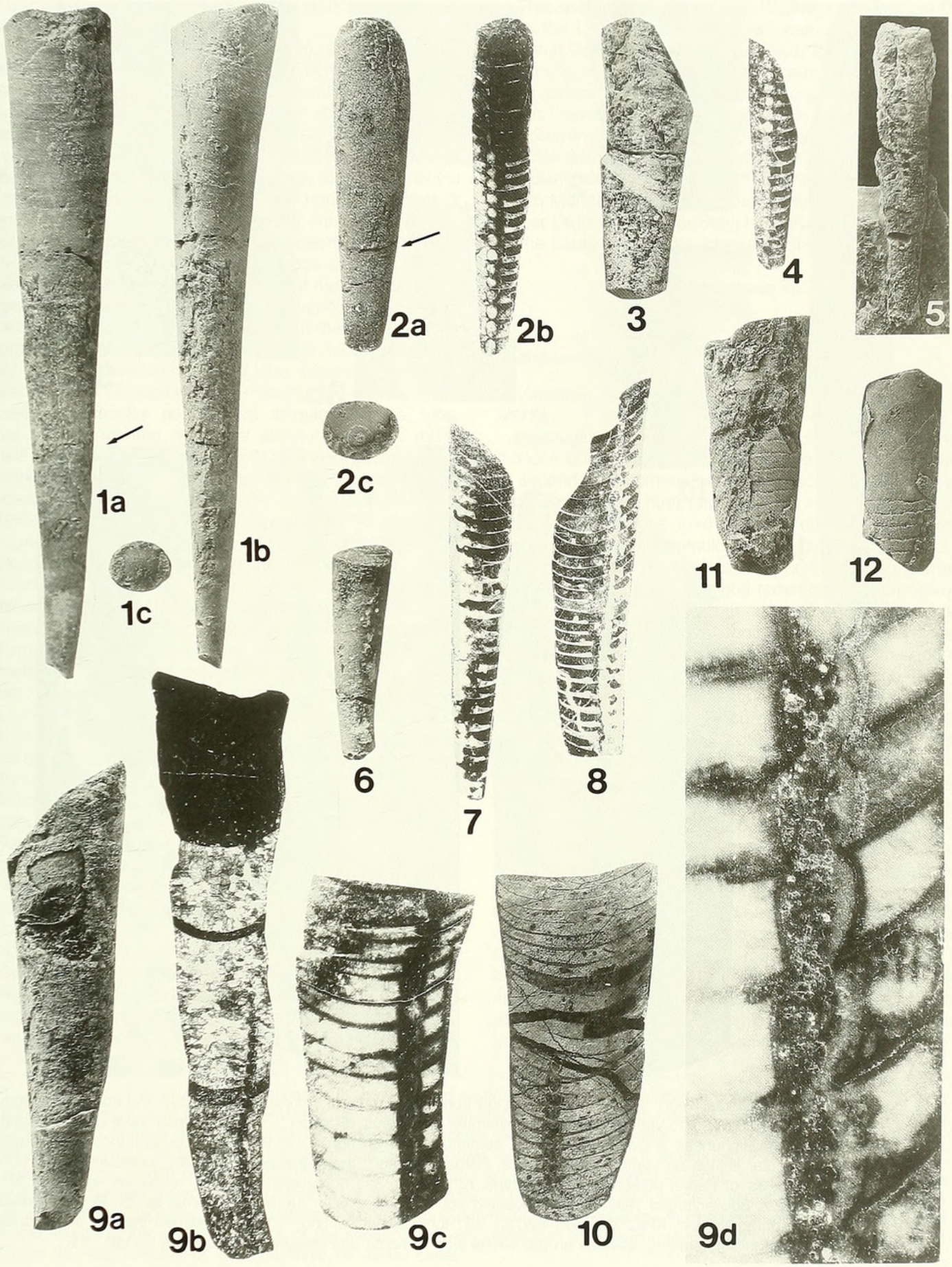
Figures 6-2 ; 10-1, 2

Jeholoceras robustum Kobayashi and Matsumoto, 1942, p. 315, pl. 30, figs. 1-5 ; pl. 31, fig. 6.
Armenoceras robustum (Kobayashi and Matsumoto). Chao *et al*., 1965, p. 70, pl. 17, figs. 7-9.
Armenoceras cf. *robustum* (Kobayashi and Matsumoto). Chen, 1983, p. 122, pl. 2, figs. 5, 6.
Wutinoceras robustum (Kobayashi and Matsumoto). Stait and Burrett, 1982, p. 194, figs. 2A-L

Material.—Two phragmocones, KPE20206, 20207 from the middle part of the Maggol Formation of Sanaegol at loc. SN712.

Diagnosis.—Siphuncle eccentric, close to venter, broad ; siphuncular segments nummuloidal, highly expanded ; thickened connecting ring ; septal brims longer than necks, varying from recumbent to slightly hooked, nearly touching the septa only at their tip ; reticulate canal system ; episeptal and hyposeptal deposits present.

Figure 8. **1-8**. *Ormoceras cricki* Kobayashi, 1934. All collected from SN741. **1a-c**. Nearly complete conch without apical portion, KPE20231, ×1.5, 1a : ventral view, 1b : lateral view, venter on right, 1c : septal view at position indicated by arrow given in 1a. **2a-c.** Partial phragmocone, KPE20232, ×1.5, 2a : ventral view, 2b : longitudinal section, venter on left, showing well developed episeptal deposits, 2c : septal view at position indicated by arrow given in 2a. **3**. Partial phragmocone, KPE20237, ventral view, ×2. **4**. Partial phragmocone, KPE20235, longitudinal section, venter on left, ×1.5. **5**. Partial phragmocone, KPE20233, ventral view, ×1.5. **6**. Partial phragmocone, KPE20245, dorsal view, ×1.5. **7**. Partial phragmocone, KPE20234, longitudinal section in slightly askew dorsoventral direction, ×1.5. **8**. Partial phragmocone, KPE20244, dorsoventral section, venter on right, ×1.5. **9-12**. *Ormoceras weoni* sp. nov. All collected from SN741. **9a-d.** Adoral phragmocone and contiguous partial body chamber, holotype, KPE20260, 9a : dorsal view, ×1, 9b : longitudinal section, venter on right, acetate peel, ×1.5, 9c : enlarged view of apical portion, ×3, 9d : details of siphuncle and septa, ×12. **10**. Partial phragmocone, paratype, KPE20261, longitudinal section, venter on left, acetate peel, ×1.5. **11**. Partial phragmocone, paratype, KPE20265, showing transverse septal sutures, ×1.5. **12**. Partial phragmocone and contiguous body chamber, paratype, KPE20264, shell exfoliated, showing transverse septal sutures, ×1.5.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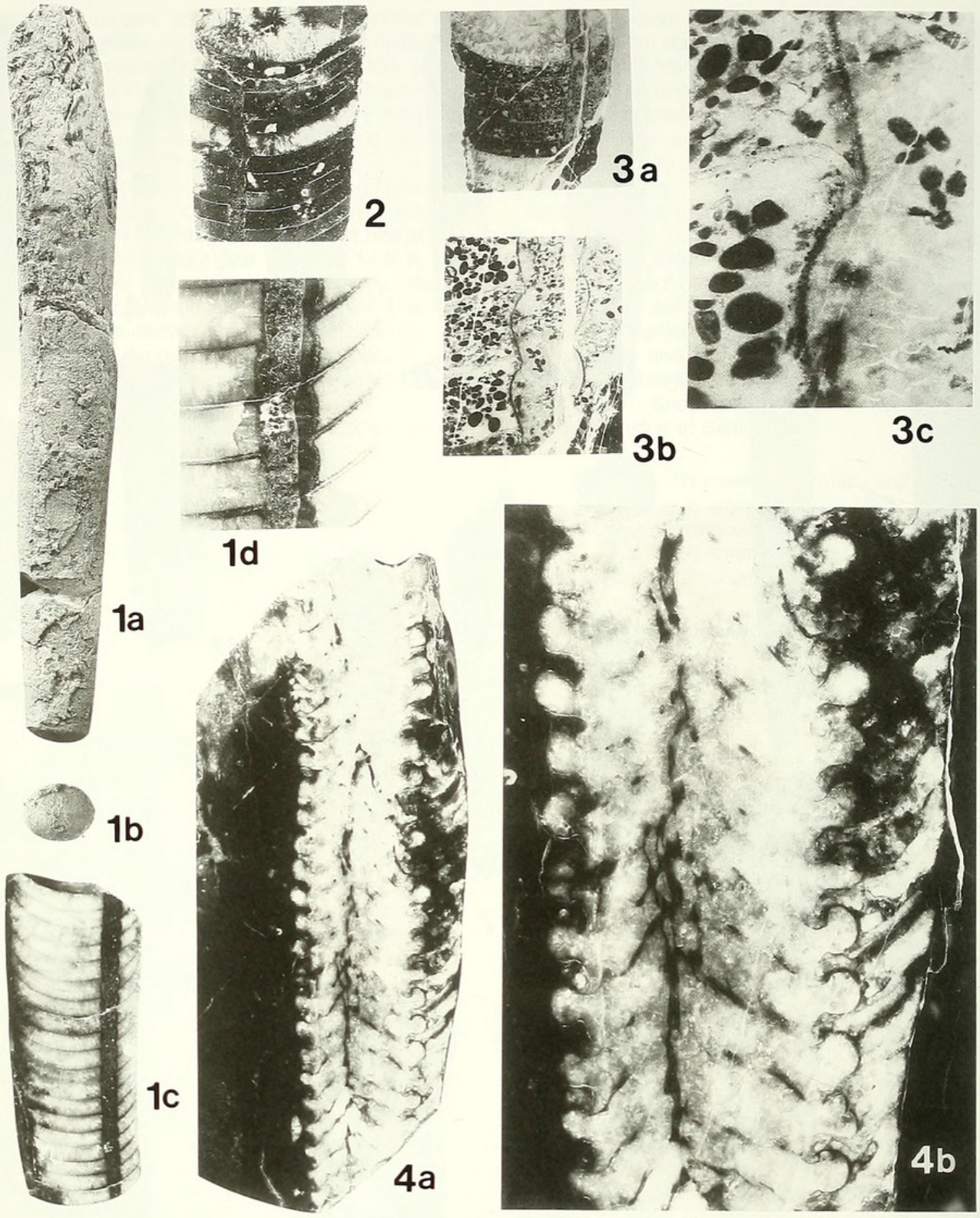


Figure 9. **1-3.** *Ormoceras weoni* sp. nov. All collected from SN741. **1a-d.** Adoral phragmocone and contiguous body chamber, paratype, KPE20262, 1a: ventral view, body chamber somewhat distorted , ×1, 1b: septal view of apical end, showing position of the siphuncle, ×1, 1c: dorsoventral section, venter on right, ×2, 1d: details of siphuncular structure, showing endosiphuncular linings on ventral side, ×7. **2.** Partial phragmocone, paratype, KPE20267, dorsoventral section, venter on left, ×2.2. **3a-c.** Partial phragmocone, paratype, KPE20263, 3a: dorsoventral section, venter on right, ×2, 3b: detail of siphuncle, ×7, 3c: enlarged view of cyrtochoanitic septal neck, ×30. **4a, b.** *Polydesmia* sp. cf. P. canaliculata Lorenz, 1906. partial phragmocone, KPE20321, loc. SN720, 4a: longitudinal section, ×1, 4b: enlarged view of siphuncular structure, showing triangular interseptal cavities on the adoral side of septa and steeply inclined radial canals, ×5.

Description.—Large-sized longiconic orthocones with well defined reticulate canal system.

KPE20206 (Figures 6-2 and 10-1a, b), a partial phragmocone with apical end, 115 mm long consisting of 10 siphuncular segments including initial chamber; presumably subcircular in cross section; cameral portion of apical part mostly lost during taphonomic process; siphuncle eccentric, its width broad, occupying nearly a half of conch diameter; siphuncular segments nummuloidal, highly expanded, having a length of 11.2 mm and a width of 27.5 mm at the point of maximum expansion, constricted to 13.7 mm at septal foramen; septa moderately curved, septal depth corresponding to a little less than one and a half times cameral height; septal necks cyrtochoanitic, recurved but free; septal brims longer than necks, varying from recumbent to slightly hooked, nearly touching the septa only at their tip; cameral height rather high, averaging 10.2 mm; connecting ring relatively thick, apically adnate for a long distance, 3.8 mm to adoral surface of septum, just meeting the septal brims adorally; siphuncular deposits of annulosiphonate type, canal system forming reticulate structure, narrow radial canals branched off from irregularly arranged central canal entering to the midpoint of perispatium; episeptal and hyposeptal deposits well developed; shell surface unknown.

KPE20207 (Figures 10-2a, b), represented by a partial phragmocone with one side crushed; a gastropod belonging to *Pagodispira* (?) detected in a camera in cross section (indicated by arrow, see Figure 10-2b); conch somewhat flattened and siphuncle slightly elliptical in cross section; siphuncle eccentric, close to venter; siphuncular segments uniform in dimension, 8.5 mm long and 23.3 mm in maximum diameter within camerae, pinched to 13.1 mm at the septal necks; posterior area of adnation moderately broad, 3.2 mm; central canal sigmoidally curved in longitudinal direction, its width ranging from 1.6 mm to 3.5 mm while radial canal is narrow, 0.4 mm or less, radially distributed bunches of annulosiphonate deposits in cross section of adoral end.

Remarks.—The present species is similar to *Wutinoceras foerstei* (Endo) from the Lower Ordovician Wuting Formation of South Manchuria (Endo, 1930, p. 208, pl. 60, figs. 1A-C) in ectosiphuncular structure and reticulate canal system, but the latter differs from the former in having a more ventrally positioned siphuncle and less cameral deposits. This species may be allied to *Wutinoceras logani* Flower from the Table Head Formation of Newfoundland (Flower, 1968, p. 8, pl. 10, figs. 1-3; pl. 11, figs. 1-7) in the large-sized conch and strongly flattened siphuncular segments, but the former is distinguished from the latter in having more thickened cameral deposits and less recumbent septal brims.

This species is also similar to *Wutinoceras remotum* Chen from the Lower Ordovician, lower part of Jiacun Group of Nielamu County, China (Chen, 1975, p. 274, pl. 1, figs. 7, 8) in the mode of endosiphuncular and cameral deposits, but the latter differs from the former in the longer septal necks and much narrower siphuncular segments.

Occurrence.—In addition to the present materials, this species is known from the Toufangian strata in the vicinity of Nanpiano Coalmine, Nanpiano County, Liaoning Province, South Manchuria (Kobayashi and Matsumoto, 1942) and the Lower Ordovician Lower Setul Limestone on Pulau Langgun of the Langkawi Islands, Malaysia (Stait and Burrett, 1982).

Wutinoceras sp.

Figures 10-3a—d

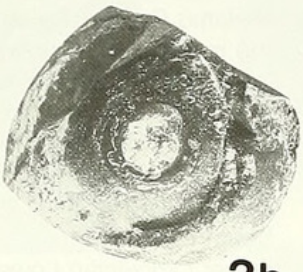
? *Wutinoceras* sp. Zhu and Li, 1996, pl. 1, fig. 11.

Material.—Partial phragmocone, KPE20202 from loc. SN713.

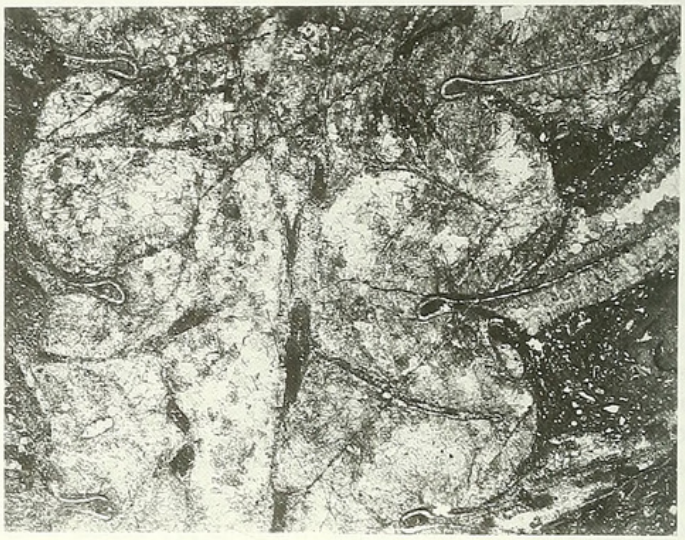
Description.—Medium-sized orthocone, preserved phragmocone 60 mm long, its expansion rate not measured owing to secondary deformation, conch subcircular in cross section; siphuncle central, large, 11.5 mm in maximum diameter, occupying about one-third of conch diameter; siphuncular segments strongly nummuloidal, 4.2 mm in length and 11.5 mm in maximum diameter at mid-portion within camerae, contracting to 6.6 mm at septal foramen; septa moderately concave adorally, septal depth one and a half times cameral height, septal necks cyrtochoanitic, strongly recurved, septal brims far longer than necks, its end adnate to the adapical surface of septum, especially in juvenile stage, but not adnate in later stage; connecting ring adnate for a relatively long distance to adoral surface of septum dorsally, but free ventrally, just meeting the tip of septal brim; suture slightly sloping from venter to dorsum, but transverse when viewed from dorsal side; camera about 4.3 mm high, 8 camerae preserved in a partial conch 37 mm in length; annulosiphonate deposits well developed (Figures 10-3c, d), annuli embracing the inner margin of septa at septal necks, gradually decreasing adorally in bulk, its shape asymmetrical in longitudinal section, more concentrated to the adoral side, adjacent annuli in contact with each other, remaining spaces forming radial canal, which branches off from much broader central canal, in some cases, radial canal divided into two branches and entering in perispatium; camerae filled with episeptal and hyposeptal deposits only on ventral side, also deposits in ventral camera forming pseudoseptum at mid-portion of camera joining to radial canal.

Figure 10. **1, 2.** *Wutinoceras robustum* (Kobayashi and Matsumoto, 1942). **1a, b.** Partial phragmocone, KPE20206 from SN712, 1a: longitudinal polished section of an originally weathered specimen, ×1, 1b: details of septal necks and reticular canal system, acetate peel, ×2.4. **2a, b.** Partial phragmocone, KPE20207 from SN712, ×1, 2a: longitudinal section, venter on left, 2b: cross section at the adapical end, venter down. Arrow indicates a gastropod, *Pagodispia* (?) sp. **3a-d.** *Wutinoceras* sp. partial phragmocone, KPE20202 from SN713, 3a: lateral view, venter on right, ×1, 3b: septal view of the apical end, venter down, showing position of the siphuncle, ×1, 3c: longitudinal section, venter on left, showing the annulosiphonate deposits, ×1, 3d: details of siphuncular structure, acetate peel, showing free septal necks, but tip of septal brims adnate to the adapical surface of the septum, and well-developed annulosiphonate deposits, ×5. Abbreviations in Figure 3d: an; annulus, cc; central canal, rc; radial canal.

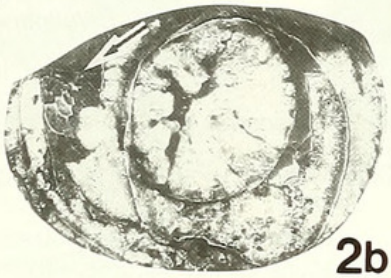
1a



3b

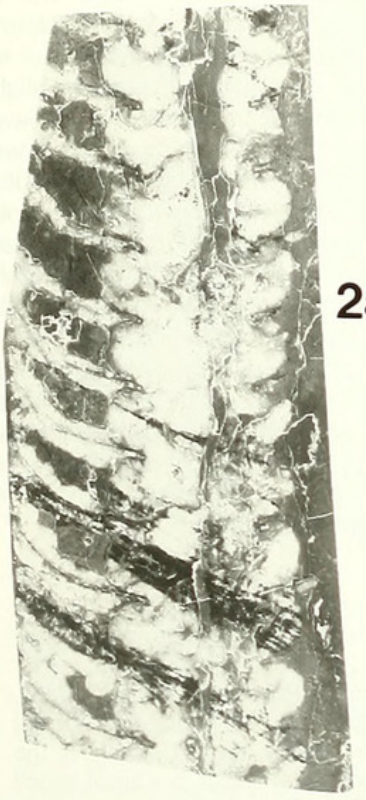


1b

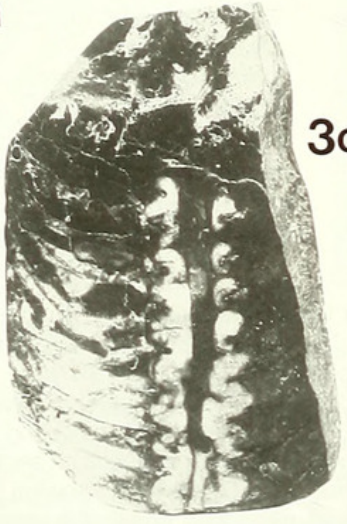


2b

3a



2a



3c

3d

Remarks.—This species resembles *Wutinoceras giganteum* Flower from the early Middle Ordovician Table Head Limestone of Newfoundland (Flower, 1976, pl. 2, fig. 4 ; pl. 3, fig. 12 ; pl. 4, figs. 1, 2 ; pl. 5, fig. 6) in the nearly central position of the siphuncle, but is distinguished by its more crowded camera, obliquely inclined septal suture and the presence of the well-developed canal system. In the flattened siphuncular segments and recumbent septal necks, this present species is somewhat similar to *Wutinoceras logani* Flower from the Table Head Limestone, Newfoundland (Flower, 1968, p. 8, pl. 10, figs. 1-3 ; pl. 11, figs. 1-7), but differs by its more undulating central endosiphuncle and thicker mural-episeptal deposits.

Wutinoceras lui Chang from the Inner Mongolia (Chang, 1959, pl. 2, fig. 3 ; pl. 3, fig. 5) is also allied to this species, but the former differs from the latter in its eccentric siphuncle and less flattened siphuncular segments. Furthermore, the present species is allied to *Wutinoceras shihuigouense* Chang from the upper part of the Lower Ordovician Tochuanshan Limestone, Shihuigou, Chinghai (Chang, 1965, p. 352, pl. 1, fig. 4) in the subcentral position of the siphuncle and the constant relation of the septa and segments, but in *W. shihuigouense*, the septa are more steeply inclined and the connecting ring is rather uneven. *Wutinoceras* sp. from the Lower Ordovician Xiamajiagou Formation of Southern Jilin, China (Zhu and Li, 1996, pl. 1, fig. 11) may be compared to the present species in its free septal necks and somewhat broader area of adnation.

Occurrence.—Known only from the middle part of the Maggol Formation of Sanaegol.

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