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Faunal and Biogeographical Characteristics of the Ordovician Cephalopods from Korea

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9 Text-Figures, 1 Table and 3 Plates

Korea
Ordovician
Joseon Supergroup
Faunal Connection
Epicontinental Seaways

Contents

Faunistische und biogeographische Charakteristika der ordovizischen Cephalopoden von Korea

Zusammenfassung

Die ordovizischen Gesteinsschichten der Joseon Supergroup sind in Gangwondo, Korea, weit verbreitet und relativ reich an fossilen Cephalopoden. Die koreanische Cephalopoden-Fauna besteht aus drei unterschiedlichen Faunen. Die unterordovizische Maggol-Fauna ist in Südostasien endemisch. Zu Beginn der mittelordovizischen Periode weist die Jigunsan-Fauna auf einen faunistischen Zusammenhang mit Europa hin, basierend auf dem Vorkommen von *Holmiceras* und *Troedssonella*. Die oberste mittelordovizische Duwibong-Fauna in Südkorea, die durch Actionoceriden gekenngezeichnet ist, hat die stärkste Affinität zur Fauna der Südmandschurei.

Daraus wird der Schluss gezogen, dass die arcto-amerikanische Fauna ausgewandert ist und sich nach Ostasien über die sibirische epikontinentale Meeresstraße ausgebreitet hat.

Abstract

The Ordovician strata of the Joseon Supergroup widely distributed in Gangwondo, Korea are comparatively rich in cephalopod fossils. The Korean cephalopod fauna comprises three different components. The Lower Ordovician Maggol fauna is characterized by endemic species in southeastern Asia. At the beginning of the Middle Ordovician Period, the Jigunsan fauna indicates a European faunal connection, based mainly on the occurrence of *Holmiceras* and *Troedssonella*. The uppermost Middle Ordovician Duwibong fauna in South Korea is characterized by actinocerids and has the strongest affinity with that of South Manchuria.

This phenomenon suggests that the Arcto-American fauna migrated and extended to East Asia through Siberian Epicontinental Seaways.

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1. Introduction

Since the pioneering efforts of KOBAYASHI (1927), much has been learned about the systematics of nautiloid cephalopods from Korea. His subsequent works (KOBAYASHI, 1934a, 1966, 1977a, 1977b, 1978) provide important phylogenetic clues and insight into the Asiatic and worldwide Ordovician palaeogeography of fossil cephalopods.

The existence of a certain barrier extending from Tsinlingshan, China to Seoul, Korea – the so called Tsinling–Seoul Line – was recognized in Southeastern Asia during the Ordovician Peroid, on the basis of remarkable faunal differences between southern and northern portions (KOBAYASHI, 1930).

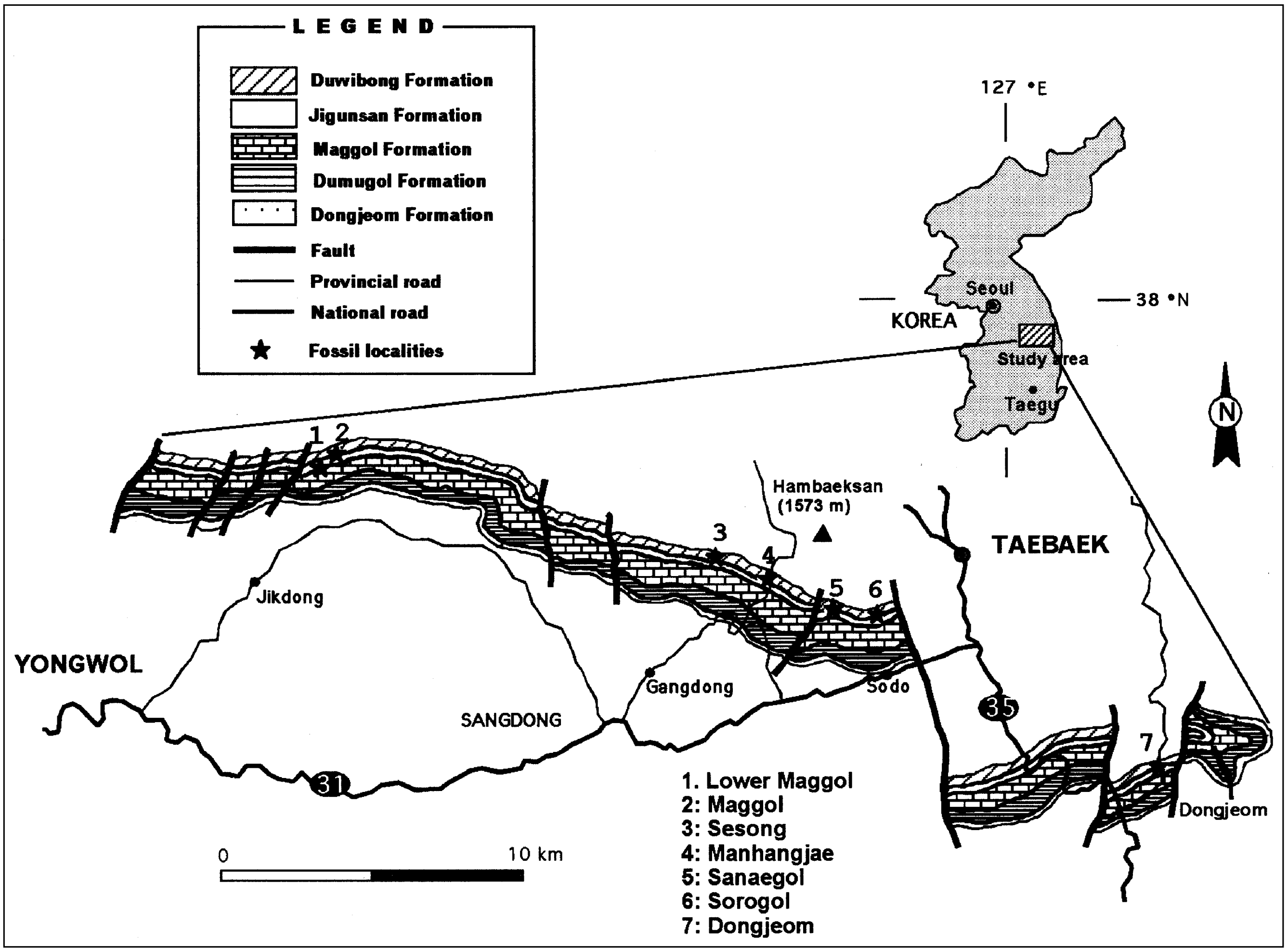
Subsequently, KOBAYASHI (1934b) stated that the northern fauna in North Korea, South Manchuria, and North China became closely tied up with the Arctic American faunas and that south of the line the relationship with European faunas is pronounced. Furthermore, KOBAYASHI (1970, 1971) emphasized the European faunal connection to the Jigunsan fauna of South Korea through a migration route.

However, the cephalopod fauna of South Korea, located in the southern part of the Tsinling–Seoul Line, is not consistent with this common tendency. Ordovician palaeogeographic patterns with reference to cephalopod fossils are less well understood in Eastern Asia.

The aims of this study are to examine the Korean cephalopod fauna – its characteristics and biogeography – and compare them with cephalopod faunas of other regions, on the basis of the Ordovician cephalopods newly collected from Korea. All specimens utilized herein are deposited in the Department of Earth Science, Teachers College, Kyungpook National University (KPE prefix), Daegu, South Korea. In addition, the cephalopod type specimens described by KOBAYASHI (1927, 1934a, 1977a, 1977b, 1978) from the Ordovician of Korea, viz. 22 syntypes, 47 holotypes and 24 paratypes, and 49 figured specimens were used for comparison and reexamination.

2. Geology and Stratigraphy

Cambro-Ordovician deposits are widely distributed in Gangwondo, Korea. The deposits are called the Joseon Supergroup. It consists of five groups, based on contrasting lithologic successions, viz. Taebaek, Yeongwol, Yongtan, Pyeongchang, and Mungyeong Groups (CHOI, 1998). Among them, the Taebaek Group comprises ten formations and has been known to represent a shallow marine continental shelf environment as its depositional background: Jangsan Formation, Myobong Formation, Daegi Formation, Sesong Formation, Hwajeol Formation, Dongjeom Formation, Dumugol Formation, Maggol Formation, Jigunsan Formation, Duwibong Formation in ascending order. The geologic map shows only the Ordovician sequence in the Taebaek Group (Text-Fig. 1). For this study, new and unstudied cephalopod specimens were collected from the Maggol Formation to the Duwibong Formation through the intervening Jigunsan Forma-



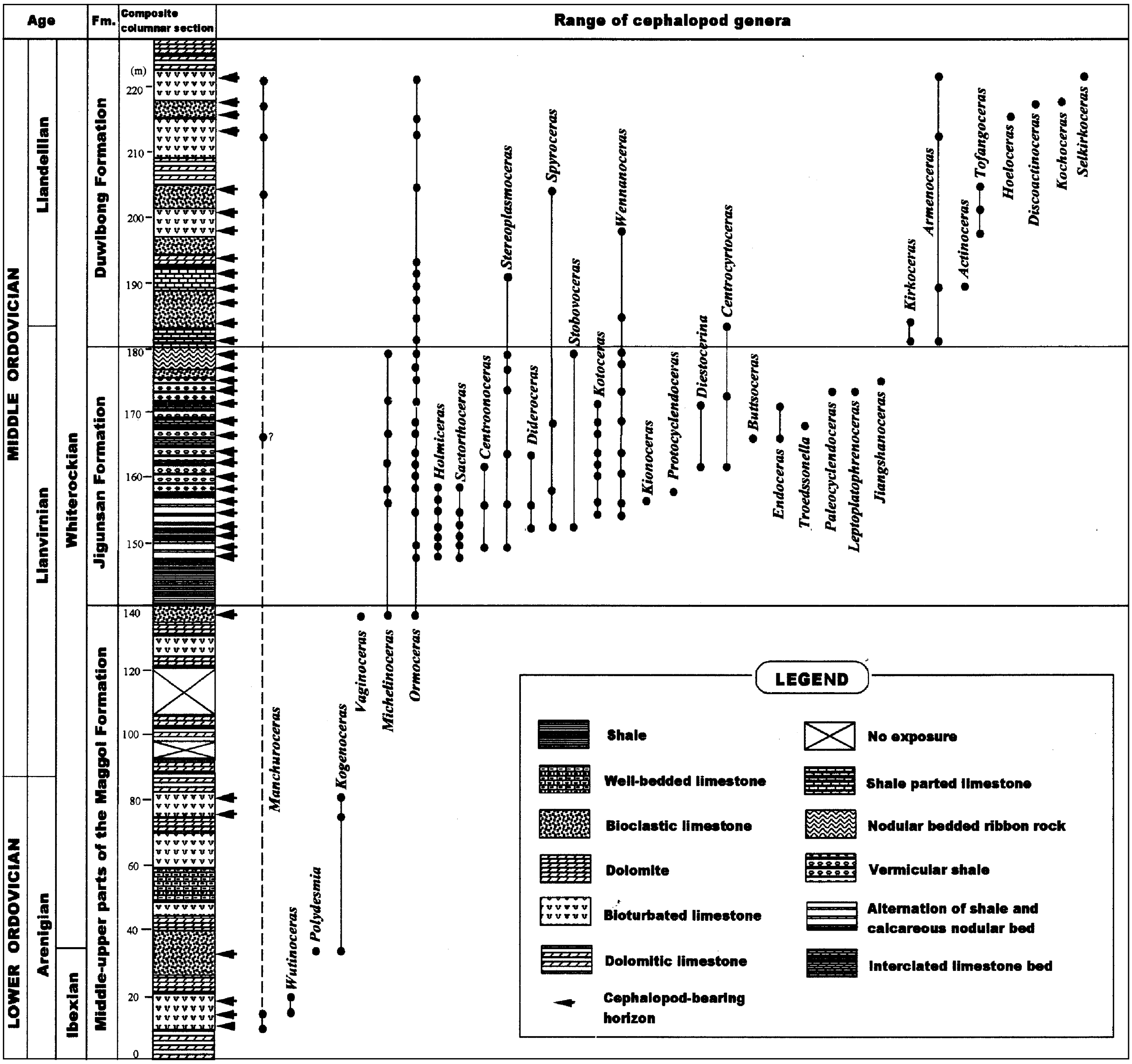
Text-Fig. 1.
Geological map of the study area, showing the Ordovician sequence and fossil localities.

tion at seven sections (Text-Fig. 1). The number of fossils examined in this study is 345 individuals.

The Maggol Formation ranges from 250 to 400 m thick. Fossil cephalopods were found in seven stratigraphic units, the middle-upper and the uppermost part of the formation, being especially abundant in the uppermost horizon of this formation (Text-Fig. 2). Lithologic components of the formation consist of bioturbated limestone with burrowing structures, 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. The lithic facies shows an abrupt change from bioclastic grainstone consisting mostly of oolitic particles to calcareous black shale in the uppermost part of this formation.

The Jigunsan Formation, about 40 m thick, conformably covers the Maggol Formation, and grades into the overlying Duwibong Formation. These features can be traced from east to west in the Taebaek region. This formation is characterized by various abundant fossils in shale (Text-Fig. 2). It consists mainly of black shale containing a little calcareous material, vermicular shale intercalated by three or four limestone beds, each about 40 cm thick, and bioclastic grainstone with intercalating calcareous shale. The amount of carbonate gradually increases toward the top of the sequence and ultimately grades into the limestone of the Duwibong Formation. The boundary between the Jigunsan and Duwibong Formations is gradual. The uppermost limit of the Jigunsan Formation was designated as the transition point from the nodular bedded ribbon rock to the shale parted limestone (Text-Fig. 2).

The Duwibong Formation, which represents the uppermost part of the Taebaek Group in the Joseon Supergroup, overlies the Jigunsan Formation conformably and is unconformably overlain by the Carboniferous–Triassic Pyeongan Supergroup. This formation is mostly composed of massive limestone, bioclastic packstone or grainstone, bioturbated limestone and some dolomitic limestone (Text-Fig. 2). Its thickness is about 40–50 m.



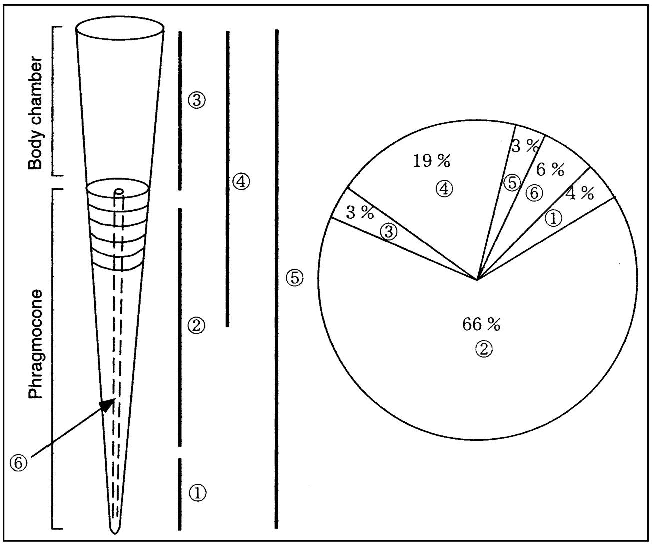
Text-Fig. 2.
Range chart showing the stratigraphic distribution of cephalopod genera in the composite section of the Taebaek-Yeongwol area.

3. General Aspects of the Korean Cephalopod Fauna

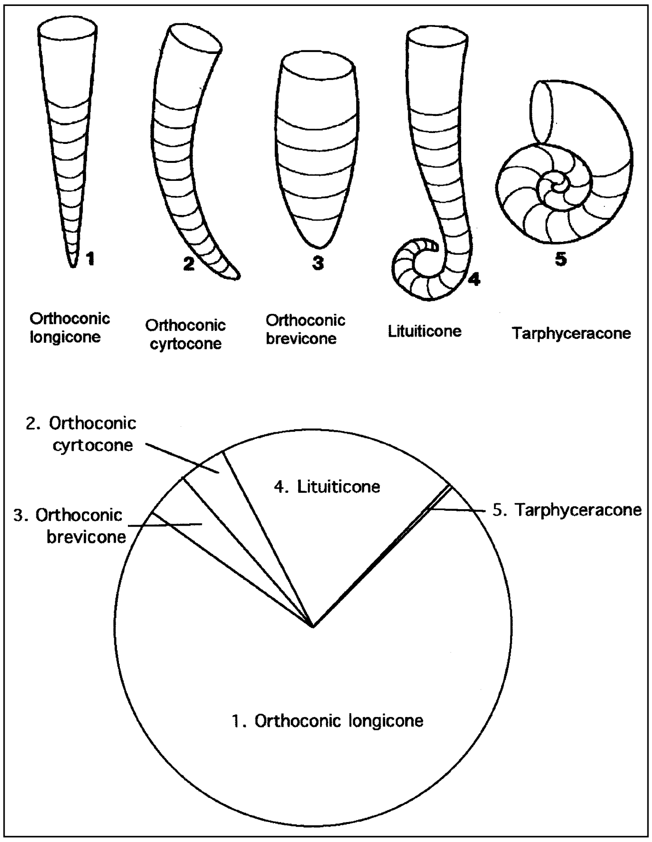
Various macroinvertebrate fossils, including trilobites, cephalopods, brachiopods, gastropods, bivalves, crinoids etc., occur in the Ordovician formations of the Taebaek Group in the Joseon Supergroup, South Korea. Of these fossils, cephalopods have been classified into 91 species belonging to 34 genera (YUN, 1999b). Regrettably, these taxonomic results contain tentative assignments because the internal structures of some specimens were strongly deformed and recrystallized during taphonomic process. Text-Fig. 3 shows the relative frequencies of the preserved parts in the nautiloids utilized herein. The majority of the specimens are represented by partial phragmocones, occupying 66 % of the total. Those with body chambers amount to 19 %. What is more, the complete conchs including an apical end account for 3 %. Taking into account the fragility of the slender conch, the foregoing statistical values on the preservation rate are rather low. This fact indicates that the nautiloids have been subjected to transport during the biostratinomic process.

The present condition of the number of individuals by each genus shows that the two genera, *Holmiceras* and *Ormoceras* occupy 56 % of the total cephalopod fossils. In particular, the genus *Holmiceras* (Pl. 1, Figs. 1–4) occupies a predominant position, almost amounting to 32 % of the total cephalopod fossils in the Jigunsan Formation. Such genera as *Kotoceras, Wennanoceras*, and *Manchuroceras* are subordinate in occurrence.

The conch forms in cephalopods are largely divided into nine types (TEICHERT, 1964). In this study, five cephalopod conch types are recognized: orthoconic longicone, orthoconic brevicone, orthoconic cyrtocone, lituiticone, and tarphyceracone (Text-Fig. 4). The tarphyceracone type is represented by *Trocholites ammonoides* from the Jigunsan Formation of Maggol, Jungdong-meyon, Yeongwol area which is an entirely coiled conch and is illustrated by KOBAYASHI (1934a). Orthoconic longicones are dominant, namely, straight and slender conchs, as in other worldwide Lower Palaeozoic cephalopods. The following order is lituiticone with an early coiled shell portion, which is represented by *Holmiceras coreanicum* (Pl. 1, Figs. 1–4) much collected from the alternating beds of shale and calcareous nodules in the lower part of the Jigunsan Formation



Text-Fig. 3.
Relative frequency by preserved parts in cephalopods from Korea.



Text-Fig. 4.
Relative proportions of shell forms in cephalopods utilized in this study.

(YUN, 1999a). The orthoconic cyrtocone and brevicone are uncommon and occur in the same degree.

Interestingly, *Manchuroceras* occurs in the Maggol Formation as well as in the Duwibong Formation (Pl. 3, Figs. 3a, 3b). Cephalopod workers experience great difficulty in procuring the cameral portion of *Manchuroceras*. No one has observed as yet the cameral portion of *Manchuroceras*. KOBAYASHI (1936) mentioned that the cameral portion was destroyed before or after death, at any rate, the destruction occurred before fossilization. In turn, *Manchuroceras* with its siphuncle strengthened by thick endosiphuncular deposits might have destroyed weaker camerae while alive and this fact supports the hypothesis of a benthic life.

The cephalopods with an ornamented shell surface are confined to the orthocerids and part of the endocerids. The recognizable patterns are growth lines, lirae, annulations, and so on. Commonly, there is a combination of two or three patterns. In *Sactorthoceras makkolense* and *Holmiceras coreanicum*, the low annulations and fine growth lines coexist (YUN, 1999a). *Spyroceras* sp. illustrated in Figs. 2a–c on Pl. 3 is characterized by strong annulations and very fine longitudinal filiform lines. The latter form is not differentiated by the naked eye. It is distinguishable only under an optical microscope. On rare occasions, three patterns of longitudinal ridges and reticulate lines coexist in *Kionoceras* sp. from the Jigunsan Formation of Sesong. The two genera, *Wennanoceras* and *Tofangoceras* are characterized by strong annulations and can be distinguished by their internal structures. The latter genus has well developed organic deposits in the camerae and siphuncle. Both genera are important elements in the Jigunsan and Duwibong cephalopod fauna. Meanwhile, actinocerid cephalopods consistently have a smooth shell. Their siphuncular position tends to be submarginal. These features are interpreted as a "benthonic adaptation" to decrease resistance to the sea bottom (TEICHERT, 1935; KOBAYASHI, 1936).

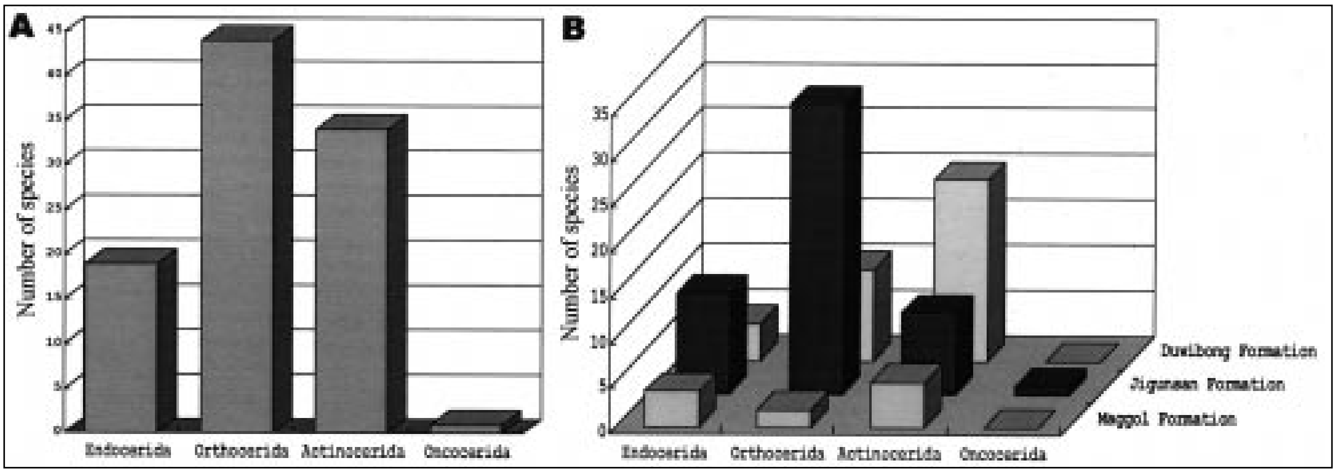
4. Faunal Composition and Biogeographical Characteristics

The cephalopods from Korea belong to four orders and largely consist of orthocerids and actinocerids (Text-Fig. 5). The remaining part is filled with endocerids, amounting to 19 % of the total cephalopods that are partly contained in each formation. The global occurrence of the cephalopod genera now known from the Ordovician rocks is summarized in Table 1. This summary makes it clear that the North China fauna shows the strongest affinities with the Korean Ordovician fauna. Of 34 genera recognized in the Korean Ordovician formations, 24 genera are also known from North China at the present state of our knowledge. Broadly speaking, the cephalopod fauna of Korea is also closely related to that of Balto-Scandinavia, North America, Manchuria, and the Siberian Platform. However, the fauna in each formation shows quite different affinities with other regions.

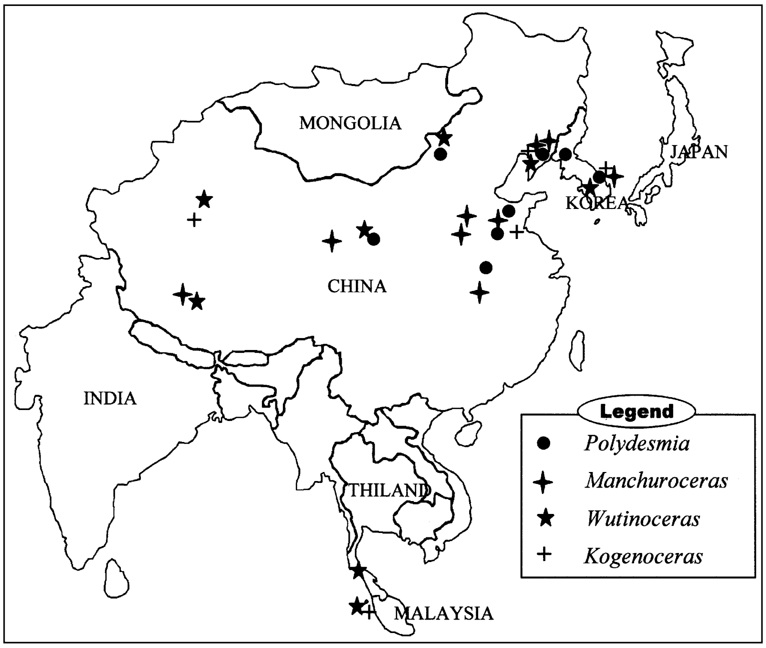
The cephalopod fauna from the Maggol Formation is characterized by *Wutinoceras* (Pl. 3, Fig. 6), which is regarded as an ancestor of actinocerids (FLOWER, 1976) and

Table 1.
Chief distribution of cephalopod genera represented in South Korea.

Genera	Manchuria	N China	S China	W China	SE Asia	Australia	Siberia	Balto-Scandinavia	Arctic region	North America
Polydesmia	x	x								
Wutinoceras	x	x		x	x	x				x
Kogenoceras	x	x		x	x					
Vaginoceras	x	x	x	x				x	x	x
Endoceras			x		x		x	x	x	x
Paleocyclendoceras								x		
Protocyclendoceras								x		
Kotoceras		x		x			x			
Dideroceras		x	x	x				x		
Troedssonella			x					x		
Buttsoceras										x
Jiangshanoceras	x	x	x	x						
Kionoceras		x					x	x	x	x
Centroonoceras		x		x						
Holmiceras								x		x
Diestocerina		x	x	x						
Leptoplatophrenoceras		x								
Sactorthoceras	x		x					x		
Stolbovoceras		x					x			
Kirkoceras		x								x
Tofangoceras	x	x					x			
Armenoceras	x	x			x		x	x	x	x
Selkirkoceras	x	x			x		x			x
Hoeloceras	x	x						x		
Discoactinoceras	x	x								
Actinoceras		x	x		x		x	x	x	x
Kochoceras							x		x	x
Michelinoceras		x	x	x	x	x	x	x		x
Centrocyrtoceras										x
Stereoplasmoceras	x	x		x				x		
Filispyroceras							x	x	x	x
Wennanoceras		x		x						
Ormoceras	x	x	?				x	x	x	x
Manchuroceras	x	x	x	x	x	x	x			x



Text-Fig. 5.
Number of species assigned to the 4 main orders in cephalopods.
A) Distribution of the 4 main orders comprising the overall Ordovician cephalopods.
B) Distribution of the 4 main orders for each formation.

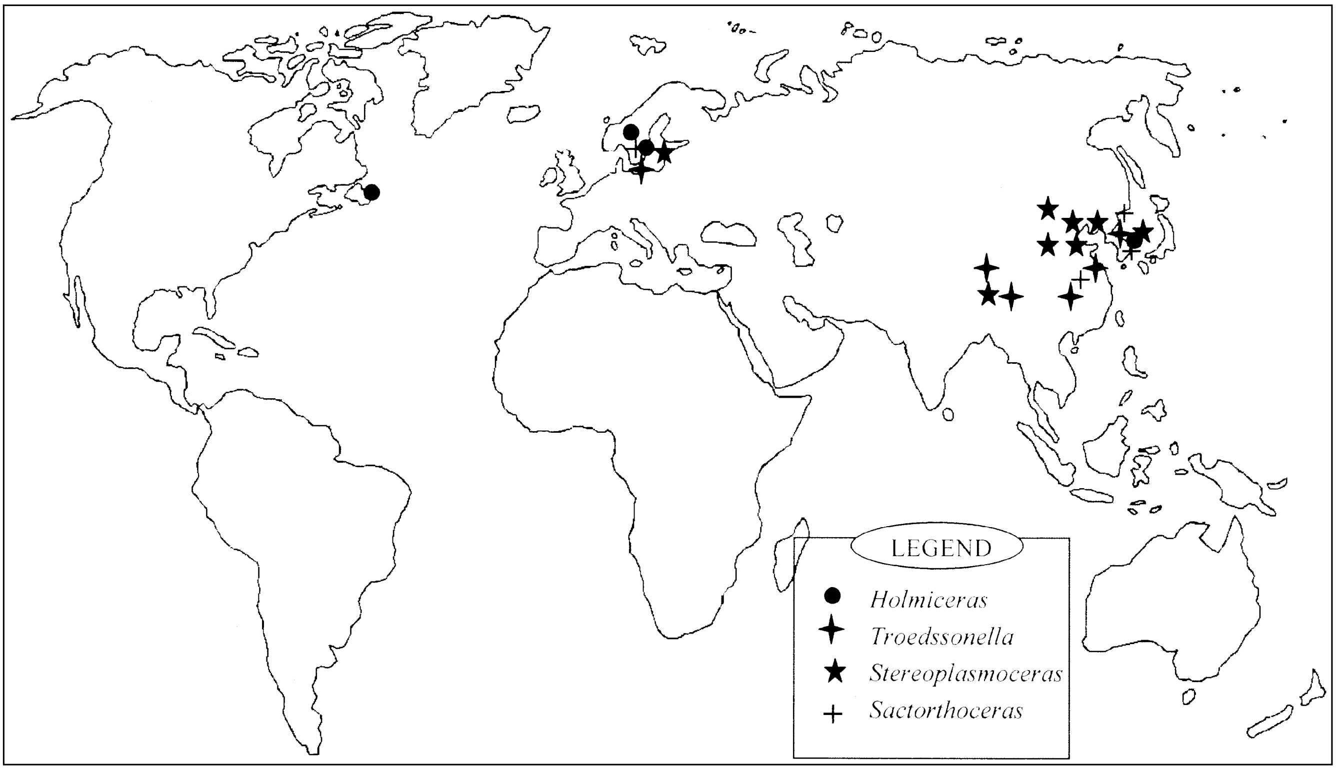


Text-Fig. 6.
Distribution of 4 selected cephalopod genera from the Lower Ordovician Maggol Formation in Korea.

is then followed by the peculiar genus *Polydesmia* (Pl. 1, Fig. 5). As mentioned in a previous paragraph, *Manchuroceras* hitherto known as the typical genus in the Lower Ordovician cephalopod fauna is noticeable in occurring in the Middle Ordovician Duwibong Formation (Text-Fig. 2). The Maggol cephalopod fauna shows the strongest affinity with that of the Liangchiashan to Beianzhuang Formations in South Manchuria in having such common genera and species as *Wutinoceras robustum, Kogenoceras nanpiaoense, Manchuroceras*, and *Polydesmia*. The Maggol fauna is also known in the Lower Setul Limestone in Thailand and Malaysia (STAIT & BURRETT, 1982, 1984; STAIT et al., 1987; YUN, 1999c; see Text-Fig. 6). The four main genera of the Maggol fauna excluding *Polydesmia* are known from Xizang and Xinjiang (CHEN, 1975; LU et al., 1976; CHEN, T.E., 1983, 1984; LAI & WANG, 1986). The Maggol fauna is, therefore, closely related to Northwestern China.

Manchuroceras lemonei from the Florid Mountain Formation of El Paso, Texas described by HOOK & FLOWER (1977) is the only Asian species of *Manchuroceras* known so far from the U.S.A. FLOWER (1968, 1976) reported 13 species of *Wutinoceras* from the Whiterockian of Nevada, Utah, and Newfoundland. Of these fossils, *W. logani* and *W. giganteum* are closely allied to *W. robustum* and *W.* sp. of this fauna. Thus, the American fauna has a somewhat intimate relationship to the Maggol cephalopod fauna. In Tasmania, the two *Wutinoceras* species, *W. pausicubiculatum* and *W. multicubiculatum* from Blenkhorn's Quarry, Railton and two *Manchuroceras* species, *M. excavatum* and *M. steanei* from the Adamsfield limestone are reported (TEICHERT & GLENISTER, 1953; FLOWER, 1957; STAIT, 1984). Accordingly, the two cosmopolitan genera, *Wutinoceras* and *Manchuroceras* are available to understand the palaeogeographical distribution of Lower Ordovician cephalopods and their migration route.

Most of the Jigunsan cephalopods are dominated by orthocerids, among which *Holmiceras coreanicum* (Pl. 1, Figs. 1–4) is the most abundant member. In the middle part of the Jigunsan Formation, the endocerid, *Kotoceras* shows a marked increase in its specific diversity. The actinocerid, *Ormoceras*, which already began to appear in the uppermost part of the underlying Maggol Formation, is a

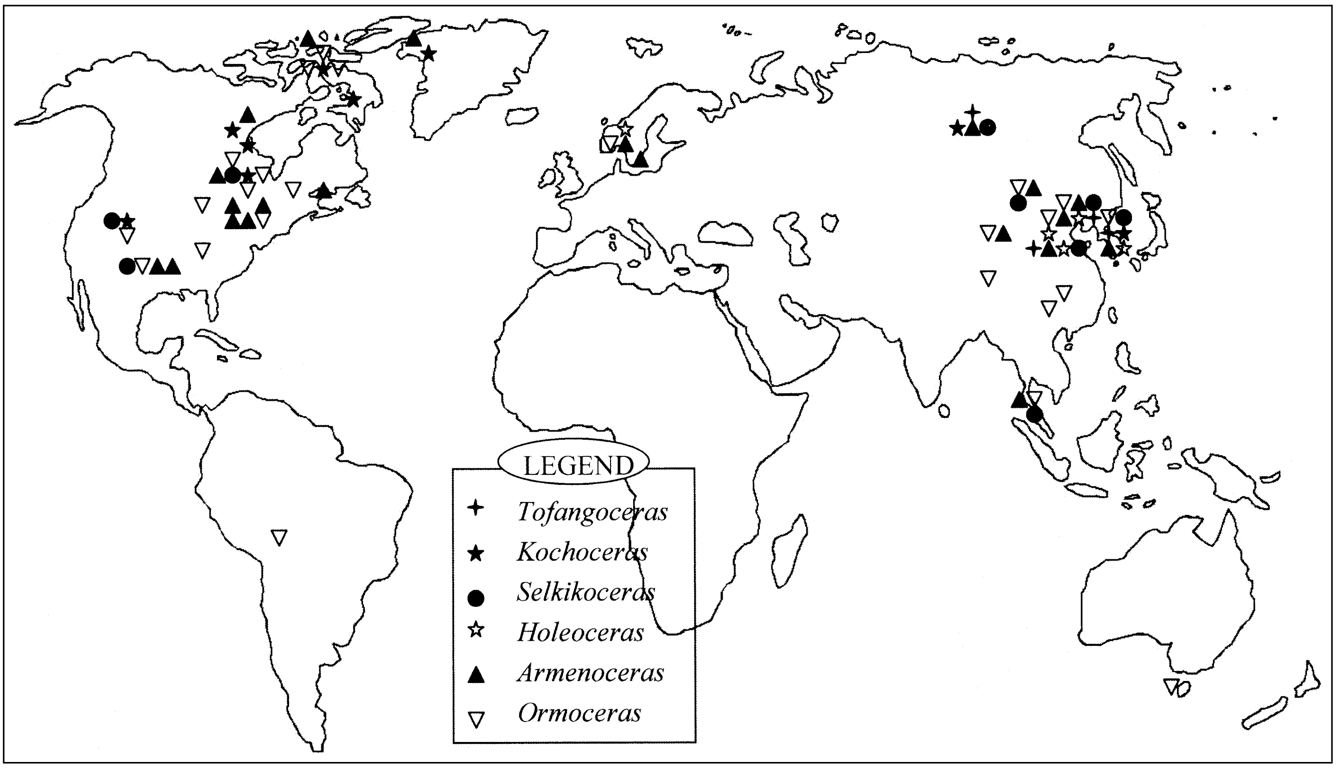


Text-Fig. 7.
Distribution of 4 selected cephalopod genera from the Middle Ordovician Jigunsan Formation in Korea.

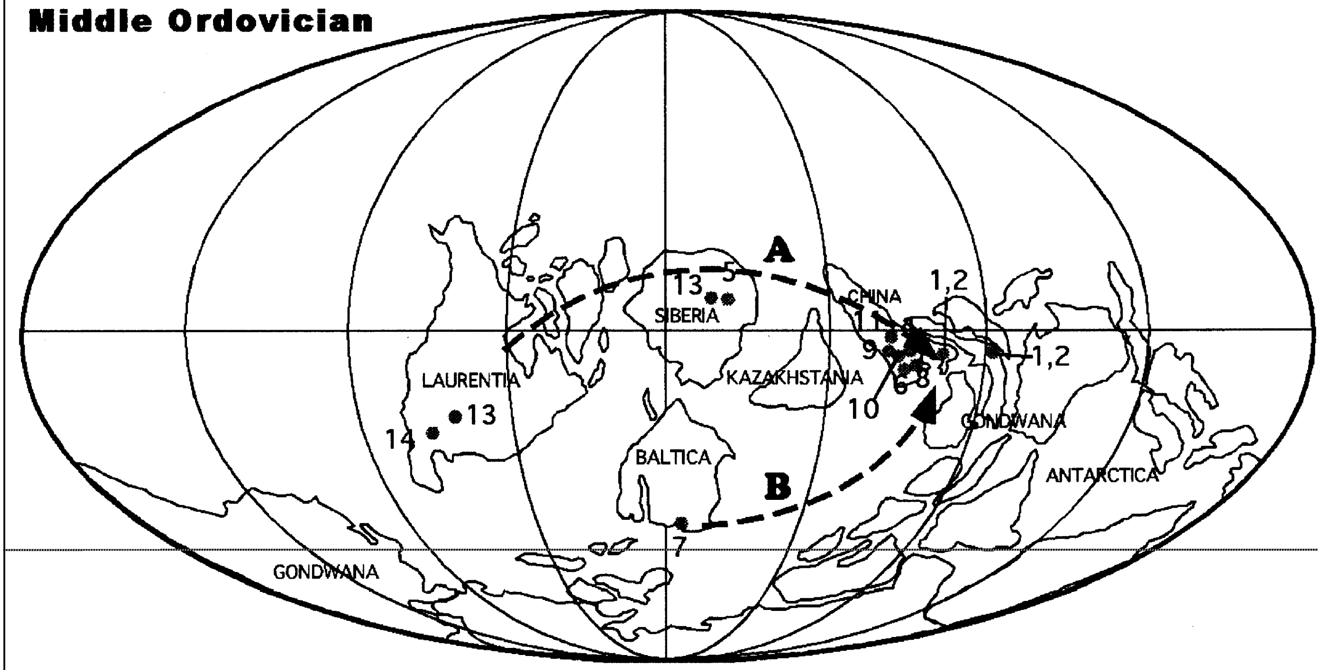
major element in the upper part of the Jigunsan Formation. Its evolution culminates in the overlying Duwibong Formation (Text-Fig. 2). The Jigunsan cephalopod fauna shows an affinity with those of North China and the Balto-Scandinavian region (Text-Fig. 7). Four genera including *Holmiceras, Troedssonella, Stereoplasmoceras* and *Sactorthoceras* are common between Northeastern Asia and Balto-Scandinavia. This fact supports the existence of a European faunal connection route during the Middle Ordovician Period (Text-Figs. 7 and 9). The Hwangho fauna in North China shares 13 common genera with this fauna, indicating close relatives. The common occurrence of *Kotoceras, Centroonoceras, Leptoplatophrenoceras, Stereoplasmoceras*, and *Wennanoceras* which are indigenous to both regions strongly supports the biogeographical affinities between them. According to SWEET (1958), the Middle Ordovician cephalopod faunas of the Oslo region, Norway and the Baltic Sea comprise many lituitids and some *Sactorthoceras* and *Stereoplasmoceras* in which 11 genera occur in common with the Jigunsan fauna. Particularly, *Holmiceras coreanicum* and *Stereoplasmoceras* aff. *tofangoense* are closely related to *H. kjerulfi* and *S. longicameratum*. KOBAYASHI (1927, 1966) suggested that the Jigunsan cephalopods show an American affinity. However, the suggestion is in conflict with this study.

On the other hand, the Jigunsan fauna characterized by orthocerids and endocerids is entirely different from that of Manchuria which comprises many actinocerids. In the Yangtze fauna of South China, the Tofangian actinocerids and Wolungian manchurocerids are exceedingly rare and absent (KOBAYASHI, 1969). In view of this, the Yangtze fauna is quite different from the Duwibong fauna. However, since *Troedssonella, Dideroceras, Jiangshanoceras*, and *Sactorthoceras* are commonly known from both regions, the Jigunsan fauna has an affinity with that of South China. Regrettably, *Sinoceras*, which is well known as a giant genus in the Pagoda Limestone of South China, and *Lituites*, which is typical of tarphyceracones, do not occur in South Korea. *Holmiceras, Kotoceras*, and *Stereoplasmoceras* which are representative genera in the Jigunsan fauna, are not reported in Yangtze fauna in South China. Consequently, the Jigunsan fauna shows some affinities with the Yangtze fauna, but its faunal contents are somewhat different. In other words, the Jigunsan fauna is intermediate in some way between the Yangtze and Hwangho faunas (KOBAYASHI, 1969).

Duwibong cephalopods are dominated by actinocerids, which consist of 7 genera among a total of 14 genera known in the formation (Text-Fig. 2). Of these cephalopods, two genera, *Ormoceras* and *Armenoceras*, are principal components. The Duwibong cephalopod fauna, characterized by actinocerids, has strong affinities with those of North China, Arcto-American and South Manchuria (Text-Fig. 8). The works by KOBAYASHI (1927), ENDO (1932, 1935), LIANG (1981), LI (1984), and ZHU & LI (1996) confined the common occurrence of *Armenoceras, Ormoceras, Hoeloceras*, and *Selkirkoceras* from the Upper Majiagou Formation and/or Ssuyen Formation (ENDO's concept, 1932) in South Manchuria. Furthermore, the above mentioned genera including *Kochoceras* had flourished from the Middle Ordovician (Black Riverian) to Late Ordovician (Richmondian) in the Arcto-American region. Previous works by TROEDSSON (1926), FOERSTE (1926, 1928, 1929, 1930, 1932, 1935a, 1935b), MILLER (1932), TEICHERT (1937), FLOWER (1957, 1968, 1976), MILLER & CARRIER (1942), MILLER et al. (1954), SWEET & MILLER (1958), WILSON (1961), and NELSON (1963) suggested that the Arcto-American region was the mecca of actinocerid cephalopods (Text-Fig. 8). This fauna migrated and extended to East Asia through Siberian Epicontinental Seaways (Text-Fig. 9). Moreover, the seven genera of actinocerids and *Tofangoceras* in the Duwibong fauna are also reported in the Siberian Platform (BALASHOV, 1962, 1964). Consequently, the Duwibong cephalopod fauna represents Arcto-American faunal elements.



Text-Fig. 8.
Distribution of 6 selected cephalopod genera from the Middle Ordovician Duwibong Formation in Korea.



1. *Kogenoceras nanpiaoense*
2. *Wutinoceras robustum*
3. *Stolbovoceras boreale*
4. *Kotoceras cylindricum*
5. *Kotoceras multiseptum*
6. *Kotoceras curvatum*
7. *Kotoceras typicum*
8. *Wennanoceras costatum*
9. *Wennanoceras xizangense*
10. *Leptoplatophrenoceras taoqupoense*
11. *Dideroceras meridionale*
12. *Kochoceras undulatum*
13. *Centroonoceras josephianum*
14. *Kirkoceras arcuatum*

Text-Fig. 9.
Palaeogeographical implications based on the occurrence of 14 common species worldwide.
A) Siberian Epicontinental Seaways.
B) Eurasiatic faunal connection route.
Middle Ordovician Palaeogeography is based on the work of CRICK (1990).

Fourteen species of Korean cephalopods are recognized as common species with other regions. Their distribution is plotted on a Middle Ordovician palaeogeographic reconstruction (Text-Fig. 9).

These faunal relations indicate two migration routes. One route indicated by A in Text-Fig. 9 is from North America through Siberia and North China to Korea. The other route indicated by B supposedly goes from Baltoscandia through South China to Korea. I think route A is the main route and route B is a temporarily formed connection route during a short time in the Middle Ordovician age. The Jigunsan Formation consists mainly of black shale intercalated with thick carbonates. In my opinion, the transition to a deep sea anaerobic environment in Jigunsan age resulted in these remarkable faunal differences.

Plate 1

Figs. 1–4: ***Holmiceras coreanicum* (KOBAYASHI, 1927).**
Jigunsan Formation (Middle Ordovician).
Fig. 1: KPE20304, Lower Maggol.
Dorsal view, showing transverse sutures and surface ornamentation on the remaining shell; × 1.
Fig. 2: KPE20003, Dongjeom.
Silicon rubber cast of external mould, showing loosely coiled embryonic shell portion with annulated surface ornamentation; × 3.
Fig. 3: KPE20302, Lower Maggol.
Loosely coiled gyroceraconic shell portion and sigmoidally curved adolescent phragmocone; × 1.5.
Fig. 4a: KPE20001, Sanaegol.
Longitudinal section of partial phragmocone, made by acetate peel; × 2.
Fig. 4b: Enlarged view of siphuncular structure in Fig. 4a; × 6.

Fig. 5: ***Polydesmia* sp. cf. *P. canaliculata* LORENZ, 1906.**
KPE20321, Maggol Formation (Lower Ordovician), Sanaegol.
Longitudinal section of partial phragmocone; × 1.

Figs. 6–7: ***Sactorthoceras makkolense* (KOBAYASHI, 1927).**
Two specimens, Jigunsan Formation, Lower Maggol.
Fig. 6: KPE20034; side view, showing septal sutures; × 1.
Fig. 7: KPE20035; adoral phragmocone; × 1.

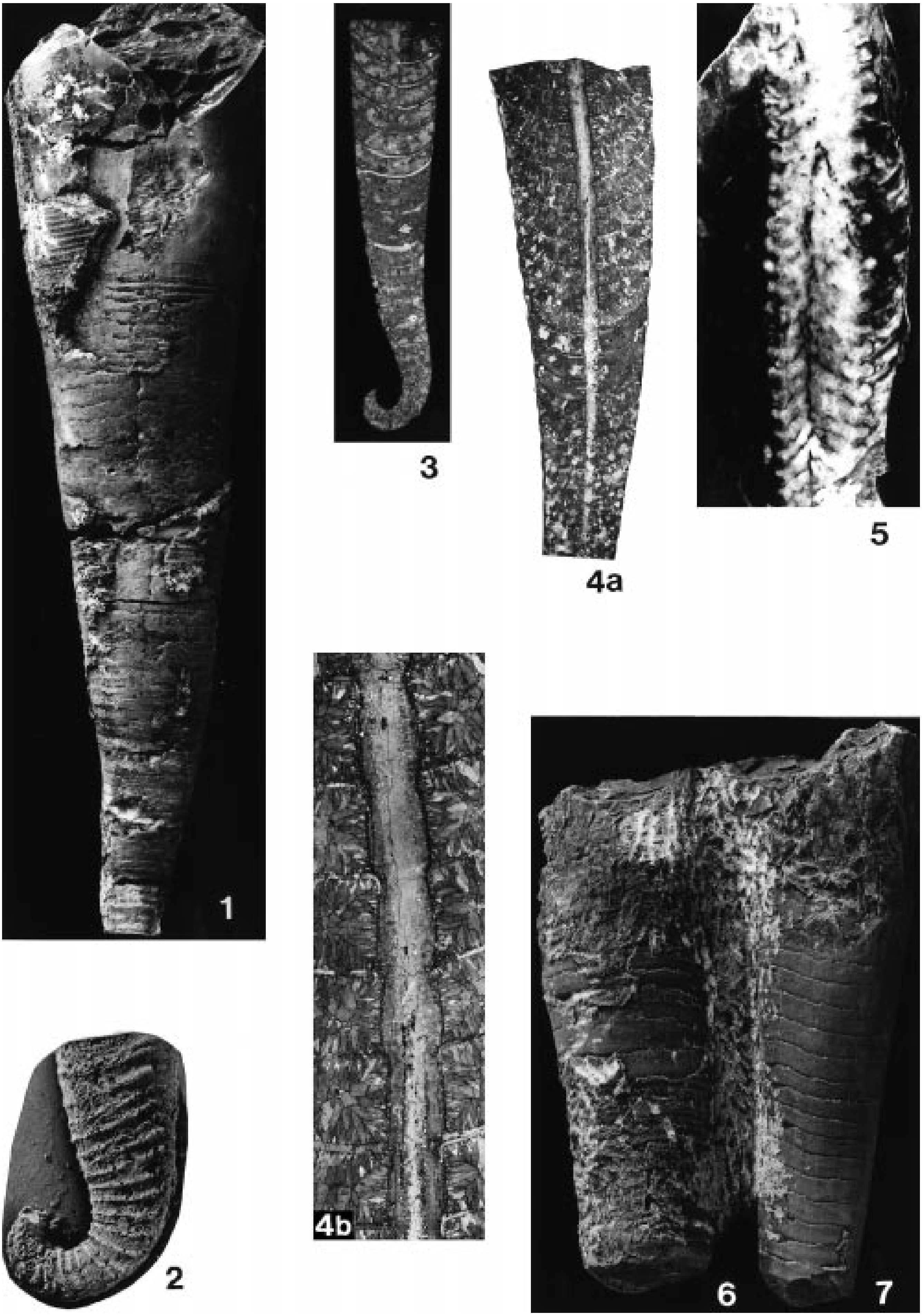

1
2
3
4a
4b
5
6
7

Plate 2

Fig. 1: ***Ormoceras koraiense*** **Kobayashi, 1934.**
KPE20166, Duwibong Formation (Middle Ordovician), Maggol.
Longitudinal section in obliquely dorsoventral direction, venter on left; × 1.

Fig. 2: ***Ormoceras shirakii*** **(Kobayashi, 1934).**
KPE20165, Jigunsan Formation (Middle Ordovician), Maggol.
Longitudinal section in lateral direction slightly askew, showing globular siphuncular segments and mural-episeptal deposits; × 2.

Fig. 3: ***Ormoceras woodwardsi*** **(Kobayashi, 1934).**
KPE20128, Duwibong Formation (Middle Ordovician), Sorogol.
Longitudinal section in lateral direction, showing mural-episeptal and hyposeptal deposits in cameral annulosiphonate deposits in siphuncle; × 2.5.

Fig. 4: ***Ormoceras*** **sp.**
KPE20133, Duwibong Formation, Sorogol.
Thin section, showing cyrtochoanitic septal necks and globular siphuncular segments; × 5.2.

Fig. 5: ***Actinoceras*** **sp. aff.** ***A. arbakunchense*** **Balashov, 1962.**
KPE20201, Duwibong Formation, Sanaegol.
Longitudinal section in lateral direction; × 1.

Fig. 6: ***Armenoceras*** **sp. aff.** ***A. asiaticum*** **Endo, 1932.**
KPE20192, Duwibong Formation, Sorogol.
Fig. 6a: Longitudinal section, showing well-defined cameral deposits and crowded septa; × 1.8.
Fig. 6b: Enlarged view of siphuncular structure in Fig. 6a; × 7.

Fig. 7: ***Armenoceras*** **sp.**
KPE20190, Duwibong Formation, Manhangjae.
Longitudinal section, showing cardiac siphuncular segments and hyposeptal deposits; × 1.

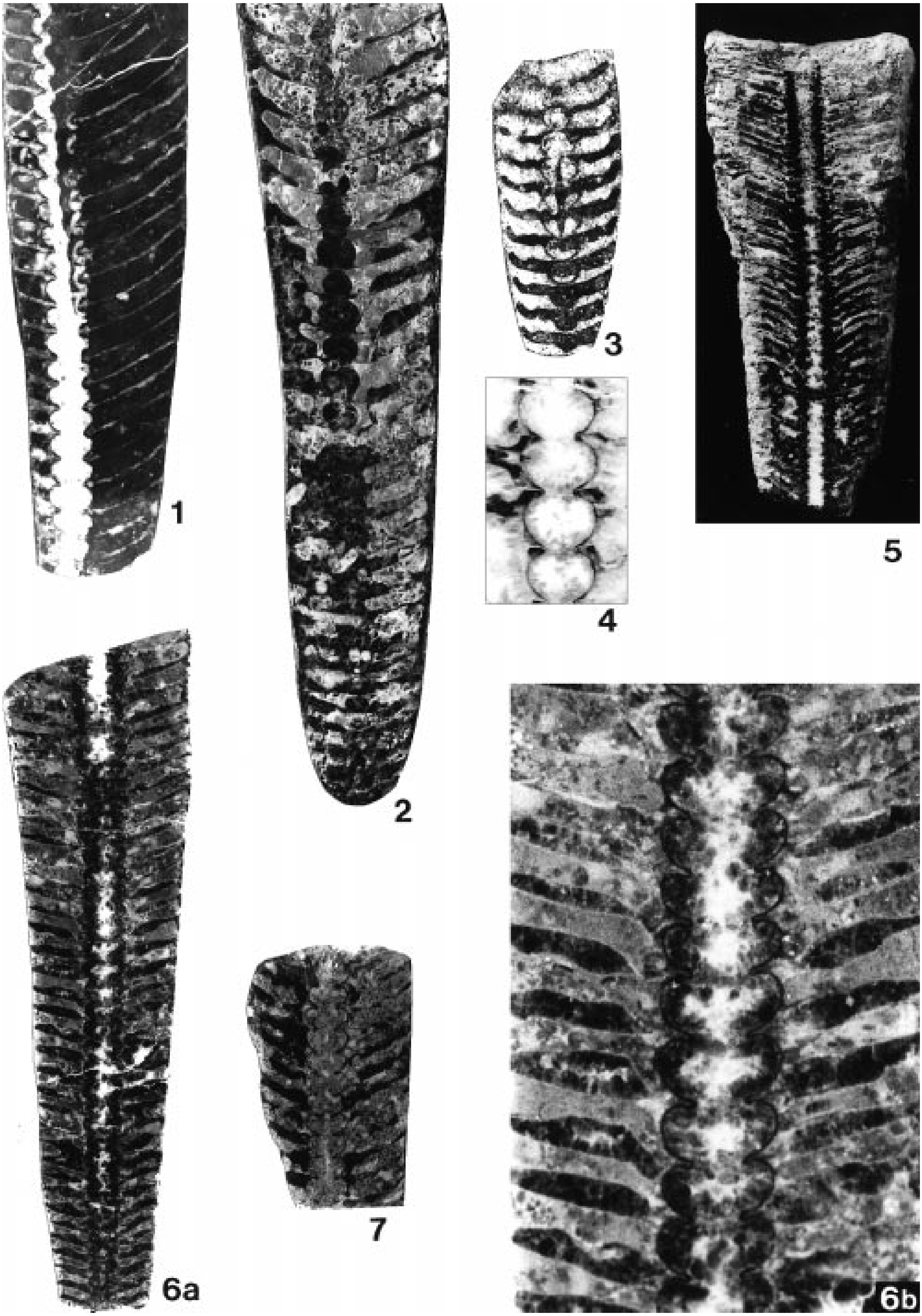

1
2
3
4
5
6a
7
6b

Plate 3

Fig. 1: ***Ormoceras weoni* Yun, 1999.**
KPE20260, Maggol Formation (Lower Ordovician), Sanaegol.
Fig. 1a: Dorsoventral section, venter on right, made by acetate peel, showing narrow siphuncle and crowded septa; × 1.5.
Fig. 1b: Dorsal view, showing faint transverse lines; × 1.

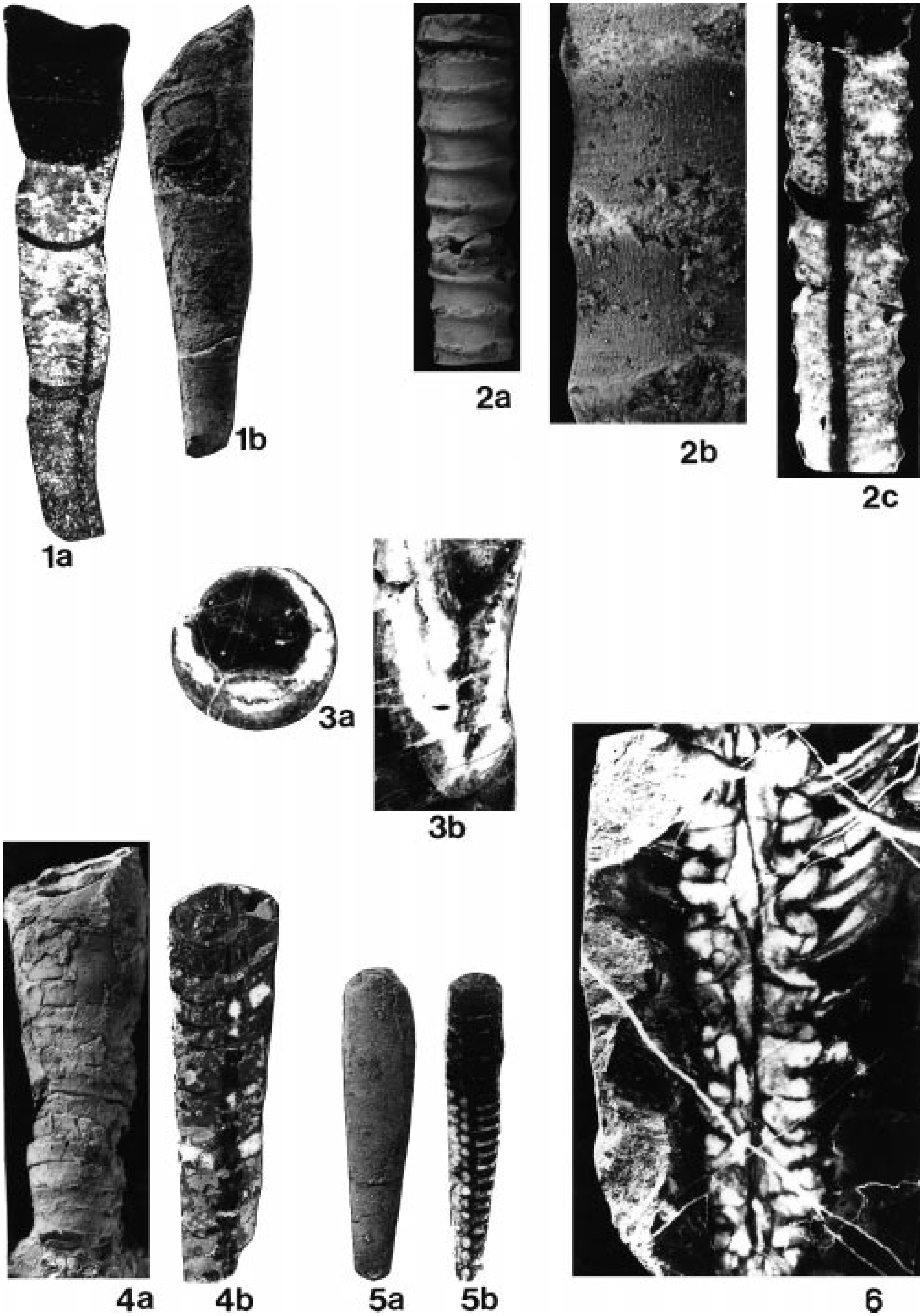
Fig. 2: ***Spyroceras* sp.**
KPE20116, Duwibong Formation (Middle Ordovician), Sorogol.
Fig. 2a: Dorsal view, showing strongly annulated surface; × 1.4.
Fig. 2b: Details of surface ornament, showing very fine longitudinal lirae between annuli; × 7.
Fig. 2c: Dorsoventral section, venter on right; × 2.

Fig. 3: ***Manchuroceras* sp. cf. *M. wolungense* (Kobayashi, 1931).**
KPE 20073, Maggol Formation (Lower Ordovician), Sanaegol.
Fig. 3a: Cross section at adoral end, venter down, showing circular outline and ventral elevation; × 1.
Fig. 3b: Longitudinal section, venter on left; × 1.

Fig. 4: ***Troedssonella* sp.**
KPE20088, Jigunsan Formation (Middle Ordovician), Maggol.
Fig. 4a: Ventral view; × 1.
Fig. 4b: Dorsoventral section, showing endosiphuncular linings of parietal deposits forming a slender endocone that is prolonged adapically; × 1.

Fig. 5: ***Ormoceras cricki* Kobayashi, 1934;** KPE20232, Maggol Formation, Sanaegol.
Fig. 5a: Ventral view; × 1.5.
Fig. 5b: Longitudinal section, venter on left, showing well developed episeptal deposits; × 1.5.

Fig. 6: ***Wutinoceras robustum* (Kobayashi & Matsumoto, 1942).**
KPE20206, Maggol Formation, Sanaegol.
Longitudinal section of an originally weathered specimen; × 1.


1a
1b
2a
2b
2c
3a
3b
4a
4b
5a
5b
6

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