

Conodonts from the Lower Paleozoic Strata in Mungyeong Area, Gyeongsangbuk-do, Korea, and their Biostratigraphic and Bioprovincial Implications

경북 문경지역의 하부 고생대 지층에서 산출된 코노돈트 미화석에 대한
생층서 및 생물지리구 고찰

Ha-Young Lee (이하영)* · Kyung-Jin Lee (이경진)* · Myung-Suk Yi (이명석)**

Abstract : The lower Paleozoic sequence in the Mungyeong Coalfield, designated as the Bugokri Formation, is divided into four members and one bed by the lithologic character. The Bugokri Formation yields 563 identifiable conodont specimens and they are classified into 22 multi-element species referable to 12 genera and 38 form-species of 22 genera. The CAI (conodont Color Alteration Index) value of the fauna is relatively high (5 to 7) indicating that the fauna was subjected to the heat at least 300°C in degree. Two conodont biozones are tentatively established, i.e. the Lower Zone and the Upper Zone. The Lower Zone is correlated with the Maggol Formation of Korea, the lower Majiagou Formation of China (specifically the *Aurilobodus leptosomatus* Zone), and the faunas 1 and 2 of the North American Conodont Faunas. The Upper Zone is similar in composition to the Jigunsan and the Duwibong formations in Samcheog-Baegunsan area of Korea, the upper Majiagou Formation of China, and the faunas 4 to 6 of the North American Conodont Faunas. Therefore, the Lower Zone and the Upper Zone established in the present study are suggested to be 'middle Arenigian' and 'middle Llanvirnian to early Llandeilian' in age. Both compositions of the Lower and the Upper zones show the characteristic of the North American Midcontinent Faunal Region. The conodont fauna studied herein is regarded to have been deposited in the shallow marine environment.

Key Words : Mungyeong, Lower Paleozoic, Bugokri Formation, Conodont, Age, Faunal Region, Environment

요 약

경북 문경탄전 동부에 분포하는 전기 고생대의 부곡리층을 암석층서에 의해 5개의 층원으로 분류하였다. 부곡리층에서 채취된 표본에서 분류 가능한 563개체의 코노돈트 미화석을 추출하였고, 이들을 12속 22종의 복합요소 및 22속 38종의 단순요소로 분류하였다. 화석군은 상대적으로 높은 (5-7) CAI 지수를 보이는 것으로 미루어 300°C 이상의 열변질을 받은 것으로 추정된다. 화석군의 특징에 따라 잠정적으로 상부화석대와 하부화석대 등 두개의 화석대 (biozone) 를 설정하였다. 하부화석대는 백운산 향사지역의 막골층, 중국 북부의 Majiagou층 하부, 북미 코노돈트화석군 1과 2에 대비되며, 상부화석대는 백운산 향사지역의 직운산층 및 두위봉층, 중국 북부의 Majiagou층 상부, 및 북미 코노돈트화석군 4에서 6까지에 대비된다. 따라서 본 연구에서 설정된 하부와 상부 화석대는 각각 '중부 Arenigian' 및 '중부 Llanvirnian에서 하부 Llandeilian'에 해당되는 것으로 판단된다. 부곡리층의 코노돈트 화석군은 북미 Midcontinent 생물구의 특징을 보이며, 천해환경에서 형성된 것으로 생각된다.

주요어 : 문경, 하부고생대, 부곡리층, 코노돈트, 시대, 생물구, 환경

* Department of Geology, Yonsei University, Seoul, 120-749, Korea (연세대학교 지질학과)

**Graduate School of Education, Inha University, Incheon, 402-751, Korea (인하대학교 교육대학원)

INTRODUCTION

The lower Paleozoic sequence is widely distributed near the Mungyeong Coalfield, Gyeongsangbuk - do. In the center of the area, the upper Paleozoic Pyeongan Group and the Jurassic Daedong Group are located, and to the east of them the lower Paleozoic Bugokri Formation occurs in wide geographic areas (Fig. 1).

Since the Mungyeong Coalfield has been one of the major coalfields in Korea, the economic importance of it has been attracting many geological investigations. The first geological approach on this area was conducted by Kobatake (1930), and subsequent studies have been undertaken by Aoti (1942), Ku (1964), Kim *et al.* (1967), Son and Paik (1972), Park (1974), Shin and Choi (1968), Lee and Kim (1968), Um *et al.* (1977), Kim (1986), and Kim *et al.* (1989). All these authors focused their interests on such

coal - forming strata as the Pyeongan Group and the Daedong Group strata. Research on the lower Paleozoic stata was accomplished first by Aoti (1942). Succeedingly Kobayashi (1958, 1961, 1966) conducted the paleontological studies, and provided with the stratigraphic information on these strata. Since most of the above studies have suggested various opinions on the lithostratigraphic divisions (Table 1), it is desired to investigate systematically the lithological characteristics and the fossil contents of the strata.

Objectives of this study are to establish the sound lithostratigraphic framework on the strata through the detailed field observations; to conduct the micropaleontological approach, chiefly by means of conodonts; and to clarify the taphonomic, biostratigraphic, bioprovincial, and paleoecologic interpretations based on the microfaunal information.

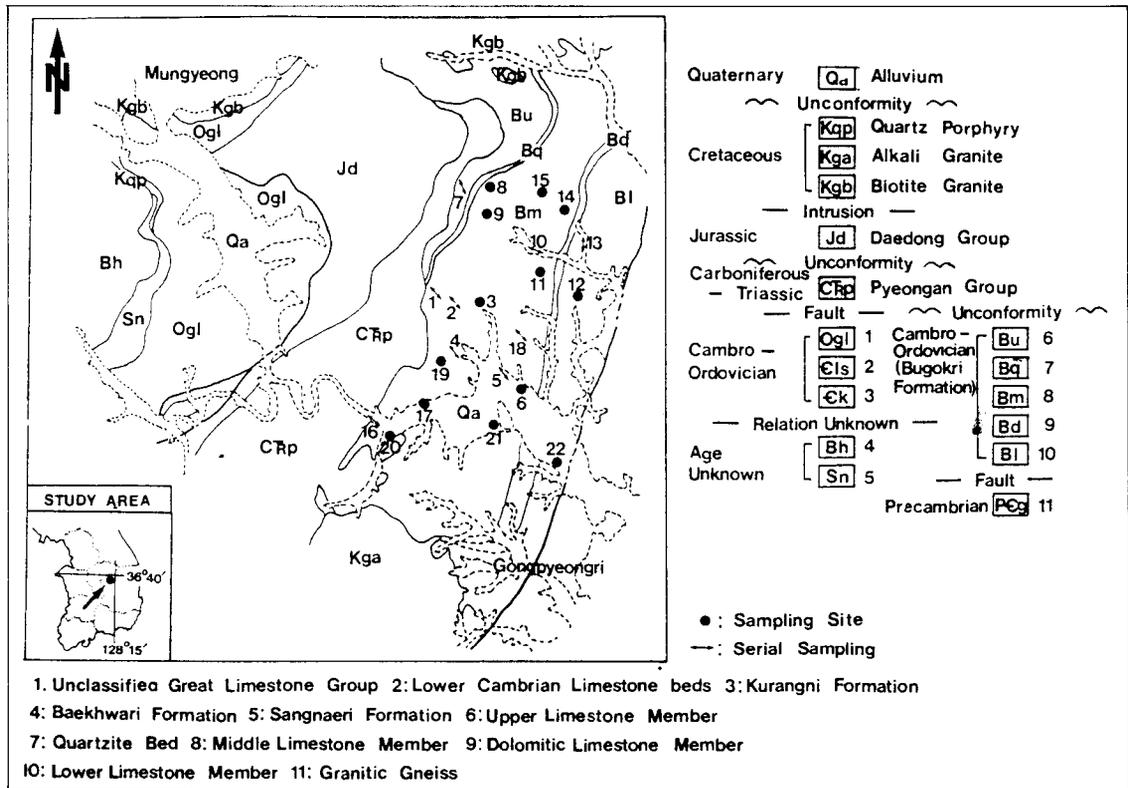


Fig. 1. Geology of Mungyeong area and the sampling localities.

Table 1. Lithostratigraphic divisions of the lower Paleozoic Sequence in Mungyeong area by different authors

Kobatake (1930)		Aoti (1942)	Ku (1964)	Kim,N.J. et al. (1967)	Shin & Choi (1968)	Lee,M.S. & Kim,S.W. (1968)	Um et al. (1977)	THIS STUDY
Choseon System	Great Limestone Series	Formation 5	Daebongri Limestone	Bugokri Formation	Sanbuk Limestone	Great Limestone Series	Great Limestone Supergroup	Upper Limestone Member
		Formation 4						Quartzite Bed
		Formation 3			Middle Limestone Member			
		Formation 2			Dolomitic Limestone Member			
	Quartzite Bed	Formation 1	---FAULT---	---UNKNOWN---	Jangsan Quartzite	---FAULT---	---UNKNOWN---	Lower Limestone Member
UNCONFORMITY-Precambrian Metamorphic Complex	---FAULT--- Precambrian Metamorphic Complex	---FAULT--- Precambrian Metamorphic Complex	---UNKNOWN--- Precambrian Metamorphic Complex	UNCONFORMITY-Precambrian Metamorphic Complex	---FAULT--- Precambrian Metamorphic Complex	---UNKNOWN--- Precambrian Metamorphic Complex	--- FAULT --- Precambrian Metamorphic Complex	

STRATIGRAPHY

The lower Paleozoic Choseon Supergroup strata in the eastern side of the coalfield are distributed in Hogye - myun, Sanbuk - myun, and Jeomchon - eub of Mungyeong - gun, Gyeongsangbuk - do. Attitude of the strata is generalized as N25 - 65°E, 26 - 65°NW. To the east of the strata, Precambrian Gneiss is widely exposed. Kobatake (1930) regarded the relationship of these two strata as unconformity, and this was later agreed by Shin and Choi (1968). Aoti (1942), however, insisted that the relationship is a fault contact, and coined the term Jeomchon Fault. Lee and Kim (1968) renamed it as Maggok Fault. Since the absence of the correlative strata to the Jangsan Quartzite and the Myobong Slate Formations which are the basal units of the Duwilyong - type Choseon Supergroup, and the presence of several sites of the fracture zone developed through the contact, the relationship is considered to be a fault in the present study.

Aoti (1942) divided the lower Paleozoic strata in the east into five units without designated names (Table 1). Ku (1964) named the Daebongri Limestone for the whole strata without a proper description for the formation. Kim *et al.* (1967) coined the term Bugokri Formation for the strata, and included the lower Paleozoic strata developed in the west of the Mungyeong Coalfield in this new formation. In the present study, the Bugokri Formation for

the strata is provisionally accepted. Since the lower Paleozoic strata distributed in the west is not lithologically correlated with those of the east, we exclusively applied the term Bugokri Formation to designate the lower Paleozoic strata developed in the east of the coalfield.

In the present study, the Bugokri Formation is divided into five members, which are the Lower Limestone Member, the Dolomitic Limestone Member, the Middle Limestone Member, the Quartzite Bed, and the Upper Limestone Member, in ascending order (Table 1).

The Lower Limestone Member is composed of gray to light gray laminated crystalline limestones with the sporadic intercalations of the gray to greenish gray shales (Fig. 2). The overlying Dolomitic Limestone Member consists of dark gray to bluish gray massive dolomitic limestones. Partially, light gray dolomitic limestones and dolomites are intercalated. The Middle Limestone Member is the thickest unit (300 m) in the formation. The member mostly consists of dark gray, bluish gray, gray, light gray laminated limestones. The light gray to milky white dolomitic limestones and the gray to greenish gray shales are locally intercalated. The small - scale folding structures are developed throughout the unit. The overlying Quartzite Bed (10 to 40 m thick) is the key bed to locate the boundaries of the Middle and the Upper Limestone members. The bed consists of milky white to light gray quartzite and

GEOLOGIC TIME	LITHOLOGIC UNIT	THICK-NESS	LITHOLOGY	DESCRIPTION
Carboniferous	Hongjeom Formation	300m		light green to greenish gray shales and light gray to gray fine to medium sandstones intercalated with purple shales and light to medium gray massive limestones
	UNCONFORMITY			
Cambro- Ordovician	Upper Limestone Member	100m		dark gray to bluish gray massive of well bedded aphanitic limestones, locally recrystallized
	Quartzite Bed	40m		milky white to light gray quartzite
	Middle Limestone Member	300m		dark gray, bluish gray, gray, light gray laminated limestones intercalated with light gray to milky white dolomitic limestones and gray to greenish gray shales, minor folding structures developed
	Dolomitic Limestone Member	100m		dark gray to bluish gray massive dolomitic limestones intercalated with light gray dolomitic limestones
	Lower Limestone Member	200m		light gray well laminated crystalline limestones, locally gray to greenish gray shales developed
Precambrian	FAULT			
	Granite Gneiss	300m		porphyroblastic granitic gneiss, biotite schist near the fault zone

Fig. 2. Generalized stratigraphic column of the Bugokri Formation in Mungyeong area with the lithologic characteristics of members established in this study (refer Fig. 3 for the legend).

disappeared by the covering of the Pyeongan Group strata in the south. The Upper Limestone Member, which is unconformably overlain by the upper Paleozoic Hongjeom Formation, is composed of dark gray to bluish gray massive or well bedded aphanitic limestones.

FOSSIL FAUNA

Thirty - six samples out of 149 collected samples yielded 740 conodont specimens in this study. Fig. 1 and Fig. 3 illustrate the geographic localities and the stratigraphic positions of samples. This productivity ratio (24%) is relatively low compared to those of the other lower Paleozoic strata in Korea. In this study, only the Middle Limestone Member and the Upper Limestone Member (representing middle to upper part of the Bugokri Formation) yielded conodonts, and other members do not produce any fossil specimen. Most specimens are fragmented and only 563 specimens are identifiable. The fauna was differentiated into 22 multi - element species representing 12 genera and 38 form - species repre-

senting 22 genera (Table 2). In the present study, both taxonomic schemes are applied, since not all the assemblages of the multi - element species are thoroughly established in the Far East.

Since Ellison (1944) conducted the experimental research on the conodont color alteration through the heat application, color of the conodont fauna has been the useful indicator for the degree of thermal alteration of the strata. Lindström (1964) attributed this color alteration to the carbon fixation in the specimen when the heat is applied, and Pietzner *et al.* (1968) and Clark and Müller (1968) were successful in subtracting the organic matter stimulating this process. Epstein *et al.* (1977) divided the color range into eight intervals, defined their temperature ranges, and established the conodont color alteration index (CAI). Most conodont specimens studied herein are dark gray or black in color (CAI 5 to 6). Some samples in the upper parts of the localities 1 and 7, and in the localities 5 and 10 yield gray to opaque white specimens which represents somewhat higher degree of thermal alterations (CAI 6 to 7).

Table 2. Conodont distribution in the productive samples of the Bugokri Formation in Mungyeong area

Locality		L1					L2					L4			L5			
Taxa	Sample No.	2921	2922	2923	2928	2929	2934	2936	2937	2939	2940	2941	2994	2995	2997	2942	2943	2945
Acodus sp.		6	2			5			3				1	1				
Acontobodus viriosus				3									1					
A. n. sp.				1					1									
A. sp.							3						5					
Aurilobodus aurilobus?																		
symmetricus el.		2																
asymmetricus el.		2																
A. leptosomatus																		
symmetricus el.													8					
asymmetricus el.													4					
A. simplex																		
symmetricus el.													2					
Belodella rigida																		
adenticulated biconvex el.													1					
denticulated plano-convex el.				2														
denticulate triangular el.								2					8					
B. sp.																		
Chirognathus sp.																		
Cordylodus sp.									2									
Dapsilodus compressus																		
distacodontiform el.		2							1									
Distacodus sp.								2										
Drepanodus homocurvatus			2										1					
D. sp.		5	3	2					3					1	1	1		1
Eoplacognathus sp.																		
Erraticodon tangshanensis																		
cordylodontiform el.																		
prioniodiniform el.																		
hindeodelliform el.																		
Gyrognathus n. sp.			3															
G. sp.				3														
Macerodus sp.													2					
Noriodus? sp.			1															
Oistodus brevicornis			1					1										
O. cf. contractus								2	2	1								
O. linguatus													3					
O. sp.		4	3				3											1
Oneotodus sp.																		1
Ozarcodina cf. joachimensis			1															
O. cf. tenuis			2															
O. sp.		25	17	7				1										
Paltodus inconstans								3		10				2	1			
P. cf. inconstans								3		5								
P. sp.																		
Panderodus gracilis																		
compressus el.				4														
Plectodina onychodonta																		
subcordylodontiform el.			4	2														
cyrtioniodiniform el.			3	3														
dichognathiniform el.			3	2														
prioniodiniform el.			4	1														
trichonodelliform el.			5	2														
Prioniodus (Baltioniodus) sp.						1												
Scandodus dubius				1	1													
S. rectus			3															
S. cf. furnish								5										
S. sp.			5	5	6									3				
Scolopodus eburnus																		3
S. euspinus		5	6	5				5	23			20		6	5			
S. filiosus									3									
S. flexilis																		
arcuatiform el.								4	2		4							
S. nogamii		3	3	3				3	3	19				5	4			
S. sp.								4						3	2	1		
Trianglodus changshanensis																		
distacodontiform el.								1	1					1				
trichonodelliform el.								1		1								
T. sp.		3	2						1	1								
Ulrichodina sp.														3				
New form A																		
New form B				1														
Indet			11		9	6	3	8	3	3	2	4	5	1	2	3	3	4
Total		15	100	66	23	12	26	36	49	31	6	35	40	26	19	5	3	7

Table 2. (continued)

Locality	Sample No	I.7						I.10			I.16						Total	
		2946	2947	2948	2949	2950	2955	2956	2962	2963	2968	2976	2977	2978	2980	2982		2988
Acodus sp.														1				18
Acontiodus vinosus														1				5
A. n. sp.																		2
A. sp.																		8
Aurilohodus aurilobus?																		
symmetricus el.																		2
asymmetricus el.																		2
A. leptosomatus																		
symmetricus el.																		8
asymmetricus el.																		4
A simplex																		
symmetricus el.																2		4
Belodelia rigida																		
adenticulated biconvex el.														1				2
denticulated plano-convex el.					1													3
denticulate triangular el.													2	3				15
B. sp.											2							2
Chirognathus sp.										3								3
Cordylodus sp.																		2
Dapsilodus compressus																		
distacodontiform el.																		3
Distacodus sp.																	2	4
Drepanodus homocurvatus						1												4
D. sp.	5	1	3		3	4						6		2	2			43
Eoplacognathus sp.				1														1
Erraticodon tangshanensis																		
cordylodontiform el.									3							3		6
prioniodiniform el.									1							2		3
hindeodelliform el.									2									2
Gyrognathus n. sp.																		3
G. sp.																		3
Macerodus sp.																		2
Noriodus? sp.																		1
Oistodus brevicornis																		2
O. cf. contractus																2		7
O. linguatus																		3
O. sp.											1							12
Onerotodus sp.								1						2	1	1	1	7
Ozarcodina cf. joachimensis										1	1							3
O. cf. tenuis																		2
O. sp.																		50
Paltodus inconstans																		16
P. cf. inconstans							4			3							1	16
P. sp.				2													1	3
Panderodus gracilis																		
compressus el.			2															6
Plectrodina onychodonta																		
subcordylodontiform el.																		6
cyrtionodontiform el.																		6
dichognathiform el.																		5
prioniodiniform el.																		5
trichonodelliform el.																		7
Prioniodus (Baltoniodus) sp.																		1
Scandodus dubius																		2
S. rectus																		3
S. cf. furnish																	1	6
S. sp.	3		2			1	1						1				1	28
Scolopodus eburnus																		3
S. euspinus			5		11									14				105
S. filiosus																		3
S. flexilis																		
arcustiform el.																		10
S. nogamii			1											6				61
S. sp.						3												13
Trianglodus changshanensis																		
distacodontiform el.																		3
trichonodelliform el.																		2
T. sp.																		7
Ulrichodina sp.																		3
New form A										1								1
New form B																		1
Indet.	5	4	3	6	1	10	4	5	4	3	1	3	13	6	10	29	3	177
Total	13	13	8	21	8	20	14	5	10	5	2	9	38	15	13	45	3	740

BIOSTRATIGRAPHY

Acontiodus viriosus, *Belodella rigida*, *Erraticodon tangshanensis*, *Scolopodus euspinus*, *Scolopodus nogamii*, *Dapsilodus compressus*, and *Ozarkodina* cf. *joachimensis* are characteristic species and occur throughout the section in the present study.

Acontiodus viriosus was first reported in the lower (middle to late Arenigian in age) and the upper (Llanvirnian in age) Majiagou Formation by Cui (in An *et al.*, 1983). *Acontiodus* sp. B and *Acontiodus* sp. described by Lee (1976, 1977) are regarded to be assignable to this species.

Belodella rigida consists of five elements, and was reported in the lower and the upper Majiagou Formation by An *et al.* (1983). *Belodella* n. sp. and *Belodella erecta*, described from the early to middle Ordovician Mystic Formation of Quebec, Canada (Barnes and Poplawski, 1973), belong to the adenticulated biconvex and the denticulated triangular elements of this species, respectively. Lee (1977, 1979) recorded this species in the Yeongheung, Jigunsan, Duwibong, and Maggol Formations of Korea.

Erraticodon tangshanensis was first described in the lower and the upper Majiagou Formation of Hubei Tangshan, China (Yang and Xu, in An *et al.*, 1983). This species consists of six elements. Trichonodelliform element was reported from the Mandalsan Formation, North Korea (Lee, 1975a, 1976) as *Trichonodella* sp. and cf. *Trichonodella barbara*. Prioniodiniform element was also recorded in the Mandalsan Formation of North Korea (Lee, 1975a, 1976) as *Prioniodina macrodenta*, and in the Yeongheung Formation of South Korea (Lee, 1979) as *Prioniodina* sp. A and E. Cordylodontiform element of this multi-element species was described in the Yeongheung Formation as *Neoprioniodus* nov. sp. This species has previous records in the Duwibong, Jigunsan, Maggol, and Yeongheung Formations of Korea (Lee, 1976, 1979; Lee and Lee, 1986; Lee and Lee, 1990).

Scolopodus euspinus was first described in Tangshan area, northern China by Jiang and Zhang (in An *et al.*, 1983), and was reported in a long stratigraphic

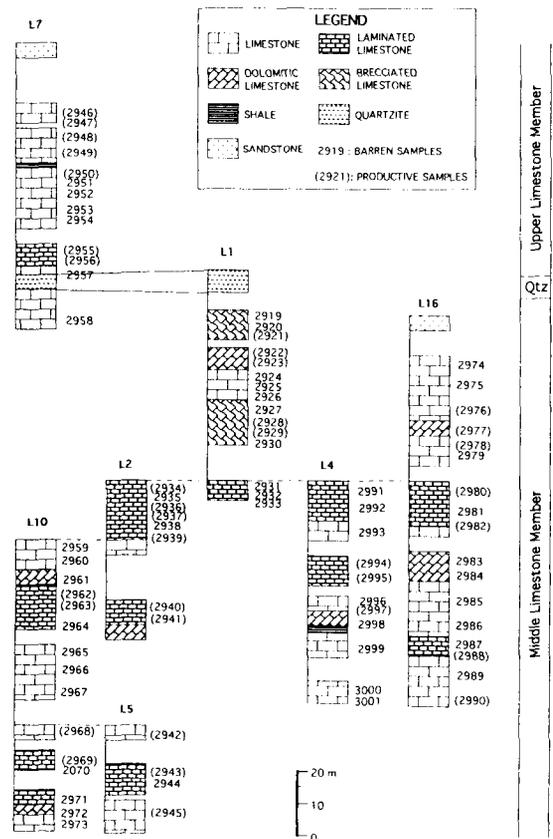


Fig. 3. Columnar sections with the sampling positions in the study area.

range, from the Llongchioshan Formation (early Arenigian in age) to the Fengfeng Formation (Llandeilian in age) in China. *Panderodus* sp. reported by Ethington and Schumacher (1969) from the Copenhagen Formation (Middle Ordovician) in central Nevada, and *Panderodus striatus* described by Lee (1975c, 1977, 1979) from the Duwibong, Jigunsan, Maggol, and Yeongheung Formations in Korea are considered to be the synonyms of the present species.

Scolopodus nogamii was first described from the Mandalsan Formation of North Korea (Lee, 1975a), and has abundant records from the Middle Ordovician strata in Korea (Lee, 1975b, 1977; Lee and Lee, 1986; Lee and Lee, 1990) and north (An *et al.*, 1983) and south (An, 1987) China. Since *S. nogamii* and *S. euspinus* are frequently occurred toge-

ther with constant ratio (4: 1), both species may represent each element of the same multi - element species.

Dapsilodus compressus was first described from the upper Majiagou Formation in Tangshan area, northern China (Zhang in An *et al.*, 1983). The species has subsequent records in the Jigunsan and the Duwibong Formations in Sangdong (Lee and Lee, 1986) and Dongjeom (Lee and Lee, 1990) areas.

Ozarkodina joachimensis was first reported by Andrews (1967) in the Joachim Dolomite (Middle Ordovician in age) of Missouri, and has subsequent records in the Duwibong Formation in Korea (Cheong *et al.*, 1979; Lee and Lee, 1986).

As a whole, conodont fauna recovered from the Bugokri Formation in Mungyeong area shows the similarity in composition to those of Maggol, Jigunsan, and Duwibong Formations of Korea, the lower and the upper Majiagou Formation of northern China, and other late Early to Middle Ordovician strata in different areas of the world.

Two conodont assemblage zones, the 'Lower Zone' and the 'Upper Zone', are tentatively proposed here, although the Mungyeong conodont fauna is not prolific enough for the zones to be formally named. The base of the Lower Zone is defined by the appearance of *Aurilobodus simplex*, *Oistodus cf. contractus*, and *Erraticodon tangshanensis*. Characteristic species of the Lower Zone, such as *Paltodus inconstans* and *Triangulodus changshanensis*, range upward to the top of the Lower Zone but are not found in the Upper Zone (Fig. 4). The occurrences of the characteristic taxa of both zones are compared with those of correlative faunas in China, Europe, and North America as well as the other parts of the Korean peninsula.

The Lower Zone

Occurrence ranges of *Oistodus cf. contractus*, *Paltodus inconstans*, *Scolopodus flexilis*, *Aurilobodus simplex*, and *Triangulodus changshanensis* are restricted in the Lower Zone.

Oistodus cf. contractus and *Paltodus inconstans*

were reported by Lindström (1955) in the lowermost Ordovician strata of south - central Sweden. Subsequently other Lower Ordovician strata such as the strata of the eastern Baltic area, the El Paso Formation, lower Arbuckle Group of North America, show the records of this species. These species are important index fossils of the Lower Ordovician strata. Lee also reported *Oistodus contractus* from the Maggol Formation (1970, 1975c), and *Paltodus inconstans* from the Dumugol (1975c) and Maggol Formations (1976) of Samcheog area. Lee and Lee (1990) also reported both species from the Maggol Formation in Dongjeom area.

Scolopodus flexilis, which consists of arcuatiform and erectiform elements, was reported by An *et al.* (1983) in the lower Majiagou Formation of Tangshan area. Lee (1976) described this species as *Scolopodus cornutiformis* from the Maggol Formation of Samcheog area, and Lee and Lee (1990) recorded it from the Maggol Formation in Dongjeom area.

Aurilobodus simplex, which consists of symmetricus and asymmetricus elements, was reported by Xiang and Zhang (in An *et al.*, 1983) in the upper Majiagou Formation of Sandong Laiwu area in northern China. Lee (1976, 1977) described this species from the Maggol and Duwibong Formations of Samcheog area as *Scandodus* sp. and *Acontiodus* sp. C.

Relatively long-ranging species, *Triangulodus changshanensis*, was reported by Zhang (in An *et al.*, 1983) from both the lower and the upper Majiagou Formation in Tangshan area of northern China. The species shows the morphologic characteristic between *Triangulodus brevibasis* and *T. alatus* in the evolutionary lineage. The Maggol, Jigunsan, and Duwibong Formations in Dongjeom area (Lee and Lee 1990) recorded the occurrences of this species.

Aurilobodus leptosomatus, *Scolopodus eburnus*, and *S. filus* also have restricted ranges in the Lower Zone, although present in only one sample each (2097, 2094, and 2036, respectively). *Aurilobodus leptosomatus* consists of symmetricus and asymmetricus elements and was compiled and named by An *et al.* (1983). This species was previously reported from the Middle Ordovician Antelope Limestone

of this study to the middle Arenigian. The zone is also correlated with the faunas 1 and 2 of the North American Conodont Faunas.

The Upper Zone

The Upper Zone is characterized by the appearances of *Plectodina onychodonta*, *Panderodus gracilis*, *Ozarkodina* cf. *tenuis*, and *Aurilobodus aurilobus*.

Plectodina onychodonta, composed of six elements, was named by An *et al.* (1983) in the upper Majiagou Formation of Tangshan, northern China. Elements of this species was noted in the Duwibong Formation of Samcheog area (Lee, 1977, 1979), Sangdong area (Lee and Lee, 1986), and Dongjeom area (Lee and Lee, 1990). Ethington and Clark (1981) also reported this species from Ibex area of Utah. An *et al.* (1983) established the *Plectodina onychodonta* Zone in the upper Majiagou Formation, and correlated it with the *Eoplacognathus foliaceus* Zone of the Kuniutan Formation in Hubei and Ichang area of China, and the Fauna 5 of the North American Conodont Faunas. This species has been used as a good index fossil for the time equivalent to the lower Duwibong Formation.

Panderodus gracilis was reported in the Jefferson City Formation of North America (Branson and Mehl, 1933). Later Bergström and Sweet (1966) redefined this as a multi - element species which consists of *Panderodus gracilis* (Branson and Mehl), *Panderodus compressus* (Branson and Mehl), and *Panderodus intermedicus* (Branson, Mehl and Branson). This species has been also recorded in the Richmond and Lexington Formations in Cincinnati area (Branson and Mehl, 1933), the Fengfeng Formation in Laiwu and Fengfeng area of China (An *et al.*, 1983), the Mandalsan Formation (Lee, 1975a), the Jigunsan and the Duwibong Formations (Lee and Lee, 1986; Lee and Lee, 1990) of Korea, and middle to upper Ordovician strata worldwide.

Aurilobodus aurilobus was first described from the Mandalsan Formation of North Korea (Lee, 1975 a) as *Tricladiodus? aurilobus*. Xiang and Zhang (in An *et al.*, 1983) instituted this species to the genus

Aurilobodus. This species has occurrences only in Korea and northern China so far. It shows records in the upper Majiagou Formation (Lanvirnian in age) in Tangshan and Laiwu area, northern China. Also it occurs in the upper part of the Yeongheung Formation (late Llandeilian to early Caradocian) (Lee, 1979) and Maggol Formation (Arenigian in age) (Lee, 1976) in Korea, thus the occurrence range of this species may be extended somewhat downward. *Aurilobodus aurilobus* consists of symmetric and asymmetric elements and abundantly occurs in Jigunsan and Duwibong Formations in Samcheog, Sangdong, and Dongjeom areas of Korea (Lee and Lee, 1986; Lee and Lee, 1990).

In the present study, the *Eoplacognathus suecicus* - *Eoplacognathus jigunsanensis* Zone, which was established between the *Aurilobodus leptosomatus* and *Plectodina onychodonta* zones in Sangdong and Dongjeom areas, is not recognized between the Lower and the Upper Zone. This absence is not considered to have resulted from the absence of the correlatable strata in the study area or the difference in faunal character between Mungyeong area and the above two areas, but regarded to be caused by the paucity of productive samples in the present study. In fact, a fragment assignable to *Eoplacognathus* was found in sample 2949. The Upper Zone in this study could probably be correlated with the *Plectodina onychodonta* and *Aurilobodus serratus* zones established in Sangdong and Dongjeom areas. Specimens assignable to *Aurilobodus serratus*, however, are not noticed in this study possibly due to the poor state of preservation.

Conclusively the Upper Zone in this study can be correlated with the Jigunsan and the Duwibong formations in Samcheog - Baegunsan area of Korea, the *Plectodina onychodonta* Zone of the upper Majiagou Formation in northern China, and the faunas 4 to 6 of the North American Conodont Faunas (middle late Llanvirnian in age).

BIOPROVINCIALISM AND PALEOECOLOGY

During the Ordovician time, two conodont biopro-

vinces were recognized by many authors: the North Atlantic Faunal Region and the North American Midcontinent Faunal Region which can be again differentiated into three or four subprovinces. Although the causes of the provincialism are not certain, the factors affecting it attribute to the paleo - ocean temperature, the environmental changes caused by oceanic currents, the ocean depths, the salinities, the substrates, and the physical barriers. Recently, Carpentier (1984) divided the Ordovician conodont distribution into the higher latitude fauna (the Baltica Block) and the low latitude fauna (including the Laurentia Block, the China Block, the Gondwana Block, and the Siberian Block). He correlated these two faunas with the North Atlantic Faunal Region and the North American Midcontinent Faunal Region, respectively. The southern and northern parts of the China Block, although geographically adjacent each other at present, show different characteristics of provincialism. Whereas the southern part shows affinity to the North Atlantic Faunal Region, the northern part to the North American Midcontinent Faunal Region.

During the early and the middle Ordovician, the Korean peninsula was recognized as a part of the China Block considering the conodont bioprovince, since the peninsula was located near the China landmass during that time and the conodont faunas derived from the two show very similar characteristics (co - occurrences of eighteen multi - element species representing eleven genera and twelve form - species representing seven genera). Also the conodont fauna of the China Block during this time span was most similar to that of the Laurentia Block (S.I.= 0.86).

The Lower Zone of the present study includes *Scolopodus flexilis*, *Trianglodus* cf. *changshanensis*, and *Scolopodus eburnus* which are important members of the north China conodont fauna, and therefore it consistently shows the characteristic of the North American Midcontinent Faunal Region. The Upper Zone of the present study contains abundant occurrences of such important members of North American Midcontinent Faunal Region as the ge-

nera *Panderodus* and *Plectodina*. This implies the Upper Zone to represent the North American Midcontinent Faunal Region, although this zone includes minor amounts of the genera *Eoplacognathus* and *Baltoniodus* which are the characteristic taxa for the North Atlantic Faunal Region.

Barnes *et al.* (1973) subdivided the North American Midcontinent Faunal Region conodont fauna into the littoral zone and sublittoral inshore shallow shelf zone, the offshore shallow shelf zone, and the deep shelf and miogeosyncline zone. This division is based on the occurrences of characteristic conodont fauna by the depths, the temperatures, and the circulation of the ocean water. The limestone beds encountered in the present study seem to be most similar to the offshore shallow shelf zone, since the important taxa of this zone such as *Plectodina* and *Ozarkodina* are present with high morphological diversity in the present fauna. Thus the depositional environment of the present fauna is considered to be the shallow marine water.

CONCLUSIONS

The lower Paleozoic strata exposed in the eastern side of the Mungyeong Coalfield area are classified into the Lower Limestone Member, the Dolomitic Limestone Member, the Middle Limestone Member, the Quartzite Bed, and the Upper Limestone Member representing the Bugokri Formation, in ascending order.

Specimens of the conodont fauna in this study are mostly fragmented and show relatively high CAI values (5 to 7). This suggests that the strata yielded conodonts were subjected to the heat at least 300°C in degree.

Thirty - six out of 149 collected samples yield 563 identifiable conodont specimens. These are differentiated into 22 multi - element species representing 12 genera and 38 form - species representing 22 genera. Two conodont biozones, although not formally named, are tentatively established: the Lower Zone and the Upper Zone. The composition of the Lower Zone in the present study shows the close similarity

to those of Maggol Formation of Korea, the lower Majiagou Formation of China (specifically the *Aurilobodus leptosomatus* Zone), and the faunas 1 and 2 of the North American Conodont Faunas. The Upper Zone in this study is correlated with the Jigunsan and the Duwibong formations of Korea, the upper Majiagou Formation of China (specifically the *Plectodina onychodonta* Zone), and the faunas 4 to 6 of the North American Conodont Faunas. Therefore, the Lower Zone and the Upper Zone are 'middle Arenigian' and 'middle Llanvirnian to early Llandeilian' in age.

The present conodont fauna shows the characteristic of the North American Midcontinent Faunal Region. The conodont fauna studied herein is regarded to have been deposited in the shallow marine environment.

ACKNOWLEDGMENT

This work is a part of the research project 'Stratigraphy and paleontology of the lower Paleozoic Sequence in the Mungyeong Coalfield, Gyeongsangbuk-do', which was carried out through the financial support by KOSEF for two years in 1987-1989. We extend our thanks to Messrs. Sung - Joo Lee and Kyung - Woo Lee, former students of the Graduate School of Yonsei University, for their effective help in the field and in the laboratory works.

REFERENCES

- An, T., 1987, The lower Paleozoic conodonts of south China, University of Beijing Press, 238p., 35pls.
- An, T., Zhang, F., Xiang, W., Zhang, Y., Xu, W., Zhang, H., Jiang, D., Yang, C., Lin, L., Cui, Z., and Yang, X., 1983, The conodonts of North China and the adjacent regions, Science Press, Beijing, 223p.
- Andrews, H. E., 1967, Middle Ordovician conodont from the Joachim Dolomite of eastern Missouri, *Journal of Paleontology*, 41, 881 - 901.
- Aoti, K., 1942, Geology of Bunkei district in Tyosen with special reference to the stratigraphy of the Tyosen Group, *Jour. Geol. Soc., Japan*, 49, 279 - 281.
- Barnes, C. R. and Poplawski, M. L. S., 1973, Lower and Middle Ordovician conodonts from the Mystic Formation, Quebec, Canada, *Journal of Paleontology*, 47, 760 - 790, pls.1 - 5.
- Bergström, S. M. and Sweet, W. C., 1966, Conodonts from the Lexington Limestone (Middle Ordovician) of Kentucky and its lateral equivalents in Ohio and Indiana, *Bulletins of American Paleontology*, 50(229), 441p.
- Branson, E. B. and Mehl, M. G., 1933, Conodont studies, *University of Missouri Studies*, 8, 349p, 29pls.
- Carpentier, R. R., 1984, Conodonts through time and space: studies in conodont provincialism, *Geological Society of America Special Paper*, 196, 11 - 32.
- Cheong, C. H., Lee, H. Y., Ko, I. S., and Lee, J. D., 1979, A study on stratigraphy and sedimentological environments of the Lower Paleozoic sequences in South Korea (chiefly Jeongseon area), *Journal of National Academy Science, Republic of Korea (Natural Science Series)*, 18, 123 - 169.
- Clark, D. L. and Müller, K. J., 1968, The basal opening of conodonts, *Journal of Paleontology*, 42, 561 - 569.
- Ellison, S. P., Jr., 1944, Composition of conodonts, *Journal of Paleontology*, 18, 133 - 140.
- Epstein, A. G., Epstein, J. B., and Harris, L. D., 1977, Conodont color alteration - an index to organic metamorphism, *U. S. Geological Survey Professional Paper*, 995, 1 - 27.
- Ethington, E. L. and Clark, D. L., 1964, Conodonts from the El Paso Formation (Ordovician) of Texas and Arizona, *Journal of Paleontology*, 38, 685 - 704, pls.1 - 3.
- Ethington, E. L. and Clark, D. L., 1965, Lower Ordovician conodonts and other microfossils from the Columbia Ice Fields Section, Alberta, Canada, *Brigham Young University Geological Studies*, 12, 185 - 205, pls. 1 - 2.
- Ethington, E. L. and Clark, D. L., 1981, Lower and Middle Ordovician conodonts from the Ibox area western Millard County, Utah, *Brigham Young University Geology Studies*, 28(2), 1 - 160.
- Ethington, E. L. and Schumacher, D., 1969, Conodonts of the Copenhagen Formation (Middle Ordovician) in central Nevada, *Journal of Paleontology*, 43, 440 - 484, pls.67 - 69.
- Harris, A. G., Bergstrom, S. M., Ethington, R. L., and Ross, R. J., Jr., 1979, Aspects of Middle and Upper Ordovician conodont biostratigraphy of carbonate facies in Nevada and southeast California and comparison with some Appalachian section, *Brigham Young University Geology Studies*, 26(3), 7 - 43.
- Hwang, I. S., 1987, A study on stratigraphy and paleontology of the Maggol Formation of the Joseon Supergroup in Sangdong area, Yeongwolgun, Gangwondo, South Korea (chiefly by means of conodont study),

- Unpublished M.E. thesis, Yonsei University, Seoul, Korea, 95p.
- Jones, P. J., 1971, Lower Ordovician conodonts from the Bonaparte Gulf Basin and the Daly River Basin, northwestern Australia, Bureau of Mineral Resources, Geology and Geophysics Bulletin, 117, 80p, 9 pls.
- Kim, J. H., 1986, Structures of the Ojeongsan area, Mungyeong Coalfield, South Korea, Jour. Geol. Soc. Korea, 22(2), 135 - 145.
- Kim, J. H., Kee, W. S., and Kim, I. S., 1989, Geological structures of the northern part of the Mungyeong Coalfield, Korea, Jour. Geol. Soc. Korea, 25(1), 72 - 81.
- Kim, N. J., Cho, S. O., and Kang, P. J., 1967, Geological Map of Korea 1:50,000, Mungyeong Sheet, Geological Survey of Korea.
- Kim, S. H., 1988, A study on stratigraphy and paleontology of Maggol Limestone distributed in the south part of the Baegunsan Syncline (chiefly by means of conodont study), Unpublished M.S. thesis, Yonsei University, Seoul, Korea, 105p., 7pls.
- Kobatake, N., 1930, Geology of the Bunkei Coal Field, Korea, Chikyu, V.8.
- Kobayashi, T., 1958, Some Cambro - Ordovician fossils from the Tangyang or Tanyo District, South Korea, Transaction Proceedings, Paleontological Society of Japan, N. S., no.30.
- Kobayashi, T., 1961, The Cambro - Ordovician formations and faunas of South Chosen (Korea), Part VIII, Palaeontology 7, Cambrian faunas of the Mungyong (Bunkei) District and the Samposan Formation of the Yengwoel (Neietsu) District, Journal of the Faculty of Science, University of Tokyo, Sec.2, v.13, pt.2.
- Kobayashi, T., 1966, Stratigraphy of the Chosen Group in Korea and South Manchuria and its relation to the Cambro - Ordovician formations of other areas, section A, the Chosen Group of South Korea, Journal of the Faculty of Science, University of Tokyo, Sec.2, v.16, 1 - 84.
- Ku, J. H., 1964, Geology of Mungyeong Coalfield, Geological Survey of Korea, no.5.
- Lee, H. Y., 1970, Conodonten aus der Chosen Gruppe (unteres Ordovizium) von Korea, N. Jb. Geol. Paleont. Abh., 136, 303 - 344.
- Lee, H. Y., 1975a, Conodonten aus der unteren und mittleren Ordovizium von Nord - Korea, Palaeontographica, Abt. A, 150, 161 - 186.
- Lee, H. Y., 1975b, Conodonts from the Dumugol Formation (Lower Ordovician), South Korea, Jour. Geol. Soc. Korea, 11, 75 - 98.
- Lee, H. Y., 1975c, Conodonts from the Upper Cambrian formation Kangweon - do, South Korea, Jour. Geol. Soc. Korea, 11, 172 - 185.
- Lee, H. Y., 1976, Conodonts from the Maggol and the Jeongseon Formation (Ordovician), Kangweon - Do, South Korea, Jour. Geol. Soc. Korea, 12, 151 - 182.
- Lee, H. Y., 1977, Conodonten aus den Jigunsan und den Duwibong Schwichten (Mittel Ordovizium) von Kangweon - Do, Sud - Korea, Jour. Geol. Soc. Korea, 13, 121 - 150.
- Lee, H. Y., 1979, A study on biostratigraphy and bioprovince of the Middle Ordovician conodonts from South Korea with special reference to the conodonts from the Yeong - heung Formation, Jour. Geol. Soc. Korea, 15, 37 - 60.
- Lee, H. Y., 1987, Discovery of the Early Cambrian small shelly fossils from the Choseon Supergroup at the Kurangni area, Mungyong - Kun, South Korea, Journal of the Paleontological Society of Korea, 3(2), 93 - 107.
- Lee, K. W. and Lee, H. Y., 1990, Conodont biostratigraphy of the upper Choseon Supergroup in Jangsung - Dongjeom area, Gangweon - Do, Journal of the Paleontological Society of Korea, 6(2), 188 - 210.
- Lee, M. S. and Kim, S. W., 1968, Geological Map of Korea 1:50,000, Hamchang Sheet, Geological Survey of Korea.
- Lee, Y. N. and Lee, H. Y., 1986, Conodont biostratigraphy of the Jigunsan Shale and Duwibong Limestone in the Nokjeon - Sangdong area, Yeongweol - Gun, Kangweondo, Korea, Journal of the Paleontological Society of Korea, 2(2), 114 - 136.
- Lindström, M., 1955, Conodonts from the lowermost Ordovician strata of south - central Sweden, Geol. Fören. Stockholm Förhandl., 76, 517 - 603, 5pls.
- Lindström, M., 1964, Conodonts, Elsevier, New York, 196p.
- Park, J. S., 1974, Stratigraphy and geologic structure of the Mungyeong Coalfield, Gyeongsangbugdo, Jour. Geol. Soc. Korea, 10, 129 - 148.
- Pietzner, H., Vahl, J., Werner, H., and Ziegler, W., 1968, Zur chemischen Zusammensetzung und Mikromorphologie der Conodonten, Palaeontographica, A(128), 115 - 152.
- Shin, B. W. and Choi, S. I., 1968, Geological Map of Korea 1:50,000, Sangkumgok Sheet, Geological Survey of Korea.
- Son, C. M. and Paik, K. H., 1972, Geologic structure of the Mungyeong Coalfield, Jour. Geol. Soc. Korea, 8, 181 - 189.
- Um, S. H., Seo, H. K., Kim, D. S., Choi, H. I., Park, S. H., Bae, D. J., Lee, H. Y., Chun, H. Y., and Kwon, M. S., 1977, Report on detailed geological investiga-

tion on the Munkyeong Coalfield, KIGAM, 61p.

Manuscript received August 20, 1993

APPENDIX

Locality data for microfossil sites shown on Fig. 1.

Locality	Productive Sample No.	Latitude(oN)	Longitude(°E)
1	2921, 2922, 2923, 2928, 2929	From 36°39'56" To 36°40'00"	128°10'40" 128°10'30"
2	2934, 2936, 2937, 2939, 2940 2941	From 36°39'52" To 36°39'56"	128°10'57" 128°10'45"
3	barren	36°39'53"	128°11'15"
4	2994, 2995, 2997	From 36°39'13" To 36°39'23"	128°10'46" 128°10'39"
5	2942, 2943, 2945	From 36°38'42" To 36°37'38"	128°11'42" 128°11'35"
6	barren	36°38'35"	128°11'54"
7	2946, 2947, 2948, 2949, 2950 2955, 2956	From 36°41'09" To 36°41'25"	128°11'04" 128°10'56"
8	barren	36°41'18"	128°11'29"
9	barren	36°40'56"	128°11'26"
10	2962, 2963, 2968	From 36°40'37" To 36°40'40"	128°12'28" 128°12'16"
11	barren	36°40'10"	128°12'24"
12	barren	36°39'39"	128°13'15"
13	barren	From 36°40'18" To 36°40'27"	128°13'30" 128°13'31"
14	barren	36°40'59"	128°12'57"
15	barren	36°41'22"	128°12'18"
16	2976, 2977, 2978, 2980, 2982 2988, 2990	From 36°38'25" To 36°38'36"	128°09'08" 128°09'03"
17	barren	36°38'47"	128°10'03"
18	barren	36°39'11" 36°39'14"	128°12'12" 128°12'01"
19	barren	36°39'06"	128°10'30"
20	barren	36°38'15"	128°09'23"
21	barren	36°38'02"	128°11'12"
22	barren	36°37'52"	128°09'50"

EXPLANATION OF PLATES

PLATE 1. **1-2.** *Acontiodus viriosus*, 1: posterior view, X150, sample 2994, 2: lateral view, X150, sample 2980. **3-4.** *Aurilobodus aurilobus*?, 3: asymmetric element, posterior view, X250, sample 2922, 4: symmetric element, posterior view, X160, sample 2982. **5-6.** *Aurilobodus leptosomatus*, 5: asymmetric element, anterior view, X220, sample 2988, 6: symmetric element, posterior view, X100, sample 2994. **7.** *Aurilobodus simplex*, symmetric element, posterior view, X90, sample 2994. **8-9.** *Belodella rigida*, 8: adenticulated biconvex element, lateral view, X180, sample 2994, 9: denticulated triangular element, lateral view, X140, sample 2994. **10.** *Dapsilodus compressus*, distacodontiform element, lateral view, X90, sample 2939. **11.** *Drepanodus homocurvatus*, lateral view, X110, sample 2994. **12-14.** *Erraticodon tangshanensis*, 12: cordylodontiform element, lateral view, X110, sample 2982, 13: hindeodelliform element, anterior view, X90, sample 2982, 14: prioniodiniform element, lateral view, X80, sample 2982. **15.** *Ozarkodina* cf. *joachimensis*, lateral view, X230, sample 2922.

PLATE 2. **1.** *Paltodus inconstans*, lateral view, X120, sample 2939. **2.** *Panderodus gracilis*, compressus element, lateral view, X280, sample 2922. **3-7.** *Plectodina onychodonta*, 3: subcordylodontiform element, lateral view, X150, sample 2923, 4: cyrtionodontiform element, lateral view, X150, sample 2923, 5: dichognathiform element, lateral view, X270, sample 2923, 6: prioniodiniform element, lateral view, X110, sample 2922, 7: trichonodelliform element, lateral view, X160, sample 2923. **8.** *Scolopodus eburnus*, lateral view, X230, sample 2997. **9.** *Scolopodus euspinus*, lateral view, X110, sample 2937. **10.** *Scolopodus filusus*, lateral view, X120, sample 2936. **11.** *Scolopodus flexilis*, arcuatiform element, lateral view, X75, sample 2937. **12-13.** *Triangulodus changshanensis*, 12: distacodontiform element, posterior view, X120, sample 2934, 13: trichonodelliform element, posterior view, X140, sample 2934. **14-15.** *Scolopodus nogamii*, 14: lateral view, X200, sample 2937, 15: enlarged from Fig.14, X540.

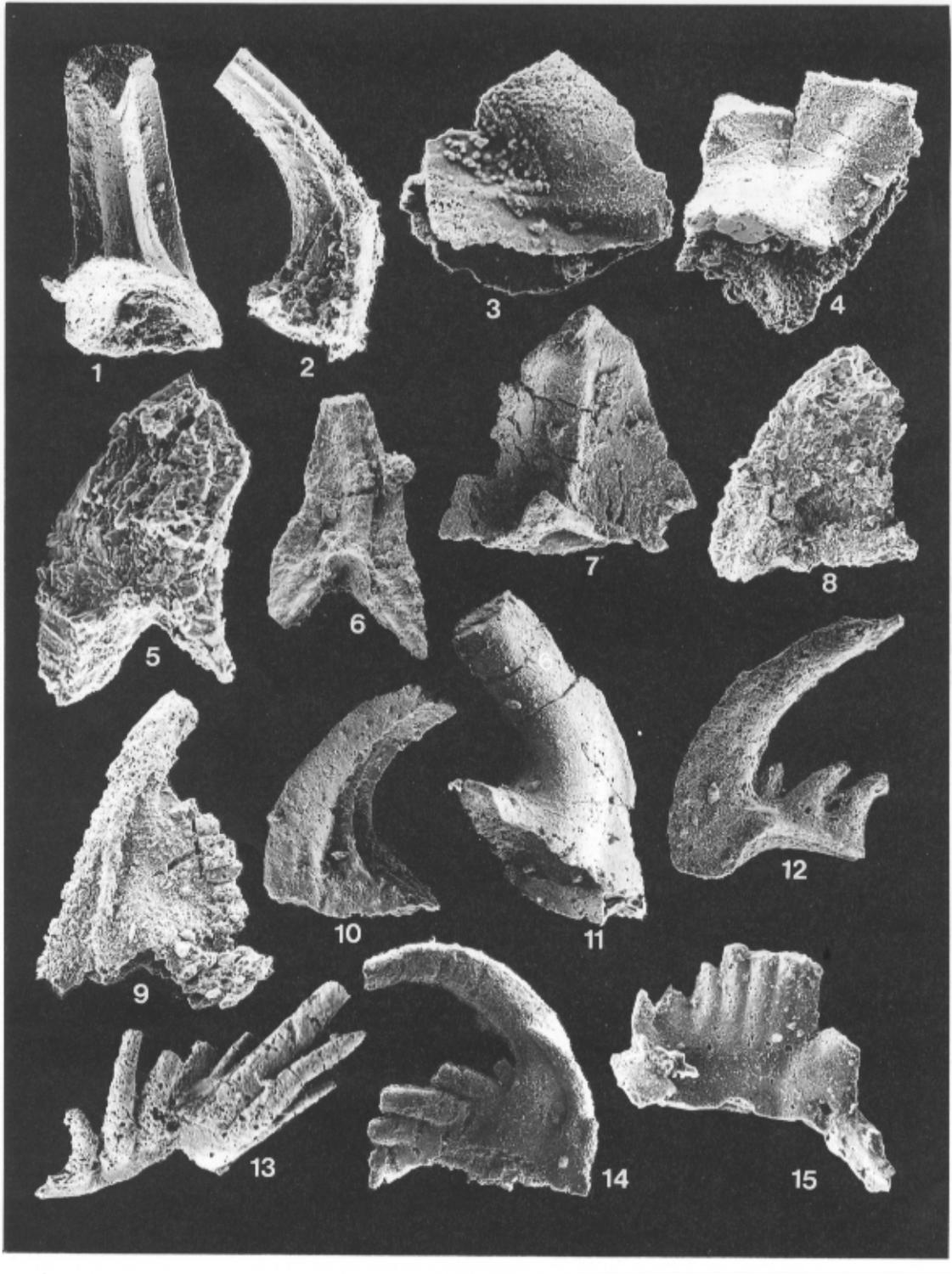


PLATE 2

