

## Conodonts from the Machari Formation (Middle ?-Upper Cambrian) in the Yeongweol Area, Kangweon-do, Korea

江原道 寧越地域, 磨磋里層(中?-上部 캄브리아系)의  
코노돈트 化石群

Byung-Su Lee(이병수)\*, Duck-Keun Choi(최덕근)\*  
and Ha-Young Lee(이하영)\*\*

**Abstract** : The Machari Formation in the Yeongweol area consists of two informal members: namely the lower, ca. 100 meters in thickness, dark-gray to black shales containing locally interbedded dark-gray sandstone and lime mudstone, and the upper, about 320 meters in thickness, gray to dark-gray thin-bedded limestones, showing peculiar banded appearance. Two conodont faunal assemblages are recognized in the formation. The lower one is characterized by the occurrence of *Gapparodus bisulcatus*, *Westergaardodina matsushitai*, *W. moessebergensis*, *Furnishina triangulata*, *Muellerodus cambricus*, *M. oelandicus* and *Nogamiconus* sp., and the upper assemblage includes *Cambroositodus cambricus*, *Proconodontus muelleri*, *P. cf. posterocostatus*, *Prosagittodontus eureka*?, *Teridontus nakamurai* and *T. n. sp.* These conodont faunas suggest that the lower assemblage is correlatable with the fauna of the lower member of the Hwajeol Formation in Korea, the conodont fauna of the early Late Cambrian of Northern Europe and North America, and the Kushan Formation (*Westergaardodina matsushitai* Zone) in China (early Late Cambrian) whereas the upper with the *Proconodontus* Zone of the Hwajeol Formation in Korea and North America, and the lower *Proconodontus-Rotundoconus* Zone in North China (middle to early-late Late Cambrian). However, it needs more refined study based on abundant conodonts for the precise determination of the lower boundary of the Machari Formation. The lowest ca. 23m interval of the formation is not considered here. Two new conodont species are proposed: *Coelocerodontus kosangolensis* n. sp. and *Hertzina*? n. sp.

### 요 약

寧越地域의 磨磋里層은 2개의 非公式層員으로 구성된다. 下部層員은 約 100m 두께의 暗灰色-黑色 세일이 우세하며 곳에 따라 암회색 砂岩과 石灰岩이 挾在한다. 마차리층의 주요 부분인 上部層員은 320m 두께의 회색-암회색 互狀石灰岩으로 구성되어 있다. 마차리층의 코노돈트 化石群은 하부의 *Gapparodus bisulcatus*-*Westergaardodina matsushitai*-*W. moessebergensis* 群集과 상부의 *Proconodontus muelleri*-*Cambroositodus cambricus* 群集으로 나뉘어진다. 하부화석군집은 白雲山向斜帶의 花折層 하부층원(小林의 細松粘板岩)과 中國 蔚山層의 *W. matsushitai* 帶를 비롯한 여러지역의 後期 캄브리아系의 初期 化石群과, 상부화석군집은 화절층의 最下位 生層序帶인 *Proconodontus*帶, 北美의 *P. tenuiserratus*-*Proconodontus*帶 하부 및 중국의 *Proconodontus-Rotundoconus*帶의 하부 등 後期 캄브리아系의 中-初後期 化石群과 각각 對比된다. 그러나 마차리층의 下部境界는 다량의 코노돈트를 통하여 精密한 檢討가 이루어져야 할 것으로 보인다. 본 연구에서 *Coelocerodontus kosangolensis* n. sp.와 *Hertzina*? n. sp.가 新種으로 記載되었다.

\*Department of Geological Sciences, Seoul National University, Seoul 151-742, Korea(서울대학교 지질학과)

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

## INTRODUCTION

The study area is located at northwestern side of Yeongweol-gun, Kangweon-do(Fig. 1). In the area, the Machari Formation, proposed by Yoshimura (1940), crops out as a broad belt across the south slope of Mt. Sambang, extending to farther south as NS-trending narrow belts in the west of the Machari and Jeolgaesan thrust faults.

The Machari Formation has been dated to late Middle to early Late Cambrian, based primarily on macrofossil study of Kobayashi (1962, 1966), who established five trilobite assemblages of *Olenoides*, *Tonkinella*, *Eochuangia*, *Komaspis-Kopturalwayaspis* and *Olenus-Glypagnostus* zones in ascending order.

Recently Lee (1975) described some Late Cambrian conodonts from two sites (samples 49 and 53) of the Machari Formation in the south side of Wondongjae.

The purpose of this study is (1) to identify and describe conodonts that were recovered from the Machari Formation in the study area and (2) to correlate the fauna with the previously established conodont zones in the world.

The figured specimens are deposited in the repository of the Department of Geology, Yonsei University, Seoul.

## STRATIGRAPHY AND SAMPLE LOCALITIES

The Machari Formation overlies the Sambangsan Formation, the lowest unit of Yeongweol area and is overlain by the Wagok Formation.

The Machari Formation consists of two informal members: the lower one, estimated to ca. 100m in thickness, is composed of fossiliferous dark-gray to black shales containing locally interbedded dark-gray sandstones and limestones; the upper, major part of the formation, consists dominantly of about 320m of gray to dark-gray thin-bedded limestones, showing peculiar banded appearance.

The lower clastic member thins markedly out along the Machari thrust fault whereas the upper

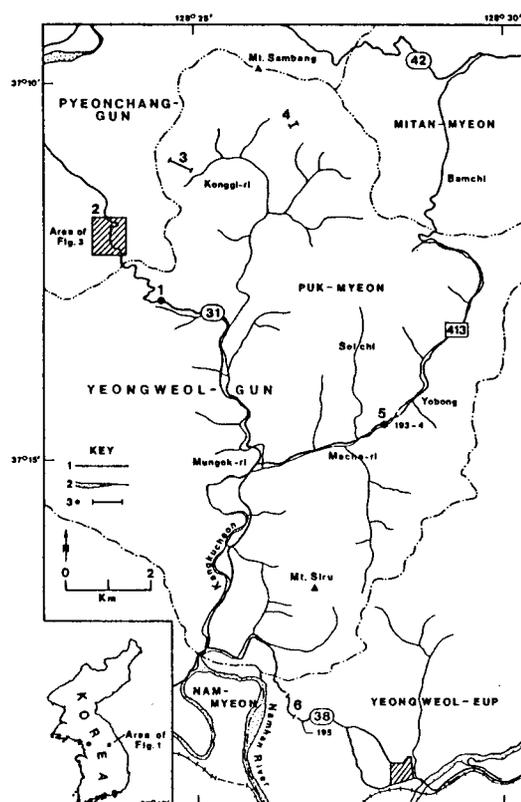


Fig. 1. Location map for measured sections (1-6) of the Machari Formation in the Yeongweol area. Numbered localities are described in the text. See Fig.3 for more detailed map of location shown by numbered, enclosed area. Key: 1. National and provincial routes; 2. Rivers and streams; 3. Measured sections.

carbonate member is continuous throughout the study area. Accordingly, the entire sequence of the formation could be traced at southern area of Mt. Sambang.

Frequent locally are buried fold so that minor thrust faults commonly occur, particularly in the south slope of Mt. Sambang.

In most study areas, the Machari Formation overlies the Sambangsan Formation with distant erosional surface lacking very contact, in contrast it is overlain by the Wagok Formation with apparent gradational contact of banded limestone and dolomitic limestone.

The basal part of the Machari Formation consi-

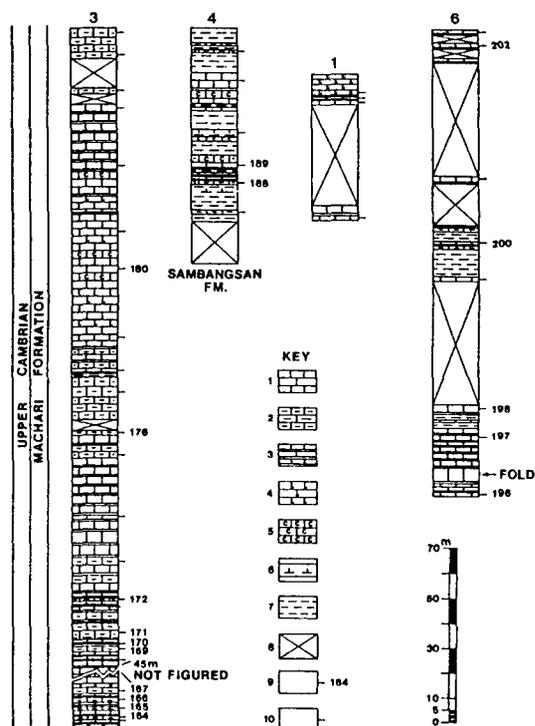


Fig. 2. Stratigraphic column of the measured sections with sample horizons in Localities 1, 3-5, and 6 of the Machari Formation in the Yeongweol area. Key: 1, Massive limestone; 2, Laminated or clayey limestone; 3, Banded limestone; 4, Dolomitic limestone; 5, Crystalline limestone; 6, Calcareous shale; 7, Non-calcareous shale; 8, Covered interval; 9, Sample with conodont; 10, Sample without conodont.

sts of black shale and dark-gray limestone in Eodungol, Konggi-ri (Locality 4 in Fig. 1) where the lower part of formation is most well exposed. These lie with an obvious conformity on thick greenish-gray shale beds of the Sambangsan Formation.

Rock exposure of the area is excellent owing to well road cutting so that it is easy to sample there. Six widely spaced sections were measured and sampled. Fig. 1 and 3 show the locations of these sections. The brief description of these locations are given below with an information concerning stratigraphic level and lithology of each sample:

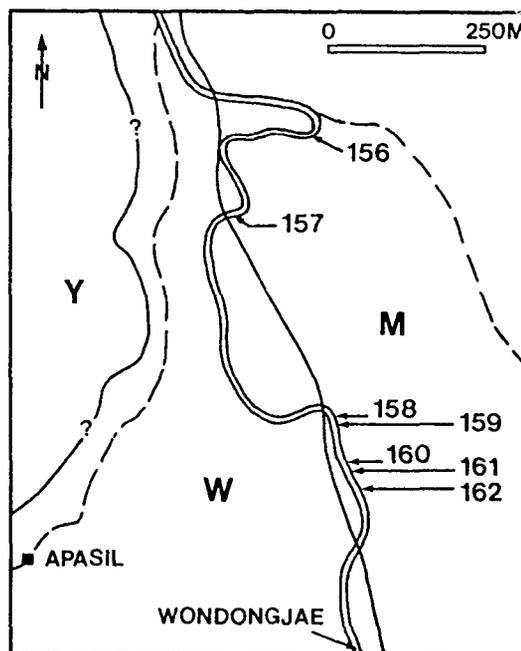


Fig. 3. Map showing sample locations near Wondongjae, Pyeongchang-gun (Locality 2) along route 31. M, Machari Formation; W, Wagok Formation; Y, Yeongheung Formation.

*Locality 1*-Cuts along route 31, 2.5 km south of Wondongjae which borders Yeongweol and Pyeongchang-guns. The upper part of the Machari Formation was measured for the study at this locality where four lime mudstone horizons were sampled (152-155).

*Locality 2*-Cuts along route 31, 0.6~1.3 km north of Wondongjae, Pyeongchang-gun. These were not measured, but seven samples (156-162) were taken from thick-bedded dark-gray lime mudstones of the upper member of the formation.

*Locality 3*-Exposures along the northwestern valley of Kosangol village, Konggi-ri, Yeongweol-gun. The section sampled herein is about 326.5m of banded limestone, dolomitic limestone and shale of the upper member of the formation (163-186), which is bounded on about 15m higher by a sequence of dolomitic limestones of the Wagok Formation.

*Locality 4*-Cuts along unnamed road for forest conservancy in south slope of Mt. Sambang, the highest peak in the study area, 0.4 km northwest

of Eodungol, Konggi-ri, Yeongweol-gun. These are the lowermost beds of the Machari Formation and are the lowermost part of the sections considered in this report. The section measured herein amounts to 69m thick starting about 20m above the thick greenish-gray shale beds of the Sambangsan Formation and consist of alternation of black shale and limestone. Six samples (187-192) were collected.

*Locality 5*-Exposures in a south-facing portion of route 413 immediately west of Machari thrust fault near Yeongweol mine office, 0.5 km northeast of Macha-ri, Yeongweol-gun. The lower member of the Machari Formation is very poorly exposed in this area, but the observed part of the area consists of black shales with thin interbeds of black sandstone and lime mudstone. Two (193 and 194) limestone interbeds were sampled.

*Locality 6*-Cuts along route 38, along south side of Sonagijae, 3 km northwest of Yeongweol-eup. Each member of the formation in this locality consists mainly of black shales with rare interbeds of dark-gray lime mudstones and scattered outcrops of dark-gray limestones of the characteristic banded appearance. One (195) and eight samples (196-203) were collected from the interbedded limestones of the lower and upper members, respectively.

## CONODONT BIOSTRATIGRAPHY

Abundant conodonts were procured from six sections of the Machari Formation in the Yeongweol area that was probably deposited in relatively deep water (Table 1). These elements are useful in assigning ages of the formation. Furthermore, the occurrence of commonly associated micro-and macrofaunal forms provide an opportunity to establish an integrated biostratigraphic framework. The carbonates of this area probably contain the most complete record of early Late Cambrian faunas in Korea with an exception of trilobite fauna. Although conodonts of this age is low in diversity, it seems that their discovery is of considerable paleogeographic and biostratigraphic significance. The stratigraphic locations of the sam-

ples collected from the measured sections are illustrated in Fig. 2.

Two conodont faunal assemblages are recognized in the Machari Formation; the lower *Gapparodus bisulcatus*-*Westergaardodina matsushitai*-*W. moessebergensis* Assemblage and the upper *Proconodontus muelleri*-*Cambroistodus cambricus* Assemblage. The lower assemblage zone is distinctly recognized from the localities 3 to 5 and is probably dated to early Late Cambrian in age. The stratigraphically higher samples in the Localities 1 to 3, and 6 are assignable to the upper *Proconodontus muelleri*-*Cambroistodus cambricus* assemblage and are probably middle to early Late Cambrian in age. Some data concerning faunal constituent, stratigraphic interval, and correlation of these two conodont assemblage zones are briefly summarized as follows.

The *Westergaardodina matsushitai*-*W. moessebergensis* assemblage ranges through the lower ca. 100m interval of the Machari Formation: lower 9.5m of the measured section of Locality 3 (sample 163-165), probably entire section of Locality 4 (sample 187-192) and 5 (sample 193 and 194), and lowest sample of Locality 6 (sample 195).

The dominant taxa of this interval are as follows; *Coelocerodontus kosangolensis* n. sp., *C. palmeri*, *C. sp.*, *Furnishina triangulata*, *F. furnishi*, *Gapparodus bisulcatus*, *G. cf. bisulcatus*, *G. n. sp.*, *G. sp.*, *Hertzina elongata*, *Muellerodus cambricus*, *M. oelandicus*, *M. sp.*, *Nogamiconus sp.*, *Phakelodus tenuis*, *Prooneotodus gallatini*, *P. rotundatus*, *Proscandodus dissimularis*, *Rotundoconus bulbosus*, *Westergaardodina bicuspidata*, *W. matsushitai* and *W. moessebergensis*.

Especially, the presence of *Gapparodus bisulcatus*, *Westergaardodina matsushitai*, *W. moessebergensis*, *Furnishina angulata*, *Muellerodus cambricus*, *M. oelandicus* and *Nogamiconus sp.* suggests that the interval is of early Late Cambrian in age and is closely correlated with the lower member of the Hwajeol Formation in Korea (Lee, 1990), early Late Cambrian of Northern Europe and North America (Müller, 1959), Kushan Formation (Nogami, 1966) and *W. matsushitai* Zone in China

**Table 1.** Numerical distribution of conodont species in productive samples from the Machari Formation in the Yeongweol area

Species	Sample																				T			
	157	160	161	164	165	166	167	169	170	171	172	176	180	188	189	194	196	197	198	200		202		
<i>Cambroistodus cambricus</i>		1																				1		
<i>Coelocerosodontus kosangolensis</i>																								
tricostate el.				4		2																6		
tetracostate el.					7	4																11		
<i>Coelocerosodontus palmeri</i>																								
acodiform el.				2	7	9																18		
distacodiform el.				2	9	5																16		
<i>Coelocerosodontus</i> sp.					1	2																3		
<i>Furnishina triangulata</i>														1								1		
<i>Furnishina furnishi</i>																								
symmetrical el.									1								1	2		1	5			
asymmetrical el.				12	15	9	6						1	1		1		1	4	1	1	53		
<i>Gapparodus bisulcatus</i>																	23					23		
<i>Gapparodus</i> cf. <i>bisulcatus</i>																	1					1		
<i>Gapparodus</i> n. sp.																	1					1		
<i>Gapparodus</i> sp.																	1					1		
<i>Hertzina elongata</i>		1				1																2		
<i>Muellerodus cambricus</i>				1	1																	2		
<i>Muellerodus oelandicus</i>					3															1		4		
<i>Muellerodus</i> sp.				1	1																	2		
<i>Nogamiconus</i> sp.																		1				1		
<i>Phakelodus tenuis</i>	3			5	29	23	6		1	1			16	1							2	2	1	90
<i>Proconodontus muelleri</i>		1				5			1														7	
<i>P.</i> cf. <i>posterocostatus</i>						11	1														1		13	
<i>Prooneotodus gallatini</i>	1			11	19	7	2		1												1		2	44
<i>Prooneotodus rotundatus</i>	2			12	16	15	2				1												48	
<i>Prosagittodontus eureka?</i>	1																						1	
<i>Proscandodus dissimularis</i>					2																	1	3	
<i>Rotundoconus bulbosus</i>																								
noncarinate el.				1					3		1												5	
<i>Teridontus nakamurai</i>								1															1	
<i>Teridontus</i> n. sp. Lee								1	2														3	
<i>Westergaardodina bicuspidata</i>				3																			5	
<i>Westergaardodina matsushitai</i>																	2						2	
<i>Westergaardodina moessebergensis</i>																	3						3	

(An *et al.*, 1983). As the conodonts of the lower assemblage, however, were recovered from the beds of more than ca. 23m above the base of the Machari Formation, it is not confirmed herein whether the lower limit of the formation ranges down to the Middle Cambrian in age or not. It needs more refined study based on abundant conodonts for the precise determination of the lower boundary of the formation.

The *Proconodontus muelleri*-*Cambroisitodus cambricus* assemblage is recognized through the upper ca. 320m interval of the Machari Formation: entire measured section of Locality 2 (sample 156-162), upper ca. 317m of the measured section of Locality 3 (sample 163-186) and probably entire section of Locality 6 (sample 196-203)

This interval contains the following significant

conodont taxa: *Cambroositodus cambricus*, *Proconodontus muelleri*, *P. cf. posterocostatus*, *Prosagittodontus eureka?*, *Terodontus nakamurai* and *T. n. sp.*

*Proconodontus cf. posterocostatus*, *P. muelleri* and *Cambroositodus cambricus* are characteristic elements of the *Proconodontus* Zone of the Hwajeol Formation in the Paekunsan synclinal area (Lee & Lee, 1988; Lee, 1989a, 1989b, 1990) and also, two teridontiids are very closely related to forms from the lower part of the Hwajeol Formation.

Therefore, the *Proconodontus muelleri*-*Cambroositodus cambricus* assemblage is closely correlated with the lower *Proconodontus* Zone of the Hwajeol Formation in Korea spanning middle to early Late Cambrian in age, the *P. tenuiserratus* Zone to *P. posterocostatus* and *P. muelleri* Subzones of the *Proconodontus* Zone in western United States (Miller, 1982), the lower part of the *P. muelleri muelleri* Subzone of the *Proconodontus* Zone in Canadian arctic islands (Nowlan, 1985), and the lower part of the *Proconodontus*-*Rotundoconus* Zone in North China (An *et al.*, 1983).

## SYSTEMATIC PALEONTOLOGY

### Genus *Coelocerodontus* Ethington, 1959

Type species.—*Coelocerodontus trigonius* Ethington, 1959 s.f.

#### *Coelocerodontus kosangolensis* n. sp.

pl. 1, figs. 8-12, text-figs. 1D, E

**Derivation of name.**—Name after the village name Kosangol, Konggi-ri, Yeongweol-gun.

**Holotype**—Tricarinate el., pl. 1, fig. 8, text-fig. 1D; tetracarinate el., pl. 1, fig. 10, text-fig. 1E.

**Diagnosis.**—Symmetrical to asymmetrical, simple hollow cones with a multielement apparatus including tricostate (triangular) and tetracostate (quadrate) elements.

**Description.**—Tricostate el.: Slightly expanded simple cone with triangular cross section. The anterior margin is prominently keeled from tip to base, otherwise the posterior is concave flanking each posterolateral costa. The faces between the

three costae are moderately concave. Basal cavity extends throughout the cone.

Tetracostate el.: Smoothly curved simple cone with quadrate cross section. The cusp is elongate with a relatively low rate of lateral expansion. It possesses two costae on each anterolateral and posterolateral side, forming rectangular in outline. It may be asymmetrical, because the costae are usually directed slightly to the inner side of each margin. The costae extend through the entire length of the cone. The faces between them are nearly flat to slightly concave. Specimens are entirely hollow.

**Remark.**—Two elements of this species are most closely related to *Coelocerodontus trigonius* Ethington and *C. tetragonius* Ethington, but are different from the latter in anterior keels and basal flaring. Also, the latter species are of Late Ordovician. *C. kosangolensis* bears more prominent costae than in *Rotundoconus bulbosus* Lee and is lacking in nodes.

**Occurrence.**—Samples 164-166 of the Kosangol section (Locality 3).

**Number of specimens.**—6 tricostate and 11 tetracostate elements.

#### *Coelocerodontus palmeri* (Müller, 1959)

pl. 1, figs. 13-15, text-figs. 1F, G

*Distacodus palmeri* Müller, 1959, p. 449, 450, pl. 14, figs. 3, 4.

*Distacodus* sp. indet. cf. *D. palmeri* Müller. Nogami, 1966, p. 253, 254, pl. 10, figs. 10, 11.

*Proconodontus tricarinatus* (Nogami). Lee, 1975, p. 81, 82, pl. 1, figs. 4, 8, text-fig. 2D; Fähræus & Nowlan, 1978, p. 453, pl. 1, fig. 4.

*Prodistacodus palmeri* (Müller). An, 1982, p. 144, pl. 5, fig. 7; An, 1987, p. 111, pl. 2, figs. 7.8, 12, 13.

*Coelocerodontus cambricus* (Nagami). Landing, 1983, p. 1172, 1173, Fig. 10A-C; Lee & Lee, 1988, pl. 1, figs. 24-27; Lee, 1989a, pl. 1, figs. 14, 15; Lee, 1989b, pl. 1, fig. 17; Lee, 1990, pl. 2, fig. 17.

*Distacodus? palmeri* Müller. An *et al.*, 1983, p. 91, pl. 4, figs. 11, 12.

Stage	North China An 1982	North America Miller 1980, 1982	Korea This study	
Upper Cambrian	<i>Cordylodus proavus</i>	<i>Cordylodus proavus</i> (part)		
	<i>Proconodontus</i>	<i>Proconodontus</i>	<i>Cambrooistodus minutus</i>	
			<i>Eoconodontus notchpeakensis</i>	
			<i>Proconodontus muelleri</i>	<i>Proconodontus muelleri</i> - <i>Cambrooistodus cambricus</i>
			<i>Proconodontus postero-costatus</i>	
			<i>Proconodontus tenuiserratus</i>	
	<i>Westergaardina aff. fossa</i> - <i>Proonetodus rotundatus</i>	Not zoned		
	<i>Muellerodus ? erectus</i>			
	<i>Westergaardodina matsushitai</i>		<i>Gapparodus bisulcatus</i> - <i>Westergaardodina matsushitai</i> - <i>W. moessebergensis</i>	
	<i>Westergaardodina orygya</i>			
Middle Cambrian (Part)	<i>Shandongodus priscus</i>			
	<i>Laiwugnathus laiwuensis</i>			

Fig. 4. Correlation of the conodont assemblages of the Machari Formation in the Yeongweol area with biozones of North China and North America.

**Proposed emendation.**—Simple conical paraconodonts(?) with two-element apparatus consisting of asymmetrical acodiform (laterally unicosate) element and less abundant, symmetrical to asymmetrical distacodiform (laterally bicostate) element possessing extremely deep basal cavity and lacking in white matter.

**Discussion.**—The acodiform element of this species occurs as both left and right forms in view of the location of costae. Distacodiform element has a lateral costa on each face running the midline of the sides. This element may be somewhat asymmetrical due to different costa plan.

*Coelocerodontus palmeri* revised herein can be distinguished from *Rotundoconus bulbosus* by the more flattened cusp, prominent costa, and the lacking of nodes on surface. This species is closely related to *Coelocerodontus trigonius* Ething-

ton, *C. tetragonius* Ethington, and *C. digonius* Sweet & Bergstöm, respectively. But the latter three form species have been known only from the Middle to Late Ordovician and are not stratigraphically related to *C. palmeri*, which occurs only from the Upper Cambrian in our collection.

**Occurrence.**—Samples 164-166 of the Kosanngol section (Locality 3).

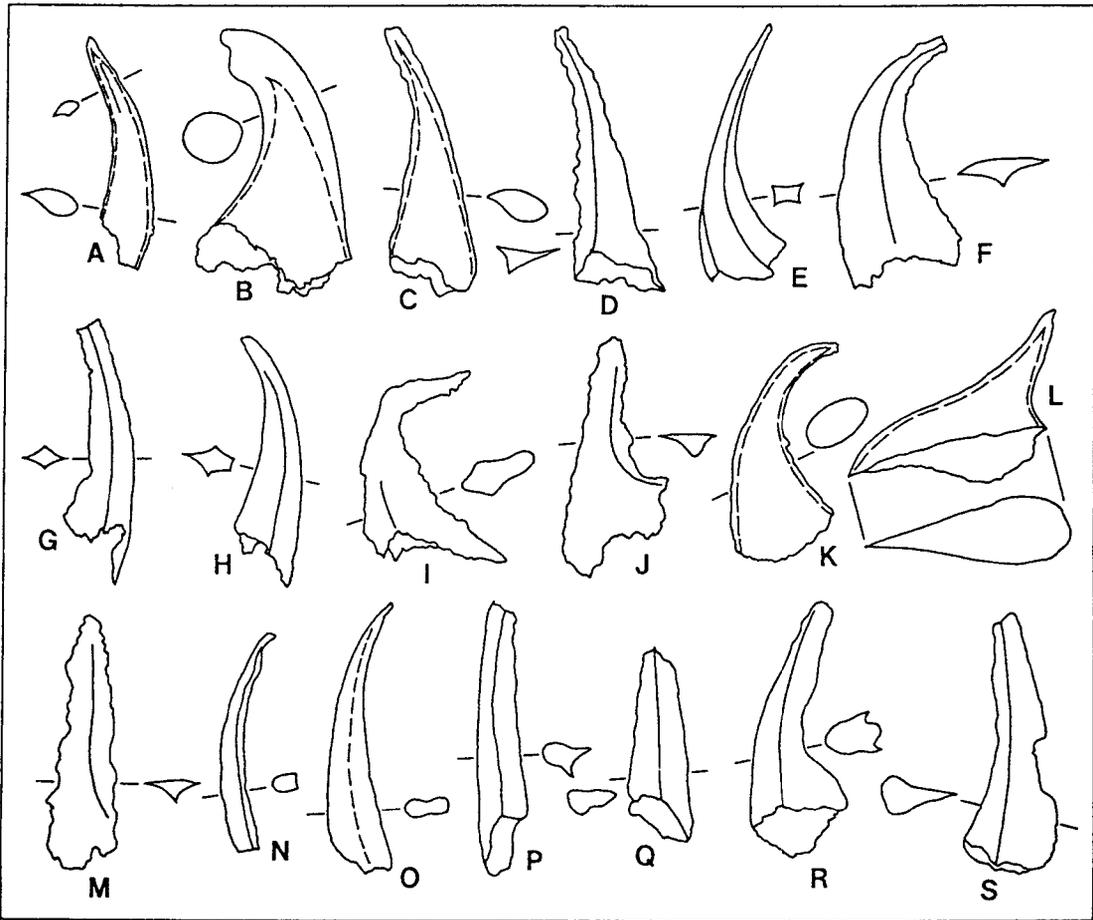
**Number of Specimens.**—18 acodiform and 16 distacodiform elements.

***Coelocerodontus* sp.**

pl. 1, figs. 16, text-fig. 1H

cf. *Proconodontus tricarinatus* (Nogami). Müller, 1973, p. 44, pl. 3, fig. 9.

**Description.**—Subsymmetrical hollow cone with five costae. The anterior region is depressed by two sharp anterolateral costae. Lateral sides bear



**Text-fig. 1.** Lateral outline, cross section and basal cavity of some selected conodonts from the Machari Formation in the Yeongweol area. A. *Proconodontus* cf. *posterocostatus* Miller, 1980, lateral view, YSUG 861 (166), x51. B. *Teridotus* n. sp. Lee, lateral view, YSUG 868 (169), x180. C. *Proscandodus dissimilaris* Lee, 1988, lateral view, YSUG 865 (165), x120. D, E. *Coelocerodontus kasangolensis* n. sp., lateral views of tricostate and tetracostate elements, YSUG 836 (166) and 838 (164), x156 and x78. F, G. *Coelocerodontus palmeri* (Müller, 1959), lateral views of acodiform and distacodiform elements, YSUG 841 (165) and 843 (166), x108 and x90. H. *Coelocerodontus* sp., lateral view, YSUG 844 (165), x90. I. *Muellerodus cambricus* (Müller, 1959), lateral view, YSUG 854 (164), x120. J. *Prosagittodontus eureka*? (Müller, 1959), posterior view, 864 (157), x96. K. *Prooneotodus rotundatus* (Druce & Jones, 1971), lateral view, YSUG 863 (165), x96. L. *Nogamiconus* sp., posterior view, YSUG 858 (194), x60. M. *Furnishina triangulata* Xiang & Zhang, 1983, posterior view, YSUG 845 (188), x144. N. *Hertzina elongata* Müller, 1959, lateral view, YSUG 848 (165), x90. O, P. *Gapparodus bisulcatus* Müller, 1959, lateral and posterolateral views, YSUG 849 (188) and 850 (188), x40 and x40. Q. *Gapparodus* cf. *bisulcatus* Müller, 1959, posterolateral view, YSUG 851 (188), x28. R. *Gapparodus* n. sp., lateral view, YSUG 852 (188), x90. S. *Gapparodus* sp., lateral view, YSUG 853 (188), x78.

costae which are medially located, and the posterior side is keeled.

**Remarks.**—This uncommon ‘multicostated form’ has similarities to elements of *Coelocerodontus*

*kosangolensis* n. sp. but has more costae in number than those of the latter.

**Occurrence.**—Samples 165 and 166 of the Kosangol section (Locality 3).

**Number of specimens.**—3.

**Genus *Gapparodus* Abaimova, 1979**

Type species.—*Hertzina*? *bisulcata* Müller, 1959

***Gapparodus bisulcatus* (Müller, 1959) s.f.**

pl. 1, figs. 33, 34, text-figs. 10, P

*Hertzina*? *bisulcata* Müller, 1959, p. 456, pl. 13, figs. 22-24, 27; Poulsen, 1966, p. 8, 9, pl. 1, fig. 9.

*Hertzina bisulcata* Müller. Clark & Robison, 1969, Text-fig. 1d; Landing, 1974, p. 1246, Text-fig. 1c.

*Hertzina bisulcata* Müller var. 1. Landing, 1974, p. 1246, Text-figs. 1d, e.

*Hertzina bisulcata* Müller var. 2. Landing, 1974, p. 1246, Text-fig. 1f.

? *Hertzina bokononi* Landing, 1974, p. 1246, Text-figs. 1h-i.

*Gapparodus bisulcatus* (Müller). Abaimova, 1978, p. 79, Test-fig. 1; An, 1987, p. 106, 107, pl. 1, figs. 6, 8-? 10, 26.

**Description.**—Cone is very long and slender, gently curved, thin-walled and is oval in cross section. It is usually symmetrical, but some specimens are slightly asymmetrical due to the lateral bend of the cone. The anterior face is rounded, but the posterior varies widely from rounded to concave. In some specimens, posterolateral edges are drawn out into two prominent keels. Each lateral side bears a deep longitudinal furrow running along the midline or slightly backwards through the entire length of the cone. The internal cavity extends to tip so that a true cusp is lacking. The cavity may be filled with secondary phosphate (pl. 1, fig. 34).

**Remarks.**—The present specimens are consistent with the original diagnosis and type figure of Müller (1959).

**Occurrence.**—Sample 188 of the Eodungol section (Locality 4).

**Number of specimens.**—23.

***Gapparodus bisulcatus* Müller, 1959, s.f.**

pl. 1, fig. 35, text-fig. 1Q

cf. *Hertzina*? *bisulcata* Müller, 1959, p. 456, pl. 13, figs. 22-24, 27.

**Description.**—Slightly curved, symmetrical simple cones with posterolateral carinae and distinct, shallow linear furrows running along the posterior border of each lateral side. Although it is fragmentary, maximum length can be estimated to be at least 2 mm. The anterior is sharply edged and the posterior is nearly flat, giving triangular cross section. The cone is entirely excavated.

**Remarks.**—The single fragmentary specimen has lateral furrow, the most diagnostic feature of *Hertzina*? *bisulcata* Müller but differs from the latter by the fact that the anterior side is sharply edged.

**Occurrence.**—Sample 188 of the Eodungol section (Locality 4).

**Number of specimens.**—1.

***Gapparodus* n. sp.**

pl. 1, fig. 36, text-fig. 1R

**Holotype.**—pl. 1, fig. 36, text-fig. 1R.

**Description.**—Gently curved, symmetrical simple cone with a large posteriorly expanded base. The anterior margin is broadly rounded whereas the posterior bears a carina on its mid-portion. Keels are presented on both of the posterolateral faces, flanked anteriorly by weak longitudinal furrows. The hollow internal cavity is filled with secondary phosphate.

**Remarks.**—The broadly rounded anterior face, lateral longitudinal furrows and posterolateral edges of this specimen show the definitive characteristics of *Hertzina* Müller. However, it differs from existing form species of the genus in having the posteriorly expanded base and a longitudinal posterior carina. It needs more sufficient material for exact taxonomy.

**Occurrence.**—Sample 188 to of the Eodungol section (Locality 4).

**Number of specimens.**—1.

***Gapparodus* sp.**

pl. 1, fig. 37, text-fig. 1S

**Description.**—Smoothly curved, subsymmetrical simple cone with subtriangular cross section. It tapers slightly toward the apex of cone. The anterior margin is keeled while the posterior is nearly flat to slightly rounded. Two carinae are present on each posterolateral face of the lower portion of the cone. Each lateral face is strongly or at least distinctly concaved throughout. The cone is subtriangular in cross section with an anterior and two posterolateral edges. The hollow internal cavity is filled with secondary phosphate.

**Remarks.**—The single specimen described here is tentatively assigned to *Hertzina* Müller owing to similarity to that of the figured holotype of *Hertzina americana*.

**Occurrence.**—Sample 188 of the Eodungol section (Locality 4).

**Number of specimens.**—1.

**Genus *Hertzina* Müller, 1959**

Type species.—*Hertzina americana* Müller, 1959 s.f.

***Hertzina elongata* Müller, 1959 s.f.**

pl. 1, fig. 32, text-fig. 1N

*Hertzina elongata* Müller, 1959, p. 445, 446, pl. 13, fig. 28; Müller, 1871, pl. 1, figs. 2, 3; Bednarczyk, 1979, p. 429, pl. 3, figs. 1, 4, 8, 11, 13; An, 1982, p. 134, pl. 10, fig. 10; Lee, 1990, pl. 1, fig. 5.

**Description.**—Long and slender, subsymmetrical simple cone. The cusp is thin-walled and oval in cross section except posterolateral sides. The anterior margin is moderately rounded whereas the posterior is nearly flat, making two posterolateral carinae; each lateral side is nearly flat to smoothly rounded. The internal cavity extends all the way to the tip, lacking true conodont proper.

**Remarks.**—The specimens at hand agree well with the original description and illustration of the species (Müller, 1959).

**Occurrence.**—Samples 157 (Locality 2) and 164 (Locality 3).

**Number of specimens.**—2.

**Genus *Muellerodus* Müller, 1980**

Type species.—*Distacodus? cambricus* Müller, 1959 s.f.

***Muellerodus cambricus* (Müller, 1959) s.f.**

pl. 1, fig. 17, text-fig. 1I

*Distacodus? cambricus* Müller 1959, p. 450, pl. 14, figs. 1, 2.

*Oneotodus cambricus* (Müller). Müller, 1971, pl. 2, fig. 3.

*Muellerodus cambrica* (Müller). Bednarczyk, 1979, p. 429, pl. 2, fig. 8.

**Description.**—Symmetrical simple conodont with a sigmoidal cusp and an expanded base. The cusp is regenerated, forming S-shape in lateral view and rounded in cross section. The base is expanded; both anterior and posterior margins are nearly rounded; each lateral face has less prominent carina; its basal cavity is wide and deep, extending almost all the way to the tip.

**Remarks.**—The present material has a sigmoidal cusp and a carinated base, which are diagnostic features of the holotype of the species from Sweden (Müller, 1959).

**Occurrence.**—Samples 164 and 165 of the Kongsol section (Locality 3).

**Number of specimens.**—2.

***Muellerodus oelandicus* (Müller, 1959) s.f.**

pl. 1, figs. 19, 20

*Scandodus oelandicus* Müller, 1959, p. 463, pl. 12, figs. 14, 15, text-fig. 10; Nogami, 1966, p. 358, pl. 9, fig. 15.

*Muellerodus oelandica* (Müller). Bednarczyk, 1979, p. 430, pl. 2, fig. 7.

*Muellerodus oelandicus* (Müller). An *et al.*, 1983, p. 109, pl. 3, fig. 9.

**Description.**—Strongly asymmetrical, conical conodont with a proclined to reclined cusp and a long base. The cusp is small to large and rounded or subrounded in cross section. Both anterior and posterior margins are sharp to narrowly rounded. The base is wide and lunate in cross section,

resulting from broadly convex outer lateral face with one or more carinae and slightly concaved inner lateral face with or without an anterolateral prominent carina. Basal cavity is extremely large and deep, extending nearly to the tip of cusp. The widest portion of the cavity is usually located at anterior side.

**Remarks.**—Specimens herein show some variability in size, curvature and lateral carina of cusp.

**Occurrence.**—Samples 165 of the Kosangol section (Locality 3) and 197 of the Sonagijae section (Locality 6).

**Number of specimens.**—4.

***Muellerodus* sp.**  
pl. 1, fig. 18

**Description.**—Small, bilaterally symmetrical simple cone with a short cusp and a flared base. The cusp is abruptly bent toward posterior side in its mid-portion and is oval in cross section of its lower half, becoming rounded above the maximum band. The base is laterally compressed, so that its length to width at basal margin is 3/1 or so. Surface is smooth, lacking in any costae. The basal cavity is deeply excavated, extending nearly to the tip.

**Remarks.**—The specimens at hand are slightly flattened laterally and has a less prominently flared base without any lateral costae. The forms are only tentatively referred to the genus *Muellerodus* Miller.

**Occurrence.**—Samples 164 and 165 of the Kosangol section (Locality 3).

**Number of specimens.**—2.

**Genus *Nogamiconus* Miller, 1981**  
Type species.—*Proacodus*? *sinensis* Nogami,  
1966 s.f.

***Nogamiconus* sp.**  
pl. 1, fig. 29, text-fig. 1L

**Description.**—Bilaterally compressed, asymmetrical simple cone with a small cusp and a large base. The cusp is slightly recurved and is oval in cross section. Anterior face is extremely broad

and weakly convex, while the posterior is strongly concave. The left lateral margin is sharply edged while the right is narrowly rounded. Base is usually flat anteriorly and strongly flared on the right posterior, giving asymmetrical outline. Cross section near basal margin is triangular. The basal cavity is largest in the flared side.

**Remarks.**—The single specimen at hand is tentatively assigned to the genus *Nogamiconus*, but it agrees fundamentally in most characteristics with the definition of the genus (Miller, 1980).

**Occurrence.**—Sample 194 (Locality 5).

**Number of specimens.**—1.

**Genus *Proconodontus* Miller, 1966**  
Type species.—*Proconodontus muelleri* Miller,  
1969 s.f.

***Proconodontus* cf. *posterocostatus* Miller,  
1980 s.f.**  
pl. 1, fig. 3, text-fig. 1A

cf. *Proconodontus posterocostatus* Miller, 1980,  
p. 30, 31, pl. 1, figs. 4-6, text-fig. 4B.

**Remarks.**—Specimens considered here are closely related to *Proconodontus posterocostatus* Miller, but the former is usually flattened, and its anterior margin is relatively narrowly rounded. Some have a lateral costa near distal portion of cusp. These preclude positive assignment of the present specimens.

**Occurrence.**—Samples 166, 167 (Locality 3) and 196 (Locality 6).

**Number of specimens.**—13.

**Genus *Rotundoconus* An & Zhang,  
1983, emend.**

Type species.—*Acodus cambricus* Nogami,  
1967, s.f.

**Proposed emendation.**—Simple conical conodont with three-element apparatus, namely symmetrical noncarinate, asymmetrical tricarinate (laterally unicarinate) and symmetrical to asymmetrical tetracarinate (subquadrate) elements; moderate to large, erect to proclined with bulbous tip; surface granulose; cross section oval, subtriangu-

lar and quadrate; basal cavity extends to tip.

**Discussion.**—The description mentioned above restricts this genus to species possessing shallow, less abundant, more or less irregular carina (carinae). Also, bulbous tip and granulose surface are the conspicuous feature of the genus.

*Rotundoconus bulbosus* Lee, 1988 s.f.  
pl. 1, fig. 6

*Acodus cambricus* Nogami, 1967, p. 213, 214,  
pl. 1, figs. 1-4, text-figs. 1A-D.

*Hertzina ? tricarinata* Nogami, 1967, p. 214, pl.  
1, figs. 5-8, text-figs. 2A-D.

*Coelocerodontus tricarinatus* (Nogami). Druce &  
Jones, 1971, p. 63, pl. 11, figs. 1-4.

*Acodus ? cambricus* Nagami. Miller & Paden,  
1976, p. 594, pl. 1, figs. 28, 29.

*Rotundoconus bulbosus* Lee, 1988, p. 367,  
368, pl. 1, figs. 35-39; Lee, 1989a, pl. 1, figs. 1-  
3; Lee, 1989b, pl. 1, figs. 20, 25, 26; Lee, 1990,  
pl. 2, figs. 24, 25, 32.

cf. *Rotundoconus tricarinatus* (Nogami). An *et*  
*al.*, 1983, p. 136, 137, pl. 3, figs. 11-13.

**Discussion.**—Asymmetrical forms with two lateral carinae (Nogami, 1967, pl. 1, figs. 2, 5-? 7, text-figs. 2A-? C) are regarded herein as a tetracarinat variant of *Rotundoconus bulbosus* Lee. Specimens under this designation are similar to *Rotundoconus tricarinatus* (Nogami) of An & Zhang in having low carinae so that they form corrugate shape. It is uncertain, however, if *R. tricarinatus* has a bulbous tip and numerous granules (tiny nodes) on the entire surface.

Landing (1983) included carinate forms such as *Acodus cambricus* Nogami, *Hertzina ? tricarinata* Nogami as elements of *Coelocerodontus cambricus* (Nogami). However, these form species appear to be elements of *Rotundoconus bulbosus* Lee which has undulatory sides with low carinae.

**Remarks.**—Some specimens of noncarinate element are recovered in this study.

**Occurrence.**—Samples 164, 170 and 176 of the Kosangol section (Locality 3).

**Number of specimens.**—5.

## ACKNOWLEDGEMENTS

We thank Messrs. S.D. Chang of Kongkeun Middle School, Hoengseong-gun, Kangweon-do and Y.D. Kim of Chunbuk National University, Jeonju for their valuable help in field work. Support for the preparation of this material came from the Korea Science and Engineering Foundation. We are grateful to the institution.

## REFERENCES

- An, Tai-Xiang, 1982, Study on the Cambrian conodonts from north and northeast China. Sci. Rep. Inst. Geosci., Univ. Tsukuba B, 113-159.
- An, Tai-Xiang, 1987, Lower Paleozoic conodonts from southern China. Sci. Publ. Co., Beijing, 238 p. (in Chinese).
- An, Tai-Xiang and others, 1983, Conodonts from North China and adjacent regions. Sci. Publ. Co., Beijing, 233 p. (in Chinese).
- Bednarczyk, W., 1979, Upper Cambrian to Lower Ordovician conodonts of Leba Elevation, NW Poland, and their stratigraphic significance. Acta Geol. Pol., 29, 409-442.
- Clark, D.L. and Robison, R.A., 1969, Oldest conodonts in North America. Jour. Paleont., 43, 1044-1046.
- Druce, E.C. and Jones, P.J., 1971, Cambro-Ordovician conodonts from Queensland, Burke River structural belt. Auster. Bur. Miner. Res., Geol. Geophys., Bull., 110, 159 p.
- Ethington, R.L., 1959, Conodonts of the Ordovician Galena Formation. Jour. Paleont., 33, 257-294.
- Fahraeus, L.E. and Nowlan, G.S., 1978, Franconian (Late Cambrian) to Early Champlainian (Middle Ordovician) conodonts from the Cow Head Group, western Newfoundland. Jour. Paleont., 52, 444-471.
- Kobayashi, T., 1961, The Cambro-Ordovician formations and faunas of South Korea, Part 8, Paleontology 7, Cambrian faunas of the Mungyeong district and the Sambangsan Formation of the Yeongweol district. Jour. Fac. Sci., Univ. Tokyo, 13(2), 181-241.
- Kobayashi, T., 1962, The Cambro-Ordovician formations and faunas of South Korea, Part 9, Paleontology 8, The Machari fauna. Jour. Fac. Sci., Univ. Tokyo, 14(1), 152 p.
- Kobayashi, T., 1966, Stratigraphy of the Chosen Group in Korea and South Manchuria and its rela-

- tion to the Cambro-Ordovician formations of other areas, Section A, The Chosen Group of South Korea. Jour. Fac. Sci., Univ. Tokyo, Sec. 2, 16, 84 p.
- Landing, E., 1974, Early and Middle Cambrian conodonts from the Tachonic allochthon, eastern New York. Jour. Paleont., 48, 1241-1248.
- Landing, E., 1983, Highgate Gorge: Upper Cambrian and Lower Ordovician continental slope deposition and biostratigraphy, northwestern Vermont. Jour. Paleont., 57, 1149-1187.
- Lee, B.S., 1989a, Conodonts from the Hwajeol Formation (Upper Cambrian-lowest Ordovician) in northern district of Taebaeg City, Kangweon-do, Korea. Jour. Geol. Soc. Korea, 25, 322-336.
- Lee, B.S., 1989b, Upper Cambrian and lowest Ordovician conodont fauna of the Hwajeol Formation, Cheungsan area, Kangweon-do, Korea. Jour. Paleont. Soc. Korea, 5, 124-136.
- Lee, B.S., 1990, Conodont fauna of the Hwajeol Formation (Upper Cambrian-lowest Ordovician) in the Sabuk area, Kangweon-do and its implication on stratigraphy. Jour. Geol. Soc. Korea, 26, 293-303.
- Lee, B.S. and Lee, H.Y., 1988, Upper Cambrian conodonts from the Hwajeol Formation in the southern limb of the Paekunsan syncline, eastern Yeongweol and Samcheog areas, Kangweon-do, Korea. Jour. Geol. Soc. Korea, 24, 356-375.
- Lee, H.Y., 1975, Conodonts from the Upper Cambrian formations, Kangweon-do, Korea. Jour. Geol. Soc. Korea, 11, 172-185.
- Miller, J.F., 1969, Conodont fauna of the Notch Peak Limestone (Cambro-Ordovician), House Range, Utah. Jour. Paleont., 43, 413-419.
- Miller, J.F., 1980, Taxonomic revisions of some Upper Cambrian and Lower Ordovician conodonts with comments on their evolution. Paleont. Contr., Univ. Kansan 99, p. 43.
- Miller, J.F. and others, 1982, Potential Cambrian-Ordovician boundary stratotype section in the western United States, pp. 155-180. In Bassett, M. G. & Dean, W.T. (eds.), The Cambrian-Ordovician boundary; sections, fossil distributions, and correlations. Nat. Mus. Wales, Geol. Ser. 3.
- Miller, R.H. and Paden, E.A., 1976, Upper Cambrian stratigraphy and conodonts from eastern California. Jour. Paleont., 50, 590-597.
- Müller, K.J., 1959, Cambrische Conodonten. Zeit. Deut. Geol. Ges., 111, 434-485.
- Müller, K.J., 1971, Cambrian conodont fauna, pp. 5-20. In Sweet, W.C. & Bergström, S.M. (eds.), Symposium on conodont biostratigraphy. Geol. Soc. Amer. Mem. 127.
- Müller, K.J., 1973, Late Cambrian and Early Ordovician conodonts from northern Iran. Geol. Surv. Iran. Rep., 30, 70 p.
- Nogami, Y., 1966, Cambrische Conodonten von China, Teil 1. Conodonten aus den ober-Kambrischen Kushan-Schichten. Mem. Coll. Sci., Univ. Kyoto B, 32, 351-367.
- Nogami, Y., 1967, Cambrische Conodonten von China, Teil 2. Conodonten aus hoch overcambrischen Yenchow-Schichten. Mem. Coll. Sci., Univ. Kyoto B, 33, 211-219.
- Nowlan, G.S., 1985, Late Cambrian and Early Ordovician conodonts from the Franklinian miogeosyncline, Canadian Arctic Inlands. Jour. Paleont., 59, 96-122.
- Poulsen, V., 1966, Early Cambrian distacodontid conodonts from Bornholm. Biol. Medd. Dan. Vidensk. Selsk, 23(10), 10 p.
- Sweet, W.C. and Bergström, S.M., 1962, Conodonts from the Pratt Ferry Formation (Middle Ordovician) of Alabama. Jour. Paleont., 36, 1214-1252.
- Yoshimura, I., 1940, Geology of the Neitsu district, Kogendo, Tyosen. Jour. Geol. Soc. Japan, 47(558), 112-122.

---

Manuscript received February 19, 1991

### Explanation of Plate 1

Conodonts from the Machari Formation in the Yeongweol area. 1. *Cambroistodus cambricus* (Miller, 1969), lateral view, YSUG 8359 (160), x132. 2. *Proconoiontus muelleri* Miller, 1980, lateral view, YSUG 860 (161), x78. 3. *Proconodontus* cf. *posterocostatus* Miller, 1980, lateral view, YSUG 861 (166), x51. 4. *Teridontus nakamurai* (Nogami, 1967), lateral view, YSUG 867 (169), x96. 5. *Teridontus* n. sp. Lee, 1989, lateral view, YSUG 868 (169), x180. 6. *Rotundoconus bulbosus* Lee, 1988, noncarinate element, posterolateral view, YSUG 866 (170), x180. 7. *Proscandodus dissimularis* Lee, 1988, lateral view, YSUG 865 (165), x120. 8-12. *Coelocerodontus kosangolensis* n. sp., 8, 9, tricostate elements, lateral and anterior views, YSUG 836 (166) and 837 (166), x156 and x108; 10-12, tetracostate elements, lateral, lateral and posterior views, YSUG 838 (164), 839 (166) and 840 (165), x78, x78 and x96. 13-15. *Coelocerodontus palmeri* (Müller, 1959), 13, acodiform element, lateral view, YSUG 841 (165), x108; 14, 15, distacodiform elements, lateral views, YSUG 842 (166) and 843 (166), x120 and x90. 16. *Coelocerodontus* sp., lateral view, YSUG 844 (165), x90. 17. *Muellerodus cambricus* (Müller, 1959), lateral view, YSUG 854

## Conodonts from the Machari Formation

(164), x120. 18, *Muellerodus* sp., lateral view, YUSG 857 (164), x78. 19, 20, *Muellerodus oelandicus* (Müller, 1959), lateral and posterior views, YUSG 855 (165) and 856 (165), x78 and x78. 21, *Prosagittodontus eurdka*? (Müller, 1959), posterior view, YUSG 864 (157), x96. 22, *Prooneotodus gallatini* (Müller, 1959), lateral view, YUSG 862 (165), x90. 23, *Prooneotodus rotundatus* (Druce & Jones, 1971), lateral view, YUSG 863 (165), x96. 24, 25, *Furnishina furnishi* Müller, 1959, 24, symmetrical element, lateral view, YUSG 846 (198), x96; 25, asymmetrical element, posterior view, YUSG 847 (198), x66. 26, *Westergaardodina bicuspidata* Müller, 1959, posterior view, YUSG 869 (165), x78. 27, 28, *Westergaardodina matsushitai* Nagami, 1966, posterior views, YUSG 870 (188) and 871 (188), x72 and x52. 29, *Nogamiconus* sp., posterior view, YUSG 858 (194), x60. 30, *Westergaardodina moessebergensis* Müller, 1959, posterior view, YUSG 892 (188), x84. 31, *Furnishina triangulata* Xiang & Zhang, 1983, posterior view, YUSG 845 (188), x144. 32, *Hertzina elongata* Müller, 1959, lateral view, YUSG 848 (165), x90. 33, 34, *Gapparodus bisulcatus* Müller, 1959, lateral and posterolateral views, YUSG 849 (188) and 850 (188), x40 and x40. 35, *Gapparodus* cf. *bisulcatus* Müller, 1959, posterolateral view, YUSG 851 (188), x28. 36, *Gapparodus* n. sp., lateral view, YUSG 852 (188), x90. 37, *Gapparodus* sp., lateral view, YUSG 853 (188), x78. 38, *Phakelodus tenuis* (Müller, 1959), lateral view, YUSG 859 (157), x72.

Plate 1

