УДК 56.016.3 (519.5)

REVISION OF CONODONT ZONES OF THE HWAJEOL FORMATION (UPPER CAMBRIAN – LOWER ORDOVICIAN), KANGWEON-DO, SOUTH KOREA

Lee, Byung-Su

Department of Earth Science Education, Chonbuk National University, Jeonju, 561-756, Korea

Through recent intensive conodont biostratigraphic study, five conodont zones were proposed in the Hwajeol Formation (Upper Cambrian-Lower Ordovician), easten Yeongweol and Samcheog areas, Kangweon-do, Korea, namely *Proconodontus* Zone, *Eoconodontus notchpeakensis* Zone, *Cambrooistodus minutus* Zone, *Cordylodus proavus* Zone and *Fryxellodontus inornatus-Monocostodus sivierensis-Semiacontiodus lavadamensis* Zone in ascending order. The zones are redefined, and partly emended herein. The possibility of subdivision of *Proconodontus* Zone is discussed. Korean conodont zones are correlatable with those of northern China, Iran, Australia, Europe and North America, respectively. The potential Cambrian-Ordovician boundary in this area appears to be the base of *Fryxellodontus inornatus-Monocostodus sivierensis- Semiacontiodus lavadamensis* Zone which lie within the uppermost part of the formation. Six species are newly described : *Hirsutodontus hwajeolensis*, *Hirsutodontus* n. sp. A, *Hirsutodontus* n. sp. B, *Proscandodus dissimilaris* n. sp., *Rotundoconus bulbousus* and *Fryxellodontus fengshanensis.*

Key words: **stratigraphy, Cambrian, Ordovician, conodonts.**

INTRODUCTION

The Lower Paleozoic strata in eastern Yeongweol and Taebaeg areas, called the Baegusan Syncline, have been assigned to the type area of the Duwibong-type Choseon Supergroup (Fig. 1). The supergroup was divided into 10 lithostratigraphic units, namely the Jangsan Quartzite, Myobong Slate, Daegi Formation, Sesong Slate, Hwajeol Formation, Dongjeom Quartzite, Dumugol Shale, Maggol Limestone, Jigunsan Shale and the Duwibong Limestone in ascending order. Among these, the Sesong Slate and the Hwajeol Formation have been correlated with the Upper Cambrian [7, 8], so this study was concentrated on the formations.

Kobayashi [6, 7, 8] carried out the biostratigraphic studies on the supergroup and recognized 23 biostratigraphic zones in the supergroup, based primarily on megafossils, such as trilobites, cephalopods and brachiopods. However, the boundary of each zone was not distinctly specified.

H. Lee and J. Lee [18] provided a preliminary report on the Cambrian – Ordovician conodonts from the Dongjeom area but described only a few from the Cambrian. Subsequently, H. Lee [17] and the senior writer [11] described small Cambrian conodonts from the Hwajeol Formation in the southern and northern limbs of the Baegunsan Syncline, and they suggested that the formation belongs to the Upper Cambrian.

The Late Cambrian conodont zones of the Hwajeol Formation were first recognized by Lee and Lee [15], and subsequently, conodont zones for the uppermost part of the formation were modified and added by B. Lee [12, 13, 14, 15].

This study is principally intended to re-examine the conodont biostratigraphic zones of the Hwajeol Formation in the southern limb of the Baegunsan Syncline, and also to correlate the zones proposed herein with those established in other countries. In addition, the boundary between the Cambrian and Ordovician in the study area is discussed.

STRATIGRAPHY

The Cambrian – Ordovician Choseon Supergroup is well exposed in the Taebaegsan region, Kangweon-do. The Duwibong-type sequence of the supergroup which is widely distributed in the eastern part of the region is best known along the southern limb of the Baegunsan Syncline (Fig. 1), and many stratigraphical and paleontological contributions of the supergroup have been made in this area.

Kobayashi [7] originally denominated dark reddish slate and limestone beds overlying the Daegi Formation near the Dongjeom area as two separate formations, that is, the lower Sesong Slate and the upper Hwajeol Formation. The Geological Investigation Corps of the Taebaegsan Region [5] and Cheong [3], however, incorporated the Sesong Slate to the Hwajeol Formation, and the latter subdivided into four informal lithostratigraphic units in the Dongjeom area, Taebaeg City: Sesong marl, lower Hwajeol member, Hwajeol quartzite and upper Hwajeol member in ascending order.

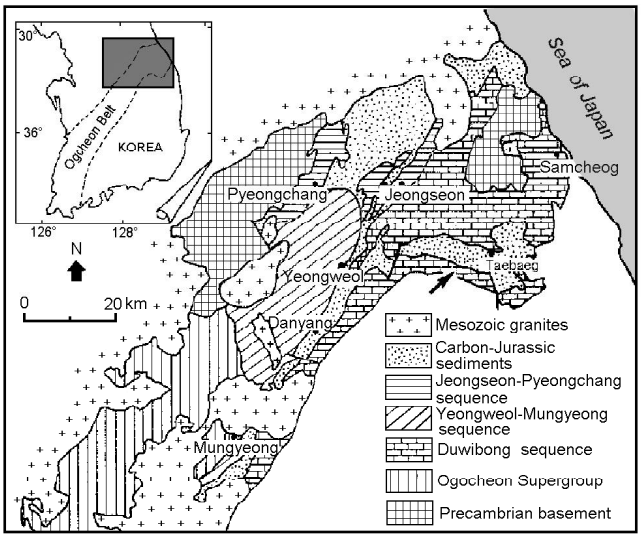


Fig. 1. Distribution of the Choseon Supergroup in the study area (arrow).

It was confirmed in this study that the Sesong Slate is not traced out through the southern limb of the Baegunsan Syncline owing to the lateral facies change; therefore, the Hwajeol Formation is divided into two informal lithostratigraphic units, the lower Hwajeol member (Kobayashi's Sesong Slate) and the upper Hwajeol member (Kobayashi's Hwajeol Formation).

The lower Hwajeol member consists mainly of dark-reddish slates or shales and dark-gray fine sandstones or quartzites with some thin intercalations of gray limestones and intraformational carbonate pebble conglomerates. The overlying upper Hwajeol member is composed predominantly of light-gray to gray vermicular limestones, shales, and pale-reddish intraformational carbonate pebble conglomerates. The sandy beds ("quartzite bed" of Cheong, [3]) are confined to the eastern part of the study area, and westernward, these beds grade laterally into limestone facies.

The top of the member is placed at a horizon where an alternation of thick-bedded shale, sandstone and carbonate pebble conglomerates is replaced by the lowest occurrence of dark-gray, thick-bedded, fine to medium quartzite.

The limestones of the formation are calcilutites including small amounts of bioclasts. The pebbles of the carbonate conglomerates interbedded in the upper part of the formation are composed mainly of calcilutite with small amounts of bioclasts, and the matrix consists mainly of sparry calcite with subangular quartz grains.

Kobayashi [8] established two biozones based largely on trilobites in the lower Hwajeol member: the lower *Stephanocare* and the upper *Drepanura* zones, and he correlated the member with the Kushanian Stage (lower Upper Cambrian) in North China. Based on macrofossils such as trilobites, brachiopods, gastropods, hyolitiids and others, he [8] established five zones in the upper Hwajeol member: *Prochuangia*, *Chuangia*, *Kaolishania*, *Dictyites* and *Eoorthis* zones in ascending order, and correlated the member with the Upper Cambrian Chaumitian Series in North China.

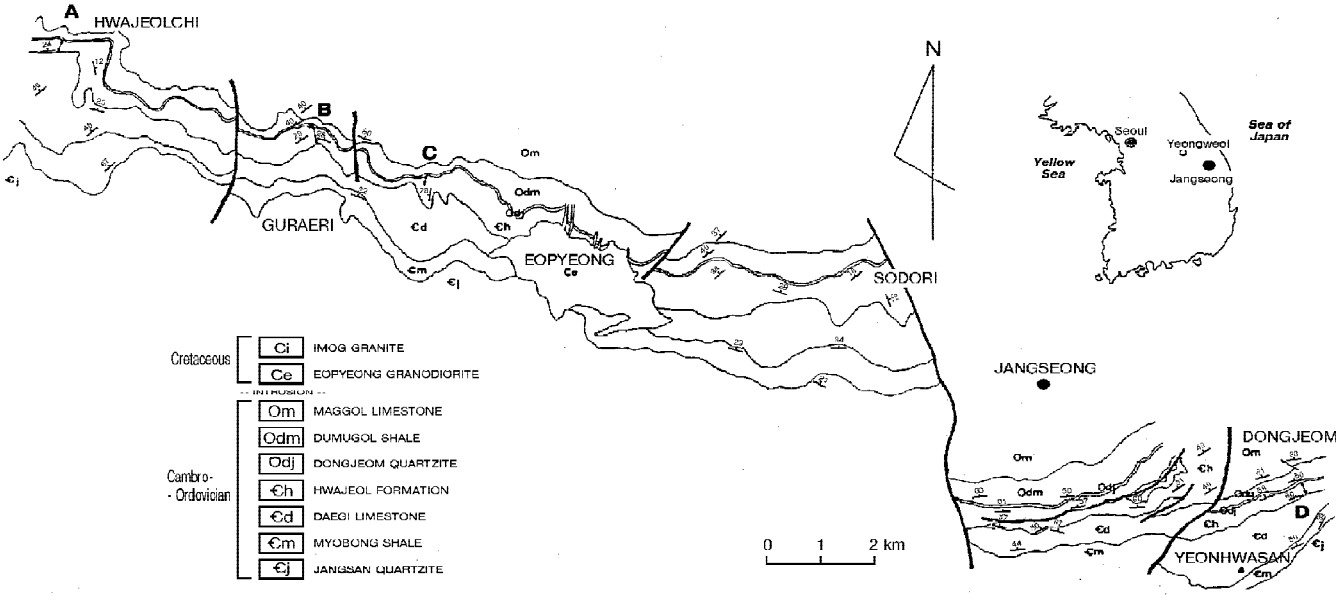


Fig. 2. Geological map of the southern limb of the Paegunsan syncline, Kangweon-do, Korea, showing localities of the measured sections(**A**-**D**) for conodont study: **A** – Hwajeolchi; **B** – Guraeri; **C** – Sesongni; **D** – Dongjeom sections.

The formation is well exposed in the study area, and its thickness varies in places from 70 to 150 meters. Vertical lithologic changes of the formation are shown in Fig. 3, and further lithologic data can be found in Lee and Lee [15].

SAMPLE LOCALITIES AND CONODONT OCCURRENCES

Samples for conodont study were collected from several fully measured sections, covering 40 km of the belt of the eastern Yeongweol and Taebaeg areas. Locations of four of them are shown in Fig. 2. The collected horizons are provided in Fig. 3. The numerical distribution of samples in each section are provided in Lee and Lee [15]. Each of samples, having the weight of 1 kg, was dissolved by acetic acid.

5,785 identifiable conodont individuals and 35 specimens of *Phosphannulus universalis* were recovered from 237 samples of the upper Hwajeol member but no conodonts were procured from the samples of the lower Hwajeol member. Specimens from the western sections are relatively well preserved as compared to those from the eastern ones of the study area. Conodonts from the Hwajeolchi Section show the best preservation among those recovered from this study.

Most of the recovered conodonts are generally well preserved, although some are corroded on the surfaces and fragmented. Both of protoconodonts and paraconodonts are dark-gray to black in color, whereas euconodonts are nearly black to translucent white ranging from 5 to 7.5 of color alteration index [4], which suggests a burial temperature of more than 300°C.

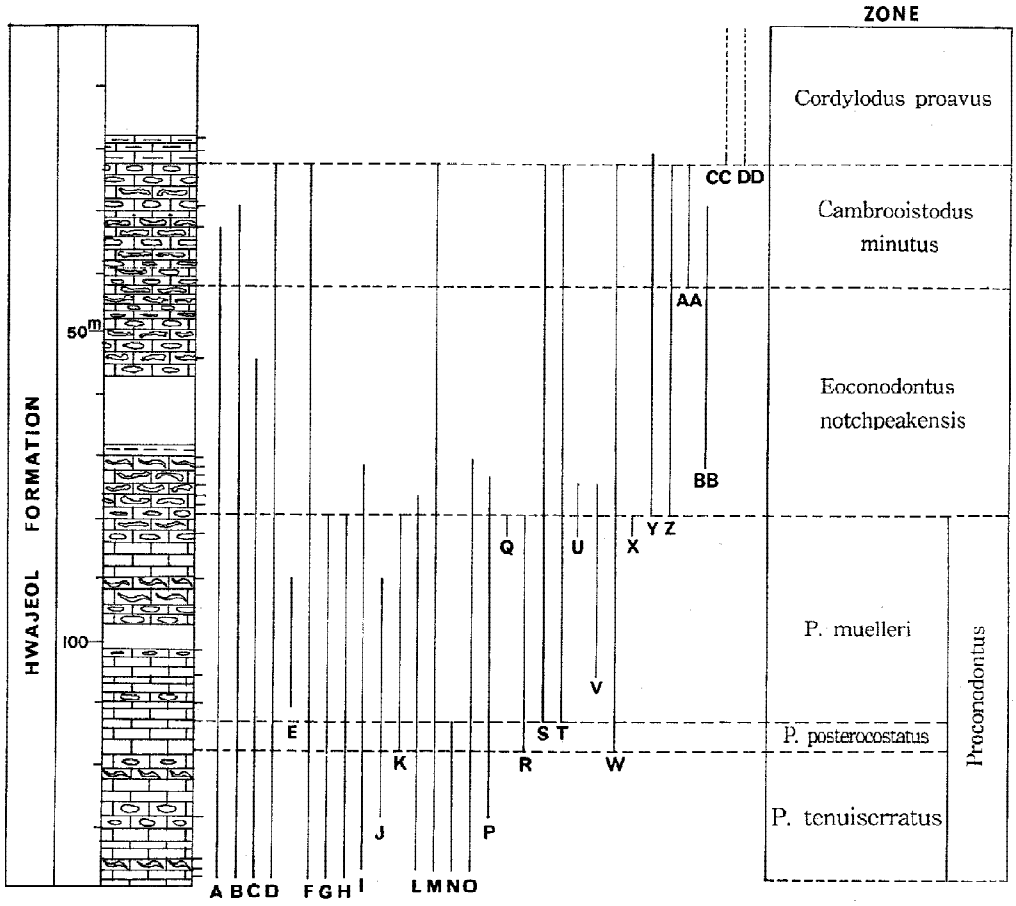


Fig. 3. Stratigraphic ranges of conodonts in the Hwajeolchi section, Yeongweol-gun, Kangweon-do, Korea.

Abbreviations: A – *Phakelodus tenuis*; B – *Prooneotodus gallatini*; C – *Prooeotodus rotundatus*; D – *Hirsutoduntus primitivus*; E – *Hirsutodontus* n. sp. A; F– *Teridontus nakamurai*; G – *Teridontus transmutatus*; H – *Proconodontus tenuiserratus*; I – *Furnishina furnishi*; J – *Furnishina longibasis*; K – *Furnishina primitiva*; L – *Westergaardodina bicuspidata*; M– *Westergaardodina ligula*; N – *Coelocerodontus cambricus*; O – *Proscandodus dissimilaris* n. sp.; P – *Hertzina*? *cornuta*; Q – *Muellerodus cambricus*; R – *Proconodontus posterocostatus*; S – *Proconodontus muelleri*; T – *Proconodontus serratus*; U – *Rotundoconus jingxiensis* n. sp.; V-X – *Rotundoconus bulbousus* n. sp., noncarinate, tricarinate, and tetracarinate elements; Y – *Eoconodontus notchpeakensis*; Z – *Cambrooistodus cambricus*; AA – *Cambrooistodus minutus*; BB – *Prosagitodontus dunderbergiae*; CC, DD – *Cordylodus proavus*, rounded and compressed elements.

Conodonts are classified into 20 multielement species referable to 11 genera and 23 form species belonging to 12 genera, of which six species are new: *Hirsutodontus hwajeolensis* n. sp., *Hirsutodontus* n. sp. A, *Hirsutodontus* n. sp. B, *Proscandodus dissimilaris* n. sp., *Rotundoconus bulbousus* n. sp. and *Fryxellodontus fengshanensis*. The most two abundant species are *Eoconodontus notchpeakensis* and *Teridontus nakamurai*, which comprise about 40 percent of the total collection.

CONODONT BIOSTRATIGRAPHY

The sequential distribution of the recovered conodonts from the upper Hwajeol member allows recognition of four local biozones: the *Proconodontus* Zone, *Eoconodontus notchpeakensis* Zone, *Cambrooistodus minutus* Zone and *Cordylodus poavus* Zone and *Fryxellodontus inornatus – Monocostodus sivierensis – Semiacontiodus lavadamensis* Zone, in ascending order. Stratigraphic ranges and biostratigraphic zonation of conodonts defined herein are shown in Fig. 3.

Zonation

***Proconodontus* Zone.** This zone represents the oldest conodont zone of the upper Hwajeol member. The base of this zone is defined by the first appearance of *P. tenuiserratus,* and the top is at the base of the overlying *Eoconodontus notchpeakensis* Zone. The zone falls within the lower 60 m of the Hwajeolchi Section, 95 m of the Guraeri Section, and about 48 m of the Dongjeomni Section, respectively. The species known from this zone are *Proconodontus tenuiserratus, P. posterocostatus, P. muelleri, P. serratrus, Clavohamulus*? *anciensis, Coelocerodontus cambricus, Fryxellodontus fengshanensis, Furnishina furnishi, F. longibasis, F. primitiva, Hertzina*? *cornuta, Hirsutodontus primitivus, H. hwajeolensis, Muellerodus pomeranensis, Phakelodus tenuis, Prooneotodus gallatini, P. rotundatus, P. terashimai, Prosagittodontus eureka, Proscandodus dissimilaris, Rotundoconus jingxiensis, R. bulbousus, Teridontus nakamurai, T. nodus, T. transmutatus, Westergaardodina bicuspidata, Westergaardodina* aff. *tricuspidata, Westergaardodina* sp. A and *Westergaardodina* sp. C.

As listed above, this zone is characterized by the abundant occurrence of paraconodonts with long stratigraphic ranges. Four species confined to this zone are *P. tenuiserratus, C.*? *anciensis, F. longibasis* and *P. terashimai*. It is remarkable that the appearance of *P. terashimai* is restricted to the lower part of the zone. *Cambrooistodus cambricus* occurs in the uppermost part of this zone and ranges into the overlying zone.

This zone in Hwajeolchi Section was partly subdivided into three parts : *Proconodontus tenuiserratus* Subzone, *P. posterocostatus* Subzone, and *P. muelleri* Subzone, in ascending order. This tripartite subdivision of the *Proconodontus* Zone is not applicable in other sections. Detailed subdivision is postponed until less ambiguous data are available from the Hwajeol Formation.

***Eoconodontus notchpeakensis* Zone**. The lower limit of this zone is marked by the first occurrence of the name-bearing species. The zone comprises the following taxons: *Teridontus, Prooneotodus, Hirsutodontus, Rotundoconus, Phakelodus tenuis, Proconodontus posterocostatus P. muelleri, P. serratus,* and others. However, some paraconodont species of such as genera *Furnishina* and *Westergaardodina* disappear near the top of the zone.

***Cambrooistodus minutus* Zone.** The base of this zone is marked by the first occurrence of *Cambrooistodus minutus,* and the top is marked by the first occurrence of *Cordylodus proavus*. The conodonts of the zone comprise *Phakelodus tenuis, Prooneotodus gallatini, P. rotundatus, Rotundoconus bulbousus, Teridontus, Hertzina*? *cornuta, Hirsutodontus primitivus, Furnishina furnishi, Proconodontus posterocostatus, P. muelleri, Eoconodontus notchpeakensis, Cambrooistodus cambricus* and *C. minutus*. This zone is characterized by the disappearance of the species listed above, except *P. tenuis, P. muelleri, E. notchpeakeinsis, T. transmutatus* and *T. nakamurai nakamurai*, which extend to the upper zone.

***Cordylodus proavus* Zone**. The base of this zone is drawn at the lowest occurrence of *Cordylodus proavus,* and the top is at the base of the first occurrence *Fryxellodontus inornatus, Monocostodus sivierensis, Semiacontiodus lavadamensis* assemblage. The striking character of this zone is that the diversity of conodont species greatly decreases, only containing the following long-ranging species, i.e. *Phakelodus tenuis, Hirsutodontus hwajeolensis, Proconodontus muelleri, Eoconodontus notchpeakensis, Teridontus nakamuri* and *T. nodus. E. alisonae* is occasionally observed within the lower part of the zone in the Guraeri Section (sample 2417).

***Fryxellodontus inornatus – Monocostodus sivierensis – Semiacontiodus lavadamensis* Zone.** The uppermost interval, 13–25 m below the top of the Hwajeol Formation, comprises *Fryxellodontus inornatus, Fryxellodontus* sp., *Monocostodus sivierensis, Semiacontiodus lavadamensis, S. nogamii, Utahconus utahensis, Utahconus* sp., *Cordylodus proavus* and *Eoconodontus notchpeakensis*. This assemblage is the uppermost conodont zone of the Hwajeol Formation and is assigned to the *F. inornatus – M. sivierensis – S. lavadamensis* Zone (see further data in [14, 15]).

Correlation

The zonation defined herein can be widely correlated with those of several continents, on which many of these taxons occur (Fig. 4).

Korea. As noted above, Lee & Lee [18] and Lee [17] described conodonts from the Upper Cambrian Hwajeol

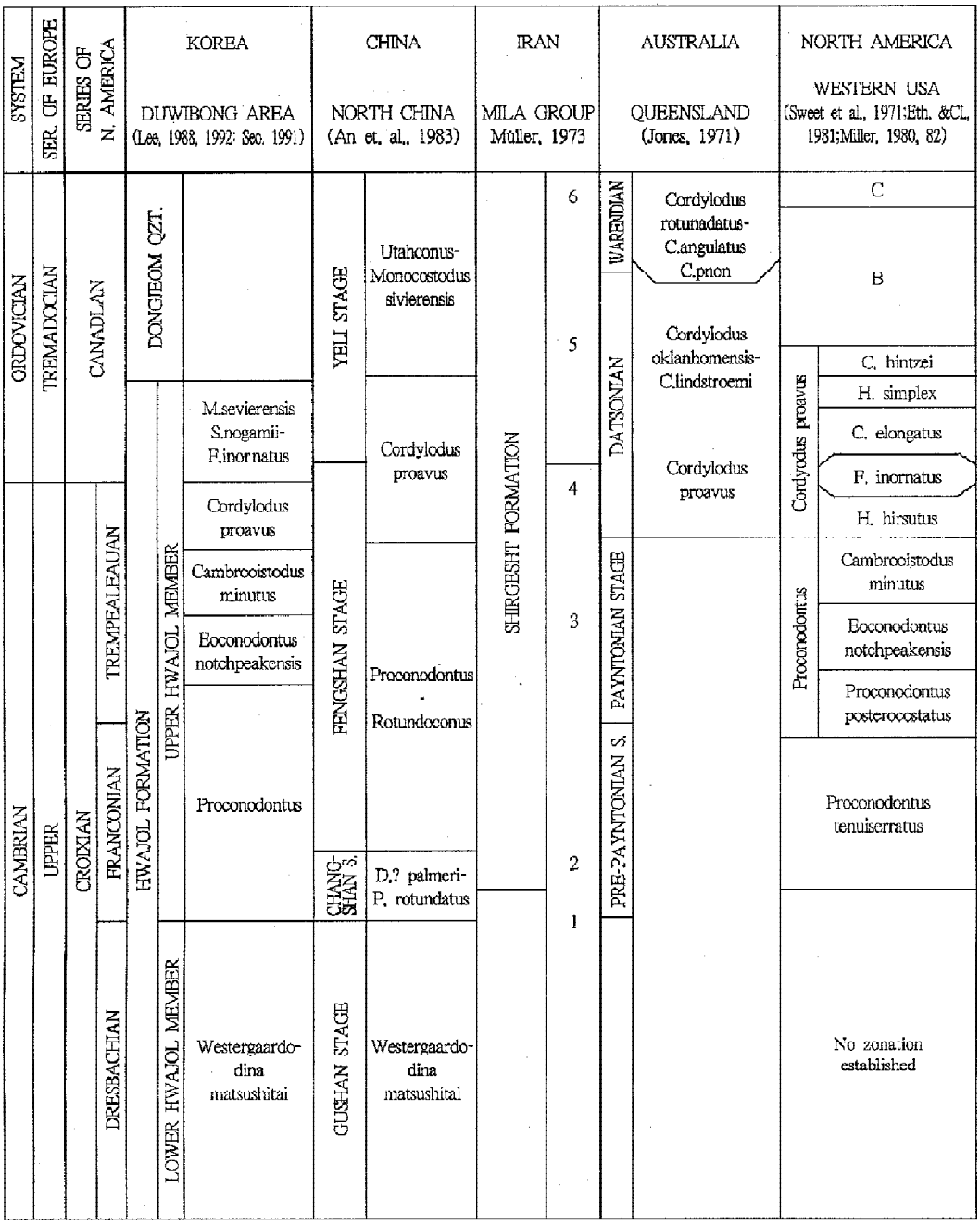


Fig. 4. Correlation of the Upper Cambrian and Lower Ordovician conodont biozones in Korea with those of China, Iran, Australia, and North America.

and Machari formations. Most of them are common in occurrence with those from the *Proconodontus* Zone.

China. Nogami [25, 26] described and illustrated the Upper Cambrian conodonts from the Kushan Formation in the Shandong and Liaoning areas and from the Yencho Formation in the Liaoning area of China, respectively. Many species from Kushan collection are also known in the Hwajeol Formation, with the exception of *Westergaardodina moessebergensis* and *W. muelleri*. Its fauna may be older than the *Proconodontus* Zone of this study, taking into consideration the more ancestral elements listed above. Nogami's collection from the Yencho Formation includes *Coelocerodontus cambricus, Muellerodus pomeranensis, Prooneotodus terashimai, Rotundoconus bulbousus, Teridontus nakamurai* and *Westergaardodina bicuspidata*. These

are common representatives approximately of the *Proconodontus* Zone, although no zone fossils are recovered.

An [1] and An *et al.* [2] established the conodont zonal schemes of the late Middle Cambrian to the Ordovician in China by their recent studies. Korean elements are very similar to those of China, especially in the co-occurrence of *Prooneotodus terashimai, Teridontus, Hirsutodontus. Fryxellodontus fengshanenis, Hertzina*? *cornuta* and *Rotundoconus*. Of these, *T. nodus, H. primitivus, F. fengshanensis, H*.? *cornuta* and *Rotundoconus* are, hitherto, confined only to Korea and China. The *Distacodus*? *palmeri – Prooneotodus rotundatus* Zone of China contains *Prosagittodontus eureka, Muellerodus pomeranensis* and several stratigraphically long-ranging forms. These representatives of the zone are recovered mainly from the *Proconodontus* Zone of the present study. Therefore, this zone in China may be equivalent to the lower portion of the *Proconodontus* Zone, although the key species of the zone has not been recovered. The *Proconodontus – Rotundoconus* Zone in China is characterized by the presence of the representatives of *Proconodontus, Eoconodontus* and *Cambrooistodus*, and this zone is well correlated with the *Proconodontus, E. notchpeakensis* and *C. minutus* zones in Korea. The *C. proavus* Zone is also characterized by an occurrence of the key taxon. This is also equivalent to the *C. proavus* Zone in Korea.

Iran. Müller [24] described many genera and species from the strata ranging from the Upper Cambrian to the lowest Ordovician in northern lran, and established seven local conodont biozones. His Assemblage Zone 1 consists of *Furnishina furnishi* and *Westergaardodina moessebergensis*. The former is inadequate for biostratigraphic zonation due to the long stratigraphic range, and the latter has been not recovered from this study. Consequently, Zone 1 is difficult to correlate with a zone proposed herein, it is suggested, however, that the zone may be older than the *Proconodontus* Zone of the present report in terms of elements included in Assemblage Zone 2. Some representatives of Assemblage Zone 2 such as *Furnishina asymmetrica, Phakelodus tenuis* and *Westergaardodina bicuspidata* also occurred in the Hwajeol Formation in Korea. Assemblage Zone 3 in lran contains *Proconodontus muelleri* and *Eoconodontus notchpeakensis* without the genera *Cambrooistodus* and *Cordylodus*. In view of the relative stratigraphic ranges of these conodonts, Zone 2 is probably equivalent to the lower part of the *Proconodontus* Zone or somewhat older, and Zone 3 may be correlative with the upper part of the Proconodontus Zone to the *Cambrooistodus minutus* Zone in Korea, respectively. The fauna of Assemblage Zone 4 is very similar to the *Cordylodus proavus* Zone of this study in possessing of *C. proavus* but the association of *Prosagittodontus eureka* and *Westergaardodina amplicava* is quite different from that of Korea.

Western Unites States. Miller [19, 21, 22, 23] carried out systematic study on conodonts spanning the Cambrian – Ordovician boundary in the western United States and proposed a zonation consisting of three biozones. His zonation has been applied widely in North America [9, 10, 27]. The faunal association of the zones proposed herein is generally similar to Miller's scheme.

The four key species of Miller's *Proconodontus* Zone, namely *P. tenuiserratus, P. posterocostatus, Eoconodontus notchpeakensis* and *Cambrooistodus minutus* were also recovered from the Hwajeol Formation. *P. tenuisarratus* Zone and *P. posterocostatus* Subzone of the USA are discriminable in Korea (Fig. 3). Also, the upper part of the *P. tenuiserratus* Zone can be roughly subdivided into *P. posterocostatus* Subzone and *P. muelleri* Subzone. The detailed subdivision is, however, postponed until laterally traceable data are available from the formation.

The key taxa of the subzones in his *Cordylodus proavus* Zone are not fully found in Korea, except *Fryxellodontus inornatus*.

Cambrian – Ordovician boundary

The worldwide definition of the Cambrian-Ordovician boundary is still under debate. In North America the base of the Ordovician has been placed at the base of the trilobite *Missisquoia* Zone. Miller [20, 21, 23] has proposed a conodont zonation for this interval in the south-western United States. The base of Miller's *Cordylodus proavus* Zone corresponds to the base of the trilobite *Corbinia apopsis* Subzone, the uppermost subzone of the *Saukia* Zone of the uppermost Trempealeauan, and the base of his *Fryxellodontus inornatus* Subzone of the *C. proavus* Zone is eqivalents to the base of the *Missisquoia typicalis* Subzone, which is the upper subzone of the *Missisquoia* Zone.

The presence of a barren interval and the poor recovery of conodonts from the boundary horizons between the Cambrian and Ordovician do not allow precise definition of the boundary in the area. As noted above, *Cordylodus proavus* appears with rare species of the subzones of Miller's *C. proavus* Zone in Korea. It is notable, however, that *Fryxellodontus inornatus, Monocostodus sivierensis, Semiacontiodus lavadamensis* and *S. nogamii* are recovered from the uppermost 13–25 m interval of the Hwajeol Formation. In North America, this assemblage occurs from the *Fryxellodontus inornatus* Subzone to *Hirsutodontus simplex* Subzone of the *C. proavus* Zone. Accordingly, the *F. inornatus – M. sivierensis – S. lavadamensis* Zone of Korea can roughly be correlated to the lowest Ordovician in age.

SYSTEMATIC PALEONTOLOGY

Conodonts and some problematic forms which have been previously well described by many authors are not discussed herein further and the following taxa are reassigned without any description.

Coelocerodontus cambricus (Nogami) is newly treated as a multielement apparatus consisting of laterally-asymmetrical unicostate (*Acodus cambricus* Nogami) and laterally-symmetrical bicostate (*Distacodus palmeri* Müller) elements.

Proconodontus transmutatus Xu and Xiang is transformed into a species of the genus *Teridontus* Miller, because it has no *Proconodontus* affinity (*sensu* Miller [21]).

Two subspecies of *Teridontus nakamurai nakamurai* (Nogami) and *T. nakamurai nodus* Zhang et Xiang are retreated as separate species *T. nakamurai* (Nogami) and *T. nodus* Zhang et Xiang.

Also, *Eoconodontus* (*E.*) *notchpeakensis* (Miller) and *Eoconodontus* (*E.*) *alisonae* (Landing) are retreated herein as *E. notchpeakensis* Miller and *E. alisonae* Landing.

All type and figured specimens are deposited at the Department of Earth System, Yonsei University, Seoul, Korea.

Genus Fryxellodontus Miller, 1969

Type species – *Fryxellodontus inornatus* Miller, 1969

Fryxellodontus fengshanensis n. sp.

Pl. 2, figs. 22, 23

Fryxellodontus n. sp. A [1] p. 131, pl. 10, fig. 13.

Derivation of name. After the name of the formation, from which the conodont was first recovered.

Holotype. Pl. 2, fig. 13, YSUG 00685.

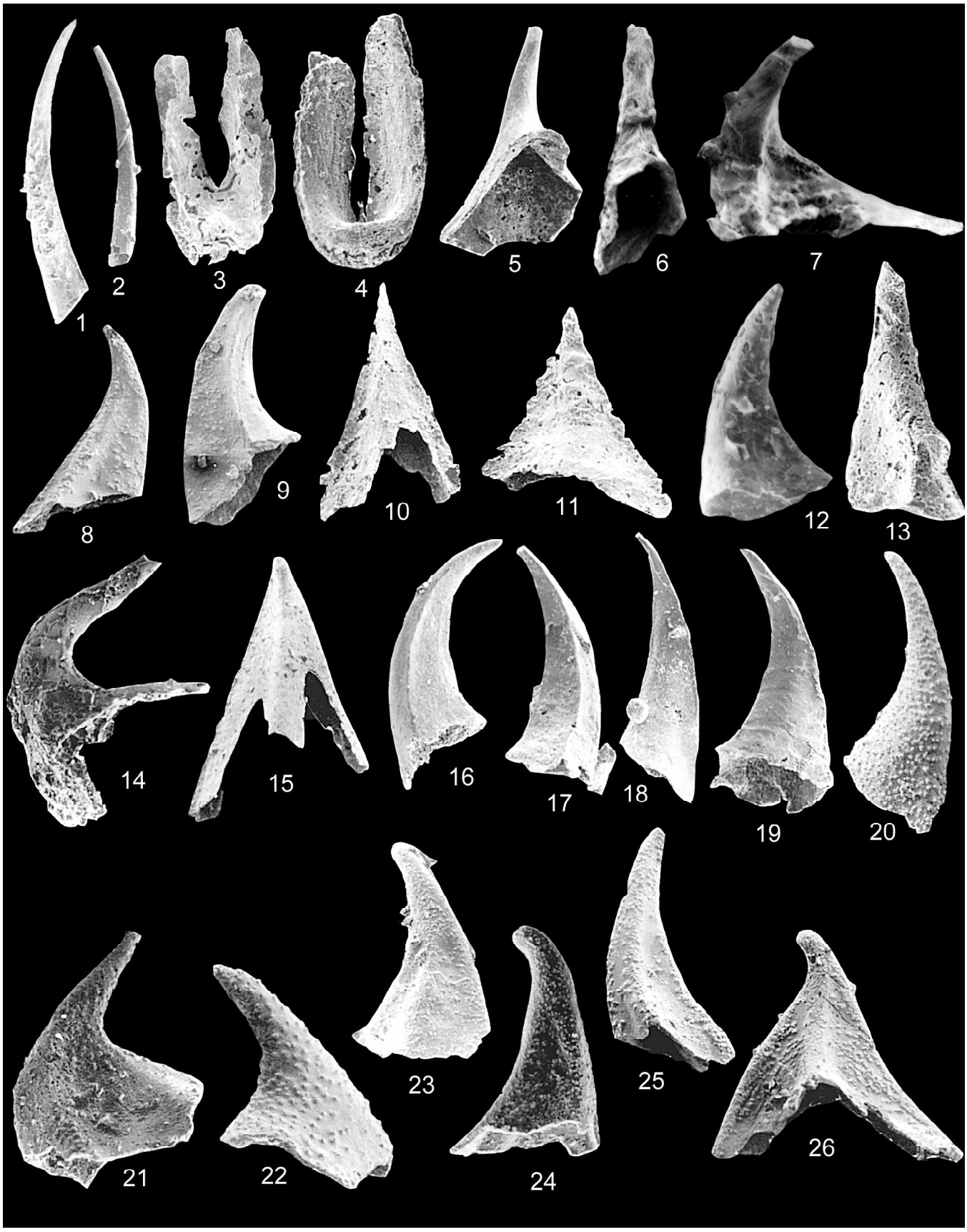
Diagnosis. Simple coniform conodont with a small cusp that bears two anterolateral and one pesterior edges.

Description. The unit is moderate to large simple coniform conodont with two anterolateral and one posterior edges, which are sharp or narrowly rounded. The short cusp is strongly recurved and tapers upwards rapidly. Some specimens are somewhat twisted and/or bent over to one side. The anterior face is nearly flat or slightly concave and both lateral facies are moderately concave. The posterior edge is straight or gently convexo-concave in lateral view. The basal margin is subtriangular in cross section. The wall covering basal cone is thin and partly exfoliated near the basal margin. The basal cavity is wide but shallow.

Plate 1

1. *Phakelodus elongatus* Müller. Lateral view of ovate hypotype, YSUG 00631(2396), ×78.
2. *Phakelodus tenuis* Müller. Lateral view of rounded hypotype, YSUG 06633(2605), ×100.
3. *Westergaardodina matsushitai* Müller. Upper views of hypotype, YSUG 00634(2365), ×120.
4. *Westergaardodina ligula* Müller. Upper view of hypotype, YSUG 00635(2487), ×110.
5. *Furnishina furnishi* Müller. Posterior view of asymmetrical element, YSUG 00648(2520), x160.
6. *Furnishina quadrata* Müller. Posterior view of hypotype, YSUG 00649(2487), ×160.
7. *Furnishina longibasis* Bednarczyk. Lateral view of hypotype, YSUG 00650(2520), ×220.
8. *Hertzina americana* Müller. Posterior view of hypotype, YSUG 00658(2575), ×130.
9. *Hertzina*? *cornuta* Xiang. Lateral view of hypotype. YSUG 00659(2362), ×160.
10. *Prosagittodontus eureka* Müller. Posterior view of hypotype, YSUG 00652(2458), x160.
11. *Prosagittodontus dunderbergiae* (Müller). Posterior view of hypotype, YSUG 00651(2457), ×240.
12. *Furnishina primitiva* Müller. Lateral view of hypotype, YSUG 00645(2523),×220.
13. *Furnishina tortilis* Müller. Posterior view of hypotype, YSUG 00644(2560), ×120. 14. *Muellerodus pomeranensis* (Szaniawski). Lateral views of hypotype. YSUG 00683(2586), ×360.
15. *Prosagittodontus dahlmani* (Müller). Posterior view of hypotype, YSUG 00653(2611), ×120.
16,17. *Coelocerodontus cambricus* (Nogami). Lateral views of hypotype. 16, acodiform element of YSUG 00656(2356), ×160; 17, distacodiform element of YSUG 00655(2262), ×130.
18,19. *Proscanododus dissimilaris* n. sp. Posterolateral views of holotype and paratype, respectively, of YSUG 00689(2370), Jш150 and YSUG 00690(2485), ×130.
20,23,24. *Rotundoconus bulbousus* n. sp. 36, lateral view of noncarinate holotype, YSUG 00667(2369), ×110; lateral view of tricarinate holotype of YSUG 00665(2358), x160; 24, tetracarinate holotype of YSUG 00669(2560), ×130.
21. *Hirsutodontus* n. sp. A. Lateral view of holotype, YSUG 00675(2236), ×220.
22. *Hirsutodontus* n. sp. B. Lateral view of holotype, YSUG 00676(2277), ×220.
25,26. *Rotundoconus jingxiensis* An et Zhang. Hypotypes. 25, lateral view of tricarinate element, YSUG 00662(2395), ×130; 26, posterior view of tricarinate element, YSUG 00661(2487), ×86.

Plate 1



Remarks. This uncommon species was first recovered from the *Mictosaukia-Calivella* Zone (trilobite) of the Upper Cambrian Fengshan Formation of China [1]. The Korean specimens at hand are well in agreement with this single specimen.

Occurrence. *Proconodontus* Zone.

Material studied. 5 specimens.

Genus Hirsutodontus Miller, 1969

Type species – *Hirsutodontus hirsutus* Miller, 1969

This genus differs from *Rotundoconus* newly defined herein in having the larger spines (or nodes) and the absence of a bulbous tip with a granulose surface.

Hirsutodontus hwajeolenis n. sp.

Pl. 2, fig. 1

Derivation of name. After the name of the formation, from which the conodont was firstly recovered.

Holotype. Pl. 2, fig. 1, YSUG 00673

Diagnosis. A simple hollow cone with numerous spines or nodes on its surface. The anterior face is nearly flat to slightly convex, whereas the posterior face is carinated, showing a triangular cross section.

Description. A symmetrical to asymmetrical simple cone with a deep basal cavity. The cusp is triangular in cross section, and its surface is nodular or spiny. The anterior face is flat to slightly convex, and the lateral sides are slightly compressed, making a weak depression between the bluntly rounded anterolateral and posterior carinae.

The base is large, and the wall is thin. The basal cavity extends to near tip of unit.

Remarks. This species is easily distinguishable from other species of the genus through a triangular (acontiodiform) cross section.

Occurrence. *Proconodontus* Zone to *Cambrooistodus minutus* Zone.

Material studied. 51 specimens.

Hirsutodontus n. sp. *A*

Pl. 1, fig. 21

Holotype. Pl. 1, fig. 21, YSUG 00675

Diagnosis. A simple hollow cone bearing numerous spines or nodes on its surface with four edges.

Description. The unit is small, with a slightly proclined symmetrical cone with a deep basal cavity. The cusp is bilaterally compressed and rapidly expanded posteriorly. The cone is anteroposteriorly sharply edged and also costated anterolaterally near its lower margin. The surface is granulose. The distal part is rounded in cross section. The base is wide, and its cavity reaches to the near tip of the unit.

Remarks. This newly proposed species is easily distinguishable from the other species of the genus in the four-sided cross sectional feature. The single represented

---

Plate 2

Fig. 1. *Hirsutodontus hwajeolensis* n. sp. Posterior view of holotype of YSUG 00673(2576), ×100.

2.3. *Teridontus transmutatus* (Xu et Xing). Hypotypes. 2, postero-lateral view, YSUG 00715(2361), ×150; 3, lateral view of YSUG 00714(2361), ×200.

4. *Semiacontiodus nogamii* Miller. Posterolateral view of hypotype, YSUG 00741(2420), ×100.

5,6. *Cordylodus proavus* (Müller). Lateral views of hypotype. 5, rounded element of YSUG 00734(2283), ×130; 6, compressed element of YSUG 00740(2361), ×150.

7. *Prooneotodus gallatini* (Müller). Lateral view of YSUG 00677(2357), ×90

8. *Prooneotodus rotundatus* (Druce et Jones). Lateral view of hypotype. YSUG 00680(2357), ×75.

9. *Hirsutodontus primitivus* An. Lateral view of YSUG 00672(2376), ×160.

10,11. *Proconodontus tenuiserratus* Miller. Lateral views of hypotype. 10, YSUG 00691(2357), ×130; 11, YSUG 00692(2550), ×150.

12. *Proconodontus posterocostatus* Miller. Lateral view of YSUG 00694(2365), ×100.

13. *Cambrooistodus minutus* (Miller). Lateral view of YSUG 00731(2260), ×180.

14. *Proconodontus serratus* Miller. Lateral view of YSUG 00702(2370), ×120.

15. *Proconodontus muelleri* Miller. Lateral view of YSUG 00701(2261), x ×86.

16. *Prooneotodus terashimai* (Nogami). Lateral view of YSUG 00681(2355), x ×260.

17,19. *Eoconodontus notchpeakensis* (Miller). Hypotypes. 17, lateral view of symmetrical drepanodiform element of YSUG 00712(2263); 19, lateral view of compressed scandodiform element YSUG 00710(2285), ×220.

20. *Teridontus nodus* Zhang et Xiang. Lateral view of hypotype. YSUG 00723(2275), ×180.

21. *Teridontus nakamurai* (Nogami). Lateral view of short-based form, YSUG 00719(2573), ×180(fig. 7).

22,23. *Fryxellodontus fengshanensis* n. sp. Hypotypes. 22, top view of YSUG 00686(2342), x ×200; 23, lateral view of YSUG 00685(2456), ×180.

Plate 2

specimen was recovered from sample 2236 in Hwawonri area, Yeongweol-gun, Kangweon-do.

Occurrence. *Proconodontus* Zone.

Material studied. One specimen.

Hirsutodontus n. sp. *B*

Pl. 1, fig. 22

Holotype. Pl. 1, fig. 22, YSUG 00676.

Diagnosis. A simple hollow cone with numerous spines on its surface. The cusp is short, and the base is greatly expanded posteriorly. The unit is rounded in cross section.

Description. The unit is a simple hollow cone with a greatly expanded base. The cusp is short, and its surface is covered with numerous tiny spines. The unit is rounded in cross section. The basal margin is flared. The basal cavity is large and extends to the near tip of the cusp.

Remarks. The difference with other species of the genus is in a rounded cross section as in *Prooneotodus gallatini* (Müller).

Occurrence. *Eoconodontus notchpeakensis* Zone.

Material studied. One specimen.

Genus Proscandodus Müller and Nogami, 1971

Type species – *Scandodus tortilis* Müller, 1959

Proscandodus dissimilaris n. sp.

Pl. 1, fig. 18,19

Derivation of name. From dissimilar lateral faces.

Holotype. Pl. 1, fig. 18, YSUG 00689.

Diagnosis. A simple coniform scandodid with a twisted cusp and a deep basal cavity.

Description. Simple coniform paraconodont(?), which is asymmetrical due to the lateral twisting of the cusp relative to the base. Both the anterior and the posterior margins are keeled. One lateral face is well rounded but the other is flattened or is slightly concave forming a lunate cross section, which is the most characteristic feature of the species. In some specimens, the lower portion is patterned by a series of growth lines, which are subparallel to the basal margin. The basal cavity is large, extending to the tip of the cusp.

Remarks. The morphological characteristics are entirely consistent with the genus *Proscandodus* Müller et Nogami. But this specimen differs from its known congeners such as *Scandodus* sp. indet. Nogami and *P. obliquus* An, which were described from the Liaoning [25] and Shandong areas, China [1] through the characteristic lunate cross section.

Occurrence. *Proconodontus* Zone to *Eoconodontus notchpeakensis* Zone.

Material studied. 23 specimens.

Genus Rotundoconus An et Zhang, 1983

Type species – *Acodus cambricus* Nogami, 1967

The genus *Rotundoconus* An et Zhang proposed herein differs from *Acodus cambricus* Nogami, *Hertzina*? *tricarinata* Nogami and *Coelocerodontus cambricus* (Nogami) in gross morphology, distal portion of the cone and the surface sculpture.

Rotundoconus bulbousus n. sp.

Pl. 1, figs. 20,23,24

Rotundoconus tricarinatus (Nogami); [2], p. 136, 137, pl. 3, figs. 11-13.

Derivation of name. From the Latin bulbus (=bulb), referring to the tip of the cusp.

Holotype. Noncarinate rounded element, pl. 1, fig. 20, YSUG 00667; tricarinate element, pl. 1 fig. 23, YSUG 00665; tetracarinate element, pl. 1 fig. 24, YSUG 00668.

Diagnosis. A simple coniform conodont consisting of noncarinate rounded, tricarinate and tetracarinate elements with corrugated lateral faces and bulbous tip.

Description. This multielement species consists of noncarinate-rounded, tricarinate and tetracarinate elements with corrugated lateral faces and the bulbous tip.

Noncarinate element: a slender, proclined, symmetrical simple cone with a granulose surface. The bulbous tip of the cone is narrowly rounded. The anterior and posterior keels are absent. The cone expands loosely in a basal direction. The unit is usually oval to rounded in cross section. The basal cavity extends to the tip of the element. The elements lack white matter.

Tricarinate element: a moderate to large, asymmetrical simple cone with three carinae. The location of the lateral carina varies from centrally to antero- and posterolaterally. Both the right and left forms are usually recognized. In some specimens, discrimination of the lateral carina is difficult due to their weak undulation. The surfaces are entirely granulose. The base is relatively large, and its cavity is extremely deep extending through the whole length of element.

Tetracarinate element: a bilaterally symmetrical to asymmetrical simple cone with a corrugated surface. Both the anterior and posterior margins bear two narrowly rounded carinae. Some specimens may carry a lateral carina, so that they are strongly asymmetrical. Granulose ornamentation covers the entire surface of cone irregularly. The tip of the cone is bulbous and narrowly rounded. The base is moderate to wide and tapers gently to the tip of cone. The basal cavity is large and deep extending nearly to tip of cone. Elements are usually light gray in color.

Remarks. *Rotundoconus bulbousus* apparatus consists of laterally noncarinate-rounded, the asymmetrical tricarinate (tricarinata element of *R. tricarinatus* An et Zhang, = [2], pl. 3, figs. 11, 12, and the asymmetrical to symmetrical tetracarinate (tetracarinata element of *R. tricarinatus* An et Zhang, = [2], pl. 3. fig. 13. *Coelocerodontus cambricus* (Nogami) may be a more distinctly costated element of this multielement apparatus. The differences between them are discussed under the genus.

Occurrence. *Proconodontus* Zone to *Cambro-oistodus minutus* Zone.

Material studied. 53 noncarinate-rounded, 62 tricarinate, and 25 tricarinate elements.

REFERENCES

1. An Tai-xiang. Recent progress in Cambrian and Ordovician conodont biostratigraphy of China // Geological Society of America. 1981. Special Paper 187. P. 209–225.
2. An Tai-xiang, Zhang F., Xiang W. and et al. The conodonts of North China and the adjacent regions: (Beijing: Science Publishing Company, 1983) (in Chinese).
3. Cheong C. H. Stratigraphy and paleontology of the Samcheog Coalfield, Gangweondo, Korea(l) // Jour. Geol. Soc. Korea. 1969. 5. P. 13–56.
4. Epstein A. G., Epstei J. B., Harris L. D. Conodont color alteration – an index to organic metamorphism. U.S. Geological Survey Professional Paper. 1977. 995. 27 p.
5. Geological Investigation Corps of Taebaegsan Region. Geological map of Taebaegsan region. Geological Society of Korea. 1962.
6. Kobayashi T. The Cambrian and Ordovician faunas of South Chosen and the bearing of the Tsinling-Keijo Line on Ordovician paleogeography // Proceedings of the Imperial Academy of Japan. 1930. 6. 423–426.
7. Kobayashi T. Journal of the Faculty of Science (Imperial University of Tokyo. Sec. 1935. 2(4).
8. Kobayashi T. The Cambrian and Ordovician faunas of South Chosen, Paleontology pt. 3, Cambrian faunas of South Chosen with special study on the Cambrian trilobite genera and families // Journal of the Faculty of Science, Imperial University of Tokyo. 1935. sec. 2(4), 344 p.
9. Landing E. Highgate Gorge: Upper Cambrian and Lower Ordovician continental slope deposition and biostratography, northwestern Vermont // Journal of Paleontology. 1983. 57. P. 1149–1187.
10. Landing E., Ludvigsen R., Von Bitter P. H. Upper cambrian to Lower Ordovician conodont biostratigraphy and biofacies, Rabbitkettle Formation, district of Mackenzie. Royal Ontario Museum, Life Sciences Contributions. 1980. 126. 42 p.
11. Lee B. S. Stratigraphy and micropaleontolgy of the Hwajeol and the Dumugol formations in Mureungri area, Jeongseongun, Kangweondo: Unpublished M. S. Thesis. Seoul: Yonsei University, 1983. 65 p. (in Korean).
12. Lee B. S. Conodonts from the Hwajeol Formation (Upper Cambrian-lowest Ordovician) in northern district of Taebaeg City, Kangweon-do, Korea // Journal of the Geological Society of Korea. 1989. 25. P. 322–336.
13. Lee B. S. Conodont fauna of the Hwajeol Formation (Upper Cambrian-lowest Ordovician) in the Sabuk area, Kangweon-do and its implication on stratigraphy // Journal of the Geological Society of Korea. 1990. 26(3). P. 293–303.
14. Lee B. S. Additional conodonts from the Cambrian-Ordovician boundary beds in the Baegunsan syncline // Journal of the Geological Society of Korea. 1992. 28(6). P. 590–603.
15. Lee B. S., Lee H. Upper Cambrian conodonts from the Hwajeol Formation in the southern limb of the Baegunsan syncline, eastern Yeongweol and Samcheog areas, Kangweon-do, Korea // Journal of the Geological Society of Korea. 1988. 24(4). P. 195–208.
16. Lee B. S., Lee J. D. Reassement of conodont biostratigraphic study on the Cambrian-Ordovician boundary // Paleontological Society of Korea. 1993. 9(2). P. 155–165 (in Korean).
17. Lee H. Y. Conodonts from the Upper Cambrian formations, Kangweon-do, South Korea. Yonsei nonchong, Yonsei // University Graduate School Bulletin. 1975 12. P. 97–110.
18. Lee H. Y., Lee, J. D. Conodont fauna from the Great Limestone Series in Dongjeom district, Samcheog-gun, Gangweon-do and its stratigraphical significance // Journal of the Geological Society of Korea. 1971. 7. P. 89–101 (in Korean).
19. Miller J. F. Conodont fauna of the Notch Peak Limestone (Cambro – Ordovician), House Range, Utah // Journal of Paleontology. 1969. 43. P. 413–439.
20. Miller J. F. Upper Cambrian and lowest Ordovician conodont faunas of the House Range, Utah // J. F. Miller(ed.), Upper Cambrian to middle Ordovician conodont faunas of western Utah. Southwest Missouri State University Geoscience Series. 1978. 5. P. 1–33.
21. Miller J. F. Taxonomic revisions of some Upper Cambrian and Lower Ordovician conodonts with comments on their evolution. University of Kansas Paleontological Contributions. 1980. Paper 99. 43 p.
22. Miller J. F., Taylor M. E., Stitt J. H., and et al. Potential Cambrian-Ordovician boundary stratotype section in the western United States // M. G. Bassett and W. T. Dean(eds.), The Cambrian-Ordovician Boundary: Sections, Fossil Distributions, and Correlations. National Museum of Wales, Geological Series. 1982. N 3. Cardiff. P. 155–180.
23. Miller J. F. Conodonts as biostratigraphic tools for redefinition and correlation of the Cambrian-Ordovician boundary // Geological Magazine. 1988. 125. P. 349–462.
24. Mьller K. J. Late Cambrian and Early Ordovician conodonts from northern Iran // Geological Survey of Iran Report. 1973. 30. 70 p.
25. Nogami Y. Kambrische Conodonten von China, Teil 1, Conodonten aus den oberkambrischen Kushan-Schichten // Memoirs of the College of Science, University of Kyoto. 1966. Series B. 32. P. 351–367.
26. Nogami Y. Kambrische Conodonten von China, Teil 2, Conodonten aus den hoch oberkambrischen Yen cho-

schichten // Memoirs of the College of Science, University of Kyoto. 1967. Series B. 33. P. 211–219.

27. Nowlan G. S. Late Cambrian and Early Orovician conodonts from the Franklinian Miogeosyncline, Canadian Arctic Islands // Journal of Paleontology. 1985. 59. P. 96–122.

Поступила в редакцию 12 сентября 2000 г. *Рекомендована к печати Л.И. Попеко*

Беон-Су Ли

Пересмотр конодонтовых зон в формации Хваджеол (верхний кембрий - нижний ордовик), провинция Кангвендо, Южная Корея

В формации Хваджеол было предложено пять конодонтовых зон (верхний кембрий – нижний ордовик). Эти зоны находятся в районе восточного Енгволя и Самчонге (провинция Кангвендо) и называются (в порядке омоложения): *Proconodontus*, *Eoconodontus notchpeakensis*, *Cambrooistodus minutus*, *Cordylodus proavus* и *Fryxellodontus inornatus – Monocostodus sivierensis - Semiacontiodus lavadamensis*. Их характеристики заново определены и частично изменены. Рассматривается возможность подразделения зоны *Proconodontus*. Корейские конодонтовые зоны, вероятно, коррелируют с такими же зонами в северном Китае, Иране, Австралии, Европе и Северной Америке. Потенциальная кембрий – ордовикская граница в этой области, является, по-видимому, основанием зоны *Fryxellodontus inornatus - Monocostodus sivierensis - Semiacontiodus lavadamensis*, которая залегает в пределах верхней части формации Хваджеол. Описано шесть новых видов: *Hirsutodontus hwajeolensis*, *Hirsutodontus* n. sp., *Hirsutodontus* n. sp. B, *Proscandodus dissimilaris* n. sp., *Rotundoconus bulbousus* и *Fryxellodontus fengshanensis*.