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CONODONT BISTRATIGRAPHY OF THE MUNGOG FORMATION (LOWER ORDOVICIAN), YEONGWEOL, KOREA

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Three sections (Golmacha, Seonghwangchon, and Mohari sections) of the Mungog Formation, Yeongweol, are examined for conodont biostratigraphy. Assemblage Zone 1 (=*Semiacontiodus nogamii – Cordylodus lindstroem – Utahconus beimadaoensis* Zone), Assemblage Zone 2 (=*Rossodus manitouensis – Chosonodina herfurthi* Zone), Assemblage Zone *3 (=Scolopodus quadraplicatus–Paroistodus proteus – Drepanoistodus forceps* Zone), and Assemblage Zone 4 (=*Paracordylodus gracilis* Zone are tentatively established within the formation. The preliminary data on correlation of these zones are briefly summarized. The Cambrian – Ordovician boundary in the Yeongweol area is probably present within beds immediately below Assemblage Zone 1, near the base of the Mungog Formation.

Key words: **biostratigraphy, Mungog Formation, Lower Ordovician, conodont, Korea.**

INTRODUCTION

The Mungog Formation, composed mainly of diverse lithotypes of limestone, calcareous or non-calcareous shale and dolostone, was first established by Yosimura [42], as one of five stratigraphic subdivisions of the Yeongweol-type Choseon Supergroup. Also, Yosimura [42] reported some macroinvertebrate fossils from the formation, including brachiopode and trilobite, which were later systematically described and illustrated by Kobayashi [14, 16, 17]. Shortly before, Kobayashi and Kimura (1942) reported a few graptolite fossils from the formation.

In recent years, very important paleontological studies of the Mungog Formation are added, including conodonts [6, 38] problematic fossil *Sphenothallus* [12], and trilobite [13,38] studies. Also, recent publications regarding sedimentological studies [7, 30, 31, 32, 40] discussed the depositional environment of the formation, ranging from subtidal to supratidal facies of the shallow shelf environment.

Some discrepancies regarding the age determination of the Mungog Formation are noted among the previous workers listed above, concerning both lower and upper limits, or one of them. On the other hand, the lowest conodont occurrence of the formation is closely related to the Cambrian – Ordovician boundary problem because of lack of any fossil present in the underlying Wagog Formation, which has been interpreted as a unit spanning the boundary [5], although the traditional boundary has been drawn between the Wagog and Mungog formations [17, 22].

Of two conodont biostratigraphic studies hitherto carried out on the Mungog Formation, the first one of Won and Lee [39] was very limited both in lateral and vertical spacing in scope, and the second one of Choi [6] employed uncertain lithostratigraphic and biostratigraphic data.

This study was intended to describe the conodont fauna of the Mungog Formation, Yeongweol, to erect biostratigraphic zonal schemes, to correlate them with coeval ones of other parts of the world, and to discuss the Cambrian-Ordovician boundary in this area, based on diverse and abundant conodont collections.

The senior author has already collected a lot of conodont specimens from the lower part of the Mungog Formation in the Mohari and Golmacha areas, Yeongweol, in the course of conodont study of the adjacent Machari Formation [21]. Supplementary limestone samples were collected chiefly at three sites in 1997 and 1998; Mohari, Seonghwangchon and Golmacha areas.

All conodont data are deposited at the Department of Earth Environmental Science, Chonbuk National University, Jeonju.

PREVIOUS WORKS

The Yeongweol-type Choseon Supergroup of the Cambro-Ordovician was first surveyed, mapped, and classified into five lithostratigraphic units, i.e. Sambangsan, Machari, Wagog, Mungog and Yeong-

heung formations in ascending order, and the Mungog Formation was further subdivided into three parts in the western part of Mt. Siru, a type locality of the formation [42].

Kobayashi [17] modified this subdivision and added some new stratigraphic data. Recently, Park et al. [32] established four informal members in the formation based on some important lithofacies such as ribbon rock, dolostone, shale and flat-pebble conglomerate etc., including basal (ribbon rock + dolostone, 50 m), lower (dolostone, 30–35 m), middle (ribbon rock + flat-pebble conglomerate, 30–60 m), and upper (shale + ribbon rock + dolostone, 50–60 m) members.

Yosimura's [42] fossil collection is systematically described by Kobayashi [14, 17], who correlated the Mungog Formation with the Dongjeom Quartzite through the Dumugol Shale to the lower part of the Maggol Limestone of the Duwibong-type Choseon Supergroup, ranging from Tremadocian to Arenigian in age, based on macroinvertebrate fossils. Kobayashi and Kimura (1942) found a few graptolite species, i.e. *Dictyonema* cf. *flabelliforme* and *Clonograptus*(?) sp. from the formation indicating Early Ordovician in age.

Recently, three Tremadocian trilobite assemblage zones were recognized within the Mungog Formation by Park et al.[32], and Kim and Choi [13], based on biostratigraphically important taxa, such as *Yosimuraspis, Jujuyaspis, Pseudokainella* (basal), *Kainella* sp. cf. K. *euryrachis* (middle), *Micragnostus coreanicus, Shumardia pellizzarii, Apatokephalus hyotan, Hystricurus megalops, Dikelokephalina asiatica, Asapellus* sp., and *Koraispis spinus* (upper) etc. These trilobite-based age determinations are somewhat different from conodont-based results mentioned below.

Won and Lee [39] studied conodont fauna of 34 species belonging to 11 genera from the Mungog Formation at two localities, and suggested that the formation could be correlated with the Late Tremadocian to the Early Arenigian. Similarly, Choi [6] correlated his five Mungog conodont zones with relevant zonal schemes of the Late Tremadocian to the Early Arenigian.

Meanwhile, Choi et al. [5] reviewed the Cambrian-Ordovician boudaries in the Taebaegsan region, based primarily on trilobite and conodont data. They regarded the boundary of the Yeongweol-type sequence as a horizon below the base of the Mungog Formation, that is, within the uppermost part of the Wagog Formation.

THE MUNGOG FORMATION

The Mungog Formation [42], a Lower Ordovician strata of the Yeongweol-type Choseon Supergroup, are well exposed in the northwestern part of Yeongweol-eup and Puk-myeon, Yeongweol-gun, Kangweon province (Fig. 1). In this study, three sectional areas were systematically examined, and lithologic details of each area are summarized in Figs 2, 3, and 4.

The Mungog Formation consists mainly of several lithofacies, including ribbon rocks of diverse patterns, such as straight or planar, nodular, and flaser or wavy bedded ones, intraclastic grainstone to packstone (=flat-pebble conglomerate), peloidal-oolitic-bioclastic grainstone to packstone (dolomitic limestone) and marlstone or shale, as noted by Choi et al. [7], and Paik et al. [31]. According to this lithologic association, the formation is subdivided into four members, which are essentially identical with those of Park et al.[32].

Both the lower and uppermost beds (Members 1, 2, and the upper part of 4) are mostly dolomitized,the upper beds (Member 3) contain frequent intercalations of flat-pebble conglomerates, and also, the uppermost beds (Member 4) are characterized by the domination of marlstone to shale.

The basal member, less than 35m in thickness, comprises ribbon rocks, thin (<25cm in thickness) flat-pebble conglomerate, and massive dolomitic limestone. Particularly, dolomitic limestones always contain dark, elongated chert nodules, which are subparallel to bedding. These are useful for stratigraphic recognition and correlation in the field.

The lower member entirely consists of grey, very thick (40-50m), poorly bedded dolomitic limestones. In this interval, no other lithofacies are intercalated.

The middle member, 45–50 m thick, is characterized by an alternation of ribbon rocks and flat-pebble conglomerates, with occasional interbeds of bedded dolomitic limestones containing sparse chert nodules.

The upper member, 50–60m thick, is also composed of ribbon rock, greenish grey shale, flat-pebble conglomerate, and dolomitic limestone, which grade into thick-bedded, tabular dolostones of the Yeongheung Formation, the top unit of the Yeongweol-type Choseon Supergroup.

MEASURED SECTION

The Mungog Formation at three sites was measured and sampled, that is the Golmacha, Seonghwangchon, and Mohari sections. The Golmacha section is well exposed on the road side of the provincial route 413, the northern part between the Macha Middle School and the entrance to the Golmacha village, Machari, Puk-myeon. The Seonghwangchon section is located near the Araegol water reservoir, Yeondeogni, Puk-myeon. The Mohari section indicates two intervals 1) along the national route 38, near the entrance to the Dumog village, and 2) a short section structurally controlled within the village, Yeongweol-eup. The location of each section is represented in Fig. 1, and lithologic details with sampling horizons are illustrated

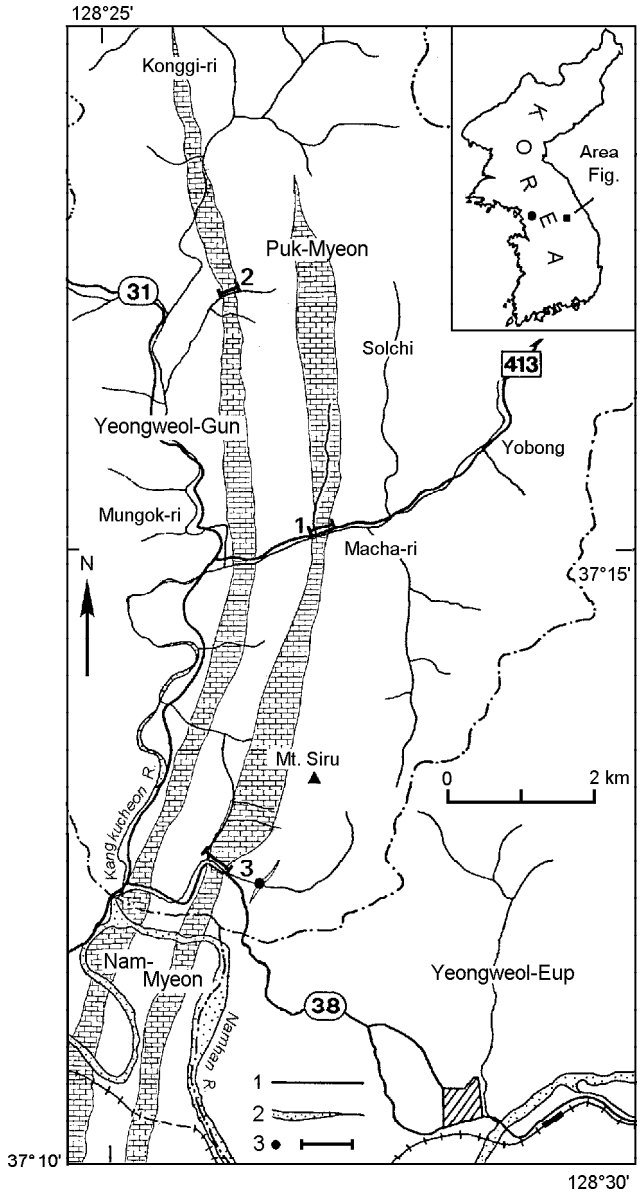

Fig. 1. Distribution of the Mungog Formation examined in this study, northwestern Yeongweol area.

1 – national and provincial roads; 2 – river and stream lines, and 3 – measured sections. Sectional localities are: Golmacha (1), Seonghwangchon (2) and Mohari (3) sections.

in Figs 2 (Golmacha), 3 (Seonghwangchon), and 4 (Mohari).

Although the vertical lithologic variation is not so great between the three sections, the Golmacha section has the best exposure among them, so we explain the section below. Sixty limestone samples for conodont study were collected in the three sections; twenty-two, in the Golmacha section; 19, in the Seonghwangchon section; and 19, in the Mohari sections, respectively.

The full length of the Golmacha section reaches more than 184m; Member 1–33.1m, Member 2–43.9m, Member 3–49.2m, and Member 4–58.0 m. Member 1 starts with shale bed, about 20 cm thick, rested directly on the dark, thick, massive dolostone bed of the underlying Wagog Formation, and most of the overlying interval consists of thick, dolomitic ribbon rocks of various patterns, except two, thin flat-pebble conglomerate, and also two dolomitic limestone beds with chert nodules (2.8 m thick), respectively, in the middle part. Five horizons of ribbon rocks and one flat-pebble conglomerate bed are sampled within Member 1.

Member 2 is composed exclusively of very thick, poorly bedded or weakly bedded dolomitic limestones, which are underlain and overlain by ribbon rocks of Members 1 and 3, respectively. No samples were collected in this interval for conodont biostratigraphic study.

In Member 3, dolomitic limestones are presented in the lower part, whereas dominant are large amount of ribbon rock with frequent intercalation of flat-pebble conglomerates in the upper part. A few beds of flat-pebble conglomerates interbedded in this unit are exceptionally thick bedded (>80cm), although they are about 20 cm in average thickness. Moreover, at least twenty beds, are intercalated within the member in the Golmacha section. These two important clues, namely thickness and frequency of intercalation of the rock type, distinguish Member 3 from other ones. A dolomitic grainstone bed about 50 cm thick with chert nodules is included near the top of the member. This bed is thin and light-colored, and chert nodules are of low density. Eight samples were collected in beds of ribbon rocks, and flat-pebble conglomerates.

The base of Member 4 is recognized by the lowest occurrence of marlstone to shale. Other constituents of the member are ribbon rock, flat-pebble conglomerate, dolomitic limestone, and massive limestone. Dolomitic limestone becomes predominant in the upper part. Flat-pebble conglomerates are interbedded within eight horizons. Eight samples were all collected from ribbon rock beds of Member 4 for conodont study. Unfortunately, the uppermost, about 15 m, interval of the member was not sampled, owing to lack of outcrop or of pure limestones.

CONODONT OCCURRENCE

From three full sections and one short interval, sixty-two limestone samples were collected for conodont biostratigraphic study, using serial sampling method. Detailed sampling localities are shown in Fig. 1, and are described in the preceding section. Each sample varied from 4.0 kg in a sample up to approximately 8.0 kg. All samples were weighed, crushed to a size as large as 2–3 cm in diameter, and then processed in dilute acetic acid of about 15%. This was followed by microscopic examination of the residues.

Fourty of sixty-two samples yielded 999 descrete conodont specimens, and these were classified into 34

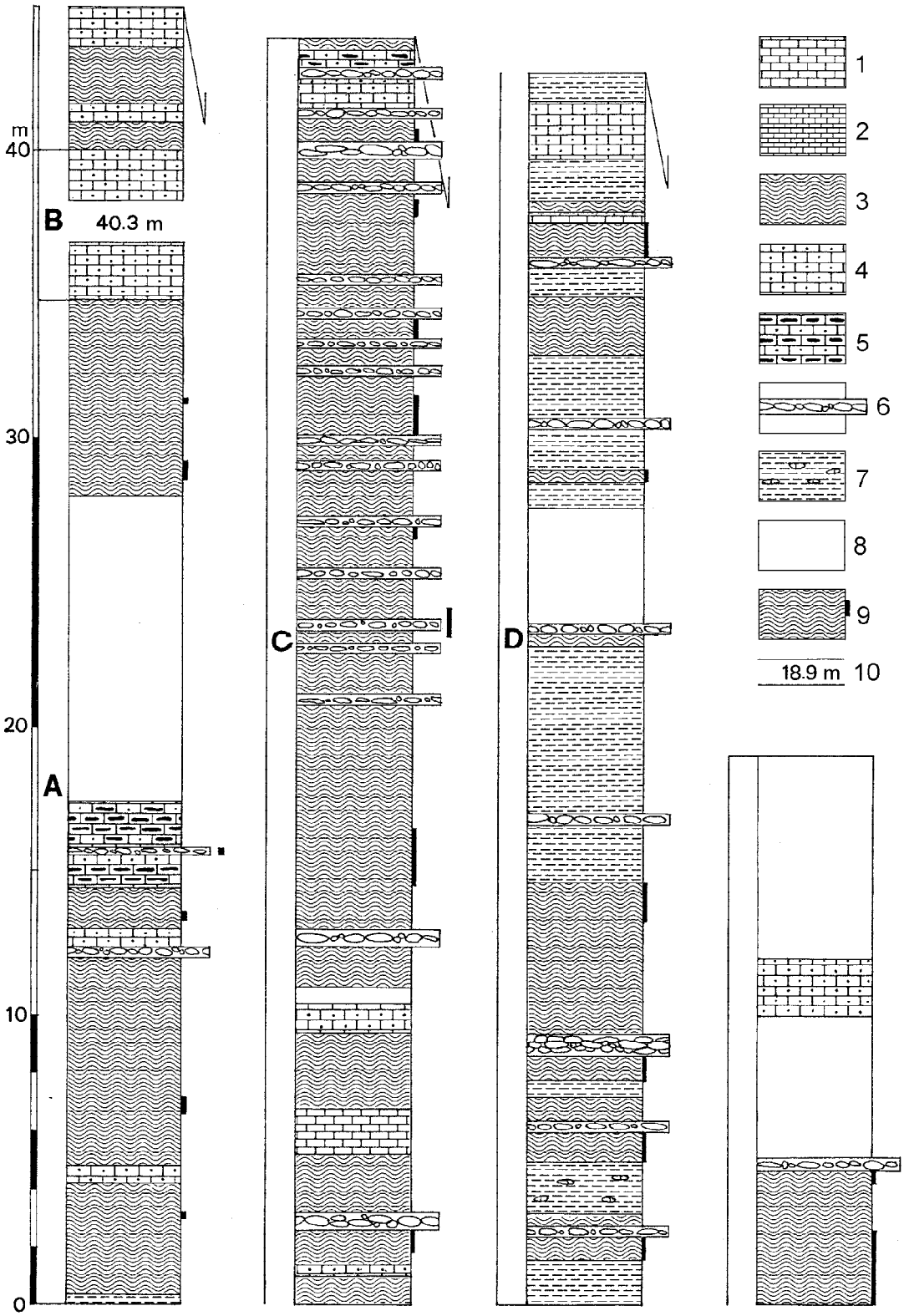

Fig. 2. Columnar stratigraphy of the Golmacha section, with sample horizons.

Abbreviation : A–D – members. 1 – massive limestone; 2 – laminated limestone; 3 – ribbon rock; 4 – dolomitic limestone; 5 – dolomitic limestone with chert nodules; 6 – flat-pebble conglomerate; 7 – shale or marlstone; 8 – soil cover; 9 – sampling interval; 10 – unfigured interval.

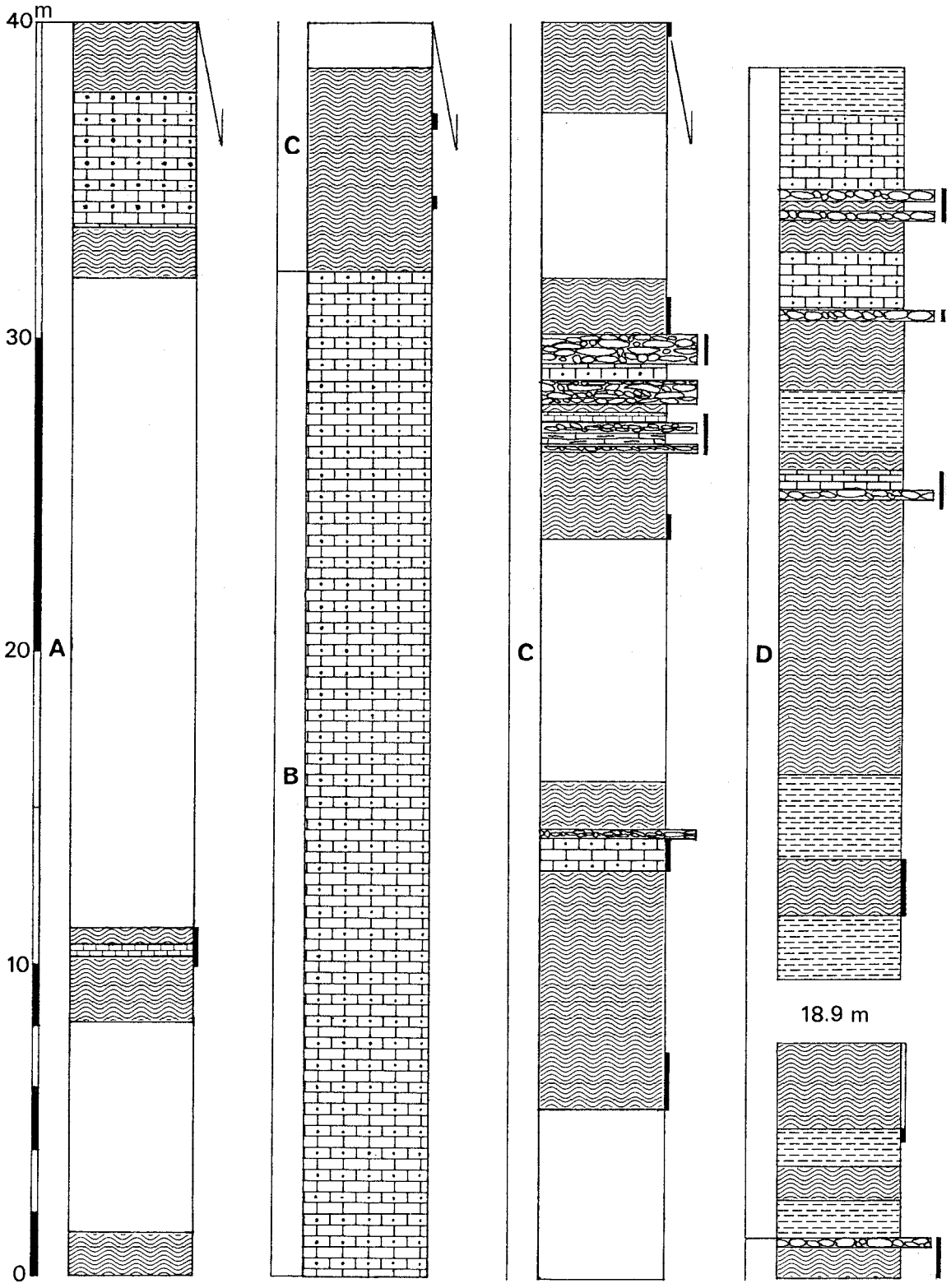

Fig. 3. Columnar stratigraphy of the Seonghwangchon section, with sample horizons.
Explanation of legend refers to Fig. 2. Abbreviation : A–D – members.

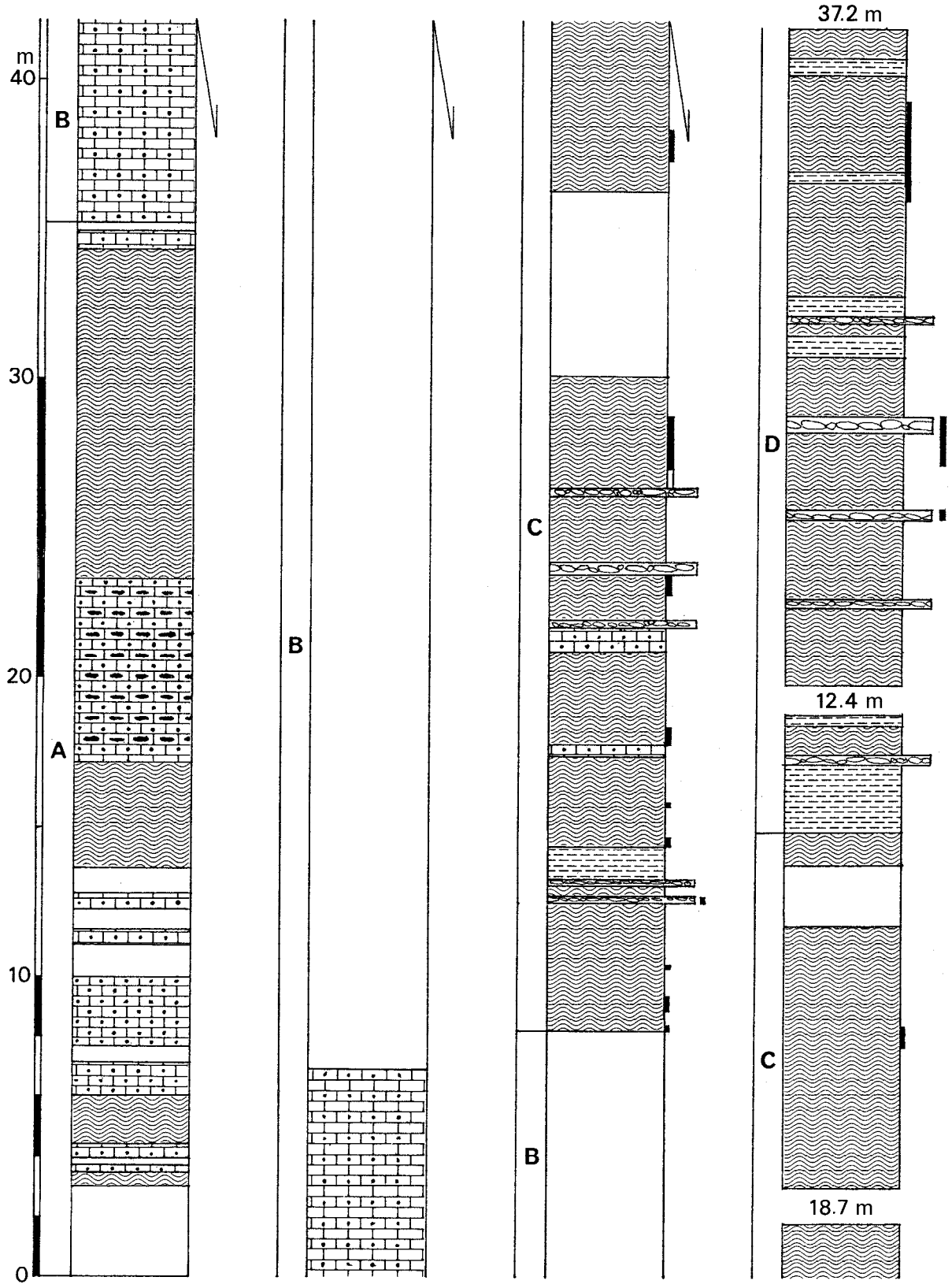

Fig. 4. Columnar stratigraphy of the Mohari section, with sample horizons.
Explanation of legend refers to Fig. 2. Abbreviation : A–D – members.

species assignable to 15 genera based on multielement and form taxonomies. Sample horizons and intervals are illustrated in Figs 2, 3, and 4. Conodont distribution in fossiliferous samples is shown in Plate 1.

Of sixty-two limestone samples collected in this study, conodonts are recovered from fourty samples at a ratio of 65%; 77% of 17 to 22 samples in Golmacha, 62% of 13 to 21 samples in Seonghwangchon, and 53% of 10 to 19 samples in two Mohari sections. Conodont recovery per sample is counted as relatively low, so only 15 samples are contained more than 10 specimens. Stratigraphically, conodonts are more abundant in the lower samples than in the upper ones.

Generally, conodonts were below the average size; variation between each conodont taxa or within a conodont taxa is great. Also, most specimens are relatively well preserved with no sign of any deformation, although some are fragmented. Elements are dark grey to black, indicating a high degree of thermal maturity.

FAUNAL SUCCESSION AND CORRELATION

Diverse conodonts of great value in biostratigraphy are recovered from three sections of the Mungog Formation in the Yeongweol area. Unfortunately, the conodont species of each section was not well differentiated stratigraphically owing to the paucity of conodont specimen, especially in the upper part of the formation, and of limestone samples collected. A more refined restudy for additional collections is required to establish a precise biostratigraphical correlation. The fauna important for biostratigraphy includes *Cordylodus proavus, C. drucei, C. intermedius, C. lenzi, C. angulatus, C. rotundatus, Semiacontiodus nogamii, Monocostodus sevierensis, Utahconus utahensis, U. beimadaoensis, Rossodus manitouensis, Chosonodina herfurthi, Acanthodus lineatus, A. uncinatus, Scolopodus quadraplicatus, Drepanoistodus forceps, Oistodus selene, Paroistodus proteus, Distacodus dumugolensis, and Paracordylodus gracilis.*

On the basis of these species, four informal conodont assemblage zones are tentatively established in the Mungog Formation, namely Assemblage Zone 1 (=*Semiacontiodus nogamii – Cordylodus lindstroemi – Utahconus beimadaoensis* Zone), Assemblage Zone 2 (=*Rossodus manitouensis – Chosonodina herfurthi* Zone), Assemblage Zone 3 (=*Scolopodus quadraplicatus – Paroistodus proteus – Drepanoistodus forceps* Zone), and Assemblage Zone 4 (=*Paracordylodus gracilis* Zone) in ascending order. The base of each zone is drawn at the lowest occurrences of the respective key taxa.

Assemblage Zones 1 and 2 are assigned to Member 1 or probably to the lower part of Member 2. Assemblage Zones 3 and 4 are assigned respectively to Members 3 and 4. Stratigraphic boundary of each zone is at hand unclear due to lack of detailed sampling. Ranges of conodont taxa are shown in Fig. 5, and correlation of the zones with those of other areas is illustrated in Fig. 6.

Golmacha section

Three lower assemblage zones listed above are recognized in Members 1 and 3 of the Golmacha section.

The lowest conodont occurrence is recorded in the sample Om 2, 6.69 m above the base of the Mungog Formation, in the Golmacha section. Om 2 *contains Cordylodus proavus, C. lindstroemi, C. angulatus, C. rotundatus, C.(?)* sp., *Semiacontiodus nogamii, Oneotodus variabilis, Scolopodus sulcatus, S. warendensis, Utahconus beimadaoensis,* and *Drepanoistodus* spp. This association allows the tentative recognition of Assemblage Zone 1 (*Semiacontiodus nogamii – Cordylodus lindstroemi – Utahconus beimadaoensis* Zone).

Cordylodus proavus is a cosmopolitan species ranging from the *Corbinia apopsis* Subzone of *Saukia* Zone to *Missisquoia* and *Symphysurina* zones of the North American trilobite zonal scheme of the uppermost Cambrian to the lowermost Ordovician. This interval is approximately equivalent to Fauna A of Ethington and Clark [10], and the *Cordylodus proavus* Zone of Miller [25, 26].

Semiacontiodus nogamii, recovered from Om 2 and Om 3, ranges from the *C. elegance* Subzone of the *C. proavus* Zone to the lower Fauna B in association with *Parutahconus nodosus* and *Jujuyaspis* (trilobite).

Cordylodus angulatus and *C. rotundatus* are recovered in Fauna B except lowermost part and lower part of Fauna C of Ethington and Clark [10] in North America. Lindstrцm [23] recorded this species through the Upper Tremadocian and into the lower part of the Arenigian in Scandinavia. *C. angulatus* persists into the overlying sample Om 3. *Cordylodus angulatus* and *C. rotundatus* have a common association, but have different ancestors; *C. intermedius* is the ancestor of *C. angulatus*, whereas *C. drucei* is the ancestor of *C. rotundatus* [26]. This lineage is not clearly documented in this study, except that *C. angulatus* and *C. drucei* are commonly obtained from the overlying sample Om 3.

Cordylodus lindstroemi first occurs at the base of Fauna B, which is within the lower part of the *Symphysurina brevispicata* Subzone of the *Symphysurina* Zone. *Utahconus beimadaoensis*, a long-ranging species, occurs in the *Utahconus beimadaoensis – Monocostodus sevierensis* Zone of the lowest Ordovician in North China [3]. However, a taxonomic revision of *U. beimadaoensis* is required for more detailed stratigraphic range of the species, which is confused at the present level in morphology with spp. of *Utahconus*, elements of *Parutahconus nodosus, Acodus tetrahedron,* and *Scando-*

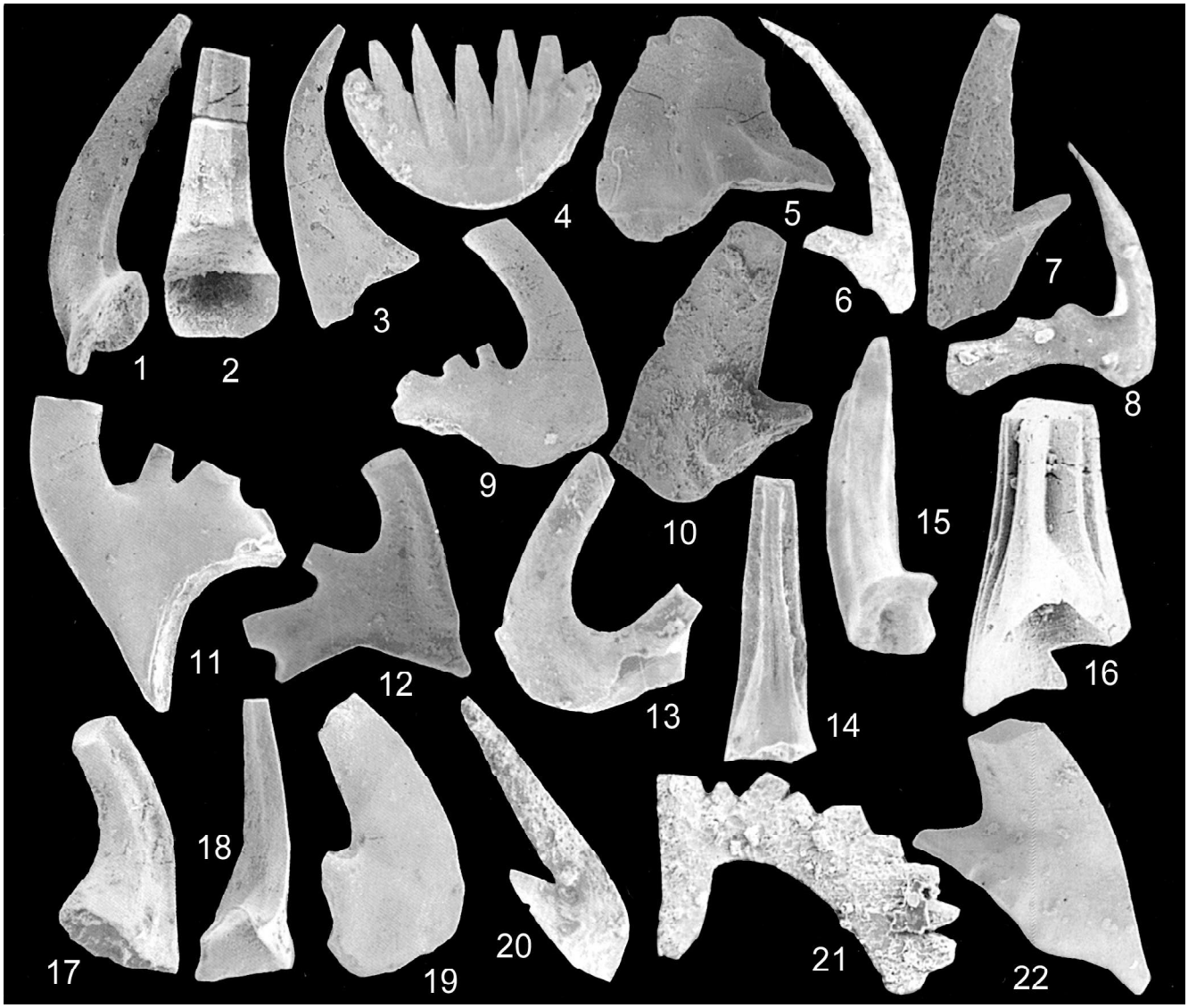

Plate 1.

1. *Acanthodus lineatus* (Furnish), Sh 6, lateral view, ×35. 2. *Acontiodus propinquus* Furnish, Sh 6, posterior view, ×132. 3. *Proconodontus* sp., Om 4, lateral view, ×106. 4. *Chosonodina herfurthi* Muller, Om 4, posterior view, ×92. 5,18. *Rossodus manitouensis* Repetski and Ethington, posterior views of acontiodiforms; 5, Om 3, ×118; 18, Sh 1, ×97. 6. *Distacodus dumugolensis* Seo, lateral view of oistodiform el., Om 6, ×101. 7. *Drepanoistodus inaequalis* (Pander), lateral view, Om 12, ×158. 8,21. *Paracordylodus gracilis* (Lindstrцm), lateral views; 8, cyrtoniodiform el., Sh 8, ×180; 21, paracordylodiform el., Sh 18, ×177. 9. *Cordylodus angulatus* Pander, lateral view, Om 3, ×118. 10. *Oistodus lanceolatus* Pander, lateral view, Om 4, ×78. 6. 11. *Cordylodus intermedius* Furnish, lateral view, Om 3, ×67. 12. *Cordylodus drucei* Miller, lateral view, Om 3, ×127. 13. *Cordylodus rotundatus* Pander, lateral view, Om 2, ×158. 14. *Scolopodus sulcatus* Furnish, posterior view, Om 2, ×185. 15,17. *Glyptoconus quadraplicatus* (Furnish), posterolateral views; 15, Om 3, ×83; 17, Sh 9, ×86. 16. *Paltodus* sp., lateral view, Sh 9, ×115. 19. *Paroistodus proteus* (Lindstrцm), lateral view, Om 9, ×51. 20. *Drepanoistodus forceps* (Lindstrцm), lateral view, Om 11,×106. 22. *Oistodus selenopsis* Serpagli, lateral view, Sh 1, ×80.

dus furnishi, and even a species of *Paltodus*. Other species from Om 2 including *Scolopodus warendensis* are relatively long-ranging species.

None of the key species as presently understood has its lowest occurrence at the same horizon, making the definition of the base of Zone 1 somewhat difficult. Detailed sampling of the basal part of the Mungog Formation is required to establish precise zonation. The top of Assemblage Zone 1 appears to be marked by the first appearance of *Rossodus manitouensis* and *Chosonodina herfurthi*, the key species of the overlying zone. Miller [25, 26] defined the base of Fauna B by the lowest occurrence of *Cordylodus lindstroemi* Druce and Jones [8], a form considered to represent ontogenetic variants of *Cordylodus* elements with secondary basal tips. Based on this idea and consideration of stratigraphic ranges of

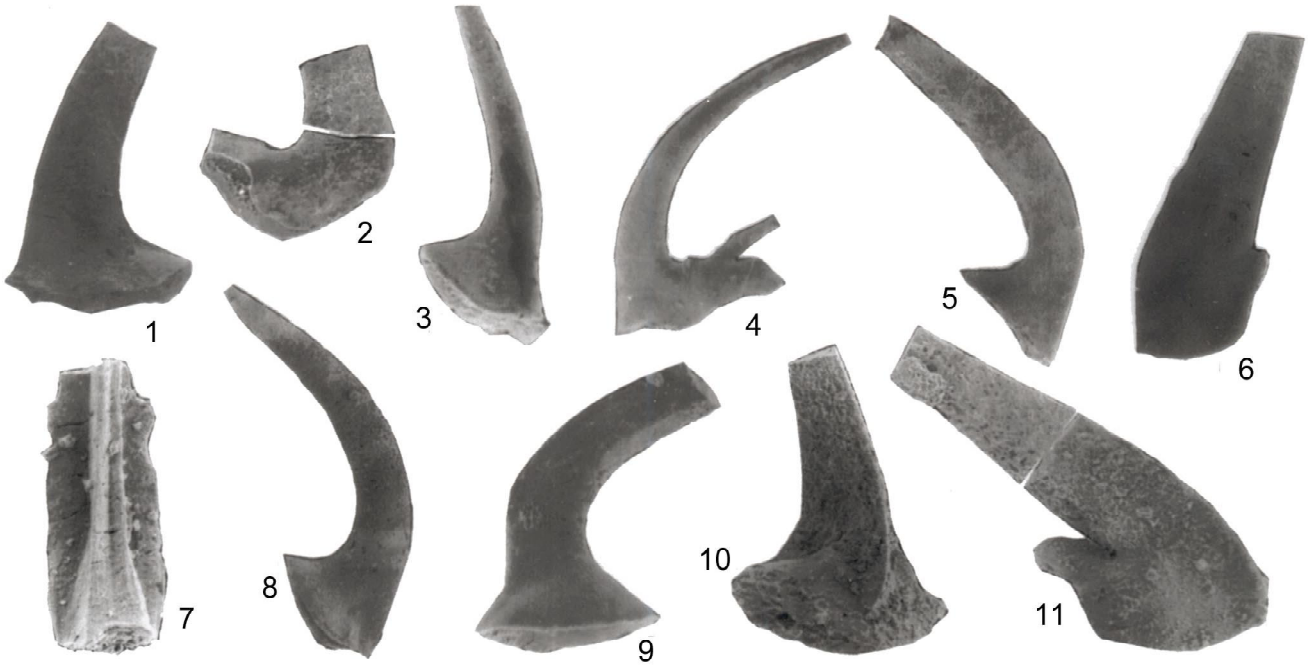

Plate 2.

1. *Drepanodus suberectus* (Branson and Mehl), lateral view, Om 8, ×77. 2. *Cordylodus rotundatus* Pander, lateral view, Om 2, ×116. 3. *Oneotodus erectus* Druce and Jones, lateral view, Om 3, ×136. 4. *Cordylodus angulatus* Pander, lateral view, Om 3,×126. *Drepanodus simplex* Branson and Mehl, lateral view, Om 7, ×73. 6. *Oistodus contractus* Linstrum, lateral view, Om 8,×42. 7. *Scolopodus bolites* Repetski, posterior view, W 11, ×136. 8. *Drepanodus homocurvatus* Linstrum, lateral view, Om 8, ×55. 9. *Drepanodus concavus* (Branson and Mehl), lateral view, Sh 1, ×58. 10. *Rossodus manitouensis* Repetski and Ethington, posterior view of acontiodiform el., Sh 1, ×131. 11. *Oistodus lanceolatus* Pander, lateral view, Sh 1, ×86.

other species of Om 2, Assemblage Zone 1 defined herein appears to be correlated with the upper part of the *Cordylodus proavus* Zone and lower *Symphysurina brevispicata* Subzone of the *Symphysurina* Zone of the uppermost part of the Lower Tremadocian or probably with the middle part of Fauna B. Accordingly, the Cambrian-Ordovician boundary in the Yeongweol area is probably present within beds immediately below Assemblage Zone 1, near the base of the Mungog Formation.

Assemblage zone 1 or the *Semiacontiodus nogami – Cordylodus lindstroemi – Utahconus beimadaoensis* Zone is the lowest conodont assemblage of the Ordovician strata in Korea. In the Taebaegsan region, the *Chosonodina herfurthi – Rossodus manitouensis* Zone is the lowest Ordovician one established in the Dumugol Shale of the Duwibong-type Choseon Supergroup.

The sample Om 3, 4.25 m above Om 2, yielded some important conodonts of *Acodus tetrahedron, Cordylodus drucei, C. intermedius, Drepanodus concavus, D. tenuis, Drepanodus suberectus, Oneotodus erectus, Rossodus manitouensis, Scandodus furnishi, Teridontus nakamurai, Scolopodus primitivus, S. shuiyuensis, and Glyptoconus bassleri*, etc., and the sample Om 4, 13.69m above the base of the Mungog Formation, yielded *C. intermedius, Rossodus manitouensis, Chosonodina herfurthi, Drepanoistodus pervetus, D. lanceolatus, Oneotodus gracilis, Scolopodus primitivus*, and *Glyptoconus bassleri*, etc. Om 5 (26.42 m above the base) contains *R. manitouensis, D. lanceolatus, A. tetrahedron*, and *Scolopodus warendensis*. Om 6 (28.62 m above the base) also contains *R. manitouensis* in association with *Oistodus inaequalis*, and *Distacodus* sp.

The stratigraphic interval from sample Om 3 to Om 6 of 17.68 m thick, is tentatively labelled as Assemblage Zone 2 (=*Rossodus manitouensis – Chosonodina herfurthi* Zone). This zone is more or less thin, relative to zones of the Dumugol Shale (27–30 m thick of Seo [34]; 30–36 m thick of Lee et al. [19] in the Duwibong and Ogdong areas. More detailed sampling may solve this problem. *Rossodus manitouensis* first occurs at 0.75 m horizon below the base of the first bed of dolomitic limestone containing chert nodules through Om 5 and Om 6, respectively, of ribbon rocks. *Chosonodina herfurthi* first occurs in flat-pebble conglomerate bed, immediately below the second chert nodule-containing bed, 13.69 m above the base of the Mungog Formation.

Cordylodus drucei occurs in the uppermost part of the *C. proavus* Zone or Fauna B. *C. intermedius* is reported hitherto in the lower to middle part of the *Symphysurina* Zone or upper part of Fauna A, and

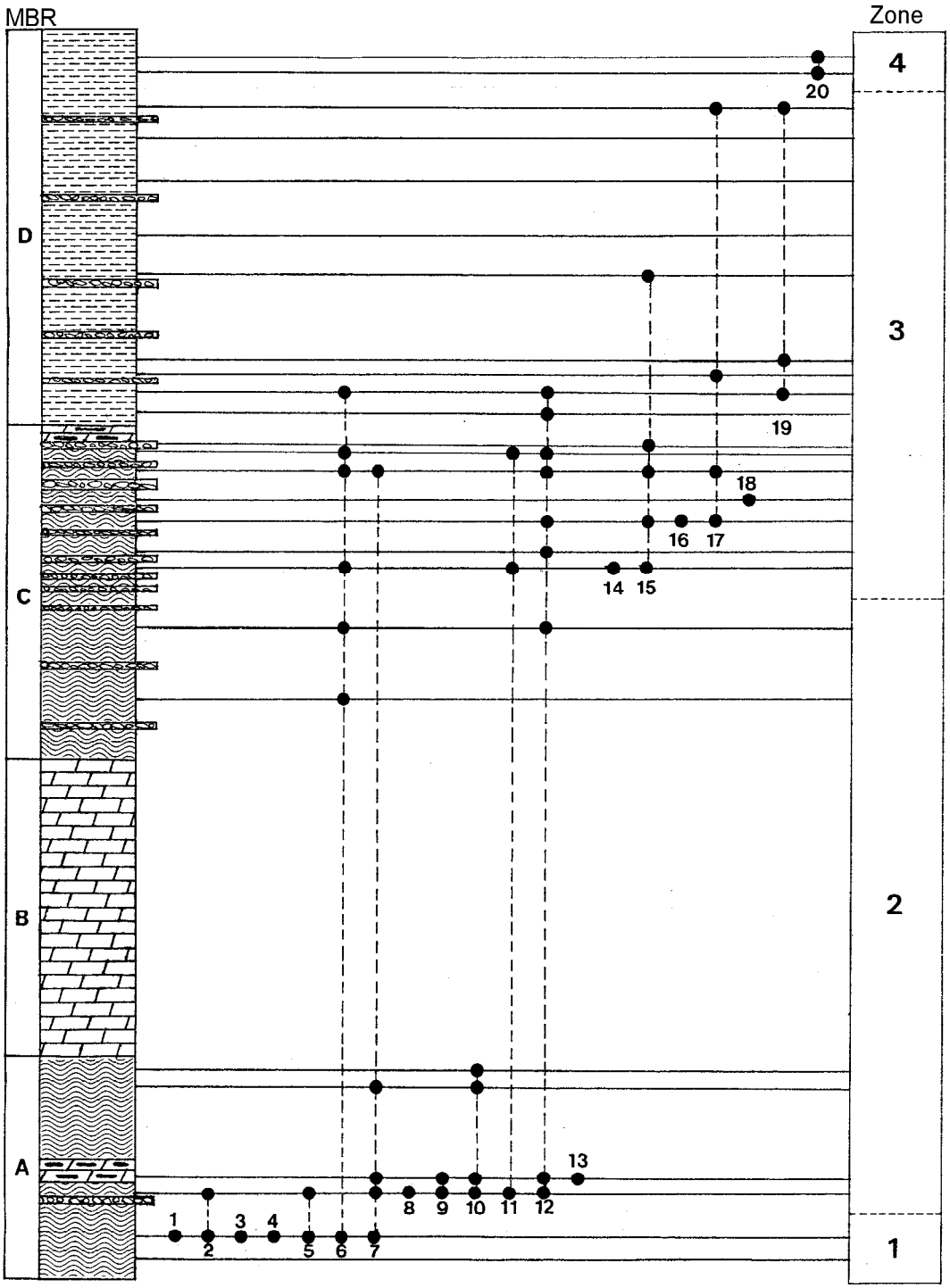

Fig. 5. Generalized stratigraphic ranges of selected conodont species from the Mungog Formation, Yeongweol area.

1 – *Cordylodus proavus*; 2 – *Semiacontiodus nogamii*; 3 – *Cordylodus lindstroemi*; 4 – *Cordylodus rotundatus*; 5 – *Cordylodus angulatus*; 6 – *Utahconus beimadaoensis*; 7 – *Scolopodus warendensis*; 8 – *Cordylodus drucei*; 9 – *Cordylodus intermedius*; 10 – *Rossodusmanitouensis*; 11 – *Scandodus furnishi*; 12 – *Glyptoconus bassleri*; 13 – *Chosonodina herfurthi*; 14 – *Paroistodus proteus*; 15 – *Scolopodus quadraplicatus*; 16 – *Drepanoistodus forceps*; 17 – *Drepanodus concavus*; 18 – *Drepanoistodus basiovalis*; 19 – *Distacodus dumugolensis*; 20 – *Paracordylodus gracilis*.

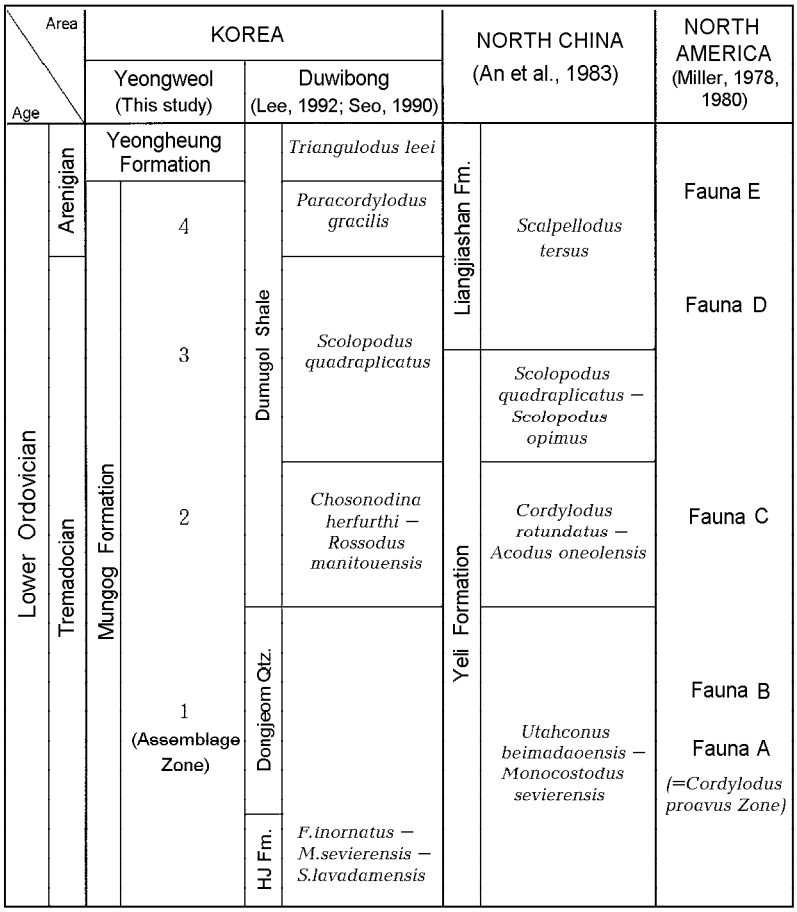

Fig. 6. Correlation of conodont biozones of the Lower Ordovician in Korea, North China, and North America.

lower part of Fauna B of Ethington and Clark [10]. This species also is known from the Upper Tremadocian strata of Sweden [28], east Baltic region [41], Oaxaca, Mexico [27], Iran [29], Australia [8, 9, 11], northwestern Greenland [36], USSR [1, 2], and North China [3, 4]. In Korea, *C. intermedius* is recovered from a bed about 5 m above the base of the Dumugol Shale near the Yeongchun area [19], in association with *Acanthodus lineatus, Chosonodina herfurthi, C. angulatus, C. rotundatus, Monocostodus sevierensis,* and *Rossodus manitouensis,* etc.

Rossodus manitouensis and *Chosonodina herfurthi* co-occurs in the Lower Ordovician of various parts of the world. *R. manitouensis,* first reported from the Upper Tremadocian strata in North America [33], appears to be restricted to the upper conodont Fauna B and Fauna C of the North American midcontinental zonal scheme [18]. *C. herfurthi* with associates of *Loxodus bransoni* and Clavohamulus densus, etc. is known from strata equivalent to the upper part of Fauna B to Fauna C of North America [37], the upper part of the Warendian of Australia [35], the Yeli Formation of North China [3], and the Dumugol Shale of Korea [19, 20, 21, 28, 34]. Meanwhile, Seo [34] and Lee et al. [19, 20, 21] correlated the *Rossodus manitouensis – Chosonodina herfurthi* Zone with the middle to upper part of Fauna C of North America, and the *Cordylodus rotundatus – Acodus oneotensis* Zone of North China [3].

No limestone samples were collected in the interval from the uppermost part of Member 1 (ca. 3.15 m thick) through Member 2 (ca. 43.86 m thick) to the lowermost part of Member 3 (ca. 6.84 m thick) below Om 7, because limestones of this range are dolomitic. Several long-ranging species are dominant in the samples Om 7, Om 8, Om 9, Om 10, Om 11, and Om 12. The conodont fauna includes *Acanthodus lineatus, Acodus triangulatus, Drepanodus arcuatus, D. concavus, D. conulatus, D. simplex, D. tenuis, Drepanoistodus forceps, Oistodus contractus, O. inaequalis, Scandodus furnishi, Scolopodus floweri,* and *Paroistodus proteus,* etc. These are assigned to Assemblage Zone 3 (=*Scolopodus quadraplicatus – Paroistodus proteus – Drepanoistodus forceps* Zone), and are approximately known from beds younger than the

Chosonodina herfurthi – Rossodus manitouensis Zone of the the Dumugol Shale in Duwibong area [34], and the *Rossodus manitouensis* Zone in the Ogdong area [19, 20], except *A. lineatus, D. conulatus, D. forceps*, and *Paroistodus proteus*. The first species is hitherto reported only from the *Rossodus manitouensis – Chosonodina herfurthi* Zone, and three remainders are all from zone(s) younger than the *Scolopodus quadraplicatus* Zone of the Dumugol Shale [34]. This fauna can be correlatable with Fauna C of North America [19, 20, 27, 34].

Accordingly, a younger conodont biozone overlying Assemblage Zone 2 can be considered to range from a bed slightly above the sample Om 9 probably through Om 11 definitely to Om 13, containing *Drepanodus conulatus, Drepanoistodus forceps, Paroistodus proteus*, and *Scolopodus quadraplicatus*. The top of the zone is unclear. Unfortunately, no time-sensitive conodonts have been recovered from the remainer of the Mungog Formation, except an occasional occurrence of *Distacodus dumugolensis* reported from the upper part of the *Scolopodus quadraplicatus* Zone of the Dumugol Shale [34]. Restudy of additional collections from the upper half of the formation may result in recovering diagnostic elements.

Seonghwangchon section

Three conodont assemblage zones are recognized in the Seonghwangchon section, namely Assemblage Zone 2 (=*Rossodus manitouensis – Chosonodina herfurthi* Zone), Assemlage Zone 3 (=*Scolopodus quadraplicatus* Zone), and Assemblage Zone 4 (=*Paracordylodus gracilis* Zone) in ascending order. Three zones are assigned, respectively, to Members 1, 3, and 4.

Strata about 30.15 m below the base of Member 2 contain diagnostic species of informal Assemblage Zone 2 or the *Rossodus manitouensis – Chosonodina herfurthi* Zone. Especially important species are *C. herfurthi, Cordylodus lenzi, C. angulatus, C. rotundatus, Juanognathus jaanusoni, Oistodus selene, R. manitouensis*, and *Utahconus beimadaoensis*. Stratigraphic extension of the zone is uncertain due to lack of detailed sampling.

The lower part of Member 3 in the Seonghwangchon section (SH 2, SH 3, and SH 4 or SH 5) contains a long-ranging assemblage *of Drepanodus arcuatus, D. homocurvatus, Glyptoconus bassleri, Scalpellodus tersus, Scolopodus acontiodiformis angularis, Utahconus utahensis*, and *U. beimadaoensis*.

Scolopodus quadraplicatus along with *Acanthodus uncinatus, Drepanodus conulatus, Drepanoistodus proteus*, and *Utahconus beimadaoensis* is recovered from the sample SH 6 21.1 m above the base of Member 3. The species also occurred in the overlying samples SH 8 and SH 9. This interval (16.7 m thick) marks Assemblage Zone 3 correlative of the *S. quadraplicatus* Zone of the Dumugol Shale in the Duwibong area [34]. Especially *S. quadraplicatus* and *S. quadrangulatus* co-occur in the sample SH 8. An et al. [3] considered that *S. quadraplicatus* is the ancestor of *S. quadrangulatus*, so the former species occurs in the strata younger than the lower part of the Yeli Formation, whereas the latter species first occurred in the base of the Liangchiashan Formation, respectively.

We were unable to recognize any conodont biozone in the uppermost part of Member 3 and through the entire length of Member 4, except the uppermost 7.62 m interval above the sample SH 18 of flat-pebble conglomerates, where some elements of *Paracordylodus gracilis* have been collected. *P. gracilis* appears to be present throughout the remainder of the Mungog Formation. These strata are all assigned to Assemblage Zone 4 or the *Paracordylodus gracilis* Zone, recognized only in the Seonghwangchon section. This is the uppermost zone of the formation erected herein, and comprises an assemblage of *Drepanodus arcuatus, Drepanoistodus inaequalis, P. gracilis, Scandodus furnishi, Scolopodus quadraplicatus, S. warendensis*, and *Utahconus beimadaoensis*. Seo [34] correlated this zone with the upper part of Fauna C and the lower part of Fauna D of North America, and the Lower Arenigian fauna of North China.

Mohari section

The sample collection for conodonts is restricted to Members 3 and 4 in a road-side (route 38) section with the entire length of the Mungog Formation, and to Member 1 in a short section along a stream line of the Dumog village. Assemblage Zone 3 or the *Scolopodus quadraplicatus – Paroistodus proteus – Drepanoistodus forceps* Zone is recognized in a road-side section, and Assemblage Zone 2 or the *Rossodus manitouensis – Chosonodina herfurthi* Zone is only recognized in a short section, respectively.

Scolopodus quadraplicatus first occurs in the sample W 4 at 4.38 m above the base of Member 3, and is associated with *Acontiodus propinquus, Drepanodus arcuatus, D. concavus, Drepanoistodus inaequalis, Glyptoconus bassleri, Monocostodus sevierensis, Semiacontiodus nogamii, Scolopodus primitivus, S. warendensis, Teridontus nakamurai, Utahconus utahensis*, and *U. beimadaoensis* etc. This fauna is tentatively assigned to Assemblage Zone 3. *S. quadraplicatus* was also recovered from the sample W 14, 20.4 m above the base of Member 4.

Of other samples above W 4 with small collections of *Scalpellodus tersus, Paroistodus cf. proteus*, and *Scolopodus longibasis*, W 13 comprises *Scolopodus bolites*, a characteristic species of the *Paracordylodus gracilis* Zone in the Duwibong area. Seo [34] correlated strata including the species with the Lower Arenigian. If this interpretation is valid, beds bearing *S. bolites* can be compared with a part of Assemblage Zone 4 or the *P. gracilis* Zone in the Seonghwangchon section.

The sample Du 1 of two productive samples in a short section along a stream line of the Dumog village, yielded conodont fauna indicative of Assemblage Zone 2. The fauna comprises *Cordylodus rotundatus, Glyptoconus bassleri, Scalpellodus tersus, Paltodus quinquecostatus, Rossodus manitouensis,* and *Scandodus* sp., etc. In 1991, Lee collected some specimens of *Chosonodina herfurthi* from immediately above Dm 1. From Dm 2, 9.6 m below Du 1, *C. angulatus, Glyptoconus bassleri, Semiacontiodus nogamii,* and *Scolopodus gracilis* have been also recoverd. This fauna is interpreted to be an older assemblage as compared the *Rossodus manitouensis – Chosonodina herfurthi* Zone, although key species have not been recovered.

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Биостратиграфия конодонтов формации Мунгог (нижний ордовик), область Енгволь (Южная Корея)

Биостратиграфия конодонтов была исследована в трех разрезах (Голмача, Сонгхвангчон и Мохари) формации Мунгог в области Енгволь. В пределах формации установлены следующие четыре зоны конодонтов: комплексная зона 1 (=*Semiacontiodus nogamii – Cordylodus lindstroemi – Utahconus beimadaoensis* зоне), комплексная зона 2 (=*Rossodus manitouensis-Chosonodina herfurthi* зоне), комплексная зона 3 (=*Scolopodus quadraplicatus – Paroistodus proteus – Drepanoistodus forceps* зоне) и комплексная зона 4 (=*Paracordylodus gracilis*). В статье кратко изложены предварительные данные по корреляции этих зон. Граница кембрия и ордовика в области Енгволь проходит, вероятно, непосредственно ниже зоны 1, вблизи основания формации Мунгог.