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CONODONTS FROM THE DUMUGOL FORMATION LOWER ORDOVICIAN, TANYANG AREA, KOREA

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This study is to clarify the geologic time of the Dumugol Formation in the Tanyang area on the basis of conodonts. A total of 245 identifiable conodonts were recovered from 56 samples. They are classified into 7 multielement species referable to 10 genera, and 9 form species belonging to 13 genera. In terms of biostratigraphic biozones, the Dumugol Formation is divided into four conodont zones, viz, *Chosonodina herfurthi – Rossodus manitouensis*, *Glyptoconus quadraplicatus*, *Paracordylodus gracilis*, and *Triangulodus dumugolensis* zones in ascending order. Conodont fauna of the Dumugol Formation is correlated with the *Chosonodina herfurthi – Rossodus manitouensis* zone to the *Triangulodus dumugolensis* zone of the Dumugol Formation in the Baegunsan Syncline region, the *Cordylodus rotundatus – Acodus oneotensis* zone to the *Scalpellodus tersus* zone of North China, Fauna C to Fauna E of North America, the *Cordylodus rotundatus* zone to the *Oepikodus evae* zone of the Baltic region, the *Chosonodina herfurthi – Acodus* zone to the *Drepanodus gracilis – Scolopodus sexplicatus* zone in Australia.

The Dumugol Formation is Late Tremadocian through Early Arenigian of Europe, Late Ibexian through Early Canadian of North America in age.

Most of the recovered conodonts are well preserved and are brownish black (5YR 2.5/1 to 2.5 YR 2.5/1 by Munsell Soil Color), displaying a color alteration index of 4–5 and indicating that these rocks have been heated to 300–400 degrees Celsius.

Key words: **Tanyang, Dumugol Formation, conodont fauna, biostratigraphy, Late Tremadocian, Early Arenigian, Korea.**

INTRODUCTION

The Lower Paleozoic sequences in south Korea, the Choson Supergroup is distributed in five basins with different lithologic and paleontologic characteristics in each basin; namely, Duwibong Basin (Samcheog-Yeongweol Basin), Yeongweol Basin, Jeongseon Basin, Pyeongchang Basin, and Munkyeong Basin; the successions of these basins are identified herein as the Duwibong-Type sequence, Yeongweol-Type sequence, Jeongseon-Type sequence, Pyeongchang Basin-Type sequence, and Munkyeong-Type sequence, respectively, following Korean stratigraphic practice.

Kobayashi [19] divided the Choson Supergroup in the Duwibong-type sequence into 10 lithostratigraphic units, namely, the Jangsan Quartzite, Myobong Slate, Taegi Limestone, Hwajeol Formation, Dongjeom Quarzite, Dumugol Formation, Maggol Formation, Jigunsan Shale, and Duwibong Limestone in ascending order.

The Duwibong-Type sequence, is exposed widely in the central region which extends between 36° 52'30" and 37°07'30" N and between 128°15'00" and 128°37'30" E, located geographically in the Tanyang area in Chungcheongbuk-do, between the Samcheog and eastern Yeongweol areas in Kangweon-do.

Following Kobayashi's [18] study, many investigators [3, 11, 13–17, 21–23, 39, 42, 43] carry out geological studies of the Duwibong-Type Choson Supergroup of this area.

Especially, Kobayashi [18] reported 5 species of trilobite from Hynchunri and Gosuri of the Tanyang region. Seo, K. S. [39] divided the Gousung Limestone named by Won, J. K. and Lee, H. Y. [43] into the Hwajeol Formation, Jigunsan Shale and Duwibong Limestone on the basis of conodonts.

Kim, J. H. and Koh, H. J. [15] divided Won and Lee's [43] Chundongri Formation into the Hwajeol Formation and Dongjeom Formation.

This study aims to establish biostratigraphic zones in the Dumugol Formation through conodont study. This study also considers the biostratigraphic correlation between the conodont fauna from the Dumugol Formation in the Tanyang area and

previously described ones in North America, northern Europe, China, Australia, and elsewhere.

STRATIGRAPHY

The Duwibong-Type sequence in the Tanyang area is located in the eastern part of the Gakdong Thrust Fault ranged from the Yongweol to the Tanyang areas. The Yeongweol-Type sequence is distributed in the western part of the Gakdong Thrust Fault (Figure 1).

The Dumugol Formation of the Duwibong-Type sequence was named by Yamanari [44] after the

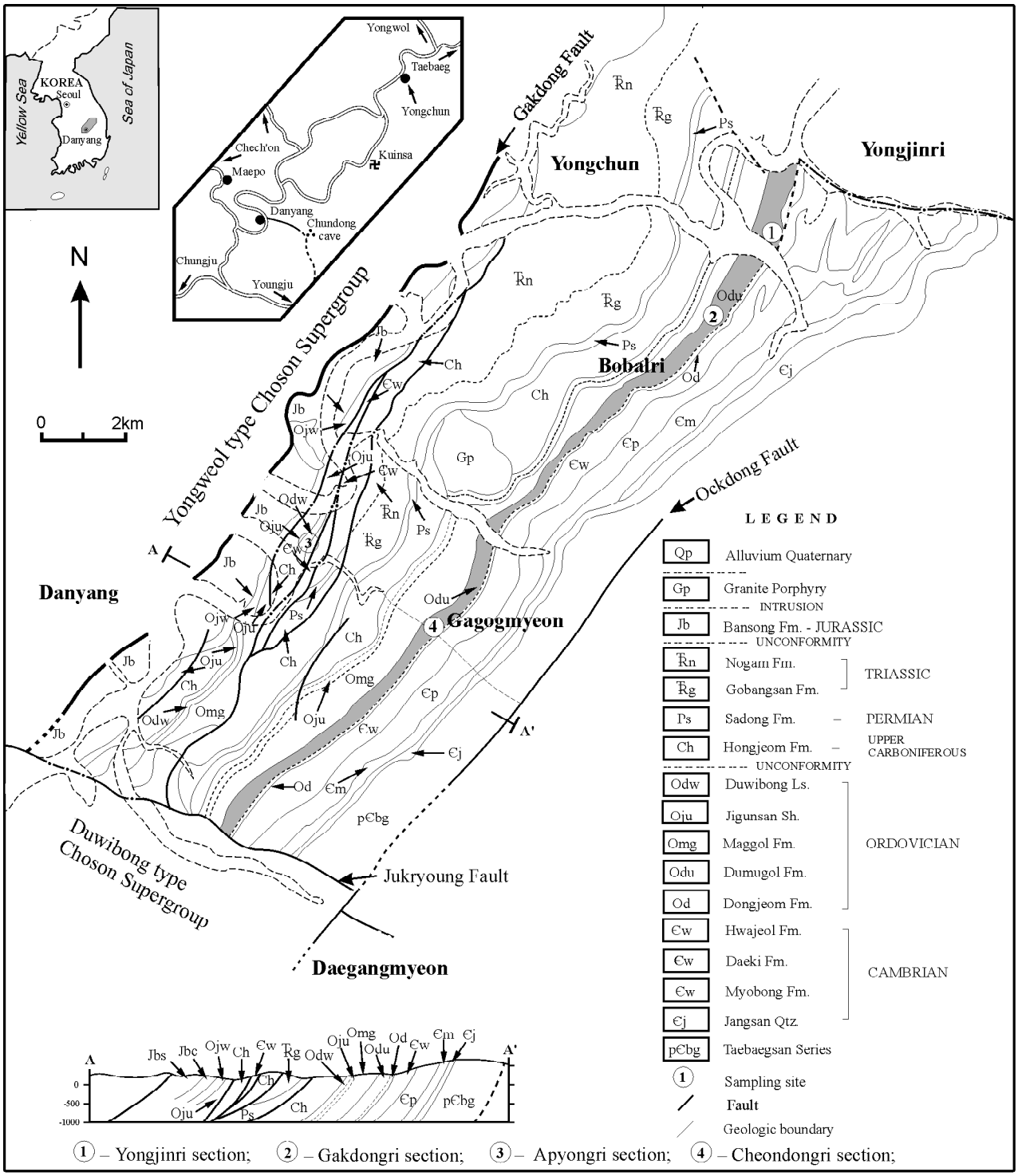

Fig. 1. Geologic map of the study area with conodont sampling localities.

geographic name of the stratotype section "Dumugol". The Dumugol Formation of the Tanyang area is southwesterly about 70 km from the Baegunsan Syncline Zone.

The Dumugol Formation overlies the Dongjeom Quartzite conformably. It underlies the Maggol Formation conformably. The Dumugol Formation consists mainly of shale and limestone. The shale is mostly calcareous and grey to greenish-grey, and is thinly laminated or bedded with intercalated shales. The upper part of the greenish-grey limestone with thin argillaceous beds marks the boundary between the Dumugol Shale and the Maggol Limestone in this study. The thickness of the Dumugol Formation varies between 250 and 300 m across. Son, C. M. and Cheong, C. H. [41] suggested, on the basis of the common alternation of shale and limestone beds, that the formation was deposited in a somewhat deeper environment than that of the underlying Dongjeom Quartzite. Kobayshi [19] established two fossil zones in this formation, namely the lower *Asaphellus* Zone and the upper *Protopliomerops* Zone, and stated that the formation is of Tremadocian age. Lee, H. Y. [24, 27] and Lee, H. Y. and Lee, J. D. [26], on the other hand, insisted that the formation is of Arenigian age based on conodonts. Seo. K. S. [38] insisted that the formation is Late Tremadocian through Early Arenigian of Europe based on conodont study. Choi, D. K. and Lee, Y. I. [4] compared the Dumugol Formation with the Tremadocian of Europe based on the invertebrate fossils.

SAMPLE LOCALITIES AND CONODONT OCCURRENCE

Samples for conodont study were collected from the four measured sections in Dumugol Formation of the study area. Locations of the sections in which samples were collected are shown in Fig. 1. The distribution of samples within the measured sections is provided on Fig. 2.

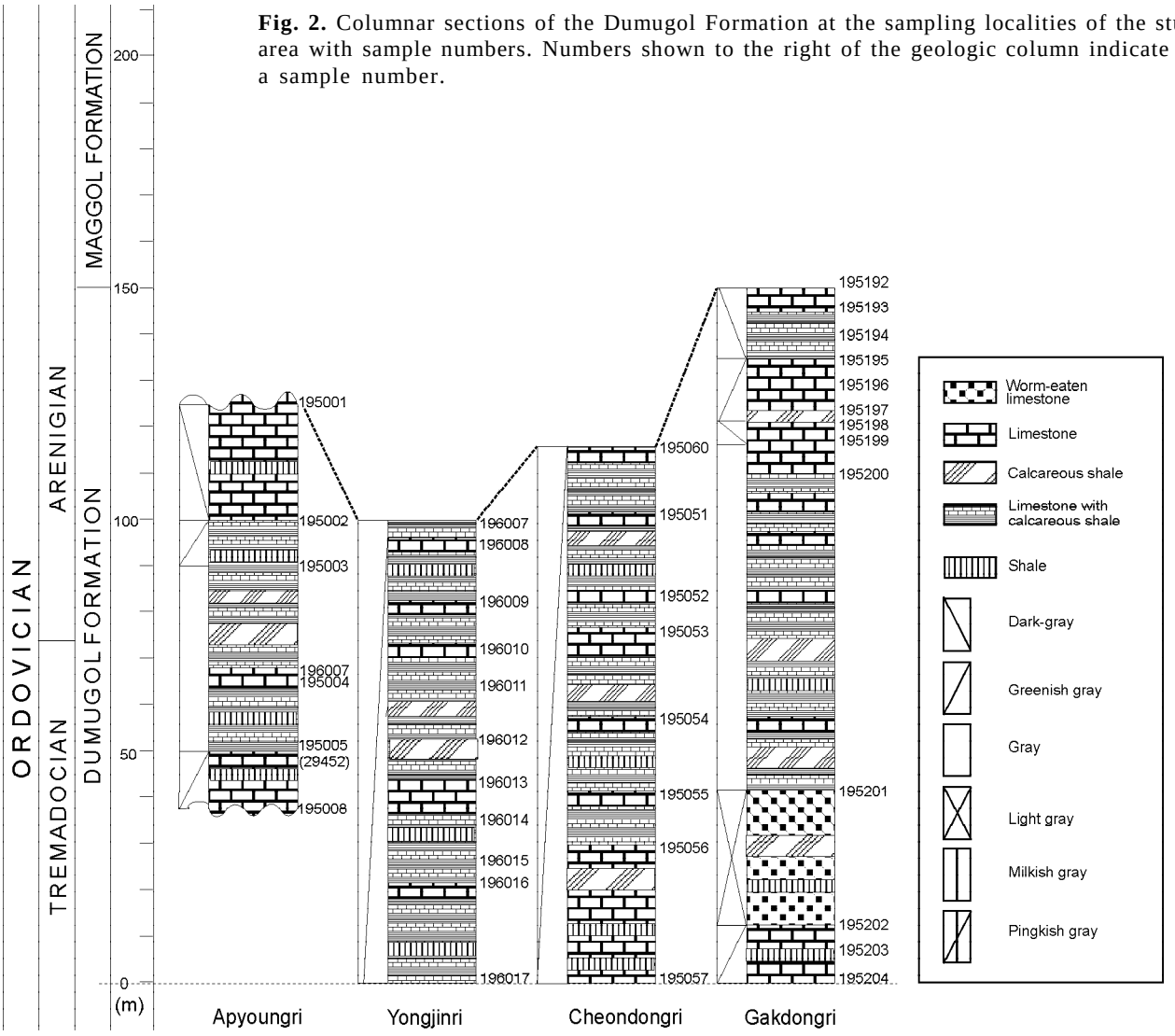

Fig. 2. Columnar sections of the Dumugol Formation at the sampling localities of the study area with sample numbers. Numbers shown to the right of the geologic column indicate the a sample number.

Samples of one kg were crushed to 2–3 cm pieces and dissolved by acetic acid (10–15% solution) for 14 days. After digestion of the matrix, the residue was caught on 100– and 200 mesh sieves and dried.

Conodonts were recovered from 21 of the 56 samples; the distribution of the taxa recovered from the measured sections is shown on Table 1. Most of the recovered conodonts are well preserved and are brownish black (5YR 2.5/1 to 2.5 YR 2.5/1 by Munsell Soil Color), displaying a color alteration index of 4–5 and indicating that these rocks have been heated to 300–400 degrees Celsius.

Elements represent 10 multielement species referable to 7 genera, and the remainder are identified with 13 form species of 9 genera.

Conodont fauna from the Dumugol Formation of the Tanyang area is as follows: *Acanthodus lineatus* (Furnish) , *Chosonodina herfurthi* Müller, *Drepanodus arcuatus* (Pander), *D.* cf. *concavus* (Branson et Mehl), *Drepanodus* sp. *Drepanoistodus basiovalis* (Sergeeva), *D. forceps* (Lindström), *D.*(?) *inaequalis* (Pander), *Glyptoconus quadraplicatus* (Branson et Mehl), *Juanognathus* sp., *Oistodus* cf. *selenopsis* Serpargli, *Paltodus* cf. *deltifer* (Lindström), *P.*(?) *parvus* An, *P. quinqecostatus* Müller, *Paroistodus* aff. *parallelus* (Pander), *Propanderodus leonardii*s Serpargli, *Scalpellodus tersus* Zhang, *Scandodus furnishi* Lindström, *Scolopodus bolites* Repetski, *S. filosus* Ethington et Clark, *S. gracilis* Ethington et Clark, *S. nogamii* Lee, *S.* cf. *pingquanensis, S. rex huolianzhaiensis* An et Xu, *Scolopodus longibasis* Seo et al., *Triangulodus dumugolensis* Seo et al., *Rossodus manitouensis* Repetski et Ethington, *Utahconus beimadaoensis* Chui et Zhang F., *Variabiloconus bassleri* (Furnish).

The Dumugol Formation is divided into four biozones based on conodont species identified in the several sections (Table 1). They are the *Chosonodina herfurthi – Rossodus manitouensis*, *Glyptoconus quadraplicatus*, *Paracordylodus gracilis*, and *Triangulodus dumugolensis* Zones in ascending order.

In this study four conodont zones were not established at only one section because of lack of conodonts. *The Chosonodina herfurthi – Rossodus manitouensis* Zone was established in the lower part of the Apyoungri Section in the Tanyang area. *The Glyptoconus quadraplicatus* Zone was established in the middle part of the Yongjinri Section and Cheondongri Section. *The Paracordylodus gracilis* Zone was established in the middle part of the Gakdong Section.

4. BIOSTRATIGRAPHIC CORRELATION

Acanthodus lineatus was reported from the Bule Earth Formation of Minnesota [10], from the Ice Fields Section of Alberta [7], Iran [32], from the Ninmaroo Formation of Australia [12], from westernmost Texas and southern New Mexico of North America [34], from the Fauna C of North America, and from Korea [38]. The fauna C of North America generally has been interpreted to be Late Tremadocian in age.

Chosonodina herfurthi was reported from Korea by Müller [31], from North America [6], from the Collier Formation of Arkansas and Oklahoma [8], from the El Paso Group of Texas [34], from the Ninmaroo Formation of Australia [5], from China [1, 2, 33], from the *Acanthodus – Chosonodina – Loxodus* Fauna of Europe [30], and from the Dumugol Formation of the Baegunsan Syncline Zone [38]. It is a representative species of Fauna C [6] in North America.

Rossodus manitouensis was reported by Repetski and Ethington [36], from Fauna C [6], from North America [20, 37], from Australia [5], from China [2], from the Dumugol Formation of Yongweol-Samchock in Korea [38].

Glyptoconus quadraplicatus was reported from the Oneota Formation of Mississippi valley by Furnish [10], from North America [9, 34, 35], from Australia [5], from South America [40], from Europe [29], from China [1, 2], and from the Dumugol Formation of the Baegunsan Syncline Zone in Korea [25, 28, 39]. This is a representative species of *Glyptoconus quadraplicatus* Zone of Dumugol Formation in the Baegunsan Syncline Zone of Korea [38].

Triangulodus dumugolensis is firstly reported from the Dumugol Formation in the Baegunsan Syncline Zone of Korea by Seo, et al. [38]. They firstly established the *Triangulodus dumugolensis* Zone within the Dumugol Formation of the Baegunsan Syncline Zone in based this species. Seo et al. [38] interpreted this zone of the Baegunsan Syncline Zone to Arenigian in age.

In this study *Paracordylodus gracilis* is not yielded from the Dumugol Formation of Tanyang area. Seo et al. [38] established *Paracordylodus gracilis* Zone at the Dumugol Formation in the Baegunsan Syncline Zone of Korea. However, conodont fauna from this zone of Tanyang is similar to that of the Dumugol Formation in the Baegunsan Syncline Zone.

We established *P. gracilis* Zone in the Dumugol Formation in Tanyang area based on conodont fauna in this study. Seo et al. [38] interpreted this zone of the Baegunsan Syncline Zone to be Arenigian in age.

Considering the above statements collectively, the biozones of Dumugol in the Tanyang Area are

Table 1. Distribution and abundance of conodonts from the productive samples of the Dumugol Formation in the Tanyany area, South Korea.

Species \ Sample No.	Gakdong Section										Choendon. Sec.				Yongj. Sec.			Apyong Sec.				Total
	195194	-195	-196	-197	-199	-201	-202	-203	-205	-206	K	195052	-053	-054	196007	196010	195001	294045	294046	294052	195005	
Conodont zone	*P. gracilis*				*T. dumugolensis*						*G. quadraplicatus*				*G. quadra-plicatus*			*C. herfurthi–R manitouensis*				
Acanthodus lineatus																				3	2	5
Chosonodina herfurthi																				3	2	5
Glyptoconus quadraplicatus																		2	2			4
Oistodus cf. *selenopsis*				4	3	1				12												20
Paroistodus aff. *parallelus*																						
drepanodiform el.	2																					2
oistodiform el.	7																					7
Scolopodus rex houlianzhaiensis																						
symmetrical el.	2		1	1	4	5					1				1							15
asymmetrical el.		1		1						7					1							10
Triangulodus dumugolensis					2				1									2				5
Scalpellodus tersus																						
acontiodiform el												1						5				5
drepanodiform el.																		7		1		8
scandodiform el.																		4				5
Scandodus furnishi			4													2	1	1				8
Scolopodus bolites																						
symmetrical el.												2										2
Scolopodus cf. *pingquanensis*					2																	2
Scolopodus nogamii						7	1		1	15	1											25
Scolopodus filosus											1											1
Scolopodus longgibasis																						
asymmetrical el.							3															3
symmetrical el.				1			1															2
Paltodus cf. *deltifer*																				5		5
Paltodus (?) *parvus*								5	1													6
Paltodus quinquecostatus													4					1				5
Propanderodus leonardii					4																	4
Drepanodus cf. *concavus*																		*2*				*2*
Drepanodus arcuatus																						
drepanodiform el.							5						6	1			1					13
acontiodiform el.							2					1	3									6
scandodiform el.							1						3				1	1			1	7
Drepanoistodus basiovalis																						
drepanodiform el..																	1	1				2
oistodiform el.																9		1				10
suberectifom el.																1		1				2
Drepanoistodus forceps																						
oistodiform el.																	4					4
drepanodiform el.																	5					5
subectidontiform el.																	6					6
Drepanoistodus inaequalis																						
oistodiform el.																				2		2
acodiform el.																				1	1	2
Juanognathus sp.								1														1
Rossodus manitouensis																						
acontiodiform el.																			4	1	1	6
drepanodiform el.																			3	1	1	5
oistodiform el.																			1	1	2	4
Utahconus beimadaoensis																						1
drepanodiform el.													1									2
acodiform el.													2									
Variabiloconus bassleri												1		1	5		1	1		2		11
T O T A L	11	1	5	7	15	13	13	6	3	34	3	5	19	2	7	12	20	29	10	20	10	245

correlated with the *Chosonodina herfurthi – Rossodus manitouensis* Zone through the *Triangulodus dumugolensis* Zone of the Dumugol Formation in the Baegunsan Syncline Zone, with the *Cordylodus rotundatus – Acodus oneotensis* Zone through the *Scalpellodus tersus* Zone in North China, with Fauna C through the *Oepikodus communis* Zone of North America, with the *Cordylodus rotundatus* Zone through the *Oepikodus evae* Zone in the North Atlantic Province, with the *Chosonodina herfurthi – Acodus* Zone through the *Drepanodus gracilis–Scolopodus sexplicatus* Zone in Australia. Biostratigraphic correlation between the conodont fauna from the Dumugol Formation of Tanyang and the previously described ones for other continents is shown in Fig. 3. Dumugol Formation in Tanyang is Late Tremadocian through Early Arenigian of Europe, Late Ibexian through Canadian of North America in age.

CONCLUSION

1. Of 56 rock samples collected from four sections in the Dumugol Formation, 21 yielded 245 identifiable conodont specimens.

2. The conodonts are assigned to 10 multielement species referable to 7 genera and 13 from species belonging to 9 form genera.

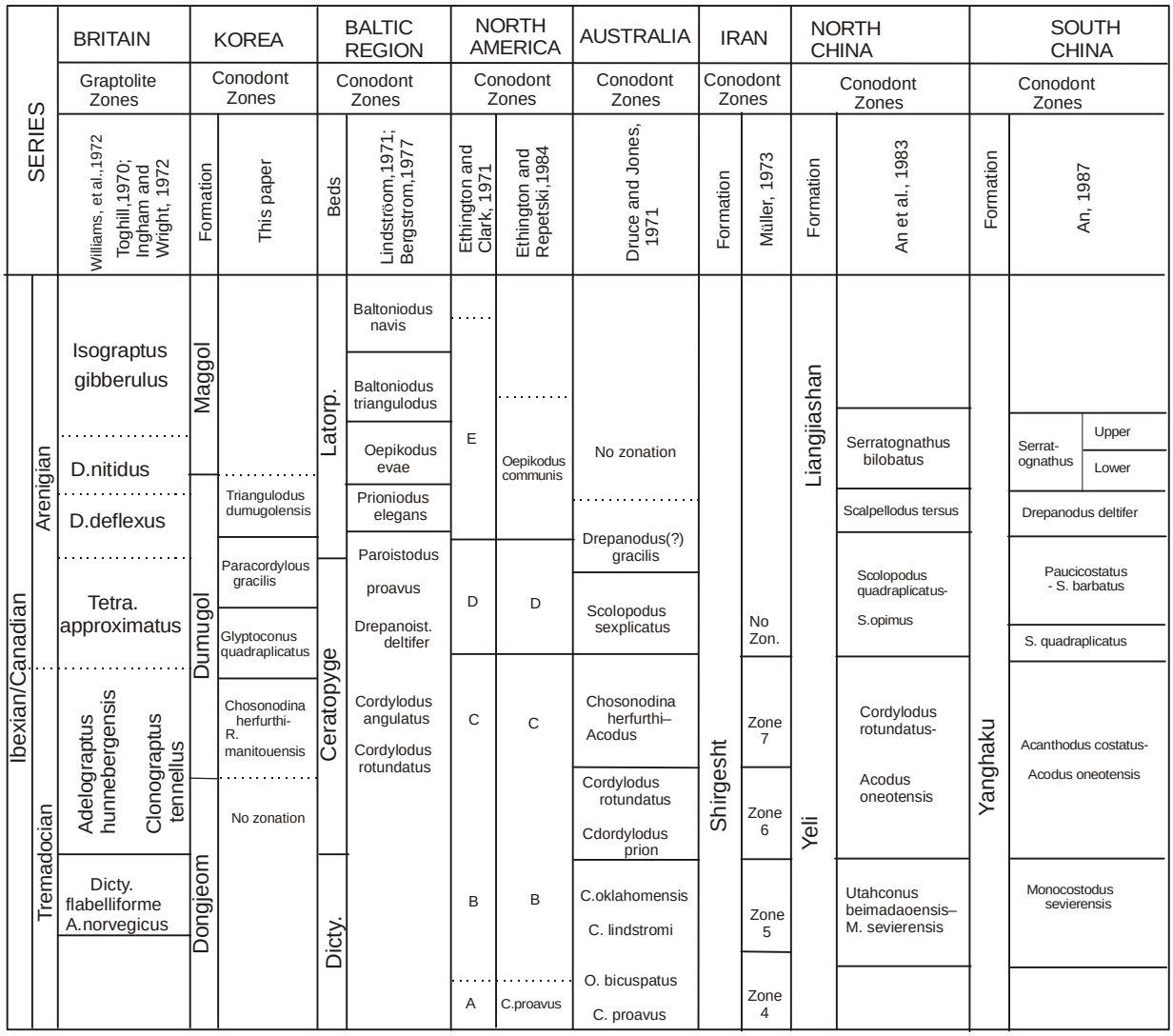

Fig. 3. Intercontinental correlation of conodont and graptolite assemblage zones in the Upper Tremadocian and Lower Arenigian.

Fig. 4.

Fig. 5.

Fig. 4. Sample numbers from which the specimens were obtained are given in parentheses.

1–2 – *Canthodus lineatus* (Furnish, 1938), lateral views of both, 1– KUG0038(N008), ×110, KUG00231(195005), ×80; 3 – *Chosonodina herfurthi* Müller, 1964. Lateral view, KUG00426(A95030), ×80; 4–6 – *Rossodus manitouensis* Repetski et Ethington, 1983. Lateral views of all, 4 – acontiodiform el., KUG00219 (294046), ×100, 5 – drepanodiform el., KUG00226(294052), ×100, 6 – oistodiform el., KUG00231(195005),×100; 7 – *Scalpellodus tersus* Zhang, 1983. Lateral view of scandodiform el., KUG00259(195053), ×80; 8 – *Utahconus beimadaoensis* Chui et Zhang F. 1983. Lateral view of drepanodiform el., KUG00259(195053), ×100; 9–11 – *Scolopodus longibasis* Seo et al., 1994. Lateral views of all, 9 – symmetrical el., KUG00405(195202), ×80, 10 – asymmetrical el., KUG00405(195202), ×120, 11 – symmetrical el., KUG00405(195202), ×100; 12 – *Paltodus quinquecostatus* Müller, 1964. Lateral view, KUG00404(195201), ×35; 13 – *Scolopodus rex huolianzhaiensis* An et Xu, 1983. Lateral view of symmetrical el., KUG00409(195206), ×35; 14 – *Variabiloconus bassleri* (Furnish). Lateral view, KUG00451(196007), ×80; 15 – *Scolopodus nogamii* Lee, 1975. Lateral view, KUG00408(195205), ×150; 16 – *Scolopodus bolites* Repetski, 1982. Posterior view of symmetrical el., KUG00258(195052), ×120; 17, 22, 23 – *Drepanoistodus* (?) *inaequalis* (Pander, 1856). Lateral views of all, 17 – oistodontiforrm el., KUG00226(294052), ×35, 22 – acontiodiform el., KUG00226(294052), ×100, 23 – acodiform el., KUG00231(195005), ×80; 18 – *Glyptoconus quadraplicatus* (Branson et Mehl, 1933). Lateral view, KUG00219(294046), ×80; 19 – *Triangulodus dumugolensis* Seo et al., 1994. Lateral view of acontiodiform el., KUG00398(195195), ×80; 20 – *Drepanodus* sp., lateral view, KUG00405(195202), ×35; 21 – *Scolopodus filosus* Ethington et Clark, 1964. Lateral view, KUG0026(K), ×80; 24 – *Scandodus furnishi* Lindström, 1955. Lateral view, KUG00399(195196), ×100; 25 – *Paltodus quinqecostatus* Müller, 1964. Lateral view, KUG00259(195053), ×80; 26 – *Scolpodus gracilis* Ethington et Clark, 1964. Lateral view, KUG00405(195202), ×120,

Fig. 5. Sample numbers from which the specimens were obtained are given in parentheses.

1–3 – *Drepanoistodus forceps* Lindström, 1955. Lateral views of all, 1– drepanodiform el., KUG00227 (195001), ×100, 2 – oistodiform el., KUG00227 (195001), ×100, 3 – suberectiform el., KUG00227 (195001), ×100; 4–5, 9–10 – *Drepanodus arcuatus* (Pander, 1856). 4, 10 – lateral views of drepanodontiform el., KUG00259 (195053), ×80 5 – lateral view of acontiodiform el., KUG00259(195053), ×80, 9 – lateral views of scandodontiform el., KUG00259 (195053), ×80; 6, 7 – *Paroistodus* aff. *parallelus* (Pander, 1856). Lateral views of all, *6*, oistodiform el., KUG00397 (195194), ×80, 7 – drepanodiform el., KUG00397 (195194), ×100; 8, 11–13, 16 – *Drepanoistodus basiovalis* (Sergeeva, 1963). Lateral views of all, 8 – suberectiform el., KUG00454 (196010), ×80, 11–13 – oistodiform el., KUG00454 (196010), KUG00454 (196010), KUG00454(196010), ×80, 16 – drepanodiform el., KUG00217 (294045), ×80; 14 – *Drepanodus* sp. Lateral view, KUG00217 (294045), ×80; 15 – *Drepanodus* cf. *concavus* (Branson et Mehl, 1933). Lateral view, KUG00217 (294045), ×80; 17–18 – *Paltodus* (?) *parvus* An, 1983. Lateral view of all, KUG00406 (195203), ×80; 19 – *Paltodus* cf. *deltifer* (Lindström, 1971), lateral view, KUG00226 (294052), ×50; 20, 22 – *Drepanodus* sp. Lateral views of all, KUG00226 (294052), ×50; 21 – *Oistodus* cf. *selenopsis* Serpargli, 1974. Lateral view, KUG00409 (195206), ×50; 23 – *Propanderodus leonardii*s Serpargli, 1974. Lateral view, KUG00402 (195199), ×50.

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3. Four biostratigraphic zones are recognized in the Dumugol Formation, viz, *Chosonodina herfurthi–Rossodus manitouensis*, *Glyptoconus quadraplicatus*, *Paracordylodus gracilis*, and *Triangulodus dumugolensis* Zones in ascending order.

4. The biozones of the Dumugol Formation are correlated with the *Cordylodus rotundatus – Acodus oneotensis*, *Scolopodus quadraplicatus – S. opimus*, and *Scalpellodus tersus* Zones in North China, with the *Cordylodus angulatus*, *Drepanoistodus deltifer*, *Paroistodus proteus*, *Prioniodus elegans*, and *Oepikodus evae* Zones in the North Atlantic Province, with the middle of Fauna C through the *Oepikodus communis* Zone of North America, and with the *Chosonodina herfurthi – Acodus* and *Drepanodus*(?) *gracilis – Scolopodus sexplicatus* Zones in Australia.

5.The Dumugol Formation in Tanyang is Late Tremadocian through Early Arenigian of Europe, Late Ibexian through Canadian of North America in age.

6. Conodonts are brownish black (5YR 2.5/1 to 2.5YR 2.5/1 in Munsell Soil Color), showing conodont Color Alteration Index value of 4–5, which indicates a thermal exposure of 300–400°C.

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Конодонты из формации Думголь области Даньянг, провинция Чунгчонгбукдо, Южная Корея

Данные исследования заключаются в выяснении геологического возраста формации Думголь в области Даньянг на основе конодонтов. Всего в 56 образцах было обнаружено 245 конодонтов. Они классифицируются как 7 мультиэлементных видов, относящихся к 10 родам, и 9 формальных видов принадлежат к 13 родам. Формация Думголь биостратиграфически разделяется на четыре конодонтовых зоны, viz, *Chosonodina herfurthi – Rossodus manitouensis, Glyptoconus quadraplicatus, Paracordylodus gracilis,* и *Triangulodus dumugolensis* в порядке омоложения. Формация Думголь с помощью конодонтов коррелируется с одновозрастными отложениями области Бэгунсанской синклинали, а также с геологическими образованиями северного Китая в стратиграфическом интервале от зоны *Cordylodus rotundatus – Acodus oneotensis* до зоны *Scalpellodus tersus,* в Северной Америке - от фауны С до фауны Е, Балтийского региона - от зоны *Cordylodus rotundatus* до зоны *Oepikodus evae,* Австралии – от зоны *Chosonodina herfurthi - Acodus* до зоны *Drepanodus gracilis – Scolopodus sexplicatus.*

Формация Думголь имеет возраст поздний тремадок - ранний аренигий по европейской классификации, и поздний ибексий - ранний канадий - по североамериканской.

Большинство полученных конодонтов имеют хорошую сохранность. По цвету они коричневато-черные (5YR от 2.5/1 до 2.5 YR 2.5/1 по определению Munsell Soil Color), при индексе цветового изменения 4–5, что указывает на температуру нагрева этих пород порядка 300–400°C.