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Graptolites from the Jigunsan Shale of Taebaeg Area, Korea

Jeong Yul Kim[1]*, Ji Yeun Kwon[1], Kyung-Soo Kim[2] and Hyun Su Cho[1]

[1]Department of Earth Science Education, Korea National University of Education, Cheongwon, Chungbuk, 363-791, Korea
[2]Chungbuk Science High School, Sangya, Gaduck, Cheongwon, Chungbuk, 363-853, Korea

Abstract: Five species of graptolites were discovered from the Jigunsan Shale of Taebaeg area, Korea. They are herein described as *Archiclimacograptus nicklellensis* (Harris, 1924), *Pseudamplexograptus distichus* (Eichwald, 1840), *Hustedograptus teretiusculus* (Hisinger) sensu Jaanusson, 1960, *Hustedograptus nikarjensis* (Jaanusson, 1960), and *Hustedograptus* sp. The graptolite assemblage from the Jigunsan Shale corresponds to those of the *Pseudamplexograptus distichus* zone in the Baltic and German areas and the geologic age of graptolites bearing beds of the Jigunsan Shale might be late Middle Llanvirn.

Keywords: graptolite, Ordovician, Jigunsan Shale, Taebaeg, Korea

Introduction

The graptolites lived from the Middle Cambrian to the Upper Carboniferous are colonial and marine organisms. Of them, graptoloid has obvious morphological changes through geological time, they have been used as a good index fossil in the Lower Paleozoic (Cooper et al., 1991).

For the first time Shiraki (1922) found out a piece of graptolite in Korea. Subsequently some Japanese geologists reported graptolites from the Joseon Supergroup of Duwibong and Yeongweol types (Kobayashi, 1934; Shimizu and Obata, 1935; Kobayashi and Kimmura, 1942). Most studies of these graptolite studies, however, did not show any systematic descriptions and illustrations.

Recently some investigators have been studying on the graptolites systematically. Jin and Kim (2000) studied on the Early Ordovician graptolites from the Joseon Supergroup of Yeongweol type. Jin (2002) reported nineteen species belonging to six genera indicated the Early Tremadoc from the upper part of the Mungok Formation of Yeongweol area. Subsequently early Ordovician graptolites have been described from the Mungok Formation (Cho, 2003; Choi, 2003; Kim et al., 2003).

However, the Middle Ordovician graptolites have never been studied systematically in Korea in spite of an initial report on them more than sixty years ago. The purpose of this study is to describe and identify the graptolites from the Middle Ordovician Jigunsan Shale, to correlate the graptolite assemblage with those of other countries, and to estimate the geologic age of the graptolite bearing beds of the Jigunsan Shale.

Geological Setting

The lower Paleozoic strata of the Joseon Supergroup are well exposed in the southern rim of the Baegunsan Syncline which trends east-west in the southern part of the Taebaegsan Basin (Chough et al., 2000). The Joseon Supergroup can be divided into five lithologic units: the Taebaeg, Yeongweol, Yongtan, Pyongchang, and Mungyong groups (Choi, 1998).

The Jigunsan Shale is the ninth formation of the Joseon Supergroup of the Taebaeg unit, conformably rests on the Maggol Limestone. This formation is 50 to 100 m in thickness, consists mainly of dark gray shale. Kobayashi (1966) reported various fossils such as cephalopods, trilobites, gastropods,

*Corresponding author: kimjy@knue.ac.kr
Tel: 82-43-230-3720
Fax: 82-43-232-7176

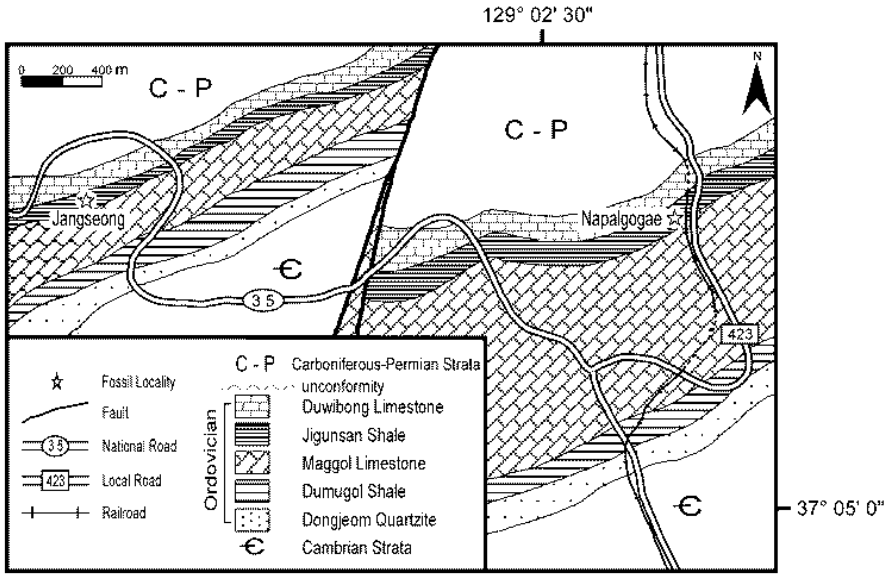

Fig. 1. Geological map of the study area and fossil localities (after Paik, 1986; Kim, 1992).

and graptolites from the Jigunsan Shale. He interpreted that the Jigunsan Shale would be correlated with the Llandeilian in the European formations and the Chazyan in the American one (Kobayashi, 1966).

Lee et al. (1980) reported 10 species of trilobites from the Jigunsan Shale and suggested that this formation would be the Llandeilian to the lower Caradian in age. On the basis of 12 species of conodont fossils from the Jigunsan Shale, Lee and Choi (1992) established *Eoplacognathus suecicus - E. Jigunsanensis* Zone in the middle and upper parts of the Jigunsan Shale, and suggested this zone has closer relationship to that of North China.

In this study, graptolite specimens were collected from the Jigunsan Shale of Napalgogae and Jangseong sections (Fig. 1). The Napalgogae section is located in the Dongjeom, Taebaeg areas and is exposed at the side of a railroad tunnel along the local road 423. The graptolites bearing bed composed of black shale is present at 16 m above the base of the section. The Jangseong section is located at Jangseong, Taebaeg. The Jigunsan Shale is merely exposed about 5 m in this section. Fossils were collected from the bed which is located about 16 m above the Maggol Limestone. This bed is 12 cm thick and it is composed of black shale (Fig. 2).

Terminology

The terms about graptolites used herein follow those of Jaanusson (1960), Bulman (1970), and Maletz (1997) (Fig. 3).

Apertural spine: projection originating on margin of aperture

Distal: last-formed part (of stipe, theca, etc) farthest away from point of origin

Free ventral wall: part of the thecal ventral wall not forming the interthecal septum

Median septum: partition in biserial graptoloids separating two series of thecae

Proximal: first-formed portion (of rhabdosome, stipe, theca, etc) nearest point of origin

Rhabdosome: sclerotized exoskeleton of entire graptolite colony

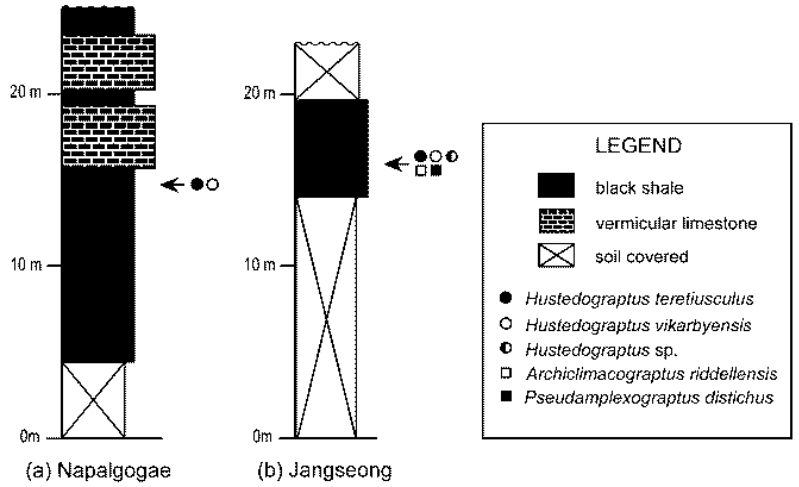

Fig. 2. Stratigraphic column of the Napalgogae and Jangseong sections showing graptolite beds.

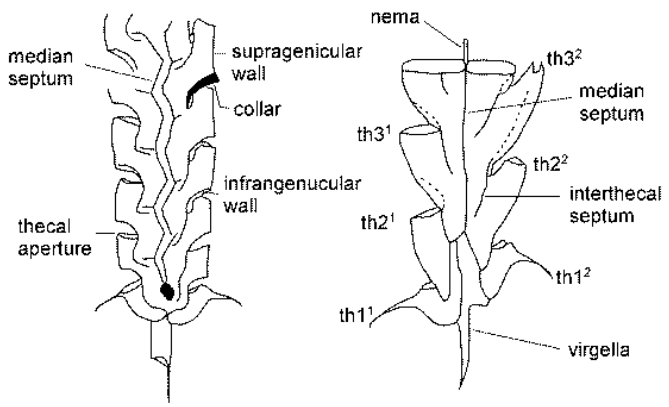

Fig. 3. Graptolite terminology (after Maletz, 1997).

Theca: sclerotized tube or cup enclosing any zooid of rhabdosome (other than sicula)

Virgella: spine developed during growth of metasicula, embedded in sicula wall and projecting freely from its apertural margin

Systematic Paleontology

All materials treated in this study are housed in the Paleontological Laboratory of the Department of Earth Science Education, Korea National University of Education.

Class Graptolithinia Bronn, 1846
Order Graptoloidea Lapworth, 1875
Suborder Diplograptina Lapworth, 1873
Family Diplograptidae Lapworth, 1873
Subfamily Diplograptinae Lapworth, 1873
Genus *Archiclimacograptus* Mitchell, 1987

Type species: *Pseudoclimacograptus angulatus sebyensis* Jaanusson (1960).

Diagnosis: Species have broadly rounded proximal end and pattern C astogeny. The complete

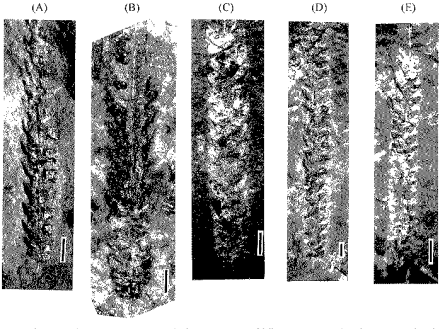

Fig. 4. Graptolites from the Jigunsan Shale. (A) *Archiclimacograptus riddellensis*, (B) *Pseudomplexograptus distichus*, (C) *Hustedcograptus teretiusculus*, (D) *Hustedograptus vikarbyensis*, (E) *Hustedograptus* sp. Scale bars indicate 1 mm.

median septum is straight to sharply zigzag shaped. Thecae with introverted aperture due to ventral apertural lips with lateral lobes, but lobes reduced in some species. Th1[1] and th1[2] bear a subapertural to apertural spine (Maletz, 1997).

Remarks: *Archiclimacograptus* is close to *Undulograptus*, especially to *Undulograptus primus* Legg (Mitchell, 1994). *Undulograptus* has a pattern U astogeny. The proximal development pattern C of *Archiclimacograptus* is a derived character, closely related to the more complex pattern U astogeny in *Undulograptus* (Maletz, 1997). *Undulograptus* and *Archiclimacograptus* have identical rhabdosome and thecal characters. Differences between the two genera are seen in the doubly sigmoid curvature of the thecae in *Undulograptus* in contrast to the shorter and simpler style in *Archiclimacograptus* (Maletz, 1997).

Archiclimacograptus riddellensis (Harris, 1924)
Fig. 4A

Holotype: The specimen occurred from southern land, Sweden (Jaanusson, 1960).

Diagnosis: *Archiclimacograptus* with strong lateral lobes and conspicuous widening of the rhabdosome distally (Maletz, 1997).

Material: JS102 (5)

Description: The rhabdosome is 7.19 mm in length. There are 8 thecae in the first 5 mm and 7 thecae in the 5 mm distally. The proximal width is 0.96 mm, increasing to a distal value of 1.48 mm. The rhabdosome widens somewhat slowly in the proximal end, but distinct around at th6. The proximal end is almost symmetrical and blunt. It has a conspicuous virgella of 0.37 mm in length. Two conspicuous subapertural spines are present on th1[1] and th1[2]. The infragenicular wall and suprageniculare wall are similar to their length. The suprageniculare wall is slightly convex in the proximal part, but becomes slightly straight near the distal part. The

genicular collar structures are present.

Remarks: *Archiclinacograptus riddellensis* is a synonym of *Pseudoclinacograptus angulatus sebyensis* from the Grey Seby Limestone, land (Maletz, 1997). Merely the rhabdosome of *A. riddellensis* is larger than that of *P. angulatus sebyensis*. Material described herein is identical to the *P. angulatus sebyensis* described from the Grey Seby Limestone of land area, although this material is smaller than the *A. riddellensis* (Jaanusson, 1960). Therefore this material could be regarded as *A. riddellensis*.

Genus *Pseudamplexograptus* Mitchell, 1987

Type species: *Lonnatoceras distichus* Eichwald, 1840.

Diagnosis: Species have nearly parallel-sided rhabdosome. These have taxonomy with broadly rounded proximal end and pattern C astogeny. The supragenicular wall is short and commonly has similar height to that of the thecal excavation (Mitchell, 1987). The median septum is sharply zigzag to straight, usually without distinct protheceal septa. $Th2^1$ generally is a dicalycal and with the region between the metatheca of $th1^1$ and $th1^2$ on the reverse side occupied by an exposed patch of the right-handed crossing canal of $th2^1$ flanked or enclosed by the protheceae of both $th3^1$ and $th2^2$. Infragenicular wall and thecal aperture are inclined towards the rhabdosome midline. $Th1^1$ and $th1^2$ have straight apertures and apertural spines (Maletz, 1997).

Remarks: The genus *Pseudamplexograptus* has been proposed by Mitchell (1987, p. 386) for archaic amplexograptus-like species of diplograptids included in *Amplexograptus*. The proximal structure of this genus is identical to that of *Archiclinacograptus* and *Haddingograptus* (Maletz, 1997). However, *Pseudamplexograptus* is distinguished from *Archiclinacograptus* in the style of the theceae, lacking the distinct ventral lip, and from *Haddingograptus* in a more highly inclined infragenicular wall (Maletz, 1997). *Pseudamplexograptus distichus* (Eichwald, 1840) resembles in general outline to *Clinacograptus bicornis*. However, they are different in the type of proximal development. The proximal development of *P. distichus* is the streptoblastic type (pattern C primordial astogeny) but those of *C. bicornis* is the prosoblastic type (pattern D primordial astogeny) (Riva and Ketner, 1989).

Pseudamplexograptus distichus (Eichwald, 1840)
Fig. 4B

Lectotype: The specimen figured by Eichwald (Jaanusson, 1960, pl. 5, Fig. 5). This comes from Lasnamägi Stage (C1b), Estonia, Osmussaar (Odinsholm) (Jaanusson, 1960).

Material: JS102 (4)

Diagnosis: The both sides of rhabdosome run parallel. The initial width of the rhabdosome is about 1.3 mm, and is widening gradually to 1.6 mm in the first 5 mm. After that it widens remarkably constantly. The numbers of theceae are 14-15 in the first 10 mm. Theceae have strong sigmoidal curvature and about half freeventral edge parallel to the rhabdosome axis. This species has the broad proximal end (Bulman, 1932).

Description: The rhabdosome length is 8 mm. The width of the rhabdosome is 0.95 mm at the proximal end and 1.60 mm at the distal part. The rhabdosome wides slowly and width of rhabdosome is almost constant near the distal part. There are 9 theceae in the first 5 mm.

The median septum is somewhat undulating, although the median septum is seen only in the proximal part. The intertheceal septum is developed from the proximal part (at th3) and is touched with the median septum. The proximal end is symmetrical to sub-symmetrical and bears three proximal

spines. One spine is a conspicuous virgella, which length is very short, 0.29 mm. The others are apertural spines on th1[1] and th1[2]. They are very short and their length resembles the virgella one. The infragenicular wall is slightly concave. The supragenicular wall is straight and parallel to the rhabdosome axis. The rhabdosome runs parallel-sided.

Remarks: The thecal style of *Pseudamplexograptus distichus* is similar to that of *Archiclimacograptus riddellensis*. Differences can be seen in the shorter, wider, and the simple outward inclined thecae in *Pseudamplexograptus* (Maletz, 1995). Most of the proximal end of *Climacograptus orthoceratophilus* figured by Bulman (1932) apparently belongs to young rhabdosome. *C. orthoceratophilus* has slender short spines and the theeal apertures of th1[1] and th1[2] approximately equal in size to those of succeeding thecae (Jaanusson, 1960). In contrast to *C. orthoceratophilus*, *C. distichus* (now *P. distichus*) mentioned by Jaanusson has stout spines and stout virgella which is 0.6 mm in length. There are 7 thecae in the first 5 mm in the rhabdosome of *C. distichus*. As *Pseudamplexograptus distichus* described herein has short and slender spines, short virgella, and a little number of thecae in the first 5 mm, this material could be regarded as a young rhabdosome.

Suborder Diplograptina Lapworth, 1873
Family Orthograptidae Mitchell, 1987
Subfamily Orthograptinae Mitchell, 1987
Genus *Ihastedograptus* Mitchell, 1987

Type species: *Diplograptus uplandicus* Wiman (1895) from the *Chasmops* Limestone of Upland, Sweden.

Diagnosis: Thecae have smoothly sigmoidal glyptograptid type in the proximal end, becoming orthograptid type distally. Theeal apertures are normal, or slightly introverted with prominent paired cusps or spines on lateral margin and with concave ventral apertural margin. Median septum is straight with dicalyeal th2[1] or substantially delayed. Primordial astogeny follows pattern A but with short descending portion in crossing canal of th2[1]. Proximal end is broad and weakly to markedly asymmetric form. Sicula with simple aperture, or aperture bearing paired lappets, of antivirgella spines flanking concave dorsal margin (Mitchell, 1987).

Remarks: Primordial development of *Ihastedograptus* species shows a pattern A astogeny with th2[2] as the dicalyeal theca. The proximal end is supplied with apertural to subapertural spines at th1[1] and th1[2]. In the closely related genus *Eoglyptograptus* spines may be missing, except for the virgella, but a subapertural spine is often present on th1[1] (Maletz, 1997).

Ihastedograptus teretiusculus (Hisinger) sensu Jaanusson, 1960
Fig. 4C

Diagnosis: *Ihastedograptus* species without antivirgella spines. Proximal end is strongly asymmetrical and slender. Rhabdosome widens distinctly from the proximal end. It has a pattern A astogeny. Theeal apertures have very slight lateral elevations (Maletz, 1997).

Material: JS103 (1)

Description: The length of the rhabdosome varies from 2.6 mm to 9.0 mm. The width of the rhabdosome is around 0.9-1.1 mm at the proximal end, is becoming 1.3-1.6 mm at the fifth theeal pair. The width at the distal part is nearly 1.4-1.9 mm. The individual width is variable but widening of material is very prominent all together. There are 7.5-8.0 thecae in the first 5 mm. The proximal end is strongly asymmetrical and narrow. The level of th1[1] and th1[2] is remarkably different. Generally conspicuous subapertural spines are present on th1[1] and th1[2]. But only subapertural spine is on th1[1] in such a

poorly preserved condition case. The proximal end has a slender virgella, which length is nearly 0.5 mm. Thecae form is glyptograptid in the proximal end, becoming orthograptid distally. The ventral wall of the metatheca is convex about halfway along its length, and the suprageniecular wall inclined outward slightly in the proximal end. The other side, the ventral wall of the metatheca becomes straighter toward the distal part. The length of the suprageniecular wall is longer than that of the infrageniecular wall near the distal part. The both sides of the rhabdosome do not run parallel. In some specimens the median septum is seen, it seems to be straight, but it is not continuous.

Remarks: *Ihustedograptus* is very similar to *Undulograptus* (the genus *Eoglyptograptus* could be regarded as a synonym of *Undulograptus*: Maletz and Mitchell, 1995). The morphologies of thecae, glyptograptid in the proximal end becomes orthograptid distally, are the same in *Ihustedograptus* and *Undulograptus*. The differentiation is seen in the proximal end. Although the proximal end has three spines in genera, one virgella and two subapertural or apertural spines, proximal end is somewhat slender in *Undulograptus*. The rhabdosome widens slowly in the *Undulograptus*, but it widens rapidly in the *Ihustedograptus*. The specimens described herein could be *U. dentatus* because materials have asymmetrical proximal end and thecal morphologies identical with that of *Undulograptus*. However, these materials have identical characters with *H. teretiusculus* in somewhat broad proximal end and rapidly widening rhabdosome. Therefore these specimens are assignable to *H. teretiusculus* rather than *U. dentatus*.

Ihustedograptus vikarbyensis (Jaanusson, 1960)
Fig. 4D

Diagnosis: *Ihustedograptus* species without antivirgella spines. Proximal end is symmetrical, comparably wide. Rhabdosome widens slowly from the proximal end. Pattern A astogeny. Thecal apertures with ventral lip (Maletz, 1997).

Material: JS102 (5)

Description: These specimens have long rhabdosome in general. The proximal width is 0.9-1.0 mm and the width at the fifth thecal pair is 1.3-1.5 mm. The width of the distal part ranges from 1.3 mm to 1.8 mm. The rhabdosome widens somewhat gradually from the proximal end to the distal end, and is nearly uniform after around th7-th8. There are 7.5-9.5 thecae in the first 5 mm, especially 8 thecae is abundant.

The proximal end is symmetrical. There are three spines, two subapertural spines on $th1^1$ and $th1^2$, and one virgella. The virgella is short, about 0.3-0.5 mm in length. Two subapertural spines on $th1^1$ and $th1^2$ are very short like virgella. Some specimens have a structure that is a right angle between virgella and subapertural spine. In other specimens, two subapertural spines tend to incline downward and they are very delicate. The thecal morphologies of *H. vikarbyensis* are identical with those of the *H. teretiusculus*. The ventral wall of the metatheca is convex in the proximal end and is straighter distally. The thecal apertures often widen due to partial flattening of the specimens. The both sides of the rhabdosome run roughly parallel. The median septum and intertheceal septum are not seen. In some specimens very short apertural spine is present here and there.

Remarks: The morphologies of theca and proximal end of these specimens are identical with those of *H. vikarbyensis* referred by Maletz (1997) and Jaanusson (1960). Merely these specimens described herein are smaller than *H. vikarbyensis* of Maletz (1997) and Jaanusson (1960).

Ihustedograptus sp.
Fig. 4E

Material: JS103 (5)

Description: This material is long and slender. The rhabdosome length is 130 mm. The proximal width is about 0.9-1.0 mm. The width is 1.18-1.39 mm at the fifth thecal pair. After that its width is nearly uniform. the final width is 1.27-1.53 mm. Rhabdosome widens very gradually. There are 8-9.5 thecae in the first 5 mm. and 15 thecae in the first 10 mm. The thecal density is somewhat high. The proximal end is triangular and blunt. They have two subapertural spines and one virgella. The virgella and subapertural spines are very short and delicate. Due to poor preservation only one short subapertural spine presents at th1[1]. The morphologies of the theca are glyptograptid type. the ventral wall of the metatheca is convex about halfway along its length. in the proximal end. But metatheca is straighter and longer toward distal part. that is. the thecal form becomes orthograptid type. Both sided thecae run parallel. The median septum is seen and it seems a straight form.

Remarks: As they have symmetrical proximal end and widen slowly. these species are very similar to *Ihustedograptus vikarbyensis*. *I.* sp. differs from *I. vikarbyensis* in its more slender rhabdosome and high thecal density.

Correlation

Ordovician macrofossils such as trilobites and cephalopods as well as microfossils including conodonts have been studied in the Jigunsan Shale. Kobayashi (1934. 1942. 1966) reported one species of Macharidia. 3 species of brachipods. 13 species of pelecypods. 6 species of gastropods. 46 species of cephalopods. 16 species of trilobites. and one species of Ostracoda from the Jigunsan Shale. He concluded the Jigunsan Shale correlated with the Llandeilo. and the Jigunsan fauna showed an affinity with the European fauna rather than the North American one (Kobayashi. 1966). Shimizu and Obata (1935) described three graptolite species from Jigunsan Shale. They correlated this formation with the Lower Llandeilian *Diplograptus teretiusculus* Zone and *Nemagraptus gracilis* Zone in the Glenkiln Shale. England. and with the Pingliang Shale of the Gansu province in North China.

On the basis of trilobites. Jigunsan Shale was correlated with the Llandeilo to Lower Caradoc in Europe (Lee et al. 1980). Lee and Lee (1986) reported 12 species conodonts from the Jigunsan Shale and established a conodont biozone. *Eoplacognathus suecicus-E. jigunsanensis* Zone. which is correlated with the Early to Middle Llanvirnian in Europe and the lower Upper Machiakou Formation in North China.

In the Napalgogae section. graptolites bearing bed is situated about 15 m above the base of the Jigunsan Shale. *Ihustedograptus teretiusculus* (Hisinger) sensu Jaanusson. 1960 and *Ihustedograptus vikarbyensis* (Jaanusson. 1960) are discovered in this section. In the Jangsoong section. graptolite bed is present at 1.3 m above the exposed Jigunsan Shale and is about 16 m above the Maggol Limestone. Five species of graptolites including *Archiclinacograptus riddellensis* (Harris. 1924). *Pseudamplexograptus distichus* (Eichwald. 1840). *Ihustedograptus teretiusculus* (Hisinger) sensu Jaanusson. 1960. *Ihustedograptus vikarbyensis* (Jaanusson. 1960). and *Ihustedograptus* sp. were found in this section.

The *Pseudamplexograptus distichus* Zone was established in the Baltic area and this zone defined as *Didymograptus calvulus* Zone by Eksträm (1937) (Cooper and Lindholm. 1990: Maletz. 1995). Maletz (1995) revised graptolite biozonation of Llanvirn in the Albjära core (western Scania. Sweden) and established five biozones of Llanvirn. Of these. the *P. distichus* Zone is the second one in the descending order in Abereiddian of European Series and this zone is composed of *A. riddellensis*. *H. teretiusculus*. *H. vikarbyensis*. and *H.* sp. Recently Maletz (1998) investigated graptolites of the Rügen area (northern Germany: western Pomerania) and established five biozones like the biozones of Albjära

Table 1. Comparison of graptolite, conodont and trilobite zones of the Jigunsan Shale

European Series		Estonian Series	Graptolite Zone Maletz (1995, 1998) Scania, Sweden /N. Germany	Conodont Zone Bergström (1986) N. Atlantic area	Correlation of the Jigunsan Shale graptolite This study Jangseong-Dongjeom area	Correlation of the Jigunsan Shale conodont Lee et al. (1986, 1990) Sangdong area/Jangseong-Dongjeom area	Correlation of the Jigunsan Shale trilobite Lee et al. (1980) Jangseong-Dongjeom-Keumcheon area	Correlation of the Jigunsan Shale Kobayashi (1966)
CARADOC		Kukrusian	*Nemagraptus gracilis*	*Pygodus anserinus*			unnamed	unnamed
LLANVIRN	Llandeilian	Uhakuan	*Hustedograptus teretiusculus*					
	Abereiddian	Lasnamägian	*Pseudamplexograptus distichus*	*Pygodus serra*	unnamed			
		Aserian	*Pterograptus elegans*					
		Aluojan	*Nicholsonograptus fasciculatus*	*Eoplacognathus suecicus*		*Eoplacognathus suecicus-E. jigunsanensis* Zone		
		Valastean	*Holmograptus lentus*	*Eoplacognathus? variabilis*				
ARENIG		Hunderumian	*Didymograptus hirundo*					

core.

Jaanusson (1960) reported *A. riddellensis*, *P. distichus*, and *H. teretiusculus* from the bed of Lasnamägi Stage of the Estonian and Viruan Limestone of Sweden. Of these, *A. riddellensis* was found from the *Didymograptus murchisoni* Zone of the Lower Lasnamägi Stage and the others were discovered from the unnamed zone of the Upper Lasnamägi Stage.

On the basis of previous studies on the Ordovician graptolites (Jaanusson, 1960; Cooper and Lindholm, 1990; Maletz, 1995; Maletz, 1998), graptolites from the Jigunsan Shale correspond to those of the Abereiddian, late Middle Llanvirn and are correlated with the fauna of the *Pseudamplexograptus distichus* Zone in the Baltica and Germany areas. The graptolite bearing beds of the Jigunsan Shale is thought to be correlated with the Lasnamägi Stage of the Estonian (Baltoscandia) Sequence (Table 1).

There are some discrepancies about the age of the Jigunsan Shale according to conodont, graptolite, and trilobite studies (Table 1). Lee et al. (1980) established the *E. suecicus-E. jigunsanensis* assemblage Zone, in the upper middle part of the Jigunsan Shale. The *E. suecicus-E. jigunsanensis* Zone is correlated with the *E. suecicus* Zone of Middle Llanvirnian in Europe and corresponds to the Aserian. On the basis of trilobites from the Jigunsan Shale, Jigunsan Shale fauna corresponded to the Llandeilian to the Lower Careadocian (Lee et al., 1980).

Based on the occurrence of graptolites in this study, however, the graptolite beds of the Jigunsan Shale is correlated with the *Pseudamplexograptus distichus* Zone and corresponds to the Lasnamägian, late Middle Llanvirn in age. This graptolite zone has been correlated with the *Pygodus serra* conodont zone (Bergström, 1971; Bergström, 1986; Finney, 1984).

Conclusions

Five species of graptolites discovered from the Middle Ordovician Jigunsan Shale at Napalgogae and Jangseong sections of the Taebaeg area, Korea, were described herein as *Archiclimacograptus riddellensis* (Harris, 1924), *Pseudamplexograptus distichus* (Eichwald, 1840), *Hustedograptus teretiusculus* (Hisinger) sensu Jaanusson, 1960, *Hustedograptus vikaryensis* (Jaanusson, 1960), and *Hustedograptus* sp. Graptolite assemblage from the Jigunsan Shale is correlated with those of the *Pseudamplexograptus distichus* zone in the Baltic and German areas. Geologic age of graptolites bearing bed of the Jigunsan Shale seems to be Abereiddian, late Middle Llanvirn of European Series, and to Lasnamägian of Estonian Series, which is slightly older than the age based on trilobite studies (Llandeilian to Lower Caradoc) and slightly younger than the age inferred from conodont studies (middle Middle Llanvirn). Further study may solve this difference in geologic age of the formation.

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