

Recognition and significance of the *Aurilobodus serratus* Conodont Zone (Darriwilian) in lower Paleozoic sequence of the Jeongseon–Pyeongchang area, Korea

Byung-Su Lee*

Department of Earth Science Education, Chonbuk National University, Jeonju 54896, Republic of Korea

ABSTRACT: A total of 286 disjunct conodont elements were recovered from 30 productive samples in 5 separate sections of the Haengmae and Hoedongri Formations, 18 m below to 36 m above the boundary between the two formations, in the Jeongseon–Pyeongchang area. Fifteen multielement and form species representing 12 genera are distinguished in the fauna of the two formations. Age-diagnostic species include *Acontiodus viriosus* Cui, *Aurilobodus serratus* Xiang and Zhang, *A. simplex* Xiang and Zhang, *Drepanodus arcuatus* Pander, *Drepanodus reclinatus* (Sergeeva), *Drepanoistodus suberectus* (Branson and Mehl), *Eoplacognathus jigunsanensis* Lee and Lee, *E. lindstroemi* Hamar, *Erraticodon tangshanensis* Yang and Xu, *Panderodus nogamii* Lee, *Parapanderodus paracornutiformis* (Ethington and Clark), *Plectodina onychodontia* An and Xu, *Scandodus choii* n. sp., and *Triangulodus changshanensis* (Zhang). This assemblage was assigned to the *Aurilobodus serratus* Zone. That zone was first erected from the Middle Ordovician Machiakou Formation in the North China platform and is known also from the Duwibong Formation in Korea. These strata represent tropical, shallow marine paleobiogeographic facies. The presence of the zone on both sides of the boundary between the two formations means that the relationship between the Haengmae and Hoedongri formations is a conformity, not an unconformity, as previously thought. It is more likely that the overlying unsampled strata of the Hoedongri Formation are also Ordovician, rather than Silurian. One new species, *Scandodus choii*, is described here.

Key words: Darriwilian, conodonts, biostratigraphy, Haengmae and Hoedongri formations, Jeongseon–Pyeongchang area

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1. INTRODUCTION

The Jeongseon area and the Pyeongchang area to the west, mid-east Korea (Fig. 1), are parts of the Taebaeksan Basin in which lower Paleozoic sedimentary strata are exposed. There, three stratigraphic units are generally accepted at present: in upward sequence, the Jeongseon Limestone (amended by GICTR, 1962), Haengmae Formation (amended by Son and Cheong, 1977) and Hoedongri Formation (renamed by Cheong et al., 1979). Hisakoshi (1943) originally called these units the Lower Limestone, Haengmak Bed, and Upper Limestone.

The Haengmak Bed and Upper Limestone of Hisakoshi (1943)

generally have been regarded as Ordovician in other parts of Korea. The fossil record of these strata was poor except for some poorly preserved actinoceroids (Kobayashi, 1966) and two conodont species, *Scolopodus alatus* Bradshaw and *Scolopodus giganteus* Sweet and Bergström (Lee, 1976).

Cheong et al. (1979) discovered a relatively abundant conodont fauna from the Upper Limestone in the western Jeongseon area, and they assigned the fauna to the Early Silurian. Afterwards, Lee (1980, 1982) revised the taxonomy of some of his Hoedongri conodonts. This resulted in the introduction of the name Hoedongri Formation to replace the name Upper Limestone of Hisakoshi (1943). They interpreted that the boundary between the Haengmae Formation and overlying Hoedongri Formation is a disconformity. This interpretation is mentioned in Korea's current high school and college textbooks.

However, An and Zheng (1990) asserted that Lee's (1980, 1982) Hoedongri conodont fauna was not Silurian but Ordovician, and that Korea was paleogeographically similar to North China in Ordovician time. This assertion was followed by Li et al. (2006)

*Corresponding author:

Byung-Su Lee

Department of Earth Science Education, Chonbuk National University, Jeonju 54896, Republic of Korea

Tel: +82-63-270-2802, E-mail address: bslee@jbnu.ac.kr

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without any concrete evidence based on additional conodont data.

This study re-examines the conodont faunas of the Haengmae and Hoedongri formations, which are exposed in five localities of Jeongseon–Pyeongchang area, Gangwon Province, and involves reconstructing the relationship between the two formations. The present contribution is the first of several publications arising from this ongoing conodont research project on the Lower Paleozoic sequence of the study area.

2. STRATIGRAPHIC SUMMARY

Geological investigation of the lower Paleozoic stratigraphy in the western Jeongseon area was initiated by Hisakoshi (1943), who recognized three stratigraphic units: in upward sequence, the Lower Limestone, Haengmak Bed, and Upper Limestone. Later, GICTR (1962) published a geological map, the Jeongseon Sheet (1:50,000), and incorporated three formations of Hisakoshi (1943) into one unit, the Jeongseon Limestone on the map.

The Haengmae Formation (Son and Cheong, 1977), as currently used, came from the original Haengmak Bed of Hisakoshi (1943). The geographic name ‘Haengmak’ is a false spelling of the Korean village name ‘Haengmae’. His ‘Bed’ was raised to

formational rank according to current usage.

Cheong et al. (1979) replaced the unit name ‘Upper Limestone’ of Hisakoshi (1943) with ‘Hoedongri Formation’ based on their discovery of Silurian conodonts from the formation. In fact, previous investigators (Hisakoshi, 1943; GICTR, 1962; Kobayashi, 1966; Son and Cheong, 1977) had interpreted that the lower Paleozoic sequence in the Jeongseon–Pyeongchang area was Late Cambrian to Middle Ordovician in age.

Today, lower Paleozoic strata in the Jeongseon–Pyeongchang area are considered to include three units, the Jeongseon Limestone, Haengmae Formation, and Hoedongri Formation, in ascending order.

Park and Chang (1985) and Chung et al. (1995) researched the sedimentary environments of the lower Paleozoic strata in the Jeongseon area and interpreted the strata as having been deposited in a shallow marine environment. In particular, Park and Chang (1985) expressed a view that the Hoedongri Formation was deposited in a saline supratidal and intertidal zone.

In the study area the Haengmae and Hoedongri formations crop well out around the Seongmaryeong mountain pass to the west (Mitan, Pyeongchang-gun and Haengmaedong, Jeongseon-gun) and in the Hoedong-Biryongdong villages to the east

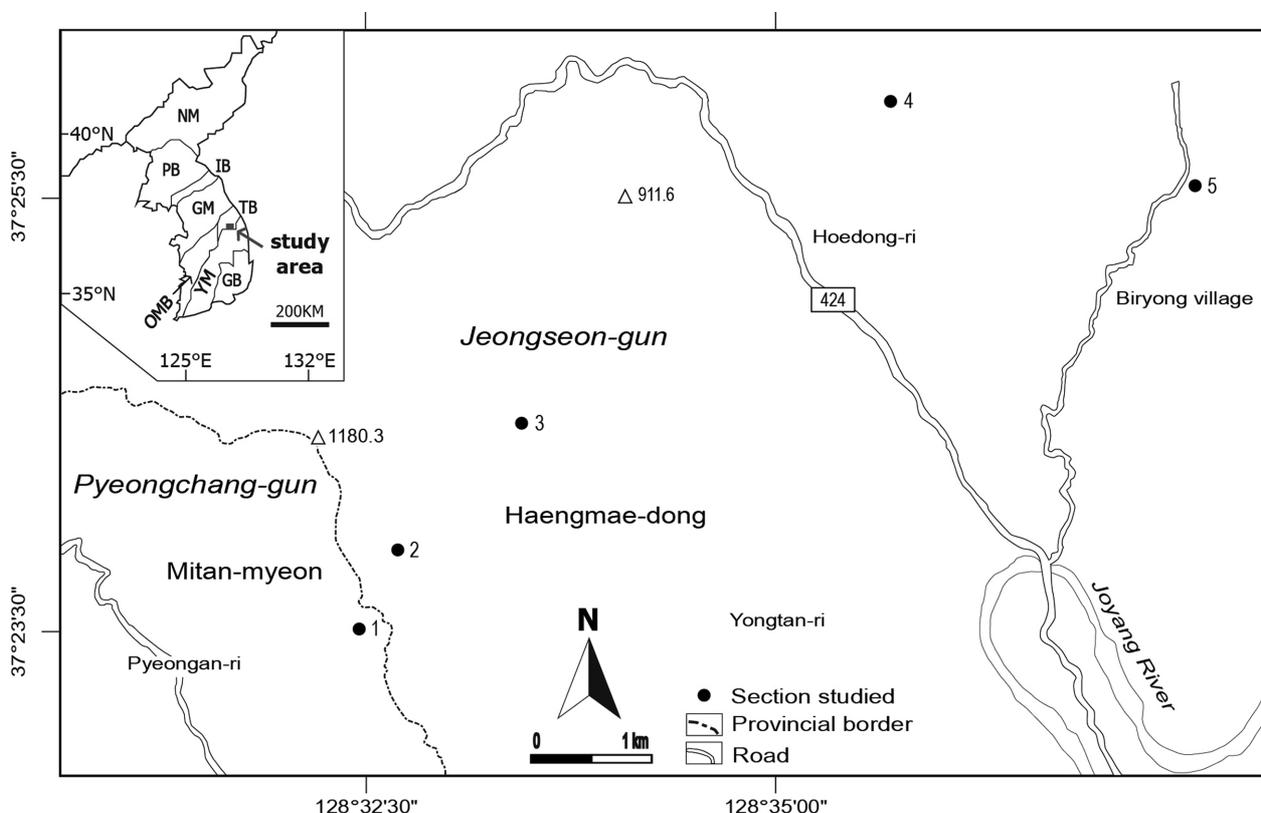


Fig. 1. Simplified map of western Jeongseon–eastern Pyeongchang showing section locations (1–5). NM = Nangrim massif, PB = Pyeongnam basin, IB = Imjingang belt, GM = Gyeonggi massif, TB = Taebaeksan basin, OMB = Okcheon metamorphic belt, YM = Yeongnam massif, GB = Gyeongsang basin.

(Jeongseon-gun), Gangwon Province (Fig. 1). Two formations are fairly well exposed along a forest road west of Seongmaryeong (Section 1, 950 m) dividing Pyeongchang-gun and Jeongseon-gun (Gun indicates a political unit similar to a county). The Hoedongri Formation overlies the Haengmae Formation and is unconformably overlain by the Upper Carboniferous Hongjeom Formation at the section.

The Haengmae Formation is easily distinguished from adjacent units particularly by its distinctive color and texture. The formation consists mainly of light gray, poorly bedded, conglomeratic limestone with mostly angular quartzite pebbles less than 5 cm in diameter, which weather yellow to brown. In addition, the

overlying Hoedongri Formation consists of gray to dark gray limestone, dolomitic limestone and minor shale, which is overlain by reddish sandstone and shale of the Hongjeom Formation.

The Hoedongri Formation at Section 1 is composed primarily of carbonate rocks and minor shale and is subdivided into four informal members. The basal (lower limestone) unit (± 43 m) consists of dark gray to mottled, massive to laminated limestone with interbedded shale, which weathers light gray. Unit 2 (dolomitic limestone, ± 117 m), is a series of milky white to gray dolomitic limestone and intermittently interbedded, light gray to gray, laminated limestone. This unit accounts for more than half the total thickness of the Hoedongri Formation. A third

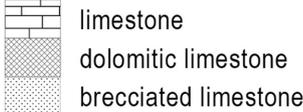
PERIOD	FORMATION	LITHOLOGY	THICK.(m)	LITHOLOGIC CHARACTER	SCOPE
ORDOVICIAN	HOEDONGRI	Alternation	200±	limestone, dolomitic, milky white to light gray; wackestone, gray, white calcite veins in the lower part	interval studied
		Upper Limestone		wacke- to packstone, partially laminated, gray to dark gray; mudstone, thick bedded, dark gray; bioturbated in the lower part	
		Dolomitic Limestone		limestone, dolomitic, milky white to light gray; limestone, calcareous, laminated, light gray to gray	
Lower Limestone		limestone, massive to laminated, dark gray-mottled; shale, argillaceous, light gray			
	HAENGMAE		120±	conglomeratic limestone with angular quartzite pebbles, poorly-bedded, light to dark gray weathers to yellow to brown; interbeds of limestone, well-bedded, light to dark gray	
	JEONGSEON		300±	limestone, massive to commonly laminated, well-bedded; interbeds of limestone, dolomitic, dark brownish	
					

Fig. 2. Generalized columnar section of lower Paleozoic sequence at section 1, forest roadcut east of Hanchidong village, Pyeongan-ri, Mitanmyeon, Pyeongchang-gun.

unit (upper limestone) (± 20 m) consists of gray to dark gray wackestone to packstone, partially laminated, and dark gray thick-bedded mudstone, bioturbated in the lower part. Unit 4 (± 20 m) consists of alternating milky white to light gray dolomitic limestone and gray wackestone. White calcite veins are present in the lower part. Detailed lithologies of the four members are shown in Figure 2 and of Unit 1 in Figures 3 and 4.

3. PREVIOUS CONODONT STUDY

The only previous investigation of conodonts from the Haengmae Formation is the brief report of Choi (1980). She recovered *Appalachignathus* cf. *delicatus*, *Acodus* sp., *Acontiodus* sp., *Drepanodus* sp., *Oistodus* sp., and *Ozarkodina* sp. from the formation. Because these are long-ranging species, she could not suggest a particular stage of the Ordovician for the formation.

Cheong et al. (1979) first reported Silurian conodonts from the Hoedongri Formation in the Jeongson area, and Lee (1980, 1982) carried out more refined taxonomic studies for the Hoedongri conodont fauna. He reported 836 conodont elements from 81 limestone samples collected at four sections around Jeongseon-eup, Gangwon Province. He classified the conodonts into 42 form species referable to 22 form genera, with two multielement species, *Pterospathodus celloni* (Walliser) and *Panderodus unicostatus* (Branson and Mehl), and one new species, *Ambalodus hoedongensis*.

Lee (1982) also erected two provisional biostratigraphic zones, identified as lower and upper zones, based on the Hoedongri conodont fauna. The lower zone corresponds to the *Distomodus kentuckyensis* Zone in North America and to the upper part of the Bereich 1 in the Carnic Alps. The upper zone corresponds to the *celloni-amorphognathoides* Zone in the Carnic Alps.

An and Zheng (1990) addressed a problem on the conodont taxonomy of Lee (1982), which was followed by Li et al. (2006) without any evidence based on their own additional collections of Hoedongri conodonts. An and Zheng (1990) claimed that seventeen Silurian species identified by Lee (1982) are actually Ordovician, and therefore, the Hoedongri Formation is an Ordovician unit deposited conformably on the Haengmae Formation. This study attempted to determine if An and Zheng's (1990) perspective on the conodont taxonomy was proper.

4. SECTIONS AND CONODONT SAMPLES

Limestone samples for conodonts were collected from intervals of the upper part of the Haengmae Formation to the lower part of the Hoedongri Formation at five sections (Fig. 1). Section 1 is located along a forest roadcut east of Hanchidong village, Pyeongan-ri, Mitan-myeon, Pyeongchang-gun. Section

2 is located along a forest roadcut about 750 m west of Haengmaedong village, Yongtan-ri, Jeongseon-eup, Jeongseon-gun. Section 3 is composed of outcrops near an isolated house north of Haengmaedong village, Yongtan-ri, Jeongseon-eup, Jeongseon-gun. Section 4, type section of the Hoedongri Formation (Cheong et al., 1979; Lee, 1982), is located on a mountain slope about 1 km northeast of Hoedong village, Yongtan-ri, Jeongseon-eup, Jeongseon-gun. Section 5 is located along stream valley east of Biryongdong village road, about 3 km northeast of Byeoktan Elementary School, Yongtan-ri, Jeongseon-eup, Jeongseon-gun.

In total, 42 limestone samples, averaging 3.5 kg in mass, were collected from the interval spanning the upper part of the Haengmae Formation (up to 18 m thick) and the lower part of the Hoedongri Formation (up to 43.0 m thick). Section 1 has one sample from a bed 18.0 m below top of the Haengmae Formation and six samples from the lower 18.0 m of the Hoedongri Formation. Section 2 has one sample from a bed 5.0 m below top of the Haengmae Formation and nine samples from the lower 29.3 m of the Hoedongri Formation. Section 3 has eleven samples from the lower 38.0 m of the Hoedongri Formation. Section 4 has seven samples. Section 5 has six samples from the lower 36.1 m of the Hoedongri Formation (Figs. 3–6). The samples were processed repeatedly through standard acid-dissolution techniques to obtain the conodonts.

5. CONODONT BIOSTRATIGRAPHY WITH COMMENTS ON MIDDLE ORDOVICIAN PALEOBIOGEOGRAPHY

A total of 286 disjunct conodont elements were recovered from 30 conodont-bearing samples from five exposures of the upper part of the Haengmae Formation to the lower part of the Hoedongri Formation in the Jeongseon–Pyeongchang area. The location of sections, the stratigraphical distribution of each sample at the sections, and the numerical conodont distribution data are shown in Figures 1 and 2, and Table 1.

Although the measured interval was intensively sampled, conodonts were very rare compared with the recovery from Ordovician strata in the Taebaek area, probably due to the unfavorable depositional environment noted by Park and Chang (1985). Fifteen species representing 12 genera are recognized; coniform conodonts make up about 85% of recovered elements. *Scandodus choii* n. sp. is recorded as the most abundant species, about 48% of the total collection.

The conodont specimens are relatively well preserved, although many are fragmentary and have corroded surfaces, particularly in coniform conodonts. Conodont color indicates a position of 5 on the Conodont Alteration Index (CAI) (Epstein et al., 1977)

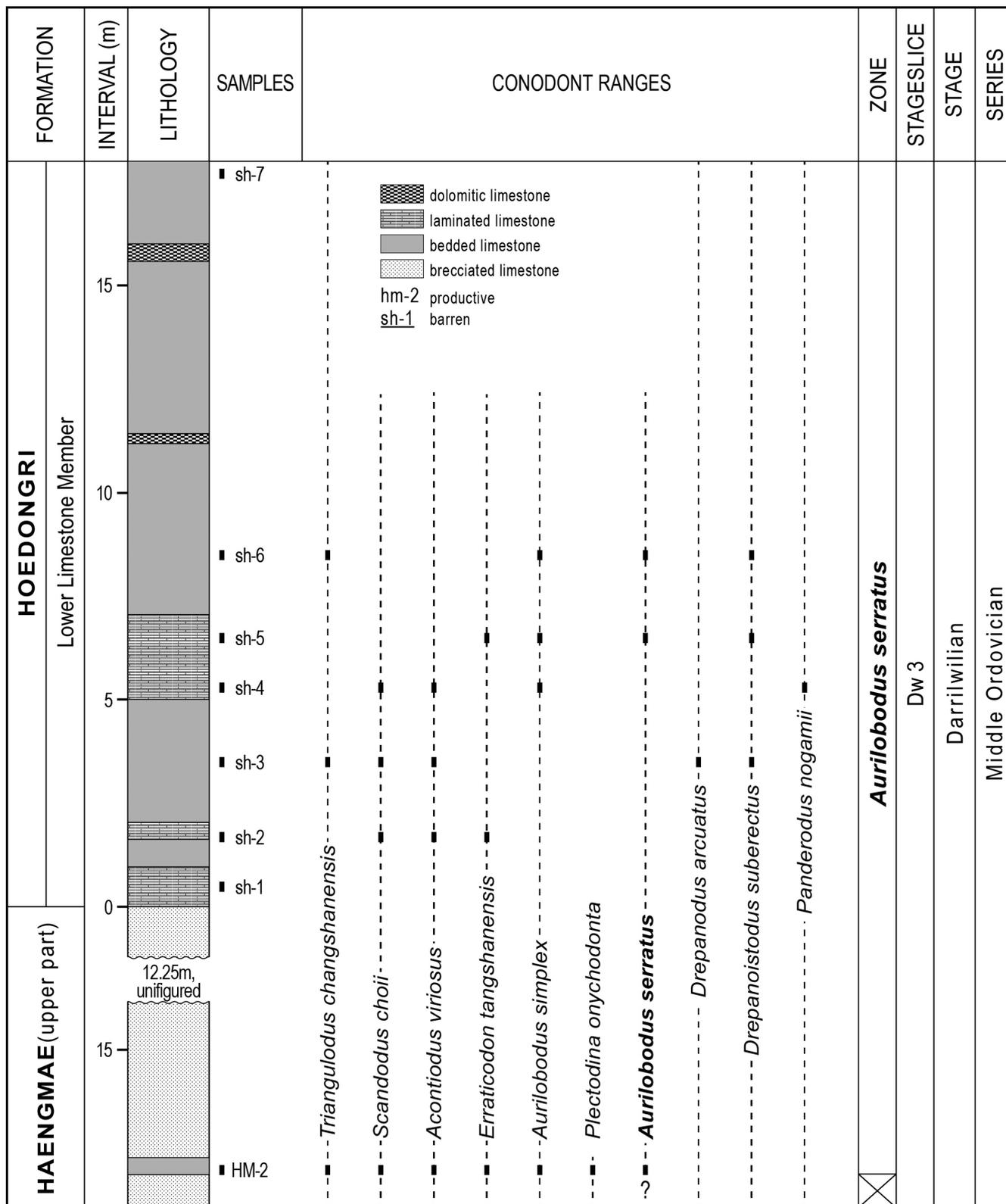


Fig. 3. Conodont distribution in the upper part of the Haengmae Formation and the Lower Limestone Member of the Hoedongri Formation at section 1, forest roadcut east of Hanchidong village, Pyeongan-ri, Mitan-myeon, Pyeongchang-gun.

reflecting burial temperatures of less than 300 °C.

Conodont recovery per kilogram was about 9 specimens.

One exceptionally abundant sample within the lower part of the

Hoedongri Formation is from sample 1.2, and it yielded over 64

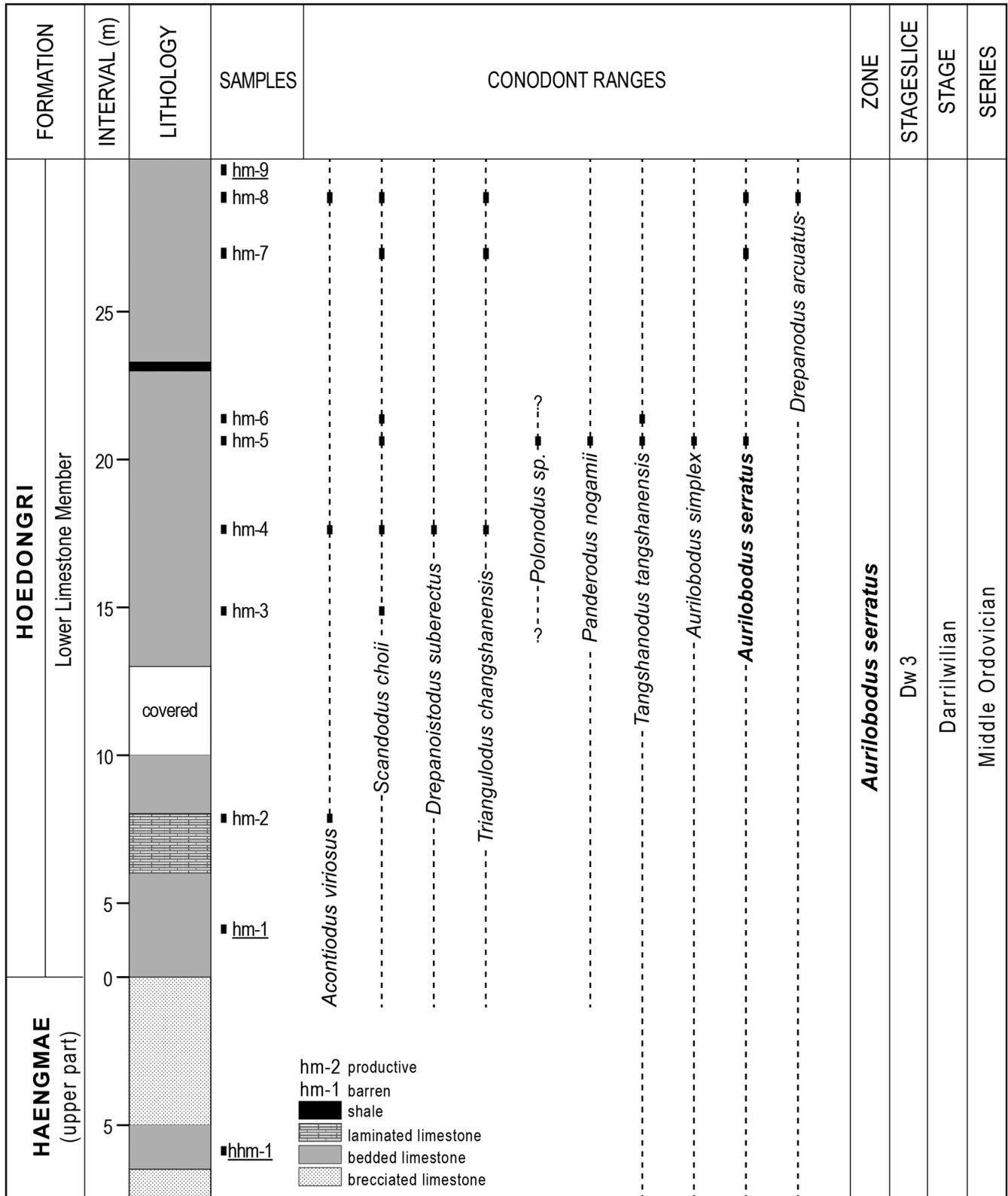


Fig. 4. Conodont distribution in the Lower Limestone Member of the Hoedongri Formation at section 2, forest roadcut west of Haengmae-dong village, Yongtan-ri, Jeongseon-eup, Jeongseon-gun.

specimens, about 23% of total collection. The diversity of this sample is approximately the same as for others of the lower part

of the formation. Fifteen samples had less than five specimens per kilogram (Table 1).

Age-diagnostic species described herein include *Acontiodus viriosus* Cui, *Aurilobodus serratus* Xiang and Zhang, *A. simplex* Xiang and Zhang, *Drepanodus arcuatus* Pander, *Drepanodus reclinatus* (Sergeeva), *Drepanoistodus suberectus* (Branson and Mehl), *Eoplacognathus jigunsanensis* Lee and Lee, *E. lindstroemi* Hamar, *Erraticodon tangshanensis* Yang and Xu, *Panderodus nogamii* Lee, *Parapanderodus paracornutiformis* (Ethington and Clark), *Plectodina onychodonta* An and Xu, *Scandodus choii* n. sp., and *Triangulodus changshanensis* (Zhang). This assemblage was assigned to the *Aurilobodus serratus* Zone.

5.1. *Aurilobodus Serratus* Zone

Conodonts from the interval from 18.0 m below to 36 m above the boundary between the Haengmae and Hoedongri Formations are assigned to this zone, which indicates a late Darriwilian age (Dw3; late Middle Ordovician). The *Aurilobodus serratus* Zone was originally erected in the upper Machiakou Formation, North China (An et al., 1983), and overlies the

Plectodina onychodonta Zone. *Aurilobodus serratus* Xiang and Zhang appears to be an endemic species that is known only from that zone in the Duwibong Formation in the Taebaeksan Basin, Korea and the Machiakou Formation in North China (An et al., 1983; Lee and Lee, 1986; Pei and Cai, 1987; An and Cheng, 1990; Lee and Lee, 1990; Seo, 1997, 2000). Other taxa in the zone in Korea are similar to coeval faunas reported from the interior North China–Korea Platform. In this study, *A. serratus* was recovered sporadically from sections 1, 2 and 5 (Figs. 3 and 4).

Acontiodus viriosus, *Aurilobodus simplex*, *Erraticodon tangshanensis*, *Plectodina onychodonta*, *Scandodus choii*, *Panderodus nogamii*, and *Triangulodus changshanensis* are species that are frequently associated with *A. serratus* in the Middle Ordovician of North China and South Korea. *A. viriosus*, *E. tangshanensis*, *Scandodus choii*, and *T. changshanensis* are the common species of the Machiakou Formation (*Histiodela holodentata*-*Tangshanodus tangshanensis* Zone to *Aurilobodus serratus* Zone) in Hubei and Hunan, North China and upper part of the Maggol Formation to Duwibong Formation (*Tangshanodus tangshanensis* Zone to

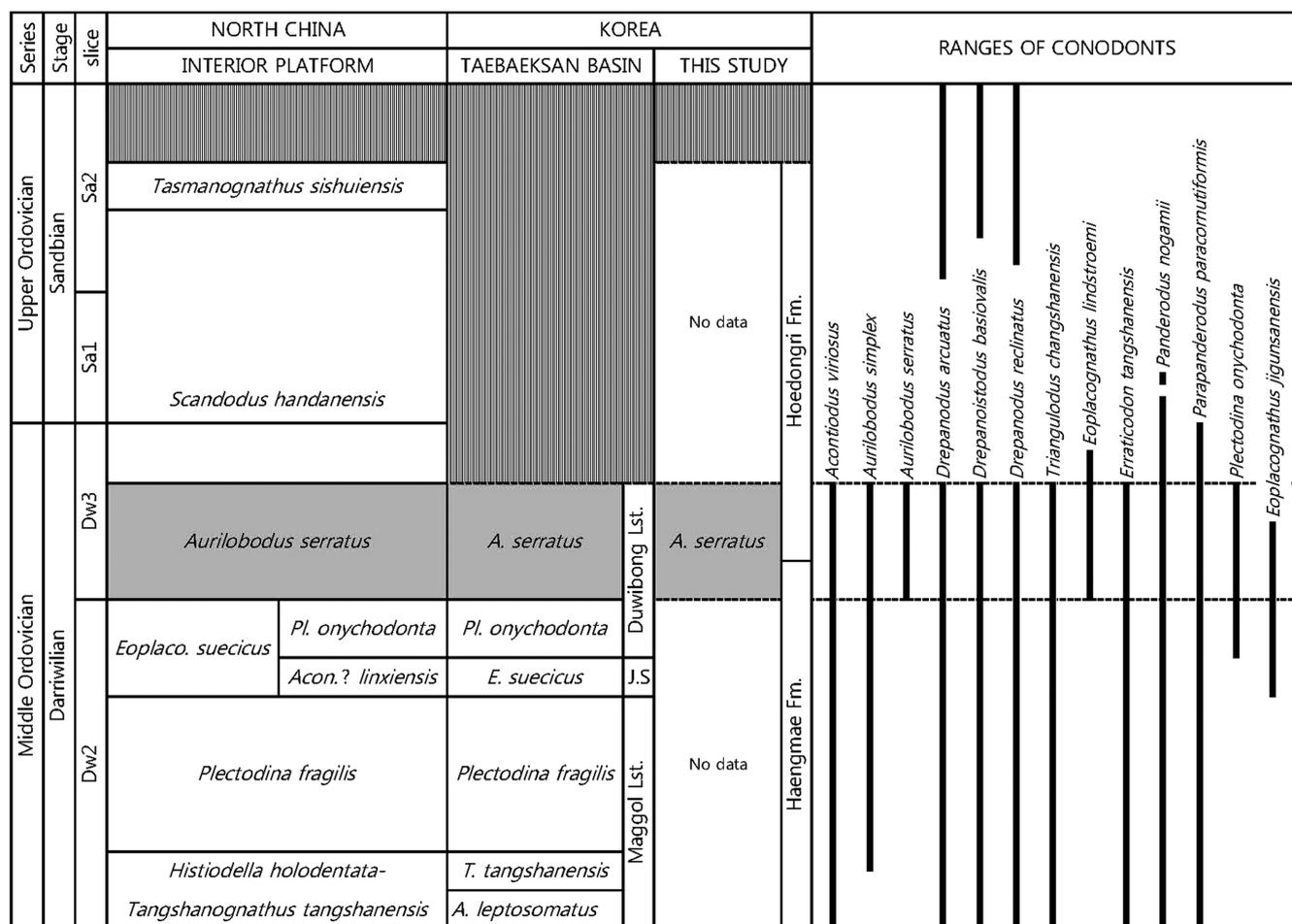


Fig. 5. Correlation of the *Aurilobodus serratus* Zone (shaded area) of the Jeongseon–Pyeongchang area with North China (An and Zheng, 1990; Wang et al., 2016) and Taebaeksan Basin of Korea (Lee and Lee, 1986; Lee and Lee, 1990; Seo, 1997, 2000), based on the stratigraphic ranges of the recovered conodont species. Abbreviation: J.S. = Jigunsan Shale.

A. serratus Zone) in the Taebaeksan Basin, South Korea (Lee, 1976, 1977; Choi, 1980; An et al., 1983; Pei and Cai, 1987; An and Zheng, 1990). *E. tangshanensis* and *S. choii* were also reported from equivalent strata in the Georgina Basin of the Australia Province, which is near the North China Province (Stait and Druce, 1993).

Aurilobodus simplex commonly occurs in the *Plectodina fragilis* Zone (Fig. 5) and persists into the *A. serratus* Zone in Darriwilian strata of the China-Korea Platform. *Plectodina onychodonta* is the zonal species between the *Eoplacognathus suecicus* Zone and the *Aurilobodus serratus* Zone (An et al., 1983; Lee and Lee, 1986; Pei and Cai, 1987; An and Cheng, 1990; Lee and Lee, 1990).

Panderodus nogamii (Lee, 1975) was described from North Korea and occurs also in the Lower Ordovician of Thailand (Agematsu et al., 2006a, b), Malaysia (Canthrell and Burrett, 2003; Agematsu et al., 2008), North and South China (An et al., 1983; Lee and Lee, 1986, 1990; Pei and Cai, 1987; Zhen et al., 2011; Jing et al., 2016), Australia (Watson, 1988; Zhang et al., 2003; Kuhn and Barnes, 2005), Nevada (Ethington and Schumacher, 1969), and in the Argentine Precordillera (Serpagli, 1974). It ranges through the Middle and early Upper Ordovician and is restricted to shallow water carbonates in tropical to subtropical paleolatitudes of greater Gondwana. *Drepanodus arcuatus*, *Drepanostodus suberectus*, *Drepanodus reclinatus*, and *Parapanderodus paracornutiformis* are all coniform conodonts previously reported from Middle Ordovician strata worldwide, including the Laurentian, Australian, North China, Argentine Precordillera, and Balto-Scandian provinces of all domains of the Shallow-Sea Realm (Sergeeva, 1963; Viira, 1967, 1974, 2011; Lindström, 1971; Barnes and Poplawski, 1973; Serpagli, 1974; van Wamel, 1974; Dzik, 1976, 1978; Löfgren, 1978, 2003; Stouge, 1984, 2012; An and Cheng, 1990; Lee and Lee, 1990; Stouge and Bagnoli, 1990; Rasmussen, 2001; Viira et al., 2001; Löfgren and Tolmacheva, 2003; Tolmacheva et al., 2003; Kuhn and Barnes, 2005; Agematsu et al., 2006a; Zhen et al., 2011; Männik and Viira, 2012; Jing et al., 2015, 2016; Feltes et al., 2016).

Three specimens of *Eoplacognathus jigunsanensis* were occasionally obtained from the lower Hoedongri Formation in two horizons of section 4. *E. jigunsanensis* was previously recovered from the Jigunsan Shale, Taebaeksan Basin, South Korea in association with *E. suecicus*, *Aurilobodus simplex*, *Erraticodon tangshanensis*, *Acontiodus viriosus* and *Panderodus nogamii*, and most of the species persisted into the younger beds of the Duwibong Limestone (Lee and Lee, 1986; Lee and Lee, 1990). The species was also previously reported from Middle Ordovician strata worldwide (An et al., 1983; An and Cheng, 1990; Rasmussen, 2001; Viira et al., 2001; Viira, 2011; Zhen et al., 2011; Hints et al., 2012).

The key species of the *Eoplacognathus lindstroemi* Subzone of

the *Pygodus serra* Zone was recovered only from sample 4.6. This is also a common species in upper Darriwilian strata (An et al., 1983; Lee and Lee, 1986, 2000; An and Cheng, 1990; Dzik, 1994; Rasmussen, 2001; Löfgren and Zhang, 2003; Viira, 2011; Zhen et al., 2011; Hints et al., 2012; Wang et al., 2014; Jing et al., 2015; Feltes et al., 2016; Wang et al., 2016).

5.2. Comments on Conodont Provincialism

Zhen and Percival (2003) reviewed the traditional separation of global Ordovician conodont distribution into the North American Midcontinent Province (NAMP) and North Atlantic Province (NAP) and proposed more detailed divisions. They put the Ordovician paleobiogeographic realm of the Taebaeksan Basin, South Korea in the North China Province, which is part of the tropical, shallow marine realm.

The presence of so many endemic species in Ordovician conodont faunas both of North China and Korea is direct evidence

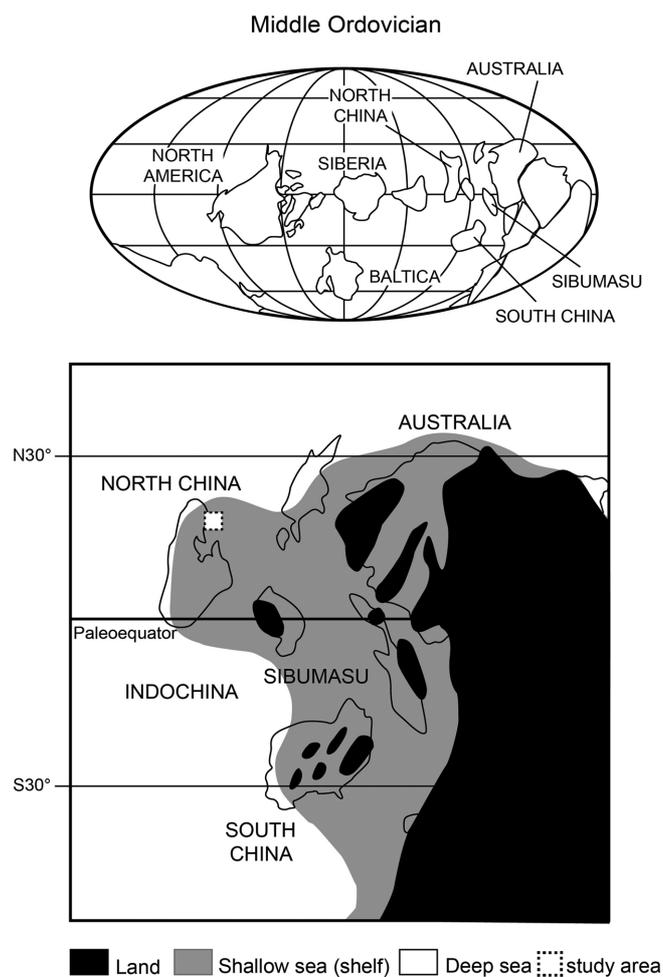


Fig. 6. Map of paleogeography of the North China Block, South China Block, Tarim Block, Siberian Plate, and Australian Plate during the Middle Ordovician (Wang et al., 2016).

that these two areas were part of the same paleobiogeographic category at that time (Fig. 6). Zhen and Percival (2003) also illustrated that provinces of the Shallow-Sea Realm are often separated from each other by deep oceans which may act as effective barriers to dispersal, resulting in a significantly higher ratio of locally distributed endemic forms.

6. CONCLUSIONS

Forty-two limestone samples were collected from the upper part of the Haengmae Formation and lower part of the Hoedongri Formation in five sections around Mitán-Hoedongri, Pyeongchang-Jeongseon area, Gangwon Province with the aim of revising the faunas to provide support for a more precise biostratigraphic correlation, both regionally and internationally.

A total of 286 identifiable conodonts were recovered from 30 productive samples of the Haengmae and Hoedongri Formations. This is a rather small conodont recovery compared within the Taebaeksan Basin. The fauna was predominated by coniform conodonts, about 85% of the total collection, and *Scandodus choii* n. sp. is the most abundant coniform species, about 48% of the total. Fifteen multielement and disjunct species representing 12 genera are distinguished in the fauna of the two formations.

Co-occurrence of *Acontiodus viriosus* Cui, *Aurilobodus serratus* Xiang and Zhang, *A. simplex* Xiang and Zhang, *Drepanodus arcuatus* Pander, *Drepanodus reclinatus* (Sergeeva), *Drepanoistodus suberectus* (Branson and Mehl), *Eoplacognathus jigunsanensis* Lee and Lee, *E. lindstroemi* Hamar, *Erraticodon tangshanensis* Yang and Xu, *Panderodus nogamii* Lee, *Parapanderodus paracornutiformis* (Ethington and Clark), *Plectodina onychodonta* An and Xu, *Scandodus choii* n. sp. and *Triangulodus changshanensis* (Zhang) in the fauna indicates a Darriwilian (mid Da3) age. This assemblage is assignable to the *Aurilobodus serratus* Zone.

Aurilobodus serratus is an endemic species originally known from the Machiakou Formation in North China and the Duwibong Formation in the Taebaeksan Basin, Korea. In this study, the species was recovered from both sides of the boundary between the Haengmae Formation (18 m below the boundary) and the Hoedongri Formation (36 m above the boundary). Accordingly, the base of the Hoedongri Formation proved to be Darriwilian (D3) in age, and the contact between the Haengmae and Hoedongri formations also proved to be a conformity. Considering the lower fauna of the Hoedongri Formation, the remainder of the formation probably is also Ordovician, not very far from the *Aurilobodus serratus* Zone.

7. SYSTEMATIC PALEONTOLOGY

Most of the conodonts from this study are well known and

have been adequately described in previous publications, so they are excluded from formal taxonomic treatment. One multielement species, *Scandodus choii*, is described here as a new species.

The specimen numbers prefixed by "JBNU" are illustrated specimens (JBNU-1701~JBNU-1794) that are deposited in the Department of Earth Sciences, Chonbuk National University, Jeonju, Korea.

Genus *Scandodus* Lindström, 1955

Type species – *Scandodus furnishi* Lindström, 1955.

Scandodus choii n. sp.

Figures 7.33–7.39

1980 *Scandodus* sp. Choi, p. 50, pl. 5, fig. 12.

1987 *Drepanodus* sp. B Pei and Cai, p. 76, pl. 6, figs. 9–13.

1987 *Scandodus* sp. Pei, p.90, pl. 6, figs. 17–18.

1993 *Scandodus* n. sp. A Stait and Druce, p. 308, fig. 18.P.

Derivation of name – After Dr. Sung-ja Choi, who first discovered this morphotype.

Type locality – Gulgol valley, Mitán-myeon, Pyeongchang-gun, Gangwon Province, Korea.

Type stratum – 2 m above the base of the Hoedongri Formation in Section 1, *Aurilobodus serratus* Zone (Darriwilian).

Diagnosis – A multielement species with symmetry transition series, comprising asymmetrical scandodontiform element and asymmetrical acodontiform element, each of which has both left and right forms.

Description – Hyaline coniform conodonts essentially having robust drepanodontiform elements with symmetry transitions. Two element types are included in this new species; scandodontiform element and acodontiform element, each element has right and left forms (Figs. 7.33 and 34; 7.35 and 36; 7.37–39).

scandodontiform element: The cusps are laterally compressed, so both anterior and posterior margins are sharp-edged. Lateral faces of inner side are flat or slightly concave, but the lateral faces of the outer side are broadly rounded, showing an asymmetrical cusp cross-section (Fig. 7.38). Sometimes elements can be observed having a weak longitudinal furrow on their outer faces (Fig. 7.37). Some specimens are somewhat twisted inwards. The basal cavities are directed inwards and are shallow (Figs. 7.35–39).

acodontiform element: General morphology of the acodontiform elements are not different from that of the scandodontiform elements, including existence of right and left forms (Figs. 33 and 34), but the former have a prominent carina on each inner face (Figs. 8.33 and 34).

Remarks – *Scandodus* sp. of Choi (1980) is a scandodontiform element of this species. Her illustrated specimens of *Acodus* species (pl. 5, figs. 1, 6, 9) are also assigned to this new species. *Drepanodus* sp. B of Pei and Cai (1987) is regarded as a scandodontiform element, and his *Scandodus* sp. is an acodontiform element of this multielement species. An illustrated specimen of *Scandodus*

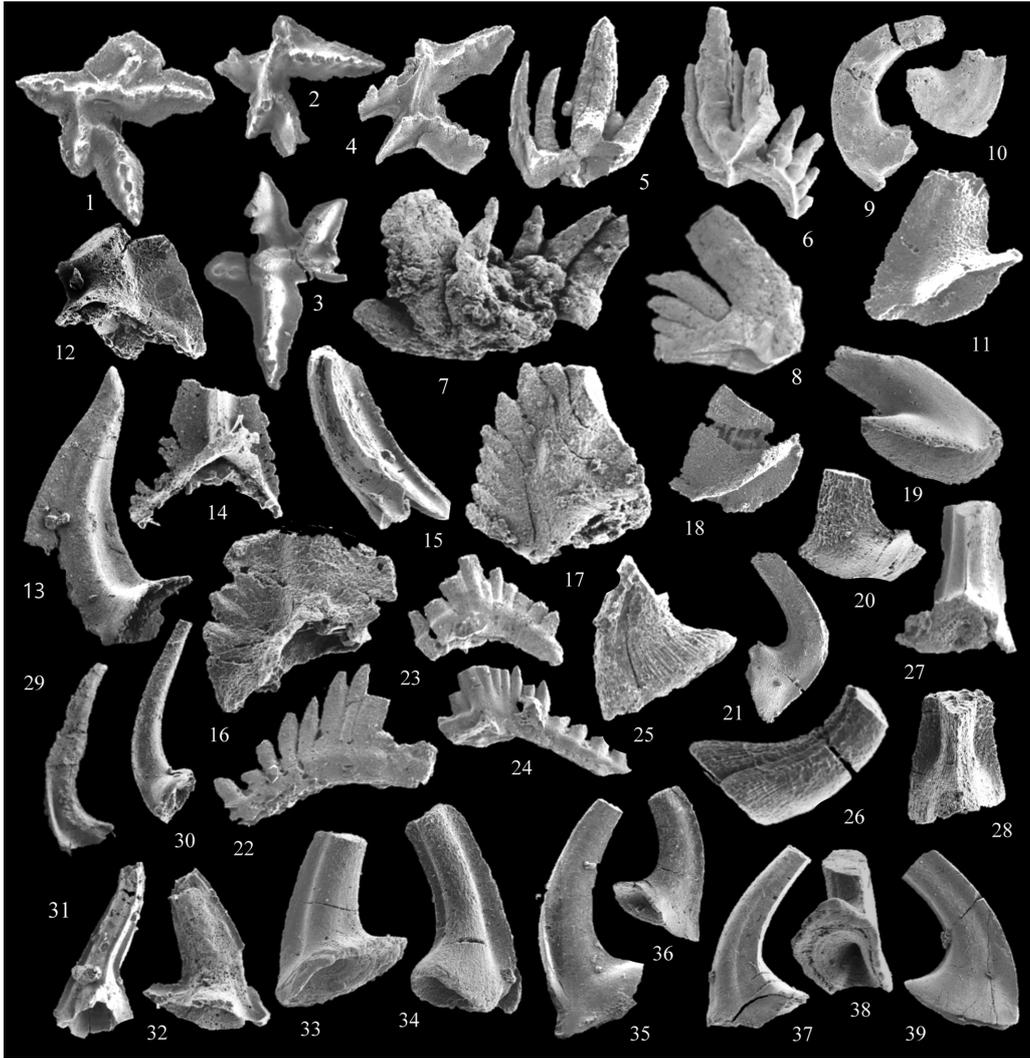


Fig. 7. (1 and 2) *Eoplacognathus jigunsanensis* Lee and Lee, 1986, stelliplanate (Pa) elements, upper views, from samples 4.2 and 4.5, Hoedongri Formation, JBNU-1759, JBNU-1784, $\times 70$, $\times 70$. (3) *Eoplacognathus linstroemi* Hamar, 1964, a juvenile form (?) of Pa element, upper view, from sample 4.6, Hoedongri Formation, JBNU-1782, $\times 85$. (4) *Polonodus* sp., symmetrical (Pa) element, upper view, from sample 2.5, Hoedongri Formation, JBNU-1795, $\times 95$. (5–8) *Erraticodon tangshanensis* Yang and Xu, 1983. 5 and 7, plectospathognathiform (Sa) elements, posterior and anterior views, from samples 1.2, Haengmae Formation and 2.5, Hoedongri Formation, JBNU-1705, JBNU-1713, $\times 45$, $\times 50$; 6, hindeodelliform (Sb) element, lateral view, from sample 2.6, Hoedongri Formation, JBNU-1724, $\times 45$; 8, cordylodontiform (M) element, lateral view, from sample 3.3, Hoedongri Formation, JBNU-1723, $\times 40$. (9 and 10) *Drepanodus arcuatus* Pander, 1856. Drepanodontiform (Sc) and oistodontiform (M) elements, lateral views, from samples 1.2 and 2.8, Hoedongri Formation, JBNU-1725, JBNU-1739, $\times 65$, $\times 70$. (11) *Drepanodus reclinator* (Lindström, 1955), oistodontiform (M) element, lateral view, from sample 4.4, Hoedongri Formation, JBNU-1766, $\times 75$. (12–15) *Aurilobodus simplex* Xiang and Zhang, 1983. 12 and 13, asymmetrical (Sc) elements, lateral views, from samples 1.2, Haengmae Formation and 1.5, Hoedongri Formation, JBNU-1706, JBNU-1702, $\times 80$, $\times 25$; 14 and 15, symmetrical (Sa) fragmentary and obliquely flattened elements, posterior and obliquely posterolateral views, from samples 1.2, Haengmae Formation and 5.3, Hoedongri Formation, JBNU-1749, JBNU-1785, $\times 65$, $\times 75$. (16 and 17) *Aurilobodus serratus* Xiang and Zhang, 1983. asymmetrical (Sc) elements, lateral views, from samples 1.2, Haengmae Formation and 1.4, Hoedongri Formation, JBNU-1711, JBNU-1708, $\times 80$, $\times 75$. (18–21) *Drepanoistodus suberectus* (Branson and Mehl). 18 and 19, oistodontiform (M) elements, lateral views, from samples 2.4 and 4.7, Hoedongri Formation, JBNU-1794, JBNU-1774, $\times 55$, $\times 65$; 20, suberectiform (Sa) element, lateral view, from sample 4.4, Hoedongri Formation, JBNU-1764, $\times 45$; 21, homocurvativiform (P) element, lateral view, from sample 4.7, Hoedongri Formation, JBNU-1780, $\times 40$. (22–24) *Plectodina onychodonta* An and Xu, 1983. prioniodiniform (Pa) elements, lateral views, from sample 1.2, Haengmae Formation, JBNU-1754, JBNU-1752, JBNU-1756, $\times 120$, $\times 65$, $\times 60$. (25 and 26) *Panderodus nogamii* (Lee, 1975), symmetrical (Pa) and asymmetrical (Sb) elements, lateral views, all from sample 3.10, Hoedongri Formation, JBNU-1778, JBNU-1779, $\times 85$, $\times 110$. (27) *Acontiodus viriosus* Cui, 1983. posterior view, from sample 1.2, Hoedongri Formation, JBNU-1720, $\times 120$. (28) *Parapanderodus paracornutiformis* (Ethington and Clark, 1982), asymmetrical (Sc) squat element, posterior view, from sample 4.5, JBNU-1772, $\times 120$. (29–32) *Triangulodus changshanensis* (Zhang, 1983). 29, trichonodelliform (Sa) element, lateral view, from sample 1.5, Hoedongri Formation, JBNU-1703, $\times 35$; 30, drepanodontiform (Sc) element, lateral view, from sample 1.2, Hoedongri Formation, JBNU-1746, $\times 175$; 31, disticodontiform (Sd) element, posterolateral view, from sample 2.7, Hoedongri Formation, JBNU-1791, $\times 125$; 32, oistodontiform (M) element, lateral view, from sample 1.2, Haengmae Formation, JBNU-1748, $\times 155$. (33–39) *Scandodus choii* n. sp. 33 and 34, acodontiform (P) elements, lateral views, from samples 1.2 and 2.8, Hoedongri Formation, JBNU-1745, JBNU-1788, $\times 60$, $\times 100$; 35–39, scandodontiform (Sb) elements, 35, 37–39, lateral and posterior views, from sample 1.2, Hoedongri Formation, JBNU-11701, JBNU-1740, JBNU-1742, JBNU-1741; 36, from sample 1.2, Haengmae Formation, JBNU-1710, $\times 35$.

n. sp. A (Stait and Druce, 1993; p. 308, fig. 18.P) appears to be an acodontiform element of *Scandodus choii* n. sp.

Scandodontiform elements of *Scandodus choii* n. sp. are very similar to P elements of *Triangulodus brevibasis* (Sergeeva) (Dzik, 1978, figs. 20c and d; Stouge and Bagnoli, 1990, Pl. 10, figs. 18 and 19) in external appearance. The former elements are short, robust forms and are recovered from upper Darriwilian beds, but the latter elements are long, slender forms and are known mainly from Dapingian strata.

Material studied – One hundred and thirty-five elements (11 acodontiform el., 124 scandodontiform el.).

Occurrence – Two elements of *Scandodus choii* n. sp. are very common in the *Aurilobodus serratus* Zone of the Haengmae and Hoedongri Formations (Darriwilian, D3), Korea, and of the Machiakou Formation, North China: sample 1.2 (Haengmae Formation), samples 1.1–1.3, 2.3–2.8, 3.2, 3.6, 3.9, 5.4, 5.6 (Hoedongri Formation).

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