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# Conodonts from the 'Lower Limestone' and Haengmae Formation in western Jeongseon, Korea and their implication for lithostratigraphic correlation

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**ABSTRACT:** The Middle Ordovician conodont fauna consisting of six species was recovered from the upper part of the Lower Limestone and the middle part of the overlying Haengmae Formation in the western Jeongseon area, Korea. Two conodont biozones are established for this interval, the *Erraticodon tangshanensis* Interval Zone for the upper part of the Lower Limestone and the *Eoplacognathus suecicus* Range Zone for the uppermost part of the Lower Limestone to the middle part of the Haengmae Formation. The first biozone is comparable to the Darriwilian (early Dw2) *Tangshanodus tangshanensis-Histiodella holodentata* Zone in North China and the *Tangshanodus tangshanensis* Zone in South Korea. The second biozone corresponds to the eponymous Darriwilian (late Dw2) zones recognized in North China and Korea. The biostratigraphy indicates that the Lower Limestone and Haengmae Formation in the western Jeongseon area is correlated only with lower and middle parts of the Jeongseon Limestone in the central and eastern Jeongseon area, and thus the Jeongseon Limestone is not a valid lithostratigraphic unit for the western Jeongseon area.

**Key words:** Darriwilian, conodonts, biostratigraphy, Lower Limestone and Haengmae Formation, western Jeongseon

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## 1. INTRODUCTION

Jeongseon is one of the areas in the Taebaeksan Basin, mid-eastern Korea where lower Paleozoic carbonate sequence is exposed (Kobayashi, 1966; Chough., 2000; Choi and Chough, 2005). Various lithostratigraphic schemes have been proposed for the area (Hisakoshi, 1943; GICTR, 1962; Son and Cheong, 1976; Cheong et al., 1979; Choi, 1998). Due to the deformed nature of the strata and paucity of biostratigraphic data, an agreement is yet to be made for the stratigraphy of the Jeongseon area.

A few conodont species were reported in the western Jeongseon area; Lee (1976) reported, from the middle part of the Lower Limestone exposed near Haengmaedong, *Scolopodus alatus* (= *Tripodus alatus*) Bradshaw, *Scolopodus giganteus* (= *Protopanderodus giganteus*) Sweet and Bergström, and *Gyrognatus* sp. (= *Erraticodon tangshanensis* Yang and Xu); Choi (1980) reported, from the Haengmae Formation, such stratigraphically long-ranging species as *Appalachignathus* cf. *delicatus*, *Acodus* sp., *Acontiodus* sp., *Drepanodus* sp., *Oistodus* sp., and *Ozarkodina* sp; Lee (1985), from the upper part of the Lower Limestone exposed near Haengmaedong, *Scolopodus nogamii* (= *Panderodus nogamii*) (Lee), *Drepanodus suberectus* (Branson and Mehl) and *Oistodus inclinatus* Branson and Mehl. No conodont biozones have been erected for the Lower Limestone.

This study describes conodont fauna of the Lower Limestone and Haengmae Formation in the western Jeongseon area, and discusses its implication for lithostratigraphical correlation between the Lower Limestone in western Jeongseon area and the Jeongseon Limestone in central and eastern Jeongseon areas.

## 2. STRATIGRAPHY

Hisakoshi (1943) established two different lithostratigraphic schemes for the lower Paleozoic strata in the Jeongseon area; Lower Limestone, Haengmak Bed and Upper Limestone, in ascending order for the western part, and Jangsan Quartzite,

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Myobong Slate, Daegi Limestone, Jukryeom Group, Dongjeom Quartzite, Dumugol Shale and Jeongseon Limestone for the eastern part. In publishing a geologic map, the Jeongseon Sheet, GICTR (1962) re-defined all the lower Paleozoic carbonate strata in the western Jeongseon area as the Jeongseon Limestone. Son and Cheong (1977) re-defined the 'Haengmak Bed' of Hisakoshi (1943) as the Haengmae Formation; the geographic name 'Haengmak' is a false spelling of the Korean village name 'Haengmae'. Cheong et al. (1979) replaced the Upper Limestone of Hisakoshi (1943) with the Hoedongri Formation, based on the discovery of early Silurian conodonts from the unit (Lee, 1980, 1982). Cheong et al. (1979) and Lee (1982) correlated the Jeongseon Limestone with the Lower Limestone of Hisakoshi (1943) without detailed account. Some authors followed this scheme of the Jeongseon Limestone, Haengmae Formation and Hoedongri Formation, in ascending order (e.g., fig. 2 in Lee, 2018). No subsequent studies have been undertaken to resolve this lithostratigraphic discrepancy.

Recent studies (Lee, 2018, 2019) indicate that the conodont fauna of the Haengmae and Hoedongri formations stratigraphically ranges from Darriwilian (late Middle Ordovician, Dw3) to Sandbian (early Late Ordovician).

The Lower Limestone and Haengmae Formation are fairly well exposed in the western Jeongseon and eastern Pyeongchang areas (Fig. 1). The Lower Limestone is in a thrust fault contact with the upper Paleozoic Pyeongan Supergroup, and the Haengmae Formation conformably overlies the Lower Limestone and is conformably overlain by the Hoedongri Formation.

The Lower Limestone, approximately 300 m thick, is mainly composed of thick-bedded massive or laminated limestone with intercalations of gray to dark gray wackestone and skeletal grainstone. The lower part consists predominantly of thick-bedded wackestone, the middle part of laminated limestone, and the upper part of alternating beds of wackestone, skeletal grainstone, and laminated limestone, occasionally with intercalations of bioturbated limestone (Fig. 2).

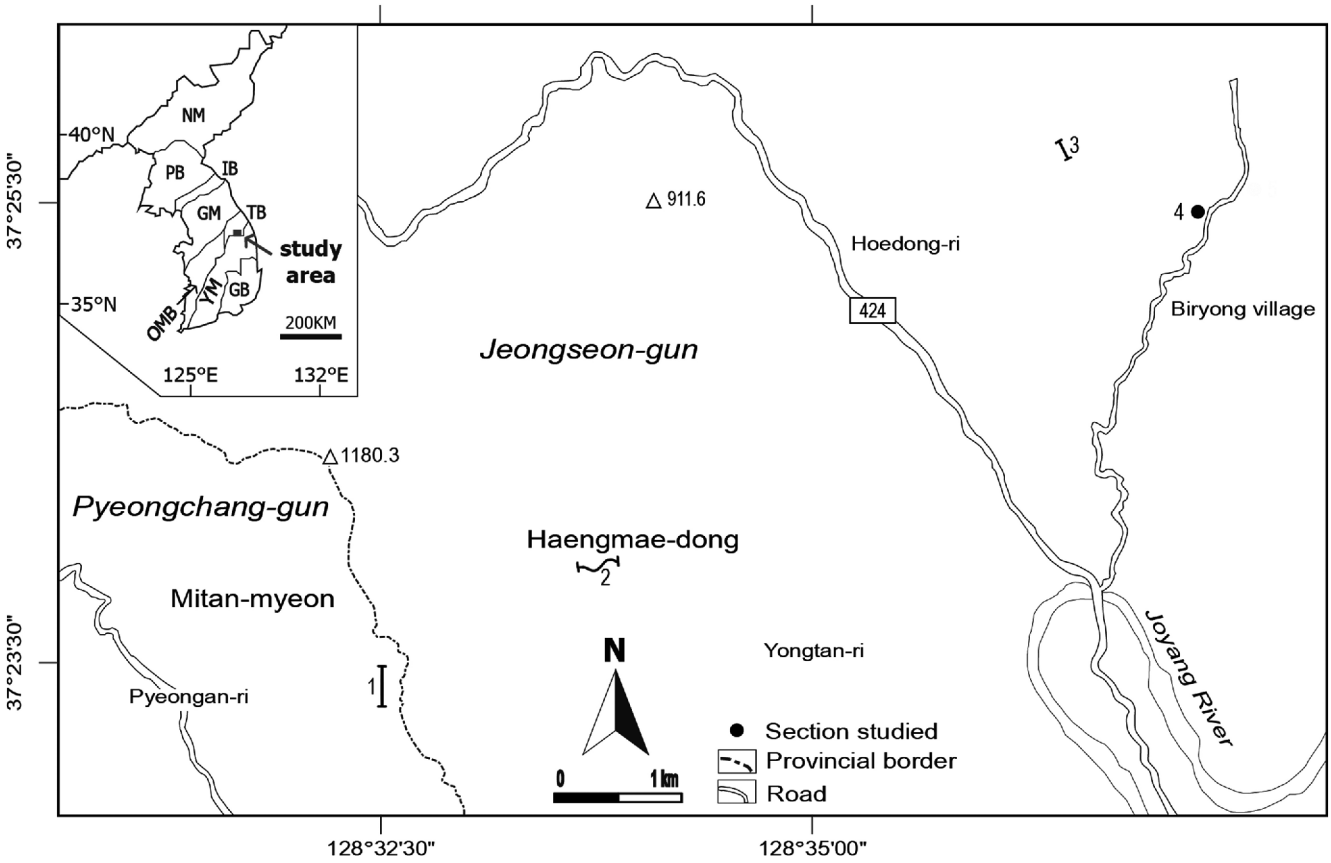


**Fig. 1.** Simplified map of western Jeongseon showing section locations (1–4). Abbreviations: NM = Nangrim massif, PB = Pyeongnam basin, IB = Imjingang belt, GM = Gyeonggi massif, TB = Taebaeksan basin, OMB = Okcheon metamorphic belt, YM = Yeongnam massif, GB = Gyeongsang basin. Section 1 is located along a forest roadcut east of Hanchidong village, Pyeongan-ri, Mitan-myeon, Pyeongchang-gun. Section 2 is located along a stream valley in Gigok village on the way to Haengmaedong village, Yongtan-ri, Jeongseon-eup, Jeongseon-gun. Section 3 is composed discontinuous stream-cut outcrops near an isolated house of Shinron village east of Hoedong-ri, Jeongseon-eup, Jeongseon-gun. Section 4 is located on a hillside near an isolated house of Biryongdong village, about 2.7 km northeast of Byeoktan Elementary School, Yongtan-ri, Jeongseon-eup, Jeongseon-gun.

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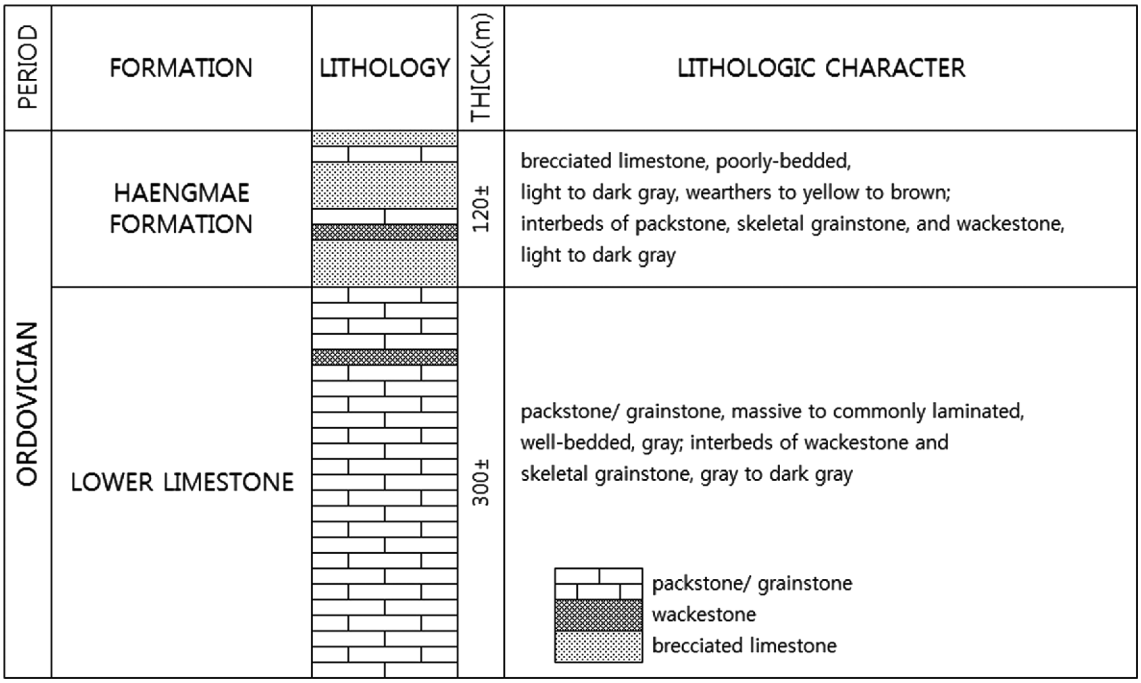


**Fig. 2.** Generalized columnar section of the Lower Limestone and Haengmae Formation at section 1, forest roadcut east of Hanchidong village, Pyeongan-ri, Mitan-myeon, Pyeongchang-gun.

## 3. SECTIONS AND CONODONT SAMPLES

A total of 30 limestone samples for conodonts were collected from the upper part of the Lower Limestone and middle part of the Haengmae Formation at four localities (Figs. 1 and 3). Section 1 has eight samples (36 kg) from the upper part of the Lower Limestone and three samples (20 kg) from the Haengmae Formation (Fig. 3). Section 2 has ten samples (20 kg) from the middle part of the Lower Limestone. Section 3 has six samples (24 kg) from the lower part of the Haengmae Formation. Section 4 has three samples (6 kg) from the upper part of the Lower Limestone (Figs. 3–5).

**Table 1.** Distribution of conodont species from the Lower Limestone and Haengmae Formation in western Jeongseon

| Section | Seongmaryeong (Section 1) | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Formation | Lower Limestone (lo) | | | | | | | Haengmae Fm. (hm) | | |
| Species / Sample number | 1 | 2 | 3 | 4 | 6 | 7 | 8 | 1 | 2 | |
| *Acontiodus viriosus* | | | 1 | | | | | | | 1 |
| *Eoplacognathus suecicus* | | | | | | | | | | |
| sinistral pastiniplanate (Pb) el. | 1 | | | | | | | | 1 | 2 |
| *Eoplacognathus* sp. | | | | | | | | | | |
| dextral stelliplanate (Pa) el. | 3 | | | | | | | | | 3 |
| *Erraticodon tangshanensis* | | | | | | | | | | |
| cordylodontiform (M) el. | 1 | 3 | 1 | 1 | | 1 | | 1 | 1 | 9 |
| plectospathognathiform (Sa) el. | | 3 | | | 1 | | | | | 4 |
| trichonodelliform (Sa) el. | | | | | | | 1 | | | 1 |
| *Panderodus nogamii* | | | | | | | | | | |
| asymmetrical (Sb) el. | | | | | | | | 1 | | 1 |
| symmetrical (Pa) el. | | | | | | | | 1 | | 1 |
| *Triangulodus changshanensis* | | | | | | | | | | |
| drepanodontiform (Sc) el. | | | | | | | | 1 | | 1 |
| oistodontiform (M) el. | | | 1 | | | | | 1 | | 2 |
| trichonodelliform (Sa) el. | 1 | 1 | | | | | | 2 | | 4 |
| Total | 6 | 7 | 3 | 1 | 1 | 1 | 1 | 7 | 2 | 29 |


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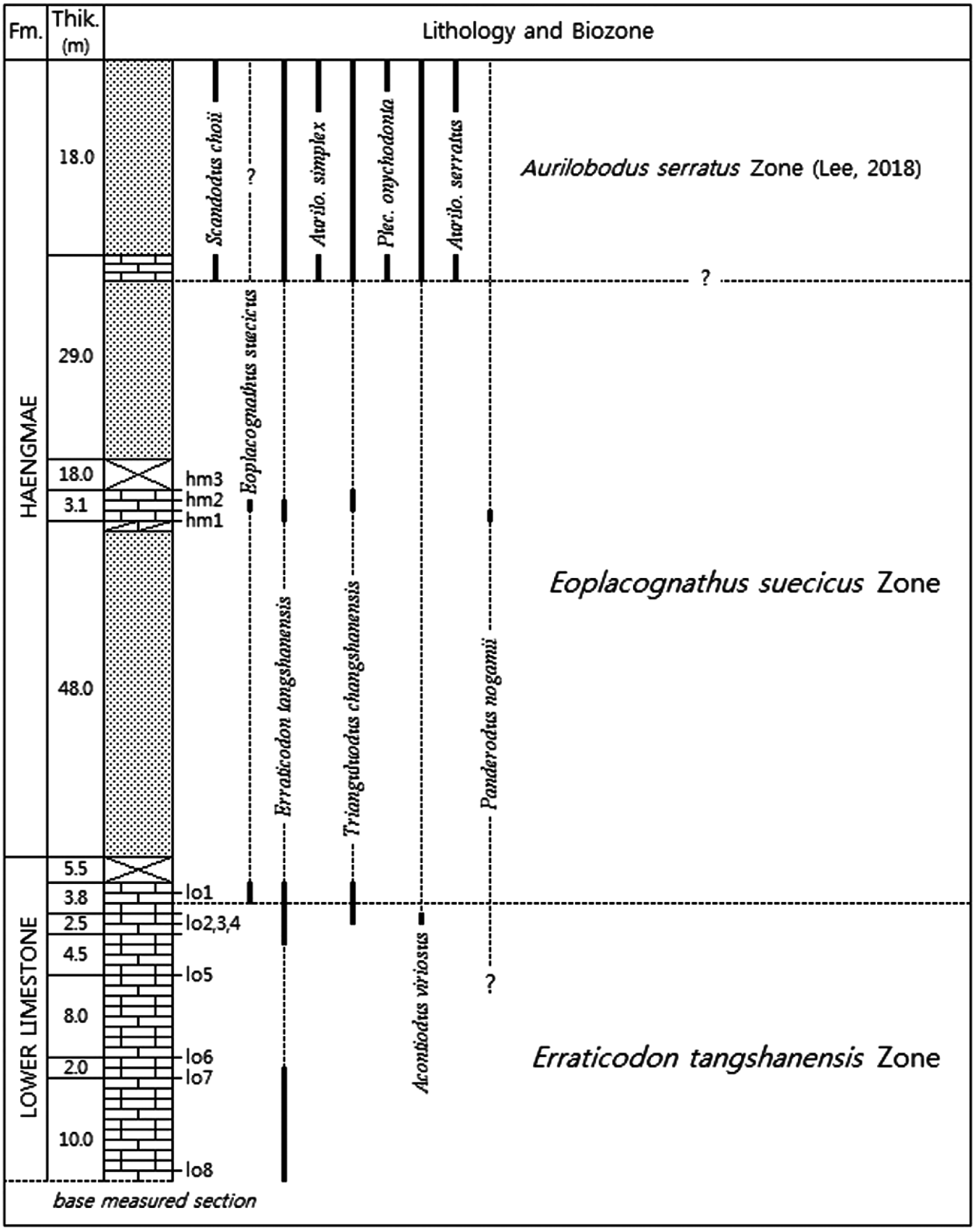


**Fig. 3.** Conodont distribution in the upper part of the Lower Limestone and Haengmae Formation at section 1, forest roadcut east of Hanchi-dong village, Pyeongan-ri, Mitan-myeon, Pyeongchang-gun.

The samples were processed through standard acid-dissolution techniques to obtain conodonts. A conodont fauna in fairly low abundance and diversity were obtained in one section (Section 1); the sample 'lo2' (Lower Limestone) and 'hm1' (Haengmae

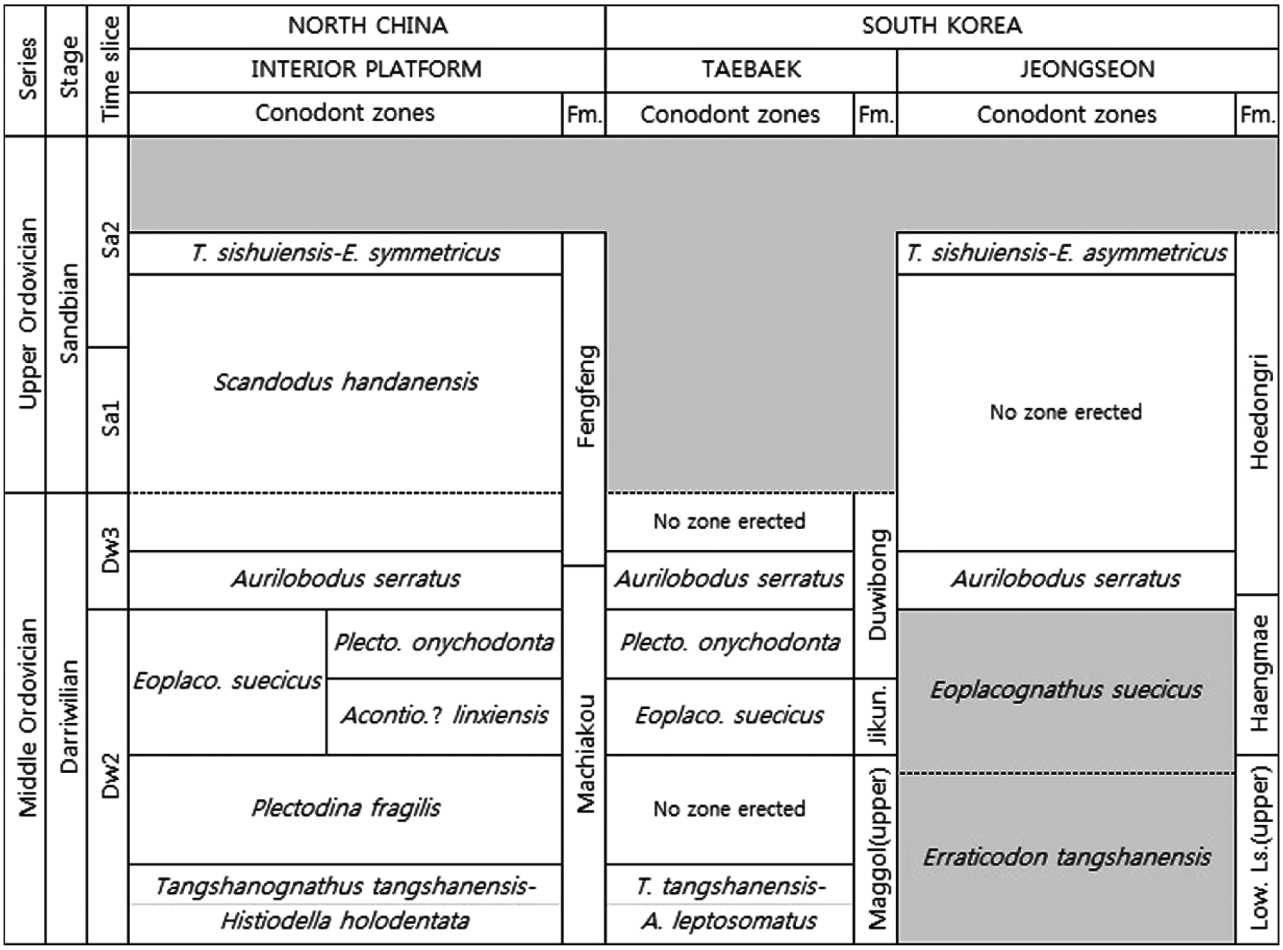


**Fig. 4.** Correlation of the *Erraticodon tangshanensis* Zone and *Eoplacoplacognathus suecicus* Zone (shadowed area) of the Lower Limestone and Haengmae Formation with the equivalent zones of North China (An et al., 1983; Wang et al., 2014), Taebaek (Lee and Lee, 1986; Kim, 1988; Lee and Lee, 1990; Seo, 2000) and Jeongseon (Lee, 2018; this study, shadowed area), Korea, based on the stratigraphic ranges of the recovered conodont species. Abbreviation: Jigun. = Jigunsan Formation.

Formation) are most abundant (Table 1). The specimens are relatively poorly preserved and some have corroded surfaces. The color alteration index (CAI) is 5, indicating burial temperature of above 300 °C (Epstein et al., 1977).

## 4. CONODONT BIOSTRATIGRAPHY

The fauna consists of six species of five genera (Table 1). The dominant species of the fauna are *Erraticodon tangshanensis* Yang and Xu (47%) and *Triangulodus changshanensis* (27%); the former occur in both Lower Limestone and Haengmae Formation.

The upper 27 m interval of the Lower Limestone contains a fauna consisting of such stratigraphically long ranging conodonts as *Acontiodus viriosus* Cui, *Erraticodon tangshanensis* Yang and Xu, and *Triangulodus changshanensis* Zhang. These species appear in stratigraphically lower intervals than the *Eoplacognatus suecicus* Zone and persist into the *Aurilobodus serratus* Zone in the lower part of the Hoedongri Formation (Lee, 2018). The *Erraticodon tangshanensis* Zone is provisionally proposed for the interval of the Lower Limestone.

The *Erraticodon tangshanensis* Zone corresponds to the Darriwilian (early Dw2) *Tangshanodus tangshanensis-Histiodella holodentata* Zone of the Machaikou and Beianzuang formations in the Tangshan area of North China (An et al., 1983; Wang et al., 2014) and the *Tangshanodus tangshanensis* Zone of the Maggol Formation in the Taebaek area of Korea (Kim, 1988; Lee and Lee, 1990).

From the horizon 'lo1' (the uppermost sampling horizon of the Lower Limestone) and 'hm2' (which is located about 48 m above the base of the Haengmae Formation), *Erraticodon tangshanensis* Yang and Xu, *Panderodus nogamii* (Lee), and *Triangulodus changshanensis* Zhang occur together with *Eoplacognathus suecicus* Bergström (Fig. 3). Based on the occurrence of the last species, the *E. suecicus* Range Zone is proposed for the interval.


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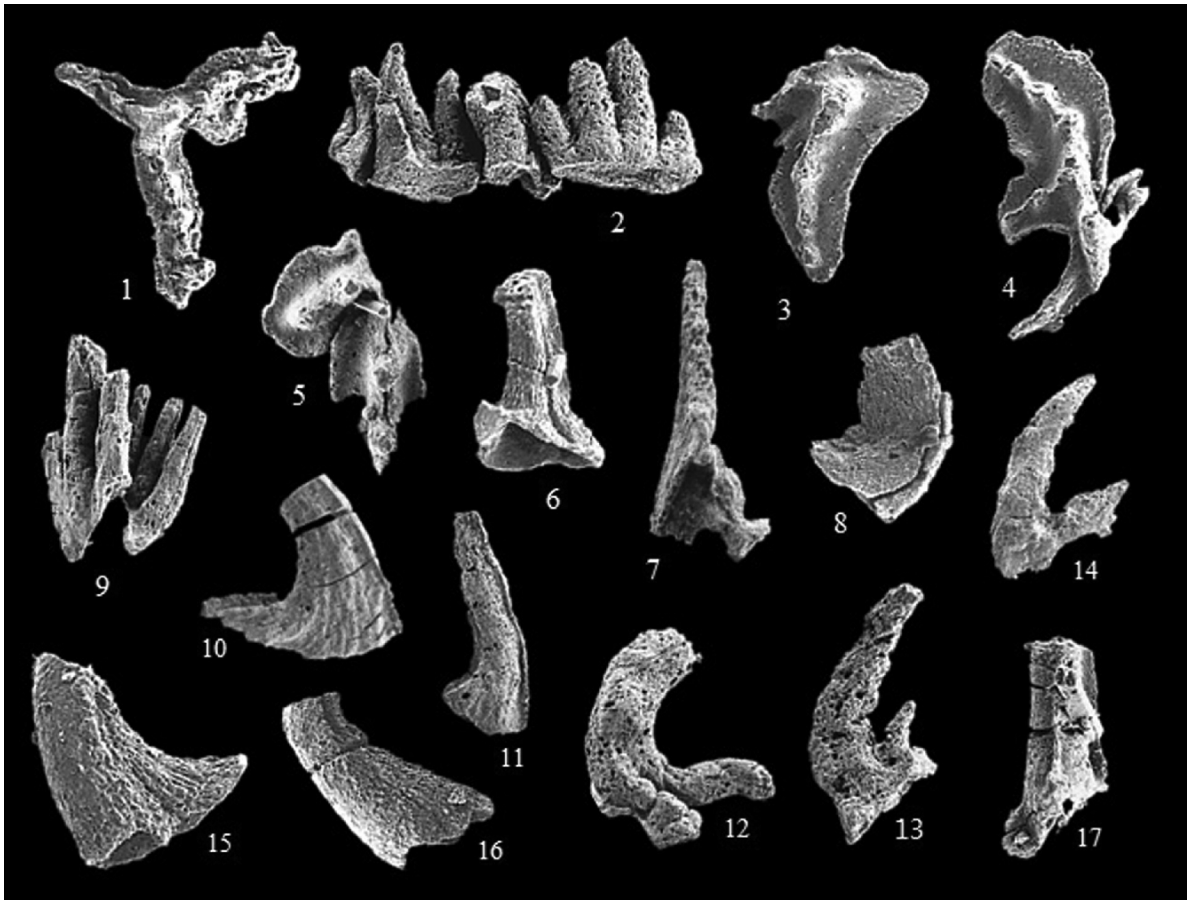


**Fig. 5.** Specimen numbers prefixed by "JBNU" are illustrated specimens (JBNU-1901~JBNU-1919) that are deposited in the Department of Earth Sciences, Chonbuk National University, Jeonju, Korea. (1) *Eoplacognathus suecicus* Bergström, 1970, sinistral pastiniplanate (Pb) element, upper view, from sample hm2 (Haengmae Formation), JBNU-1902, ×75. (3–5) *Eoplacognathus* sp., dextral stelliplanate (Pa) elements, upper views, all from sample lo1 (Lower Limestone), JBNU-1908, JBNU-1912, JBNU-1912, ×70, ×75, ×75. (2, 5, 12–14) *Erraticodon tangshanensis* Yang and Xu, 1983, 2, 5, plectospathognathiform (Sa) elements, posterior views, from sample lo2 and lo6, Lower Limestone, JBNU-1911, JBNU-1918, ×50, ×60; 12, trichonodelliform (Sa) element, lateral view, from sample lo8, Lower Limestone, JBNU-1914, ×45; 13, 14, cordylodontiform (M) elements, lateral views, from sample lo2 and lo1, Lower Limestone, JBNU-1915, JBNU-1910, ×55, ×50. (6–11) *Triangulodus changshanensis* Zhang, 1983, 6, 7, trichonodelliform (Sa) elements, posterior views, from samples hm2 and hm2, Haengmae Formation and Lower Limestone, JBNU-1903, JBNU-1904, ×35, ×45; 8, 10, oistodontiform (M) elements, lateral views, from samples lo3 and hm3, Lower Limestone and Haengmae Formation, JBNU-1919, JBNU-1907, ×90, ×65; 11, drepanodontiform (Sc) element, lateral view, from sample hm3, Haengmae Formation, JBNU-1901, ×55. (15 and 16) *Panderodus nogamii* (Lee, 1975), symmetrical (Pa) and asymmetrical (Sb) elements, lateral views, all from sample hm3, Haengmae Formation, JBNU-1906, JBNU-1905, ×80, ×75. (17) *Acontiodus viriosus* Cui, 1983, posterior view, from sample lo3, Lower Limestone, JBNU-1917, ×85.

*E. suecicus* is a pandemic species well known from the Darriwilian (late Dw2) (Bergström, 1970; Viira, 1972, 1974; Dzik, 1976; Löfgren, 1978; An et al., 1983; Lee and Lee, 1986; An, 1987; Lee and Lee, 1990; Sarmiento, 1991; Wang et al., 1996; Zhang, 1998, 1999; Seo, 2000; Zhen et al., 2011a, 2011b; Wang et al., 2014; Jing et al., 2015, 2016).

The *Eoplacognathus suecicus* Zone has been established in the Machiakou and Klimoli formations in North China (An et al., 1983; Wang et al., 2014; Jing et al., 2015), the Guniutan Formation in South China (Zhang, 1998), and the Jigunsan and Goseong formations in South Korea (Lee and Lee, 1986; Seo, 2000). The uppermost 18 m interval of the Haengmae Formation is assignable to the *Aurilobodus serratus* Zone (Fig. 3; Lee, 2018).

## 5. IMPLICATION FOR LITHOSTRATIGRAPHY

In establishing the Jeongseon Limestone in the eastern and central Jeongseon area, Hisakoshi (1943) mentioned that the unit can be correlated with the Maggol, Jigunsan and Duwibong formations of the Taebaek Group. Comparison of the two conodont biozones defined in this study with those of the Taebaek Group indicates that the upper part of the Lower Limestone corresponds with the upper part of the Maggol Formation and the uppermost part of the Lower Limestone to middle part of the Haengmae Formation with the Jigunsan Formation and lower part of the Duwibong Formation (Fig. 4). Therefore, the upper part of the Lower Limestone and the uppermost part of

the Lower Limestone to middle part of the Haengmae Formation each can be correlated with the lower and middle part of the Jeongseon Limestone in the eastern and central Jeongseon area, respectively. This suggests that contrary to Cheong et al. (1979) and Lee (1982), the Jeongseon Limestone as defined by Hisakoshi (1943) cannot be correlated with the Lower Limestone, and the lithostratigraphic unit is not applicable to the western Jeongseon area.

## 6. CONCLUSIONS

A total of 29 conodonts of fairly low abundance and diversity were recovered from the upper part of the Lower Limestone and middle part of the Haengmae Formation in the western Jeongseon–Pyeongchang area.

The conodont fauna from the upper part of the Lower Limestone includes *Acontiodus viriosus* Cui, *Erraticodon tangshanensis* Yang and Xu, and *Triangulodus changshanensis* Zhang. The *Erraticodon tangshanensis* Interval Zone is proposed for this assemblage. The zone corresponds to the Darriwilian (early Dw2) *Tangshanodus tangshanensis* Zone defined in the upper part of the Maggol Formation of the Taebaek Group.

The conodont fauna from the uppermost part of the Lower Limestone and middle part of the Haengmae Formation includes *Eoplacognathus suecicus* Bergström, *E.* sp., *Erraticodon tangshanensis* Yang and Xu, *Panderodus nogamii* (Lee), and *Triangulodus changshanensis* Zhang. This assemblage is assigned to the *Eoplacognathus suecicus* Range Zone, which is correlated to the eponymous Darriwilian (late Dw2) zone recognized worldwide including the Jigunsan Formation of the Taebaek Group.

This biostratigraphic data indicates that the Lower Limestone and Haengmae Formation in the western Jeongseon area are only correlatable to lower and middle parts of the Jeongseon Limestone in the central and eastern Jeongseon area which is considered to be correlated with the Maggol, Jigunsan and Duwibong formations of the Taebaek Group. Therefore, the Jeongseon Limestone as a lithostratigraphic unit cannot be applied to the western Jeongseon area.

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