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New occurrence of *Cupressinocladus* sp. from the Lower Cretaceous Jinju Formation, Shindong Group, Korea

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Abstract: *Cupressinocladus* sp. found from the upper part of the Jinju Formation of the Shindong Group, Korea is described here based on the newly found leafy shoots. This species is characterized by the branched leafy shoot with decussate scale leaves. The presence of *Cupressinocladus* in the Jinju Formation indicates that the Early Cretaceous flora-sites in Eastern Eurasia are in a close association with territories of the mixed-type floras. The finding of this species records the first report for the Nakdong flora.

Keywords: *Cupressinocladus*, Jinju Formation, mixed-type flora, Lower Cretaceous

Introduction

The Lower Cretaceous Shindong Group (formerly called Nakdong Series) has been yielding abundant plant fossils called the Nakdong flora, while containing other vertebrate and invertebrate fossils at the same time. Since the first study of the Nakdong flora by Yabe (1905), some paleobotanical studies from the Gyeongsang Basin and its equivalent were carried out by Ogura (1927), Tateiwa (1929), Hatae (1937), Oishi (1939, 1940), Kobatake (1958), Chun et al. (1994), Kenrick et al. (2000), and Kimura (2000). As already mentioned by Kenrick et al. (2000), the Cretaceous flora has been poorly studied in Korea despite the widespread occurrence of non-marine sediments and a long history of paleontological investigation.

Tateiwa (1976) reviewed the plant fossils described or illustrated by the previous workers as mentioned above. According to his study, the Nakdong flora consists of 50 species. However, his review has not been descriptive enough. Kimura (2000) also reviewed the Nakdong flora based on the recent paleobotanical knowledge and reclassified them into 36 species without detailed descriptions. As a result, it is highly desirable to conduct the systematical and critical re-examination of the Nakdong flora.

Kimura (2000) mentioned that the Haman flora from the Haman Formation in the Daegu area consists of 27 species including 14 species of angiosperms. However, the plant fossils called as Haman flora by Kimura (2000) did not occur in the Haman Formation. Instead, it occurred in other formation of Cretaceous strata distributed in the Jinan (Tateiwa, 1929) and Yongdeok (Hatae, 1937) areas. The fossil plants from the Haman Formation in the Daegu and Yongcheon areas have been scarcely investigated until now. According to Hatae (1937), there are two Cretaceous floras in the Yongdeok area; Kyeongjeongdong and Sinyangdong floras. The former does not include any angiosperms and is correlated with the Nakdong flora (Chang and Yang, 1970; Chun et al., 1994), and the latter includes various angiosperms, while being correlated with the Geoncheonri Formation of the Hayang Group in the Daegu area (Chun et al., 1994). Accordingly, the name of Haman flora is not appropriate. It seems to be the result of mis-reading of Jinan as Haman. The plant fossils described by Kenrick et al. (2000) from the Kohung area, Chonnam Province is similar in floristic composition to the Nakdong flora.

In this study, *Cupressinocladus* sp. from the Jinju Formation distributed in the Gunwi area, Kyeongsangbuk-do has been examined and explained based on the newly found leafy branches.

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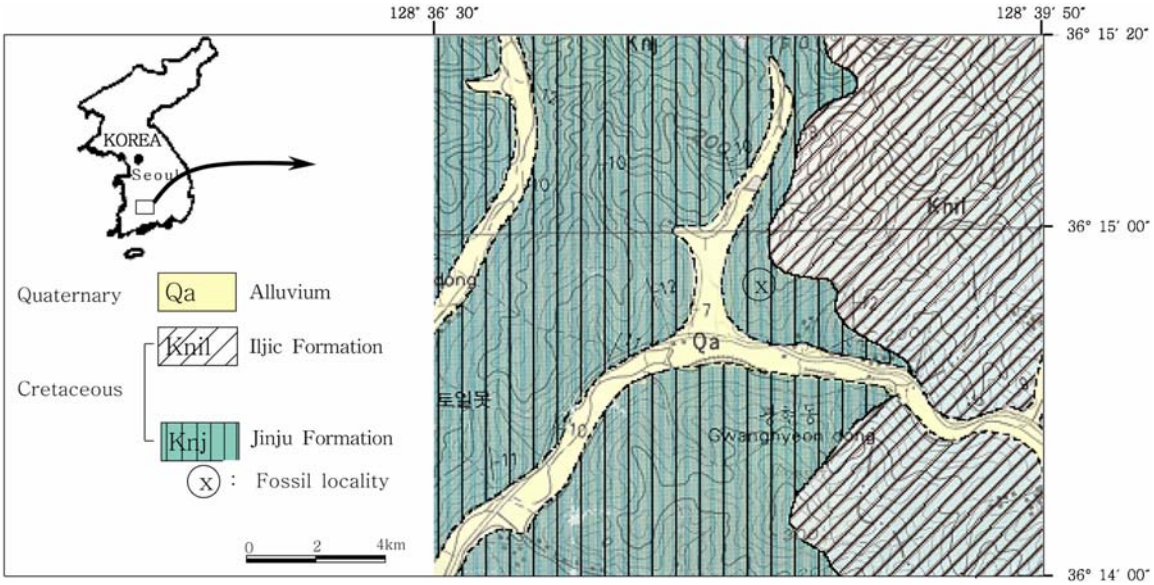

Fig. 1. Geologic map of the Gunwi area (partly redrawn after Chang et al., 1981) and fossil locality.

Geological Setting and Fossil Locality

The Early Cretaceous Gyeongsang Supergroup of non-marine origin is widely distributed in the southeastern Korean Peninsula which is divided into the Shindong, Hayang and Yucheon Groups in the ascending orders (Chang, 1975). Of these, both the Shindong and Hayang Groups yielded abundant vertebrate and invertebrate fossils, while plant fossils are mainly found in the Shindong Group in the Gyeongsang Basin.

The Shindong Group is geographically restricted to the western part of the Kyeongsang Basin which can further be divided into the Nakdong, Hasandong, and Jinju Formations in the ascending order. As already mentioned by Kimura (2000), many fossil plants have been identified from the Nakdong Formation (Yabe, 1905; Ogura, 1927; Oishi, 1939, 1940), and a few were described from the Hasandong and Jinju Formations (Tateiwa, 1929). Besides plant fossils, the Jinju Formation yields many kinds of fossils such as microfossils of spore and pollen (Choi, 1985; Choi and Park, 1987; Yi et al., 1994), charophytes (Choi, 1989), stromatolite (Lee and Woo, 1996; Lee and Gong, 2004; Choi, 2007), conchostracans (Park and Chang, 1998; Lee et al., 1993), molluscs (Kobayashi and Suzuki, 1936; Yang, 1978), and trace fossils (Kim et al., 2000).

Fig. 2. Outcrop photo exposed along the bottom of stream in the Gwanghyeonri area.

According to Chang et al. (1981), the Jinju Formation is about 900 m thick and consists of sandstone and dark gray shale, conglomerate, and limestone thin beds. The plant fossils occurred in the shale and were closely associated with insect and conchostracan fossils. The fossil locality is shown in

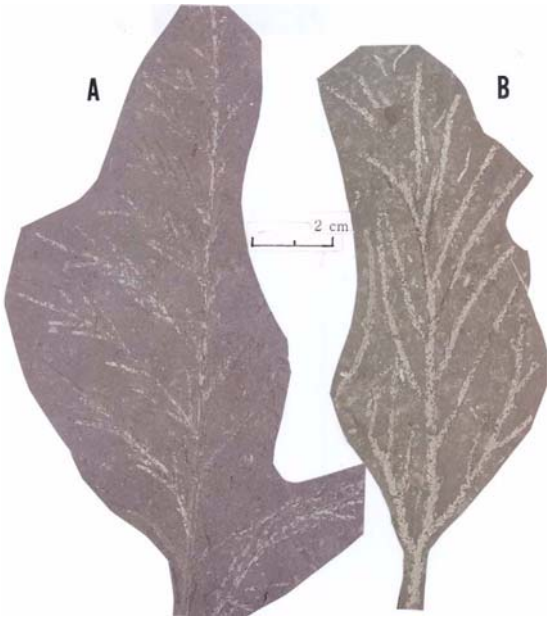

Fig. 3A, B. Branched leafy shoots of *Cupressinocladus* sp.

Fig. 1 and 2. The geological age of the Jinju Formation has generally been estimated as the Neocomian or Aptian-Albian based on the spore and pollen (Choi, 1985; Choi and Park, 1987) and fossil plants (Kimura, 2000).

Material and Method

Ten leafy branches were obtained from a locality of the upper part of the Jinju Formation distributed along the small stream in the Gwanghyeonri area of Gunwi-gun, Kyeongbuk Province. The plant fossils are preserved as impression on the bedding plane of the shale where insect and conchostracan fossils are quite abundant. In this study, the leafy branches were examined and compared with other specimens of *Cupressinocladus*. The specimens examined in this study will be preserved at the Department of Earth Science, Kongju National University.

Description of specimen

Order Coniferales

Family Cheirolepidiaceae

Form-genus *Cupressinocladus* Seward, 1919

Cupressinocladus sp.

Figs. 3A, B

Cupressinocladus sp.: Kimura, Ohana, and Naito, 1992, p. 83, figs. 3a-b

Material: KNU-20090328001, 20090328004

Description: Two fragments of coniferous leafy-shoot were obtained. Preserved main branch is more than 19.5 cm long, 3 mm wide below and sends alternately disposed penultimate leafy-branches at a wide angle and at intervals of 1-2 cm. Penultimate leafy-branch is linear in form, up to 2 cm wide and 6 cm long as seen. Ultimate leafy-branches are closely set, alternate or subopposite, up to 2 cm long and 1 mm wide, nearly parallel-sided for the most part, straight or sometimes falcate, and originated at a wide angle to the penultimate axis and at intervals of 1 cm-3 mm. Ultimate and penultimate axes are entirely covered by scale leaves. Leaves are rhomboidal in form, with acutely pointed apex and decurrent base, decussate, entirely appressed to the axis and 1.5 mm long and 0.75 mm wide. No interstitial appendages originated from the main axis have been recognized between adjacent penultimate branches. Cuticle is not preserved. Reproductive organs are not known.

Occurrence: Two specimens occurred in the upper part of the Jinju Formation.

Comparison and Discussion

As already mentioned by Kimura et al. (1992), Seward (1919) proposed a non-committal genus *Cupressinocladus* for coniferous leafy-shoots having external resemblance to those of extant conifers belonging to Cupressaceae. Later additional diagnostic features were mentioned by Chaloner and Lorch (1960), Harris (1969), and Barnard and Miller (1976). The present leafy-shoot is characterized by the branched leafy shoot with decussate leaves. These characters of the present specimens can be included in Seward's form-genus.

Although no details of reproductive organ and cuticle have been known in the present specimens, the

present leafy shoots agree in decussate leaf arrangement well with *Cupressinocladus* sp. described from the Lower Cretaceous Wakino Formation, West Japan (Kimura et al., 1992).

Cupressinocladus sp. is similar in external appearance to *C. mimotoi* known from the Lower Cretaceous plant-bed in the Outer Zone of Southwest Japan (Kimura and Ohana, 1987), but differs from the latter by its shorter ultimate branches.

Cupressinocladus obatae described by Okubo and Kimura (1991) from the Lower Cretaceous Choshi Group in the Outer Zone of Japan differs in leaf size and shape from the present *C.* sp.

Cupressinocladus sp. differs in leaf arrangement from those of the form genus *Brachyphyllum*. In the latter, the leaves are spirally arranged (Harris, 1979).

Many *Cupressinocladus* species have been described from the Late Triassic or Jurassic plant-beds to the Cretaceous plant-beds in the Northern Hemisphere (e.g. Chaloner and Lorch, 1960; Sze et al., 1963; Barnard and Miller, 1976; Harris, 1979) and it also from the Tertiary flora in the Spitzbergen (e.g. Schweitzer, 1974) and in the Outer Zone of Japan (e.g. Kimura and Ohana, 1987; Ohana and Kimura, 1989; Okubo and Kimura, 1991). Most of these species are not only based on macroscopic features but also on their cuticles (Chaloner and Lorch, 1960; Barnard and Miller, 1976; Watson, 1977, 1982; Okubo and Kimura, 1991). If the leafy-shoots are associated with reproductive organs or their cuticles as mentioned above, the taxonomic affinity of the present *Cupressinocladus* sp. can be precisely made clear.

The form genus *Cupressinocladus* is characterized by its vegetative shoots with decussate leaf arrangement, and these characters closely resemble those of some extant conifers belonging to the living Cupressaceae. But, most fossil species belong to the fossil Cheirolepidiaceae. Watson (1988) reviewed 22 foliage species as fairly securely attributable to the family Cheirolepidiaceae. According to him, among 22 species, 15 have actually been identified based on the evidence of associated or even attached reproductive organs. 22 species are currently distributed to 7 genera, such as *Brachyphyllum, Cupressinocladus, Frenelopsis, Hirmeriella, Pagiophyllum, Pseudofrenelopsis*, and *Tomaxellia*.

Similar thought was mentioned by Okubo and Kimura (1991). After studying cuticles of extant cupressaceous conifers and extinct chirolepidiaceous conifers, Okubo and Kimura (1991) showed in detail the differences between two groups. According to them (1991), *Cupressinocladus obatae* Okubo and Kimura, together with *Frenelopsis choshiensis* (Kimura et al., 1985) from the Lower Cretaceous Choshi Group, Japan, apparently does not belong to Cupressaceae, but to Cheirolepidiaceae based on their cuticle features. Under the circumstances, it is highly probable that the present *Cupressinocladus* sp. newly found from the Jinju Formation belongs to Cheirolepidiaceae and not to Cupressaceae.

In addition, on the basis of an insufficiently preserved single broken leafy shoot, Chun et al. (1994) reported *Cupressinocladus* sp. from the Gyeongjeongdong Formation in the Yongdeok area without description. Unfortunately it is not clear whether they are decussate or spiral. Thus it is difficult to compare with other species.

No similar leafy shoot to the present *Cupressinocladus* sp. has been yet recorded from the Lower Cretaceous strata in the Korean Peninsula except for *Cupressinocladus* sp. from the Gyeongjeongdong Formation

Paleophytogeographical Significance

It is commonly accepted that paleophytogeophycally that three floristic provinces did exist during Late Jurassic to Early Cretaceous time in Eastern Eurasia; Ryoseki-type floras distributed in the Outer Zone of Japan, Tetori-type floras in the Inner Zone of Japan, and Mixed-type floras in the western part of Japan (Kimura, 1961, 1987, 2000b; Kimura and Ohana, 1987, 1992). The Ryoseki-type floras flourished in the subtropical - tropical regions with annual dry season. The Tetory-type and Mixed-type floras flourished in

the subtropical or warm-temperate and in the temperate regions, respectively (Kimura, 2000b). According to Kimura (2000a), the Nakdong flora from the Shindong Group is of the Mixed-type flora. The Early Cretaceous floras belonging to the Mixed-type flora in Eastern Eurasia commonly include conifers with scale-leaves, such as *Cupressinocladus*, *Brachyphyllum*, and *Frenelopsis* (or *Pseudofrenelopsis*) which are characteristic elements of the Ryoseki-type flora (Kimura, 2000b; Kimura and Ohana, 1992). However, in Tetori-type floras, no conifers with scale-leaves such as *Cupressinocladus*, *Brachyphyllum*, and *Frenelopsis* have been found until now (Kimura et al., 1992) except for the Wakino Formation in Japan. According to the plant taxa reported from the Shindong Group (Tateiwa, 1976; Kimura 2000a), the Nakdong flora commonly includes *Brachyphyllum* and *Frenelopsis*. Accordingly, the presence of *Cupressinocladus* in the Nakdong flora indicates that the Early Cretaceous flora-sites are in a close association with territories of the Mixed-type floras in Eastern Eurasia.

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