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New Materials of *Leptostrobus myeongamensis* Kim (Czekanowskiales) from the Upper Triassic Amisan Formation of Nampo Group in Korea

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Abstract: Some materials belonging to the *Leptostrobus myeongamensis* Kim were found in the Upper Triassic Amisan Formation, Nampo Group, Korea. This species is closely associated with the foliage of *Czekanowskia* ex gr. *rigida* Heer. Although none of *Leptostrobus myeongamensis* Kim has been found in organic connection with *Czekanowskia* leaves, it is considered that they belong to the same taxa based on their common occurrence. The occurrence of *Leptostrobus myeongamensis* Kim from the Late Triassic floras of Korea is one of the oldest records in the Mesozoic floras found in the world.

Keywords: *Leptostrobus myeongamensis, Czekanowskia* ex gr. *rigida,* Late Triassic, Amisan Formation, Czekanowskiales

Introduction

The genus *Leptostrobus* belonging to Czekanowskiales is characterized by a slender cone axis bearing rather distant fertile cones above and small scale leaves at the base. This genus has been known as a female reproductive organ of *Czekanowskia* Heer (Harris, 1951). The genus *Leptostrobus* was first established by Heer (1876) from the Middle Jurassic in Ust-Balei and Kajamundung of the Amurland region, Siberia. It is now mostly recorded from the Mesozoic strata in the northern Hemisphere (e.g., Harris, 1951; Vakhrameev, 1964; Samylina, 1967; Krassilov, 1968, 1970; Harris and Miller, 1974; Kimura and Tsujii, 1984; Kim et al., 2002; Miao, 2003; Liu et al., 2006) but rarely in the southern Hemisphere (Jones and De Jersey, 1947; Clifford and Camilleri, 1998).

To date twenty species of *Leptostrobus* have been identified and described from the Mesozoic strata of the world (Kim et al., 2002). Among them, most species of *Leptostrobus* have been known from the Lower Jurassic to Lower Cretaceous strata of the world. In the Late Triassic, reproductive organ fossils belonging to *Leptostrobus* are very rare, and only five species of them have been identified from the Upper Triassic strata of the world (Oishi and Takahashi, 1936; Oishi, 1940; Jones and De Jersey, 1947; Wang and Wang, 1984, Clifford and Camilleri, 1998; Kim et al., 2002; Liu et al., 2006).

In Korea, the existence of Czekanowskiales was first recognized, when Kawasaki (1939) described *Czekanowskia setacea* Heer from the Bansong Group in the Yeongweol area, Gangweon-do. On that date, Kawasaki (1939) regarded it as belonging to a genus of Ginkgoales. However, Kawasaki's *Czekanowskia setacea* Heer has been transferred to *C*. sp. belonging to Czekanowskiales by Kimura and Kim (1984a). The genus *Leptostrobus* was first described in Korea as *L. myeongamensis* Kim from the Late Triassic Amisan Formation of Nampo Group distributed in the Chungnam Basin (Kim et al., 2002).

Recently, although incomplete, one cone axis and two cone bases of reproductive organs belonging to *Leptostrobus* with many other fossil plants were collected from the Amisan Formation at the inkstone quarry in the Myeongam area, Dongdae-dong, Boryeong-city, Chungcheongnam-do. In this study, this author described the reproductive organs of *Leptostrobus* based on the new materials and explored its paleogeographic significance.

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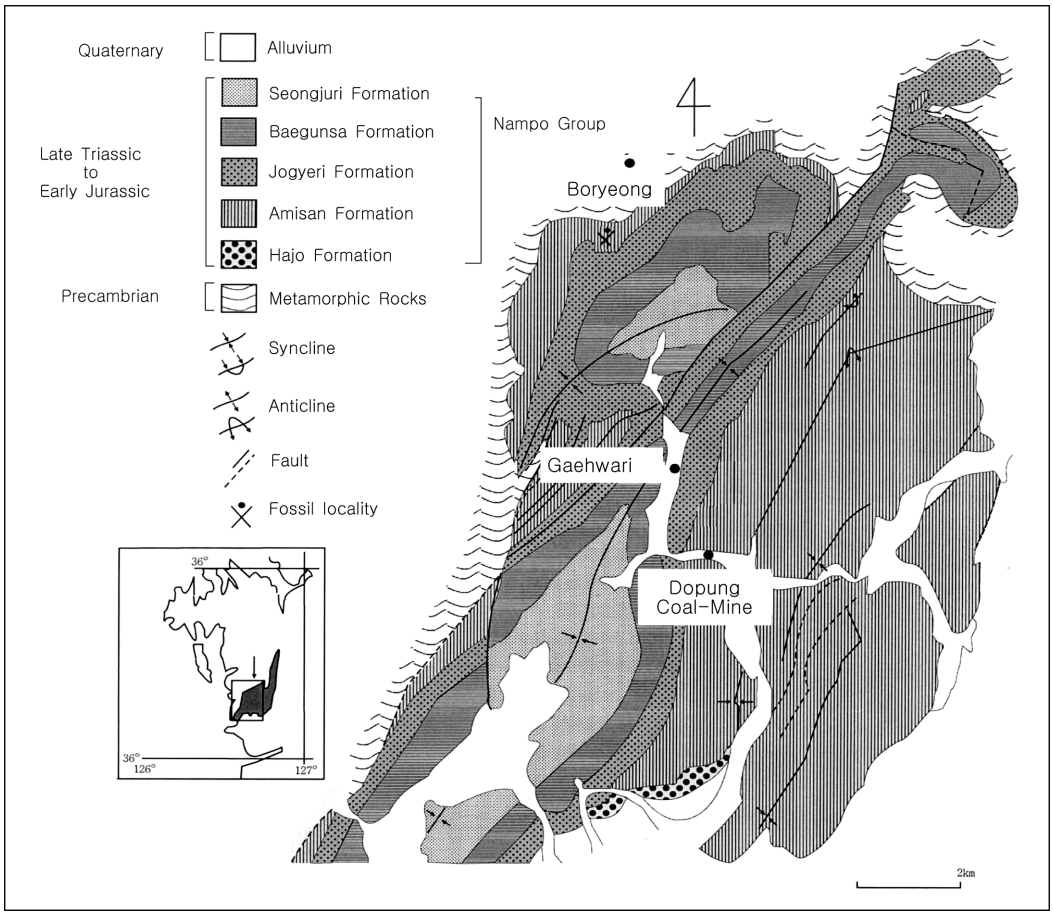

Fig. 1. Geologic map of the study area (partly modified from Choi et al., 1986) and fossil locality.

Stratigraphy

The Nampo Group is distributed in the Chungnam Sedimentary Basin of the southwestern part of Chungcheongnam-do, Korea. Shimamura (1931) first surveyed geological investigation in the Chungnam Sedimentary Basin, and then some geological studies were carried out by several geologists (e.g., Reedman and Um, 1975; Suh et al., 1980). According to Suh et al. (1980), the Nampo Group is subdivided into five formations, i.e., the Hajo, Amisan, Jogyeri, Baegunsa and Seongjuri Formations in an ascending order. Depositional environment of the Nampo Group has been considered to be an alluvial fan, fluvial plain, and lake environment (Choi et al., 1986, 1988). The fossil locality is the Myeongam area (N 36°28'02", E 127°08'40") shown in Fig. 1. The geologic age of the Amisan Formation based on the fossil plants and conchostracans has been considered to be Late Triassic (Kimura and Kim, 1984a, 1984b; Kobayashi, 1975; Kim and Kimura, 1988, 1989; Kim, 1993, 2001).

Systematic Description

Order Czekanowskiales

Genus *Leptostrobus* Heer 1876 emended Harris 1951

Type species *Leptostrobus laxiflora* Heer 1876

Leptostrobus myeongamensis Kim 2002

Figs. 2A-C

Leptostrobus myeongamensis Kim: 2002, text figs. 3-4, Figs. 5-6.

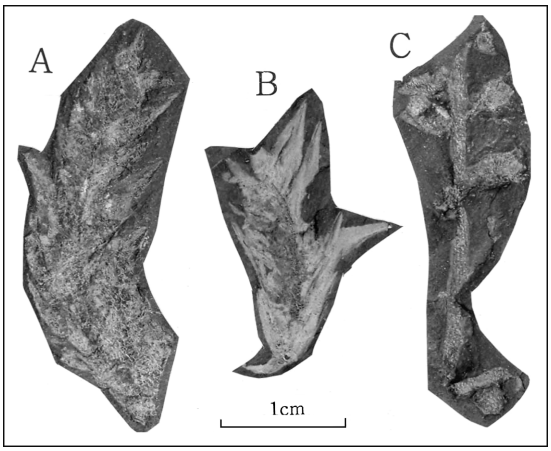

Fig. 2. Cone axis and cone base of *Leptostrobus myeongamensis* Kim. A, B; A part of cone base, covered with compact scale leaves. C; A upper part of cone axis bearing lateral capsules, all scale leaves are detached.

Material: KNU-2009-0001, 0002, 0003. The specimens herein examined will be deposited at the Department of Earth Science, Education of College., Gongju National University. The specimens are associatied with *Czekanowskia* ex gr. *rigida* Heer, *Neocalamites carrerei* (Zeiller), *Baiera* cf. *furcata* Braun, and *Sphenobaiera* cf. *spectabilis* (Nathorst).

Distribution and occurrence: This species is only known from the Amisan Formation and very rare in occurrence.

Description: A single cone axis and two cone bases were obtained from the Amisan Formation, but they are all broken and preserved as impression.

Cone axis: A fragment of cone axis is probably middle parts of cone axes (Fig. 2C). Cone axes is slender and unbranched, 3 cm in length and 1-2 mm in width, bearing loose spirally disposed capsules at intervals of 5 mm. Capsule is poorly preserved, obovate or rounded in shape and sessile, 5-6 mm in length and 3-4 mm in width. The structure of capsule is uncertain and seeds and two valves of capsule are not recognized

Cone base: Two broken small fragments of cone bases were obtained. One is 3 cm in length and 1 cm in width. The axis is covered with compact scale leaves (Fig. 2A), but it's exact phyllotaxy is unknown. The scale leaf is lanceolate in shape with acutely pointed apex, 6-7 mm in length and 2 mm in the widest basal part. Another cone base (Fig. 2B) is 2.5 cm in length and 1.5 cm in width, covered with small scale leaves. The scale leaves are similar in size and form to those of Fig. 2A as mentioned above. Although their size differs, the present two fragments of cone base are considered to be the same species because of the similarity of their scale leaves in size and form.

Discussion

The morphological features of the present cone axis and cone base are nearly identical in all respects to *Leptostrobus myeongamensis* Kim originally described by Kim et al. (2002) from the same locality except for the absence of subtending scale leaves on the cone axis. According to Kim et al. (2002), the cone axis of *L. myeongamensis* Kim is characterized by the presence of capsules in loose spiral, each capsule consisting of a rounded capsule and its subtending a scale leaf. Among twenty species of *Leptostrobus* including 15 species reviewed by Liu et al. (2006), *L. myeongamensis* Kim is unique in the presence of scale leaves on the cone axis. The presence of scale leaves on the cone axis was already mentioned by Krassilov (1968, 1970) and Harris and Miller (1974). According to Harris and Miller (1974), seed capsule is wedge-shaped or rounded, almost sessile on cone axis, or shortly stalked and stalk sometimes with a few scale leaves. However, most species of *Leptostrobus* did not associate with scale leaves as shown in the present material. Judging from this fact, scale leaves on the cone axis appears to be caducous. The same feature is also shown in *L. myeongamensis* Kim (Kim et al., 2002, Fig. 5c).

Harris and Miller (1974) also mentioned that each capsule has two valves, each valve bearing small elongated seeds on its inner face. In the present cones, any valves and seeds on capsules are not recognized. It means that the present cone axis is considered to be immature or abortive. When the cones are fully

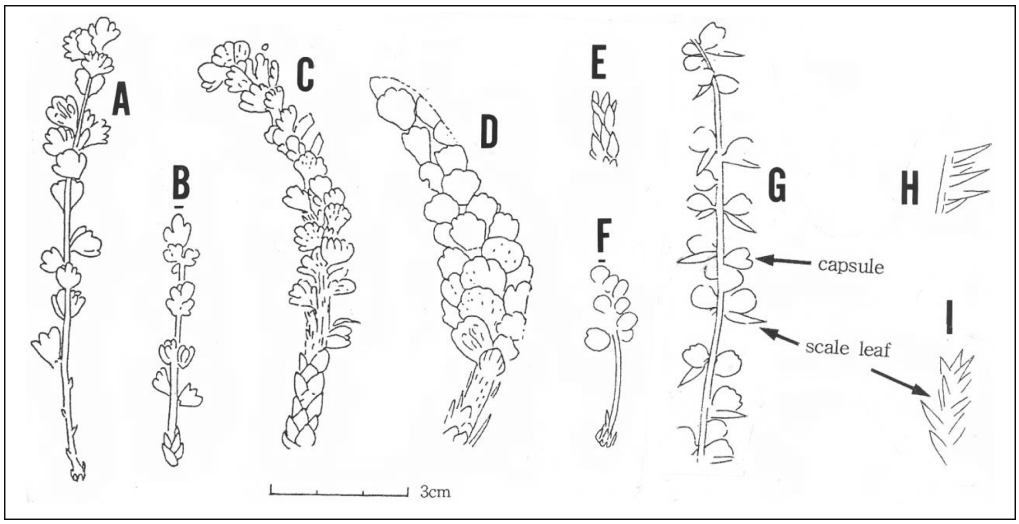

Fig 3. Comparison of *Leptostrobus myeongamensis* Kim with four species of *Leptostrobus* with basal scale leaves. A, B; *Leptostrobus laxiflora* Heer(1876, pl. 13, Fig. 10A;1880, pl. 7, Fig. 4). C, D; *Leptostrobus crassipes* Heer(1876, pl. 13, Fig. 15; 1880, pl. 8, Fig. 2). E; *Leptostrobus sphaericus* Wang(Wang and Wang, 1984, pl. 154, Fig. 7). F; *Leptostrobus cancer* Harris (Harris and Miller, 1974, pl. 7, Fig. 4). G-I; *Leptostrobus myeongamensis* Kim (Kim et al., 2002, Figs. 3, 4)

grown, scale leaves appear to be easy to shed from ripe capsules or during the fossilization.

Apart from the presence of scale leaves on cone axis, most species of *Leptostrobus* did not associate with cone base bearing compact scale leaves. Only four species are known to have the scale leaves on the cone base like those of the *L. myeongamensis* Kim (Fig. 3). They are *Leptostrobus laxiflora* Heer, *L. crassipes* Heer (1876, 1880), *L. cancer* Harris (in Harris et al., 1974), *L. sphaericus* Wang (Wang and Wang, 1984; Liu et al., 2006). They are easily distinguished in shape and size of scale leaves from *Leptostrobus myeongamensis* Kim (Kim et al., 2002).

The genus *Leptostrobus* has been associated with *Czekanowskia* leaves as fully discussed by Harris and Miller (1974). This association has been based on their common occurrence in the same horizon and the similarity of the cuticles (Harris and Miller, 1974; Taylor and Taylor, 1993; Taylor et al., 2010). Besides the *Czekanowskia* leaves, species of the *Leptostrobus* has been associated with foliages of *Sphenobaiera, Phoenicopsis* and *Solenites* (Taylor et al., 2010). However, the characters of *Czekanowskia* leaves are easily distinguished from those assigned to *Neocalamites*, *Baiera* and *Sphenobaiera*. In Korea, *Leptostrobus myeongamensis* Kim has been closely associated with a foliage of *Czekanowskia* ex gr. *rigida* Heer, but none of them has been found in organic connection with *Czekanowskia* leaves. However, their common occurrence would indicate that they belong to the same taxa. Apart from the *Czekanowskia* leaves from the Nampo Group, the following species are described from the same locality: *Neocalamites carrerei* (Zeiller), *Dictyophyllum exile* (Braun), *Baiera* cf. *furcata* (Lindley et Hutton), *Sphenobaiera* cf. *spectabilis* (Nathorst), *Phoenicopsis* ex gr. *angustifolia* Heer and *Podozamites* ex gr. *distans* (Presl) (Kim, 1993, 2001; Kim and Roh, 2008).

Taylor and Taylor (1993) mentioned that Czekanowskiales extends from the Jurassic into the Early Cretaceous. However, many species belonging to Czekanowskiales have been described from the Late Triassic to Early Cretaceous floras in the northern Hemisphere (Vakhrameev, 1964; Krassilov, 1968; Kimura and Tsujii, 1984). Therefore, the geologic range of Czekanowskiales is to be extended back from the Late Triassic to the Early Cretaceous (Ash, 1994). Judging from the Mesozoic records of Czekanow-

skiales, it seems to have reached its maximum development during the Early Jurassic and Early Cretaceous and, it shows world-wide distribution in the northern Hemisphere. Krassilov (1968) suggested that the geologic and geographic distribution of the Czekanowskiales was limited to the northern Hemisphere. He also mentioned that the Czekanowskiales acted as a dominant group from the Late Triassic to the Early Cretaceous and even persisted into the Cenomanian and Turonian in the Siberian Paleofloral Province (Krassilov, 1968). In the northern Hemisphere, high abundance and diversity of the Czekanowskiales can be taken as a good indicator of northern type, because only a minority of the Czekanowskiales are adapted to the warm climate in the southern Hemisphere (Jones and De Jersey, 1947; Clifford and Camilleri, 1998).

The Czekanowskiales is not a dominant group in the Late Triassic to Early Jurassic floras of East Asia, but, it generally occurs both in the *Danaeopsis-Symopteris* and *Dictyophyllum-Clathropteris* Provinces in Late Triassic to Early Jurassic of East Asia (Kimura and Kim, 1984a; Kim, 1993). The former represents a subtropical to temperate climate and the latter a tropical to subtropical climate (Li and Zhou, 1979). The fossil flora from the Nampo Group is obviously a members of the *Dictyophyllum-Clathropteris* Province based on the their floristic composition (Kimura and Kim, 1984a; Kim, 1993). The presences of *Czekanowskia* and *Leptostrobus* in the Korean Late Triassic floras indicate that there were some interchanges between the Korean Late Triassic floras and the coeval *Dictyophyllum-Clathropteris* and Siberian floral Provinces mentioned above during the Late Triassic time. Ash (1994) mentioned that the *Czekanowskia* leaves were deposited under a humid, temperate to tropical climate based on the presence of leaves in Eurasian coal-bearing sequences. This climate condition partly agrees with that of the Daedong flora which might have been flourished under tropical to subtropical climate (Kimura and Kim, 1984a).

As mentioned before, twenty species of *Leptostrobus* have been reported from the Late Triassic to the Lower Cretaceous floras of the world (Liu et al., 2006). In the Late Triassic floras, *Leptostrobus* is very rare in occurrence, and only five species of *Leptostrobus* were known from the Upper Triassic strata of the world as follows: *Leptostrobus* cf. *laxiflora* Heer (Oishi and Takahashi, 1936; Oishi, 1940), *L.* sp. (Jones and De Jersey, 1947), *L. sphaericus* Wang (Wang and Wang, 1984; Liu et al., 2006), *L. cookii* Clifford and Camilleri (Clifford and Camilleri, 1998), and *Leptostrobus myeongamensis* Kim (Kim et al., 2002). Therefore, the occurrence of *Leptostrobus myeongamensis* Kim from the Late Triassic of Korea is one of the oldest records of the world.

Pant (1957) named Czekanowskiales as an isolated gymnosperm group. Apart from the classical studies, subsequent contributions were made to this order by Harris (1935, 1951), Krassilov (1968, 1970, 1972), Harris and Miller (1974), Samylina and Kiritchkova (1993), and Liu et al. (2006). However, as mentioned by Taylor et al. (2010), even now the affinities of the Czekanowskiales remains problematic.

Conclusion

A single cone axis and two cone bases were discovered from a single locality of the Upper Triassic Amisan Formation, Nampo Group, Korea. They belong to *Leptostrobus myeongamensis* Kim based on the their morphological features of cone axis and base. *Leptostrobus myeongamensis* Kim is closely associated with foliage of *Czekanowskia* ex gr. *rigida* Heer. Although, none of them has been found in organic connection with *Czekanowskia* leaves, it is considered that they belong to the same taxa based on their common occurrence. *Leptostrobus* species is very rare in occurrence in the Late Triassic floras of the world, only five species of *Leptostrobus* were known. Therefore, the occurrence of *Leptostrobus myeongamensis* Kim in the Late Triassic flora of Korea is one of the oldest records of the Mesozoic floras in the world.

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