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A New Species of *Leptostrobus* from the Upper Triassic Amisan Formation of the Nampo Group in Korea

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Abstract: *Leptostrobus myeongamensis* sp. nov. is newly described from the well-preserved but broken material occurring in the Upper Triassic Amisan Formation of the Nampo Group in Korea. This species is characterized by its lateral appendages of cone axis, each consisting of a rounded capsule and small scale leaf, and by its cone base covered with small scale leaves, the same size as in cone axis. This species is the first record from the Mesozoic strata in Korea.

Key words: *Leptostrobus myeongamensis*, Upper Triassic, Amisan Formation, cone axis, cone base

INTRODUCTION

Leptostrobus is a not well-known genus of Mesozoic reproductive organs. Heer (1876) first established the genus *Leptostrobus* from the Siberian Mesozoic flora, and assigned three species, *Leptostrobus laxiflora*, *L. crassipes* and *L. microlepis*, to the genus *Leptostrobus*. *Leptostrobus* has the remarkably slender cones bearing rather distant fertile appendages above and small scale leaves at the base. Describing the genus *Leptostrobus* from Siberia, Heer (1876, 1880) considered that it is a conifer female cone allied to *Voltzia*, and that its association with *Czekanowskia* was accidental. Kryshtofovich (1933) figured another good one from Heer's locality. The next account of *Leptostrobus* was one by Harris (1935) in the Rhaetic flora of Scoresby Sound, East Greenland. Harris (1951) found a strong evidence of *Leptostrobus* being the female reproductive organ of a plant with the *Czekanowskia* leaves. Krassilov (1970) confirmed Harris's interpretation of *Leptostrobus* on the basis of the new materials from the Mesozoic Bureja Basin. Harris and Miller (1974) also described in detail *Leptostrobus* organs based on the well-preserved materials from the Middle Jurassic of Yorkshire. Most *Leptostrobus* species hitherto known have been recorded from the Upper Jurassic to Lower Cretaceous strata of Russia (Vakhrameev and Doludenko, 1961; Vasylevskaya and Pavlov, 1963; Krassilov, 1968, 1970; Samylina, 1967).

In East Asia, only two species of *Leptostrobus* have been known from the Upper Triassic to the Upper Jurassic strata of Japan and China (Oishi and Takahashi, 1936; Oishi, 1940; Wang and Wang, 1984). Now most authors think that *Leptostrobus* is a female reproductive organs of *Czekanowskia* species, described from the older and younger Mesozoic strata in the Northern Hemisphere (Vakhrameev, 1964; Kimura and Tsujii, 1984).

Kim (1993) found four *Leptostrobus* cone-like specimens in the Middle Shale Member of Amisan Formation, Nampo Group at the inkstone quarry in the Myeongam locality, and described them as a unclassified reproductive organ. Recently five additional cones were collected from the same locality. The authors report the occurrence of *Leptostrobus* organs and describe them as a new species of *Leptostrobus*. This study provides a new information about the fossil cone called *Leptostrobus*.

All the specimens herein examined and figured

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are deposited at the Department of Earth Science, College of Education, Kongju National University, Korea.

GEOLOGICAL SETTING

The Nampo Group is distributed in the Chungnam Sedimentary Basin of the southwestern part of Chungcheongnam-do and consists of about 3,000 m-thick sequence of terrestrial sediments (Reedman and Um, 1975). Depositional environment of the Nampo Group has been considered to be an alluvial fan, fluvial plain, and lake environment (Choi *et al.*, 1986, 1988).

Since Shimamura's (1931) geological investigation on the Chungnam Sedimentary Basin, some geological studies were carried out by Korean geologists. The correlation of stratigraphic sequence of the Nampo Group was made by Kim (2001), together with description of new fossil plants. 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 ascending order. The geological age of the Amisan Formation based on the fossil plants and conchostracans has been considered to be Late Triassic(Kimura and Kim, 1984a, b; Kobayashi, 1975; Kim, 1989, 1993; Kim and Kimura, 1988). Sampling locality and its columnar section are shown in Figs. 1 and 2 respectively.

SYSTEMATIC DESCRIPTION

Order Czekanowskiales Pant 1958

Pant (1957) named this order as an isolated gym-

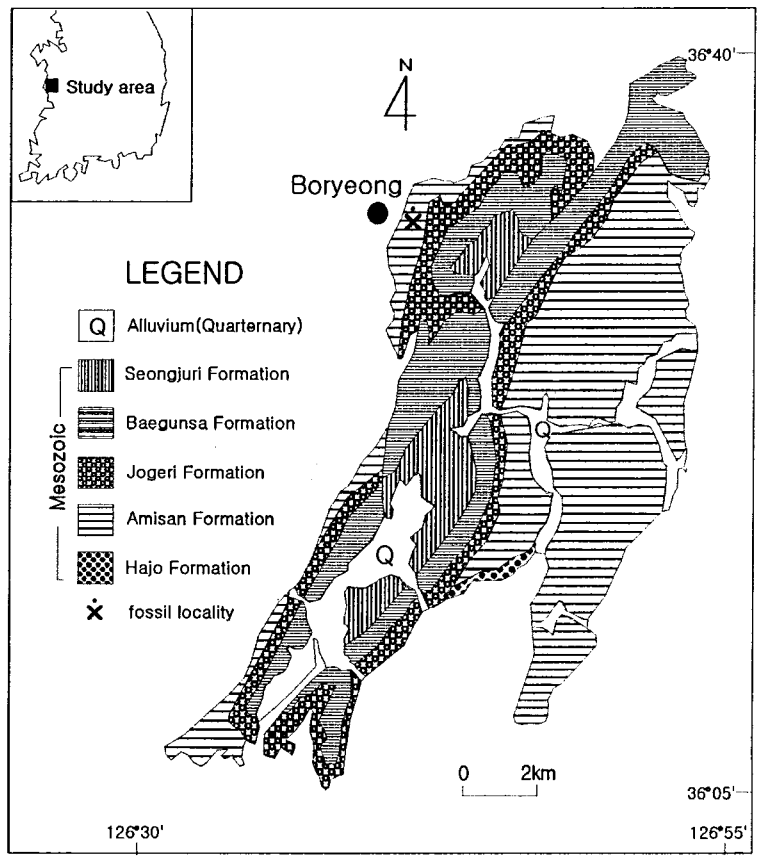


Fig. 1. Geological map of the study area (partly redrawn after Choi *et al.*, 1986) and fossil locality.

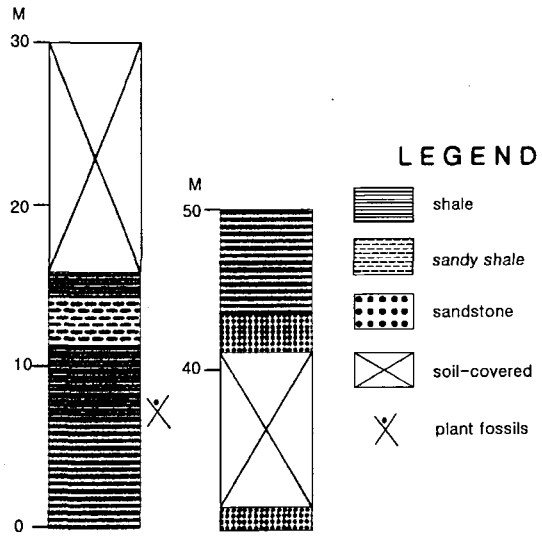


Fig. 2. Columnar section of the study area in which the plant fossils were collected.

nosperm group. Apart from the classical studies, subsequently contributions were made to this order by Harris (1935), Krassilov (1968, 1970, 1972), and Harris and Miller (1974). But even now the affinities of the Czekanowskiales continue to remain problematic (Taylor and Taylor, 1993).

Genus *Leptostrobus* Heer 1876 emended Harris 1951

Type species: *Leptostrobus laxiflora* Heer 1876

Diagnosis. Cone axis elongated, lower part covered with small scale leaves, upper part bearing seed capsules in loose spiral. Capsules almost sessile, not abscissed but readily torn off, composed of similar upper and lower valves, valves with thickened and more or less lobed terminal margin. Outer surface valves convex, interior concave, margins of valves in contact but not joined. Each valve with single row of 3~8 small seeds, one to each lobe, micropyle facing cone axis. Megaspore membrane cutinized. Cone axis and capsules well cutinized externally. Cell outlines nearly straight. Stomata frequent but scattered on outer surface of capsule, surrounded by ring or somewhat elongated or rounded pit over guard cells. Encircling cells often present but variable, lower part covered with small scale.

Leptostrobus myeongamensis sp. nov.

Material: Holotype; KNUM-850015. Paratype; KNUM-850016 and other 5 specimens.

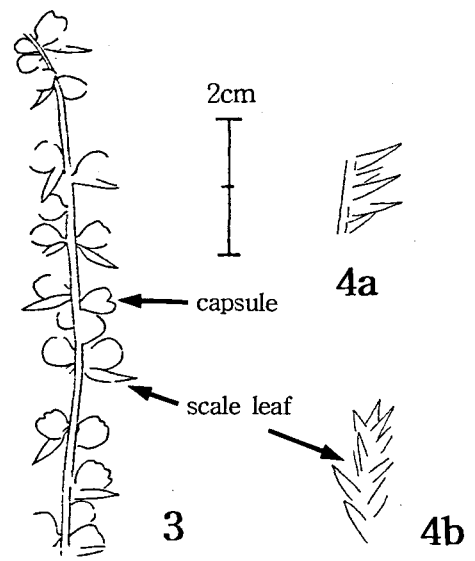
Locus typicus: Myeongam, Dongdae-dong, Boryeong City, Chungcheongnam-do, Korea (36° 20' 08", 126° 37' 40").

Stratum typicum: Amisan Formation of the Nampo Group

Derivatio nominis: Specific name refers to its geographic occurrence, Myeongam where the holotype and paratypes were collected.

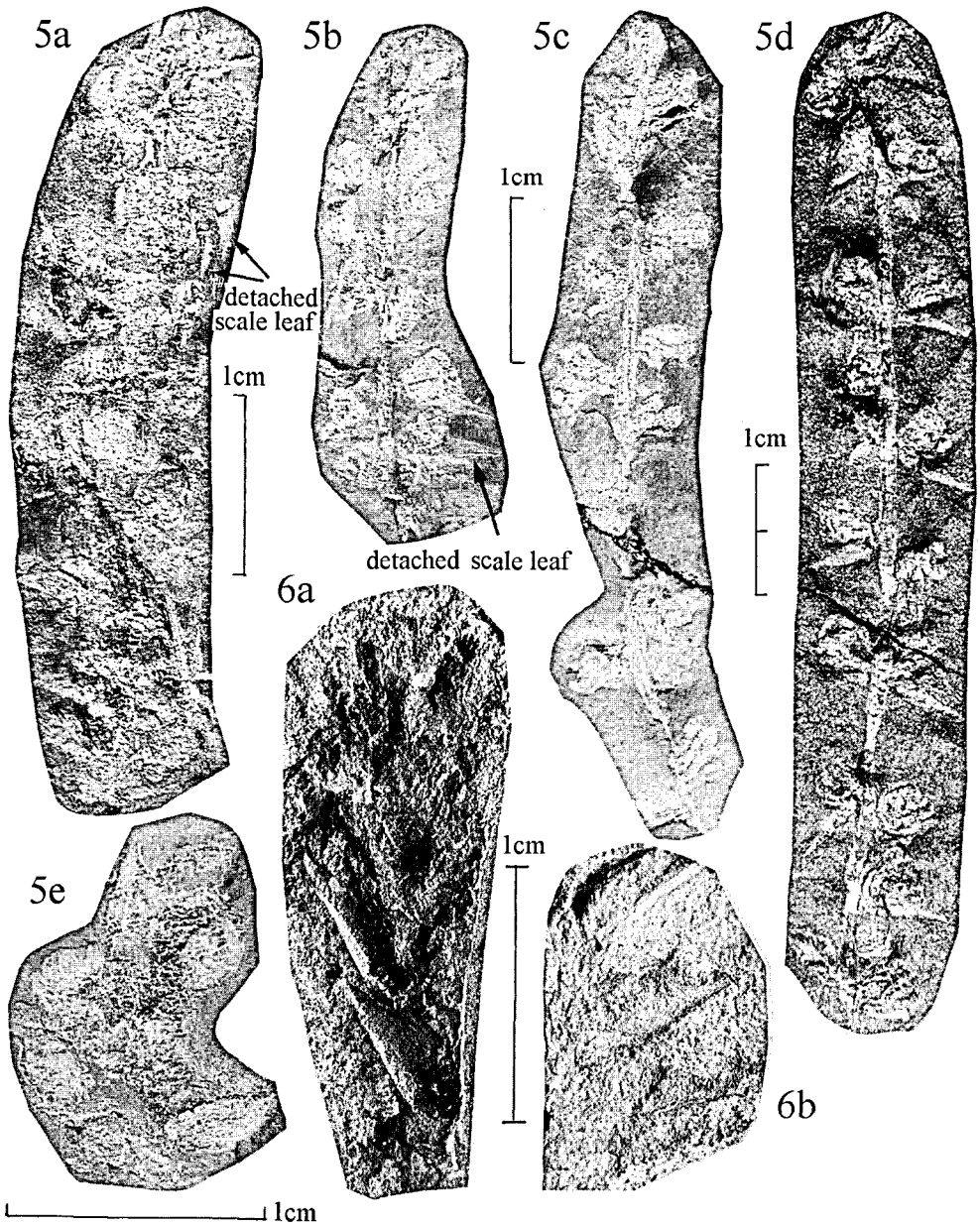
Distribution and occurrence: Nine cone-fragments were obtained from a single locality in association with *Czekanowskia*, *Baiera*, *Sphenobaiera* leaves and other insect fossils.

Specific diagnosis: Cone axis relatively slender, more than 8 cm long and 1 to 2 mm wide, upper part bearing compactly disposed lateral appendages, middle part bearing lateral appendages in loose spiral, typically at intervals of 6~8 mm. Cone



Figs. 3-4. Cone axis and cone base of *Leptostrobus myeongamensis* sp. nov. 3. A sketch of middle part of cone axis, bearing spirally disposed lateral appendages, each consisting of a capsule and its subtending a scale leaf (holotype, KNUM-850015, drawn from Fig. 5d). 4a. A sketch of cone base with scale leaves(paratype, KNUM-850017, drawn from Fig. 6b). 4b. A sketch of cone base with scale leaves (paratype, KNUM-850018, drawn from Fig. 6a).

base covered with small scale leaves. Each appendage consists of a capsule and its subtending a scale leaf. Capsule sessile, circular and with irregularly crenated distal margin, typically 3~5 mm long and 3~5 mm wide. Detailed features of this cone invisible. Scale leaf lanceolate in form with acutely



Figs. 5-6. *Leptostrobus myeongamsis* sp. nov. 5a. A upper part of cone axis (paratype, KNUM-00011), bearing compactly disposed lateral appendages, scale leaves are mostly detached. 5b. A middle part of cone axis (paratype, KNUM-00012), bearing lateral appendages in loose spiral, some appendages still bearing scale leaves. 5c. A middle part of cone axis (paratype, KNUM-00022), bearing lateral appendages in loose spiral, scale leaves are mostly detached. 5d. A middle part of cone axis (holotype, KNUM-850015), bearing lateral appendages in loose spiral. 5e. A upper part of cone axis (paratype, KNUM-00019), bearing compactly disposed lateral appendages. 6a. A part of cone base (paratype, KNUM-850018), covered with compact scale leaves. 6b. A part of cone base (paratype, KNUM-850017), covered with compact scale leaves.

pointed apex, 7 mm long and up to 2 mm wide.

Description: Nine cones were obtained. they are all broken and preserved as impression. Thus we cannot mention their cuticular features and internal anatomy of the present specimens. Typical cone axis and cone base are shown in Figs. 3-4.

Cone axis. Seven cone axes are obtained; two cones are upper parts of cone axes and five ones are probably middle parts of cone axes. Cone axes are slender and unbranched, their length is more than 8 cm long; their width ranging from 1mm to 2 mm wide. Upper part of cone axis bearing very compactly lateral appendages as shown in Figs. 5a, 5e, but the scale leaves are mostly detached. Middle parts of cone axes bearing lateral appendages in loose spiral at intervals of 6~8 mm, each appendage consists of a capsule and its subtending a scale leaf, each capsule is still bearing a scale leaf as shown in Fig. 3 and Figs. 5b, 5d.

Cone base. There are no good specimens of cone bases but there are two small fossils thought to be fragments of cone bases. Figs. 4a-b and Figs. 6a-b show scale leaves disposed with very short internodes, but their phyllotaxy is unknown. Their size and form are similar to those on the upper and middle parts of cone axes as mentioned above. It is highly probable that these scale leaves represent those around the basal part of the cone axis, because these two specimens are in very close association in occurrence with the cone axes as shown in Figs. 3-4.

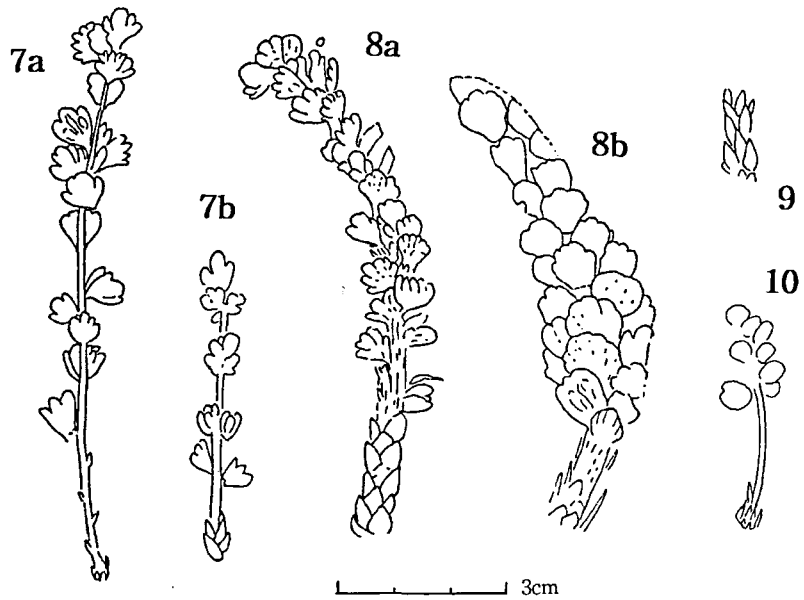
Capsules. The capsules are mostly rounded, sessile, and with rounded or irregularly crenated distal margin, their sizes ranging from 2~5 mm long and 4~5 mm wide. Capsules are mostly still in position in their phyllotatic spiral in our materials, but the structure of capsule is uncertain and seeds and two valves of capsule were not recognized.

Comparison and *discussion*: *Leptostrobus myeongamensis* is characterized by the presence of spirally disposed appendages, each consisting of probable a capsule and its subtending a scale leaf. At first glance of the specimens (Figs. 3-6), they are similar in external form to typical *Leptostrobus* species, female reproductive organ of *Czekanowskia*, except for the presence of scale leaves at the cone axis. According to the diagnosis of *Leptostrobus* given to Harris and Miller (1974), the scale leaves are seen in the cone base. However, based on the well-preserved rich specimens in the Mesozoic of Bureja Basin, Krassilov (1968, 1970) mentioned that short stalk of capsule at cone axis bears sometimes ill-defined marks or scars of scale leaves, and identical scars were found on the flattened basal part of the capsule as shown in our materials. Thus we here place our material in *Leptostrobus* and propose *L. myeongamensis* sp. nov.

According to Harris and Miller (1974), capsules have two valves, each valve bearing of small elongated seeds on its inner face. In our cones, any valves and seeds on capsules are not recognized but with distinct scale leaves. Judging from their characters, the present cone axis is considered to be immature or abortive. When the cones are fully grown, scale leaves appear to be easy to shed from ripe capsules.

So far as is known about 20 species of *Leptostrobus* have been described from the Upper Triassic to the Lower Cretaceous strata in the Northern Hemisphere as female cone species (Harris, 1935; Krassilov, 1972; Vakhrmeev *et al.*, 1980), but all of them do not represent obvious scale leaves on the cone axis like those of the present specimens. However, only four species have been known to have the scale leaves on the cone base like those of the present specimens. They are *Leptostrobus laxiflora* Heer, *L. crassipes* Heer (1876, 1880), *L. cancer* Harris (in Harris *et al.*, 1974) and *L. sphaericus* Wang (in Wang and Wang, 1984) as shown in Figs. 7-10. The comparison of *Leptostrobus myeongamensis* with four species with scale leaves mentioned above is shown in Table 1. The scale leaves of four species are distinguished in shape and size from those of *Leptostrobus myeongamensis*.

Leptostrobus sphaericus Wang originally described by Wang and Wang (1984) from the Upper Juras-



Figs. 7-10. Some *Leptostrobus* species with basal scale leaves. 7a. *Leprostrobus laxiflora* Heer (1876, pl. 13, fig. 10A). 7b. *Leprostrobus laxiflora* Heer (1880, pl. 7, fig. 4). 8a. *Leptostrobus crassipes* Heer (1876, pl. 13, fig. 15). 8b. *Leptostrobus crassipes* Heer (1880, pl. 8, fig. 2). 9. *Leptostrobus sphaericus* Wang (Wang and Wang, 1984, pl. 154, fig. 7). 10. *Leptostrobus cancer* Harris (Harris and Miller, 1974, pl. 7, fig. 4).

Table 1. Comparison of cone basal scale leaves.

Species	shape	size	arrangement
L. myeongamensis (Kim *et al.*, 2001)	linear lanceolate	7×2 mm	compact
L. laxiflora Heer (1876, 1880)	small lanceolate	2 ~ 5×1 ~ 2 mm	compact
L. crassipes Heer (1876, 1880)	broad lanceolate	5×4 mm	compact
L. cancer Harris (Harris and Miller, 1974)	broad lanceolate	4×2.5 mm	compact
L. sphaericus Wang (Wang and Wang, 1984)	small lanceolate	3×1 mm	compact

sic Zhangjiakou Formation of North Hebei, China, is similar in having compact and rounded capsule to the present species, but is distinguished by its small-sized scale leaves at the cone base.

Similarly looked organs have been described under the generic name *Staphidiophora* by Harris (1935) and Krassilov (1972), but unfortunately the present organs are incompletely preserved to make further comparison with the *Staphidiophora*.

Species of the *Leptostrobus* have 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 fossil beds and the similarity of the cuticles (Taylor and Taylor, 1993). *Leptostrobus myeongamensis* is in very close association in occurrence with the leaves regarded as *Czekanowskia* ex gr. *rigida* Heer, but none of them has been found in organic connection with *Czekanowskia* leaves.

Apart from the present taxa described in this paper, fossil plant taxa hitherto reported from the Myeongam locality are : *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).

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