

## A Revision of Mesozoic Equisetales *Annulariopsis bunkeiensis* Kimura et Kim from the Amisan Formation of Nampo Group, Korea

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**Abstract:** Some fine specimens of *Annulariopsis bunkeiensis* were collected from two fossil sites of the Amisan Formation of Nampo Group distributed in the Jogaegol, Boryeong City, Chungnam Province. According to our detailed study from our new material, the leaves of *A. bunkeiensis* are not mucronate, but emarginate at their apices. Accordingly, we revised the diagnostic characters given by Kimura and Kim (1988) mainly in regard to the leaf apex.

**Keywords:** Amisan Formation, *Annulariopsis*, leaf apex, emarginate

### Introduction

The generic name *Annulariopsis* was established by Zeiller (1902-03) for leaf-whorls consisting of small lanceolate and uninerved leaves from the Upper Triassic strata of Tonkin, Vietnam. As already pointed out by Kimura and Kim (1988), this genus has been defined somewhat vaguely for leaf-whorls of small lanceolate uninerved leaves borne in a terminal position due probably to breaking off a stem or bud above. However some leaf whorls of *Annulariopsis*, such as *A. inopinata* Zeiller (Kiritchkova, 1969), *A. hashimotoi* Kon'no (Kon'no, 1972), *A. annulariopsis* Huang et Zhou (Huang and Zhou, 1980), and *A. bunkeiensis* (Kobatake) (Kimura et Kim, 1988), *A. sp.* (Kim and Kimura, 1992), are attached clearly to the successive stem nodes as leaf whorls, like those of other sphenophytes. Thus Kimura and Kim (1988) established a new combination of *Annulariopsis bunkeiensis* (Kobatake) and gave emended diagnosis of the genus on the basis of their new materials from the Upper Triassic Amisan Formation and its equivalents in Korea.

The relation between *Lobatannularia* Kawasaki

(1927) and *Annulariopsis* Zeiller (1903) has been discussed by such authors as Halle (1927), Yabe and Koiwai (1928), Kawasaki (1934), Kon'no and Asama (1950), Harris (1961) and Kimura and Kim (1988).

According to Harris (1961), *Annulariopsis* is distinguished from *Phyllothea*, *Schizoneura* and *Lobatannularia* by having leaves which are free at their bases. It differs from the leafy twigs of *Neocalamites* chiefly in that the *Neocalamites* shoots do not originally break just above a leafy whorl but bear successive whorls (Kimura and Kim, 1988).

According to Kimura and Kim (1988), *Annulariopsis* is close in form to *Annularia* and *Lobatannularia* because of the recent discovery of shoots bearing successive whorls. *Annulariopsis* differs from *Annularia* in its leaves being free to their bases except for about 1 mm at the base, instead of the leaves forming a basal leaf-sheath as in *Annularia*. On the other hand, *Lobatannularia* is easily distinguished from *Annulariopsis* by its whorl consisting of markedly anisophyllous and largely fused leaves.

Recently, we collected some fine specimens referable to Kimura and Kim's *Annulariopsis bunkeiensis* from the Amisan Formation of Nampo Group distributed in the Jogaegol. This study deals with the description of *Annulariopsis bunkeiensis* on the basis of our new material, together with the revision of diagnosis of *A. bunkeiensis*.

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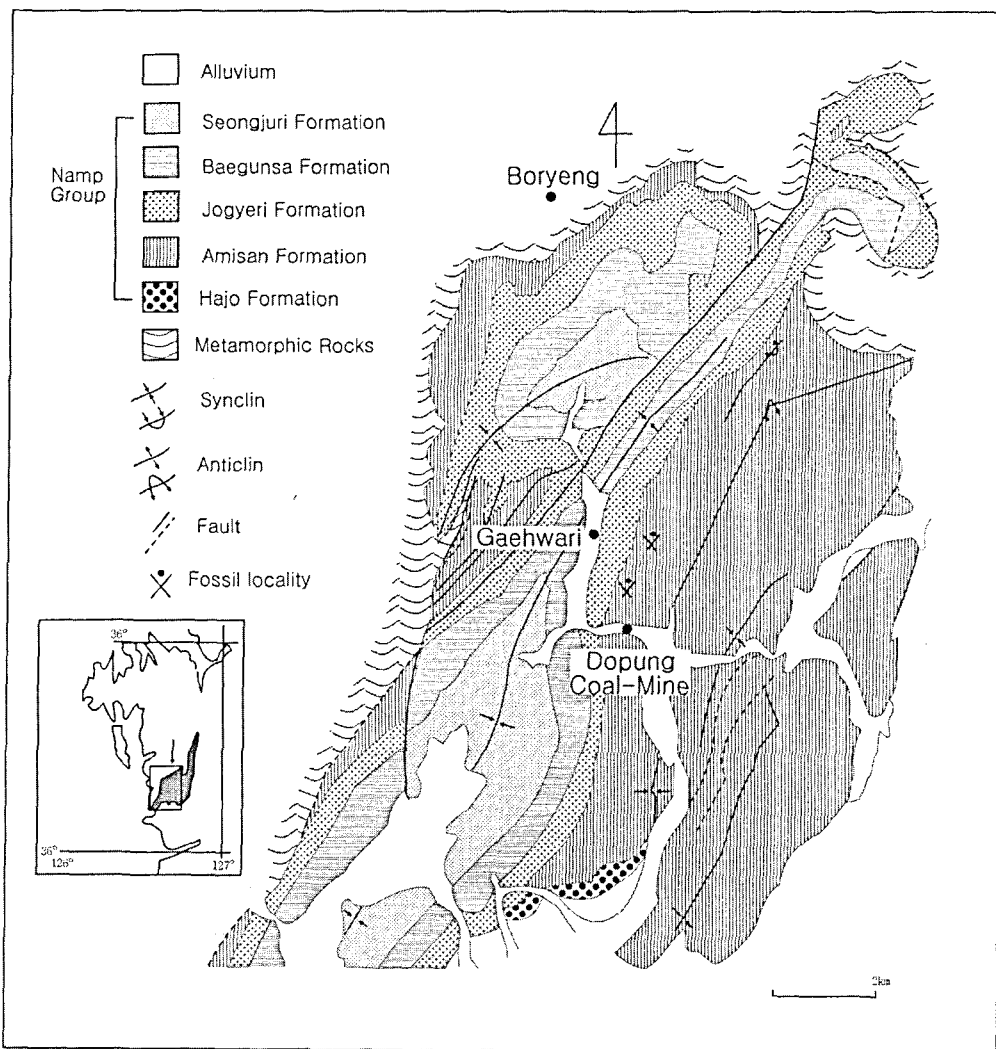


Fig. 1. Geological map of the Nampo Group in the study area (after Suh et al., 1980).

## Geological Setting

Since Shimamura's (1931) geological investigation on the Chungnam Sedimentary Basin distributed in the southwestern part of Chungnam Province, some geological studies were carried out by Um et al. (1965), Son et al. (1967), Lee et al. (1975), Reedman and Um (1975), Suh et al. (1980), and Choi et al. (1986). The Nampo Group is usually divided into five formations, the Hajo, Amisan, Jogyeri, Baegunsa and Seongjuri Formations in ascending order (Fig. 1).

According to Suh et al. (1980) and Choi et al. (1986), the Amisan Formation is subdivided into five zones based on its lithology, lower sandstone, lower shale, middle sandstone, middle shale, upper sandstone zones. The fossil plants described here were obtained from two fossil sites of lower shale zone. The lower shale zone mainly consists of shale and siltstone, and its maximum thickness is about 600 m. One of the fossil site is located at the inkstone quarry near the Dopung Coal-Mine. There is no other plant taxa except a large community consisting only of *Neocalamites carrerei* in a swamp

brought up several species of estherians and bivalves (Kimura et al., 1982). The other fossil site is located near the Jogaegol in the Gaehwari. A various plant taxa belonging to Equisetales have been occurred in the outcrop together with *A. bunkeiensis* (Kim, 1990). Most of plant fossils are faintly preserved under impression state.

Depositional environment of the Nampo Group has been considered to be an alluvial fan, fluvial plain, and lake environment (Choi et al., 1986, 1988).

All the specimens described herein are deposited at the Department of Earth Science Education, Kongju National University.

## Geological Age

The geological age of the plant-bearing Amisan and Baegunsa Formations of Nampo Group had long been regarded as Early Jurassic (Liassic) according to its floristic composition (Kawasaki, 1925, 1926, 1939). Kobayashi (1951) and Takahasi (1973) reviewed the Daedong flora and conchostracans known from the Daedong Supergroup including the Nampo Group and thought the age to be Late Triassic to Middle Jurassic. However, the Amisan and Baegunsa Formations are yielding plant taxa indicating precise age as mentioned below. According to recent knowledge, the following species and genus are restricted in occurrence to the Permian to Late Triassic floras or Late Triassic floras in the world; especially the first three genus have been known in the Permian Cathaysia floras in Asia: *Chiropteris coreanica* Kimura et Kim (Kimura and Kim, 1988), *Lobatannularia nampoensis* (Kawasaki) (Kim and Kimura, 1988), *Sphenophyllum* sp. (Kim, 1989), *Chiropteris coreanica* Kimura et Kim (Kimura and Kim, 1988), *Podozamites* ex gr. *schenki* Heer (Kimura and Kim, 1989), and *Baiera* cf. *furcata* (Lindley et Hutton) (Kimura and Kim, 1989), *Anthrophyopsis decurrens* Kimura et Kim (Kimura and Kim, 1989), and *Drepanozamites* sp. A (Kimura and Kim, 1989).

In addition, several types of conchostracans indicating Late Triassic age in Amisan Formation have also been found (Kobayashi, 1975; Kim, 1976; Kimura and Kim, 1984a, 1984b). Accordingly, the age of the Amisan and Baegunsa Formation is not Early Jurassic as formerly presumed by the previous authors (e. g. Kawasaki, 1925, 1926, 1939), but obviously Late Triassic (Kim and Kimura, 1987). However, The geological age of the Seongjuri Formation which is the uppermost formation of Nampo Group is still uncertain because of lack of fossils indicating of precise age. It is sure that the geological age of the Nampo Group would be settled in Late Triassic or Late Triassic to Early Jurassic, but most probably Late Triassic.

## SYSTEMATIC DESCRIPTION

Order Equisetales

Family Equisetaceae

Genus *Annulariopsis* Zeiller 1903 emended

Kimura et Kim 1988

Type species: *Annulariopsis inopinata* Zeiller 1903

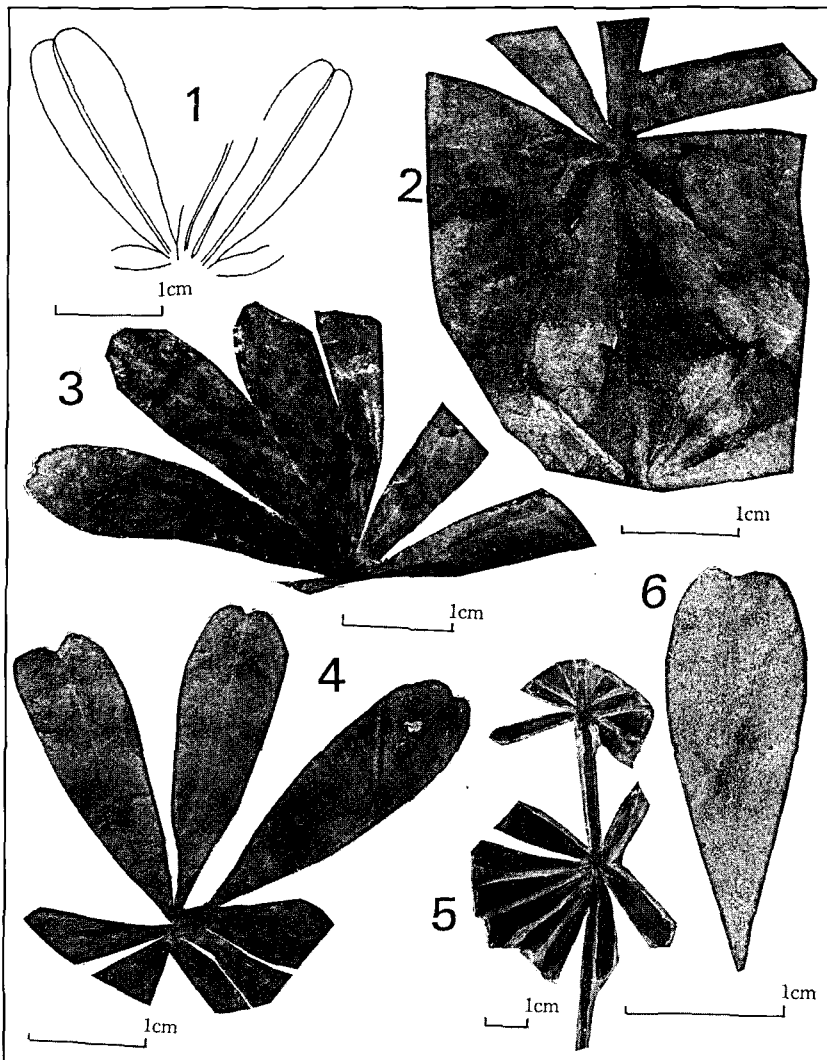
Emended diagnosis: Articulate plant. Stem slender, marked with longitudinal ridges; internodes rather long. Leaf-whorls circular or oval, often divided into lobes, spread out in one plane, obliquely attached to the stem and persistent. Leaves equal or sometimes unequal in size. Adjacent leaves united for about 1mm at the base, then free. Leaf linear-lanceolate, or broadly spatulate in form with a rounded or pointed or emarginate apex, generally broadest at or near distal end and uninerved; margins entire or sinuous. Stem easy to break off at the node; thus most of the specimens showing the leaves in a terminal position on the shoot. Fructification unknown.

*Annulariopsis bunkeiensis* (Kobatake)

Kimura et Kim 1988

Fig. 2, 1-6

Material: Ten specimens of *Annulariopsis bunkeiensis* were obtained. The leaves of *A. bunkeiensis* are abundant but fragmented in the lowest



**Fig. 2.** Leaves of *Annulariopsis bunkeiensis* Kimura et Kim. 1. Partly preserved a leaf whorls, each leaf showing broadly spatulate in outline with an emarginate apex (redrawn from 1a, Kimura and Kim, 1988). 2. Leafy stem bearing two leaf whorls (KNU-2001001). 3. Leafy stem bearing six leaves with an emarginate apex (KNU-2001005). 4. Vertically compressed a leaf whorl, each leaf with an emarginate apex (KNU-2001012). 5. Leafy stem bearing two leaf whorls (KNU-2001004). 6. Single leaf with an emarginate apex (KNU-2001011).

member of Amisan Formation distributed in the Jogaegol and Dopung Coal-Mine.

Emended diagnosis: Stem slender, 1.5 mm wide, its surface-ornamentation indistinct. Internode more than 2 cm long. Leaf-whorl oval, not divided into two lobes, spread out in one plane, obliquely attached to the stem and persistent; smaller whorl, 1.2 cm (major) and 2.0 cm (minor) in diameter. Uninerved leaves more than 10 in a whorl, unequal

in size, broadly spatulate in outline with emarginate apex and broadest near the distal end; largest one 2.5 cm long and 0.8 cm wide; margins entire or faintly undulate. Leaves mostly free but adjacent ones united for about 1 mm at the base. Midnerve thick, persisting to the tip.

Description: Stem is slender, 2 mm wide. Internode is smooth and 4-4.5 mm long. Leaf-whorl is borne at node, spread out in one plane, obliquely

attached to the stem, and persistent. Uninerved leaves are 9-12 in a whorl, unequal size, broadly spatulate in outline with emarginate apex and broadest near the distal end. The largest ones is 3 cm long and 8 mm wide. Margins are entire. Midnerve is thick and persisting to the tip.

Distribution and occurrence: *Annulariopsis bunkeiensis* has been recorded by Kawasaki (1939) as *A. inopinata* from the Bansong Group at Yeonhari (Danyang Coal-field) and by Kobatake (1954) as *Pseudolobatannularia ? bunkeiensis* from the Dangi Formation at Gujeomri (Mungyeong Coal-field) and by Kimura and Kim (1988) as *A. bunkeiensis* from the middle shale zone of Amisan Formation near the Dopung Coal-Mine (Chungnam Coal-field).

Discussion and comparison: We avoid to mention the attribution of this species to *Annulariopsis*, because it was already discussed in detail by Kimura and Kim (1988).

According to Kimura and Kim (1988), *Annulariopsis bunkeiensis* was said to characterized by its leaf whorls each consisting of more than 10 small spatulate and uninerved leaves with mucronate apices. According to our detailed study from our new material, apices of leaves are not mucronate, but emarginate as shown in Fig. 2-1, the sketch of a leaf of *A. bunkeiensis* figured by Kimura and Kim (1988), is not shown mucronate apex, but obviously emarginate apex, but they did not mention about it. Accordingly, we emended the diagnostic character given by Kimura and Kim (1988) mainly in regard to the leaflets.

So far as we know, 6 species and 4 spp. of *Annulariopsis* were described from the Mesozoic plant-beds in the world. They are as follows: *Annulariopsis inopinata* (Zeiller, 1903; Yabe, 1922; Kiritchkova, 1969), *A. simpsoni* (Harris, 1947, 1961; Chen et al., 1984), *A. annularioides* (Huang and Zhou, 1980), *A. lobatannularioides* (Huang and Zhou, 1980), *A. 3 spp.* (Huang and Zhou, 1980), *A. oishii* (Kimura and Hirata, 1975), *A. sp.* (Kim and Kimura, 1995), *A. ? sinensis* (Ngo) Lee (Sze et al.,

1963). Of these, *A. lobatannularioides* described from the Upper Triassic Yanchang Formations by Huang and Zhou (1980) was synonymous with *Lobatannularia chuandinensis* described by Duan and Chen (1984b) from the Upper Triassic Qinghe Formation of southwest of Sichuan and Ipinglang Formation of Yunnan, China. All the species mentioned above were described from the Upper Triassic plant-beds except for *A. simpsoni* known from the Yorkshire Jurassic flora (Harris, 1961) and from the Middle Jurassic Upper Yaopo Formation of West Hill of Beijing (Chen et al., 1984). They also differ in leaf apex from our *A. bunkeiensis*.

Among the above mentioned species, the following species would be comparable with *A. bunkeiensis* in their stems still preserved with successive lateral whorls in position. Such stems were described by Kiritchkova (1969) as *A. inopinata* from the middle Keuper beds of Ural, by Kon'no (1972) as *A. hashimotoi* from the Upper Triassic of Sarawak, East Malaysia, by Huang and Zhou (1980) as *A. annularioides* and *A. spp.* from the Upper Triassic Yanchang Formation, and by Kim and Kimura (1992) as *A. sp.* from the Carnian Momonoki Formation of Japan.

The genus of *Annulariopsis* is ranging from Late Triassic to Jurassic in age and one of the older type in the Mesozoic plant genus together with *Lobatannularia*.

## Acknowledgments

This study was supported by the research funds of priority rearing field of Kongju National University provided to Kim et al. in 2003. We thank for financial support of the Kongju National University. We also thank to three anonymous reviewers for their critical reading and valuable comments.

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Manuscript received, December 7, 2003

Revised manuscript received, January 19, 2004

Manuscript accepted, January 30, 2004