Geosciences Journal
Vol. 6, No. 2, p. 131 − 140, June 2002

Some coniferous fossil woods from the Cretaceous of Korea

Kyungsik Kim* *Faculty of Biological Sciences, Chonbuk National University, Chonju 561-756, Korea*
Eun Kyoung Jeong *Department of Biology, Graduate School of Chonbuk National University, Chonju 561-756, Korea*
Mitsuo Suzuki *Botanical Garden, Graduate School of Science, Tohoku University, Sendai 980-0862, Japan*
Min Huh *Faculty of Earth Systems and Environmental Sciences, Chonnam National University, Kwangju 500-757, Korea*
In Sung Paik *Departmant of Environmental Geosciences, Pukyong National University, Pusan 608-737, Korea*

ABSTRACT: Thirteen silicified fossil woods were collected from the Cretaceous deposits of Haenam Basin and islands of Gwanmae and Byeongpung, Jeollanam-do as well as from the Cretaceous Dadaepo Formation, Busan, Korea. Anatomical features of all of these specimens showed that they were coniferous woods. On the basis of the detailed anatomical features they were identified as *Dadoxylon byeongpungense* sp. nov., *Cupressinoxylon uhangriense* sp. nov., *Taxodioxylon* cf. *nihongii* Nishida et H. Nishida, *Taxodioxylon albertense* (Penhallow) Shimakura, and *Mesembrioxylon* sp. All of them, except *Mesembrioxylon*, are described for the first time from the Korean Peninsula. It should be noted that no dicotyledonous wood has been found from this study. Generally the sampled horizons are considered as Upper Cretaceous with dinosaur footprint fossils. In Japan, the Upper Cretaceous sediments bear abundant dicotyledonous fossils. Therefore further studies should be needed to clarify the age of these horizons and the vegetation in the ancient world with dinosaur.

Key words: coniferous, fossil wood, Cretaceous, Korea

1. INTRODUCTION

Although the first paleobotanical study on the fossil plants of the Korean Peninsula was performed on fossil wood by Felix (1887; Seward, 1919), very few studies of fossil wood have been done so far (Shimakura, 1936, 1937; Ogura, 1944). Only three species of fossil woods, *Xenoxylon latiporosum, X. phyllocladoides,* and *Phyllocladoxylon heizyoense,* have been reported by Shimakura (1936) and Ogura (1944) from the Lower Mesozoic formations of Korea. This limitation of fossil wood studies is mostly attributed to the limited occurrence of well-preserved fossil woods in Korea.

Recently, the Cretaceous basins in southern Korea have been paid paleontological attention due to the presence of dinosaur fossils, such as footprints, eggs and bones (Huh et al., 1996, 1998, 1999; Paik, 2000; Paik et al., 1998a, 1998b, 2001a, 2001b). However, paleobotanical studies on fossil woods have never been done from these dinosaur fossil-bearing Cretaceous sequences. In this study, several fossil woods were found with other fossil plants from the Haenam Basin and the islands of Gwanmae and Byeongpung, Jeollanam-do, and from the Cretaceous Dadaepo Formation in Busan, Korea (Fig. 1). Anatomical observations were performed on these fossil woods, in order to describe the structures and to elucidate the affinities. This paper reports the anatomical descriptions and affinities of a part of these Cretaceous fossil woods.

*Corresponding author: kksik@moak.chonbuk.ac.kr

2. GEOLOGICAL SETTING

A number of Cretaceous sedimentary basins (nonmarine) are distributed throughout South Korea. All of them are pull-apart (or transtensional) basins formed by the northward subduction of the Izanagi Plate (Chough et al., 2000), and consist of alluvial fans, fluvial plains, lacustrine deposits, and volcanics. The Gyeongsang Basin is the largest one composed of a 9,000 m thick sequence of deposits assigned to the Gyeongsang Supergroup which is divided into the Sindong, Hayang, and Yucheon Groups, in ascending stratigraphical order (Chang, 1975). The Dadaepo Formation is the lowest part of the Yucheon Group and is composed of volcanics in addition to alluvial and lacustrine deposits (Um et al., 1983; Choi, 1985).

In the western part of the Gyeongsang Basin, several subordinate basins including the Haenam and Neungju Basins are present (Lee, 1999; Chough et al., 2000). A number of dinosaur tracks are preserved both in the Haenam and Neungju Basins. The Haenam Basin consists of andesitic tuffs and flows, rhyolite, and epiclastic Uhangri Formation. Dinosaur tracks occur in the Uhangri Formation consisting of alluvial fan, lacustrine deltas, and lake deposits (Chun and Chough, 1995). The K–Ar age of the tuff (84–85 Ma) (Huh et al., 1998) and the frequent intercalations of volcanics indicate that the sequence of the Haenam Basin is correlated with the uppermost part of the Hayang Group to Yucheon Group in the Gyeongsang Basin. The sedimentary sequences of the islands Gwanmae and Byeongpung are correlated with that of the Haenam Basin.

3. MATERIALS AND METHODS

The fossil woods described here were found in the Cretaceous deposits located in the southwestern and southeastern parts of Korea. Thirteen samples were collected from

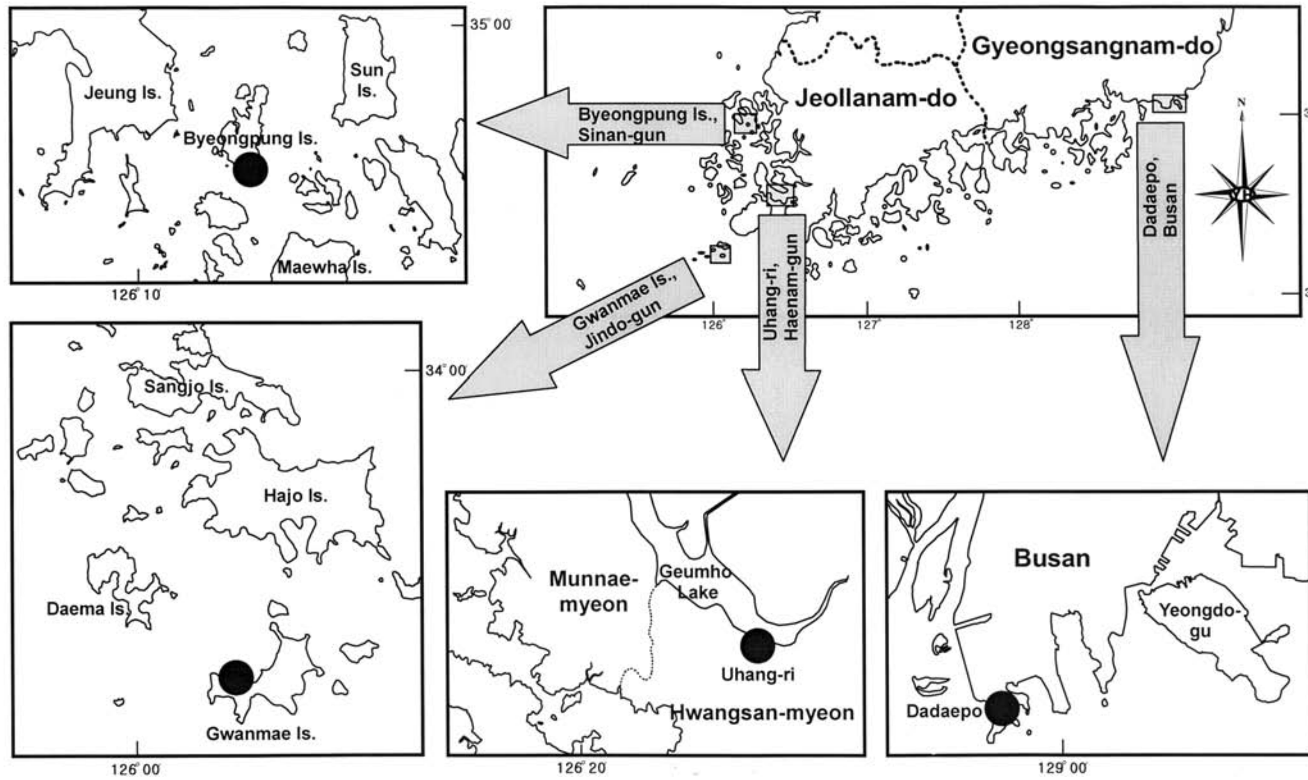


Fig. 1. Maps showing the sampling sites.

the Uhangri Formation (which is famous for footprints of dinosaurs and located in Haenam-gun) and from the Cretaceous deposits of the islands of Gwanmae and Byeongpung in Jeollanam-do, and from the Dadaepo Formation in Busan (Fig. 1).

All the fossils are silicified woods. The ground transverse, tangential, and radial thin sections were prepared by conventional technique. In order to observe anatomical features, the preparates were examined using a Zeiss Axiophot compound microscope. All fossil woods and microscopic slides under study are deposited in the Fossil Collection, Herbarium of Chonbuk National University, Faculty of Biological Sciences, Chonbuk National University.

4. RESULT

4.1. *Dadoxylon byeongpungense* sp. nov. (Figs. 2–5)

4.1.1. Material

Specimen no. CN 1202 (holotype) is a fragment of coniferous secondary wood, about 10 cm long and 5 cm wide, and collected from the island of Byeongpung, Sinan-gun, Jeollanam-do. This specimen is well preserved in histology.

4.1.2. Description

Coniferous wood constitutes of tracheids and rays. Lacking resin canal and axial parenchyma. Growth ring absent. Tracheids elliptical or rectangular in cross section, uniform in size, 36–82×45–63 μm in tangential × radial diameter, pitted only on radial walls. Bordered pits on radial walls arranged contiguously in one to three, mostly two rows, and alternately when in two or three rows (araucarian pitting), hexagonal, about 12–15 μm in diameter, with circular or more or less vertically elongated apertures; pits on tangential walls invisible. Rays uniseriate, sometimes partly biseriate, 1–19, mostly 5–11 cells tall, arranged at intervals of 3–10, average 5.9 rows of tracheids, consisting wholly of parenchyma cells. Ray cells ovoidal in tangential section, 30–40 μm in height and 20–30 μm in width. Cross field pits 5–9, circular with elliptical and obliquely inclined aperture, arranged in two, mostly three horizontal rows.

4.1.3. Notes

The present fossil is characterized by 1) absence of growth ring, 2) typical araucarian pitting, 3) absence of axial parenchyma, 4) almost uniseriate rays and 5) many (5–9) circular cross field pits arranged in 2–3 horizontal rows. Therefore this specimen can be identified as *Dadoxylon* on account of these characteristics (Seward, 1919).

Wood with araucarian pitting and without axial parenchyma is generally belonged into *Dadoxylon* and/or *Araucarioxylon.* Although there is no diagnostic difference between the two genera, *Dadoxylon* is historically adopted to the fossils from Palaeozoic while *Araucarioxylon* is for

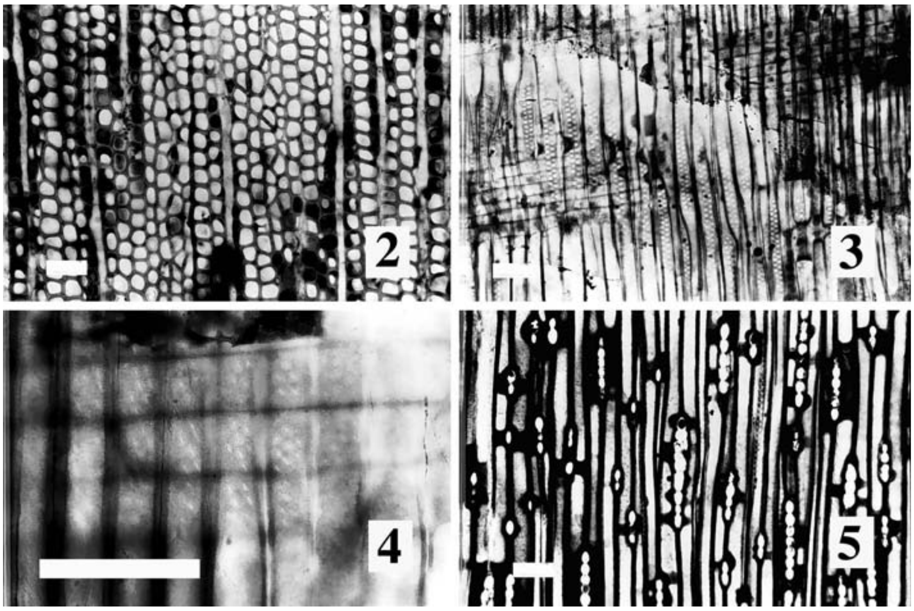


Fig. 2-5. Photomicrographs of *Dadoxylon byeongpungense* (No. CN 1202). **Fig. 2.** Transverse section showing secondary xylem without growth rings. **Fig. 3.** Radial section showing two rows of araucrian pitting on radial wall of tracheids. **Fig. 4.** Radial section showing 5-7 pits on cross fields. **Fig. 5.** Tangential section showing uniseriate and partly biseriate rays (Bars=100 μm).

Mesozoic and Tertiary fossil woods. As Seward (1919) pointed out, there is no anatomical distinction between *Dadoxylon* and *Araucarioxylon*, *Dadoxylon* has priority for such fossils with aruacarian pitting without axial parenchyma excepting for certain fossils which shows direct affinity to the Araucariaceae. Although the present fossil is from Upper Cretaceous, it will be more appropriate to describe under the generic name *Dadoxylon*.

Felix (1887) described *Araucarioxylon koreanum* from the Lower Mesozoic formation in Pyeongyang area. This is the first record of fossil wood in the Korean Peninsula. However, this species was included in *Xenoxylon latiporosum* by Gothan (1905). Therefore the present fossil is the first record of *Dadoxylon* in the Korean Peninsula.

About thirteen taxa of *Dadoxylon* (*Araucarioxylon*) are known from the Mesozoic strata in the north earstern Asia; *Araucarioxylon tankoense* Stopes et Fujii (1910), *Dadoxylon* cf. *tankoense* (Shimakura, 1937), *D.* (*Araucarioxylon*) *japonicum* Shimakura (1936, 1937), *D.* (*A.*) *sidugawaense* Shimakura (1936), *A. jeholense* Ogura (1944), *A. kiiense* Ogura (1944; Nishida and Nishida, 1983, 1986b; Nishida et al., 1993a), *A.* cf. *kiiense* (Nishida, 1962, 1965), *A. mineense* Ogura (1960), *A. huzinamiense* Ogura (1960), *A. inuboense* Nishida (1965), *A. choshiense* Nishida (1965), *A. biseriatum* Nishida et al. (1993b), *A. pseudochoshiense* Nishida et M. Nishida (1986a). All of these species are provided with araucarian pitting of 2–3 rows of bordered pits on radial walls of tracheids and more than 5 pits arranged in 1–3 horizontal rows in cross fields. Among them, the present fossil is the most similar to *A. kiiense* from the Upper Cretaceous formation of the Wakayama Prefecture, *A.* cf. *kiiense* from the Choshi Peninsula, Chiba Prefecture and *D. japonicum* from the Upper Jurassic Torinosu Group, Koti Prefecture and Lower Cretaceous Monobegwa Series, Iwate Prefecture, Japan (Table 1). All of them share common characteristics such as 2–3 rows of bordered pits on the radial wall of tracheids and more than 5 pits arranged in 1–3 horizontal rows in a cross field. However, in contrast to the others, *D. japonicum* has a growth ring and *A. kiiense* and *A.* cf. *kiiense* has only uniseriate rays. And also the radial diameter of the tracheids is larger than the tangential diameter in transverse section of the most *Dadoxylon* (*Araucarioxylon*) species. However most tracheids of our present specimen from the isalnd of Byeongpung have larger tangential diameter than radial. Therefore, it should be appropriate that this specimen is designated as a new species of *Dadoxylon, D. byeongpungense.*

4.2. *Cupressinoxylon uhangriense* sp. nov. (Figs. 6–11)

4.2.1. Materials

Specimens no. CN 1102, 1107, 1108 (holotype) are fragments of coniferous secondary wood, about 7 cm, 9 cm, and 10 cm in length respectively from the Uhangri Formation at Uhangri, Haenam-gun, Jeollanam-do. The specimen no. CN 1108 is the best preserved in histology among the three specimens.

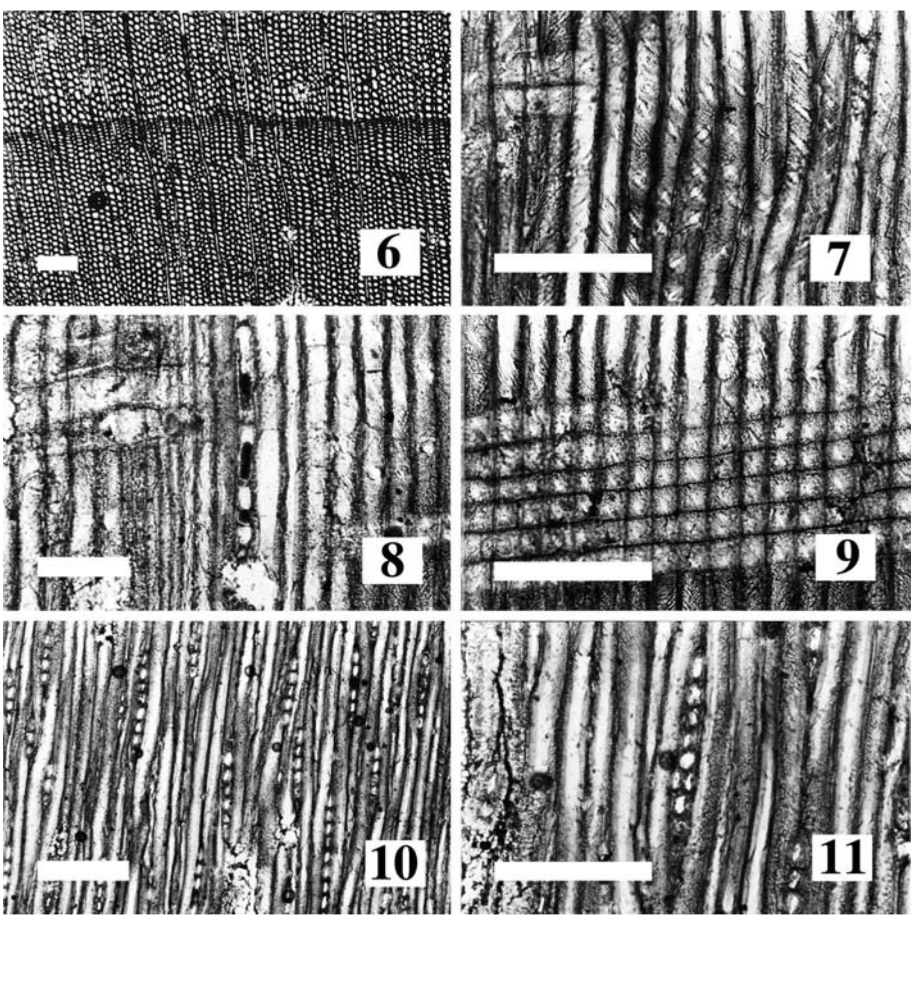
4.2.2. Description

Coniferous wood constitutes of tracheids, rays and axial parenchyma. Resin canal absent. Growth rings distinct with 4–5 layers of radially flattened latewood tracheids; width variable 0.3–4.5 mm; transition from earlywood to latewood abrupt, false growth rings sometimes present. Earlywood tracheids round or elliptical in cross section, uniform in size, 15–18×17–20 μm in tangential × radial diameters,

Table 1. Camparison of representitive anatomical features between *Araucarioxylon* spp. from north eastern Asia.

Botanic Name	GR	RPT	AP	NCP	HRC	VRC	Ray		RD	Reference
							Seriation	Height		
A. tankoense	+	2-4	-	4-8	2-3	n. r.	uniseriation	1-15(1-8)	-	Stopes et Fujii 1910
Dadoxylon cf. tankoense	+	2-4	-	4-8	2-3	n. r.	uniseriation	1-15(1-8)	-	Shimakura 1937
A. mineense	+	1 (2)	-	1-2	n. r.	n. r.	uniseriation (biseriation)	1-29(3-14)	-	Ogura, 1960
D. japonicum	+	2(1-3)	-	5-14	2-3	n. r.	uniseriation (biseriation)	1-24(3-10)	-	Shimakura, 1936
D. sidugawaense	+	1-2	(+)	1-3	1	3	uniseriation	1-14(3-10)	-	Shimakura, 1936
A. chosiense	-	1(2)	+	1-4	n. r.	1-2	uniseriation	1-3	-	Nishida, 1965
A. huzinamiense	-	2-3	-	1	n. r.	n. r.	uniseriation (biseriation)	4-13	+	Ogura, 1960
A. biseriatum	-	1-3	-	2-3	n. r.	n. r.	uniseriation (biseriation)	6-42(2-10)	-	Nishida, 1993
A. jeholense	-	1(2)	-	2	n. r.	n. r.	uniseriation	10-20	-	Ogura, 1944
A. inuboense	-	1-2	-	3(2-4)	n. r.	n. r.	uniseriation	1-8	-	Nishida, 1965
A. pseudochoshiense	-	1	-	2-5	n. r.	2	uniseriation	1-6(2-3)	-	Nishida, 1986
A. kiiense	-	2(1-3)	-	5-8	n. r.	n. r.	uniseriation	1-20(1-8)	-	Ogura, 1944
A. cf. kiiense	-	1-2 (3)	-	3-8(6)	2 (1)	n. r.	uniseriation	1-20(1-8)	-	Nishida, 1962
D. byeongpungense (CN 1202)	-	2(1-3)	-	7(8-13)	3	2-3	uniseriation (biseriation)	2-19(5-11)	-	

GR: Growth ring, RPT: Rows of bordered pits on tracheid, AP: Axial parenchyma, HRC: Horizontal rows of cross field pits, VRC: Vertical rows of cross field pits, RD: Resin duct, NCP: Number of cross field pits, n. r.: not reported.

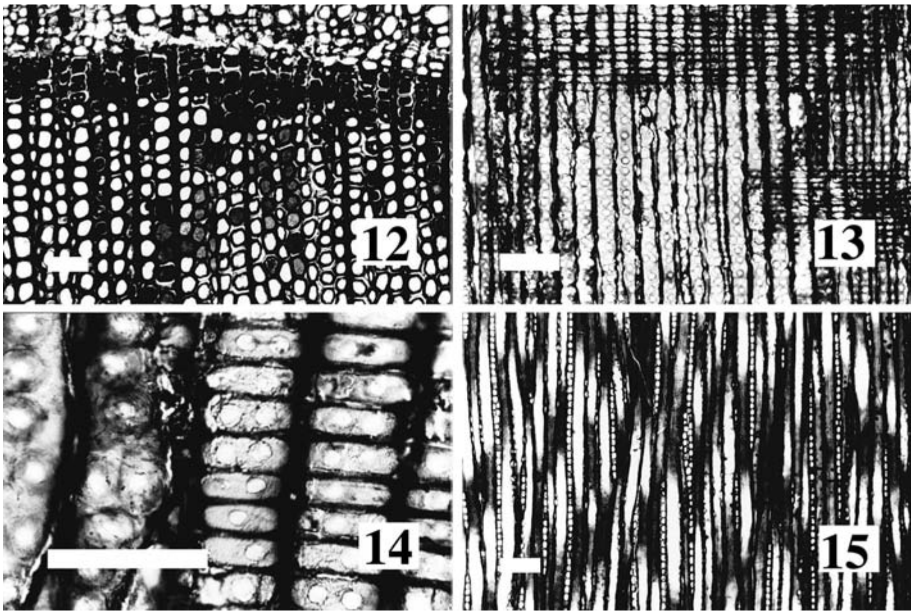


Figs. 6-11. Photomicrographs of *Cupressinoxylon uhangriense* (No. CN 1108) from Uhagnri. **Fig. 6.** Transverse section showing growth ring. **Fig. 7.** Radial section showing uniseriate bordered pits on the radial wall of tracheids. **Fig. 8.** Radial section showing axial parenchyma strand. **Fig. 9.** showing uniseriate rays. **Fig. 10.** Tangential section showing uniseriate, rays. **Fig. 11.** Tangential section showing partly biseriate rays (Bars=100 μm).

Table 2. Camparison of representitive anatomical features between *Cupressinoxylon* spp. from north eastern Asia.

Botanic Name	GR	TD	RWP		TWP	AP	CP			Ray		Reference
			Rows	Arr.			Num.	Type	Arr.	Seriation	Height	
C. mcgeei	conspicuous, abrupt	34-54/32-50	2(3)	opposite	small, abudant,	+++	1-2	taxodioid	horizontal	uni	2-49	Knowlton, 1898
C. sachalinense	conspicuous, gradual	n. r.	1-2	opposite	large, few scattered	+	1(2-3)	small, half borderd	horizontal	uni,bi(tri)	1-25	Shimakura 1937
C. vectense	conspicuous composite	17/25	1(2)	separate (opposite)	small few	+++	1-2(3-4)	cupressoid	horizontal	uni(bi)	1-12 (2-6)	Barber, 1898
C. cryptomerioides	faint, gradual	15-22/15-25	1	separate	small, few	+++	2	taxodioid	vertical	uni	1-6 (2-3)	Stopes, 1915
C. sp.	conspicuous gradual	n. r.	1	separate	n. r.	+	1-2	simple	n. r.	uni	n. r.	Shimakura 1937
C. sp.	faint	n. r.	1-2	separate	n. r.	+++	1-2(3-4)	n. r.	n. r.	uni	n. r.	Shimakura 1937
C. ? sp.	conspicuous gradual	n. r.	1-2	separate (opposite)	large separate	++	1-2 (more)	simple or half bordered	n. r.	uni(bi)	1-25 (30)	Shimakura 1937
C. cfr. hortii	not visible	33-42/36-57	1	separate	small separate	+++	1	oval, half bordered	n. r.	uni(bi)	2-35 (4-10)	Nishida, 1965
C. sp.	conspicuous abrupt	30-51/22-50	1(2)	separate (opposite)	small	+	1(2)	large, oval	horizontal	uni(bi)	1-30 (5-12)	Nishida and Hara, 1937
C. uhangriense CN 1102, 1107, 1108	conspicuous abrupt	15-18/17-20	1	separate	absent	+	1(2)	cupressoid	horizontal	uni(bi)	2-15 (4-10)	

GR: Growth ring, TD: Tracheid diameter (Tangetial/Radial), RWP: Radial wall pits, Arr.: Arrangement, TWP: Tangential wall pits, AP: Axial parenchyma, CP: Cross field pits, Num.: Number, n. r.: not reported.



Figs. 12-15. Photomicrographs of *Taxodioxylon albertense* (No. CN 1302). **Fig. 12.** Transverse section showing growth ring. **Fig. 13.** Radial section showing the pitting on the radial walls of tracheids. **Fig. 14.** Radial section showing taxodioid cross field pits. **Fig. 15.** Tangential section showing and partly biseriate rays (Bars=100 µm).

pitted only on radial walls. Latewood tracheids radially flattened, 13–15×5–11 µm in tangential×radial diameters; walls 3–6 µm thick. Bordered pits distinct on radial walls; arranged in one row separately, circular, about 8 µm in diameter, with circular apertures. Rays uniseriate, rarely partly biseriate, 2–15, mostly 4–10 cells tall, arranged at intervals of 1–10, average 5.9 rows of tracheids, consisting wholly of parenchyma cells. Ray cells vertically-elongated rectangular with round corners, or barrel-shaped in tangential section, 12 µm in height and 8 µm in width. Cross field pits cupressoid, one or rarely two, circular half bordered, about 8 µm in diameter. Axial parenchyma scattered and abundant; cells 100–160 µm in length often with dark contents.

4.2.3. Notes

The present three fossil woods are coniferous wood which consist of tracheids, rays and axial parenchyma. They are characterized by distinct growth rings of narrow latewood, scattered axial parenchyma with dark contents and cupressoid cross field pits. These characters indicate that those fossils belong to the genus *Cupressinoxylon*. In addition to that they have fairly small tracheids whose size of earlywood is about 15–18×17–20 µm in tangential × radial diameters in transverse section.

Nine taxa of *Cupressinoxylon* are known from north eastern Asia (Table 2); *C. vectense* Barber (1898; Shimakura, 1937; Nishida, 1965; Nishida et al., 1993a), *C.* sp. (Nishida and Hara, 1978), *C. mcgeei* Knowlton (1889; Nishida and Hara, 1978), *C. cryptomerioides* Stopes (1915; Nishida and Nishida, 1986b; Nishida et al., 1993b), *C. sachalinense* Shimakura (1937; Nishida, 1973) and three types of *Cupressinoxylon* spp. (Shimakura, 1937) from Japan, Manchuria and Saghalien, and one type from Choshi (Nishida, 1965). Among them diameters of tracheids in *C. vectense* and *C. cryptomerioides* are small like the present specimens (Table 2). However *C. vectense* has one to four pits in its cross field but our present specimens have only one or rarely two pits. And also rays of *C. cryptomerioides* is consisted with one to three seriate rays but uniseriate and partly biseriate in our specimens. Therefore our specimens are different from *C. vectense* and *C. cryptomerioides*. There are four types of *Cupressinoxylon* species whose size of tracheids were not recorded. Among them *C. sachalinense* has characteristic by its small pits in cross field, and is easily distinguished from our specimens. The other Shimakura's *Cupressinoxylon* types (Shimakura, 1937) are differ from our specimens by the characteristics of cross field pits and seriation of rays (Table 2). Therefore, the present three specimens collected from Uhangri (CN 1102, 1107, 1108) designated as a new species of *Cupressinoxylon, C. uhangriense.*

4.3. *Taxodioxylon albertense* (Penhallow) Shimakura (Figs. 12–15)

Taxodioxylon albertense (Penhallow) Shimakura Sci. Rep. Tohoku Imp. Univ. 2nd ser. 19: 45, 1937

4.3.1. Material

Specimen no. CN 1302 is a fragment of coniferous secondary wood, about 8 cm long and 3 cm wide, from island Gwanmae, Jindo-gun, Jeollanam-do. This specimen is well preserved in histology.

4.3.2. Description

Coniferous wood constitutes of tracheids, rays and axial parenchyma. Resin canal absent. Growth rings distinct with about 15 layers of radially flattened latewood tracheids; ring width 2.5–3 mm. Earlywood tracheids round or rectangular in cross section, uniform in size, 30–52×45–52 µm in tangential × radial diameters. Latewood tracheids radially flattened, 20×38 µm in tangential × radial diameters. Bordered pits distinct on radial wall, dense and one or two rows on the earlywood tracheids, separate or contiguous, oppositely arranged when in two rows, about 21–25 µm in diameter, with circular apertures of about 10 µm in diameter. Pits on tangential walls small and separated. Rays uniseriate, and sometimes partly biseriate, 1–72, mostly 5–15 cells tall, consisting of wholly parenchyma cell. Cross field pits taxodioid, 1–3 per field, circular or elliptical in outline, about 10 µm in diameter. Axial parenchyma scattered; cells 150–200 in length, often with dark contents.

4.3.3. Notes

This specimen is characterized by having an ordinary coniferous type of bordered pits on the radial wall of the tracheids, small separate pits on the tangential wall, a relatively large transverse diameter of earlywood tracheids (up to 52 µm), scattered axial parenchyma, high (up to 72 cells) and uniseriate or often partly biseriate rays, and 1–3 taxodioid half bordered pits in a cross field. All of those characteristics agree with *Taxodioxylon* Felix (1887). There are about seven taxa of this genus from the Mesozoic in eastern Asia; *T. nihongii* Nishida et H. Nishida (1985; Nishida and Nishida, 1986a), *T. paranihongii* Nishida et H. Nishida (1985), *T. pseudoalbertense* Nishida et H. Nishida (1985, Nishida and Nishida, 1986a), *T. compressum* Ogura (1944), *T. sequoianum* (Mercklin) Gothan (Seward, 1919; Shimakura, 1933; Ogura, 1944), *T. albertense* (Penhallow) Shimakura (Penhallow, 1908; Shimakura, 1937; Nishida and Hara, 1978; Nishida and Nishida, 1985, 1986b), *T. taxodii* Gothan (1906; Seward, 1919; Ogura, 1944; Nishida, 1962; Nishida and Hara, 1978). Among them the *T. albertense* is but only one which sometimes has no traumatic resin canal (Nishida and Hara, 1978; Nishida and Nishida, 1985). Therefore it could be appropriate that this specimen could be identified as *T. albertense* without traumatic resin canals and also many other characteristics.

4.4. ***Taxodioxylon*** **cf.** ***nihongii*** **Nishida et H. Nishida (Figs. 16–19)**

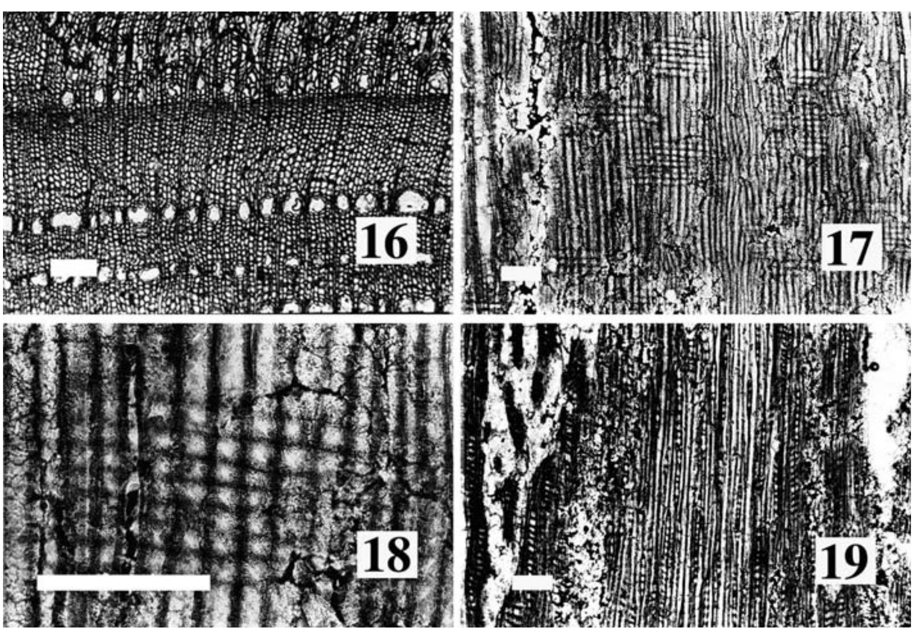
Taxodioxylon nihongii Nishida et H. Nishida J. Jpn. Bot. 60: 314, 1985

4.4.1. Materials

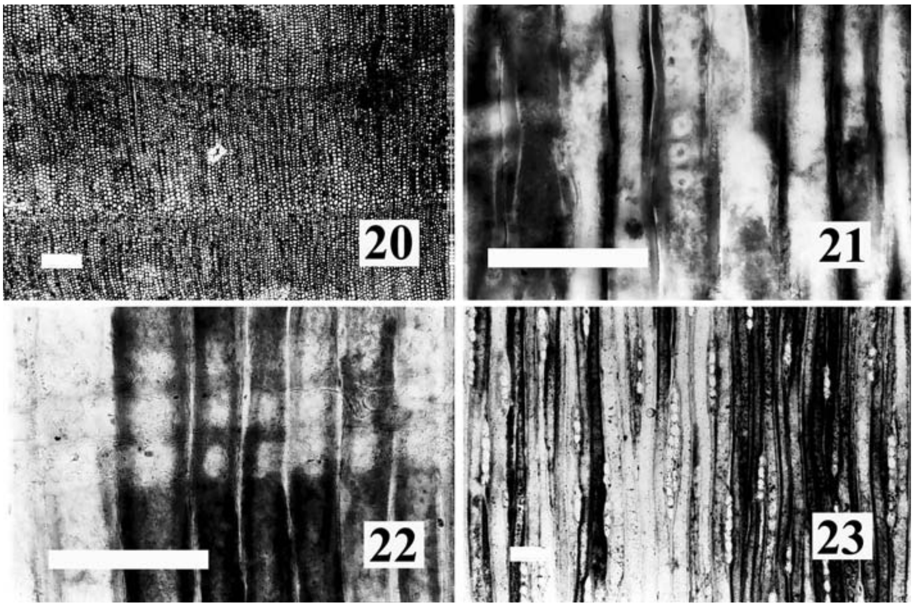
Specimens no. CN 1101, 1103 are fragments of coniferous secondary wood, about 5 cm long and 3 cm wide, from Uhangri Formation, Uhangri, Haenam-gun, Jeollanam-do. These specimens are not so well preserved in histology.

4.4.2. Description

Coniferous wood constitutes of tracheids, rays and axial parenchyma. Traumatic resin canals present. Growth rings distinct with 4–5 layers or more of radially flattened latewood tracheids, transition from earlywood to latewood abrupt. Earlywood tracheids round or rectangular in cross section, almost uniform in size, 15–30×14–25 µm in tangential × radial diameters, pitted only on radial walls. Latewood tracheids radially flattened, 9–15×12–17 µm in tangential × radial diameters, walls about 3 µm thick. Bordered pits distinct, arranged separately in a one row on the



Figs. 16-19. Photomicrographs of *Taxodioxylon* cf. *nihongii* (No. CN 1103) from Uhangri Foramtion. **Fig. 16.** Transverse section showing traumatic resin canals and a growth ring. **Fig. 17.** Radial section showing traumatic resin canals and parenchyma strands. **Fig. 18.** Radial section showing single cross field pitting. **Fig. 19.** Tangential section showing uniseriate rays (Bars =100 µm).



Figs. 20-23. Photomicrographs of *Mesembrioxylon* sp. (No. KS 1202). **Fig. 20.** Transverse section showing a faint growth ring. **Fig. 21.** Radial section showing separated uniseriate bordered pits on radial wall of tracheids. **Fig. 22.** Radial section showing single window-like pits on cross fields. **Fig. 23.** Tangential section showing uniseriate and partially biseriate rays (Bars=100 μm)

earlywood tracheids; circular, about 12 μm in diameter, with elliptical apertures; pits on tangential walls invisible. Rays uniseriate, 3–24, mostly 3–8, average 9 cells tall; arranged at intervals of 4–14, average 7 rows of trachids, consisting wholly of parenchyma cells. Ray cells vertically-elongated rectangular with round corners, or barrel-shaped in tangential section. Cross field pits one large circular half-bordered, about 8 μm in diameter, cupressoid with vertically or obliquely oriented elliptical apertures (axial parenchyma).

4.4.3. Notes

The preservation of these specimens was not so good, however several important characteristics could be observable for making identification possible. It is a coniferous wood consisting of tracheids, rays and axial parenchyma with dark contents and well developed traumatic resin canals. Traumatic resin canals are known in some genera of Taxodiaceae and Pinaceae among the extant conifers, and *Taxodioxylon* and some genera that have affinities with the Pinaceae among fossil conifers. The presence of scattered axial parenchyma with dark contents and absence of any normal resin canals nor the ray tracheids in the present fossil indicate that the fossil belongs to *Taxodioxylon*. As mentioned above, there are seven species of *Taxodioxylon* which are provided with tramatic resin canals in the Mesozoic of eastern Asia. In addition, other detailed characteristics such as small pits on the radial wall of tracheids arranged in single rows and separate (ca. 12 μm in diameter), uniseriate rays with 3–8 cells tall, and one cupressoid pit in the cross field well coincide with *T. nihongii* and *T. paranihongii* (Nishida and Nishida, 1985). The differences between these two species are based on the shapes of their pith cells. Because the present specimen does not have pith, exact identification was not possible. Therefore it could be appropriate that this fossil was regarded as *T. nihongii* because of the priority of nomenclature.

4.5. *Mesembrioxylon* sp. (Figs. 20–23)

4.5.1. Material

Specimen no. KS 1202 is a fragment of coniferous secondary wood, about 5 cm long and 3 cm wide, from Dadaepo Formation, Dadaepo, Busan. The preservation of this specimen is not so well in histology.

4.5.2. Description

Coniferous wood constitutes of tracheids and rays, with faint growth ring. Resin canal and axial parenchyma absent. Latewood narrow; 5–8 cells in width. Tracheids elliptical or rectangular in cross section, uniform in size, 40–44× 40–52 μm in tangential × radial diameters, pitted only on radial walls. Bordered pits on radial walls arranged separate in one row; pits on tangential walls invisible. Rays uniseriate, sometimes partly biseriate, 1–7, mostly 3–5 cells tall, arranged at intervals of 3–9, average 5.5 rows of tracheids, consisting wholly of parenchyma cells. Ray cells ovoidal in tangential section, 30–36 μm in height and 18–22 μm in width. Cross field pits large and window-like, one pit per cross field.

4.5.3. Notes

The preservation of this specimen was not so good that some of the detailed characters could not be observed sufficiently. However, based on the observable characteristics, the present fossil is characterized by 1) presence of faint growth ring, 2) absence of resin canal and axial parenchyma, 3) ordinary coniferous pitting on tracheids, and 4) large single pit per cross fields. These characteristics indicate that this fossil could be associate with *Mesembrioxylon* (Nishida, 1966). However, due to the poor preservation, the amount of appearance of detailed features, such as cross field pitting and arrangement of bordered pits on the radial wall of tracheids, was not sufficient enough to confirm the identification of specific level. Therefore it would be appropriate that this specimen is regarded as a taxon of *Mesembrioxylon*.

5. CONCLUSIONS

On the basis of detailed anatomical features for thirteen silicified fossil woods collected from the Cretaceous of Korea, five species of coniferous woods, they are, *Dadoxylon byeongpungense* sp. nov., *Cupressinoxylon unhanriense* sp. nov., *Taxodioxylon* cf. *nihongii* Nishida et H. Nishida., *Taxodioxylon albertense* (Penhallow) Shimakura, and *Mesembrioxylon* sp. were identified.

The most prominent feature of the present study is the entirely lack of dicotyledonous woods. We collected many plant remains that are silicified and/or charcoalized from the sites, Uhangi, Dadaepo and islands of Gwanmae and Byeongpung, and thirteen silicified wood could be observed anatomically. As described in this paper all fossils identified are Conifers. Generally the sampled horizons are considered as Upper Cretaceous with abundant dinosaur footprint fossils. In Japan, although dicotyledons are not yet known from the Lower Cretaceous sediments (Nishida, 1962, 1965, 1973; Nishida and Hara, 1978; Suzuki et al., 1991), the Upper Cretaceous sediments bear fairly much amount of dicotyledonous fossils (Stopes and Fujii, 1910; Shimakura, 1937; Takahashi and Suzuki, 2002). Althouth limited number of specimens are studied in the present paper, the result, that is the only occurrence of conifers, is quite strange in comparison with the studies in Japan. It may be said that there are some possibilities of biased collection of the fossil samples or inappropriate geological aging of fossil bearing sediment.

Anyway, this is the first report on fossil woods in the Mesozoic in southern Korean Peninsula. Further studies with much more samples will be strongly expected for clarifying the vegetation in the ancient world with dinosaur.

ACKNOWLEDGEMENTS: This study was supported by Korea Science and Engineering Foundation (KOSEF R01-1999-00053).

REFERENCES

Barber, C.A., 1898, *Cupressinoxylon vectense*; a fossil Conifer from the Lower Greensand of Shanklin, in the Isle of Wight. Annals of Botany, 12, 329–361.

Choi, H.I., 1985, Sedimentology and its implication for stratigraphic classifications of the Cretaceous Gyeongsang Basin. Journal of the Geological Society of Korea, 21, 26–37.

Chang, K.H., 1975, Cretaceous Stratigraphy of Southeast Korea. Journal of the Geological Society of Korea, 11, 1–23.

Chough, S.K., Kwon, S.T., Ree, J.H. and Choi, D.K., 2000, Tectonic and sedimentary evolution of the Korean Peninsula: a review and new view. Earth-Science Reviews, 52, 175–235.

Chun, S.S. and Chough, S.K., 1995, The Cretaceous Uhangri Formation, SW Korea: lacustrine margin facies. Sedimentology, 42, 293–322.

Felix, H.J., 1887, Untersuchungen über fossile Hölzer 1. Holz von Phyöngyang in Korea. Z. Deut. Geol. Ges., 39, 517–528.

Gothan, W., 1905, Zur Anatomie lebender und fossiler Gymnospermen-Hölzer. Abhandl. k. Preuss. Geol. Landesanst, (N.F), Bd. XLIV, 1–108.

Gothan, W., 1906, Die Fossilen Coniferenhölzer von Senftenberg. Abhandl. k. Preuss. Geol. Landesanst, 46, [quoted in Ogura (1944)].

Huh, M., Lim, S.K. and Yang, S.Y., 1996, First discovery of Pterosaur tracks from Asia. Journal of the Geological Society of Korea, 32, 526–528.

Huh, M., Lee, Y.N., Lim, S.K. and Hwang, G.G., 1998, Integrative Study on Haenam Dinosaur Site: Chollanam-do. 491 p.

Huh, M., Paik, I.S., Lee, Y.I. and Kim, H.K., 1999, Dinosaur eggs and nests from Boseong, Chullanam-do. Journal of the Geological the Society of Korea, 35, 229–232.

Knowlton, F.H., 1889, Fossil Wood and Lignite of the Potamac Formation. Bulletin U.S. Geological Survey, 56, 46 [quoted in Seward (1919)].

Lee, D.W., 1999, Strike-slip fault tectonics and basin formation during the Cretaceous in the Korean Peninsula. The Island Arc, 8, 218–231.

Nishida, H. and Nishida, M., 1986a, Structure and affinities of the petrified plants from the Cretaceous of Northern Japan and Saghalien IV. Petrified plants from the Upper Cretaceous of Saghalien (2). The Botanical Magazine, Tokyo, 99, 205–212.

Nishida, M., 1962, On some petrified plants from the Cretaceous of Choshi, Chiba Prefecture. Japanese Journal of Botany, 18, 87–104.

Nishida, M., 1965, On some petrified plants from the Cretaceous of Choshi, Chiba Prefecture II. The Botanical Magazine, Tokyo, 78, 138–146.

Nishida, M., 1966, On Some Petrified Plants from the Cretaceous of Choshi, Chiba Prefecture III. The Botanical Magazine, Tokyo, 79, 226–235.

Nishida, M., 1973, On some petrified plants from the Cretaceous of Choshi, Chiba Prefecture VI. The Botanical Magazine, Tokyo, 86, 189–202.

Nishida, M. and Hara, Y., 1978, Taxodioid Woods from the Cretaceous of Choshi, Chiba Prefecture. Bulletin Marine Laboratory Chiba University, 10, 1–15.

Nishida, M. and Nishida, H., 1983, Petrified Plants from the Cretaceous of the Kwanto Mountains, Central Japan I. The Botanical Magazine, Tokyo, 96, 85–91.

Nishida, M. and Nishida, H., 1985, Structure and affinities of the petrified plants from the Cretaceous of northern Japan and Saghalien. II Petrified plants from the Upper Cretaceous of Hokkaido (2). Journal of Japanese Botany, 60, 312–319.

Nishida, M. and Nishida, H., 1986b, Structure and affinities of the petrified plants from the Cretaceous of Northern Japan and Saghalien I. Petrified plants from the Upper Cretaceous of Saghalien (1). The Botanical Magazine, Tokyo, 99, 191–204.

Nishida, M., Nishida, H. and Sugiyama, R., 1993a, Studies in the Petrified Plants from the Cretaceous of Northern Japan and Saghalien X IV. Coniferous Woods from the Upper Crataceous of Taneichi, Iwate Perfecture. Research Institute of Evolutionary Biological Science Report, 7, 69–86.

Nishida, M., Nishida, H. and Suzuki, Y., 1993b, On some petrified plants from the Cretaceous of Choshi, Chiba Prefecture VIII. Journal of Japanese Botany, 68, 289–299.

Ogura, Y., 1944, Notes on fossil woods from Japan and Manchoukuo. Japanese Journal of Botany, 8, 345-365, pls. 3–5.

Ogura, Y., 1960, Tyloses in Tracheids in *Araucarioxylon*. Journal of Faculty Science University, Tokyo Section III. (Botany) 7, 501–509.

Paik, I.S., 2000, Bone chip-filled burrows associated with bored dinosaur bone in floodplain paleosols of the Cretaceous Hasandong Formation, Korea. Palaeogeography, Palaeoclimatology, Palaeoecology, 157, 213–225.

Paik, I.S., Lee, Y.I. and Kim, H.J., 1998a, Dinosaur beds of the Gyeongsang Supergroup: taphonomy and paleoenvironments. Journal of the Geological Society of Korea, 34, 243–265.

Paik, I.S., Kim, H.J. and Lee, Y.I., 2001a, Dinosaur track deposits from the Cretaceous Jindong Formation, Korea: Occurrence, paleoenvironments and preservation. Cretaceous Research, 22, 79–92.

Paik, I.S., Lee, Y.I., Lee, Y.U., Cheong, K.K. and Kim, S.J., 1998b, Dinosaur beds in the Cretaceous Hasandong Formation in the vicinity of Jinju City, Gyeongnam, Korea. Journal of the Paleontological Society of Korea, 14, 14–32.

Paik, I.S., Kim, H.J., Park, K.H., Song, Y.S., Lee, Y.I., Hwang, J.Y. and Huh, M., 2001b, Palaeoenvironments and taphonomic preservation of dinosaur bone-bearing deposits in the Lower Cretaceous Hasandong Formation, Korea. Cretaceous Research, 22, 627–642.

Penhallow, D.F., 1908, Report on a Collection of Fossil Woods from the Cretaceous of Alberta. Ottawa Naturalist, 112, 83–84.

Seward, A.C. 1919, Fossil Plants Vol. IV Ginkgoales, Coniferales, Gnetales. Cambridge University Press, 543 p.

Shimakura, M., 1933, Notes on the fossil woods. Journal of the Geological Society of Tokyo, 40, 533–540.

Shimakura, M., 1936, Studies on fossil woods from Japan and adjacent lands. Contribution I. The Science Report of the Tohoku Imperial University Section Series, 18, 267–310.

Shimakura, M., 1937, Studies on fossil woods from Japan and adjacent lands. Contribution II. The Science Report of the Tohoku Imperial University Section Series, 19, 1–73.

Stopes, M.C., 1915, Catalogue of the Mesozoic Plants in the British Museum (Natural History). The Cretaceous flora part II. Lower Greensand (Aptian) Plants of Britain. Langmans & Green, London, p. 55–246.

Stopes, M.C. and Fuji, K., 1910, Studies on the Structure and affinities of Cretaceous Plants. Philosophical Transaction Royal Society London Series B, CCI, 23–70.

Suzuki, M. Joshi, L. and Noshiro, S., 1991, *Tetracentron* wood from the Miocene of Noto Peninsula, central Japan, with a short revision of homoxylic fossil woods. The Botaical Magazine, Tokyo, 104, 37–48.

Takahashi, K. and Suzuki, M., 2002, Dicotyledonous Fossil Wood Flora and Early Evolution of Wood Characters in the Cretaceous of Hokkaido, Japan. IAWA Journal (in press).

Um, S.H., Choi, H.I., Son, J.D., Oh, J.H., Kwak, Y.H., Shin, S.C. and Yun, H.S., 1983, Geological and geochemical studies on the Gyeongsang Supergroup in the Gyeongsang Basin. Korea Institute of Energy and Resources, Bulletin, 36, 124.

Manuscript received February 5, 2002
Manuscript accepted June 3, 2002