

CONIFEROUS FOSSIL WOODS FROM THE JOGYERI FORMATION (UPPER TRIASSIC) OF THE NAMPO GROUP, KOREA

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SUMMARY

Ninety-four fossil woods were collected from the Upper Triassic Jogyeri Formation of the Nampo Group in the County of Cheongyang-gun, Chungcheongnam-do Province, Korea. Eight of the specimens were preserved well enough to identify them down to species or genus. All were coniferous woods. On the basis of their detailed anatomical features, four specimens were identified as *Xenoxylon phyllocladoides* Gothan and the other four as *Agathoxylon* sp. Therefore six taxa of fossil woods, *Cedroxylon regulare* Göppert, *Xenoxylon phyllocladoides* Gothan, *X. latiporosum* (Cramer) Gothan, *X. japonicum* Vogellehner, *Phyllocladoxylon heizyoense* Shimakura and *Agathoxylon* sp., have now been reported from the Early Mesozoic Daedong Supergroup in the Korean Peninsula.

Key words: Coniferous fossil wood, Upper Triassic, Nampo Group, Daedong Supergroup, *Xenoxylon*, *Agathoxylon*, Korea.

INTRODUCTION

Mesozoic deposits in the Korean Peninsula consist of three groups: the Lower Mesozoic Daedong Supergroup considered of Late Triassic to Early Jurassic age (Kimura & Kim 1984a; Yang 1999), the Jurassic Myogok Formation (Cheong & Lee 1966), and the Cretaceous Gyeongsang Supergroup (Chang 1975; Son 1997). The Daedong Supergroup is distributed sporadically throughout North Korea and the western and central part of South Korea (Fig. 1).

Many palaeobotanical studies of the Lower Mesozoic Daedong Supergroup have been performed on macrofossils such as leaves (Yabe 1905; Kawasaki 1925, 1926, 1939; Kimura & Kim 1984a, 1988, 1989; Kim & Kimura 1988; Kim 1993). However, little is known about fossil woods from the Lower Mesozoic Daedong Supergroup. Five taxa of fossil woods have been reported from the Middle Formation of the Songnim-san Series (or Daedong Group) in North Korea by Félix (1887; *Cedroxylon regulare*

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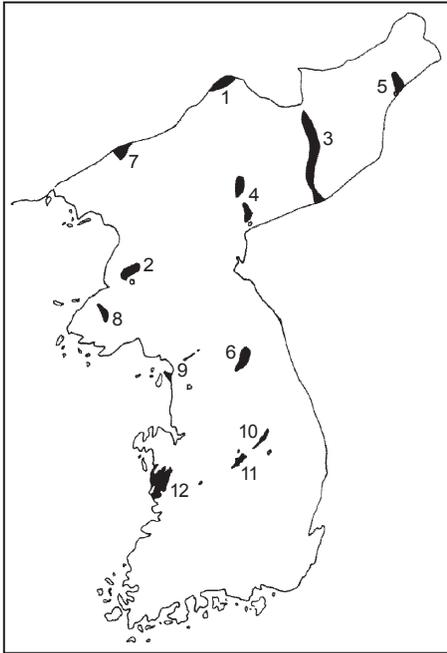


Fig. 1. Distribution of Lower Mesozoic (Daedong Supergroup) strata in the Korean Peninsula (modified by Yang 1999).

- 1: Junggang Series;
- 2: Songnimsan Series;
- 3: Jangphari Series;
- 4: Sansuri Series;
- 5: Chongjin Series;
- 6: Chonri Series;
- 7: Changseong;
- 8: Jaerye-onggang;
- 9: Kimpo Group;
- 10: Bansong Group;
- 11: Mungyeong Coalfield;
- 12: Nampo Group.

Göppert, *Araucarioxylon koreanum* Félix), Shimakura (1936; *Xenoxylon phyllocladoides* Gothan, *X. latiporosum* (Cramer) Gothan, *Phyllocladoxylon heizyoense* Shimakura), and Ogura (1944; *X. latiporosum* (Cramer) Gothan).

The Jogyeri Formation forms the middle part of the Nampo Group, belonging to the Daedong Supergroup (Fig. 2). The Nampo Group is a non-marine deposit and mainly distributed in Boryeong City and Cheonyang-gun County, the western part of Chungcheongnam-do Province in Korea. Shimamura (1931) was the first to carry out a geological investigation of this region, and mapped the Cheongyang, Daecheon, Nampo and

Daedong Supergroup	
Songnimsan Series	Nampo Group
Pak & Kim (1996)	Suh <i>et al.</i> (1980)
Upper Fm.	Seongsuri Fm.
	Baegunsa Fm.
Middle Fm. ☐=☐	Jogyeri Fm. ☐=☐
Lower Fm.	Amisan Fm.
	Hajo Fm.

Fig. 2. Stratigraphic comparison between the Songnimsan Series of North Korea and the Nampo Group of South Korea of the Daedong Supergroup in the Korean Peninsula. (☐=☐): horizons where fossil wood has been found).

Buyeo sheets. According to him, the Nampo Group forms a linear belt of sedimentary rocks surrounded by Precambrian metamorphic rocks, and is divided into two, the western and eastern parts, by a tear fault trending NW-SE. Detailed stratigraphy of the Nampo Group was undertaken by Um *et al.* (1965), Son *et al.* (1967), Lee *et al.* (1974) and Suh *et al.* (1980). Based on these stratigraphic and geologic studies, the Nampo Group is now divided into five formations, *viz.* Hajo, Amisan, Jogyeri, Baegunsa and Seongjuri Formations in ascending order (Fig. 2) and is considered to be Upper Triassic (Suh *et al.* 1980; Kimura & Kim 1984a; Kim & Kimura 1988; Kim 1993). A simplified geological map showing the locality in the Cheongyang area from which the fossils described below, is given in Figure 3.

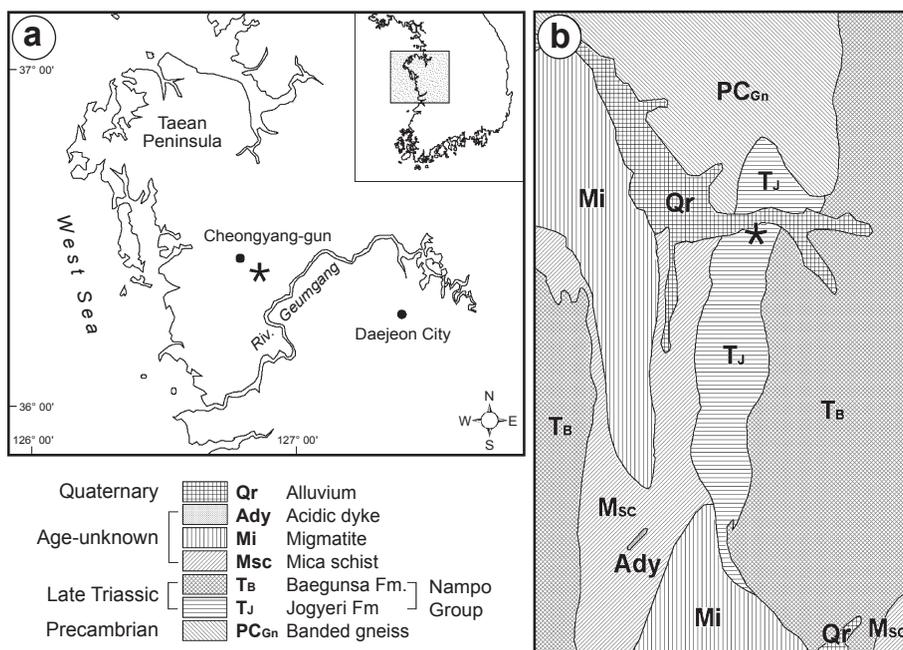


Fig. 3. Simplified geological map showing the fossil wood locality mentioned in the text (a: local map; b: magnified geological map).

The Jogyeri Formation is considered to have been deposited in a braided stream environment and divided into a lower feldspar breccia bearing sandstone zone and the overlying conglomerate zone (Choi *et al.* 1988). The fossil woods are mostly intercalated in the upper conglomerate zone as transported logs and wood fragments of about 5 to 30 cm long, alongside well-rounded pebbles, cobbles, and boulders. Therefore it is suggested that the fossil woods represent allochthonous material.

In this study, the fossil wood specimens were studied to determine their affinity in order to contribute to our understanding of the palaeoflora and palaeoenvironment of the Korean Peninsula during the early Mesozoic.

MATERIALS AND METHODS

During road construction works, the outcrops of the Jogyeri Formation, which are located about 55 km to the west of Daejeon City, were accidentally unearthed and ninety-four fossil woods were collected from this site. The outcrop of the Jogyeri Formation of the Nampo Group is located at Gwangdae-ri of Daechi-myeon in Cheongyang-gun County, Chungcheongnam-do Province (Fig. 3a).

The samples were silicified and broken into many fragments and not well preserved. Therefore a transverse thin section was made of each specimen and only when the preservation appeared adequate, tangential and radial thin sections were prepared using conventional techniques (Barefoot & Hankins 1982). In order to observe anatomical features, the microscopic slides were examined using a Zeiss Axiophot compound microscope, and described following the terminology of "Identification of Modern and Tertiary Woods" (Barefoot & Hankins 1982). All fossil woods and microscopic slides studied have been deposited in the Fossil Collection, Herbarium of Chonbuk National University, Division of Biological Sciences, Chonbuk National University, Chonju, Korea.

RESULTS

Unfortunately most of the fossil woods were not preserved well enough to enable identification. However, eight fossil woods did show such a good preservation that two taxa of fossil woods could be identified.

Order: CONIFERALES

Family ?Protopinaceae Kräusel 1917 / *incertae sedis*

Genus: *Xenoxylon* Gothan 1905

Type species: *Xenoxylon latiporosum* (Cramer) Gothan 1905

Xenoxylon phyllocladoides Gothan 1906 (Fig. 4–9)

Materials: KNUM 2000-0016, 2000-0020, 2000-0047, 2000-0050.

The four specimens are fragments of secondary xylem, which are lacking pith, but are fairly well preserved. Among them, KNUM 2000-0016 shows the best preservation.

Description: Based on one piece of coniferous wood (KNUM 2000-0016) composed of tracheids and rays, lacking axial parenchyma and resin canals. Growth rings about 2 mm wide, boundaries distinct with 4 or 5 layers of radially flattened latewood tracheids; transition from earlywood to latewood abrupt. The earlywood tracheids squarish or rectangular to elliptical and radially elongated in cross section; dimensions 40–50 × 50–80 μm in tangential and radial diameter. Bordered pits mainly preserved as internal casts of pit chambers ("Steinkerne"). Pits on radial walls of earlywood tracheids arranged contiguously or sometimes distant in one or rarely two rows; opposite when in two rows; usually horizontally flattened elliptical or sometimes rounded; about 22 × 16 μm in horizontal and vertical diameter; with apertures of about 6 μm in diameter.

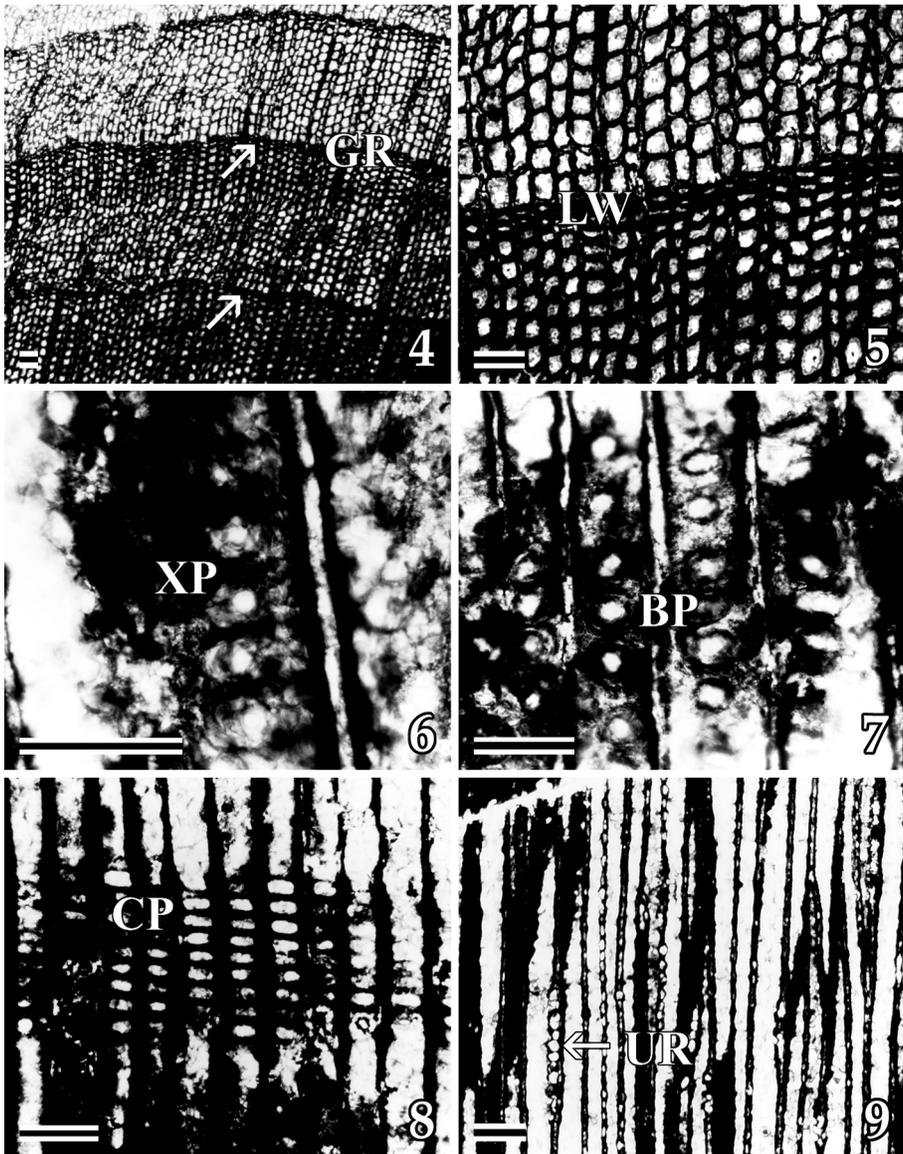


Fig. 4–9. *Xenoxylon phyllocladoides* Gothan (4–6: KNUM 2000-0016, 7: KNUM 2000-0050, 8 & 9: KNUM 2000-0047) – 4: Cross section showing growth rings (GR). – 5: Cross section showing narrow latewood (LW) and abrupt transition between earlywood and latewood. – 6: Radial section showing xenoxylloid pitting (XP) on the radial tracheid walls. – 7: Radial section showing barberi-type pitting (BP) on the radial tracheid walls. – 8: Radial section showing one large simple cross-field pit (CP). – 9: Tangential section showing uniseriate rays (UR). — Scale bars: 100 μm for 4 & 5, 8 & 9; 50 μm for 6 & 7.

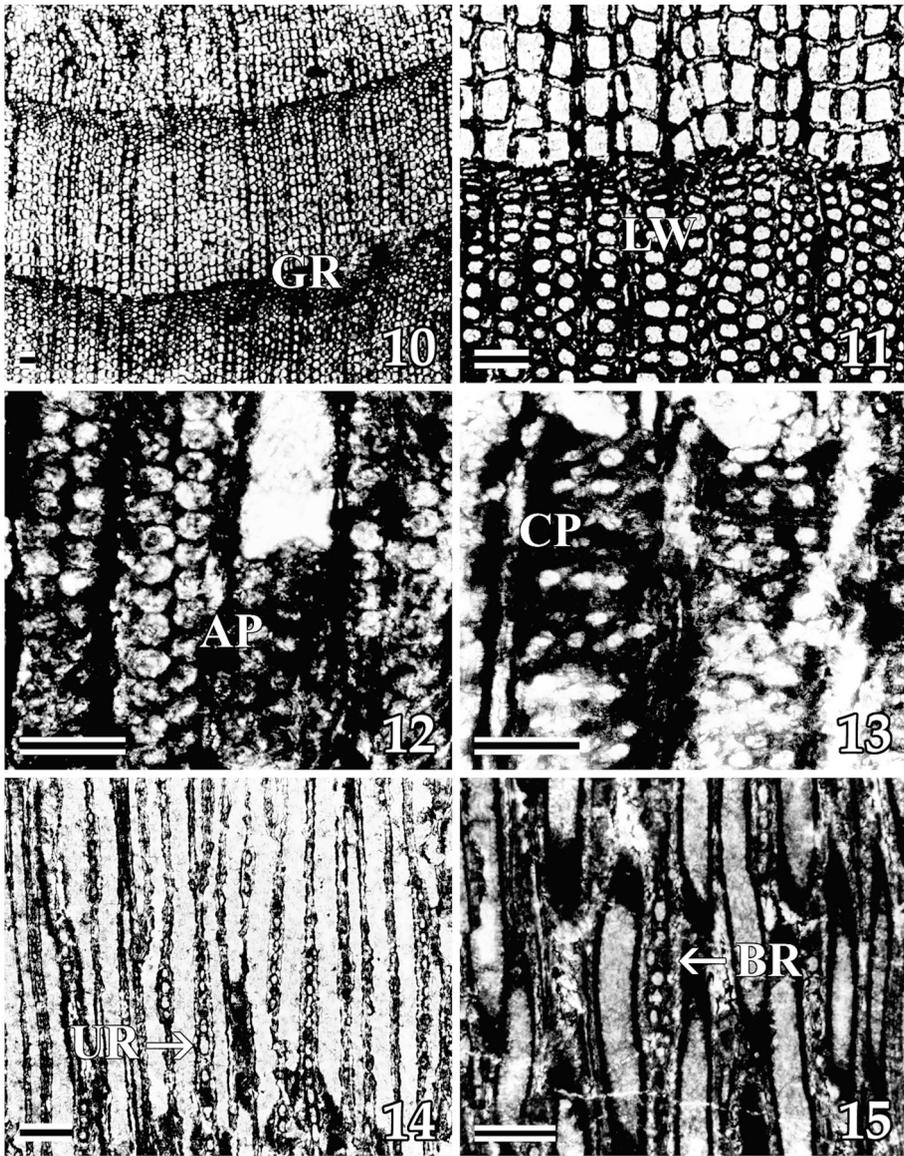


Fig. 10–15. *Agathoxylon* sp. (10 & 11: KNUM 2000-0039, 12–15: KNUM 2000-0013) – 10: Cross section showing growth rings (GR). – 11: Cross section showing wide latewood (LW) and gradual transition between earlywood and latewood. – 12: Radial section showing three rows araucarian pitting (AP) on the radial tracheid walls. – 13: Radial section showing taxodioid or simple cross-field pits (CP). – 14: Tangential section showing uniseriate rays (UR). – 15: Tangential section showing biseriate ray (BR). — Scale bars: 100 μm for 10 & 11, 14 & 15; 50 μm for 12 & 13.

The latewood tracheids squarish and radially flattened in cross section; dimensions 40–45 × 15–20 µm in tangential and radial diameter. Pits on tangential walls of tracheids absent.

Rays usually uniseriate and rarely partly biseriate; 1–10 (mostly 2–6) cells high, 18–180 µm in height; separated by 1–16 (average 5.6) rows of tracheids; consisting wholly of parenchyma cells. Ray cells vertically elongated oval or elliptical in tangential section; 16–20 × 20–24 µm in horizontal and vertical diameter. Cross-field pits simple; one or rarely two large and window-like. Pits on tangential and horizontal walls of rays absent.

Family? Araucariaceae Henkel & Hochstein 1865 / *incertae sedis*

Genus: *Agathoxylon* Hartig 1848

Type species: *Agathoxylon cordaianum* Hartig 1848

***Agathoxylon* sp.** (Fig. 10–15)

Materials: KNUM 2000-0001, 2000-0013, 2000-0019, 2000-0039.

The four specimens are fragments of secondary xylem, lacking pith and fairly well preserved.

Description: Based on one piece of coniferous wood (KNUM 2000-0013) composed of tracheids and rays, lacking axial parenchyma and resin canals. Growth rings about 2–4 mm wide, boundaries distinct with 10–15 layers of radially flattened latewood tracheids; transition from earlywood to latewood gradual. The earlywood tracheids squarish and radially elongated in cross section; dimensions 50–65 × 65–80 µm in tangential and radial diameter. Bordered pits on radial walls of the earlywood tracheids arranged contiguously and alternately in 1–3 rows, usually 2–3 rows; round to elliptical or vertically flattened when in one row; about 20 µm in diameter; with apertures of about 6 µm in diameter. The latewood tracheids tangentially flattened in cross section; dimensions 40–45 × 20–25 µm in tangential and radial diameter. Pits on tangential walls of tracheids absent.

Rays usually uniseriate and rarely partly biseriate; 1–15 (mostly 6–10) cells high; separated by 1–5 (average 3.6) rows of tracheids; composed entirely of parenchyma cells. Ray cells vertically elongated oval or elliptical in tangential section; 16–24 × 28–32 µm in horizontal and vertical diameter. Cross-field pits simple or taxodioid; 3–6 in one or two rows; about 10 µm in diameter. Pits on tangential and horizontal walls of rays absent.

AFFINITIES

Among the 94 samples, four of them are characterized by 1) coniferous wood without either axial parenchyma or resin canals, 2) the presence of distinct growth rings, 3) horizontally flattened radial wall pitting of tracheids, 4) mostly uniseriate rays, 5) mostly one large and window-like cross-field pit. These samples show greatest anatomical similarity to woods assigned to the genus *Xenoxylon* Gothan.

Twenty-five taxa of *Xenoxylon* have been reported throughout the world from the Late Triassic to the Late Cretaceous (Zheng & Zhang 1982; Yamazaki *et al.* 1984; Wang 1991; Khudaiberdyev 1993; Dechang 1995; Duan & Wang 1995; Philippe & Thévenard 1996; Zhang & Shang 1996; Morgans 1999; Ding *et al.* 2000; Duan 2000; Liu *et al.* 2000; Wang *et al.* 2000; Zheng *et al.* 2001; Kim *et al.* 2002; Youssef 2002). The most important feature of infrageneric classification of the genus *Xenoxylon* is the types and arrangement of radial wall pitting of tracheids. All of these samples have bordered pits that are either horizontally flattened and contiguous, or round or spatially separated along the radial wall of tracheids. This pitting type of tracheids is the salient feature of *X. phyllocladoides* Gothan (1906). Therefore it is appropriate to identify our four samples related to *Xenoxylon* as *X. phyllocladoides*.

Xenoxylon phyllocladoides has been reported from the Middle Formation of Songnimisan Series in Pyeongyang City, North Korea (Shimakura 1936). Shimakura also reported *X. latiporosum* (Cramer) Gothan from the quarry with the same formation as the Songnimisan Series. However, Vogellehner (1968) divided *X. latiporosum* into two groups based on ray height and established a new species, *X. japonicum* Vogellehner, for *X. latiporosum* from the Songnimisan Series described by Shimakura (1936). Suzuki and Terada (1992) agreed with Vogellehner's classification after re-examining the material described by Shimakura.

Ogura (1944) also reported *X. latiporosum* from the Songnimisan Series and Nakdong Formation, which is the lowermost formation of the Gyeongsang Supergroup and regarded as Lower Cretaceous. Thus three species of *Xenoxylon*, *X. latiporosum*, *X. japonicum* and *X. phyllocladoides*, have been reported from the Upper Triassic (Songnimisan Series and the Nampo Group) and the Lower Cretaceous (Gyeongsang Supergroup) of the Korean Peninsula. The intervening Jurassic Myogok Formation, which is confined to a very small basin, has yielded no fossil wood to date. Therefore it can be suggested that *Xenoxylon* was one of the major constituents of the palaeoflora growing on the Korean Peninsula at this time. The occurrence of *Xenoxylon* in the Late Triassic of Korea confirms that the genus covered an extensive geographical area ranging from easternmost to central Asia (Yamazaki *et al.* 1980; Wang 1991; Khudayberdyev 1993) when compared with the scarce (Vogellehner 1965) or doubtful (Fliche 1910) evidence from the Triassic of Europe.

The other four samples are characterized by 1) coniferous wood without axial parenchyma and resin canals, 2) round or vertically flattened alternate bordered pits in the radial tracheid walls, 3) three to six araucarioid cross-field pits arranged in one or two layers. These samples show the greatest anatomical similarity to the genus *Agathoxylon* Hartig (1848).

There has been a long controversy concerning the nomenclature of fossil woods of the araucarioid type with several generic names proposed, including *Agathoxylon* (Philippe 1993; Bamford & Philippe 2001), *Dadoxylon* (Endlicher 1847; Seward 1919), *Araucarioxylon* (Maheshwari 1972; Jeyasingh & Kumarasamy 1995), and *Chapmanoxylon* (Pant & Singh 1987). There are currently two schools of thought regarding the assignment of fossil material to *Araucarioxylon*. One school insists that *Araucarioxylon* Kraus is invalid under the ICBN because it is a synonym of *Agathoxylon* Hartig

(Philippe 1993; Bamford & Philippe 2001). However, the second school argues that the generic name of *Araucarioxylon* should be retained to avoid confusion since the name has been used for more than 100 years and is linked to many (>45) specific names (Falcon-Lang & Cantrill 2001). Since the generic name of *Araucarioxylon* has been shown to be illegitimate (Bamford & Philippe 2001), we consider it appropriate to assign our araucariaceous material to *Agathoxylon*.

The most important character of the infrageneric classification of *Agathoxylon* is usually considered to be the seriation of bordered pits on the radial tracheid walls. Other defining characters include the arrangement of the cross-field pits in the earlywood and ray height. Our specimens have 1–3 rows (usually 2 or 3 rows) of pits on the radial tracheid walls, 3–6 araucarioid pits per cross-field, and rays that are 1–15 (usually 6–10) cells high. Twenty-four species of *Araucarioxylon* (or *Dadoxylon*) which have 1–3 rows of pits on the radial tracheid walls have been reported (Shimakura 1936; Ogura 1944; Surange & Sah 1956; Veillet-Bartoszewska 1956; Kräusel & Jain 1963; Sah & Jain 1963; Maheshwari 1963, 1964; Maithy 1964; Vogelgehner 1965; Boureau & Koeniguer 1966; Lemoigne & Demarcq 1967; Japiassu 1970; Desplats 1976; Prasad 1982; Roselt 1986; Giraud 1991; Nishida *et al.* 1993). Among them seven species have usually 3–6 pits per cross-field (*D. duartei*, *D. (A.) gesoriacense*, *D. jhariense*, *D. kharkhariense*, *D. maharashtraensis*, *D. (A.) aff. sahariense*, *D. trungphanense*), two of which, *D. (A.) gesoriacense* and *D. duartei*, have axial parenchyma and thus differ from our specimens. *Dadoxylon jhariense* differs from our specimens in having pits on the tangential tracheid walls and lower ray heights (i.e. less than 6 cells). Three species of *D. (A.) aff. sahariense*, *D. trungphanense* and *D. kharkhariense*, differ from our specimens in having higher rays (i.e. >29, often up to 43 cells). *Dadoxylon maharashtraensis* most closely resembles our specimens but differs in having non-contiguous pits on the radial tracheid walls (Prasad 1982). Although our specimens do not have the complete suite of characters affiliating them to one particular species of araucariaceous wood, we can assign them to *Agathoxylon*. Due to the limited number of specimens, we are reluctant to assign these specimens to an existing morphotype, or create a new species.

DISCUSSION

The Nampo Group consists of five formations. Among them abundant fossil plants have been found from the Amisan and the Baegunsa Formations but until now no material has been described from the Jogyeri Formation intercalated between them. During the course of this study, however, a considerable number of fossil wood specimens were found. Kim (1993) described the Nampo leaf flora based on material from the Amisan and the Baegunsa Formations. He found that they were similar to one another and assigned the leaves to the *Dictyophyllum-Clathropteris* type of palaeoflora (Kim 1993). This flora is known from the southern part of China from Late Triassic to Early Jurassic (Li & Zhou 1979), with more occasional occurrences as far north as the Korean Peninsula, and characterized by plants typical of the tropical to subtropical climate (Kimura & Kim 1984b). It is plausible, therefore, that the Jogyeri Formation, sand-

wiched between Amisan and Baegunsa Formations, was deposited under similar palaeoclimatic conditions. However, it can also be suggested that some cold periods may have occurred during the Late Triassic in southern Korea, based on study of distribution and palaeoecology of the genus *Xenoxylon* (Philippe & Thévenard 1996) and as evidenced by the more temperate *Danaeopsis* and *Symopteris* type of palaeoflora (Kimura 1996).

Two conifers, *Agathoxylon* and *Xenoxylon*, have now been documented from the Jogyeri Formation of the Nampo Group. The genus *Agathoxylon* has a very broad temporal range occurring from the Palaeozoic to the present. Mesozoic agathoxyloid woods are usually regarded as having araucarian affinity. Araucarian conifers are among the oldest gymnosperms originating in the Middle Triassic (Miller 1977). Extant araucarian species are distributed from tropical to cool temperate regions throughout the Southern Hemisphere. Therefore the occurrence of *Agathoxylon* from the Nampo Group agrees well with the palaeoclimate inferred from the study of leaf material from the Nampo Group by Kim (1993).

However, in a detailed review of the distribution of *Xenoxylon*, Philippe and Thévenard (1996) suggest that this genus, thought to be the secondary wood of extinct Mesozoic coniferous plants, had a circumpolar distribution restricted to the Northern Hemisphere. Moreover, these authors suggest *Xenoxylon* is indicative of wet and/or cool climate conditions. During the Triassic, the distribution of *Xenoxylon* was higher in latitude than during the Jurassic and the Cretaceous (Philippe & Thévenard 1996). Thus either Philippe and Thévenard's study (1996) shows disagreement with the study on the palaeoclimate based on the leaf fossils of the Nampo Group (Kim 1993), or the wood deposits represent a cooler (or wetter) period/event during the deposition of the Nampo Group.

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