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ARTICLE

# FIRST REPORT OF FOSSIL WOOD FROM THE UPPER CRETACEOUS IZUMI GROUP IN AWAJI ISLAND, JAPAN

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## ABSTRACT

A calcified fossil wood from the Shimonada Formation (early Maastrichtian) of the Upper Cretaceous Izumi Group collected at the coast of Nadachino, Minamiawaji City in the Awaji Island, Hyogo Prefecture is studied anatomically. The fossil has the axial and radial intercellular (resin) canals and is identified as *Piceoxylon* sp. of Pinaceae. The fossil is similar to fossil woods of *Piceoxylon* reported from the Upper Cretaceous of Hokkaido of Japan, Russian Far East and Canadian Arctic Archipelago, but is different from them in having indistinct growth ring boundaries and variable types of cross-field pitting. This represents the fossil wood reported from the Izumi Group for the first time.

Key words：Awaji Island, early Maastrichtian, fossil wood, Hyogo Prefecture, Izumi Group, *Piceoxylon*, Shimonada Formation, Upper Cretaceous

**寺田和雄・半田久美子（2014）淡路島の上部白亜系和泉層群から産出した材化石の初報告．福井県立恐竜博物館紀要 13：17–23.**

兵庫県淡路島南部に分布する上部白亜系和泉層群下灘層（前期Maastrichtian）から産出した石灰化した材化石について樹種を検討した．この化石は垂直・水平樹脂道を有し，マツ科の*Piceoxylon* sp.と同定した．本化石は北海道や極東ロシア，カナダ北極諸島の上部白亜系から報告されている*Piceoxylon*の材化石に類似しているが，不明瞭な年輪界や非常に様々なタイプの分野壁孔を持つことで異なっている．本報告は和泉層群からの材化石の最初の報告である．

## INTRODUCTION

The Izumi Group is one of representative Upper Cretaceous strata of Southwest Honshu Island, Japan and is widely distributed for about 300 km from western Shikoku Island eastward to the Izumi Mountains of Honshu Island along the north border of the Median Tectonic Line (e.g., Ichikawa, 1961; Tanaka, 1989). The group constitutes a thick sequence of marine deposits, mainly composed of alternating beds of conglomerate, sandstone and mudstone of a turbidite facies (e.g., Ichikawa, 1961; Morozumi, 1985; Tanaka, 1989; Noda and Toshimitsu, 2009), and yields a lot of rhizarian fossils such as radiolarian and foraminiferan (Yamazaki, 1987), invertebrate fossils such as mollusks, ammonites and crustaceans (e.g., Morozumi, 1985; Iwaki and Maeda, 1989; Nanko, 1996; Karasawa, 1998), and some vertebrate fossils such as dinosaurs, pterosaurs, mosasaurs and fishes (Sasai, 1936; Nanko, 1996; Saegusa and Furutani, 2004; Tanimoto, 2005; Kishimoto, 2014). The age of the group becomes younger towards the east from western Shikoku Island (Campanian), across Awaji Island (Campanian and Maastrichtian) to the Izumi Mountain Range (Maastrichtian), based mainly on international correlation of ammonite faunas (e.g., Morozumi, 1985; Tanaka, 1989).

As for the plant fossils from the group, a few reports were published (Matsuo, 1954, 1964, 1966; Iwaki and Maeda, 1989; Nanko, 1996). The plant megafossils from the group were firstly reported by Matsuo (1954), who illustrated a small shoot and a cone as *Cunninghamia* sp. that was later described as *C. izumiensis* Matsuo (1966). He further reported some plant megafossils including *Zamites* sp. of the gymnosperms and "*Ficus*" sp. of the angiosperms (Matsuo, 1966). This flora was called the Izumi Flora (Matsuo, 1964). Iwaki and Maeda (1989)

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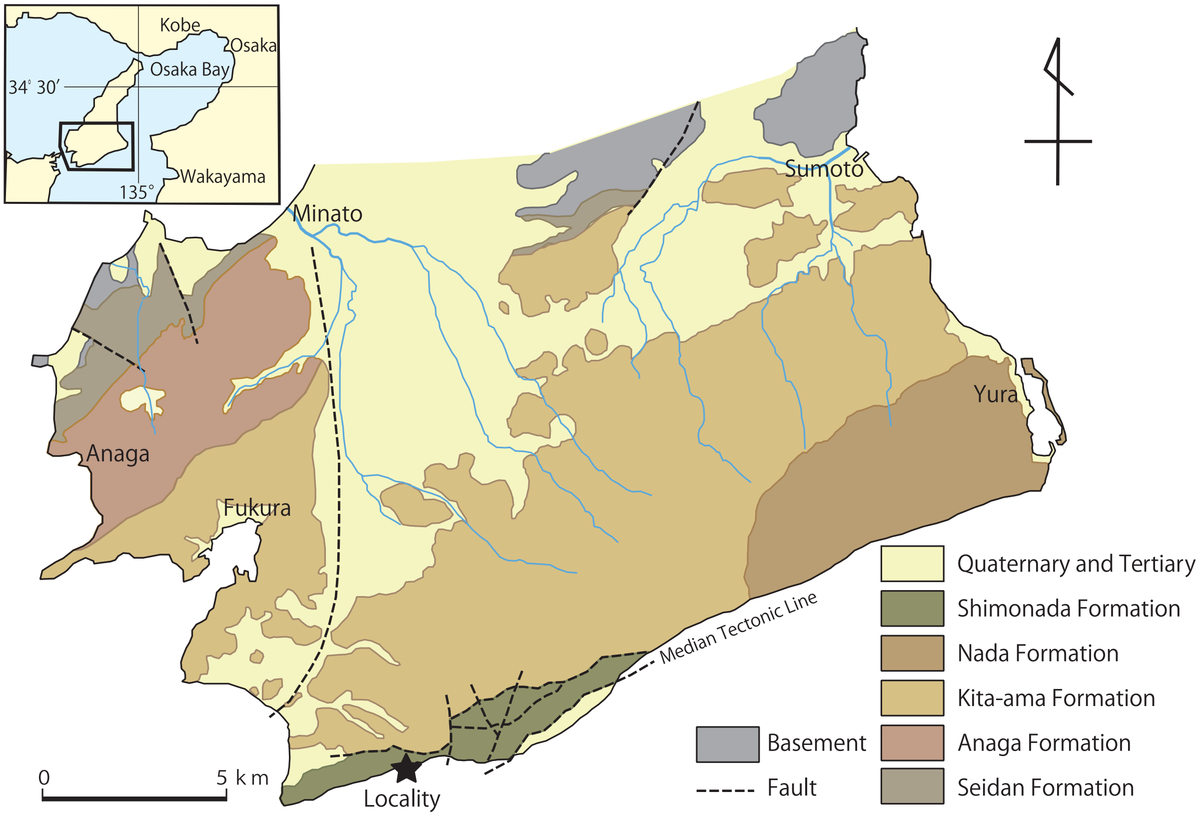

FIGURE 1. Locality of studied fossil wood on the geological map of the southern Awaji Island showing the distribution of the Izumi Group (modified from Morozumi (1985)).

reported a few leaves of the angiosperms such as *Platanus*? sp. and *Ulmus* sp., which were identified by Dr. Hidekuni Matsuo. Nanko (1996) showed some photographs of plant fossils including cycadalean stems and leaves, coniferous shoots and cones, ginkgoalean leaves of the gymnosperms, and an angiospermous leaf, but no detailed information of the fossils was described.

As for the fossil wood from the group, no report has been published. Only one guidebook showed one photograph of fossil wood (Nanko, 1996). We had opportunities to study a fossil wood from the Izumi Group of the Awaji Island. The fossil is a calcified (calcium-carbonated) wood. Although Nanko (1996) mentioned his fossil as silicified wood, Nanko's fossil may be a calcified wood because it was collected from the same locality as our fossil, where the marine deposits were distributed.

Here we report the result of anatomical study on the fossil wood.

## GEOLOGY

The Awaji Island is located in the eastern part of the Seto Inland Sea between the islands of Honshu and Shikoku, and is separated from Honshu Island by the Akashi Strait and from Shikoku Island by the Naruto Strait. The Izumi Group in the island is distributed in the southern half of the island (Fig. 1), being over 10,000 m in integrated thickness, overlies unconformably the acidic pyroclastic rocks of the Sen-nan Group, and is divided into five formations; the Seidan, the Anaga, the Kita-ama, the Nada and the Shimonada formations in ascending order (Ichikawa, 1961; Morozumi, 1985).

Morozumi (1985) studied the ammonite fauna of the Izumi Group in the Awaji Island biostratigraphically in detail and referred to for analysis of the age of the group. The stratigraphic position of the Shimonada Formation, which is distributed in a narrow area along the most southwestern margin of the island, is not precisely determined, because the formation is separated from the main part of the group by a fault (Fig. 1). Morozumi (1985) referred the formation to be synchronous with part of the Kita-ama and/or Nada formations based on the contained ammonites. The age of the Shimonada Formation is estimated as the early Maastrichtian of the Upper Cretaceous within the *Pachydiscus* aff. *subcompressus* Zone of ammonites (Morozumi, 1985).

## MATERIALS AND METHODS

**Specimen.**—MNHAH-D1029085

**Repository.**—Museum of Nature and Human Activities, Hyogo, Hyogo Prefecture (MNHAH).

The specimen was collected as a washed-out rock on the coast of Nadachino, Minamiawaji City in the Awaji Island, where the Shimonada Formation is distributed (Fig. 1). This specimen is a calcified fragment of secondary xylem and rather rounded by erosion, and 9 x 6.5 cm in diameter with 9 cm long (Fig. 2A). This is probably derived from a mature stem due to the presence of pith.

The specimen was thin-sectioned in cross, tangential and radial dimensions by a diamond saw, and ground to make thin microscopic slides. These slides were studied and photographed with an optical microscope.

## RESULT

The specimen (MNHAH-D1029085) was identified as *Piceoxylon* sp. The technical terms for microscopic features follow IAWA Committee (2004). Technical terms for microscopic features particularly important to the distinction of Mesozoic woods follow Philippe and Bamford (2008).

## SYSTEMATIC PALEONTOLOGY

Class PINOPSIDA Burnett, 1835
Order PINALES Dumortier, 1829
Family PINACEAE Lindley, 1836
Genus *PICEOXYLON* Gothan, 1905.
*PICEOXYLON* sp.
(Figs. 2, 3)

### Description

Coniferous wood constituted of tracheids, ray tracheids, ray parenchyma, and epithelial cells of axial and radial intercellular (resin) canals. Whole tracheids in second xylem thick-walled like compression woods. Growth rings indistinct, 3–5 mm wide (Fig. 3A, B). Transition from earlywood to latewood gradual (Fig. 3A. B). Nests of sclereids in pith absent (Fig. 3A)..

Earlywood tracheids rounded-square, rounded-rectangular or rounded-polygonal in cross section, 20–75 x 25–52 $\mu$m in tangential x radial diameters; thick-walled 7.5 $\mu$m thick, because of the formation of compression wood. Latewood tracheids rounded-rectangular, radially flattened in cross section, 25–58 x 15–30 $\mu$m in tangential x radial diameters; thick-walled, 7.5 $\mu$m thick.

Tracheid walls slightly decomposed, spiral grooves of S2 of secondary wall layers distinct in tangential and radial sections. Helical thickenings on the longitudinal tracheid walls absent (Fig. 3E, G).

Pitting on the radial walls contiguously uniseriate (Fig. 3F), or rarely biseriate. Crassulae absent. The pits are circular or somewhat elliptic, horizontally elongated, 10–25 $\mu$m in diameter with round to oval aperture of about 5 $\mu$m in diameter.

Axial parenchyma absent. Axial and radial intercellular canals present. Axial intercellular canals in all annual rings, mostly in earlywood, commonly occurring singly along rays, sometimes in pairs; usually round, 125–225 $\mu$m in diameter, with both thick-walled and thin-walled epithelial cells (Fig. 3A, B, C). Tylosoids in resin ducts present, distinct. Traumatic resin canals absent. Radial intercellular canals rather small, 55–87 $\mu$m in diameter, thick-walled epithelial cells in biseriate, bi-triseriate, and triseriate rays.

Rays consisting of ray parenchyma and ray tracheids, usually uniseriate or partly biseriate, 1–21 (commonly 4–8) cells tall (40–575 $\mu$m) with 30–50 $\mu$m wide (Fig. 3D). The horizontal walls of the ray parenchyma pitted (Fig. 3G, H. I). *Abietineentüpfelung* on tangential walls of ray cells present, distinct (Fig. 3E). Ray tracheids sometimes present at margin of rays; possibly helical thickenings present in ray tracheid walls (Fig. 3G). Pit borders of ray tracheids not observed. Cross-field pitting variable, slit-like pinoid (Fig. 3H), half bordered taxodioid or cupressoid with oblique oriented elliptical apertures (Fig. 3I), or possibly large to

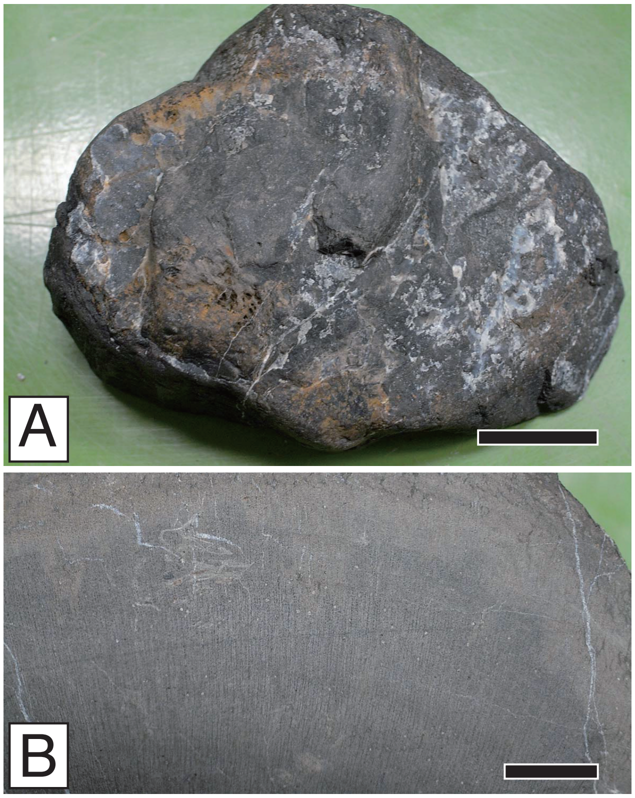

FIGURE 2. *Piceoxylon* sp. (MNHAH-D1029085). A, Original material. Scale bar: 2 cm. **B,** Close-up of the cut surface of cross direction of the fossil, showing indistinct growth rings and axial intercellular canals. Scale bar: 1 cm.

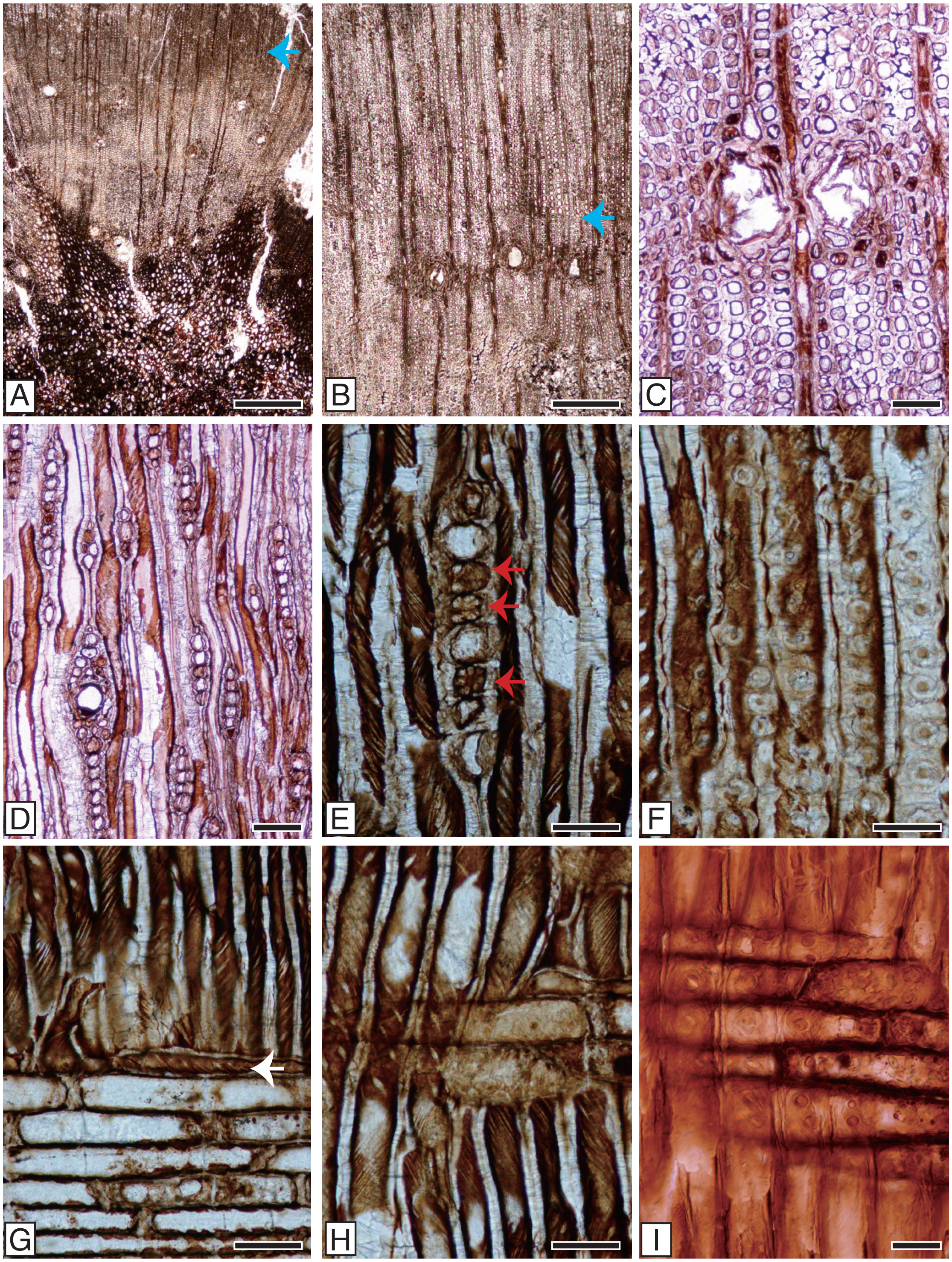

FIGURE 3. *Piceoxylon* sp. (MNHAH-D1029085). **A–I**, Microphotographs of the fossil. **A**, Cross section showing the pith of wood, axial intercellular canals, one indistinct growth ring boundary (blue arrow). Scale bar: 500 μm. **B,** Cross section around the ninth-year growth ring, showing one indistinct growth ring boundary (blue arrow) and axial intercellular canals. Scale bar: 250 μm. **C,** Cross section showing axial intercellular canals. Scale bar: 100 μm. **D,** Tangential section showing uniseriate rays and a radial intercellular canal. Scale bar: 100 μm. **E,** Tangential section showing *Abietineentüpfelung* (red arrow) on ray cells. Scale bar: 50 μm. **F,** Radial section showing predominantly uniseriate tracheid pitting in the radial walls. Scale bar: 50 μm. **G,** Radial section showing ray tracheid with probably helical thickenings (white arrow), and pitted horizontal walls of ray parenchyma cells. Scale bar: 50 μm. **H,** Radial section showing slit-like pinoid cross-field pitting. Scale bar: 50 μm. **I,** Radial section showing cupressoid to taxodioid cross-field pitting. Scale bar: 25 μm.

small oopores (Fig. 3G, I); one to four per cross-field (Fig. 3G, H, I).

## AFFINITY AND DISCUSSION

The fossil wood is prominently characterized by the presence of (1) both axial and radial intercellular (resin) canals, (2) both thick-walled and thin-walled epithelial cells, (3) contiguously uniseriate radial wall pitting, (4) *Abietineentüpfelung* on the tangential walls of ray cells, (5) pitted horizontal ray walls, (6) ray tracheids with possibly helical thickenings, (7) slit-like pinoid, half bordered taxodioid or cupressoid, and possibly oopores cross-field pitting.

These wood anatomical features were initially identified having affinities with the morphogenera of Pinaceae. Especially, *Abietineentüpfelung* is one of the important microscopic features for the distinction of the Mesozoic woods (Philippe and Bamford, 2008), which was coined by Gothan (1905) to describe rounded pits, areolate or not, occurring on the transversal wall of ray cells (Fig. 3G).

According to a key for the identification of the Mesozoic coniferous woods by Philippe and Bamford (2008), the morphogenera which have both axial and radial intercellular canals and *Abietineentüpfelung* limited the following four genera; *Palaeopiceoxylon* Kräusel, *Pinuxylon* Gothan, *Laricioxylon* Greguss and *Piceoxylon* Gothan. Although *Pityoxylon* Kraus is described as having both axial and radial intercellular canals (Kraus, 1882, see Harland et al., 2007), this morphogenus name should not be used until its revision because of the problems of typification and specimen (Philippe and Bamford, 2008).

*Palaeopiceoxylon* is obviously different from our fossil in having araucarian, or araucarian and abietinean mixed pitting on the radial walls of tracheids (Kräusel, 1949, see Philippe and Bamford, 2008). *Pinuxylon* is apparently different from our fossil in having thin-walled epithelial cells of intercellular canals and large window-like cross-field pitting (Gothan, 1905, see Philippe and Bamford, 2008).

In wood anatomical features, *Laricioxylon* and *Piceoxylon* are very similar to each other and share characteristics with extant genera, *Picea*, *Larix* and *Pseudotsuga* of the Pinaceae. According to a key of the identification for the Mesozoic coniferous woods by Philippe and Bamford (2008), they could be separated by the feature of ray tracheid tips. The ray tracheid tips of *Laricioxylon* are elongated, crooked, overlapping with one another (Greguss, 1967, see Philippe and Bamford, 2008). Contrarily, the ray tracheid tips of *Piceoxylon* are short, straight, not overlapping (Gothan, 1905, see Philippe and Cantrill, 2007; Philippe and Bamford, 2008). Furthermore, Harland et al. (2007) mention *Laricioxylon* has a relatively high proportion of latewood cells and displays characteristics similar to extant *Larix* wood. Our fossil does not have distinctly elongated ray tracheid tips or a high proportion of latewood cells. Therefore, our fossil could be placed in the restricted genus *Piceoxylon*.

Although no genus name is mentioned in the key by Philippe and Bamford (2008), *Pseudotsugoxylon* Blokhina also has both axial and radial intercellular canals and *Abietineentüpfelung*, which described from the Pliocene of the Southern Primorskii Region in the Russian Far East (Blokhina and Bondarenko, 2004). *Pseudotsugoxylon* is, however, different from our fossil in having distinct helical thickenings on the longitudinal tracheid walls, and typical picenoid cross-field pitting in the diagnosis (Blokhina and Bondarenko, 2004).

Therefore, our fossil is assigned to *Piceoxylon* of the Pinaceae. *Piceoxylon* was firstly described as *P. antiquius* by Gothan (1905), which was designated its lectypification by Philippe and Cantrill (2007). *Piceoxylon* includes more than 20 reported species from a large area of the Northern Hemisphere. Even just limited to Upper Cretaceous to Paleogene woods of *Piceoxylon*, the genus has been reported from Russian Far East (Sakhalin and Kamchatka) (Shimakura, 1937; Nishida and Nishida, 1995; Blokhina and Afonin, 2009; Afonin, 2012), Northern China (Sze, 1951; Zheng et al., 2008), Japan (Shimakura, 1937; Nishida and Nishida, 1995; Nishida et al., 1993, 1995) and Canadian Arctic Archipelago (Harland et al., 2007). Most of the Upper Cretaceous *Piceoxylon* in Japan have been described from the Yezo Group of Hokkaido. Only one species, *P. iwatense* M. Nishida, H. Nishida et Sugiyama, is described from the Kuji Group at Iwate Prefecture in Honshu Island (Nishida et al., 1993).

Among fossil woods of the *Piceoxylon*, the wood of our fossil resembles those of *P. scleromedullosum* Shimakura (Shimakura, 1937), *P. takahashii* M. Nishida et H. Nishida (Nishida and Nishida, 1995), *P. pseudoscleromedullosum* M. Nishida, H. Nishida, Yoshida et Kaiho (Nishida et al., 1995), and *P. burejense* M. Afonin (Afonin, 2012) in having taxodioid to cupressoid, or oopores cross-field pitting without typically piceoid cross-field pitting distinctive of extant *Picea*. Among them, our fossil is similar to *P. takahashii* from the Yezo Group of Hokkaido, in having lower rays, ray tracheids, tylosoids in axial intercellular canals, and a few cross-field pits. However, the wood of our fossil is obviously different from that of *P. takahashii* in lacking distinct growth ring boundaries and nests of sclereids in pith (Nishida and Nishida, 1995).

Although it is probably a new species of *Piceoxylon*, the anatomical features may not be preserved well because of its compression wood or its decomposition of tracheid walls (For example, helical thickenings on longitudinal tracheid wall). Therefore, our fossil is identified as *Piceoxylon* sp. Our study adds new geographic and stratigraphic information on *Piceoxylon* in Japan.

### Comparison with extant woods

The wood of our fossil is initially identified as having affinities with the Abietoideae form of Pinaceae due to the lack of typically “pinoid” cross-field pits and thin-walled epithelial cells distinctive of *Pinus*. Among the Abietoideae, *Abies*, *Cedrus*, *Tsuga* and *Pseudolarix* lack both axial and radial intercellular canals, and *Keteleeria* and *Nothotsuga* lack radial intercellular canals (Lin et al., 1995, 2000; IAWA Committee, 2004; Esteban and de Palacios, 2009). Thus, our fossil has affinities with *Picea*, *Larix* and *Pseudotsuga* which have normal axial and radial intercellular canals surrounded by thick-walled epithelial cells (IAWA Committee, 2004; Esteban and de Palacios, 2009). As *Pseudotsuga* may be readily distinguished from most of *Picea* and *Larix* by the presence of well-developed helical thickenings on longitudinal tracheid walls (IAWA Committee, 2004). In the wood of our fossil, helical thickenings on longitudinal tracheid walls are not preserved. Both the woods of *Picea* and *Larix* are very similar. Noshiro and Fujii (1994) revealed that *Larix* was distinguished anatomically from *Picea* by the presence of fusiform parenchyma and marginal parenchyma in secondary xylem. In the wood of our fossil, both of the fusiform parenchyma and the marginal parenchyma are absent. According to wood anatomical studies of *Picea* (Sudo, 1955; IAWA Committee 2004), the cross-field pitting of *Picea* is relatively uniform, small slit-like piceoid to cupressoid. Our fossil is different from *Picea* in having large slit-like pinoid, half bordered taxodioid or cupressoid, and possibly oopores cross-field pitting. Therefore, our fossil belongs to no extant genera.

Recent cladistic analyses using cone characters suggest that many *Pityostrobus* species would be placed into intermediate position between the extant genera of Pinaceae (e.g., Klymiuk and Stockey, 2012; Ryberg et al., 2012). Some *Pityostrobus* species are suggested to have abietoid affinity, but these are distinct from the extant genera. The wood morphotaxa including our fossil might be born at the tip of which such *Pityostrobus* cones. Our result might suggest that there is the hidden diversity of the Pinaceae during the Cretaceous.

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## REFERENCES

Afonin, M. A. 2012. Fossil wood of *Piceoxylon burejense* sp. nov. (Pinaceae) from the Upper Cretaceous of Zeya-Bureya Basin, Amur Region (Russian Far East). Paleontological Journal 46 (3): 324–329.

Blokhina, N. I., and M. A. Afonin. 2009. New Species of *Piceoxylon* Gothan (Pinaceae) from the Cretaceous and Paleogene of the Northwestern Kamchatka Peninsula. Paleontological Journal 43 (10): 1190–1201.

Blokhina, N. I., and O. V. Bondarenko. 2004. Fossil wood of *Pseudotsugoxylon* gen. et sp. nov. (Pinaceae) from the Pliocene of the Southern Primorskii Region. Paleontological Journal 38 (3): 327–334.

Burnett, G. T. 1835. Outlines of Botany. Renshaw, London, 1068 pp.

Dumortier, B. C. J. 1829. Analyse des families des plantes avec l'indication des principaus cenres que s'y rattachent. J. Casterman, Tournay, 105 pp.****

Esteban, L. G., and de Palacios, P. 2009. Comparative wood anatomy in Abietoideae (Pinaceae). Botanical Journal of the Linnean Society 160 (2): 184–196.

Gothan, W. 1905. Zur Anaromie lebender und fossiler Gymnospermen-Hölzer. Abhandlungen der Preussischen Geologischen Landesanstalt 44: 1–108.***

Greguss, P. 1967. Fossil Gymnosperm Woods in Hungary from the Permian to the Pliocene. Akadémiai Kiadó, Budapest. 136 pp.

Harland, M., J. E. Francis, S. J. Brentnall and D. J. Beerlingb. 2007. Cretaceous (Albian–Aptian) conifer wood from Northern Hemisphere high latitudes: Forest composition and palaeoclimate. Review of Palaeobotany and Palynology 143 (3): 167–196.

IAWA Committee. 2004. IAWA list of microscopic features for softwood identification. IAWA Journal 25: 1–70.

Ichikawa, K. 1961. Izumi Group; pp. 56–61 *in* K. Ichikawa. The explanatory text of geological map, Hyogo Prefecture, scale 1:170,000, Hyogo Prefecture. Kobe. **

Iwaki, T., and H. Maeda. 1989. Mudstone facies and the fossil molluscan assemblages of the Upper Cretaceous Izumi Group in the southeastern Awaji Island, southwest Japan. Research Report of Kouchi University 38: 187–201, pls. 1–6.*

Karasawa, H. 1998. Two new species of Decapoda (Crustacea) from the Upper Cretaceous Izumi Group, Japan. Paleontological Research 2 (4): 217–223.

Kishimoto, S. 2014. Vertebrate fossils from the Izumi Group in Awaji Island. Kyousei-no-hiroba 9: 68–72.**

Klymiuk, A. A., and R. A. Stockey. 2012. A Lower Cretaceous (Valanginian) seed cone provides the earliest fossil record for *Picea* (Pinaceae). American Journal of Botany 99 (6): 1069–1082.

Kraus, G. 1882. Über eine neue Protopitys aus der Lettekohle. Sitz. Ber. Naturforsch Gesellschaft Halle 1882: 7–8. ***

Kräusel, R. 1949. Die Fossilen Koniferen-Hölzer (Unter Ausschluss von *Araucarioxylon* Kraus). II: Kritische Unertsuchungen zur Diagnostik Lebender und Fossiler Koniferen-Hölzer. Palaentographica, Abteilung B 89: 83–203.***

Lin, J.-X., Y.-S. Hu and F.-H. Wang. 1995. Wood and bark anatomy of *Nothotsuga* (Pinaceae). Annals of the Missouri Botanical Garden 82: 603–609.

Lin, J., E. Liang and A. Farjon. 2000. The occurrence of vertical resin canals in *Keteleeria*, with reference to its systematic position in Pinaceae. Botanical Journal of the Linnean Society 134 (4): 567–574.

Lindley, J. 1836. A natural system of botany, or, A systematic view of the organization, natural affinities, and geographical distribution, of the whole vegetable kingdom: together with the uses of the most important species in medicine, the arts, and rural or domestic economy, Second edition, Longman, Rees, Orme, Brown, Green, and Longman, London, 526 pp.

Matsuo, H. 1954. On the occurrence of the genus *Cunninghamia* from the Izumi Sandstone Group (Upper Cretaceous). Journal of the Geological Society of Japan 60 (707): 362.**

Matsuo, H. 1964. On the late Cretaceous Floras in Japan. Annals of Science, College of Liberal Arts, Kanazawa University 1: 39–65.*

Matsuo, H. 1966. Plant fossils of the Izumi Group (Upper Cretaceous) in the Izumi Mountain Range, Kinki District, Japan. Annals of Science, College of Liberal Arts, Kanazawa University 3: 67–74, pl. 1.

Morozumi, Y. 1985. Late Cretaceous (Campanian and Maastrichtian) ammonites from Awaji Island, Southwest Japan. Bulletin of the Osaka Museum of Natural History 39: 1–18.

Nanko, S. 1996. Fossils of Awaji Island. Awajisima Museum, Sumoto City. 80pp **

Nishida, M., and H. Nishida. 1995. Pinoid woods with resin canals from the Upper Cretaceous of Hokkaido and Saghalien. Journal of Plant Research 108: 161–170.

Nishida, M., H. Nishida and R. Sugiyama. 1993. Studies on the petrified plants from the Cretaceous of northern Japan and Saghalien XIV. Coniferous woods from the Upper Cretaceous of Taneichi, Iwate Prefecture. Science report of the Research Institute of Evolutionary Biology 7: 69–86.

Nishida, M., H. Nishida, A. Yoshida and K. Kaiho. 1995. *Piceoxylon pseudoscleromedullosum* sp. nov. from the Upper Maastrichtian of Hokkaido. Science report of the Research Institute of Evolutionary Biology 8: 11–18.

Noda, A., and S. Toshimitsu. 2009. Backward stacking of submarine channel-fan successions controlled by strike-slip faulting: The Izumi Group (Cretaceous), southwest Japan. Lithosphere 1 (1): 41–59.

Noshiro, S., and T. Fujii. 1994. Fusiform parenchyma cells in the young wood of Pinaceae, and their distinction from marginal parenchyma. IAWA Journal 15: 399–406.

Philippe, M., and M. Bamford. 2008. A key to morphogenera used for Mesozoic conifer like woods. Review of Palaeobotany and Palynology 148: 184–207.

Philippe, M., and D. J. Cantrill. 2007. Nomenclatural types and taxonomy of Gothan's Arctic fossil conifer wood. Taxon 56: 551–566.

Ryberg, P. E., G. W. Rothwell, R. A. Stockey, J. Hilton, G. Mapes and J. B. Riding. 2012. Reconsidering relationships among stem and crown group Pinaceae: oldest record of the genus Pinus from the Early Cretaceous of Yorkshire, United Kingdom. International Journal of Plant Sciences 173 (8): 917–932.

Saegusa, H., and Furutani, H. 2004. A cervical vertebra of azhdarchid pterosaur from the Seidan Formation, Izumi Group. Abstract of Papers presented at the 111 Annual Meeting of the Geological Society of Japan: 252.**

Sasai, H. 1936. Izumi Sandstone Group in the Awaji Island. Journal of the Geological Society of Japan 43 (515): 590–602.**

Shimakura, M. 1937. Studies on fossil woods from Japan and adjacent lands, II. The Cretaceous woods from Japan, Saghalien, and Manchoukuo. Science Reports of Tohoku Imperial University Series 2 (Geology) 19: 1–73.

Sudo, S. 1955. Wood anatomical studies on the genus *Picea*. Bulletin of the Tokyo University Forests 49: 179–204.

Sze, H. C. 1951. Petrified Woods from Northern Manchuria, Science Record 4 (4): 443–457.*****

Tanaka, J. 1989, Sedimentary facies of the Cretaceous Izumi turbidite system, southwest Japan—An example of turbidite sedimentation in an elongated strike-slip tectonic basin. Journal of the Geological Society of Japan 95 (2): 119–128.

Tanimoto, M. 2005. Mosasaur remains from the Upper Cretaceous Izumi Group of southwest Japan. Netherlands Journal of Geosciences-Geologie en Mijnbouw 84–3: 373–378.

Yamazaki, T. 1987. Radiolarian assemblage of the Izumi Group in Shikoku and western Awaji Island, Southwest Japan. Journal of Geological Society of Japan 93 (6): 403–417.*

Zheng, S.-L., Y. Li, W. Zhang, N. Li, Y.-D. Wang, X.-J. Yang, T. Yi, J. Yang and X.-P. Fu. 2008. Fossil woods of China. China Forestry Publishing House, Beijing. 356 pp.

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| * | ：in Japanese with English abstract |
| ** | ：in Japanese |
| *** | ：in German |
| **** | ：in Flemish |
| ***** | ：in Chinese with English summary |

＜ 地名・地層名 ＞

| | |
|---|---|
| Anaga Formation | 阿那賀層 |
| Awaji Island | 淡路島 |
| Yezo Group | 蝦夷層群 |
| Fukura | 福良 |
| Izumi Group | 和泉層群 |
| Kita-ama Formation | 北阿万層 |
| Kuji Group | 久慈層群 |
| Minamiawaji City | 南あわじ市 |
| Nada Formation | 灘層 |
| Nadachino | 灘地野 |
| Seidan Formation | 西淡層 |
| Shimonada Formation | 下灘層 |
| Sen-nan Group | 泉南層群 |
| Sumoto | 洲本 |