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BRACHYPHYLLUM OBESUM, NEWLY DISCOVERED THERMOPHILIC CONIFER BRANCH FROM THE LOWER CRETACEOUS KITADANI FORMATION OF THE TETORI GROUP, CENTRAL JAPAN

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ABSTRACT

A compressed coniferous leafy branch was collected from the Lower Cretaceous Kitadani Formation, the uppermost unit of the Tetori Group in the Takinami River area, Fukui Prefecture, Central Japan. The specimen has been identified as *Brachyphyllum obesum*, which was initially described from the Early Cretaceous (late Aptian to early Albian) of Portugal. This species was first to the temperate Tetori Flora, but has been reported from the Late Jurassic to the Early Cretaceous of China and the Early Cretaceous of England, North America, and southern Primorye in Russia. These localities are attributed to the Euro-Sinian floristic region, which was proposed as one of the four divisions of the paleophytogeographic region during late Mesozoic, representing the subtropical climate zone in the Northern Hemisphere. Occurrence of this species supports the opinion that a floristic change in the upper part of the Tetori Group may represent warming and possibly drying climate in late Early Cretaceous.

Key words: *Brachyphyllum obesum*, Kitadani Formation, Tetori Group, Early Cretaceous

矢部　淳・久保田克博（2004）福井県勝山市の下部白亜系北谷層から新たに発見された好熱性針葉樹枝条 *Brachyphyllum obesum*．福井県立恐竜博物館紀要３：23–29．

福井県勝山市に分布する手取層群最上部の下部白亜系北谷層から，圧縮された針葉樹枝条化石を発見した．本標本は，ポルトガルの下部白亜系から最初に報告された *Brachyphyllum obesum* と同定された．本種はこれまでに中国の上部ジュラ―下部白亜系，イギリス，北米およびロシアの下部白亜系から報告されており，その産地はすべて，北半球の亜熱帯気候帯を代表するEuro-Sinian floristic regionに含まれる．本種は温帯的な気候を代表するとされる手取植物群からははじめての産出となり，手取層群上部の植物相変化が，白亜紀前期におけるユーラシア東部地域の気候の温暖化および乾燥化を反映しているという考えを支持する．

INTRODUCTION

Two phytogeographic provinces have been recognized in the late Mesozoic strata of Japanese Islands (Kimura, 1961, 1980) : the Inner Zone and the Outer Zone paleophytogeographic provinces. Kimura (1987) subsequently recognized the ecotone in the former province where elements of both the phytogeographic provinces co-occurred. Therefore, he proposed three phytogeographic provinces and named the floras within them as the Tetori-type, Ryoseki-type, and Mixed-type floras. On the basis of the floristic compositions and the morphological features of fossil plants, it is suggested that the Tetori-type flora represents a temperate and moderately humid climatic condition, whereas the Ryoseki-type represents a tropical or a subtropical condition with a long arid season (e.g. Ohana and Kimura, 1995).

The Middle Jurassic to Early Cretaceous Tetori Group, which is a reference stratum of the temperate “Tetori-type flora”, yields abundant fossil plants at various stratigraphic levels. Recently,

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Yabe et al. (2003) reported the occurrence of some thermophilic plants, such as *Cyathocaulis naktongensis*, *Nilssonia* sp. cf. *N. schaumburgensis*, and *Brachyphyllum* sp., all of which are typical to the Ryoseki-type flora, from the upper part of the Tetori Group, and pointed out that the floras of the upper part of the Tetori Group should be assigned to the "Mixed-type". Further, they recognized the warmer and dryer trends on the basis of the change in floristic composition, physiognomy as well as the presence of thermophilic plants. Although some difficulties of regional correlation prevail, this trend is, as Yabe et al. (2003) stated, also observed in Early Cretaceous floras of Southwest Japan, Korea, China, and Siberia. Plant fossil assemblages of the Tetori Group, referred to as the Tetori Flora, have a potential for precise dating and regional stratigraphic correlations, because they are intercalated with well-dated marine deposits containing index fossils in their lower part (Fujita, 2003). Non-marine mollusks, mainly from the upper part of the Tetori Group, are also important for a regional correlation between Japan and China (e.g. Komatsu et al., 2003). Thus, research on Early Cretaceous flora of the Tetori Group can contribute to the discussion on the change of climatic conditions in the Eurasian continent.

In this paper, we describe a coniferous leafy branch with helically disposed leaves, identified as *Brachyphyllum* sp. by Yabe et al. (2003), which was treated as one of the indices of climatic changes within the Tetori Flora. This is the first report on *Brachyphyllum obesum* from Japan. Paleoclimatic implications of this species have been briefly presented.

GEOLOGIC SETTING

The specimen discussed in this paper was collected from the Kitadani Formation, the uppermost unit of the Tetori Group, distributed in the Takinami River area in Central Japan (Yabe et al., 2003; Fig. 1). The Tetori Group has been divided into three subgroups in an ascending order namely, Kuzuryu, Itoshiro, and Akaiwa (Maeda, 1961b; Kusuhashi et al., 2002; Fujita, 2003), and only the Akaiwa Subgroup is exposed in this area (Maeda, 1958, 1961a). The Akaiwa Subgroup in the Takinami River area is subdivided into the Akaiwa Formation and the overlying Kitadani Formation. The Akaiwa Formation is mainly composed of alternating beds of mudstone and fine to medium sandstone in its lower part and coarse sandstone that sometimes contains pebbles and cobbles of orthoquartzite in the upper part. This formation yields a few fossils, except in its lowest part from where we collected *Myrene* sp. cf. *M. tetoriensis, Myrene* ? sp. and Gastropoda gen. et sp. indet. (Kubota, 2002MS). The Kitadani Formation consists of alternating beds of sandstone and mudstone and contains abundant freshwater molluscs, terrestrial vertebrates, and plants (e.g. Tamura, 1990; Azuma, 2003; Yabe et al., 2003). Plant fossil assemblage of the Kitadani Formation of the Takinami River area is characterized by ferns (*Onychiopsis elongata* and *Gleichenites nipponensis*), cones and

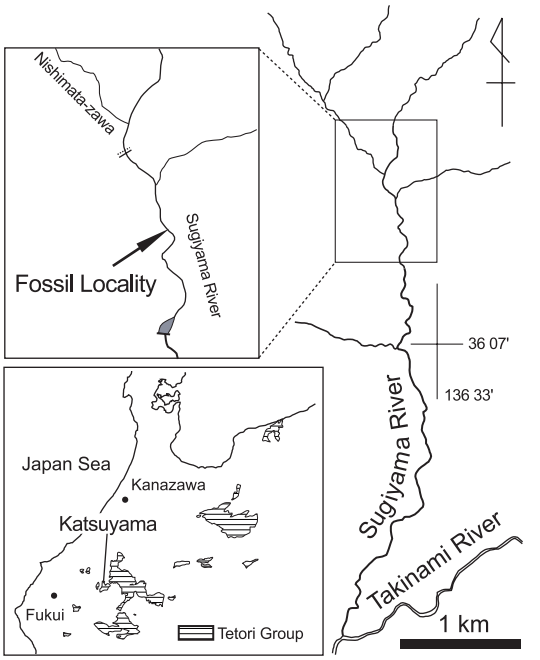

FIGURE 1. Map of the Takinami River area, showing the locality of fossil.

shoots of cycadales and conifers (Yabe et al., 2003). According to Isaji (1993), molluscan fossil of the Kitadani Formation consists of *Nippononaia ryosekiana, Plicatounio* (s.s.) *kobayashii, Pseudohyria matsumotoi, Nagdongia soni, Nippononaia* aff. *tetoriensis, Trigonioides* (*Wakinoa*) *tetoriensis,* and *Viviparus* sp. This assemblage was compared to the Sebayashi-type non-marine bivalve fauna (Kozai et al., 2002), and its age was assigned to late Barremian (Kozai and Ishida, 2003).

The specimen of *Brachyphyllum obesum* was collected from the outcrop at the middle reaches of the Sugiyama River, a tributary of the Takinami River (Fig.1). The outcrop is characterized by alternating beds of fine sandstone and black-colored mudstone of the Kitadani Formation. The specimen was collected as a fragment of a compressed leafy branch from the mudstone, where it was associated with fragments of ferns and conifer branches.

A few objections can be raised against the stratigraphic correlation of Maeda (1958, 1961a) (e.g. Matsukawa et al., 2003). On the basis of the brackish-water bivalves found in the lower part of the Akaiwa Formation (Tsukano, 1969) as well as the depositional cycles, Matsukawa et al. (2003) correlated the Akaiwa Formation of the Takinami River area to the Otaniyama Formation of the Itoshiro Subgroup in the Shiramine (= Tedori River) and Shokawa (= Makito) areas, which represent the proximal part of the basin. The lower and the upper part of the Kitadani Formation were correlated to the Okurodani Formation of the Itoshiro Subgroup and the Amagodani Formation of the Akaiwa Subgroup, respectively. However, *Myrene* spp. was

found in several stratigraphic units, such as Okurodani Formation (Matsukawa and Nakada, 1999; Matsukawa et al., 1999) and Amagodani Formation (Matsukawa et al., 1999). Therefore, one cannot readily conclude on its level. Further, the depositional cycle observed in the "Akaiwa" and the "Kitadani" Formation is also comparable to that of the Akaiwa Subgroup in the Shokawa area (e.g. Matsukawa et al., 1999). Taking into account the occurrence of pebbles and cobbles of orthoquartzite in the upper part of the Akaiwa Formation, it appears reasonable to follow Maeda's concept.

SYSTEMATIC PALEONTOLOGY

Coniferae incertae sedis

Genus *BRACHYPHYLLUM* Brongniart, 1828 emend. Harris, 1979

Type species.— *Brachyphyllum mamillare* Brongniart ex Lindley et Hatton, 1835

Remarks.— We followed Harris (1979) and used *Brachyphyllum* as a generalized morphogenus (Greuter et al., 2000) for conifer foliage with short, broadly attached leaves.

Brachyphyllum obesum Heer, 1881
(Fig. 2 A-D)

Brachyphyllum obesum Heer, 1881, p. 20, pl. XVII, figs. 1—4 (not seen, after Seward, 1895, p. 218; Seward, 1919, fig. 757). Saporta, 1894, p. 112, pl. XXI, figs. 1—7; pl. XXII, fig. 9a (non pl. XXVII, figs. 7, 8). Seward, 1895, p. 218, pl. XVII, fig. 9; pl. XX, figs. 1, 2, 4. Sze et al., 1963, p. 305, pl. 93, figs. 1—3. Cao, 1999, p. 95, pl. 27, figs. 1—8.

Brachyphyllum obesiforme Saporta, 1894, p. 176, pl. XXXI, figs. 12, 13; pl. XXXIII, fig. 4b; pl. XXXIV, fig. 8.

Brachyphyllum crassicaule Fontaine, 1889, p. 221, pl. C, fig. 4; pl. CIX, figs. 1—7; pl. CX, figs. 1—3; pl. CXI, figs. 6, 7; pl. CXII, figs. 6—8; pl. CLXVIII, fig. 9. Berry, 1911, p. 393, pl. LXIV, figs. 1—6.

Brachyphyllum ex gr. *obesum* Heer, Krassilov, 1967, p. 247, pl. LXIII, figs. 9, 10.

Brachyphyllum elegans Cao, 1989, p. 443, pl. II, figs. 8—11; pl. III, figs. 1—3.

Brachyphyllum sp., Yabe et al., 2003, p. 29, fig. 3.

Material.— One leafy branch was collected from the Kitadani Formation at the middle reaches of the Sugiyama River, Katsuyama City, Fukui Prefecture, Central Japan (Fig. 1). It has been preserved as a compression. However, the lower half was destroyed during collection. Therefore, only the impression can be recognized. This specimen is the one reported by Yabe et al. (2003, Fig. 3) as *Brachyphyllum* sp.

Repository.— Fukui Prefectural Dinosaur Museum (FPDM-P 30).

Description.— It is a leafy branch showing pinnate branching, probably in one plane (Figs. 2-A, B). The penultimate branch gives the ultimate branches at a 60—70 degrees angle, curved upwards. The ultimate branches, though some have not been preserved, are arranged in a sub-alternate to opposite position. The penultimate branch is 5 mm wide, with almost the same width till the apex. The ultimate branches are approximately 3—4 mm in width and 12—14 mm in length. The leaves appear to be arranged in 2 + 3 helical phyllotaxis at the upper part. They appear to be rhomboidal with an obtuse apex, strongly appressed to the stem, and are at least 3.6 mm long and 3.4 mm wide (Fig. 2-C). The leaf arrangement at the lower part appears variable, probably due to compression. The leaf cushions are not observable. The free part of the leaf is probably extended from the apex to the lateral edges, slightly overlapping the basal part of the leaf above (Fig. 2-D). The two lateral edges of the leaf form a wide angle of approximately 80—110 degrees. The surface of the leaf is ornamented by longitudinal striations, up to nine in number per millimeter, converging at the apex. The leaf margins are entire. The cuticle has not been preserved.

Comparison and discussion.— The present specimen is identical to *Brachyphyllum obesum*, which was originally described from "Couches d'Almargem" (late Aptian to early Albian) in Portugal (Heer, 1881: after Seward, 1895 and 1919; stratigraphy is after Choffat, 1894), in helically arranged appressed leaves with an obtuse apex and longitudinal striations on the surface. Saporta (1894) described this species from several different localities in Portugal. The specimens from Caixaria (pl. XXI, figs. 1—7; pl. XXII, fig. 9a), which are contemporaneous to Heer's locality, are safely identical to this species. On the other hand, those from Cercal (pl. XXVII, figs. 7, 8), differ in their thickened leaves. *B. obesiforme* described from Buarcos (lower "Bellasien": Albian) in Portugal (Saporta, 1894) cannot be distinguished from this species.

Some coniferous twigs reported from the English Wealden (Seward, 1895) and the Upper Jurassic to the Lower Cretaceous of China (Sze et al., 1963: Shandong and Fujian provinces; Cao, 1999: Zhejiang Province), which were assigned to *Brachyphyllum obesum*, are also comparable to this species. Some American specimens described as *B. crassicaule* Fontaine from the Patuxent and the Patapsco Formation of the Potomac Group (Aptian—Albian: e.g. Doyle, 1992) (Fontaine, 1889; Berry, 1911); are hardly distinguishable from this species. This was also suggested by Berry (1911); however, he tentatively separated them from the geographical viewpoint. His treatment is not acceptable because the basins of western Europe and northeast America were located much closer than today during the Early Cretaceous (e.g. Hay et al., 1999). Krassilov (1967) noted the occurrence of this species in Lipovetsky (Aptian) and Frentsevsky (Albian) Formation of Suifun (Razdolnaya) and Suchan (Partizansk) basins, southern Primorye in Russia. He described and identified two leafy branches as *B.* ex gr. *obesum*. Although the illustrations are not sufficient for observing the leaf surface in detail, we provisionally included them in the

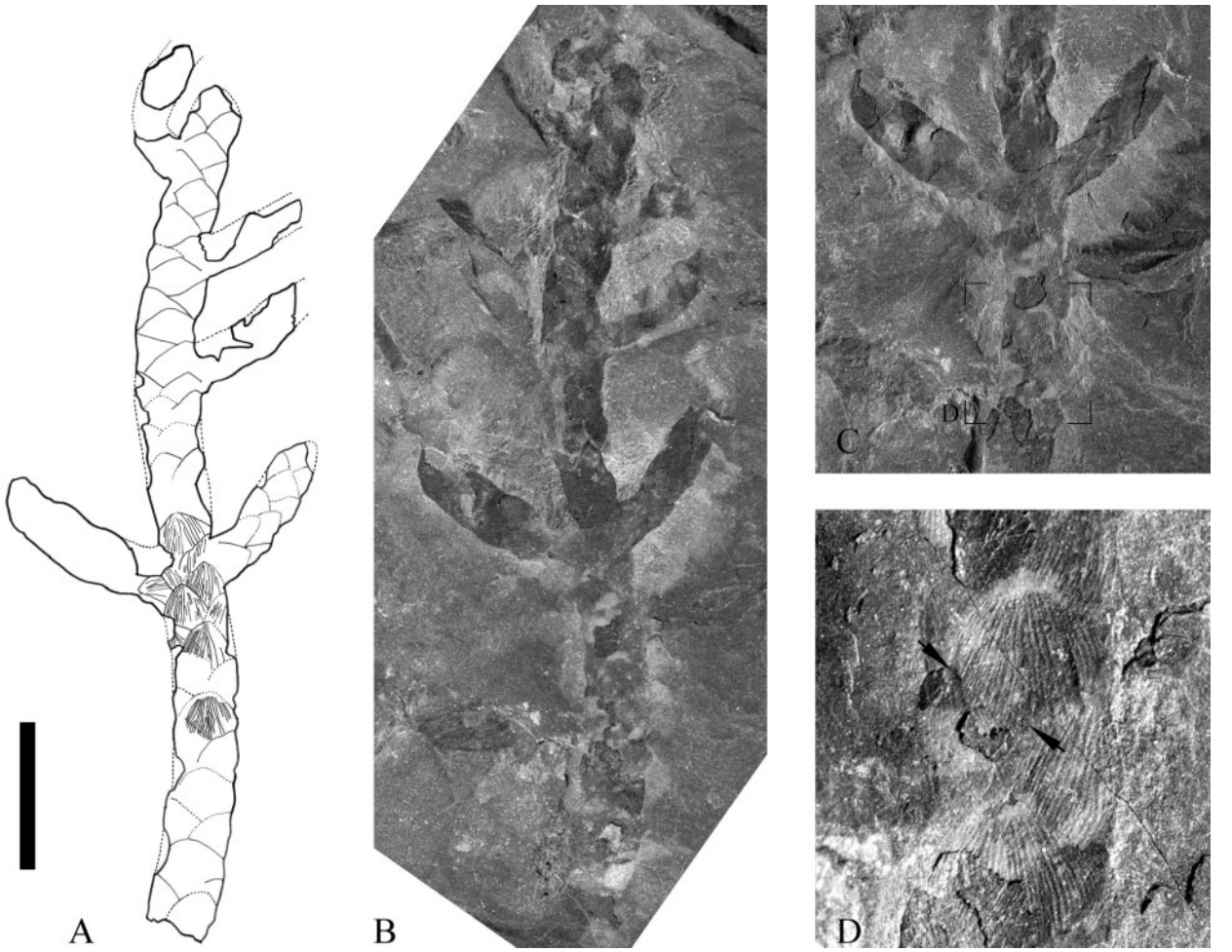

FIGURE 2. *Brachyphyllum obesum* (FPDM-P30) from the Lower Cretaceous Kitadani Formation in the Takinami River area, Katsuyama City, Fukui Prefecture (Fig.1). **A, B**: Leafy shoot, x2.0. Scale bar equals 1 cm. **C**: Lower half of the specimen, showing helically arranged, appressed leaves. **D**: Close up of the lower part of C, showing striations on the leaves. Note that leaves are preserved as an impression. Arrow indicates trace of leaf margin covering the leaf above.

synonymy on the basis of his description. Cao (1989) described new *Brachyphyllum* species as *B. elegans* from the Lower Cretaceous strata of Zhejiang Province in China on the basis of one fragmental shoot yielding cuticle. Later, he (1999) reported *B. obesum* from the same locality as well as from different localities. Both the species are quite similar, but Cao (1989) separated them since the former species is slender and has relatively narrower and loosely disposed leaves. As observed in the present specimen and specimens listed in the synonymy, the size of the twig and the disposition of the leaves is variable. Therefore, we prefer to describe them as conspecific. Our opinion is supplemented by the evidence that the cuticular structure of *B. elegans* (Cao, 1989, pl. II, figs. 9—11, pl. III, figs. 1—3) is similar to that of the *Brachyphyllum* species reported by Oldham (1976, pl. 77, figs. 1—7), which Oldham compared to *B. obesum* described by Seward (1895) from English Wealden.

Among the *Brachyphyllum* species described, *B. rhombicum* (Wu, 1999) and *B. longispicum* (Sun et al., 2001), from the lower part of the Yixian Formation (Late Jurassic or Early Cretaceous) in Liaoning Province, North China and *B. vulgare* (Stopes et Fujii) Jeffrey from the Upper Yezo Group (Coniacian—Santonian), Japan (Ohana and Kimura, 1993), are also similar to the present species. However, *B. rhombicum* and *B. vulgare* differ in their acuminate-pointed leaves, and *B. longispicum* differs in its branching pattern, where the penultimate branch goes zigzagged and narrower ultimate branch departs alternately.

Two ill-preserved leafy branches described as *Brachyphyllum expansum* from the late Jurassic "Kiyosue Group" (Oishi, 1940) are also similar to *B. obesum*. Oishi (1940) mentioned that no surface markings were recognized in his specimens. However, it was proved from the observation of the figured specimens stored in the Hokkaido University Museum that longitudinal striations are present and are similar to that of *B. obesum* from the Kitadani Formation. The leaf margins of "*B. expansum*" are

straight or gently curved inward and do not change their course to the apex, where they are attached to the other side at a wide angle of approximately 100 degrees. These are the different characters from those of the type specimen of *B. expansum* (Kendall, 1949). Oishi's specimens are quite similar to those of *B. obesum* with regard to leaf shape and arrangement; however they differ in their thick texture and long, closely spaced ultimate branches. Taxonomic status of "*B. expansum*" from the Utano Formation is yet to be proved until well-preserved specimens are collected. Kimura and Kansha (1978a, b) reported *B.* ex gr. *expansum* from the Hauterivian Yuasa Formation. However, their specimen is too ill-preserved to be identified as *B. expansum* or any other species.

PALEOPHYTOGEOGRAPHY AND PALEOCLIMATIC IMPLICATIONS

Brachyphyllum is the morphogenus for Mesozoic conifer foliage with short and helically disposed leaves (e.g. Harris, 1979). Its affinity is still controversial; however, paleobotanists advocate it as a thermophilic and xeromorphic plant, based on the anatomical features represented by several species (e.g. Watson and Alvin, 1996) as well as the geographic distribution (e.g. Spicer et al., 1993). As for the Mesozoic flora of Japan, this genus has been reported only from the Outer Zone paleophytogeographic province, which represents tropical to subtropical climatic conditions with a continuous dry season (e.g. Ohana and Kimura, 1995).

As mentioned in the preceding chapter, *Brachyphyllum obesum*, newly described from the Inner Zone paleophytogeographic province was first reported in Japan. However, it has been reported from the Early Cretaceous of Portugal, England, North America, southern Primorye, and the Late Jurassic to Early Cretaceous of China. Phytogeographically these localities are attributed to the Euro-Sinian floristic region in Vakhrameev (1991), which was proposed as one of four divisions of the paleophytogeographic region during late Mesozoic, representing a subtropical climatic zone in the Northern Hemisphere. Therefore, we may say that *B. obesum* adapted to subtropical climatic conditions. Yabe et al. (2003) reported brachyphyllous conifer with *Cyathocaulis naktongensis* and *Nilssonia* sp. cf. *N. schaumburgensis* from the upper part of the Tetori Group as one of the indices of climate change. The results of this paper will provide a supporting evidence of the suggestion that floristic changes in the upper part of the Tetori Group may represent warming and a possibly drying climate that occurred in the late Early Cretaceous (Yabe et al., 2003).

Recently, Saiki and Wang (2003) reviewed the distribution area of climate indicator plants found in China to locate the phytogeographic province boundaries. A detailed study of species distribution of "climate indicator plants" in time and space should be, as Spicer et al. (1993, 1996) have already noted, necessary to illustrate the climatic changes more precisely. It may be worth pointing out, in passing, that *Brachyphyllum obesum* has not been reported from the Outer Zone Paleophytogeographic Province. It is necessary to first examine the specimens described as *B.* ex gr. *expansum* from the Yuasa Formation. We should also consider whether absence of this species in the Outer zone of Japan has other climatic implications.

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