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Cupressinocladus obatae, sp. nov., from the Lower Cretaceous Choshi Group, in the Outer Zone of Japan

By

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Abstract A new species, *Cupressinocladus obatae* is proposed for the pinnately branched coniferous shoots with decussate opposite scale-leaves, collected from the Lower Cretaceous Choshi Group of marine origin, in the Outer Zone of Japan. The cuticular structure of the leaves is unlike cupressaceous. It is cheirolepidiaceous. Difference of cuticular features between Cheirolepidiaceae and Cupressaceae is also discussed.

Key words: *Cupressinocladus*, Cheirolepidiaceae, Lower Cretaceous, Choshi Group.

Introduction

Many leafy-shoots assignable to the coniferous form-genus *Cupressinocladus* have been known from the Jurassic and Lower Cretaceous plant-sites in the Outer Zone of Japan. They resemble in external appearance those of extant Cupressaceae (Figs. 2A-B). The present leafy-shoots were collected by Dr. OBATA and others in the calcareous nodules ('ammonite nodules') in the Lower Cretaceous Choshi Group, in the Outer Zone of Japan. They resemble in external appearance those of extant Cupressaceae, but so far as their leaf-cuticle is concerned, they do not belong to Cupressaceae but to the extinct family Cheirolepidiaceae. This paper deals with the description of the leafy-shoots and leaf-cuticle. This is the first description of a leaf-cuticle of the Japanese *Cupressinocladus* leafy-shoots.

Mesozoic fossil plants are varied and abundant in the Japanese Islands, but most of them are preserved only by impressions. Fortunately the Lower Cretaceous Choshi Group yields fossil plants with cuticles preserved. Following taxa are already known:

Sagenopteris inequilateralis OISHI (KIM and KIMURA, 1987)
Ptilophyllum elongatum KIMURA et OHANA, 1984 (non DOUGLAS)
P. spp. (5 forms) (KIMURA, OKUBO and MIYAHASHI, 1991 MS)
Zamites choshiensis KIMURA et OHANA, 1985
Nilssonia dictyophylla KIMURA et OKUBO, 1985

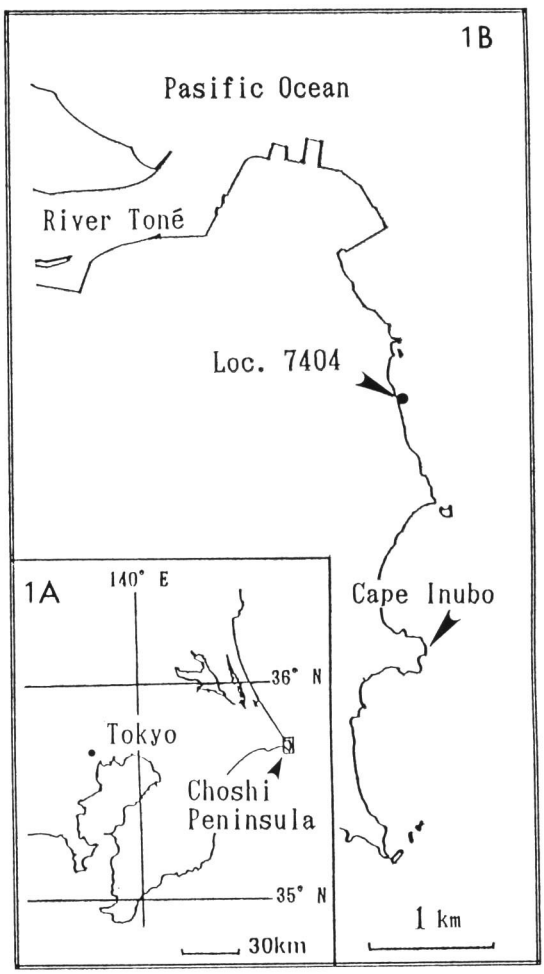

Fig. 1. Studied area (Fig. 1A) and detailed fossil locality (no. 7404 of OBATA *et al.*, 1975; indicated by an arrow).

Frenelopsis choshiensis KIMURA, SAIKI et ARAI, 1985

Although fossil plants derived from the Choshi Group have cuticles preserved in general, unfortunately they are mostly of tiny fragments. Hence it is advisable to make further collections.

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University and Mr. Ichiyoshi FUKUMOTO of the Kobe Municipal Arboretum for their help in collecting the extant cupressaceous conifer specimens. We are indebted to Dr. Shya CHITALEY of the Cleveland Museum of Natural History, Ohio for her linguistic check on the present manuscript. We are also indebted to Prof. Masumi OSAWA, Assoc. Prof. Megumi OKAZAKI and Dr. Shigeki MAYAMA of the Tohyo Gakugei University for giving us the facilities for SEM observation of our specimens. We are also grateful to Mrs. Akemi OKUBO for her unpublished information. This study was supported in part by Sasakawa Scientific Research Grant (no. 034, given to OKUBO) and the Grant-in-Aids for Scientific research from the Ministry of Education, Science and Culture of Japan (no. 02640615, given to KIMURA).

Description

The specimens are six fragments of leafy-shoots.

External morphology of the leafy-shoots: Lateral branches are alternate, pinnately disposed and making 40–50 degrees angle to the shoot-axis. Leaves are scale-like, opposite decussate, appressed to the axis, decurrent at base and with pointed apex. Small leaf is 2 mm long and 1 mm wide and large one is up to 14 mm long and 4 mm wide.

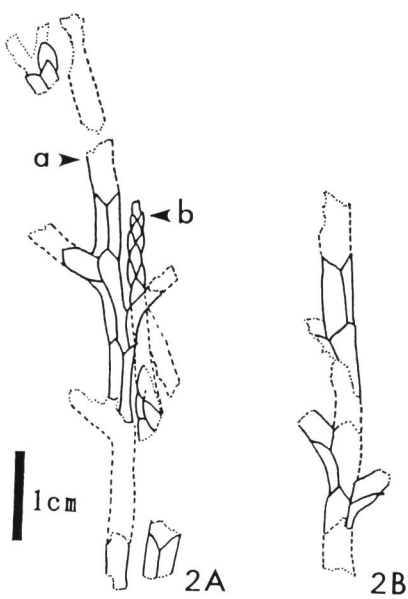


Fig. 2. *Cupressionocladus obatae* OKUBO et KIMURA, sp. nov.: Two-types of leafy-shoots. Both Fig. 2Aa (holotype; NSM PP-9010) and Fig. 2B (paratype; NSM PP-9012D) have normal-sized leaves, while Fig. 2Ab (paratype in association with the holotype) has small leaves.

Cuticle details: Cuticle is ca. 10 μm (8–11 μm) thick and hypostomatic. Stomata are 90–150 in number per square mm in density and arranged in rather indefinite stomatal rows. In a single stomatal row, there are 1–5 ordinary cells between adjacent stomata. Sometimes two stomata come in contact with each other, but they do not share their subsidiary cells (Figs. 11–12). Orientation of stomatal aperture is random. The stoma is of cyclocytic-type, 60–70 μm long and 50–60 μm wide. Guard cells are sunken, 40 μm long and 20 μm wide, and cuticular surface of their dorsal thickening is smooth. Subsidiary cells are 4–7 in number, 6 in general. They cover the stomatal aperture to form a stomatal pit. Near the border of the pit, thickened cuticle forms an elliptical rim, 30–35 μm and 20–25 μm in diameters. On the rim, papillae originated from subsidiary cells are present. They cover the pit-border almost entirely (Fig. 20). Ordinary cells are distributed on both ventral and dorsal surfaces of a leaf between the adjacent stomata and between the stomatal rows (0–7 cells wide) respectively. They are squarish, rectangular and polygonal. Their anticlinal walls are 4–8 μm thick, periclinal walls 2–3 μm thick (the total thickness of cuticle is 10 μm), and inner periclinal walls are smooth. Papillae and trichomes are present on the outer periclinal walls (Figs. 13, 15). Trichomes are present on the lateral leaf margins (Fig. 6, indicated by an arrow; Fig. 8), whereas scarious frill is present at the tip of the leaf, 20–30 μm wide (Fig. 5, indicated by an arrow; Fig. 9).

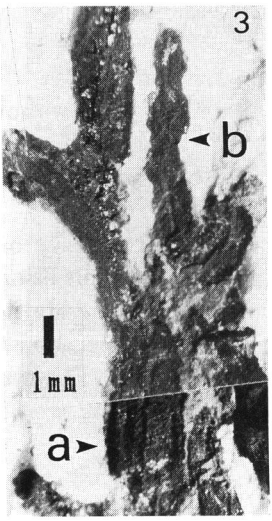
In our leaves, the ventral part is very narrow (Fig. 6; the dark zone indicated by the width of 'a'). The ventral cuticle is very thick and devoid of stomata. We could not separate the ventral cuticle from the dorsal one. The stomata are densely crowded (Fig. 6; Fig. 19A), but less crowded on the leaves at the distal part of the shoot (ca. 50 per square mm) (Figs. 5, 7). The cuticle of dorsal surface does not stand maceration (Fig. 11). Anticlinal walls of ordinary cells are thicker than those of subsidiary cells (Figs. 12, 16).

The papillae on the stomatal edge are also destroyed in maceration, and those originated from the subsidiary cells as shown in Fig. 14 (P3-P5) are lost in maceration. As seen under light-microscope, papillae do not exist inside the pit-chamber (Fig. 10).

Discussion and *comparison*: In external features of our leafy-shoots agree with those of *Cupressinocladus* SEWARD, 1919. Characteristic features of the leaf-cuticle of our leafy-shoots are as follows:

1) Hypostomatic.

Figs. 3–10. *Cupressinocladus obatae* OKUBO et KIMURA, sp. nov.: Fig. 3. Leafy-shoots; Fig. 3a (holotype) and Fig. 3b (one of the paratypes). Fig. 4. One of the paratypes (NSM PP-9012A). Figs. 5–10. Light micrographs. Scale-bars indicate 500 μm except for Figs. 8–10 where they are 10 μm. Fig. 5. Dorsal cuticle (slide no. 9012D-L1). Fig. 6. Dorsal and ventral cuticles (slide no. 9011A-L1). Ventral cuticle overlaps dorsal one each other at marginal dark zone (indicated by 'a'). Fig. 7. Dorsal and ventral cuticles (slide no. 9011B-L1). Ventral cuticle overlaps dorsal one each other at marginal dark zone (indicated by 'a'). Fig. 8. Trichomes enlarged from a part of Fig. 6 (indicated by an arrow). Fig. 9. Marginal scarious frill enlarged from a part of Fig. 5 (indicated by an arrow). Fig. 10. A stoma on the dorsal cuticle (slide no. 9012A-L1).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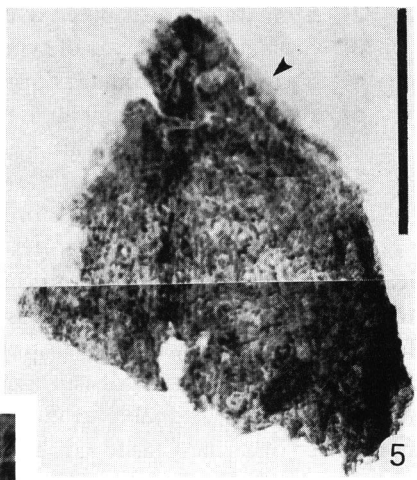
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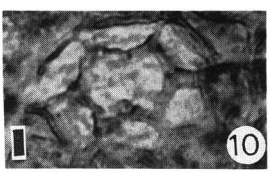
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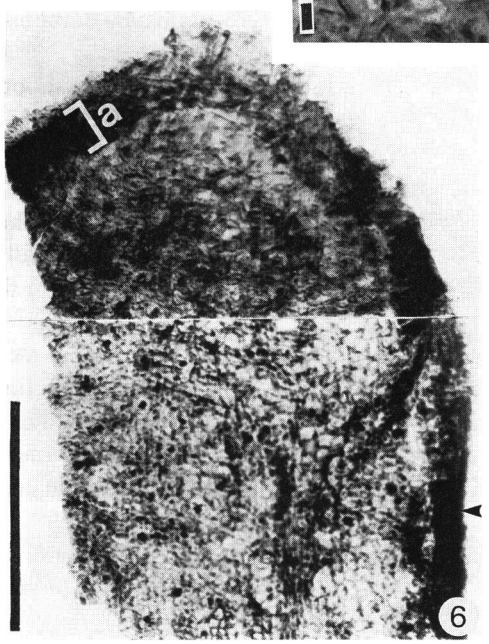
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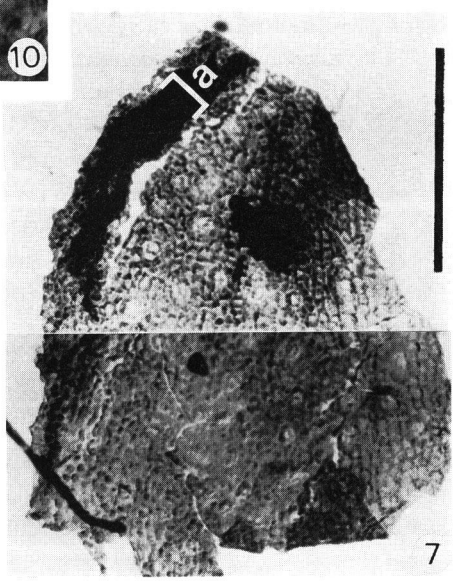
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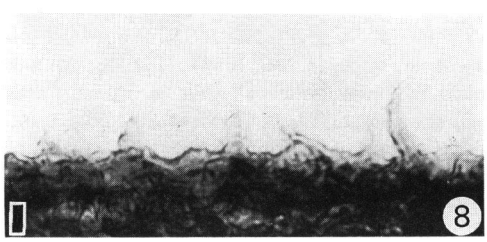
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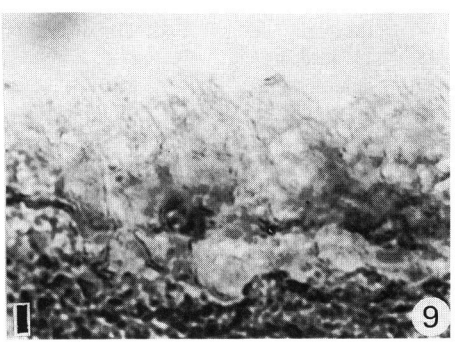
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2) Stomata are distributed over the dorsal surface of each leaf.
3) Stomatal complex is of typical cyclocytic-type.
4) Two adjacent stomata do not share a subsidiary cell in between.
5) Papillate edge originated from the subsidiary cells is present, but without papillae on the pit wall.
6) Papillae and trichomes are present on the periclinal walls of ordinary cells.
7) Inner periclinal walls of ordinary cells are smooth.

The above-mentioned features are common with those of cheirolepidiaceous leaves (Table 3). Accordingly, it is highly probable that the present leafy-shoots belong to some cheirolepidiaceous conifer, though reproductive organs of our plant are not found so far. Many *Classopollis* pollen grains were recognized by us (Fig. 22) and also by Akemi OKUBO (MS) in association with the present leafy-shoots. However, no pollen grains assignable to the Curessaceae with certainty has been recognized by us and her from the Choshi Group.

Among the *Cupressinocladus* species recorded so far, following taxa are said to belong to Cheirolepidiaceae (WATSON, 1989):

Cupressinocladus pseudoexpansum BARNARD et MILLER (1976, Bajocian-Bathonian of Iran, leafy-shoots and male cone)

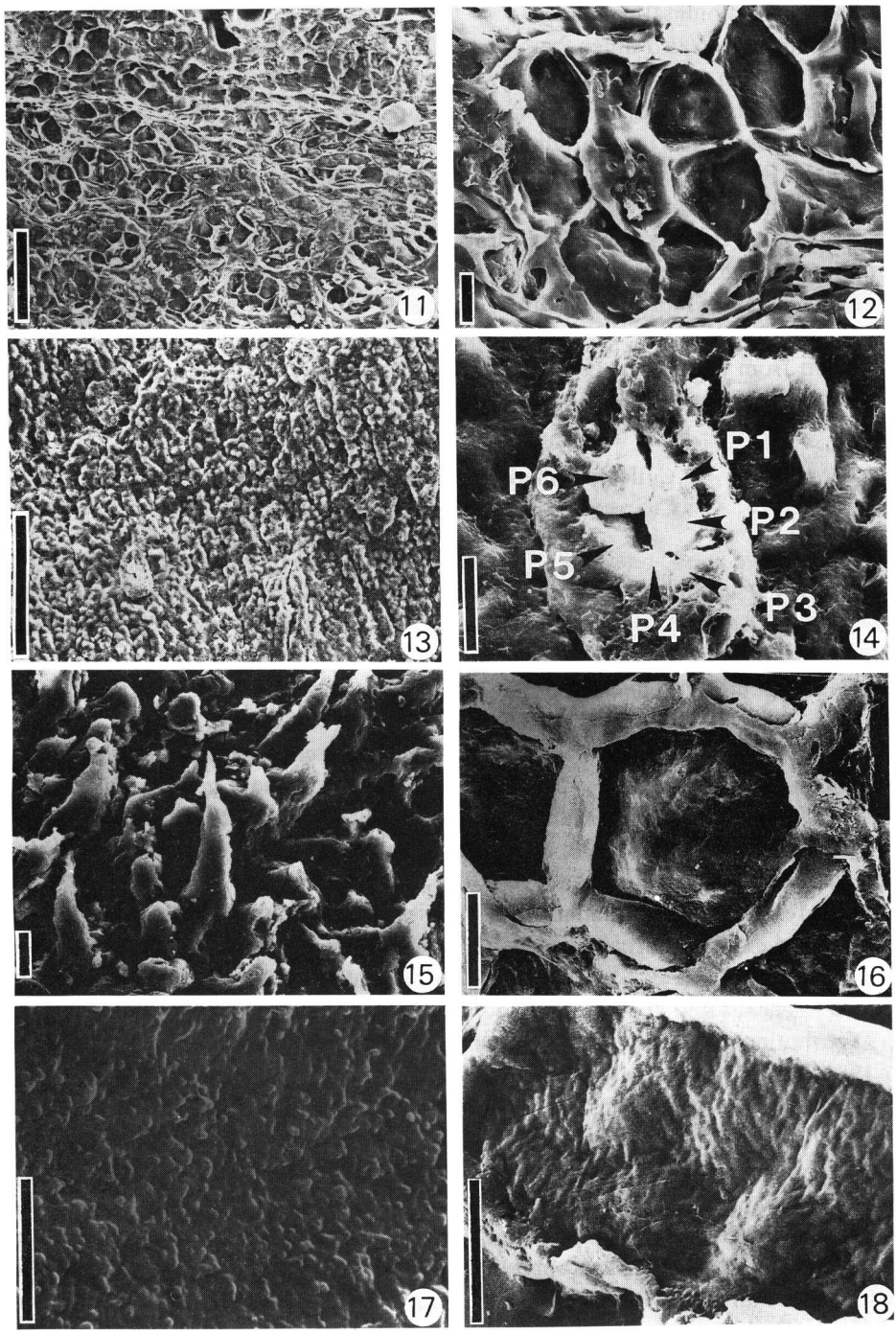
C. ramonensis CHALONER et LORCH (1960, Lower Jurassic of Israel, leafy-shoots; LORCH, 1968, male cones and pollen)

C. valdensis (SEWARD) SEWARD (WATSON, 1977, Purbeckian-Berriasian of England, leafy-shoot; FRANCIS, 1983, leafy-shoots, wood, male cones and pollen).

Of these, the leafy-shoots of *Cupressinocladus pseudoexpansum* are distinguished from the present leafy-shoots in having 1) both tricyclic and decussate leaves, and 2) having thin periclinal wall of ordinary cell (2–3 μm) and absence of trichomes on the periclinal walls of the ordinary cells.

The leafy-shoots of *Cupressinocladus ramonensis* are different from the present leafy-shoots, because they lack trichomes along the leaf margins and on the periclinal walls of ordinary cells and because they have broad papillae below the thickened edge of stoma (WATSON, 1989, her table 9–1). The leafy-shoots of *Cupressinocladus valdensis* are also different from the present ones in having thick cuticle (15–20 μm) and

Figs. 11–18. SEM-micrographs. Scale-bars indicate 10 μm except for Figs. 11 and 13 where they are 100 μm. Figs. 11–16. *Cupressinocladus obatae* OKUBO et KIMURA, sp. nov.: Fig. 11. Internal view of dorsal cuticle (stage no. 9012D-S1). Fig. 12. Internal view of a stoma enlarged from Fig. 11. Fig. 13. External view of dorsal cuticle (stage no. 9011B-S1). Fig. 14. External view of a stomatal aperture enlarged from Fig. 13. Six stomatal papillae originated from subsidiary cells are indicated by 'P1-P6' (stage no. 9011B-S2). Fig. 15. Trichomes on the external surface of dorsal cuticle (stage no. 9011B-S4). Fig. 16. Smooth inner periclinal surface of the dorsal cuticle and thick anticlinal walls of ordinary cells (stage no. 9011B-S1). Fig. 17. Extant *Thujopsis dolabrata* (LINNÉ fil.) SIEBOLD et ZUCCARINI. Sculptured inner periclinal surface of the dorsal cuticle of an ordinary cell. Fig. 18. Extant *Libocedrus formosana* FLORIN. Sculptured and nodulous periclinal surface of the dorsal cuticle of an ordinary cell.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papillae on the stomatal pit walls.

Our specimens also differ from those of *Cupressinocladus crassirameus* originally described by CAO (1989) from the Lower Cretaceous of Southeastern China, because they have papillae around the stomatal aperture.

Cupressionocladus itieri originally described by BARALE (1981) from the Upper Jurassic of France also is different from ours because of having papillae and trichomes on the periclinal walls of the ordinary cells.

Under the circumstances, we propose *Cupressionocladus obatae*, sp. nov. to accommodate the present leafy-shoots.

In the external morphology of the leafy-shoots, our specimens resemble *Curpressinocladus* sp. A (KIMURA *et al.*, 1986) and *C.* sp. C (KIMURA and OHANA, 1987). But we refrain from making precise comparison of the latter two with our new species, because the latter two do not show the cuticles preserved.

Cuticular differences in leaves of the extant Cupressaceae and extinct Cheirolepidiaceae

So far as we know, reference of the above-mentioned title was made by CHALONER and LORCH (1960) and ALVIN (1982). According to the former, stomata of *Cupressinocladus ramonensis* are distributed almost over the dorsal side of leaf, whereas in extant cupressaceous conifers, they are restricted to two marginal stomatal bands, and in the latter, papillae around the stomatal aperture are less developed than those of the former.

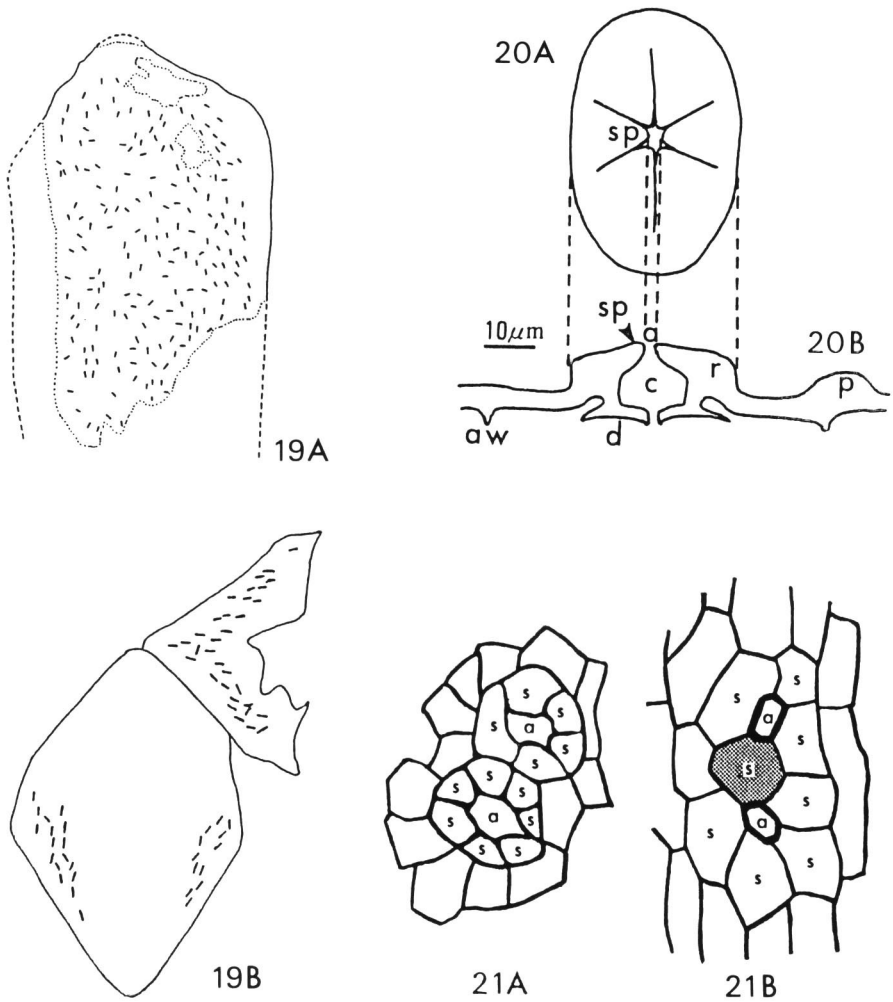
ALVIN (1982) noted very thick cuticles of such cheirolepidiaceous conifers as *Frenelopsis* and *Pseudofrenelopsis*. However, among some *Cupressinocladus* leafy-shoots hitherto described as belonging to Cheirolepidiaceae, thin cuticles were observed. In fact, periclinal walls of the ordinary cells of the present *Cupressinocladus obatae* are only 2–3 μm thick (total cuticular thickness 10 μm).

As a result of our examination of cuticles of the extant cupressaceous conifers (Table 1) and extinct cheirolepidiaceous conifers (Table 2), the difference seen between two is shown in Table 3. We feel that the distinguishing cuticular features between cheirolepidiaceous and cupressaceous conifers are:

1) Distribution of stomata (corresponding to the character no. 40 of ALVIN *et al.*, 1982).

In the present species *Cupressinocladus obatae*, stomata are distributed all over the dorsal surface of leaf, and they do not form stomatal bands. WATSON and FISHER (1984) described stomata grouped in the stomatal chambers in their cheirolepidiaceous genus *Glenrosa*.

In some cheirolepidiaceous conifers, stomata are arranged in stomatal rows, and not in stomatal bands. In the specimens of *Cupressionocladus obatae*, the stomatal rows are less marked and indefinite in general, whereas, in extant cupressaceous conifers stomatal bands are rather well developed as shown in Fig. 19B.



Figs. 19–21. Fig. 19. Distribution of stomata and orientation of stomatal apertures (dashed lines). Fig. 19A. *Cupressinocladus obatae* OKUBO et KIMURA, sp. nov. (slide no. 9011A-L1). Fig. 19B. *Fokienia hodginsii* (DUNN) HENRY et THOMAS (redrawn from FLORIN, 1931, Taf. 50–4). Fig. 20. Diagramatic reconstruction of a stoma of *Cupressinocladus obatae* OKUBO et KIMURA, sp. nov.: Fig. 20A. A stomatal aperture in external surface view. Fig. 20B. A vertical section of a stoma. Scale-bar indicates 10 μm, but the vertical scale is exaggerated [a; aperture, aw; anticlinal wall of subsidiary cell, c; stomatal pit chamber, d; dorsal thickening of guard cell, p; papilla, r; stomatal edge (rim), sp; stomatal papilla]. Fig. 21. Arrangement and form of subsidiary cells (a; aperture, s; subsidiary cell). Fig. 21A. *Cupressinocladus obatae* OKUBO et KIMURA, sp. nov. (stage no. 9012D-S1). Fig. 21B. *Thujopsis dolabrata* (LINNÉ fil.) SIEBOLD et ZUCCARINI. Sharing a subsidiary cell is shown (indicated by dark area).

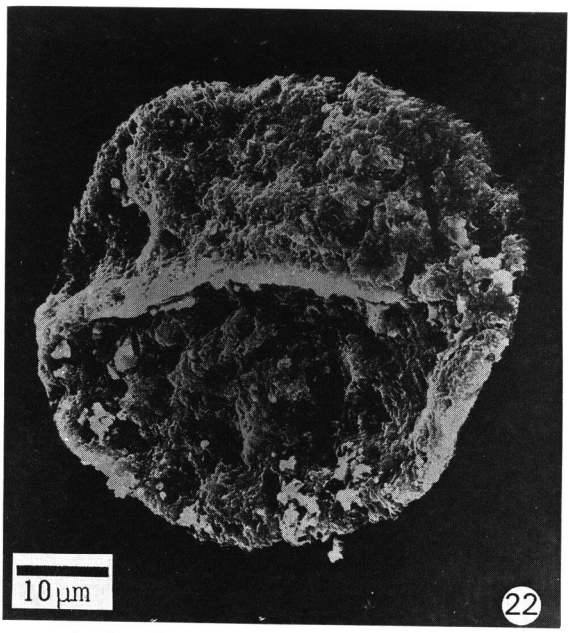


Fig. 22. SEM-micrograph of a *Classopollis* pollen grain in association with the present leafy-shoots.

2) Stomatal complex.

In *Cupressinocladus obatae*, subsidiary cells are distributed around the guard cells to form a ring-like structure as shown in Fig. 21A. Such a structure is observed in most of the cheirolepidiaceous conifers, whereas in most of the extant cupressaceous conifers, it is indistinct (corresponding to the character nos. 28–35 of ALVIN *et al.*, 1982). In these cupressaceous conifers, two adjacent stomata often share a single subsidiary cell as shown in Fig. 21B (indicated by dark area), whereas such a joint ownership has not been seen in the present leafy-shoots (Figs. 11–12; Fig. 21A) and other cheirolepidiaceous conifers except in *Pseudofrenelopsis parceramosa* (WATSON, 1977) and *Glenrosa pagiophylloides* and *G. texensis* (WATSON and FISHER, 1984) (corresponding to the character no. 36 of ALVIN *et al.*, 1982).

3) Papillate stomatal edge.

In cheirolepidiaceous conifers, papillae on the stomatal edge formed from the subsidiary cells cover the border of pit chamber (Fig. 14). They are sometimes developed also on the pit chamber walls. So far, according to our study, such a distinct development of papillae has not been observed in the extant cupressaceous conifers. In the present species, papillae on the pit chamber walls have not been observed under light microscopy.

4) Trichome.

Figs. 13 and 15 (SEM-micrographs) show the presence of papillae and trichomes on the ordinary cells of the leaves of the present leafy-shoots. Such-like trichomes

TABLE 1
Cuticular characters of Cupressaceae.
SNFG : Stomata forming groups(including stomatal zones), RSP: Rim of stomatal pit, PPIS: Papillae presenting inside stomatal pit, SCFCE: Subsidiary cells forming a circle or ellipse, SSC: Sharing of subsidiary cells, SPS: Sculptured of inner periclinal surface(normal cells), +: yes, −: no, ±: yes and/or no, /: unknown.

Species	References or sources	SNFG	RSP	PPIS	SCFCE	SSC	SPS
Actinostrobus pyramidalis Miquel	Florin,1931 Taf.43-2,4	+	/	−	−	+	/
Actinostrobus acuminatus Parlatore	Florin,1931 Taf.43-3	+	/	/	−	+	/
Austrocedrus chilensis (D.Don)Florin et Boutelje	Alvin et al., 1982 Fig.22	/	/	−	/	/	/
Callitris endlicheri (Parlatore)F.M.Bailey	Alvin et al., 1982 Fig.2	/	/	/	−	+	+
Callitris tasmanica Baker	Florin,1931 Taf.43-5	+	rounded: without papillae	/	±	+	/
Callitris sulcata (Parlatore)Schlechter	Florin,1931 Taf.43-6,7,8	+	−	−	−	+	/
Callitris propinqua Brown,R.	Florin,1931 Taf.43-9,10	+	rounded: without papillae	−	−	+	/
Callitris quadrivalvis Vent	Osaka City Univ.	+	rounded: without papillae	−	−	+	+
Chamaecyparis formosensis Matsumura	Kobe Municipal Arboretum	+	rounded: without papillae	−	−	+	/
Chamaecyparis lowsoniana (A.Murray)Parlatore	Kobe Municipal Arboretum	+	rounded: without papillae	−	−	+	/
Chamaecyparis nootkatensis (D.Don)Spach	Florin,1931 Taf.51-8,52-1 Alvin et al., 1982 Figs.6,7, 8,23	+	rounded: without papillae	−	−	+	+
Chamaecyparis obtusa (Siebold et Zuccarini) Endlicher	Tokyo Gakugei Univ.	+	rounded: without papillae	−	−	+	+
Chamaecyparis pisifera (Siebold et Zuccarini) Endlicher	Tokyo Gakugei Univ.	+	rounded: without papillae	−	−	+	/
×Cupressocyparis leylandii (Jackson et Dallimore) Dallimore	Alvin et al., 1982 Fig. 4	/	/	/	/	/	+
Cupressus arizonica Greene	Kobe Municipal Arboretum	+	rounded: without papillae	−	−	+	/
Cupressus sp.	Florin,1931 Taf.51-5,7	/	rounded: without papillae	−	−	/	/
Cupressus funebris Endlicher	Kobe Municipal Arboretum	+	rounded: without papillae	−	−	+	/
Cupressus macrocarpa Hartweg	Kobe Municipal Arboretum		rounded: without papillae	−	−	+	+
Cupressus sempervirens Linné	Kobe Municipal Arboretum	+	rounded: without papillae	−	−	+	+
Diselma archeri Hooker fil.	Florin,1931 Taf.45-5	+	rounded: without papillae	−	−	+	/

TABLE 1(continued)

Fitzroya cupressoides (Molina)Johnston	Florin,1931 Taf.45-6,7 Alvin et al., 1982 Fig.1	+	-	-	-	+	+
Fokienia hodginsii (Dunn) Henry et Thomas	Florin,1931 Taf.50-3,4,5	+	rounded: without papillae	-	-	+	/
Juniperus sp.	Florin,1931 Taf.52-8	+	rounded: without papillae	-	-	+	/
Juniperus barbadensis Linné	Florin,1931 Taf.53-4	+	rounded: without papillae	/	-	+	/
Juniperus brevifolia (Seubert)Antoine	Florin,1931 Taf.52-7	+	rounded: without papillae	/	-	+	/
Juniperus chinensis Linné	Tokyo Gakugei Univ.	+	rounded: without papillae	-	±	+	+
Juniperus communis Linné	Alvin et al., 1982 Fig.3,11	/	rounded: without papillae	-	-	+	+
Juniperus formosana Hayata	Florin,1931 Taf.52-5,6	+	rounded: without papillae	-	-	+	/
Juniperus lemeeana Léveillé et Blin	Florin,1931 Taf.53-7	/	rounded: without papillae	-	-	/	/
Juniperus lucayana Britton	Florin,1931 Taf.53-8	/	rounded: without papillae	-	±	+	/
Juniperus pinchotii Sudworth	Florin,1931 Taf.53-1,6	+	rounded: without papillae	-	±	+	/
Juniperus procumbens Siebold	Tokyo Gakugei Univ.	+	rounded: without papillae	-	-	+	+
Juniperus recurva Buchanan-Hamilton	Alvin et al., 1982 Fig.10	/	rounded: without papillae	-	/	/	/
Juniperus rigida Siebold et Zuccarini	Tokyo Gakugei Univ.	+	rounded: without papillae	-	-	+	+ (nodulus)
Juniperus saxicola Brittinger et Wils	Florin 1931 Taf.53-3	+	rounded: without papillae	/	-	+	/
Juniperus sabina Linné	Alvin et al., 1982 Fig. 20	/	-	/	/	/	/
Juniperus virginiana Linné	Kobe Municipal Arboretum	+	-	-	-	+	/
Libocedrus arfakensis Gibbs	Florin,1931 Taf.47-7	/	rounded: without papillae	-	-	+	/
Libocedrus bidwillii Hooker fil.	Florin,1931 Taf.47-5,50-2	+	rounded: without papillae	-	-	+	/
Libocedrus chilensis (D.Don)Endlicher	Florin,1931 Taf.47-6	/	-	-	-	+	/
Libocedrus decurrens Torray	Florin,1931 Taf.47-1,2	±	rounded: without papillae	-	-	+	/
Libocedrus formosana Florin	Osaka City Univ.	+	rounded: without papillae	-	-	+	+
Libocedrus macrolepis (Kurz)Bentham	Florin,1931 Taf.51-1	/	rounded: without papillae	-	-	+	/
Libocedrus torricellensis Schlechter	Florin,1931 Taf.48-1,47-8	±	rounded: without papillae	-	-	+	/

TABLE 1(continued)

Microbiota decussata Komarow	Florin, 1931 Taf. 51-2 54-1, 2, 3	+	rounded: without papillae	-	-	+	/
Neocallitropsis araucarioides (Compton) Florin	Alvin et al., 1982 Fig. 12	/	rounded: without papillae	-	/	/	/
Pilgerodendron uviferum (D. Don) Florin	Florin, 1931 Taf. 48-2~8 49-1~6 50-1 Alvin et al., 1982 Fig. 9	+	-	-	-	+	/
Tetraclinis articulata (Vahl) Masters	Florin, 1931 Taf. 44-8, 9 45-1, 2	+	rounded: without papillae	-	-	+	/
Thuja orientalis Linné	Kobe Municipal Arboretum	+	rounded: without papillae	-	-	+	+
Thuja plicata D. Don	Florin, 1931 Taf. 47-4	/	rounded: without papillae	-	-	+	/
Thuja standishii (Gordon) Carrière	Tokyo Gakugei Univ.	+	rounded: without papillae	-	-	+	+
Thujopsis dolabrata (Linné fil.) Siebold et Zuccarini	Tokyo Gakugei Univ.	+	rounded: without papillae	-	-	+	+
Widdringtonia juniperoides (Linnē) Endlicher	Florin, 1931 Taf. 44-6 45-8	+	-	-	-	+	/
Widdringtonia whytei Rendle	Florin, 1931 Taf. 44-7	+	/	/	-	+	/

are common in most cheirolepidiaceous conifers, whereas they have not been observed in extant cupressaceous conifers so far examined, except for thickening of periclinal walls and/or papillae of the ordinary cells.

5) Inner periclinal walls of the ordinary cells.

According to the SEM-micrographs, inner periclinal walls of the ordinary cells of the present species are smooth (Fig. 18) as well as those of other cheirolepidiaceous conifers examined by SEM (corresponding to the character nos. 6–9 of ALVIN *et al.*, 1982). Whereas, in extant cupressaceous conifers so far examined by us, their inner periclinal walls of the ordinary cells are sculptured (Fig. 17) or nodulous (Fig. 18). The same result was shown by ALVIN *et al.*, (1982, figs. 1–7).

Concluding remarks

So far as the cuticular features mentioned above are concerned, the present species does not belong to Cupressaceae but to Cheirolepidiaceae. The precise record of the cheirolepidiaceous conifer (*Frenelopsis choshiensis*) was first made by KIMURA *et al.* (1985) from the Lower Cretaceous Choshi Group. This paper is the second record of cheirolepidiaceous conifer from the same group in the Outer Zone of Japan.

In addition, many coniferous leafy-shoots without preserved cuticles considered to belong to the Cheirolepidiaceae have been described from the Jurassic-Cretaceous plant-sites in the Toyora District, Southwest Japan. Also are described from the Outer Zone of Japan, Southern Primorye, China (southeastern part of Northeast

TABLE 2
Cuticular characters of well-authenticated and doubtful members of Cheirolepidiaceae.
SNFG: Stomata forming groups(including stomatal zones), RSP: Rim of stomatal pit, PPIS: Papillae presenting inside stomatal pit, SCFCE: Subsidiary cells forming a circle or ellipse, SSC: Sharing of subsidiary cells, SPS: Sculptured of inner periclinal surface(normal cells), +: yes, -: no, ±: yes and/or no, /: unknown

Species	References or sources	SNFG	RSP	PPIS	SCFCE	SSC	SPS
Brachyphyllum ardenicum Harris	Harris,1979	-	+ (without papillae)	-	+	-	/
Brachyphyllum carpentieri Fisher et Watson	Fisher and Watson,1983	-?	+ (with papillae)	-	/	/	/
Brachyphyllum castatum Watson et al.	Watson et al., 1987	-	-	-	+	-	/
Brachyphyllum crucis Kendall	Kendall,1947 Harris,1979	-	+ (with low papillae)	-	+	-	/
Brachyphyllum desnoyersii (Brongniart)Saporta	Barale,1981	-	+ (without papillae)	-	+	/	/
Brachyphyllum elegans Cao	Cao,1989	-	- (without papillae)	-	+	-	- ?
Brachyphyllum hegewaldia Ash	Ash,1973	-	+ (with papillae)	-	+	-	-
Brachyphyllum ningshiaense Chow et Tsao	Chow and Tsao, 1977	-	+ (with low papillae)	-	+	-	/
Brachyphyllum pulcher Lorch	Lorch,1968 Watson,1989	-	+ (with papillae)	-	+	-	/
Brachyphyllum scottii Kendall	Kendall,1949	-	+ (without papillae)	-	+	-	/
Brachyphyllum speciosa (Pomel)Saporta	Barale,1981	-	+ (without papillae)	-	+	-	/
Brachyphyllum trautii Barale et Contini	Barale,1981	-	+ (without papillae)	-	+	-	/
Brachyphyllum sp. (35 CONiF BrB)	Oldham,1976	-	+ (with papillae)	-	+	-	/
Cupressinocladus crassirameus Cao	Cao,1989	-	-	-	+	-	-
Cupressinocladus pseudoexpansum Barnard et Miller	Barnard and Miller,1976	-	+ (with papillae)	-	+	-	-
Cupressinocladus itieri (Saporta)Barale	Barale,1981	-	+ (with papillae)	-	+	-	/
Cupressinocladus ramonensis Chaloner et Lorch	Chaloner and Lorch,1960 Watson,1989	-	+ (papillae below thickend rim)	-	+	-	/
Cupressinocladus valdensis (Seward)Seward	Watson,1977 Francis,1983	-	+ (variable)	+	+	-	/
Cupressinocladus sp. (33 CUPR CuA)	Oldham,1976	-	+ (with papillae)	-	+	-	/
Frenelopsis alata (K.Feistmantel) Knobloch	Alvin,1977 Watson,1977	-	+ (stellate)	+	+	-	-
Frenelopsis choshiensis Kimura et al.	Kimura et al., 1985	-	+ (with papillae)	+	+	-	-
Frenelopsis harrisii Doludenko	Doludenko,1978 Doludenko and Reymanówna,1978	-	+ (with papillae)	+	+	-	-

TABLE 2 (continued)

Frenelopsis hoheneggeri Reymanówna et Watson	Reymanówna and Watson, 1976	-	+ (lobed)	+	+	-	-
Frenelopsis occidentalis Heer	Alvin, 1977	-	+ (without papillae)	+	+	-	-
Frenelopsis oligostomata Romariz	Alvin, 1977	-	+ (without papillae)	+	+	-	-
Frenelopsis ramosissima Fontaine	Watson, 1977	-	+ (lobed or papillate)	-	+	-	/
Frenelopsis rubiesensis Barale	Barale, 1973	-	-	-	+	-	/
Frenelopsis silfloana Watson	Watson, 1983	-	+ (without papillae)	+	+	-	/
Frenelopsis teixeirae Alvin et Pais	Alvin and Pais, 1978	-	+ (without papillae)	+	+	-	/
Geinitzia rigida (Phillips)Harris	Harris, 1979	-	+ (without papillae)	-	-	-	/
Glenrosa pagiophylloides (Fontaine)Watson et Fisher	Watson and Fisher, 1984	+	+ (with papillae)	-	+	±	/
Glenrosa texensis (Fontaine) Watson et Fisher	Watson and Fisher, 1984	+	+ (with papillae)	-	+	±	/
Hirmeriella muensteri (Schenk)Jung	Harris, 1957 Jung, 1968 Watson, 1989	-	+ (without papillae)	-	+	-	/
Pagiophyllum araucarinum (Pomel)Saporta	Barale, 1981	-	+ (with papillae)	-	+	-	/
Pagiophyllum duttonia Ash	Ash, 1978	-	+ (with papillae)	-	+	-	+
Pagiophyllum insigne Kendall	Harris, 1979	-	+ (without papillae)	-	+	-	/
Pagiophyllum maculosum Kendall	Harris, 1979 Van Konijnenburg, 1987	-	+ (without papillae)	-	+	-	/
Pagiophyllum navajoensis Ash	Ash, 1978	-	+ (with papillae)	-	+	-	- (angular cavities)
Pagiophyllum ordinatum Kendall	Harris, 1979	-	+ (without papillae)	+	+	-	/
Pagiophyllum peregrinum (L. et H.) Kendall	Kendall, 1948	-	+ (with papillae)	-	+	-	/
Pagiophyllum readiana Ash	Ash, 1978	-	+ (with papillae)	-	+	-	+ (nodulus)
Pagiophyllum zumiana Ash	Ash, 1978	-	+ (with papillae)	-	+	-	+
Pseudofrenelopsis intermedia Chow et Tsao	Zhou, 1983	-	-? (without papillae)	-	+	-	-
Pseudofrenelopsis parceramosa(Fontaine)Watson	Watson, 1977 Cao, 1989	-	+ (with papillae)	-	+	±	-
Pseudofrenelopsis varians (Fontaine)Watson	Watson, 1977	-	+ (with papillae)	-	+	-	- ?
Tomaxellia biforme Archangelsky	Archangelsky, 1968	-	- (without papillae)	-	+ (dicyclic)	-	/

Table 3. Comparisons of leaf cuticules between cheirolepidiaceous and cupressaceous conifers.

	Cheirolepidiaceae	Cupressaceae
common features	1. Stomata are distributed mostly over the dorsal surface of a leaf. 2. Stoma is of cyclocytic-type and subsidiary cells form distinct ring-like structure. 3. Adjacent stomata do not share a subsidiary cell. 4. Inner periclinal surface of ordinary cells is smooth.	1. Stomata are restricted in distribution to two marginal stomatal bands. 2. Stoma is of cyclocytic-type, but ring-like structure is less distinct. 3. Adjacent stomata often do share a subsidiary cell. 4. Inner periclinal surface of ordinary cells is sculptured and/or nodulous.
features not common	1. Rim is present at the stomatal aperture often with papillae on it. 2. papillae are occasionally present on the stomatal pit-chamber walls. 3. Thickening, papillae and/or trichomes are present on the periclinal surface of ordinary cells.	1. Rim and papillae on stomatal aperture are not always present. 2. papillae are absent on the stomatal pit-chamber walls. 3. Trichomes are absent on the periclinal surface of ordinary cells.

China; eastern part of North China; eastern and middle part of Northwest China; northern part of Southeast China; eastern part of the Yangzi River area; western part of Sichuan and Yunnan) and Southeast Asia.

It is worth mentioning that the precisely determined cheirolepidiaceous conifers have not been recognized in the Late Jurassic-Early Cretaceous Tetori-type floras in the Inner Zone of Japan and Northeast China (except for its southeastern part) and the coeval Siberian-type floras in East Siberia.

Taxonomy

Order Coniferales

Family Cheirolepidiaceae

Form-genus *Cupressinocladus* SEWARD, 1919

Cupressinocladus obatae OKUBO et KIMURA, sp. nov.

(Figs. 2–16, 19A, 20, 21A)

Material (specimens): Holotype; NSM PP-9010. Paratypes; NSM PP-9011A, 9011B, 9012A, 9012B, 9012D (All specimens are kept in the National Science Museum, Tokyo). *Stratum typicum*: Kimigahama Formation (late early Barremian in age), Choshi Group. *Locus typicus*: Isejigaura Coast (Loc. no. 7404 of Obata *et al.*, 1975), Choshi City, Chiba Prefecture.

Occurrence: Rather rare. *Derivatio nominis*: After Dr. Ikuwo OBATA who collected the holotype.

Diagnosis: Pinnately branched shoots bearing decussate opposite leaves. Leaves scale-like, appressed, decurrent, pointed at apex, fimbriate with hairs up to 20 μm long, forming scarious frill near the apex. Cuticle 10 μm thick (periclinal wall 2–3 μm thick). Stomata distributed mostly over the dorsal leaf-surface, 70–150 in number per square mm, arranged in indefinite stomatal rows; apertures random. Stomatal complex of cyclocytic-type, 50–60 μm to 60–70 μm in diameter. Guard cells sunken, 40 μm long and 20 μm wide. Subsidiary cells 6 (4–7) in number, forming a stomatal pit chamber and oblong edge with papillae almost covering. Adjacent stomata not sharing a subsidiary cell. Ordinary (matrix) cells squarish, rectangular or polygonal; anticlinal walls thick, 4–8 μm wide. Papillae and trichomes present on the pericilinal walls; inner periclinal walls smooth.

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