

北日本及びサハリンの白亜紀石化植物IX: 北海道白 亜紀産コウヤマキ属石化球果化石

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Takeshi OHSAWA*, Makoto NISHIDA* and
Harufumi NISHIDA** : Structure and
Affinities of the Petrified Plants from the
Cretaceous of Northern Japan and Saghalien IX***
A Petrified Cone of *Sciadopitys* from the
Upper Cretaceous of Hokkaido

大沢毅守*・西田 誠*・西田治文** : 北日本及びサハリンの
白亜紀石化植物IX 北海道白亜紀産コウヤマキ属石化球果化石

Abstract

A petrified cone of *Sciadopitys* is described as the first record of the reproductive organ of this genus. The bract-scale complexes are non-peltate with tapered apices and are composed of large scale and small bract. The vasculature and resin canals show an affinity to a specimen of *S. verticillata*. The number of chalaza and vascular supplies to chalaza suggest that there are nine to thirteen inverted ovules on the bract-scale complex.

Key Words: Cretaceous—Petrified cone—*Sciadopitys*—Taxodiaceae

Several *Sciadopitys*-like fossils have been reported from the post-Triassic era in the northern hemisphere (MANUM, 1987). Most are vegetative organs particularly leaves fossilized as impressions or compressions. Only one species of a petrified leaf of *Sciadopitys cretacea* OGURA (1932) has been described from the Upper Cretaceous of Hokkaido. Reproductive organs of *Sciadopitys* have never been described from the Mesozoic worldwide.

Material and Methods

We were presented with a petrified cone in a derived nodule by Mr. Masanao KOSHIZAKA who collected it from the riverbed of the River Ikushumbetsu just below the dam of Lake Katsurazawa. Although the geological age of the nodule is not certain, it is probably derived from upper part of Middle Yezo Group or Upper Yezo Group sediments that are distributed widely in the upper reaches of Lake Katsurazawa. Their geological ages are Turonian to Santonian (MATSUMOTO *et al.*, 1976).

The cone was embedded in a sandy shale nodule and the whole external morphology could not be examined. The fossil was cut transversely at the uppermost and lowermost parts. The middle large part was cut longitudinally into three. Micropreparations were made from these five pieces by using the peel technique with 1.8% hydrochloric acid as an etching reagent.

On the whole, the cone was not well preserved, and only a few parts had a well-preserved histology.

Results

Systematic treatment

Family Taxodiaceae (Sciadopityaceae)

Genus *Sciadopitys* SIEB. et ZUCC.

Sciadopitys yezo-koshizakae sp. nov.

Diagnosis. Coniferous cone, cylindrical-ellipsoid bearing more than 20 bract-scale complexes arranged helically. Complexes bifurcating distally into bract and scale. Scale somewhat larger than bract, fused with bract in proximal two-thirds part and separated in distal one-third part.

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Dense trichomes growing on abaxial surface of scale and adaxial surface of bract. Pith of cone axis composed of parenchyma cells and nests of sclerenchyma cells. Vascular cylinder composed mostly of secondary xylem, lacking wood parenchyma and resin canals; primary xylem endarch. Cortex consisting of parenchyma cells, scattered sclerenchymatous cells and numerous resin canals. Inner hypodermis composed of several layers of thin-walled parenchymatous cells. Outer hypodermis composed of few layers of thick-walled parenchymatous cells. Fundamental tissue of complex composed of parenchyma cells and scattered sclerenchyma cells. Inner hypodermis composed of several layers of thin-walled parenchyma cells of the same form as cortex of cone axis. Outer hypodermis of bract, scale and abaxial side of complex composed of few layers of thick-walled parenchyma cells like that of cone axis. Outer hypodermis of adaxial side of complex composed of thick-walled fibers. Vascular traces to bract-scale complex diverging as two independent bundles; small bract trace diverging from bottom of vascular-cylinder gap and scale trace of abaxially opened horseshoe shape in transverse section diverging from lateral side and top of gap. Bract trace never dividing and remaining as single strand through bract. Scale trace extended laterally, dividing into about 15; branching off adaxially 9-13 vascular supplies to ovule. Nine to thirteen seeds arranged in transverse row on complex; probably inverted.

Holotype and deposition. Specimen no. 73012 and micropreparations. Laboratory of Phylogenetic Botany, Chiba University.

Locality and Horizon. Riverbed of River Ikushumbetsu, just below dam of Lake Katsurazawa, Mikasa City, Hokkaido. Upper Cretaceous (possibly Turonian to Santonian).

Etymology. Specific epithet dedicated to Mr. Masanao KOSHIZAKA, collector of the specimen.

Description.

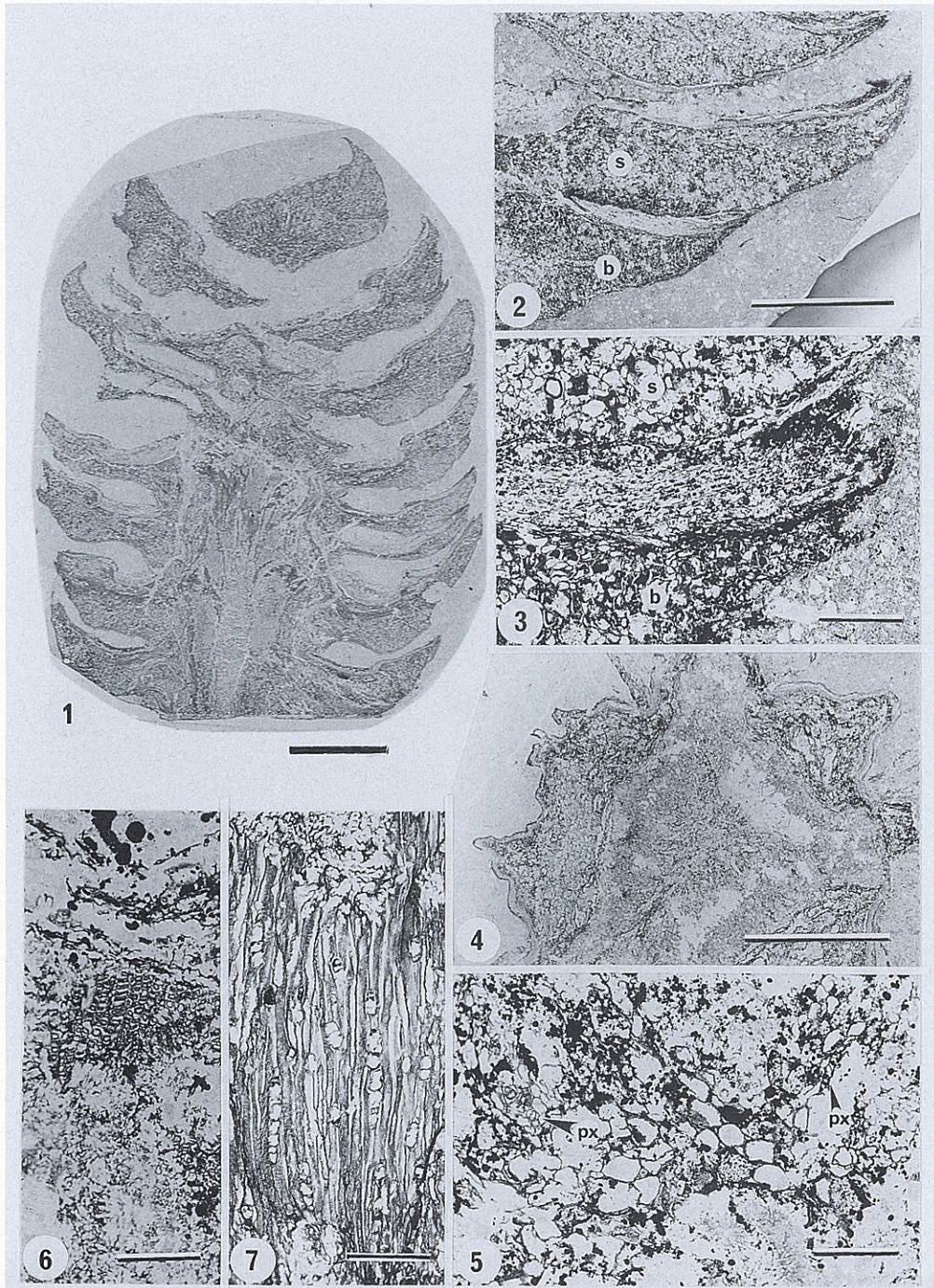
Cone structure. The cone is cylindrical-ellipsoid, about 59mm long and 45mm in maximum diameter (Fig. 1), bearing more than 20 helically arranged bract-scale complexes. Bract-scale complexes are 13-23mm long including the scale, 17-18mm wide and 6-7mm thick at the base and 24-27mm wide at the wide region. The complexes

project at angle of 90° from the axis with the apices turned slightly apical. The distal one-third is bifurcated dorsiventrally into a bract and scale (Fig. 2). The separation of the bract and scale begins from the lateral sides and extends medially. The scale is slightly larger than the bract and 5-12mm long; the bract is 3-6mm long (Fig. 2). Dense trichomes grow on the abaxial surface of scale and on the adaxial surface of bract (Fig. 3).

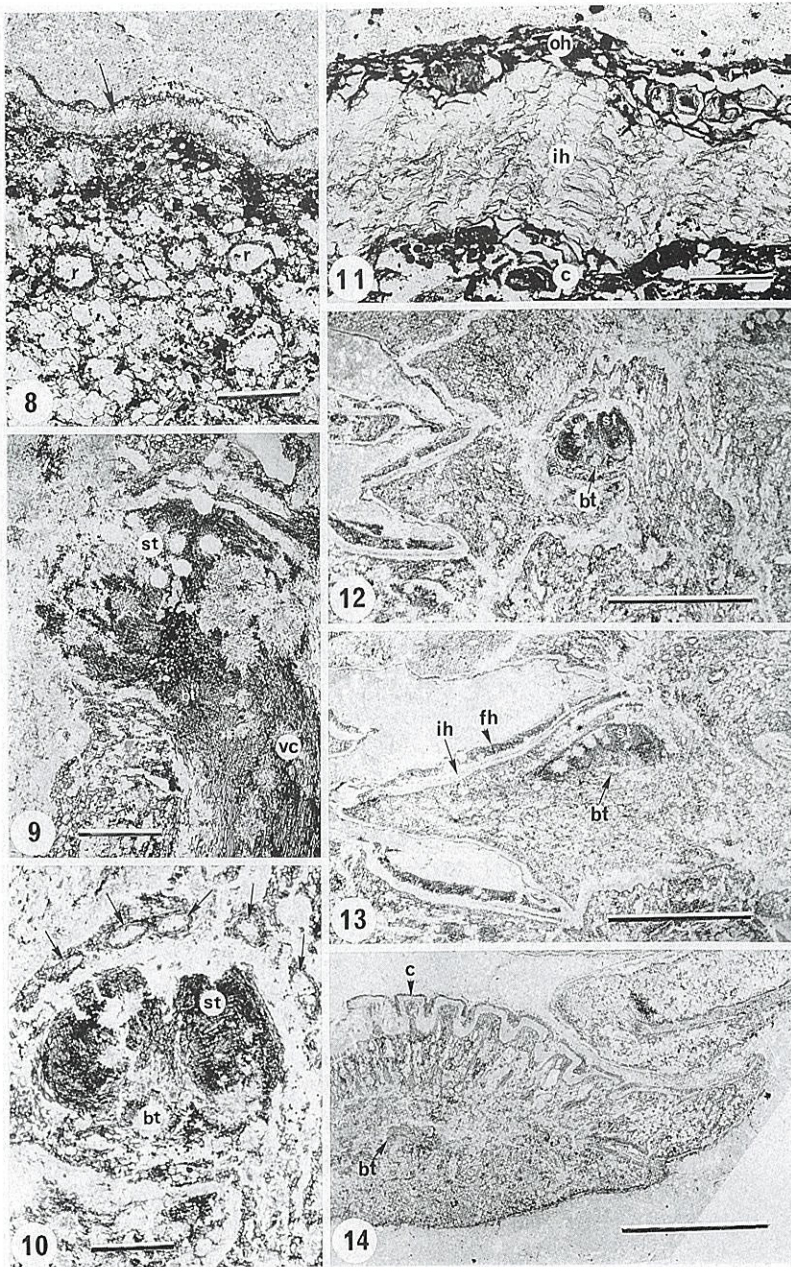
Cone axis. The cone axis is 13-16mm in diameter (Fig. 4). The pith is 3.0-3.4mm in diameter and consists of thin-walled parenchyma cells and scattered nests of sclerenchyma cells. The parenchyma cells are 70-180 μ m in diameter, and circular or polygonal in transverse section (Fig. 5). The sclerenchyma cells are 34-100 μ m in diameter with walls 20-36 μ m thick.

The vascular cylinder is endarch, 1.6-2.3mm thick and 7.5-9mm in diameter. It consists mostly of secondary xylem; primary xylem strands are visible at the inner edge (Fig. 5). The primary xylem tracheids are circular to rectangular in cross section, measuring 12-24 μ m in diameter. Their walls are 2-4 μ m thick with annular or spiral thickening. The secondary xylem consists of tracheids and rays and lacks wood parenchyma and resin canals. The secondary xylem tracheids are rectangular in cross section; they are 16-40 μ m in the tangential dimension and 22-40 μ m in the radial dimension with walls 2-4 μ m thick at the inner part of the vascular cylinder. At the outer part of the vascular cylinder, they are 18-22 μ m in the tangential dimension and 14-20 μ m in radial dimension with walls 4-6 μ m thick (Fig. 6). The rays are uniseriate and usually 1-3 or rarely up to 6 cells high (40-104 μ m, or rarely up to 240 μ m in height) (Fig. 7).

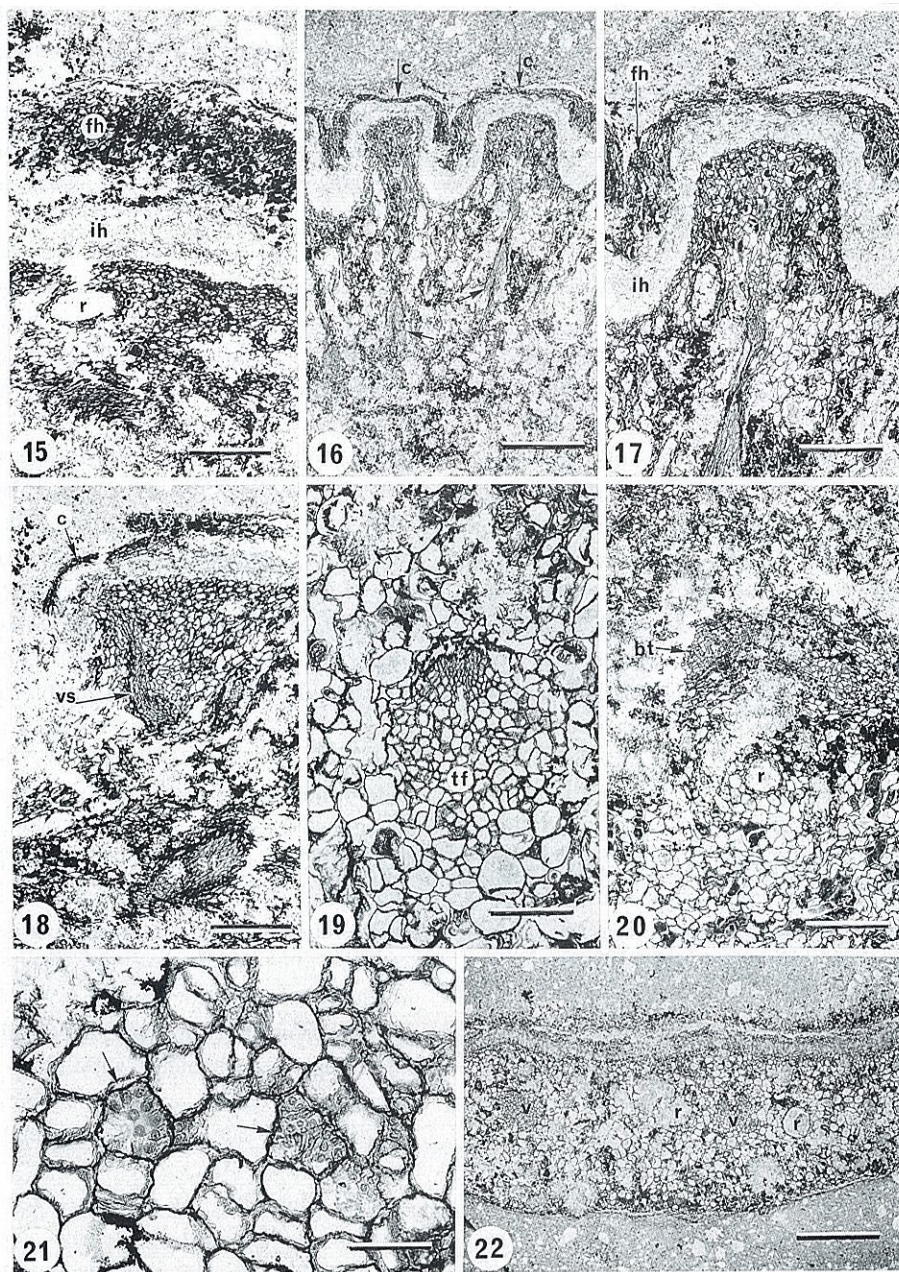
The cortex is 2.4-4.0mm thick and consists of thin-walled parenchyma and scattering sclerenchyma cells that are round or polygonal in cross section (Fig. 8). The parenchyma cells are 70-180 μ m in diameter; the sclerenchyma cells are 56-120 μ m in diameter with walls 20-44 μ m thick. More than 30 resin canals are scattered in the cortex; the correct number is unknown, because of poor preservation. Most of them are 160-280 μ m in diameter but those near the vascular cylinder is 360-800 μ m \times 240-400 μ m in tangential and radial dimensions, respectively. The inner



Figs. 1-7 *Sciadopitys yezo-koshizakae*, sp. nov. 1: Longitudinal section of cone showing 15 bract-scale complexes. bar 1cm. 2: Radial section of distal part of bract-scale complex where bract (b) and scale (s) separated from each other. bar 5mm. 3: Radial section of distal part of bract-scale complex. Note dense trichomes filling a space between bract (b) and scale (s). bar 0.5mm. 4: Transverse section of cone axis. bar 5mm. 5: Transverse section of cone axis showing periphery of pith and primary xylem strands (px). bar 0.2mm. 6: Transverse section of secondary xylem of cone axis. bar 0.2mm. 7: Tangential section of secondary xylem of cone axis showing low rays. bar 0.2mm.



Figs. 8-14 *Sciadopitys yezo-koshizakae*, sp. nov. 8: Transverse section of cone axis showing cortex and hypodermis (arrow). Resin canals (r) occur in cortex. bar 0.5mm. 9: Tangential section of cone axis (= section cut transversely the bract-scale axis) showing vascular supply to bract (bt) and scale (st) diverging independently from vascular cylinder (vc) of cone axis. Part of scale trace destroyed. bar 1mm. 10: Transverse section of bract trace (bt) and scale trace (st) (=enlargement of Fig. 12). Resin canals supplying bract-scale complex (arrows) arranged in arched line on adaxial side of vascular bundles. bar 1mm. 11: Transverse section of cone axis. Enlargement of hypodermis showing inner hypodermis (ih) and outer hypodermis (oh) on outer edge of cortex (c). bar 0.1mm. 12: Tangential section of cone axis showing transverse section of vascular supply to bract (bt) and scale (st). bar 5mm. 13: Transverse section of base of bract-scale complex. Note horizontally-stretched scale trace (st), small bract trace (bt), inner hypodermis (ih), and fibrous outer hypodermis (fh). bar 5mm. 14: Transverse section of distal part of bract-scale complex showing chalaza (c). Only one vascular bundle is supplied into bract (bt). bar 5mm.



Figs. 15-22 *Sciadopitys yezo-koshizakae*, sp. nov. 15: Enlargement of adaxial side of bract-scale complex. Note thick outer hypodermis composed of thick-walled fibers (fh), inner hypodermis composed of thin-walled parenchyma cells (ih), and resin canal (r). bar 0.5mm. 16: Transverse section of bract-scale complex cutting portion of chalaza (c). Single bicollateral vascular bundle (arrows) is supplied into each chalaza. bar 1mm. 17: Enlargement of Fig. 16 showing undulating inner hypodermis (ih) and fibrous outer hypodermis (fh). bar 0.5mm. 18: Radial section of chalaza on bract-scale complex. Vascular supply to seed (vs) branched off from vascular bundle of scale incurve towards base and entering chalaza (c). bar 0.1mm. 19: Transverse section of scale showing vascular bundle with transfusion tissue (tf) on abaxial side. bar 0.2mm. 20: Transverse section of bract-scale complex showing bract trace (bt) consisting of single bundle. Resin canal (r) occurs just abaxial to vascular bundle. bar 0.5mm. 21: Enlargement of transfusion tissue showing cells with bordered pits on walls (arrows). bar 0.05mm. 22: Transverse section of distal part of scales. Resin canals (r) and vascular bundles (v) are seen. bar 1mm.

hypodermis is 80-260 μm thick and consists of thin-walled cells that are rectangular in cross section (Figs. 8, 11). These cells are 30-44 μm in the tangential dimension and 18-26 μm in the radial dimension. The outer hypodermis consists of a few layers of thick-walled parenchyma cells measuring 32-54 μm in diameter (Fig. 11). The epidermis of the cone axis consists of rectangular cells that measure 22-42 μm × 24-30 μm in the tangential and radial dimensions.

Bract-scale complex. The vascular traces to each bract-scale complex diverge from the vascular cylinder of the cone axis as two independent bundles. A small terete bract trace diverges from the bottom of the vascular-cylinder gap, and a scale trace with an adaxially-opened horseshoe-shaped cross section diverges from the sides and top of the gap (Figs. 9, 10, 12). The vascular trace to the scale extends and stretches both its lateral ends horizontally to form a horizontally stretched bundle (Fig. 13). This bundle divides repeatedly into 13-15 strands in the middle of the complex. Nine to thirteen strands branch off each single strand adaxially (Figs. 14, 16, 17, 18). These strands are ectophloic bicollateral (Fig. 16). They curve in towards the base and enter each chalaza (Fig. 18). The bract trace located just below the median scale vascular strand (Fig. 13) never divides and only one strand enters the bract (Fig. 20).

The resin canals of the bract and scale are probably branched off from the cortical canals of the cone axis. About a dozen canals occur along the adaxial side of the scale trace in the cortex of the cone axis, and are arranged in an arched line (Fig. 10). The resin canals increase in number and extend laterally around the peripheral zone of the fundamental tissue at the upper (adaxial) and lateral sides of the complex. Finally, they extend to the lower (abaxial) periphery of the complex. More than fifteen canals are arranged in an arched line in adaxial side of the scale vascular strands and about ten canals are arranged in a line in the abaxial peripheral zone of the complex. At the distal part of the scale, resin canals tend to be located in the fundamental tissue between vascular bundles (Fig. 22). In the bract, 10-11 canals, one of which occurs just abaxial to the vascular bundle, are arranged in a horizontal line

in the abaxial side of the bract trace; a few peripheral canals occur in the fundamental tissue near the abaxial surface.

The fundamental tissue of the bract-scale complex, bract, and scale consists of parenchyma cells and scattered or grouped sclerenchyma cells, and lacks fibrous tissues (Fig. 17, 20, 22). The parenchyma cells are 30-140 μm in diameter at the basal part and 70-150 μm in diameter at the distal part of the complex. The sclerenchyma cells at the basal part are 50-100 μm in diameter with walls 22-50 μm thick; those at the distal part are 74-160 μm in diameter with walls 20-74 μm thick. The inner hypodermis consists of several layers of thin-walled cells of the same form as those of the cone axis and rectangular cross section. The outer hypodermis of the bract, scale and abxial side of the bract-scale complex consists of a few layers of thick-walled parenchyma cells like those of the cone axis. The outer hypodermis of the adaxial side of the bract-scale complex consists of thick-walled fibers that are 50-100 μm in diameter with walls 24-50 thick (Figs. 13, 15). The chalazal ends project prominently on the upper (adaxial) surface of the scale to form 9-13 chalazas (Figs. 14, 16, 17). So the inner hypodermis is actually undulate.

The fundamental tissue of chalaza is composed of thin-walled small parenchyma cells, 28-60 μm in diameter and of polygonal in cross section (Fig. 17). Transfusion tissue consisting of cells measuring 24-60 μm in diameter with walls that have bordered pits measuring 5-8 μm in diameter occur on the abaxial side of the vascular bundles in the scales (Figs. 19, 21).

Seed. The seeds are not preserved. Judging from the number and portion of chalazal tissue and from the vascular supplies, nine to thirteen inverted ovules should be arranged in a transverse row on the scale.

Affinities and Discussion

The newly-described cone resembles cones of the Pinaceae in having an incompletely-fused and distally-free bract with one vascular bundle and tapered tips of the bract and scale. However, it differs from the Pinaceae in having nine or more ovules per bract-scale complex arranged in a transverse row and in not having scaly and

papery bract. The bract-scale complex of our specimen separates dorsiventrally into a bract and scale at the distal one-third part but the bract and scale of the Pinaceae are almost free from each other. A basally-fused and distally-separated bract-scale complex bearing many seeds per scale is characteristic of some taxodiaceous genera. Taxodiaceous cones are classified into four types by the size of the bract and scale, the vasculature, and the orientation of ovules (LAPASHA and MILLER, 1981). We have also discussed this respect in a previous paper (NISHIDA *et al.*, 1991).

Of the Taxodiaceae, *Sciadopitys* has a large scale with several vascular strands and slightly-smaller bract with one vascular strand. The distal part of the bract and scale are separated and tapered. The vascular trace to the bract and scale diverges independently from the vascular cylinder (RADAIS, 1984; SATAKE, 1934; LEMOINE-SEBASTIAN, 1968). The outer hypodermis composed of fibers occur on adaxial side of the complex (RADAIS, 1894). Seven to nine inverted ovules are arranged in a transverse row on the scale (SATAKE, 1934; LEMOINE-SEBASTIAN, 1968). Moreover, many trichomes grow between the bract and scale.

Our specimen is indistinguishable from *Sciadopitys* in these respects. However, it differs slightly from *S. verticillata* SIEB. et ZUCC., the only extant species of the genus, in having just one vascular trace to the scale when it diverges from the vascular cylinder of the cone axis; the scale trace in *S. verticillata* diverges as two or three independent strands (RADAIS, 1894; SATAKE, 1934). The fossil specimen is also different from *S. verticillata* in having only a few peripheral canals near the abaxial surface of the bract, while the latter has numerous peripheral canals in the abaxial peripheral zone of the bract. We did not observe the abaxial scale canals that are the characteristic of *S. verticillata* (RADAIS, 1984; TAKASO and TOMLISON, 1991). Although there are some minor differences, our specimen closely resembles *S. verticillata* and should be a new member of the genus.

Only two types of *Sciadopitys*-like reproductive organs have been reported so far; 1) *Sciadopitys terciaria* MENZEL (1913) from the Tertiary of

Germany which resembles extant *S. verticillata* in the shape and size of the bract-scale complex and in having more than five seeds per complex; and 2) An unnamed specimen from the Jurassic of Norway (BOSE, 1961) which has small, 2mm long, bract-scale complexes bearing three seeds. Our specimen differs from these in having large, more than 1.8cm long complexes with more than nine seeds per complex.

Nine genera of taxodiaceous cones have been described from the Cretaceous worldwide. Of these, *Austrosequoia* PETER et CHRISTOPHEL (1978) and *Nephrostrobus* LAPASHA et MILLER (1981) resemble the *Sequoia* group. *Cunninghamiostrobus* STOPES et FUJII (1910), *Elatides* HEER (1876), *Parataiwania* NISHIDA *et al.* (1992) and *Sphenolepis* SCHENK (1871) resemble *Cunninghamia* and *Taiwania*. *Athrotaxites* MILLER et LAPASHA (1983), *Rhombostrobus* LAPASHA et MILLER (1981), and *Yezosequoia* NISHIDA *et al.* (1991) show similarities to *Athrotaxis* and exhibit an intermediate form between *Cunninghamia* and *Sequoia*. None exhibits affinities with *Sciadopitys*. *Sciadopitys yezokoshizakae* is the first record of a *Sciadopitys* cone from the Mesozoic worldwide.

Numerous species of *Sciadopitys*-like leaves, which exhibit a unique single median stomatal groove on the lower abaxial surface, have been described. Recently, MANUM (1987) reviewed most of them and classified them into two genera, *Sciadopitys* and *Sciadopityoides* (including *Sciadopitytes* GOEPPERT et MENGE, 1883). However, they do not show the parallel veins that are an important characteristic of *Sciadopitys*. Thus, the so-called "double-needle" nature of these fossil leaves as seen in extant *S. verticillata* has not been examined exactly. *Sciadopitophyllum* (CHRISTOPHEL, 1973) is another genus of compression fossils of leafy shoots resembling extant *Sciadopitys verticillata* because it shows the same phyllotaxis and similar stomata and papillae in the stomatal grooves on the abaxial surface of the leaves. However, *Sciadopitophyllum* differs from *Sciadopitys* in having leaves without bifurcate apices. Moreover two parallel veins is not also certified in *Sciadopitophyllum*. The oldest and only histologically preserved fossil leaf of *Sciadopitys* is *S. cretacea* OGURA (1932) from the Upper

Upper Cretaceous of Yubari, Hokkaido (15km south of where the present specimen was found). *Sciadopitys cretacea* closely resembles *S. verticillata* in having a median stomatal groove on the lower surface, a median furrow on the upper surface, and the double parallel veins. Occurrence of *S. yezo-koshizakae* and *S. cretacea* in the Upper Cretaceous sediments means that the characteristic forms of *Sciadopitys* cone and leaf had already appeared by the late Cretaceous.

Sciadopitys cretacea differs slightly from *S. verticillata* in being devoid of idioblasts in the spongy tissue of the mesophyll and transfusion tissue in the bundle sheaths. *Sciadopitys yezo-koshizakae* is also devoid of idioblasts, but has transfusion cells on the abaxial side of scale vascular bundles. *Sciadopitys yezo-koshizakae* differs from *S. verticillata* and *S. cretacea* in these respects. This fact indicates that *Sciadopitys*, which is monotypic in the Recent, was diverse in the late Cretaceous.

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摘 要

○ 余呉湖北岸の埋没林から採取された木材化石（植田弥生・辻誠一郎・村上宣雄）Yayoi UEDA, Sei-ichiro TSUJI and Nobuo MURAKAMI: Wood Fossils Obtained from the Buried Forest along the Northern Coast of Lake Yogo.

滋賀県伊香郡余呉町の余呉湖北岸（北緯 35°31'37"，東経 136°12'）には余呉町指定天然記念物の湖底埋没林が保在されている。この埋没林は 1970 年に湖岸工事にともなう湖水面底下の際発見されたもので、かつて湖水面が底下していたことをものがたる資料として注目された。その際採取された埋没林の木材の放射性炭素年代が学習院大学において 2040±80 y.B.P.と測定された（藤本，1973）。その後 1972 年に再び埋没林が調査され、現湖水面より 2 m 下位の標高 131 m に埋没する 36 本の立株および倒木が確認された。HORIE (1975) はその際採取された木材化石の放射性炭素年代が同じく学習院大学において 3230±260 y.B.P.および 2780±110 y.B.P.と測定されたことを報告し、約 3000 年前の低湖水面期を裏付けるものとした。この湖底埋没林は低湖水面を示すばかりでなく、約 3000 年前の低地の植物相を復元する上でも貴重であるが、古植物学的な検討は加えられないままであった。1990 年の夏、植田・辻は余呉低地帯の埋没林探索に訪れた折、1972 年の調査の際に記録された埋没林の木材の一部が保管されていることを村上から知った。そこで保管状況を調査するとともに、今後の資料に供するために樹種同定を試みたところ、以下のような結果を得ることができた。

保管されていた木材化石は、鏡岡中学校に 9 点、鏡岡小学校に 3 点、北国街道歴史資料館に 1 点の合計 13 点であった。樹種同定のために保管標本から横・接線・放射断面の 3 方向の切片をとりガムクロラール封入の切片標本を作成した。標本には YW-34~38・348~355 の番号を付し、大阪市立大学理学部に保管した。切片標本の顕微鏡写真を Fig.1 に示すが、すべて落葉広葉樹に同定された。その内訳は、ハンノキ属ハンノキ亜属 *Alnus* subgen. *Alnus* が 7 点、ヤナギ属 *Salix* が 3 点、ニレ属 *Ulmus*・トネリコ属 *Fraxinus*・コナラ属 *Quercus* sect. *Prinus* が各 1 点であった。これらのうちトネリコ属は根材であった。

1972 年の調査によって記録された埋没林のうち 31 本は立株として記載されている (HORIE, 1975) ので、同定された分類群は互いに近接して現地に生育していたものと考えてよいであろう。同定結果では種の階級までは明らかになっていないものの、ハンノキ亜属やヤナギ属が多いこととトネリコ属の根材が識別されたことを併せ考えること、氾濫低地に成立することの多い湿地林に近い性格をもったものと考えられよう。ただし、HORIE (1975) が報告した放射性炭素年代の測定結果には、年代値が与えられず modern とされたものが含まれるので、同定された分類がすべて当時の森林を構成していたかは問題の残るところである。また、HORIE (1967) は 1961 年の北岸の導水路工事の際、水田面の 2 m 下位から得られた木材が学習院大学において 3180±180 y.B.P.と測定され、島地 謙によってカキ属 *Diospyros* に同定されたとしているが、もしそれが同時期のものであったとすると、北岸一帯の森林の種構成は案外複雑であった可能性もある。余呉町では埋没林の詳細な調査を実施する計画が進められているので、上記の問題も含めて近い将来埋没林の性格が解明されることを期待したい。

引 用 文 献

藤本秀弘, 1973. 余呉湖の地形—余呉湖のおいたち—. 「余呉湖自然調査報告書, No.3 余呉湖周辺の自然」(鏡岡中学校科学部編): 29-32, 鏡岡中学校.

北海道三笠市の幾春別川・桂沢湖のダムサイトの少し下流から、越坂正直氏が採集した、上部白亜系に由来したと思われる転石の中から見つかった球果は、円筒形の楕円体で、20 個以上の果鱗複合体が球果軸上にらせん配列し、先端の三分の一が分離した大きな種鱗と、種鱗に比べてやや小さな苞鱗とからなり、その先端は肥厚しない。種鱗維管束は十数本あるのに対して、苞鱗維管束は 1 本のみである。種子は倒生で 9 個から 13 個あったと思われる。これらの特徴は、日本固有の現生属であるコウヤマキ属 (*Sciadopitys*) と一致する。コウヤマキ様の化石は、三疊紀以降、主に葉の圧縮化石が、北半球各地から知られているが、組織の保存された石化球果化石は初めての記録である。(Received June 8, 1991)