FOSSIL WOODS OF TAXODIACEAE FROM THE KUNGKUAN TUFF (EARLY MIOCENE) OF NORTHERN TAIWAN

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ABSTRACT - The paper deals with a species of taxodiaceous fossil wood collected from the Kungkuan Tuff (Early Miocene) of Kueishan, Taoyuan County, northern Taiwan. The characters of the specimens indicate a close similarity with *Taxodioxylon sequoianum.*

KEY WORDS: Early Miocene, Fossil Wood, Kungkuan Tuff, Taiwan, Taxodiaceae

INTRODUCTION

Sedimentary formations are widely distributed throughout the western part of Taiwan. Plant remains, including leaf and wood, have been found in various locations but their investigations are relatively rare. A brief summary is given here. Deguchi (1912) listed a catalogue of fossils from Formosa that fifteen plant taxa are noted. Iizuka (1929) reported fragment of palm leaf from Quaternary sediments. Hayasaka (1931) reported carbonized wood in Taipei basin. Tan (1940) noted that Endo had recognized *Ficus filliaefolia, Ficus* sp., *Cassia* sp., *Cinnamomum* cf. *vera* and *Podogonium*? sp. from the Lower Coal-bearing Formation in northern Taiwan. Chaney and Chuang (1968) recognized ferns, a conifer, and members of twelve families of angiosperms from Shiti Formation in northeastern Taiwan and indicated the occurrence of the flora at or near sea level during Middle Miocene. Canright (1972) discovered carbonized compressions of leafy branches and a single ovulate cone of *Metasequoia* in an argillaceous shale in the Middle Miocene Shiti Formation southeast of Taipei. Cheng and Tang (1974) reported a fossil forest preserved in an upright position in the basal part of the Nanchuang Formation of Late Miocene age. Lin and Liew (1974) list 40 taxa of fossil plant from Taiwan. Hu (1989) reported *Salix miocinica* from Alishan. Chen (1990) reported a petrified hardwood from Toukoshan Formation. Three taxa of palm leaves are found in the strata of Oligocene age (Lai, 1995; Juang and Li, 1997). A carbonified wood of Taxodiaceae was found in taff of Miocene age (Juang and Li, 1999).

In the Kungkuan Tuff at the Shantzechiao Anticline (Fig.1), two specimens of coniferous fossil wood were discovered in the Kueishan, Taoyuan County by the third

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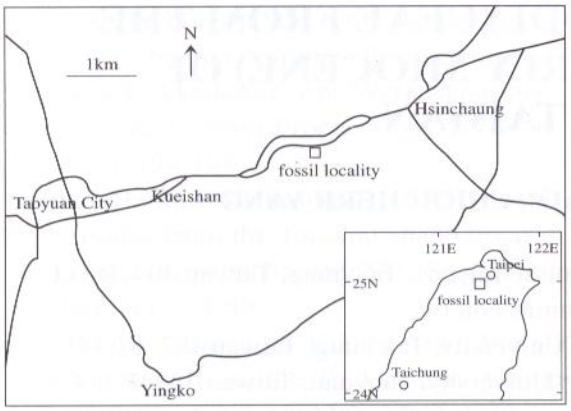


Text-figure 1
Locality of the fossil wood reported in this study.

author. The strata of the area include the Mushan Formation at the bottom and successively the Taliao Formation, the Nanchuang Formation, and the Nankang Formation at the top (Fig. 2). All formations in the area are of Miocene age. Kungkuan Tuff is a discontinuous unit distributed in northern Taiwan. This unit is exposed sporadically in Keelung city, Taipei city, Taipei-hsien, Taoyuan-hsien and Hsinchu-hsien. The Kungkuan Tuff is composed mainly of clastic volcanic rocks and subordinately of basalt. Lenticular beds of limestone, sandstone and shale are also intercalated in the massive tuff but are rather limited distribution. Limestone or taffaceous limestone is best developed in the Shantzechiao area. The vocanism in the Kungkuan stage continued throughout the time of the Mushan Formation and the Taliao Formation (Ho, 1967, 1969).

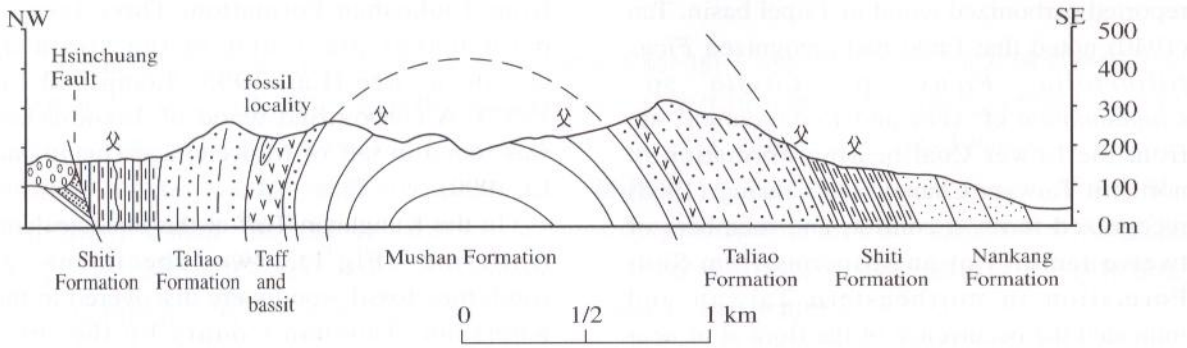
The present study deals with two fossil wood specimens discovered from the Shantzechiao Anticline at an estimated 25° 00'N, 121°22'E, next to Provincial Highway 1 (Text-fig. 1). The fossils were found embedded in dark green, medium to fine vitric and lithic tuff belonging to the Kungkuan Tuff (Text-fig. 3).

The fossils are calcified and well preserved. Thin sections of the transverse, tangential, and radial facets have been made for studying. The specimens are deposited at the National Museum of Natural Science, Taiwan, and are available for examination upon request.

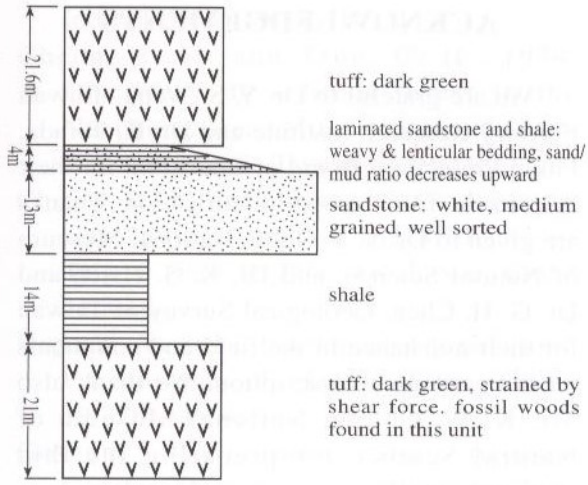
SYSTEMATIC DESCRIPTION

Class: Coniferopsida
Order: Coniferales Jussieu, 1789
Family: Taxodiaceae Warming, 1890
Genus: *Taxodioxylon* (Hartig) Gothan 1905
Species: *Taxodioxylon sequoianum* (Merckl.) Gothan 1906

The two specimens measure 20 x 15 x 10 cm (Plate A) and 4 x 8 x 13cm, and are parts of large stumps. Wood consists of tracheids, axial parenchyma, and rays. The fossil shows



Text-figure 2
Generalized structure section across the Shantzechiao Anticline. (after Ho, 1967)



Text-figure 3
Litho-column of the study area.

marked, narrow growth rings of 0.6 mm wide in average (plate B). The transition from early wood to late wood is abrupt (plate C).

The late wood consists of 1-4 layers of radially flattened, rectangular, thick-walled tracheids with small or slit-like lumen, 25-45 x 28-45 μm (radial x tangential diameter) in cross section (plate C). The early wood consists of 5-10 layers of large, thin-walled, squarish to polygonal tracheids with large, open lumen, 28-88 in tangential x 60-95 μm in radial diameter. Border pits on the radial walls are uni- to quadraseriate, mostly bi- to triseriate, and opposite, circular in outline with round apetures (plate D). Fairly thick straight or curved crassulae between pits are very common in the radial section. Uniseriate, small pits are occasionally found on the tangential walls of tracheids at growth ring boundaries (Plate E).

Axial parenchyma is common in both early and late wood but not abundant. The parenchyma is solitary and diffuse; cells are smaller than tracheids (23-33 μm) in cross section and often plugged with dark-brown contents; horizontal walls are thin and unpitted (plate F).

Rays are all parenchymatous; mostly uniseriate and 1-24, mostly 1-12, cells high (Plate G), sometimes entirely or partly biseriate of up to 6-8 cells high (plate H). The adjacent rays are separated by 1-12 rows of tracheids. Both horizontal and tangential walls of ray cells are smooth. In early wood there are typically 3-8 taxodioid pits in a cross field. Cross field of median cells of rays have 3-4 pits in a single horizontal row, while those of marginal cells have 3-8 pits aligned in 1 or 2 horizontal rows (plate I). The pits are up to 10-15 μm in diameter.

Traumatic resin canals are found occasionally. (Plate J).

COMPARISON

The distinct growth rings, large tracheids with multiseriate and opposite radial pits, resinous axial parenchyma, taxodioid cross-field pits, and lack of spiral thickening clearly indicate that the current fossils are typical taxodiaceous (Pierce, 1936; Phillips, 1941; Greguss, 1955).

The form genus *Taxodioxylon* is assigned to fossil woods having the characteristics of the extant Taxodiaceae and some genus of Cupressaceae (Stewart and Rothwell, 1993). Torrey (1923) erected *Sequoioxylon* for inclusion of woods with traumatic resin canals but otherwise conforming to *Cupressionxylon* or *Taxodioxylon.*

A comparison with the known *Sequoioxylon* fossils and other taxodiaceous fossil woods (Jeffrey, 1904; Yasui, 1917; Torrey, 1923; Takamatsu, 1929; Shimakura, 1933; Andrews, 1936; Watari, 1941; Ogura, 1943; Beyer, 1961; Greguss, 1967; Prakash, 1968; Ramanujam and Stewart, 1969; Seward, 1969; Du, 1987; Blokhina, 1986, 1997) have been made and reveals that the present fossil woods agree in most characteristics with *Taxodioxylon sequoianum.* The species *T. sequoianum* is known from the Palaeogcene to Pliocene in Japan (Suzuki and Watari, 1994)

and the Cretaceous to Paleocene in China (Du, 1987).

AFFINITIES WITH EXTANT CONIFERS

Among the modern members of Taxodiaceae, *Taxodium, Glyptostrobus, Cryptomeria,* constitute a closely related group on the basis of course simple pits on the horizontal walls of axial parenchyma cells; *Sequoia, Athrotaxis* and *Taiwania* combine to form a second group with entire walls. *Cunninghamia* links these distinct groups in possessing slight thickings in rare instance (Peirce, 1936). On the other hand, Greguss divided them into two groups on the basis of dentate (including *Taxodium* and *Glyptostrobus*) or smooth *(Metasequoia, Sequoia, Sequoiadendron, Cryptomeria, Cunninghamia, Athrotaxis* and *Taiwania)* horizontal walls of axial parenchyma cells (Greguss, 1955). The present fossils belong to the group of smooth walls. Traumatic resin canals have been reported for *Metasequoia, Sequoia, Sequoiadendron* (Torrey, 1923; Greguss, 1955). Woods of *Sequoia sempervirens, Sequoiadendron giganteum,* and *Metasequoia glyptostroboides* is probably indistinguishable, although some difference may be evident (Greguss, 1955). While resin cysts may be found in all woods of *S. sempervirens* and *M. glyptostroboides,* resin cysts are restricted to juvenile wood and seed cone axes of *S. giganteum* (Basinger, 1981). Multiseriate bordered pits on radial wall of tracheids are common in very old trunks of Sequoia, Sequoiadendron, Cryptomeria and also Taxodium (Greguss, 1955; Barefoot and Hankins, 1982; Panshin and Zeeuw, 1970). Therefore, the present fossil woods are believe to have a close relationship with extant *Sequoia.*

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台灣北部早期中新世之杉科木化石

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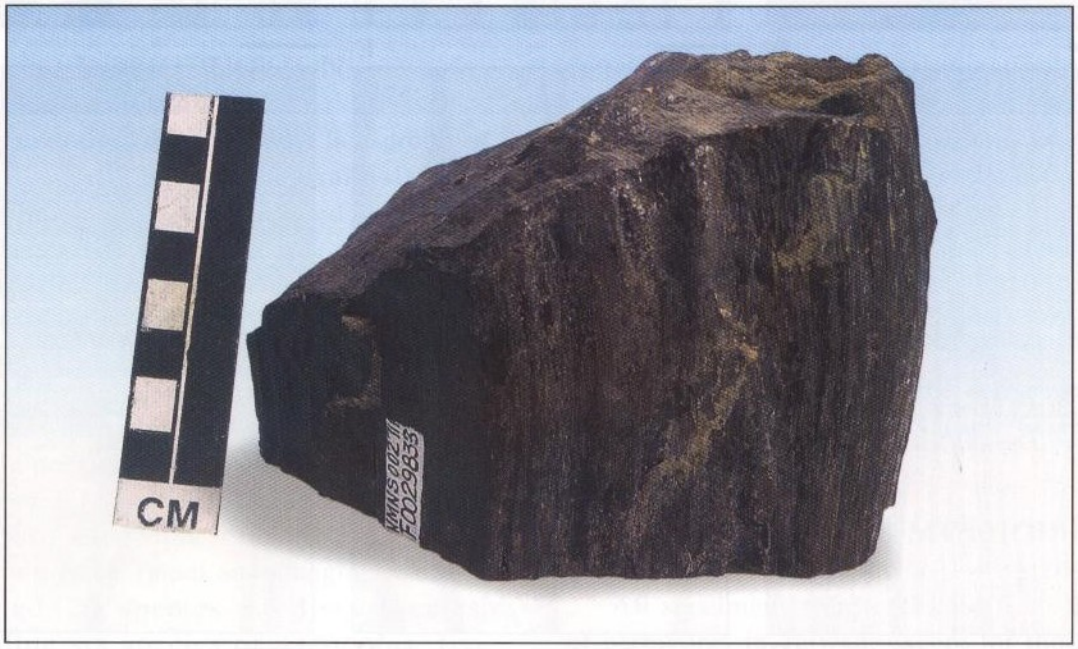
摘要

標本爲採自台灣北部桃園縣龜山鄉，早期中新世公館凝灰岩中的一塊杉科植物木材化石。此木材化石的組織構造類似分布於日本古新世至上新世及中國白堊紀至古新世地層的*Taxodioxylon sequoianum*。

關鍵詞：中新世早期，公館凝灰岩，木材化石，台灣，杉科

PLATE

A. The specimen.
B. Transverse section of fossil wood showing marked and narrow growth rings. Units of the ruler = 1 mm.
C. Transverse section showing abrupt early and late wood transition. The smaller-diameter and dark-brown-containing xylem parechyma cells are scattered in the early wood zone. Scale bar = 100 μm.
D. Border pits with round apertures on the radial walls. Note the opposite arrangement and their being up to quadraseriate. Scale bar = 50 μm.
E. Uniseriate border pits on the tangential wall of tracheids. Scale bar = 200 μm.
F. Tangential section showing xylem parechyma with thin smooth horizontal walls and dark-brown contents. Scale bar = 100 μm.
G. Tangential section showing wood rays mostly 1-12 cells high. Scale bar = 0.4 mm.
H. Tangential section showing biseriate wood ray. Scale bar = 50 μm.
I. Taxodioid pits in the cross fields. Scale bar = 50 μm.
J. Transverse section showing the traumatic resin cannals. Scale bar = 0.4 mm.



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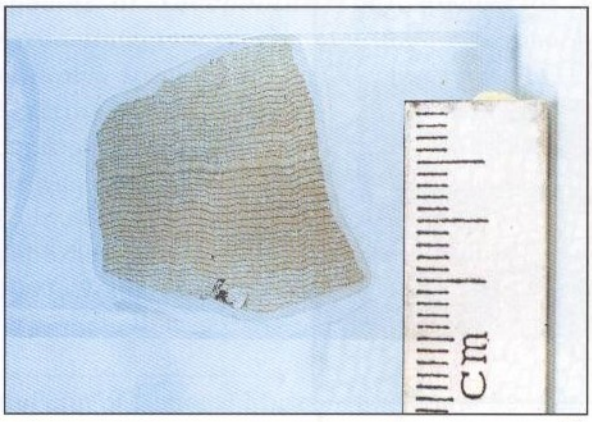

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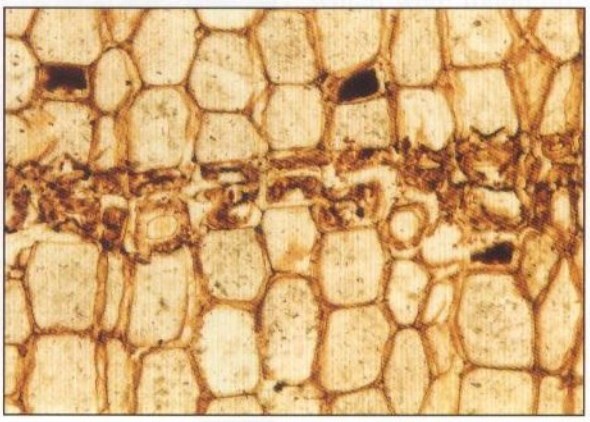

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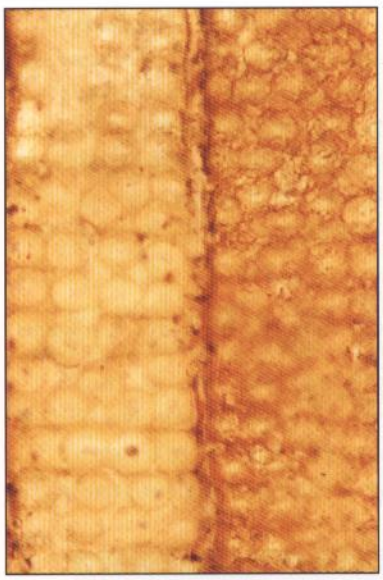

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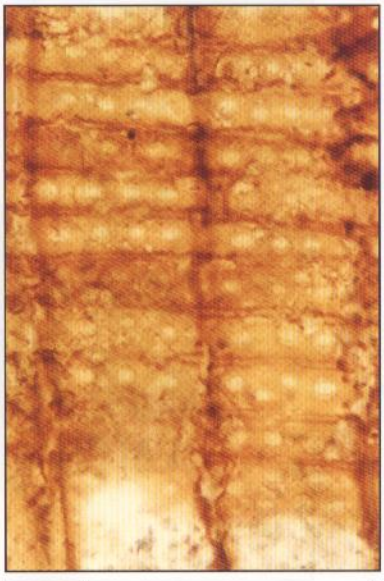

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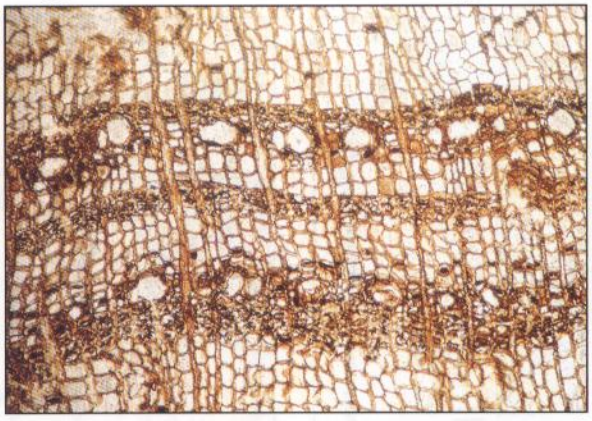

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