EVIDENCE OF THE EXISTENCE OF *METASEQUOIA* IN THE MIOCENE OF TAIWAN[1]

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Abstract: Although *Metasequoia occidentalis* (Newberry) Chaney is now known to have been widely distributed throughout the northern hemisphere during the Tertiary, including abundant remains in Japan as late as the Pliocene, it has never been previously reported from Taiwan. In 1971 the author discovered carbonized compressions of leafy branches and a single ovulate cone of *Metasequoia* in an argillaceous shale in the Middle Miocene Shihti Formation southeast of Taipei. In addition, numerous pollen grains of the taxodiaceous type were recovered by maceration of the matrix containing the macrofossil material, as well as from the underlying coal beds of the same age.

INTRODUCTION

Fossil species of the cone-bearing *Sequoia* (Redwood) have been recognized by paleobotanists for over a century from Cretaceous and Tertiary horizons in the north temperate regions of both the Old and New World. However, it was not until 1941 that the Japanese botanist, Shigeru Miki, in studying some putative specimens of *Sequoia* from Pliocene lignite beds of Honshu, noted a number of morphological discrepancies in his fossil material which caused him to erect a new genus, *Metasequoia*, in the coniferalean family Taxodiaceae. The main characteristics noted by Miki (1941) that distinguish specimens of *Metasequoia* from *Sequoia* are opposite leaves, a deciduous habit, and decussate scales on the ovulate cones of the former genus.

Only a few years later, Hu and Cheng (1948) published their startling discovery that numerous large *Metasequoia* trees still live in the Lichuan district in northwestern Hupeh and eastern Szechuan Provinces of central China. Because the examples of a plant genus being known from fossil material prior to its discovery as being extant are extremely rare, a spate of papers soon appeared describing this remarkable event (Andrews, 1948; Chaney, 1948; Florin, 1952; Hu, 1948; Li, 1957; Merrill, 1948a). *Metasequoia glyptostroboides*, with the specific epithet referring to its resemblance to *Glyptostrobus* (shui-sung or water pine), another monotypic deciduous taxodiaceous genus of southern China (Li, 1964).

Initially, controversy arose among certain plant taxonomists and paleobotanists concerning the legality of applying the same generic name to a living plant which had originally been described from fossil material (Schopf, 1948a, b; Merrill, 1948b). However, this taxonomic problem was finally setted at the Ninth International Botanical Congress at Montreal when the fossil genus *Metasequoia* was placed on the list of *nomina conservanda* (Lanjouw, 1961).

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Paleobotanical investigations in Taiwan are relatively rare. The late Professor Chaney of the University of California, who had so ably revised the fossil taxodiads based upon the discovery of *Metasequoia* (1950), first visited Taiwan in 1964 and collected some leaf impressions from the Shihting Coal Field of Middle Miocene age southeast of Taipei. During the second visit in 1966, he collected additional fossil plants from the dumps of the Shihti Mine of the Taiyang Mining Company. These collections were later described in a preliminary paper (Chaney and Chuang, 1968) and included 19 genera in 13 families. A single fern was described, with the remainder assigned to the angiosperms. Chaney stated (p. 6) that he had found a single coniferous foliage shoot "which may represent the Taxaceae," but it was neither assigned generic status nor was it listed. Professor Chaney had planned to return to Taiwan in 1971 (pers. comm.) to continue this work, despite his advanced age (80), but his death intervened.

The only previous paleopalynological studies in Taiwan are those of Ling (1965) and Canright (1972). Ling described the relative abundance of 14 palynomorphs recovered from 2 coal mines in Chilung, and Canright delineated the kinds of palynomorphs recovered from 51 samples of coals, shales and sandstones, ranging in age from the bottom of the Miocene up to the base of the Pliocene in northern and western Taiwan.

The present paper describes the first evidence of the existence of *Metasequoia* in Taiwan, and extends the distribution of this interesting conifer to its most southernmost range (25° N).

MATERIALS AND METHODS

During the course of 6 months of collecting rock samples from every known Miocene formation in northern and western Taiwan for a palynological study, only a single site and a single horizon revealed plant macrofossils. These were represented by compressions of 3 carbonized leafy coniferous branch tips and a single ovulate cone in a dark gray argillaceous shale from the dump of the Chung Yang Keng Mine of the Taiyang Coal Mining Company, located about 20 km southeast of Taipei. This mine is reportedly working the Middle Miocene Shihti Formation in the Shihting Coal Field (Cheng, 1957; Ho, 1966).

Because the carbonizd macrofossils embedded in the dark gray shale afforded very little contrast, they were immersed in water and photographed under reflected light with a Leitz 4×5″ camera with automatic exposure control.

In an attempt to discover corroborative microfossil evidence for the presence of *Metasequoia* in the Shihti Formation, about 30 g of the shale matrix exclosing the coniferous macrofossils were macerated in 52% HF, followed by 10% KOH, and then a heavy liquid flotation of the organic content in a bromoform-alcohol mixture (sp gr 2.3). The organic residue was then strewn on slides and mounted in the colorless acrylic medium Elvacite (Lucite #2,044) for scanning under a compound microscope. Stage coordinates were recorded for all taxodiaceous types of pollen grains for later relocation and photomicrography with a Leitz Orthomat camera. Identifications were made by comparison with slides of vouchered gymnosperm pollen in the Arizona State University Palynology Reference Collection, as well as with descriptions and illustrations in the *Pollen Flora of Taiwan* (Huang, 1972). Additional macerations in Schulze's solution were made of the coal underlying the shales

containing the macrofossil specimens, and the microfossil residue was examined as explained previously.

RESULTS

Leafy branches.—The three individual branches which were discovered, apparently represent the the terminal portions of leafy short shoots (Fig. 1, 2). The longest shoot of the 3 specimens measures 4 cm and is covered by distichously-arranged leaves, with the largest measuring 11×2 mm. One of the most important characteristics distinguishing *Metasequoia* from *Sequoia* and *Taxodium* is that the leaves are borne in opposite pairs in the first-named genus, whereas they are spirally arranged in the other two genera (Miki, 1941). Unfortunately, due to the loss of many carbonized basal portions of the leaves and the shoot axes in these specimens, this feature is difficult to demonstrate. However, oppositely-attached leaf pairs are best illustrated near the top of the lefthand specimen in Fig. 1 and near the base of the leafy shoot shown in Fig. 2 (at arrows). Chaney (1950, p. 177) has pointed out that leafy shoots of *Metasequoia* resemble *Taxodium* in their slender form, whereas those of fossil *Sequoia* are usually relatively thick—this feature is ascribed to the deciduous feature of the first two genera (although the extant Mexican *T. mucronatum* is an exception to this deciduous habit). The shoot diameter of my specimens never exceeds 1 mm.

Ovulate cones—An examination of Figure 3 reveals that the single ovulate cone specimen (measuring 16×11 mm) is obliquely oriented in the matrix. That is, the direction of fracture of the matrix was such that only the middle 2–3 pairs of scales show the decussate feature, which distinguishes them from cones of *Taxodium* and *Sequoia*. The uppermost scales on the cone axis are flattened and curled upward by the previous weight of the overlying sediments, whereas the basal stalk must have ranged obliquely into the counterpart of the specimen, which was not found.

Pollen—Numerous spheroidal (to prolate when split open) psilate to granulate grains, ranging in size from 18 to 38 μ, were recovered by maceration of the matrix from the macrofossil specimens, as well as from the underlying coals (Fig. 4, 5). Because several genera of modern Taxodiaceae, viz., *Metasequoia, Cryptomeria, Sequoia, Sequoiadendron, Glyptostrobus* and *Taxodium*, share a number of pollen features, they are difficult to differentiate pollenmorphologically, even with freshly-prepared material. Several authors, e. g., Kaeiser, 1939; Campo, 1951; Ueno, 1951, have described modern pollen of the above listed genera, yet did not agree on the size ranges, sculpturing elements, and degree of protrusion and/or curvature of the papilla. However, there is general agreement that the thin papilla does not act as a germ pore, yet creates a zone of weakness that marks the point of rupture of the exines when they are moistened (Ueno, 1951). Accordingly, since the papilla of this type of grain is commonly destroyed, distorted or covered in dispersed fossil pollen, many paleopalynologists refer to this palynomorph by the artificial name *Taxodiaceaepollenites* Kremp. Since Potonié (1967) has recently discussed and illustrated (see his Pl. 17) the problem of attempting to reliably identify fossil taxodiaceous pollen, there is no necessity for me to cover the same ground. Because I found no fossil staminate cones of *Metasequoia* (from which pollen might have been extracted), I have chosen to take the more cautious nomenclatural approach and refer to my taxodiaceous grains by the artificial name *Taxodiaceaepollenites.* This decision was

made despite the fact that these palynmorphs were recoverd from the same matrix as the macrofossils of *Metasequoia*.

DISCUSSION

Despite the rather indifferent preservation and the paucity of my gymnosperm fossil specimens, Chaney's (1968) tentative identification of the presence of Taxaceae in the Shihti Formation of Taiwan can be ruled out. In the first place, Taxaceae with flattened needles (*Taxus* and *Torreya*) are characterized by the possession of single fleshy ovules, not cones. Furthermore, the spirally-arranged needles of the taxads are much larger, thicker, and have a heavier cuticle than most of the taxodiad leaves. The shoot axes of my specimens are extremely slender (<1 mm), a feature shared with *Taxodium*, but not with *Sequoia*. However, although admittedly a type of negative evidence, fossil remains of *Taxodium* have never been found in Asia (Florin, 1963), despite numerous investigations of Tertiary plants in that region. In addition, the ovulate cone scales in *Taxodium* are spirally arranged and deciduous, whereas the cone scales on my specimen are decussate and persistent. In the absence of the long naked stalk (which characterizes *Metasequoia*), only the decussate nature of the scales distinguishes ovulate cones of *Metasequoia* from *Sequoia*. Nevertheless, Chaney (1950) states that *Sequoia* cones are commonly persistent, thus are often found attached to leafy shoots, whereas *Metasequoia* cones are deciduous. Although Chaney (loc. cit.) claims that *Metasequoia* leaves are blunt at their tips (not acicular as in *Sequoia* and *Taxodium*,) this is seen to be a variable feature, not only in living specimens, but also in his own illustrations of putative fossil specimens of *Metasequoia*. Finally, leaves of *Sequoia* are strongly decurrent, whereas those of *Metasequoia* are only weakly so, a further reason for identifying my mtaterial as *Metasequoia*.

Comparisons were made with the Cretaceous Alaskan conifer, *Parataxodium*, described by Arnold and Lowther (1955). Although the basic ovulate cone morphology and size are close to those of my specimen, differences in leaf shape and prominence of the midrib in *Parataxodium*, as well as its Arctic distribution, would seem to negate the possibility that this genus once occurred in Taiwan.

To my knowledge, Rouse (1962) is the only palynologist to have formally described fossil *Metasequoia* pollen. He designated *M. papillapollenites* for a spheroidal grain, finely granulose, 24–26 μ in diameter, and with a papilla 3 μ long from the Eocene Burrard Formation of British Columbia. His illustration and description of this species compares favorably with the grain shown in my Figure 4, with the exception of the smaller size (18 μ) and shorter papilla in my specimen.

Simpson (1949) published a short note regarding fossil pollen of the *Metasequoia* type from a Tertiary coal in Scotland. However, the exines in his illustrated forms appear to be too thick and coarsely granular to verrucate, rather than thin and psilate, which is more characteristic of *Metasequoia* pollen.

A large number of pollen species with taxodiaceous features from the Tertiary of Europe are described and illustrated by Krutsch (1971) under the generic epithets *Inaperturopollenites* and *Sequoiapollenites*. However, it would seem to serve no useful purpose to attempt to match my Taiwan palynomorphs with these European forms, due to the extreme variation of taxodiaceous pollen, both extinct and extant. It is presumed that my grains are similar to the palynomorphs previously listed as occurring in the Shihti Formation of Taiwan by Ling (1965) under the name *Inaperturapollenites*, although he did not describe its morphological features. Nevertheless,

I still favor applying the more indicative (yet noncommittal) name of *Taxodiaceae-pollenites* to my Miocene forms from Taiwan.

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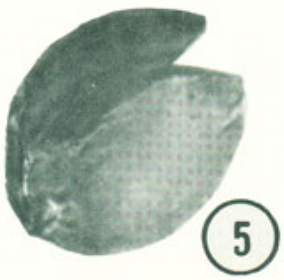

Fig. 1 *Metasequoia occidentalis* (Newberry) Chaney.
Terminal portions of two leafy short shoots, ca. X3.

Fig. 2 Portion of previous figure, only inverted and slightly enlarged. Arrows in Fig. 1 and 2 indicate sites of most conspicuous pairings of the needlelike leaves.

Fig. 3 Compression of ovulate cone of *Metasequoia* X 3. 5.

Fig. 4 Polar view of ***Taxodiaceaepollenites*** showing psilate exine and flattened papilla. (18 μ) Shihti Fm. (M. Miocene).

Fig. 5 Equatorial view of ruptured grain of ***Taxodiaceaepollenites.*** (27 μ in polar dimension). Shihti Fm.