162. *Protosequoia* (n. g.) in *Taxodiaceae* from *Pinus trifolia* Beds in Central Honshu, Japan

By Shigeru MIKI

Mukogawa Women's Univ., Nishinomiya City, Hyogo

(Comm. by Hitoshi KIHARA, M. J. A., Oct. 13, 1969)

In my previous paper,³⁾ I have reported the occurrence of *Meta-sequoia* and *Sequoia* among the fossil remains from *Pinus trifolia* Beds in Central Honshu, Japan. Later⁴⁾ a new species of *Sequoia-dendron* was described from the same source. It was named *Sequoia-dendron primarium*. Recently, well preserved fossil remains of *S. primarium* from the same beds were collected in large amounts for a more thorough investigation. Described at first as a new species of *Sequoiadendron* these fossils appeared to have the same evergreen character and spiral arrangement of cone scales and leaves as *Sequoiadendron* and *Sequoia* but they differed from the two genera and also from *Metasequoia* in having convex cone scales, cuspidate bracts, indistinct seed wings and an abscission layer at the base of the branching shoots.

Therefore it seems justified to establish for these fossils a new genus, *Protosequoia* (n.g.).

A) Characteristics of the fossil remains. a) *Morphology*. The cone is elliptic or orbicular, 10–15 mm long and 10–12 mm wide, with a short, thick peduncle, 5 mm long and 3 mm wide, attached to the top of lateral twigs. The phyllotaxis of the cone scales is in 2:3 conjugated parastichous rows (Fig. 1 Da). The outside of the cone scale is convex (Fig. 1 E, Fig. 2 Ac) with many stomata on the surface (Fig. 1 Fb, Fig. 2 Ad). The bract is cuspidate judging from young cones (Fig. 1 C, Fig. 2 Aa–b).

Staminate strobiles are on the top of the lateral twigs; they are small, 3 mm long and 2 mm wide (Fig. 1 H). The seed is obovate, 4–5 mm long and 3 mm wide, without distinct wings and its surface consists of polygonal cells (Fig. 1 G).

The shoots, about 15 cm long, 3–4 mm wide, have an expanded base and many twigs in their upper part (Fig. 1 Aa). Leaves, which are scaly or subulate (1–4 mm long, 1 mm wide), are attached to shoots spirally. The epidermal cell wall is not undulated. Stomata on the upper side of leaves are arranged irregularly around the vein (Fig. 1 B).

b) *Habit*. The fossil remains were judged as evergreen from

Fig. 1. *Protosequoia primaria* (Miki) Miki n. g. n. comb. from *Pinus trifolia* Beds Akadzu, Seto City (except Cc from Osusawa, Tokitu City). Scales in mm.

A Shoot with a female cone (a), shoots with swollen base (b, c, d, e)
a, b, c, d, $\times 1$, e $\times 0.8$

B Stomata on leaf $\times 48$

C Young cones showing a cuspidate top of bract (a $\times 1$, b-c $\times 1.6$)

D Mature cone $\times 1$; Underside view showing the phyllotaxis of cone scales (a), Lateral view (b-c)

E Cone scales seen from above $\times 1$

F Section of cone (a $\times 1$) and stomata (b $\times 48$)

G Seed: a $\times 1.6$, b Seed coat enlarged $\times 48$

H Twig with staminate flowers (a $\times 1$), b Enlarged (a part of a marked with an arrow showing two male cone scales) $\times 12$

Fig. 2. Cone of *Protosequoia* and living *Sequoia*. Scales in mm.

A *Protosequoia primaria* (Miki) Miki

a-b Young cones $\times 2$, c Top of cone scale showing many branched xylem $\times 15$, d Epidermis of cone scales with stomata $\times 60$

B Living *Sequoia sempervirens* Endl.

a Aristate bracts on a young cone $\times 2$, b Section of cone $\times 1.2$, c Depressed top of a cone scale $\times 15$, d Epidermis of a cone scale without stomata $\times 60$

the scale leaves which consist of thick epidermal cell walls. Growth of the shoot was judged to be continuous from the lateral formation of male and female cones and the absence of winter buds. However the lateral shoots seem to fall in the autumn due to an abscission layer, as the swollen base of the branches and flat separation faces indicate (Fig. 1 Ab-e). This character might have been acquired by adaptation to the climate, smaller precipitation and cold winter. The characteristic such as the separation of lateral branches in autumn at the base is observed also in living *Glyptostrobus*, which grows well in marshes.

Seeds are supposed to mature in the autumn of the same year, since some ripe cones are found attached to the deciduous twigs (Fig. 1 Db).

B) Relation to allied genera. The differences between the fossil remains and living *Sequoia*, *Sequoiadendron* and *Metasequoia* are given in the following table.

C) Description of *Protosequoia* (n.g.). The fossil remain resembles more closely *Sequoia* and *Sequoiadendron* than *Metasequoia*, as

Table I

	Fossil remains	<i>Sequoiadendron</i>	<i>Sequoia</i>	<i>Metasequoia</i>
Phyllotaxis of cone	2 : 3	3 : 5	2 : 3	Decussate
Cone scales	Convex, thick	Depressed, thick	Depressed, thin	Depressed, thin
Tip of bract on cone	Cuspidate (Fig. 2 Aa-b)	Acuminate	Aristate (Fig. 2 Ba)	Acuminate
Stomata on cone	Many (Fig. 2 Ad)	Many	Absent or rare (Fig. 2 Bd)	Absent or rare
Cone size and maturing of seed	Small (Same year)	Large (Second year)	Small (Same year)	Small (Same year)
Leaves	Scaly, evergreen	Subulate, evergreen	Pinnate, evergreen	Opposite-pinnate, deciduous
Male strobiles	At top of twig	At top of twig	At top of twig	Axile, spike
Stomata on leaves	Upper side, irregular	Upper side, irregular	Underside, Parallel (except scales)	Underside parallel
Membrane of epidermal cells	Straight	Straight	Straight	Wavy
Abscission layer	+ (Branch) (Fig. 1 A b-e)	—	+ (Twig)	+ (Twig)

Fig. 3. Three genera in *Sequoieae* (schematic representation)

A Fossil remain of *Protosequoia primaria* (Miki) Miki (n. g. n. comb.)

B Living *Sequoia sempervirens* Endl.

C Living *Sequoiadendron giganteum* Buchh.

a Seed, b Cone scales, c Tip of leaf.

shown in the table (Table I). Florin²⁾ and Engler¹⁾ came to the same conclusion that *Metasequoia* should be separated as an independent tribe from *Sequoia* and *Sequoiadendron*.

At a glance the shoot remains look similar to those of living *Sequoiadendron* by continuous growth, but it differs from *Sequoiadendron* by abscission of branches from the base and some characteristics of the cone. The cone remains resemble as to their shape *Sequoia* but differ from it by formation of cones on the top of lateral twigs, the convex cone scales, cuspidate bracts, and many stomata on the cone scales. The differences among three genera in *Sequoieae* are shown in Fig. 3 diagrammatically.

The remains resemble in some characteristics two living genera of *Sequoieae* but are not identical with them. I consider the fossil remains to be more primitive than the two living genera, judged from the large portion occupied by the bracts on the cone scales and no formation of special winter buds. Therefore, I named the fossil remains *Protosequoia* (n.g.).

Protosequoia primaria (Miki) n.g. n. comb. *Sequoiadendron primarium* Miki in Bull. Mukogawa Women's Univ., 13, 1.

Shoot with abscission layer at the base, absence of winter buds, leaves scaly or subulate, arrangement of stomata on upper face of leaves irregular in relation to the vein. Membrane of epidermal cells not undulated.

Cones elliptic or orbicular 10–15 mm long, 10–12 mm wide, attached to the top of the lateral twig, phyllotaxis of cone scales in 2:3 conjugated parastichous rows. Outside of cone scales convex, cuspidate bracts and many stomata on the surface. Staminate strobiles attached to the tope of lateral twigs, 3 mm long, 2 mm wide. Seed obovate without distinct wings, 4 mm long, 3 mm wide.

Habitat. *Protosequoia* is presumed to have grown in inundated places in the delta region, judging from deciduous lateral shoots which separate at the base in autumn by abscission layer and association with many annual water plants such as *Eoeryale*, *Eotrapa*, *Hemitrapa*, *Trapella* and *Trapa*.⁵⁾

Nom. Jap. Numa-sequoia. (Nov.). The author wishes to express his gratitude to Dr. Ralph W. Chaney for giving many valuable materials of living *Sequoia* and *Sequoiadendron*.

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