A Fossil Wood of Sequoia from the Tertiary of Japan.[1]

BY

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With Plate IV.

THE Aichi-Gifu coal-field, situated in the middle region of Hondo (the main island of Japan), belongs to the Tertiary, and the lignitic coal from this field contains large quantities of wood belonging for the most part to the *Cupressinoxylon* type. The identification of woods and even genera of living Cupressineous types, as was long ago pointed out by Goeppert, is extremely difficult, and in most cases quite impossible in view of the simplicity of organization of *Cupressinoxyla*. The genus, which can be most definitely diagnosed, is one which is characterized by a unique reaction to wounding. The material which I am about to describe fortunately shows modifications of structure, such as, in living material, are formed as a response to injury, and this evidence, together with other and normal structural features, supplies a sufficiently exact diagnostic description.

Sequoia hondoensis, sp. nov.

Gross Features.

The wood is dark reddish brown in colour, and the annual rings are very narrow but quite distinct, particularly with the lens. The narrowness of the annual increments, as will be shown later, is due to a considerable extent to the action of fossilization on the width of the ring. Making allowance for the exiguity of the zones of woody growth resulting from the conditions accompanying lignitic transformation, it must still be conceded that in life the annual rings were narrow, as would be the case in the later development of an old tree. From the somewhat frequent occurrence of alternate pitting in the tracheides of our specimen, it seems not unlikely that it was derived from the root system of the prehistoric tree. Our specimen was too small and too much distorted to permit of any accurate inference in regard to the diameter of the trunk from which it originated. Traumatic resin canals reveal their presence by thin white lines running across the specimen tangentially in distant annual rings.

[1] Contribution from the Laboratory of Plant Morphology of Harvard University.

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Microscopic Organization.

Pl. IV, Fig. 1 shows a transverse section of the wood in the region of a line of traumatic resin canals. The spring tracheides by reason of the thinness of their walls have usually almost entirely collapsed as a result of the maceration and crushing accompanying fossilization. The summer fibres by contrast, on account of the greater resistance to obliteration offered by their much thicker walls, are still largely intact. As indicated above, the growth rings are rather thin, and the transition from spring to summer wood somewhat abrupt. By attentive examination it may be seen that the tracheides of the summer wood are provided with tangential pits. The 'resin cells' are very prominent, and are scattered through the spring and summer wood. The rays are less clearly seen, and as a sequel of compression appear as meandering lines always uniseriate. Occasionally dark resinous contents may be distinguished in the cells of the rays, similar to those occurring in the parenchymatous elements of the wood. In length the ray cells correspond to from two to four tracheides. About one-third of the distance from the top of the figure appears a tangential row of traumatic resin canals, resembling the similar structures in the two living species of *Sequoia*, namely *S. gigantea* and *S. sempervirens*. As my specimen is merely a fragment from a large trunk, it does not show the region of actual injury, but the sporadic and abnormal appearance of the secretory canals under discussion appears to leave no doubt as to their traumatic origin.

Pl. IV, Fig. 2 shows the traumatic resin canals and the surrounding cellular elements, somewhat more highly magnified. The resiniferous cavities are, as in the case of the species of the living genus, surrounded by secretory cells, which are to a very limited extent characterized by the dark brown contents, which mark the so-called 'resin cells' of the wood. The resiniferous elements, in fact, in the case of traumatic resin canals in both living and extinct species of *Sequoia* are comparable rather with the resin-secreting cells surrounding the resin ducts of the wood of the Abietineae, than with the longitudinal parenchymatous strands of Cupressineous woods. Certain of the short cells in proximity to the resin canals are neither resiniferous elements nor 'resin cells', but are short tracheides of the type to which Penhallow gives the name 'parenchyma tracheides'. They in fact correspond very accurately to the structures shown in Text-fig. 40 in his 'North American Gymnosperms'.[1] Attentive examination of this figure shows the bordered pits in the transverse end walls of cells of this type.

Pl. IV, Fig. 3 illustrates the radial view of the wood under discussion. In the centre the abundant parenchyma (only a small part of which consists

[1] Penhallow, D. P.: North American Gymnosperms, Boston, 1908, Text-fig. 40, p. 126.

of true 'resin cells') surrounding the traumatic resin canal can be readily distinguished. A close study reveals septate tracheides ('parenchyma tracheides' of Penhallow) in a more lateral position. The resiniferous space is obviously discontinuous and fistular in the longitudinal direction, as is commonly found to be the case with traumatic resin canals in the living representatives of the Coniferales. Pl. IV, Fig. 4 reproduces the upper region of the foregoing, more highly magnified. A row of short tracheary elements can be discerned a little to the left of the secretory space. Farther to the left lies a row of 'resin cells'. In Pl. IV, Fig. 5 is exhibited a radial view of the uncollapsed spring wood, and at the same time a tangential section of the summer tracheides. This unconformable arrangement is the result of the distortion accompanying fossilization. In our species the radial pits of the walls of the tracheides are usually in a single row in the summer elements, and are frequently biseriate and opposite in the broader tracheides of the spring growth. These pores are round or oval in shape. The lateral pits of the rays are oval with a distinct border, a feature considered by Penhallow to be of diagnostic value for the genus *Sequoia*. Pl. IV, Fig. 6 shows the 'bars of Sanio' in a spring tracheide, much magnified. They present an unusual condition, for Haidenhain's haematoxylin stains them a deep blue as in recent material of *Sequoia*, showing that the pectic cellulose has here for some reason maintained its position and not been macerated away, leaving an empty space, as is more usually the case in fossil coniferous woods, both Mesozoic and Tertiary. It is difficult to imagine why such delicate features have in this case been preserved. Possibly the large amount of tannin present in the cell-wall has acted inhibitively on the common pectic dissolution. The distinct presence of 'bars of Sanio' clearly fixes the general systematic position of our fossil. It has been pointed out by Jeffrey [1] and Holden [2] that traumatic resin canals may occur in the Araucarian series as well as among those Conifers with immediate Abietineous affinities. A satisfactory criterion for separating such woods in those instances where they manifest traumatic resin canals is the presence or absence of the 'bars of Sanio'. Clearly on this evidence our *Cupressinoxylon* belongs to the general Abietineous series, and since only *Sequoia* here possesses traumatic resiniferous spaces, a reference to that genus is unquestionably indicated. Penhallow was the first to call attention to the presence of resin canals in *Sequoia*.[3] He considered them, however, to be normal features of wood structure, and only noted their presence in *S. sempervirens*. Jeffrey has demonstrated that rows of resin

[1] Jeffrey, E. C.: The History, Comparative Anatomy, and Evolution of the Araucarioxylon Type. Proceedings of the American Academy of Arts and Sciences, vol. xlviii, No. 13, Nov. 1912.

[2] Holden, Ruth: Contributions to the Anatomy of Mesozoic Conifers, No. 1. Annals of Botany, vol. xxvii, No. 107, July, 1913.

[3] Cf. North American Gymnosperms and literature there cited.

canals occur in both the living species of *Sequoia* and that they are due to injury.[1]

The structure of our wood as described above, particularly the pitting of the ray cells, the distribution of the so-called 'resin cells', the presence of 'bars of Sanio', and above all the phenomenon of traumatic resin canals, points strongly to an affinity with the living *S. sempervirens*. Many species have been described as ancestral to or closely related to *S. sempervirens* (the Redwood of the Californian coast range). In 1899 Knowlton gave an account of *S. magnifica* as a fossil form from the Yellowstone National Park, and expressed the opinion that it was the ancestor of *S. sempervirens*, but saw no traumatic resin canals in his material.[2] *S. Langsdorfii* has been elucidated from its vegetative habit for both the European and American Tertiary, and it is recognized as the prototype of the living *S. sempervirens*. In 1908 Penhallow described *S. albertensis* as a lignitoid specimen form of the Edmonton series of Canada, and called attention to its close resemblance to the existing *S. sempervirens*. It is of interest that although he had previously recognized the occurrence of vertical resin canals in the wood of the living Redwood, and had even noted horizontal canals in another fossil species, he failed to observe anything of the kind in *S. albertensis*.[3] With the exception of the three species mentioned, we have no really conclusive diagnosis of woods of extinct species of *Sequoia*. In the three species regarded as probably correctly assigned to the genus on the basis of ligneous diagnosis, *S. magnifica* and *S. albertensis* have not yet been shown to produce traumatic resin canals, and by this defect of diagnosis are still somewhat in a dubious position systematically. It accordingly appears that *S. Langsdorfii* (as defined by Penhallow) is on the whole the best authenticated Mesozoic *Sequoia*, although the original diagnosis supplies us with no information as to the important feature of the lateral pitting of the ray cells.

A comparison with *S. sempervirens* and *S. Langsdorfii* indicates that our fossil has a somewhat closer relationship with *S. sempervirens* than the other species. Because it is a fossil and its geographical occurrence is remote from that of the living Redwood (*S. sempervirens*), it seems advisable to assign a new specific name after its place of origin.

The diagnosis of *Sequoia hondoensis*, sp. nov., is as follows:

Transverse. Growth rings clearly defined; transition from spring to summer wood somewhat abrupt; summer wood very prominent, and of from two to ten tracheides in breadth. Spring wood very open and with thin-walled tracheides. Resin cells prominent and scattered throughout

[1] Jeffrey, E. C.: The Comparative Anatomy and Phylogeny of the Coniferales. Part I. The Genus *Sequoia*. Memoirs of the Boston Society of Natural History, vol. v, No. 10, Nov. 1903.

[2] Knowlton, F. H.: Description of Known Fossil Plants from the Laramie of the Yellowstone National Park. Mon. U. S. Geol. Surv., No. xxxii, Part II, p. 761, Pl. CXL, 1899.

[3] Penhallow, D. P.: Report on a Collection of Fossil Woods from the Cretaceous of Alberta. The Ottawa Naturalist, vol. xxii, No. 4, July, 1908.

the wood. Medullary rays somewhat prominent and uniseriate, distant by two to ten or more rows of tracheides.

Radial. Ray cells rather straight, somewhat resinous, equal to two to four tracheides; horizontal walls thick and without pits, terminal walls thin and unpitted, lateral walls with large oval narrowly bordered pits, two to six in number per tracheide and generally in two rows; radial pits of the tracheides round or oval in one or two rows and then opposite; 'bars of Sanio' prominent and staining strongly in haematoxylin.

Tangential. Rays somewhat resinous and from two to eleven cells high. Bordered pits on the tangential walls of the summer tracheides small and in one or two rows. Traumatic resin canals absent in the horizontal plane, and as a consequence seen only in the radial and transverse sections.

The traumatic resin canals occur in tangential series in remote annual rings. They are surrounded by strongly pitted parenchyma cells, with a few so-called 'resin cells', and more externally by septate tracheides (the 'parenchyma tracheides' of Penhallow).

The occurrence of the wood of a fossil *Sequoia* in the Tertiary of Japan completes in an interesting way the evidence for the existence of that genus in Cenozoic time throughout temperate regions of the whole Northern hemisphere. The ligneous structure of *S. hondoensis* also adds somewhat to our knowledge of the phylogeny of the Coniferales. The question of the presence of the genus *Sequoia* in the Mesozoic period need not be raised in this connexion, although it has been pointed out by Professor Jeffrey and his students that it is extremely doubtful if our modern genus antedated the Tertiary, since the types referred to it in the Cretaceous are clearly not anatomically in agreement with the living genus, and do not exhibit even the organization of the *Cupressinoxylon* type.

At the present time there are two opposed views in regard to the phylogenetic position of the *Cupressinoxylon* type of wood. One school recognizes this type as young among the Coniferales and as ancestral to the *Pityoxylon* type characteristic of the Abietineae. A more recent view, for which Professor Jeffrey is sponsor, is that the simpler type of wood found in *Sequoia* and its allies has originated as the result of simplification and specialization from the ligneous type characteristic of *Pinus* and related genera. The genus *Sequoia* stands always at the critical point in these two opposed hypotheses. The study of the living *Sequoia* appears to have made it clear that the view which regards it as more primitive than the Abietineae is due to the error of mistaking the resin canals which occur in the wood of *Sequoia* as a normal feature of structure instead of as the result of traumatic reaction. The discovery in the Mesozoic of Japan of a member of the genus manifesting the same interesting abnormality of the presence of ligneous resin canals appears to furnish another good proof of the derivation

of *Sequoia* from types characterized by the normal occurrence of resin canals in their woods—that is, from the *Pityoxylon* type.

Summary.

1. A wood occurring in the lignitic Tertiary coals of the Aichi-Gifu coal-fields of Hondo is clearly closely related to *Sequoia*, both on the grounds of its traumatic and normal characters.

2. The presence of this type of lignitic remains is further evidence for the widespread distribution of the genus *Sequoia* in the Tertiary of the Northern hemisphere.

3. It supplies confirmation for the hypothesis that the *Sequoias* have come from pine-like ancestors.

DESCRIPTION OF PLATE IV.

Illustrating Professor Kono Yasui's paper on a Fossil Wood of *Sequoia* from the Tertiary of Japan.

Fig. 1. Transverse section of wood of *Sequoia hondoensis*. × 40.

Fig. 2. Transverse section of wood of *Sequoia hondoensis*, showing traumatic resin canals more highly magnified. × 125.

Fig. 3. Longitudinal view of same. × 60.

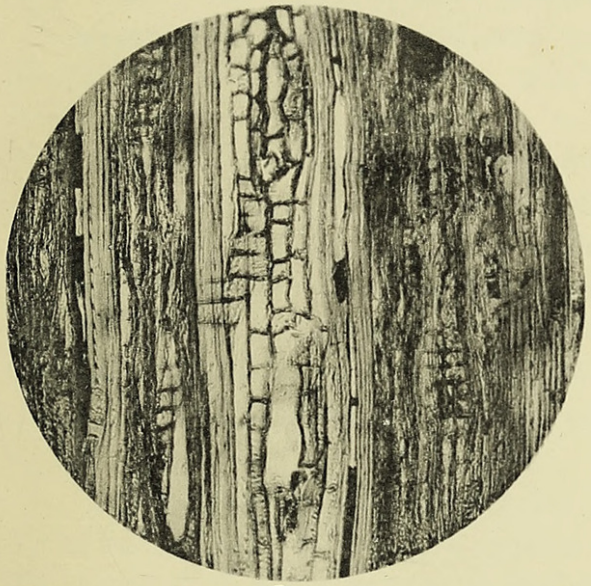
Fig. 4. Longitudinal view of part of the foregoing more highly magnified. × 125.

Fig. 5. Longitudinal, approximately radial, view of the same. × 60.

Fig. 6. Longitudinal section of tracheid of the same, showing 'bars of Sanio'. × 500.

1.

2.



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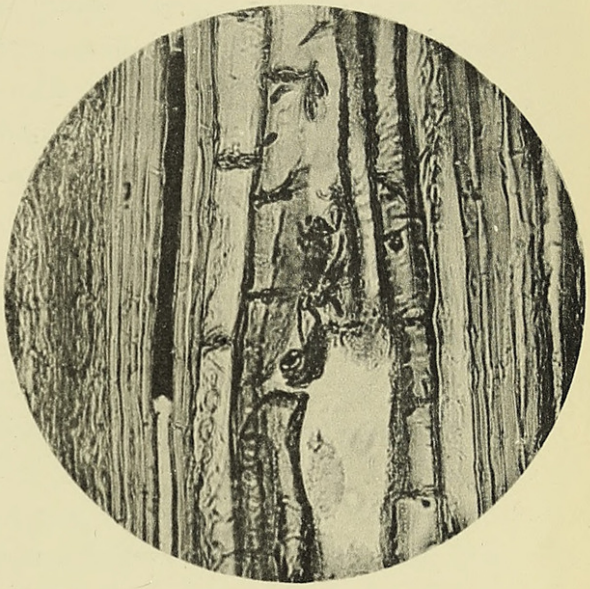

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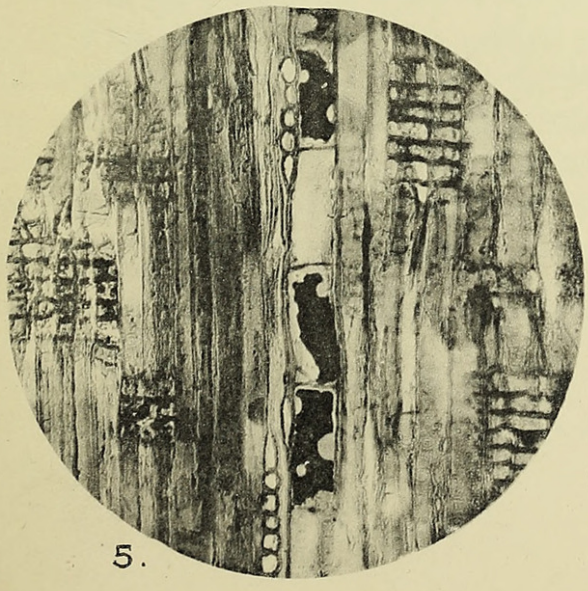

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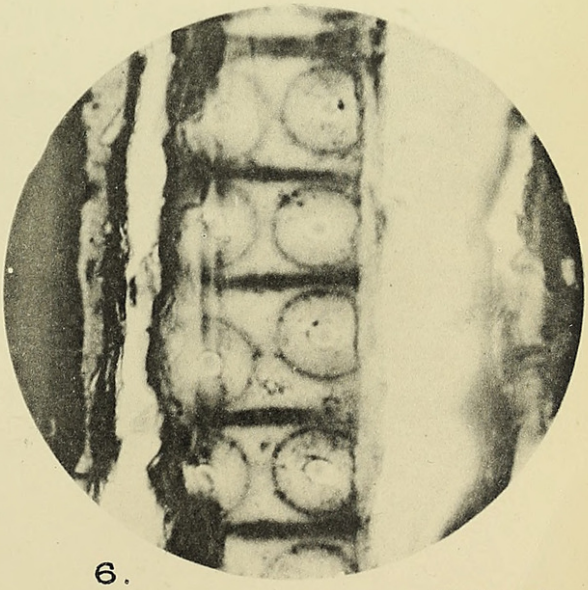

6.

Huth. coll.

YASUI — A TERTIARY SEQUOIA.