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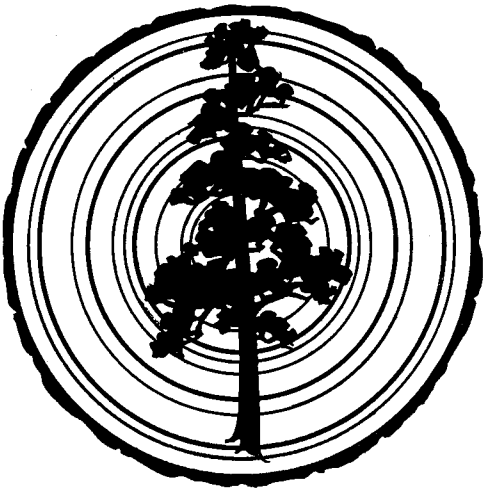

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DENDROCHRONOLOGY IN MEXICO, I.

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Though many inviting problems make a dendrochronologic survey of Mexico very appealing, no conclusive study has yet appeared for that country in spite of the activity of the past 40 years in this field centered at Tucson. Not the least of the obstacles to such an investigation has been the difficulty in analysis of ring chronologies in southern Arizona itself which have only recently been surmounted.

With the convening in Mexico City of the Third Round Table Conference of the Sociedad Mexicana de Antropología in September, 1943 ,an opportunity presented itself to initiate such a study. To Dr. Alfonso Caso and Dr. D. F. R. de la Borbolla for their interest and cooperation are due many thanks. The writer is grateful to Mr. A. W. Edelen, Jr. for personal aid, and to Mr. Clarence H. Cooper of the Durango Lumber Company at El Salto, whose placing of various transportation facilities at his disposal made possible the necessary selection of proper sampling sites.

INTRODUCTION*

A. *Objectives:* (1) to set up, with a length and reliability as great as possible, a tree-ring index of variation in precipitation, temperature, river runoff, or any other element which may be related to variations in seasonal ring-width, and (2) to construct a master calendar or ring spectrum, which will make it possible to precisely date the year of cutting of beams in ancient structures of Mexico.

B. *Requirements.* Since a tree-ring calendar can be safely used only if it has a reasonably clear physical interpretation, it is necessary first of all to thoroughly study living trees. Wide selection is then possible so that ring growth under various environments may be studied, the more-or-less complete range of ring types set up, and some explanation, environmental or otherwise, proposed for these types. Instrumental records of climate for the recent decades make possible some comparisons with concurrent tree growth: tests of expected climatic dependencies of such growth in selected environments. Specific requirements are:

1. Sampling of *selected* living trees and determination of those species and environments which yield the most significant and longest chronologies.
2. Preparation of the material so that difficult ring sequences may be studied by sufficiently accurate quantitative methods.
3. Analysis of the ring spectra, *uniquely* solving all problems in dating related to non-annual and locally-missing rings.
4. Reduction of the ring series to growth curves.
5. Analysis of the rings and of the mean areal curves in relation to the environmental factors to determine the physical significance of the fluctuations in chronology.

*For background material see the files of the Tree-Ring Bulletin; archaeological dating is treated especially in A. E. Douglass, Dating Pueblo Bonito and other Ruins of the Southwest, National Geographic Society Tech. Papers, P.B.S. No. 1, 1935.

6. Derivation of a master chronology, which may be generally applicable to a relatively homogeneous climatic region but which indicates the expected local deviations from and variations in that chronology.

C. *Special problems.* There seems to exist in certain species of almost all extra-tropical regions of the earth what may be called a fundamental regional ring chronology, of highly different quality, consistency, and areal extent in different climatic regions. This chronology is recorded more clearly in some trees than in others; in the dry Southwest the qualities of crossdating and sensitivity are closely related to each other and to particular species within the forest conifer zones on specially dry, and thus severe, growth sites.

Only in recent years have completely satisfactory chronology specimens been obtained in southern Arizona, in contrast to the long available chronologies farther north. This latitude difference is traceable to the longer growing season and increased effect of the summer rains in the more southerly areas which results in excessive "doubling" of rings and other irregularities in stem growth, particularly in pine. By recourse to Douglas fir (*Pseudotsuga taxifolia* or *P. mucronata*), which in the dry Southwest seeks the higher, more moist, and shaded sites, this factor is largely eliminated.

Some specific problems in Mexico are:

1. Does the superiority of Douglas fir as a source of chronology hold good and, if so, to what most southerly latitude?
2. What new species are usable for chronology?
3. Does the summer rain maximum intensify false-ring formation?
4. Is modification needed for the criteria for selection of sensitive records as developed in the dry Southwest?
5. Does the characteristic spottiness of summer storms result in highly localized ring chronologies?
6. How far south does the Arizona chronology extend?
7. How are the progressive changes in ring chronology with increasing distance from the Southwest related to the changes in the relevant climatic elements?

Numerous problems of a particular archaeological nature, such as the availability of various species in the ruin material and the bridging of the gap between modern and ancient chronology, will require serious consideration in future stages of this study.

THE RECENT RING CHRONOLOGY IN DURANGO

The Durango area was selected for this first study for several reasons. Work in the Southwest indicated that the adjacent Mexican states of Chihuahua and Sonora, with much similarity in climate, would almost certainly yield ring chronologies of similar datability. Farther south in Durango, however, the excessive dominance of the summer rains and the low latitude suggested that the tree-ring material found there might be of a new type. At the same time, nearness to desert-like areas suggested that a drought relationship might appear in selected trees.

D. *Collections**. Although Douglas fir, the most advantageous species to

*The field work was greatly aided by members of the Durango Lumber Company staff: Assistant Manager Clyde Arne, Engineer J. Fernández, Engineer Tec, and especially the student engineers Luís Sanchez Mejorada and David Gonzales.

Relevant data are found in:

P. C. Standley. Trees and shrubs of Mexico. U. S. National Herbarium Contrib., *23*, Parts 1-5, 1920-26.

C. E. Blanco. Los pinos de Mexico. Boletín del Depart. Forestal y de Caza y Pesca, No. 11, 237-255, 1938.

M. Martinez. Tres especies nuevas mexicanas del genero abies. Anales del Instituto de Biología, *13*, 621-634, Mexico, 1942. Prof. Martinez has in ms an extensive study of trees in Mexico (personal conversation).

H. A. Meyer and C. T. Saldaña. Estudio sobre la constitución normal de los bosques vírgenes del Estado de Durango. Boletín Forestal, no. 9, 125-154, 1938.

H. A. Meyer. Forestry in Mexico. Chronica Botanica, *6*, 395-399, Nov., 1941.

use for chronology studies in the Southwest, is found also in Mexico, it exists only in relatively rare, scattered patches. Its range, however, is almost the entire Sierra Madre Occidental, and the Sierra Madre Oriental as far south as latitude 19° in the state of Puebla. In this first reconnaissance three well-distributed groups of this species were sampled during August, 1943, in the high forests about El Salto (lat. 23° 46′ N, long. 105° 22′ W), in Durango State, about 60 miles northeast of the Pacific coast city of Mazatlán and some 600 miles south of the border at El Paso, Texas. One increment boring from the uphill side of each tree was obtained. Supplemented by pine borings, these groups were found to provide a firm basis for the modern anchor of a projected master chronology for this region.

Some preliminary observations on other species in central and southern Mexico are discussed in Section G.

El Salto South group: A small stand of Douglas fir, in a west-east tributary of Quebrada Chapultepec, at an elevation of about 8000 feet and some 8 miles south of El Salto. The comparatively moist conditions of this north exposure permitted the growth also of *Pinus ayacahuite*. Other trees represented were *Juniperus* sp. ("taxcate"), *Quercus* spp. (the several species of oak were characterized by very tall branch-free boles, in great contrast to the scrubby oaks of the Southwest), *Abies durangensis* ("oyamel"), madroño, and "aile;" the relatively dense ground cover of ferns and other growth emphasized the locally-favorable moisture conditions. The drier sunny slopes nearby were dominated by various species of yellow pine. The clayey soil was however very thin, as shown everywhere by the bedrock outcrops (rhyolitic, andesitic). Five relatively slow-growing firs were sampled on the steepest slopes near the head of the canyon. One specimen of *Abies durangensis* and two of *Pinus durangensis* were also procured; the latter, proving to represent young trees, were not used.

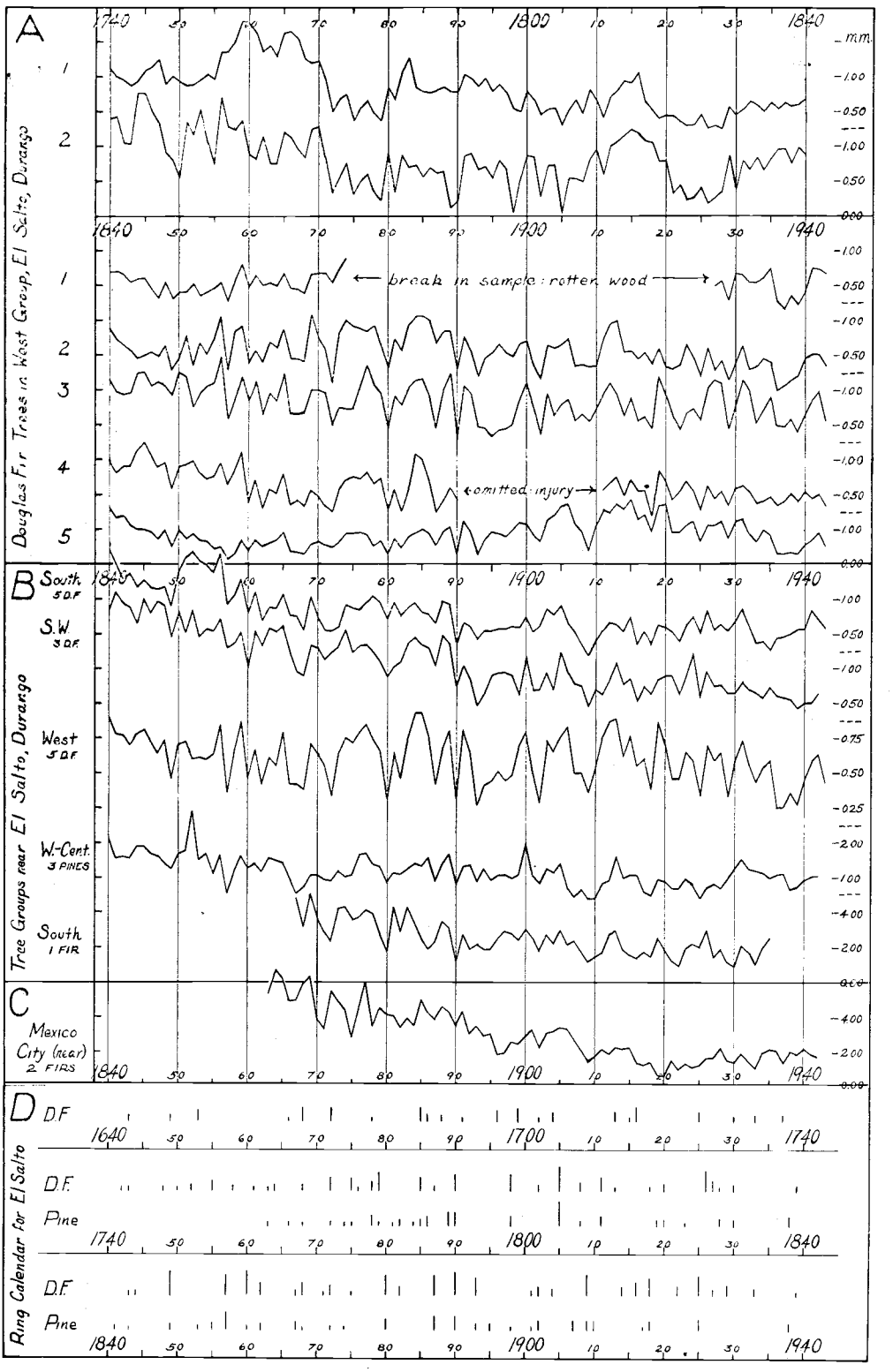
El Salto Southwest group: Three large Douglas fir logs in the lumber yards at El Salto. These trees, cut in the spring of 1943, came from an area about 10 miles southwest of El Salto near the highest part of the local range. Although the immediate environment of these trees was impossible to determine it was probably similar to that of the West group.

El Salto West group. A somewhat inaccessible, but unusually heavy local stand of Douglas fir at an elevation of 8500 feet in Quebrada de la Huisache, some miles by horseback west-southwest of the lumber camp of Campana and about 15 miles airline west of El Salto. The forest association is similar to that of the South group, the even more moist conditions being evidenced perhaps by the presence of "cedro" (*Cupressus thurifera?*). Five Douglas firs along the upper rim of the canyon only, as well as two yellow pines, were sampled. The soil here is very thin and andesitic outcrops are everywhere, but lower down in the steep north-facing canyon wall could be seen some very large Douglas fir trees, probably fast-growing in the more continuously moist and deeper soil.

El Salto Central group. A number of species of pine were sampled on various sites in the immediate vicinity of El Salto, particularly along the upper slopes of the Quebrada El Salto. In this area pine is dominant; also present are much oak and an occasional juniper. The record from one *P. teocote* core was merged with that of the two samples of *P. durangensis* in the West group to form the west-central group (see Section F).

E. *Chronology in Douglas fir.* Although no specimens of this species were found whose sensitivity equalled that of the drought-stunted firs of the Southwest, every core secured was readily crossdated.

The growth curves of the individual trees of the El Salto West group are plotted in Panel A of the figure and show the definitive nature of the crossdating between these trees during the interval 1840-1943.


A
Douglas Fir Trees in West Group, El Salto, Durango
1740
1800
1840
1900
1940
mm.
1
2
1
2
3
4
5
← break in sample: rotten wood →
← omitted injury →
B
Tree Groups near El Salto, Durango
South 5 D.F
S.W. 3 D.F
West 5 D.F
W.-Cent. 3 PINES
South 1 FIR
C
Mexico City (near) 2 FIRS
D
Ring Calendar for El Salto
D.F
D.F.
Pine
D.F.
Pine

Locally-absent rings were noted for only three of a total of 2700 rings in 13 specimens. This rarity of locally-absent rings seems to be related (1) to the generally sufficient moisture in almost all years for at least a small amount of cambial activity on all radii of young and mature trees, and (2) to the failure to locate over-age trees (400-500 years old or more).

False annual rings, while numerous in many specimens, are of the easily-identified "Douglas fir type" so characteristic of this species in southern Arizona and in some supersensitive groups farther north.

The number of extremely deficient growth years is considerably less than is characteristic of the best chronology material in the Southwest; the uniformity of record or crossdating is substantially less but is nevertheless better than that of a great many groups of average dating quality in the Southwest.

Panel B indicates that the crossdating pattern in the trees of the West group is general in the El Salto area. A mean group curve has been constructed by direct averaging of individual growth records for each of the three Douglas fir areas sampled. It appears from this graph, and from the experience with a large number of essentially similar complexes throughout western United States, that the chronology here indicated is essentially representative of a much larger region than the 100 sq. mi. or so of the sampling area.

The records of the two oldest trees have been plotted in Panel A for the 1740-1840 century also, and show substantially the same quality of crossdating as indicated in the outside century. The inner score or two of rings of all firs were complacent.

Specimen 1 of the West group illustrates in part the archaeological type of dating. On sampling this tree the increment borer soon encountered a zone of rotted, powdery wood so that the inner part of the core was separated from the short outer piece by a break of unknown time duration. By crossdating with other specimens the outside ring on the larger piece of core was dated at 1874. While the agreement in the graphs from 1840 to 1874 might fix the date tentatively, it requires for finality the assurance of crossdating over the entire range of data, as shown in part on the graph for the 1740-1840 interval. This dating, as all other proper dating, is done directly on the specimen material and is tested by all the manifold peculiarities of ring characters; all secondary material such as skeleton plots, growth curves, and coefficients of correlation can, from the point of view of dating, serve merely to indicate possibilities or illustrate results.

A master skeleton-plot chronology for Douglas fir of the Durango region has been constructed for the interval 1640-1943 on the basis of these collections, and is shown in Panel D. This plot represents a mean of all Douglas fir specimens individually and independently "skeleton-plotted." Eleven trees or more support the record from 1780 to the present, but only three trees enter in the mean chronology preceding 1740.

F. *Chronology in pine.* Numerous species of pine exist in Durango which are apparently unknown in the United States. These appear to fall generally into three groups, however: (1) long-leafed yellow pines similar to *P. ponderosa* var, *arizonica* (*P. durangensis, P. montezumae*), (2) minor species of yellow pine (*P. teocote, P. teocote* var. *macrocarpa, P. leiophylla,* and *P. lumholtzii*), and (3) a white pine apparently similar to sugar pine, *P. lambertiana* (*P. ayacahuite*). In the forests of Durango the yellow pines dominate; extensive pure stands of any one species are rare. The ponderosa-like pines showed the best crossdating possibilities. However, the dozen or so cores from the minor pines could also be crossdated at least in part, but in most cases showed compressed series of rings requiring a dating effort not justified in these preliminary collections. A characteristic of

these species is the very much greater variability in chronology as compared with the Douglas firs of Durango and with the ponderosa pines of the Southwest. Nevertheless, a real chronology which appears to be the same as that in fir does exist in these pines, as shown in the growth curve of Panel B. This preliminary curve represents the mean growth of the only three pines completely dated (see Section D, Central group).

When only the outstanding thin rings are used and a skeleton plot constructed from them the agreement in chronology of pine with Douglas fir is somewhat more conspicuous, as shown in Panel D.

Species in these collections about El Salto included all those above listed except *P. lumholtzii*. Several cores of this species were obtained at Desierto de los Leones near the "cedro blanco" group described below; no crossdating was found.

Missing and false rings both offer serious problems in pine dating in Durango, the former because erratic variations in chronology often make the exact placement of such absences uncertain and the latter because of the extraordinary annual-like character of some false rings. These conditions are merely an accentuation of the difficulties long recognized in the chronology of pines at the lower forest edge in southern Arizona and point to the special caution and effort which will be needed in the interpretation of such material in archaeological dating.

G. *Chronology in some miscellaneous species.* Only a very few samples of species other than Douglas fir and pine were obtained; the peculiarities of record briefly stated below, believed to be generally valid, must thus be considered tentative.

a. True fir, "oyamel" (*Abies* spp.). The chronology in the only specimen of *A. durangensis* obtained near El Salto is shown in Panel B; it is much like the neighboring Douglas firs, but is of rapid growth and complacent character.

A stand of true fir (*A. concolor?*) was sampled at Desierto de los Leones, about 20 miles southwest of Mexico City and some 500 miles southeast of El Salto. These fast-growing firs were found near Cueva Grande, a 50-foot cave in a very moist upland region at 11,500 feet elevation and some four or five miles south of park headquarters. The rings in the two oldest and most slowly growing firs have been measured and averaged to produce the growth curve of Panel C. Though there was faint crossdating in these firs, the very insensitive character of the record is obvious from the figure.

b. White cedar, "cedro blanco," (*Cupressus thurifera?*): This species is of interest partly because it is said to have been used to build the stables of Cortez. Three fine-looking trees were sampled near the convent of the Desierto de los Leones. No crossdating could be obtained. The rings look like those in the undatable Arizona cypress.

c. "Ahuehuete" (*Taxodium mucronatum*): Widely found in the ancient ruins of Mexico, this species shows significant characteristics which make its usefulness for dendrochronology doubtful. It seeks moist sites such as stream banks and its ring record seems to lack circuit uniformity*.

The famous Tule cypress** near Oaxaca, which has been variously reported at 2000 to 4000 years old or more, was examined during September, 1943. The tree grows in a very flat valley and taps the shallow water-table;

*A downed "ahuehuete" in the Bosque de Chapultepec in Mexico City, 30 feet of the basal section of which had been left in place, permitted a complete cross-sectional view of a 425-year ring series. Though its sensitivity was promising, the chronology was highly variable about the circuit. This quality seems, however, to characterize even the best dendrochronologic trees under cultivation.

**C. Conzatti. Arbol de Santa María del Tule. Secretaría de Educación Publica, México, 66 pp., 1921.

the writer is inclined to agree with Prof. Conzatti that its age has been overestimated. A branch section in Conzatti's laboratory at Oaxaca, cut July, 1937, showed a remarkable local wedging-out character of rings apparently similar to that which reduces to meaninglessness the chronology in some specimens of coast redwood, *Sequoia sempervirens*.

The study of the rings of this long-lived species under *natural* and varied environmental conditions would be desirable.

H. *Chronology and climate.* Weather records in the vicinity of Durango were found to be too short to provide any decisive correlations with growth. Such studies must await the collection and analysis of proper tree-ring groups in such well-documented areas as Mexico City.

The higher sensitivity of the records on the drier sites would seem to indicate some relation to precipitation, since this parallels the results in the Southwest.

Examination of Panels C and D of the figure indicate traces of a slight agreement in chronology between El Salto and Mexico City. Somewhat stronger relationships in chronology could be interpreted as present between El Salto and southern Arizona. But the Mexico City group is a very poor one and probably only approximates the chronology of that area; the El Salto-S. Arizona relationship is weak and requires substantiation by some intermediate groups; and thus further field work is required.

I. *Conclusions.* Since the material of this report is very limited no general statement may be made about the climatic significance of tree-rings and the possibilities of dating ruins in central Mexico and elsewhere by their use. Nevertheless, the agreement of the results of this reconnaissance in Durango with the general conclusions of work in the Southwest permits considerable confidence in the eventual success of both the climatic and the archaeologic phase of these studies. Specific conclusions for Durango State are:

1. Douglas fir, as in the dry regions of the United States, yields the most sensitive and consistent tree-ring records.
2. The yellow pines may also be crossdated and used for chronology but are subject on at least some sites to false rings, which may provide considerable difficulties in dating work.
3. "Oyamel" (true fir) is too fast-growing and insensitive to offer much promise of use in chronology (the excellent Douglas fir is also called "oyamel" in some localities). "Cedro blanco" is subject to erratic growth and supernumerary rings which destroy the significance of its ring record as an index. "Ahuehuete" appears to show serious irregularities in chronology, but this species especially requires further study.
4. Groups of Douglas firs, from areas in Durango 20 miles apart, show essentially identical chronologies; thus a general factor or complex, probably climatic, underlies the fluctuations in ring-width so that crossdating over a very much larger, though undetermined, region probably exists.
5. A 300-year "master" chronology for Douglas fir in the El Salto, Durango area has been derived. A parallel but less well substantiated chronology for pine, 180 years long, is found to agree with the preceding in general.
6. The Durango chronology is quite different from that of southern Arizona, as variations within the Southwest itself would lead one to expect.