Colorado. Considerable interest is attached to the date as the log was found in association with cultural material dating from the Basket-Maker II horizon. On carefully reviewing the evidence it seems altogether likely that the log was planted in Basket-Maker II rubbish by later occupants of the area. A ruin not far away (Colorado B:9:1), giving dates very close to 600, was already in a Basket-Maker III stage of culture.

(4) From Group C-3. (See Roberts, F. H. H. Jr., 1930. Early Pueblo Ruins in the Piedra District, Southwestern Colorado. Bureau of American Ethnology, Bulletin 96, Washington, D. C.) Dated by I. F. Flora, checked by E. W. H.

(5) From specimens collected by Earl H. Morris and the undersigned in May, 1936. These partly duplicate an earlier collection made by Morris and dated by Douglass, a summary of which will appear in a forthcoming instalment of this series.

(6) In presenting this date it is realized that almost no tree-ring studies have been made in northern Mexico and that it may therefore be subject to question. But the cross-dating of this 111 year sequence is very satisfactory. This date is given with the hope that it will inspire further work in the area involved.

CLASSIFICATION OF FALSE ANNUAL RINGS IN MONTEREY PINE

By EDMUND SCHULMAN

In a recent volume (whose treatment of wood anatomy would repay reading by workers in all branches of tree-ring analysis) there is found the following definition:(1) "a double ring or multiple ring is due to the interruption of the normal course of growth of a season; one of the zones of growth of such a ring is known as a false annual ring." The main purpose of the present note is to discuss and extend the concept involved in the preceding definition.

Multiple rings may result from a number of causes: Antevs(2) discusses the work of a score of authors, mostly botanists, and mentions damage of storms, damage to growing tip, insect damage, defoliation, girdling, decapitation, specially favorable following unfavorable climatic conditions, and frost. False rings resulting from the first group of six factors have commonly been called injury rings; appearing usually in isolated specimens only, and frequently broken-celled in structure, they are readily distinguishable from the more consistent multiple rings resulting from special climatic eccentricities. Frost, in the climate and consequent growing season of the Pueblo Area, results in an injury ring usually early in the spring. A study of frost rings in Canada by Bailey(3) shows them to be characterized by deformed tracheids and by rays laterally displaced. Bailey emphasizes in this paper a special pest effect—the complete omission of one or more rings.

False rings climatic in origin are those most commonly met with. As a result of observations on the characteristics of ring sequences in the Southwest, criteria have been established by Douglass(4) for the recognition of such false annual rings. The outside boundary of the zone of non-annual late wood is seen to be diffuse, as distinguished from the abrupt termination of the zone of late wood at the end of the annual growing season; the false ring lies inside the true annual late wood, and is thus usually nearer the annual ring following than the annual ring preceding. Douglass has shown that when the winter snows at Prescott, Arizona, are small, the tree may begin to lay down a layer of late wood

(1) Record, S. J. Timbers of North America, New York, 1934. p. 87.

(2) Antevs, E. Die Jahresringe der Holzgewachse und die Bedeuting derselben als klimatischer Indikator, Progressus Rei Botanicae, Bd. V, 285-386, 1917. pp. 326-332.

(3) Bailey, I. W. Frost Rings as Indicators of the Chronology of Specific Biological Events, Bot. Gazette, Vol. 80, pp. 93-101, Sept. 1925.

(4) Douglass, A. E. Climatic Cycles and Tree Growth, Carnegie Inst. Washington pub. 289, Vol. I, 1919, pp. 18-20, Vol. II, 1928, pp. 94-96.

before the end of the usual spring dry period, and gradually resuming normal early wood growth with onset of the summer rains, lay down a double ring for the year. If the snows have been heavy, stored moisture will be sufficient to cross the dry interval, and a large single ring for the year will result. In more moist areas, climatic false rings are likely to be rare.[5] In the South, the late wood is usually a single well-defined and relatively thick zone, and readily permits quantitative studies. Lodewick[6] has found good correlation between the amount of late wood and summer rain.

Half-a-million rings or more, examined at the Tree-Ring Laboratory and mainly from the Southwest, have presented innumerable cases of double rings, all conforming to the criteria stated above. However, in the course of the recent reduction by the writer of a group of Monterey pine specimens collected about Monterey Bay, California, it was necessary to set up new criteria for the recognition and classification of such multiple rings, made necessary by the special Coastal climatic conditions and the type of tree. A report on the details of reduction of this interesting group is in preparation; the resolution of the problem presented by the multiple rings was perhaps the most important feature of it.

The Monterey pine (**Pinus radiata**) is one of the fastest growing of trees; however, while rings in the mature tree not uncommonly reach 10 mm or more in thickness, and growth in the first two decades may average this much per year, with occasional rings as much as 15-20 mm (a diametral increase of 49 mm in one year has been recorded,) the age curve is extraordinarily steep, and the rare specimen attaining the age of a hundred shows rings usually averaging less than 1 mm in thickness.

Extraordinarly fast growth of this sort distinctly favors the development of multiple rings, for such trees may falter in growth as a result of minor adversities, which a more phlegmatic tree or type can take in its stride. The greater frequency of false rings in the younger trees is a well-known characteristic of ponderosa pine.

As contrasted with the double rainy season of Arizona (winter and summer), the rainfall at Monterey begins in late autumn, reaches a maximum during the winter, and becomes very small by the end of the spring. The summers are completely rainless, but fog is more prevalent than in winter. Occasionally rains fall in September or October. The temperature is mild and the annual range is surprisingly small; however, heavy frosts occasionally occur, especially at the lower elevations.

MacDougal, at the Carnegie Coastal Laboratory at Carmel, has recorded the day-to-day fluctuations in growth of Monterey pine and other trees for almost twenty years by means of his dendrographs. He was able to note the renewal of growth in a Monterey pine following the unprecedented rainfall of mid-September, 1918. Subsequent borings showed that the growth was represented by a ring with a very sharp outside and quite indistinguishable from a true annual in appearance. MacDougal[7] has pointed out the errors these and other growth char-

(5) Douglass, A. E., op. cit., 1919, p. 19.

(6) Lodewick, J. E. Effect of Certain Climatic Factors on the Diameter Growth of Longleaf Pine in Western Florida. Journ. Agri. Research, Vol. 41, pp. 349-363, Sept. 1, 1930.

(7) MacDougal, D. T. Studies in Tree-Growth by the Dendrographic Method, Carnegie Inst. Washington pub. 462, 1936. pp. 24-25, 30

acteristics might introduce into a curve of tree-growth for climate correlation purposes.

Two recent collection trips by the writer (December 1936 and March 1937) yielded a set of highly selected specimens in which these peculiarities of growth could be studied. As a result of cross-comparisons between specimens, and correlation with rainfall, the false rings in Monterey pines were found to fall generally into two principal types, either one or both of which might be present in addition to the normal sharply-bounded annual layer of late wood completed by early summer; (1) a late spring extra ring with hazy outside and (2) an autumn ring with sharp outside boundary.

When as a result of temporarily unfavorable growing conditions a band of late wood is laid down, following which there is a gradual return to the early wood type of growth before the final sharply-bounded annual layer of late wood is put on, the inner component of this double ring exhibits the irregular, ill-defined outer margin so familiar in the false ring in the Pueblo area. Not infrequently climatic vicissitudes will cause not one but several false rings of this type to occur. In a number of specimens of Monterey pine, both 1896 and 1898 are so characterized; the latter although the total growth was small because of a very dry year, frequently is represented by four extra rings in addition to the annual layer. All these are however easily recognized; the rings might be called partly differentiated.

The autumn growth, on the other hand, represents a quite different type of false ring. Its outside boundary is quite sharp although usually the late wood is not as thick a band as that of the true annual of the preceding summer; it may thus be called completely differentiated. It is represented by the years 1889, 1899, 1904, 1907, and 1918; the rainfall records show that these were the only years in the last half-century with exceptionally heavy September-October rainfall. Rainfall was not the only criterion, however, for in each of these five cases specimens could be found in which the double ring consisted of an outer zone of sharply-bounded late wood (the autumn extra ring) and an inner one of diffusely-bounded late wood (normally sharply bounded and the true annual.) Occasionally the inside ring is so diffuse as to leave no doubt that both components were laid down in the same year. The autumn type of false ring represents an extension rather than an interruption of the growing season.

Transitional forms of the late type false ring are not infrequent. If heavy rains come in November and temperatures are not too low, an extra ring of the September-October type with sharp boundary may be laid down. November 1903 is the example of this in the last 50 years. Especially favorable growing conditions in November-December more usually result in a diffuse band of late wood in the early portion of the 'spring' growth representing largely the following year. It is evident that after such heavy rains coming so late in the year, the tree slows down in growth but does not have time to go into a resting period before the normal seasonal growth of the following year begins. Examples of this are the extra rings laid down at the end of the years 1885, 1896, 1900. Since most of these transitional types of false rings have no well-defined outside boundary and are thus very difficult to separate from the growth of the following year, it was found expedient to set the limits of the rain-

interval to be correlated with tree-growth as November 1 to October 31, thus dating the extra rings accordingly.

What criteria are necessary then, in order to distinguish between the autumn false ring and the true thin annual ring of a dry year, in the absence of rainfall records? It is evident that the evidence from any single specimen might be completely ambiguous. With a selected group of at least five, however, there should be little difficulty. We may summarize our previous results as follows: (1) if the suspected double ring is a single ring in some specimens, or represented by a double with inner component diffuse, then it is probably an autumn ring, laid down in September or October, (2) if it is in most specimens a fuzzy band in the early wood of the following year, it was laid down in November or December, (3) if all specimens show it as sharply-bounded, it is true annual. The autumn false ring and the dry-year annual both usually have very thin late wood, but in the faster growing trees the latter will frequently show a thick band of late wood, while the former very rarely does.

The selection of specimens is most important; stump tops especially are to be avoided; old trees are desirable. It should be pointed out that the cross-dating character of selected Monterey pines has been found to be very high. In the usual fast-growing tree, missing rings are unknown. The occasional old and slow-growing tree does show occasional omission of annual rings; in these trees, however, the dating is simplified by the rarity of false rings. Two century-old trees in our collection do not show any of the rings of the last 50 years as double, a valuable check on the correctness of the chronology.

Since the autumn growth was seldom as great as the annual ring representing the normal season following, we have the case of a false annual but sharp ring lying outside of the annual ring to which it belongs, and thus closer to the ring preceding than to the one following. But for the indications through cross-dating, it would not be distinguished from the normal ring of a dry year.

It may be stated in conclusion, therefore, that the criteria for the recognition of double rings developed in the Southwest, need not apply elsewhere; in advance into new territory, there is ever present the possibility of having to set up new criteria for this, as well as other, phenomena.