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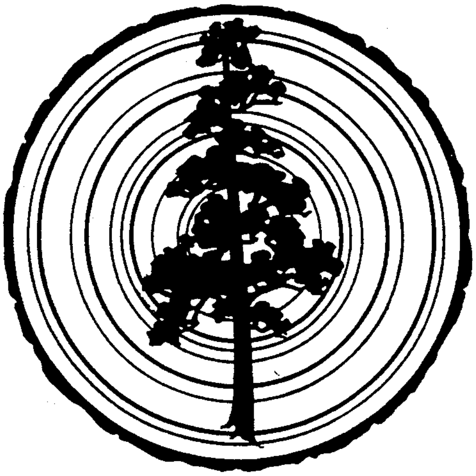

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TYPICAL SITE OF TREES PRODUCING THE BEST CROSSDATING

A. E. DOUGLASS

Highly desirable crossdating qualities in tree-ring records consist of large and irregular differences in thickness from ring to ring. Many beams from the Hopi villages give very fine quality with respect to this ring sensitivity. The Chinle area some 75 miles east has shown still more striking dating qualities. Farther to the northeast in the Red Rock Valley the rings often vary magnificently from year to year so that in some cases the large rings may be twenty times the thickness of the small ones. We have felt sure that this quality is closely related to environment, and perhaps to species.

Some of this effect was first traced to the species by microscopic tests upon pines and Douglas firs which have shown that the great majority of ring records of the highest character are in the latter. The pines sometimes show very high quality but as a rule do not equal the best firs, partly because they have more doubles. These doubles are easily identifiable but as they probably introduce another factor in the tree's growth, namely an increased effect of the summer rains, they reduce the tree's sensitivity.

The site of the tree, however, is of vital importance. A trip (July, 1939) to southwestern Colorado, chiefly Durango and Mesa Verde, gave an opportunity for studying the environment of Douglas firs that give this remarkable crossdating. One of the very best specimens is IF-20,* whose "mean sensitivity" is extraordinarily high—the crossdating characters are greatly emphasized and the rings are strongly individualized. It grew on a 35 degree easterly slope extending several hundred feet above and below. Bedrock was very near the surface and outcropped within fifteen feet of the stump of IF-20. Here and there some firm mass of rock underneath had permitted the accumulation of many feet of soil, in some of which prehistoric ruins of constructions more than 1000 years old have been excavated. In the immediate vicinity of IF-20 the accumulation of earth was very small. Here abundant evidence was found that shallow sandstone soil on a steep rocky slope makes a typical site on which Douglas firs produce the highest character of crossdating ring patterns.

Mesa Verde was then visited and with the permission of the superintendent a number of borings were made in Douglas firs whose location topographically was very similar to that of IF-20. Two of the trees near Spruce Tree House gave rings respectively at 1461 and 1405 at the inner end of 10-

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*Collected and dated by Mr. I. F. Flora of Durango.

inch increment cores. The photograph herewith shows a grove of firs (locally called spruces) near the outlet of Fewkes canyon, seen from Sun Temple point. The superb crossdating character in these trees was proved by a visit to the grove and a half-dozen borings, testing young and old trees and upper and lower sides. The slope was perhaps a little steeper than at the site of IF-20; rocks, loosened, rolled down 100 feet before stopping. Large rocks were apparent and the soil was obviously very limited indeed. There could be no source of water supply from above and as the grove reached down to the top of a cliff there was no chance of conservation of water from other localities. These trees must exist on the moisture that comes in the annual precipitation, and it is believed their character is such that they represent first and foremost the precipitation of the preceding winter and secondarily in very rare cases an effect of the summer rains. The photograph tells the story of trees that show splendid crossdating.

Outpost of Douglas Fir in Dry Climate. Fewkes Canyon, Mesa Verde, Colorado.

CLASSIFICATION OF FALSE ANNUAL RINGS IN WEST TEXAS PINES

Edmund Schulman

Capping Mt. Locke (elev. 7,200 feet), about 200 miles east-southeast of El Paso, is a small stand of pinyon pine, including also about half-a-dozen ponderosa past the sapling stage. Borings of all of the latter and some pinyon were taken on May 6, 1939; several full sections were supplied by Dr. C. T. Elvey of the McDonald Observatory on Mt. Locke.

Numerous false rings were recognized in all specimens. For the interval 1908-1939, 147 of the 372 rings in 12 specimens contained one or more false rings. The two youngest ponderosa, both with pith at 1907, showed only 20 rings free of 'doubles' out of 62; the two oldest ponderosa, with pith at 1846 and 1855, showed 130 with no 'doubles' out of 175. While at first glance extra rings seemed so complex as to make impossible the assignment of absolutely correct dates to the ring record (the prime essential in tree-ring analysis), further study completely resolved their identity.

As a working hypothesis, the Douglass criterion for false rings (those with hazy outer boundary), almost universally applicable to pines in the Pueblo area, was applied here also and a tentative dating assigned. Fine crossdating was found not only in ring thickness but also in the false rings, many of which appeared consistently in about the same form* throughout

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*In studying false rings, the following facts about the extra latewood were found useful: (1) type of outer limit (i.e., hazy, semi-sharp, sharp); (2) position—early, middle, or late in earlywood of annual, or in latewood of annual; (3) color and extent; (4) thickness, including preceding earlywood, in per cent of the total annual growth.

the group from Mt. Locke and also in two ponderosa from Madera Canyon about 15 miles west.

The possibility was considered that microscopic rings for 1904, 1910, and 1917 might be examples of annual-like false rings. But no specimens showed them with hazy outsides; in some specimens the last two were either locally or completely absent. Thus, again on the basis of the Arizona experience, these rings were called true annuals.

The comparison with the rainfall records of El Paso and Fort Davis (20 miles south of Mt. Locke) completely substantiated the dating. It was evident that winter precipitation had a dominant influence on the ring thickness although it amounted to only about a fourth of the annual total. Thus, 1904, 1910, and 1917 were outstanding minima in terms of November-April precipitation. It seems probable that in a majority of years only the earliest part of the summer rains are made use of for radial growth by these Texas trees. But many of the cores collected in early May showed that no diametral increase for 1939 had yet begun, while others showed a little growth; nevertheless, the winter rainfall of this year was normal. Thus a conservation of the effect of the winter rains is indicated.

Outstanding years of thin rings are 1934, 1928, 1917, 1910, 1907, 1904, 1895, 1887, and 1880. The similarity to the record since 1934 of the series of thin or locally absent rings in the late nineties implies a possible pest outbreak at that time. Very thick rings are usual for 1923, 1920, 1914, 1913, 1908, 1906, 1905, 1886, 1885, and 1879. Frost rings are rare, but several are present near 1850, close to the centers of the older ponderosa, and show good crossdating.

The extra rings in these pines fall into two types: (1) a latewood false ring, commonly with hazy to semi-sharp outside boundary and (2) an earlywood false ring, commonly with semi-sharp boundary.

The extra ring appearing in the latewood region is occasionally emphasized by a discontinuity between the thick flattened cells of its final growth and the following moderately open cells characteristic of latewood well before the season's end. Unless examined under high power and in the most favorable illumination, such false rings, called semi-sharp, might be mistaken for annuals. Most of the latewood false rings however, are of hazy outer boundary and easily classified. Considering the group as a whole, even the semi-sharp false rings of the latewood type offered no difficulty in identification, since for every specimen showing such character several showed the same ring with hazy boundary.

Earlywood false rings tend to be semi-sharp and are sometimes not easily differentiated from true annual rings except under the compound microscope. Such rings were found in most or all specimens for the years 1906, 1916, and 1928. The latewood of this type consists usually of only a few cells, so that there is some similarity to what Douglass has called a midline in Arizona pines. It differs from the latter in showing a tendency to a gradual change from early to latewood type of cell on its inner boundary, rather than an abrupt change of type at both limits, and consists of perhaps half-a-dozen or more cells rather than only two or three as in the midline. But the small number of cells gives it an apparently sharp annual-like outside. In the present collection of twelve specimens, the semi-sharp earlywood false ring appeared only in the young and comparatively fast-growing specimens, in which the latewood of the true annual is rather dark and composed of dozens of cells even for the drouth rings. Thus in young trees a fairly dependable solution of such uncertain rings may be made on the basis of cell count.

The preceding criterion probably cannot be applied to old trees, in which microscopic rings may be numerous. However, while no specimens more than a century in age could be located on the site examined, the older ones in the group show the usual tendency for suppression of false rings with advancing age. But a more definite solution of these earlywood false rings is obtained by crossdating with the pinyons, in which all extra rings were of the diffuse-boundary type.

No examples were found in any specimen of the extreme case of a false annual ring with truly sharp annual-like boundary, such as can be laid down by the Monterey pine.

THE CHRONOLOGY IN OL-12, A DISSECTED PONDEROSA

E. SCHULMAN AND G. C. BALDWIN

To determine the variability within a single tree, complete studies were made of the rings at 10 levels from base to top in the trunk of a normally sensitive ponderosa (OL-12) from the Flagstaff area. The results, supplemented by studies of tip growth and of branch and root rings, have been published by Glock.[1] We consider now some further details in the chronology, especially with reference to climate.

Locally absent rings[2]*—an extreme case*: The only appearance of the 1902 ring was as a lens of about .07 mm average thickness on only 2 mm of the circuit of section G, (33 ft. level). If we assume that the proportions of ring growth as observed on the 10 sections apply to the tree as a whole, it then appears that in 1902 only about one four-thousandth of the cambium was active. In 1903 about 25000 times as great a volume of wood was laid down as in 1902. The average yearly volume growth in the 1920's was apparently about 80000 times that for 1902 and about 300 times the growth for 1904 (next in smallness to 1902). These are striking illustrations of over-accentuation of drouth by the tree-trunk.

False rings: The consistent distribution of false rings throughout the stem of OL-12 is shown in the accompanying table. All rings are listed for which doubles, no matter how faint, appeared in any section.

For studies of rings and climate, inquiry may be directed primarily to the main portion of the stem. It is one of the principles of selection of climatic trees that basal regions be avoided; thus a sample, commonly taken on the uphill side, may be five to seven feet above the base. Since section B came from the 7½ foot level and section G from just within the branches, we can appropriately examine in particular the region between these limits. All false rings which are spotty in distribution, and present on no section of B to G inclusive for as much as one-fourth of the circuit, were separated from the more consistent false rings of table 1a.

From table 1a, we see that in 26 out of 28 cases, false rings appearing in section B appeared also in section G and in all of the intervening slabs. Likewise, 27 out of 34 false rings appearing in G could be followed downward to section B, with few or no complete failures in between; four of those which faded out were the relatively youthful rings of 1774, '86, '89, and '92.

None of the 20 scattered and weakly developed doubles of table 1b appears as double in section B, and but few appear in any of the lower sections. The greater tendency for doubling in the upper and therefore younger portions of the stem[3] is well shown. A similar but weaker tendency for doubling near the base is also indicated, as in 1868, '27, '11, and '10.

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[1] W. S. Glock: Principles and Methods of Tree-Ring Analysis. Carnegie Inst. Wash. pub. 486, Washington 1937.

[2] *Ibid.*, pp. 48-51.

[3] *Ibid.*, p. 53.

1a. PRINCIPAL DOUBLES. PER CENT OF CIRCUIT. SECTION OF OL-12

	A	B	C	C	E	F	G	H	I	J
1932	40	50	40	40	25	30	05	20	35	20
30	60	50	75	90	75	70	65	75	40	40
29	65	60	90	90	90	90	75	75	70	*75*
28	75	65	95	98	100	100	100	100	90	100
23	•	•	•	20	10	20	*10*	*60*	*60*	
22	25	25	20	25	15	15	*10*	*10*		
21	35	75	*75*	*80*	*50*	*50*	*40*	*30*	*15*	*20*
20	•	•	•	•	•	30	50	50	50	*65*
1914	35	*50*	*35*	*35*	*25*	*25*	*20*	20	05	
1896	25	*30*	*35*	*30*	*25*	*35*	*50*	65	60	*50*
89	75	85	85	*80*	*80*	*80*	*90*	*90*	75	*50*
72	25	60	50	50	50	60	*50*	*50*	05	10
71	25	60	80	80	75	75	*90*	*95*	*60*	*20*
69	05	10	05	10	25	50	*50*	80	60	*25*
68	25	*30*	•							
61	•	•	05	25	10	20	30	40	*70*	90
60	5	5	5	15	10	30	30	50	*40*	60
50	10	10	15	10	25	80	90	90	98	*65*
42		5	•	•	•	10	30	30	30	
36	25	50	75	75	70	75	50	45	90	
33	10	10	•	5	10	25	10	5		
30	50	40	70	60	45	40	60	70	65	*40*
29			05	05	05	05	15	30	50	..
27	30	*25*	*15*	*10*					...	.
19	*35*	*35*	*10*	*10*	*05*	*15*	*30*	*50*	05.. ..	
09	40	40	60	*95*	*90*	*90*	*10*		.. .	
1805	•	15	30	80	*90*	*90*	*60*	*75*	. ... ..	
1798	20	15	20	70	80	80	100	100	98.. .	
97	20	15	15	80	75	100	100	100	98...	.
95	20	15	25	60	90	95	100	100	100....	
92				05	20	60	*95*	100	100..	...
89				20	20	50	40	40	30. .	
86				05	30	100	100	100	75..	
74					*40*	100	100	..	.....	
73	90	50	90	100	100	100	60..		. .	
71	60	100	100	100	100	100	100 . ..		.. ..	

1b. OCCASIONAL DOUBLES. PER CENT OF CIRCUIT. SECTION OF OL-12

	A	B	C	D	E	F	G	H	I	J
1899								02		10
95									*20*	
93									*10*	
91								05	•	
87								05	*15*	20
85				10	10	10		05		
76									*10*	10
52			05			•	05	*30*	*50*	
48	•	•	•	05	05					
46							10	25	*10*	*40*
35			•	•	•	•	•	30		
26[1]	•	•	•	•	•	•	•	•	•	
24							•	25		
11	*30*									
10	*20*									
1800	•		•	05		*10*	*10*	*30*		
1794			10	15	10	•	•	20	100	
84					•	•	*20*	*15*		
82	•				•	•	15			
77							20	20	50	

• Especially heavy latewood.

[1] 1826 A: Faint suggestion of double on one radius.

The increase in the per cent of doubling about the circuit with increasing heights in the tree is a strong feature of the inner rings of OL-12.[*] However, this relation breaks down for the outer rings. In the last 50 years of growth there are nine double rings present in all sections from B to G. The average per cent of doubling is as follows (B, C, . . ., G): 54, 61, 63, 54, 55, 56. This essential constancy may of course signify merely a mutual cancellation of two opposite tendencies seen in the table, one a gradual decrease in per cent of doubling from the base upwards in some years, the other a decrease from the upper trunk downwards in other years.

Italicized figures in the tables represent false rings which disappeared "in mid-air"—an indication that latewood cells were forming in some regions at the same time that earlywood cells were forming in adjacent regions. Localized occurrences of doubles seem to favor this type, as in 1895, '93, '11, and '10. In 1914, section B, we have a case of a false ring which faded "in mid-air" on one side, and merged with the true annual latewood, the more usual phenomenon, at the other limit of its arc.

To summarize: it appears that the excellent crossdating of doubles from tree to tree in Monterey pine,[†] and in ponderosa in Texas is matched by the consistency of record in false rings within the main portion of the stem of OL-12. However, a high degree of circuit and vertical uniformity in the matter of doubles may be a necessary condition but it is not a sufficient one to establish as a satisfactory climatic index the partial-ring record of the tree. Such individual records may be influenced by non-climatic factors and they therefore need to be supported by the data from other trees.

Sap-heartwood contact. The mean number of years in sapwood decreased from section A, (1½ foot level) to J (45 foot level) as follows: 144, 138, 134, 125, 114, 110, 109, 104, 104, and 101. The ratio of sapwood ~~of~~ to heartwood rings increased steadily from about one-half in section A to one in section J. The *average* thickness of the sapwood varied little; it was 90 mm on A (diam. 550 mm) and 80 mm on I (diam. 220 mm), decreasing only at the top of the tree.

Dissected ponderosa DST-2. Detailed analysis of another pine from the Flagstaff area revealed a circuit and vertical uniformity approaching in quality that of OL-12. DST-2 was more complacent than the latter, and had fewer missing rings. Examination of the longest radials of 11 sections at various levels throughout the trunk showed 1847 present on only two and 1822 present on none. 1902 was consistently thicker than 1904 and present on all radii. On section 2, the only one tested for circuit uniformity, 1822 did appear on one radius, but as a microspic lens of small arc; 1904 was locally absent on one radius. Examination of the complete circuit of each section would doubtless reveal other locally absent rings.

While the chronology was in general similar to OL-12, an interesting variant is 1894, represented by a consistently thin ring in DST-2. In OL-12 it was consistently thick and thus not in agreement with the slight rainfall (see below). 1861 was another erratic year for OL-12. The results of this supplementary study emphasize the fact that the mean of the records from many radials in one tree, no matter how superb its consistency may be, is of far less reliability as a climatic index than the mean record based on different trees.

Precipitation and tree growth. The striking similarity in the synchronous fluctuations in growth throughout the trunk of OL-12 is displayed in two curves of the figure. The mean curve from 10 sections averages the possible

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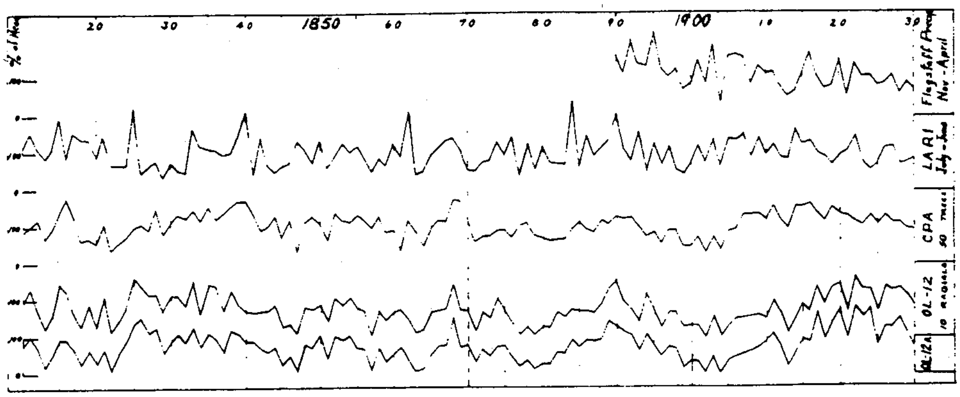
[*] Table 1a shows a tendency for decrease in the per cent of doubling near the top of the tree, sec. J.

[†] E. Schulman: Classification of False Annual Rings in Monterey Pine. Tree-Ring Bulletin, v. 4, no. 3, Jan., 1938.



Synchronous Changes in Precipitation and Tree Growth.

differences in the growth record both vertically and about the circuit. The correlation coefficient, 1775-1934, between the growth curve from section A and the mean of the remaining nine was 0.91±0.01.

The general course in tree growth over the southern Colorado Plateau is represented by the CPA (Central Pueblo Area) curve, derived from 50 highly sensitive trees, distributed in ten groups.* While local climatic effects are of course subdued in this curve, it has high climatic significance, for in general the entire region acts as a unit with respect to rainfall.

In 29 of the CPA trees there were from one to five locally absent rings during the interval 1800-1930. The precision of dates assigned to a ring sequence is primarily dependent of course on the recognition of such absences. Conversely, the agreement of the resultant growth curve with rainfall records is one of the stronger proofs that the criteria for recognition of the true or false annual character of rings are valid.

Comparison with the winter rainfall (November to April) at Flagstaff** reveals that the CPA curve, including trees from regions over two hundred miles to the northeast, more closely follows the rainfall than does OL-12, which grew only a few miles away. Such years as 1892, 1894, 1900, and 1917 support this statement. On the other hand, the dry winter of 1920-21 at Flagstaff is well represented in OL-12 but not in the CPA curve. No conservation factors or corrections for early summer rains have been applied.[3] On the whole, the relationship to winter rainfall is largely direct, and is especially emphatic in the drought years, as in 1902 and 1904.

The long index of Los Angeles rainfall (LARI) compiled by H. B. Lynch shows considerable similarity to the Arizona growth curves. Precipitation on the southern California coast is confined almost entirely to the winter months, during which most storms normally travel eastward and reach Arizona. However, considerable differences in precipitation appear in the two regions in some years, as in 1847 and 1892, probably as the result of temporary changes in the general circulation of the atmosphere. The very reliable dating year 1813, a thin ring, is well shown in LARI, as is the configuration of 1820-22. Again, as in the Flagstaff rainfall and Rio Grande runoff,[4] the relation to the CPA is even better than to OL-12.

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*Johnson Canyon, Lukachukai Mts., Pinyon, Chinle, Kayenta, Chaco Canyon, Black Mesa, Rainbow Lodge, Aztec, and Basin Mountain.

**Data for 1890-97 partly estimated from neighboring stations.

[3] A. E. Douglass: Climatic Cycles and Tree Growth, vol. III. Carnegie Inst. Wash. pub. 289, Washington 1936, p. 14.

[4] *Ibid.*, p. 15.