

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

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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 overaccentuation 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 stem³ is well shown. A similar but weaker tendency for doubling near the base is also indicated, as in 1868, '27, '11, and '10.

¹W. 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	40	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	*	*	*	*	*	*	*	*	*	*
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.

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,⁴ 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 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.

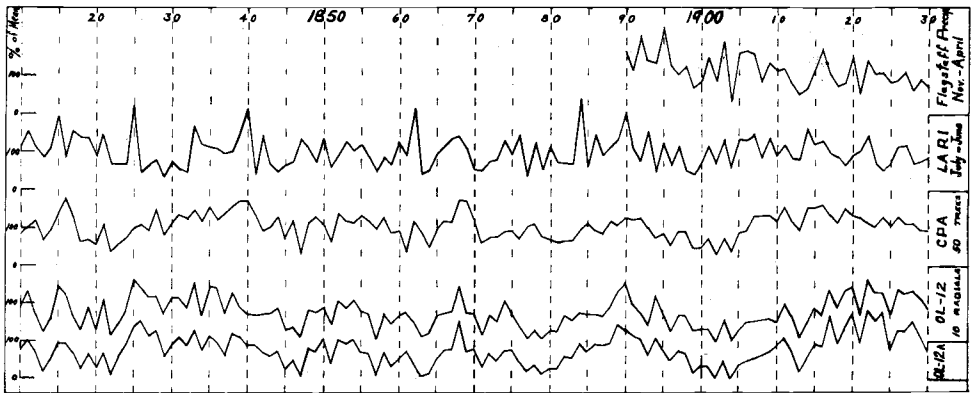
Dissected ponderosa DST-2. Detailed analysis of another pine from the Flagstaff area revealed a circuit and vertical uniformity approaching in quality that of OL-12. DST-2 was more complacent than the latter, and had fewer missing rings. Examination of the longest radials of 11 sections at various levels 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 microscopic 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

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

⁴E. 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.⁵ 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,⁶ the relation to the CPA is even better than to OL-12.

*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.

⁵A. E. Douglass: Climatic Cycles and Tree Growth, vol. III. Carnegie Inst. Wash. pub. 289, Washington 1936, p. 14.

⁶*Ibid.*, p. 15.