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RIO GRANDE CHRONOLOGIES[1]

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That tree-ring chronologies in the Rio Grande basin in New Mexico show much parallelism with those in neighboring areas of the Colorado River basin to the west and north has long been known as a result of the masterly work of W. S. Stallings in establishing an independent archaeological chronology for that region.[2] That chronology, in the form of skeleton plots,[3] was built with the rings in a very large number of beams from Pueblo ruins, Spanish Colonial buildings, and other sources, relatively few ring sequences representing much more than a century of record. Since much of the archaeological wood is ponderosa pine, the living-tree anchor for that chronology was largely based on this species, which in the Rio Grande basin includes few trees exceeding 300 years of age. The short average length of record, which the Stallings chronology has in common with series from several other archaeological areas, is of no great import in archaeological dating—apart from the added difficulties it presented to the original builder of the master chronology!—but puts limits on the interpretation of the chronology in terms of climatic history.

The special need just noted in dendro-climatology for the homogeneous series of great length obtainable from long-lived, sensitive trees has led in recent years to an intensive search for such trees in the Rio Grande basin, as in other areas. Enough of these have now been found in the northern part of that basin to permit the construction of statistically sound numerical indices.

[1]Eleventh report on quantitative dendrochronologies in the Southwest. This paper deals only with the Upper Basin of the Rio Grande, in New Mexico and adjacent parts of Texas and Colorado. Previous contributions in this Bulletin as follows: Mesa Verde, 12:18-24, 1946; Mesa Verde, 14:2-8, 1947; Flagstaff (by A. E. Douglass), 14:10-16, 1947; Navajo National Monument, 14:18-24, 1948; Northeastern Utah, 15:2-14, 1948; San Juan Basin, 15:24-32, 1949; Durango, 16:12-16, 1949; Bryce Canyon, 17:2-16, 1950; Big Bend (Texas), 18:18-27, 1952; San Juan, 18:30-35, 1952. Work since April, 1950, on the Rio Grande chronologies, among others, was supported in part by the Office of Naval Research. The unfailing cooperation of the U.S. Forest and Park Services proved most helpful on many occasions during the various field trips. Recent data were supplied by the U.S. Weather Bureau, U.S. Bureau of Reclamation, and the U.S. Geological Survey. Special thanks are due Mr. C. W. Ferguson, Jr., for aid in the field and laboratory.

[2]*Proc. National Academy Sciences* 19:803-806, 1933; *Tree-Ring Bulletin* 4(2);3-5, 1937.

[3]Reduction of selected specimens in the Stallings collection and some other Rio Grande specimens to quantitative form, after the fashion of the reports in this Bulletin, is now under way at the Tree-Ring Laboratory.

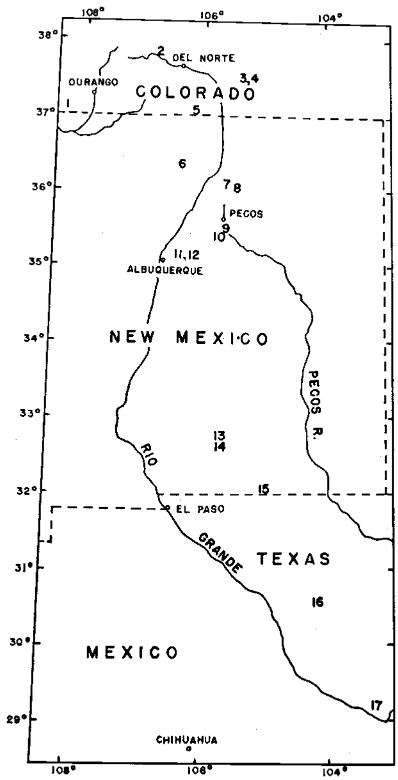


Fig. 1. Sampled sites of chronology trees in the upper basin of the Rio Grande. Station No. 1, at Mesa Verde, in the Animas River basin.

The various collections by the writer in this basin, representing increment borings of living trees only, are here assembled to provide (a) a map of changes in chronology across a north-south belt of some 600 miles within the Rio Grande drainage, including its Pecos River sub-region, (b) quantitative indices for north-central New Mexico based on individual ring records up to 596 years in length, and (c) a view of the significance of tree-ring chronologies in the project area as indexes of rainfall and river flow. The charts of data in this report represent some 15,100 measured rings from sixteen stations within the Rio Grande basin; chronologies representing about 2,500 additional measured rings in the west Texas area were presented in a recent report in this series (TRB 18:18-27).

COLLECTIONS AND DATING OF CHRONOLOGY GROUPS

The climatic importance of getting the longest and most sensitive ring sequences in living trees has largely controlled the field search by the writer for proper material in this region. Thus, almost all of the collections reported here include trees generally over-mature and growing slowly, under a seldom broken stress of water deficiency, on marginal sites; enough young trees were sampled at most sites, however, to assure proper dating of the crowded outer decades in the longer ring records. It was found, as elsewhere, that the chronology in sensitive trees was essentially the same in both young and old individuals. As in other areas of the Southwest, the most consistent and readily datable sequences were found in Douglas-fir. No stands of long-lived ponderosa pine, such as are common in regions to the west and north, were found, though many fine shorter sequences are obtainable; it should be noted that the survey here reported is quite incomplete with regard to that species. Pinyon pine, however, as emphasized by Stallings, is an excellent species in this region, for it tends to grow slowly even during its youth and provides many long and sensitive ring records.

Two areas of relatively dense forest and comparatively heavy rainfall were sampled: one in the Sangre de Cristo range and the other in the Sacramento Mountains near Cloudcroft. Even here, however, rainfall seems to be less than the optimum for the sampled species in a large proportion of the years, for the drier years are consistently indicated by smaller rings in these groups. It thus appears that significant drought chronologies may, in general, be obtained wherever, in the Rio Grande basin, the three chronology species noted above exist. Exceptions to this generalization, especially with respect to hypersensitivity or erratic growth in ponderosa pine, are briefly discussed below.

The map, Figure 1, shows in a general way the distribution of analysed chronologies in the Rio Grande drainage. Pertinent data on these ring series are assembled in Table 1. In most areas the collections include, in addition to short records from young trees, several cores showing heart rot, fire, or other obvious injury. These cores were valuable in checking portions of the chronology but were not used in the group mean curves. An occasional hypersensitive specimen, not dated, is to be found in these groups; on the whole, however, all the specimens in any homogeneous group in which crossdating is present were found to be datable.

SPECIES AND CHRONOLOGY

It is important in both dendro-climatology and dendro-archaeology to consider the frequency of occurrence and areal distribution of non-usable ring series in species commonly suitable for such analysis. Such series may be of three types: (a) variant records in an otherwise crossdating group (injury effects and local accessibility to moisture seem to be common causes for this type), (b) obscure chronologies in complacent, countable, or even faintly crossdatable records from well-watered sites, and (c) hypersensitive series, from marginal sites, often crowded with false rings, showing great ring variability from year to year but no apparent crossdating.

The experience of the writer in sampling several hundred localities throughout western North America amply confirms the conclusions of others as to the dependence of chronology on species.

Douglas-fir is almost everywhere datable, though it may be very complacent on moist sites along the Pacific Slope and even in areas of low rainfall if it taps an underground water supply; only in the Rio Grande basin, thus far, have a very few apparently hypersensitive records in this species been found.

In the timber pines (ponderosa, limber, Jeffrey, sugar, etc.), obscure chronologies are typical of many moist sites in the Sierra Nevada and Cascade Mountains and, less commonly, in the central and northern Rocky Mountains; the drier sites along the margins of and within this mountain system tend to yield chronologies in the timber pines approaching the good climatic records in Douglas-fir. Hypersensitive pines are occasionally found on outlier sites of the lower forest margin in central and southern Arizona and New Mexico and in northern Mexico.

Table 1. Data on Chronology Groups of Increment Cores

	(1) Station	(2) Coll.[1] Date	(3) Lat.	(4) Long.	(5) Elev., ft.	(6) No. Trees	(7) Species[2]	(8) Cores Begin, A.D.[3]
	COLORADO							
1	Mesa Verde	7-19-41	37°11′	108°29′	6800	7	DF	—
2	Wagon Wheel Gap	10- 8-41	37 48	106 50	9000	5	DF	1500, 1550, 1589, 1602, 1619
3	Ft. Garland	10- 1-48	37 30	105 19	8600	3	DF	1655, 1712, 1764
4	Ft. Garland	7- 8-51 10- 1-51	37 27	105 21	8400	10	PNN	1355, 1380, 1405 1481, 1570, *1590*, 1628, 1757, *1770*, 1793
5	Antonito	10- 2-48	37 04	106 11	8500	5	DF	*1390*, *1430*, 1660, 1697, 1812
	NEW MEXICO							
6	Cebolla	10- 2-48	36 21	106 32	6500	3	DF	1557, 1620, 1626
7a	Taos	7- 9-51	36 11	105 37	7800	4	DF	1452, *1500*, 1738, 1769
7b	Taos	"	"	"	"	2	PP	1710, 1711
7c	Taos	"	"	"	"	4	PNN	1690, 1712, 1760, 1770
8a	Taos Upper	10- 7-41	36 06	105 28	9000	4	DF	1390, *1500*, 1572, 1696
8b	Taos Upper	7- 9-51	36 07	105 29	8700	5	DF	1437, 1592, 1615, 1734, 1761
9	Pecos	7-17-46 9-30-51	35 35	105 46	7500	4	DF	1378, 1397, 1440, 1442
10a	Pecos South	10- 7-41	35 28	105 41	7500	5	DF	1506, *1595*, 1669, 1670, 1794
10b	Pecos South	"	"	"	"	1	PNN	*1550*
11a	Albuquerque	7-16-46	35 11	106 23	8200	2	DF	*1720*, *1730*
11b	Albuquerque	"	"	"	"	1	PNN	1637
12	Albuquerque	7-17-46	35 13	106 24	9000	2	CBS	1867, 1874
13	Cloudcroft	7-14-46	32 56	105 45	8800	5	DF	1611, 1696, 1721, 1735, 1839
14	Cloudcroft	7-14-46	32 45	105 46	9000	2	P[4]	1792, 1849
15	Guadalupe	6- 7-42	32 02	104 49	6500	5	DF	1701, 1715, 1720, 1730, 1747
	TEXAS							
16a	McDonald	5- 6-39	30 40	104 00	6800	5	PP	1847, 1856, 1900, 1900, 1901
16b	McDonald	"	"	"	"	2	PNN	*1850*, 1861
17	Big Bend[6]	11-28-45	29 13	103 19	6000	5	DF	1676, 1678, 1682, 1690, 1700
	MEXICO							
18	El Salto	8-24-43	23 46	105 22	8500	5	DF	
	SOUTHERN ARIZONA							
19	So. Arizona[7]	1939				27	DF	

[1]First day when more than one day was spent in the area. Localities 1 and 19 were sampled again during several later years. The exact dates are of interest primarily in cambial-activity studies, to be reported elsewhere.

[2]DF: Douglas-fir *(Pseudotsuga taxifolia)*; PNN: pinyon pine *(Pinus edulis)*; PP: ponderosa pine *(P. ponderosa)*; CBS: Colorado blue spruce *(Picea glauca)*.

[3]Dates in italics represent series not completely crossdated, owing to crowded rings or other factors. In many cases, too, the tree is much older than indicated by the center date on the core, which was incomplete because of center rot or other injury.

[4]One *Pinus ponderosa*, one *Pinus strobiformis*.

[5]Several specimens from Dark Canyon Lookout area 4 mi. to northeast.

[6]Detailed report on this area in TRB 18 (2/3).

[7]A regional mean. For local chronologies in this area see *Bull. Amer. Meteorol. Soc.* 23:148, 1942.

Remarks on groups:

1. MVR. See TRB 12(3), 14(1), and later issues; the DF record at this station begins in A.D. 465. Various collections, the latest on Oct. 2, 1951, provided data for recent years.
2. WWG. Spring Gulch Canyon, near Wagon Wheel Gap.
3a. FTG. About 5 mi. n.e. of Ft. Garland, on Hwy 160.
4. FTG. Rolling hills n. of Ft. Garland. Oct. 1, 1951, collection provided five cores, supplementary to those listed in col. 8, which aided in solving some difficult early portions of the chronology.
5. ANT. 12 mi. w. of Antonito on Hwy 17. Scopulorum juniper difficult.
6. CEB. Echo Cliffs Amphitheatre, about 15 mi. s. of Cebolla on Hwy 84. Tentative dating on several over-age PP and PNN but difficult.
7a. TAO. Above Rio Pueblo, about 15 mi. w. of divide (Holman Pass) on Hwy 3 from Las Vegas to Taos. Three old scopulorum junipers not dated; one 50-yr. complacent juniper dates.
7b. TAO. See 7a.
7c. TAO. See 7a.
8a. TAOh. (Taos High.) About one mi. w. of Holman Pass. This group was labelled SFEe in TRB 8(4).
8b. TAOh. 1-3 miles w. of pass.
9. PEC. Near Glorieta Pass on Hwy 85 s.w. of Pecos. The longest series of the 1946 collection was combined with the three longest series in the 1951 group.
10a. PECs. Shallow canyon in mesa about one mi. w. of Hwy 85 and 5 mi. s. of Pecos Ruins. This group was labelled SFEs in TRB 8(4).
10b. PECs. See 10a.
11a. ALB. Sandia Mts., 2-3 mi. n.w. of Sandia Park on Hwy 44.
11b. ALB. See 11a.
12. ALB. See 11a. La Madera Winter Sports area.
13. CCR. About one mi. s. of Cloudcroft. Two specimens in this group from Site 14.
14. CCR. Sacramento Lookout, Lincoln Nat. Forest.
15. GUA. Guadalupe Mts. Near mouth of Devils Den Canyon s. of El Paso Gap (2 trees) and 0.5 mi. s. of Dark Canyon Lookout (3 trees). PNN datable; scop. juniper difficult.
16a. MCD. Mt. Locke, site of McDonald Observatory. All center dates on cores are at or near pith; no old tree found.
16b. MCD. See 16a.
17. BBN. Boot Springs Area, several miles s. of Big Bend Nat. Park headquarters.
18. MDU. El Salto West Group, Durango State, Mexico; see TRB 10(3).

Pinyon pine seems to be generally datable throughout its range from Idaho to Mexico; however, on many, though by no means all sites at the dry limit of its range, particularly in more southerly latitudes, older trees, usually stunted and gnarled, may show such crowded and erratic ring series, with so many omitted rings, as to make increment borings and even full sections undatable.

Scopulorum juniper, easily datable in many areas of the central and northern Rockies, was sampled in several localities of northern New Mexico and nowhere found datable except for very young and fast-growing trees; large trees of this species on relatively well-watered sites may prove useful in this region.

Attention may be called to a critical difference between very complacent and hypersensitive records. The former seem to have little to offer the dendrochronologist. Records of the latter type may, however, in many instances be dated, with sufficient comparative material and professional study; such dating requires that the high ring variability be associated with crossdating, the records then taking their place among the most valuable sources of climatic history.

Three of the nineteen localities in the Rio Grande basin sampled by the writer since 1939 show irregular, nondatable ring records in ponderosa pine of the hypersensitive type: near Magdalena, near Pie Town, and in the Organ Mountains, all in the southern half of New Mexico. All of these sites are marginal. It seems probable that higher levels in the same general localities would yield crossdatable records in this species.

SUPERSENSITIVE CHRONOLOGIES

The capacity of Douglas-firs on some sites east of the Continental Divide to provide consistent, supersensitive growth records (as distinct from erratic hypersensitive ones) is well exemplified by the Pecos collection, Station 9 of Table 1. The average mean sensitivity per century of 0.61 for the 500-600 year trees in this group (TRB 18:12) is about half again as large as that of the type trees of this species at Mesa Verde. The photographed Pecos ring records (TRB 18:15) show high parallelism to fluctuations from year to year in regional water supply.

Although the locally-absent rings in such series represent, of course, an exaggeration of the growth-climate effect, they are valuable indicators in both climatic and archaeologic dating. Single increment cores from three trees sampled September 30, 1951, have records beginning at A.D. 1442 or earlier. Dates of locally absent rings are as follows:

PEC 3911: 1516, 1585, 1625, 1628, 1676, 1702, 1705, 1714, 1716, 1730, 1737, 1739, 1748, 1822, 1842, 1870, 1899, 1904, 1950
PEC 3912: 1445, 1480, 1496, 1893, 1899, 1904, 1911, 1925
PEC 3921: 1449, 1455, 1471, 1516, 1524, 1748, 1750, 1757, 1814, 1822, 1893, 1899, 1904

For each of the five successive centuries beginning with A.D. 1401, the number of rings from 0.01 mm to 0.10 mm wide in specimen 3911 and the average ring-width per century are as follows: 1—0.83 mm; 10—0.46; 4—0.35; 12—0.28; 8—0.38. For 1901 to 1951 the corresponding data are 7—0.28.

Other collections in Table 1 which have supersensitive records are at Stations 10a (Pecos South—see TRB 8:31) and 17 (Big Bend, Texas—see TRB 18:18-27). There must exist, of course, a continuous range of ring sensitivity; some of the other groups in Table 1, as at Antonito, Colorado, are intermediate between Mesa Verde and the above.

LOCAL VARIATIONS IN CHRONOLOGY

As compared with the classic Mesa Verde area, how do the ring chronologies in the Rio Grande basin differ? What is the variation in chronology from area to area within this region? How different are the chronologies in different species at any given site?

Answers to such questions may perhaps be obtained, to a first approximation, by inspection of the chronology transect, Figure 2. The twenty-two series from the Rio Grande basin and three comparative chronologies from outside the basin represent the recent decades in the collections described in Table 1 and are plotted in the same general north-south order.

It appears that many diagnostic rings, such as those for the dry years 1934, 1904, 1902, and 1899, are characteristic of the upper Rio Grande as at Mesa Verde. Differences in chronology, as expected, become greater with increasing distance between the source areas. As in other areas, systematic chronology differences between the major dendrochronologic species are small in the Rio Grande; some apparently consistent differences in the growth in pinyon as compared with Douglas-fir in the northern Rio Grande are, however, probably significant indicators of slightly different reactions to growth factors in different years.

Correlation coefficients for pairs of key series are collected in Table 2. Chronologies in Douglas-fir from the northern (Antonito), central (Pecos South), and southern (Guadalupe) parts of the basin show the expected decrease in correlation with increasing distance when compared with the Mesa Verde and Wagon Wheel Gap stations to the northwest. That the latter station shows lower coefficients than the more distant Mesa Verde is probably a consequence of its less representative character rather than

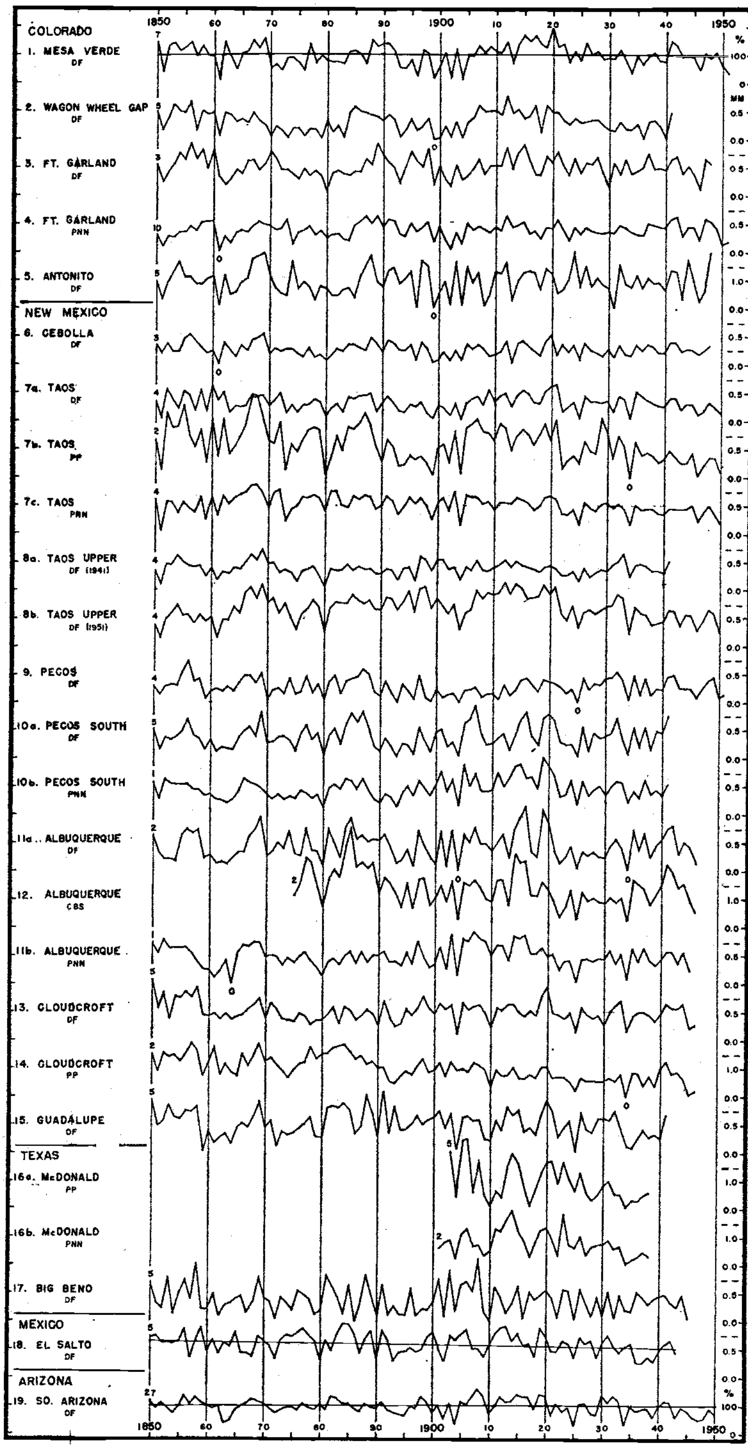


Fig. 2. A north-south chronology transect for the Rio Grande basin. The Mesa Verde comparison series is relatively close to the northern Rio Grande sites; the two lower comparison series are relatively distant from the southern sites. The number of trees on which each chronology is based is noted above the curves; zeros below the curves denote locally-absent rings.

Table 2. Correlation coefficients between various Douglas-fir chronologies in and near the Rio Grande basin*

	Antonito (5)		**Pecos South (10a)**		**Guadalupe (15)**	
	1850-99	**1900-41**	**1850-99**	**1900-41**	**1850-99**	**1900-41**
Mesa Verde (1)	+.601	+.583	+.486	+.579	+.407	+.470
Wagon Wheel Gap (2)	.406	.443	.393	.238	.196	.314
Pecos South (10a)	.320	.409	—	—	.422	.545
Big Bend (17)	—.042	.149	.338	.268	.631	.485
So. Arizona (19)	.137	.281	.254	.513	.448	.533

*Mesa Verde-Wagon Wheel Gap, [illegible] miles; Mesa Verde-Pecos South, 198 miles; So. Arizona-Big Bend, about 400 miles.

an indication of a local pocket of specially variant chronology, for the Mesa Verde index is based on a collection from a number of localities, the other from one small hillside.

The Big Bend series in the extreme south has little relation in chronology to the northernmost Rio Grande area, though a very good relation to the Guadalupe index for southern New Mexico is evident. The latter chronology is almost as closely related to that for southern Arizona; the evidence in this table extends other observations regarding west-east similarity in low latitudes of the Southwest (e.g., TRB 7:19), which seems, in fact, to be somewhat greater than for corresponding distances north-south. The relation of the southernmost chronologies to the Mexico series was briefly noted in TRB 18:24.

REFINEMENTS IN TECHNIQUE

Averaging. The availability of many long ring records has made it possible to abandon the earlier practice of standardizing each tree's ring-widths by removal of age trend in order to derive areal averages. Replacing this is the simpler process of a direct average with common starting date for all trees in a group, the resulting series providing a generally more sure view of long period changes in the data (TRB 17:11). The mean curve may then be standardized and extended by the standardized early portions of the records in the older trees.

Standardizing. It has long been recognized that fitting trend lines by eye leaves something to be desired; however, the common-sense advantages of this procedure, when properly done, are considerable, in view of its rapidity, cancellation of some of its imperfections in the averages and the impossibility, because of end effect (TRB 17:11). of determining and removing the true age trend with absolute accuracy by any numerical method.

To aid in placing eye-fitted trend lines more accurately, long-period means may be plotted on the curve to be fitted; for example, 10- or 20-year averages of the annual data are convenient for most tree-ring series. Use of a flexible curve rule enables even the inexperienced operator to draw a satisfactory line which will fit these averages and thus also the annual data; without good cause, no modification of the natural age trend in trees, a single early maximum followed by a regular decrease, should be introduced. The earliest decades of growth often contain a specially steep age trend and may frequently be omitted with little loss. The rings adjacent to the pith, often subject to strong suppression and release effects, are usually quite impossible to standardize with any degree of confidence, and should be dropped unless little or no other ring data are available for the years concerned. Examples of such quickly fitted smooth trend lines are shown at upper left in Figure 3.

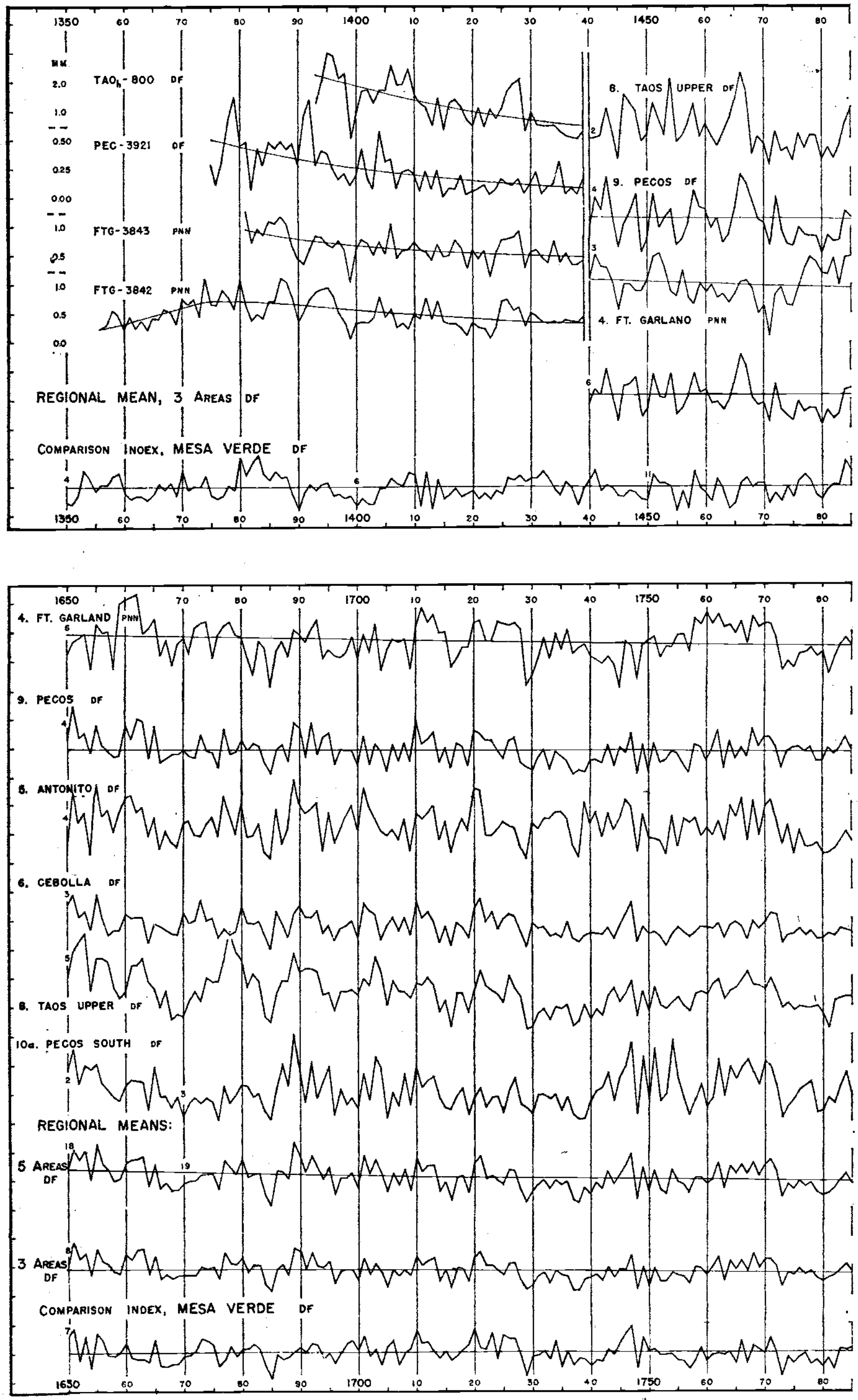
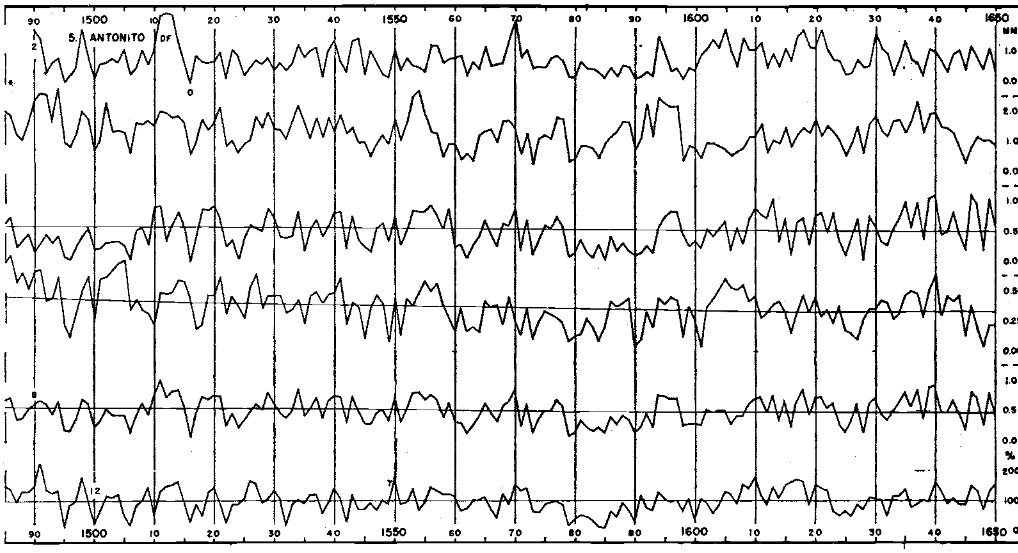


Fig. 3. Five Douglas-fir groups and one pinyon pine group based on specially long-lived trees of the Rio Grande basin are reduced to homogeneous indices. The regional mean for three areas represents the growth of eight trees in the 500-



year age class; the 5-area mean from A.D. 1650 includes all trees over 350 years old. Ring measures of the inner decades of the four oldest trees are plotted at upper left.

Table 3. Upper Rio Grande Douglas-fir.*
Ring-Widths in Per Cent of the Growth Trend

A.D.	0	1	2	3	4	5	6	7	8	9
	(See Figure 3 for pinyon data, 1356-1374)									
1370	—	—	—	—	—	57	22	69	144	193
1380	102	115	17	107	72	126	113	136	120	138
1390	88	220	270	74	112	136	114	81	96	21
1400	64	132	85	52	178	122	162	80	120	150
1410	110	60	106	36	129	16	78	82	119	42
1420	42	82	61	66	68	127	151	172	210	41
1430	121	142	51	82	98	191	36	52	22	128
1440	80	126	107	191	102	24	135	142	162	40
1450	64	171	98	95	173	45	62	98	173	111
1460	122	78	82	60	85	149	233	195	98	73
1470	80	18	138	58	42	24	82	53	66	66
1480	11	55	31	46	122	126	133	67	71	96
1490	113	126	113	84	124	35	33	67	129	115
1500	40	60	98	82	82	82	25	80	116	82
1510	146	186	132	152	155	105	15	86	140	129
1520	144	142	48	87	41	67	98	115	97	151
1530	114	88	73	93	163	79	105	137	73	126
1540	144	142	59	142	91	55	55	91	99	61
1550	138	59	107	155	157	135	152	135	79	125
1560	62	58	25	52	79	129	93	64	117	132
1570	170	51	123	27	74	100	100	138	116	20
1580	26	71	46	36	46	28	82	56	86	72
1590	32	46	92	46	156	155	145	147	54	60
1600	61	55	106	99	106	106	59	86	86	127
1610	148	154	99	156	70	138	52	136	180	91
1620	154	158	114	135	58	29	73	130	31	132
1630	152	97	72	105	139	174	121	180	76	190
1640	196	102	98	143	96	39	172	152	56	170
1650	101	152	125	149	76	168	117	102	74	79
1660	121	131	133	138	62	119	57	72	49	54
1670	69	78	78	94	96	97	57	137	115	98
1680	140	90	97	101	39	11	111	109	86	195
1690	151	107	154	121	88	125	41	92	92	106
1700	65	158	104	151	108	52	109	70	122	55
1710	158	116	136	138	54	86	25	98	105	51
1720	146	167	97	107	91	82	126	125	65	21
1730	55	77	93	64	93	78	90	29	19	71
1740	50	89	68	125	80	114	144	187	28	141
1750	58	130	64	52	137	95	83	57	106	108
1760	86	100	160	68	151	124	158	123	165	113
1770	159	177	131	42	85	68	100	81	92	58
1780	45	56	71	104	128	91	81	136	70	77
1790	110	144	142	158	111	109	87	103	128	104
1800	124	75	100	84	144	96	44	131	88	100
1810	83	107	105	110	75	122	165	130	59	45
1820	81	53	36	93	89	116	130	119	180	73
1830	120	117	130	128	135	105	62	144	164	135
1840	198	135	45	128	106	73	91	31	84	125
1850	113	36	106	103	114	132	159	104	102	63
1860	97	24	95	66	69	109	133	171	147	199
1870	83	94	89	100	125	54	95	126	78	93
1880	33	97	114	81	120	131	134	146	152	79
1890	65	119	94	54	94	94	32	149	101	26
1900	87	96	38	96	15	120	106	147	68	59
1910	80	77	122	48	108	151	136	103	76	158
1920	162	119	89	43	111	31	106	62	109	88
1930	107	98	158	104	38	133	73	131	71	100
1940	94	161	*134*	*69*	*101*	*94*	*38*	*84*	*143*	*155*
1950	*39*	*15*	—	—	—	—	—	—	—	—

*1 tree, 1375-1392; 2, 1393-1439; 5, 1440-1441; 6, 1442-1489; 8, 1490-1649; 18, 1650-1669; 19, 1670-1941; 7, 1942-1948; 5, 1949-1950; 4, 1951.

LONG RING RECORDS

On the whole, experience has shown that the chronology species provide shorter records in the Rio Grande basin than in higher latitudes. Nevertheless, the number of Douglas-firs and pinyon pines of high sensitivity and exceeding 500 years of age which have already been found in the northern part of this basin indicates that many more in this age class await sampling.

The most sensitive and longest records currently available for the Rio Grande basin are plotted in Figure 3. A homogeneous 512-year chronology for the northern portion, characterized by a minimum in statistical manipulation, has been derived by taking a straight average of ring growth in the two oldest Douglas-firs in the Antonito and Taos collections and the four old Douglas-firs of the Pecos group for the interval 1440-1951 (the means from 1440 to 1489 and 1949-1951 have been adjusted to the 8-tree means).

The good cancellation of random error in such an average, representing only a few sensitive and widely spaced ring records, is well shown in Figure 3, in which records at least 300 years long in the north-central Rio Grande basin are also plotted. The 19-tree mean of five groups of Douglas-firs in this category shows only differences in detail as compared with the 8-tree mean of three groups in the 500+ year class. Reference to Table 1 will show that both means primarily represent the Rio Grande chronology in northern New Mexico; as suggested above, they also give a good first approximation to the chronology in this basin in southern Colorado. The close relation to the Mesa Verde chronology (TRB 14:6-7 and recent extensions) is also very evident in the figure.

Although the long pinyon record from Ft. Garland, Colorado, represents an area well north of the source of the longer Douglas-fir series for the Rio Grande, it is evident in Figure 3 that only minor differences in chronology exist. Even these differences are in part random, the effect of the small number of available records in the age class of 500+ years in pinyon pine.

Standardized indices for Douglas-fir in the northern Rio Grande are collected in Table 3. These are based principally on the 3-area mean to 1649 and the 5-area mean from 1650 on, and thus are of good weight since 1439.

Extended ring records for the Guadalupe Mountains near the Texas-New Mexico border and for the Rio Grande in the Big Bend, Texas, area have been published earlier (TRB 18:23).

TREE GROWTH AND RUNOFF

It is possible in this progress report to present the significance of growth as an index of rainfall and runoff in qualitative terms only. Photographs of sensitive Rio Grande ring series and relevant runoff data (TRB 18:15) provide direct illustrations of the growth-runoff relationship. Southeast of Taos, Glock[4] analysed in careful detail the growth of timber pines near Holman Pass (area of Station 8, Table 1 of this paper); he found the fluctuations in ring-width to most nearly parallel the variations in local rainfall of March-July. However, the analysis of many stations briefly noted in TRB 18:16 suggests that an underlying tendency exists for ring growth in the Rocky Mountains to show the highest correlation with the total annual rainfall of a year ending in June for Douglas-fir or July for ponderosa and limber pines, though some slight relation to latitude is indicated and a number of stations show correlations about equally good for various shorter intervals.

[4]W. S. Glock, *Smithsonian Misc. Collections* 111 (18), 1950.

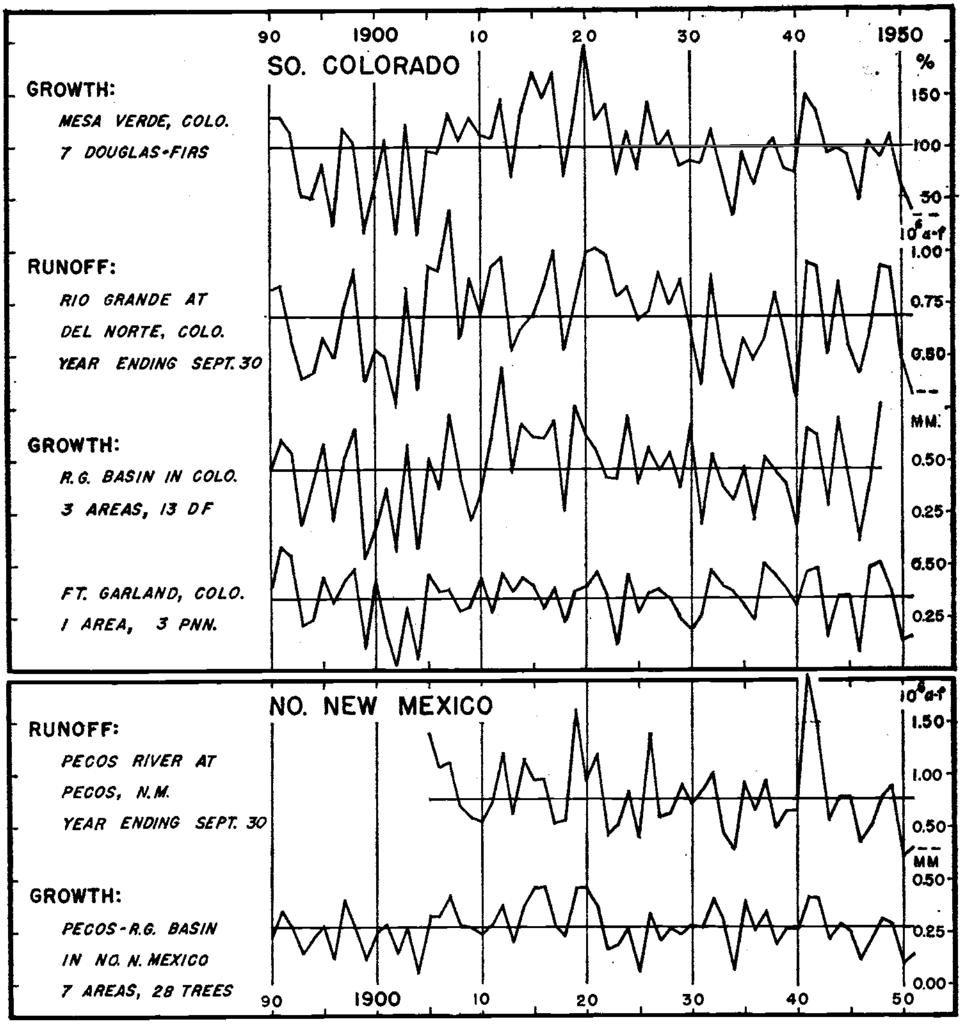


Fig. 4. Sensitive ring growth and water-year runoff are closely parallel in the upper basin of the Rio Grande. The unit of scale for the runoff is one million acre-feet.

Three well separated Douglas-fir groups of the upper Rio Grande basin in Colorado (nos. 2, 3, and 5) have been averaged to give a preliminary regional tree index for comparison in Figure 4 with the record of runoff since 1890 of the Rio Grande at Del Norte. Plotted also is the standard Mesa Verde Douglas-fir index, representing the Animas River basin just west of the upper Rio Grande. It is evident that the larger swings and most of the minor fluctuations are roughly parallel in all three series, the Mesa Verde tree record showing, perhaps, a slightly better relation to Rio Grande runoff. This should occasion no surprise, for the excellent Mesa Verde sites are as close to the headwaters area as the average distance for the three Rio Grande sites, and the prevailing storm tracks result in almost parallel flow records for the Animas River and the upper Rio Grande. It may be noted in passing that these two long flow records, taken from the U.S.G.S. Water-Supply Papers, are affected only to a small extent by depletions above the gaging stations.

The limitations of a single-station record are well shown by the Ft. Garland pinyon series as compared with Rio Grande runoff. Although the 10-tree mean for Ft. Garland is, of course, somewhat less subject to random fluctuations, use of the 3-tree mean, representing the 500-year pinyons at this station, is of aid in estimating the significance of that long record, plotted in part in Figure 3.

The flow of the Pecos River at Pecos, plotted in the lower panel of Figure 4, represents a catchment area of only 189 square miles along the southwest flank of the Sangre de Cristo range near Santa Fe; upstream depletions are minor. The several Taos and Pecos tree-ring stations are all in or very near this basin and their growth records in general compare specially well with the flow records.

For a more general comparison in Figure 4, a regional mean growth index for north-central New Mexico, which, of course, represents the Rio Grande as well as the Pecos River, was derived from seven stations, nos. 6, 7a, 8, 9, 10a, 11a, and 12; all trees are of Douglas-fir except for the closely parallel Colorado blue spruce of Station 12 (see Figure 2). Growth and river flow fluctuate in closely parallel fashion, though it appears that the ring indices may underestimate such extremely wet years as 1941. It should be noted that the reference lines for the three Rio Grande growth records plotted in this figure are at their respective means; standardizing lines fitted to the entire interval of available growth record would vary somewhat from these short-term means.

FLUCTUATIONS IN RIO GRANDE CLIMATE

Just as the weather in a given locality or region is often intelligible only by reference to the synoptic situation over a far larger region, so it is desirable to consider the long-period fluctuations in the Rio Grande tree-ring chronology in terms of all other regions of the western United States. Such an analysis is now in progress and will be reported in detail elsewhere.

In a general way, the longer swings in chronology are similar in the Rio Grande and the Colorado River basins. However, the severe deficiency in growth during the recent two decades seems to be decidedly more pronounced in the Colorado basin, and in some localities of the Rio Grande the long but broken Colorado basin drought of 1871-1905 seems to have continued for some years. Both series show a major maximum to have set in after a deep drought ending in 1593; this drought, apparently the most generally severe and extensive one of recent centuries in the western United States as a whole, began in 1573 in the Colorado River basin but seems to have started as early as 1560 in some portions of the Rio Grande basin. A similar, only slightly differing duration in the Rio Grande for the Western Pueblo drought of 1276-1299 has been reported by Stallings.

The great 200-year oscillation, which now seems to be definitely indicated for the Colorado River basin—the 1200's extremely dry, the 1300's extremely wet—perhaps prevailed also in the Rio Grande basin but may be difficult to establish, for such long-period changes cannot yet be safely deduced from the relatively short sequences in archaeological beams which at present provide the only data for these centuries.