AD664014

TREE-RINGS AND CLIMATIC CHANGES

IN WESTERN NORTH AMERICA

Edmund Schulman

Reproduced by the
CLEARINGHOUSE
for Federal Scientific & Technical
Information Springfield Va. 22151

Final Report on Contract NR089-020 Between

the Office of Naval Research and the University of Arizona

University of Arizona, Tucson June 20, 1953

FILE COPY - ONR GEOGRAPHY BRANCH

TREE-RINGS AND CLIMATIC CHANGES

IN WESTERN NORTH AMERICA

Edmund Schulman

NR-089-020

Final Report on Contract NR089-020 Between

the Office of Naval Research and the University of Arizona

University of Arizona, Tucson June 20, 1953

Table of Contents

I. INTRODUCTION

The primary objective of this research has been the discovery and development of the longest significant chronologies of year-by-year rainfall and river flow obtainable from tree-rings in western North America. The extension of the relatively short gage records for many centuries into the past by means of growth indices can represent, in the writer's opinion, perhaps the most important service of tree-ring analysis to science. But data which may perhaps stimulate investigators to create new climatic theories and by which existing climatic theories are to be tested are not to be casually derived from so characteristically complex a biologic variable as cambial growth. It is thus of profound importance that, in the areas surveyed in this report, the growth indices may, by successive refinement of field criteria of selection of specimens and of laboratory methods, be extended and in part replaced by successively more significant ones.

That conifers severely limited in growth rate by an extremely dry environment were found to exhibit great sensitivity to fluctuations in seasonal moisture supply was perhaps to be expected, but that such stunted trees were found also to live for centuries beyond the normal life span of their species was indeed fortunate for this research in dendroclimatology.

Numerous reports, particularly in North America and in Scandinavia since the turn of the century (see Bibliography), contain significant ring chronologies of climate and have shown that both drought chronologies in the warm-dry lands and temperature chronologies in the arctic tend to reach greater sensitivities as the sites become more limiting in terms of the respective climatic element; at the same time, almost all investigators have pointed out at least some of the many factors which may disturb the growth-ring series as an index of climatic history. Application of the analysis to central Europe and other areas is under way.

In 1939 the writer undertook to extend in both time and space the ring chronologies of rainfall which A. E. Douglass had shown to be obtainable in specially clear form in the southwestern United States. This program culminated in an intensive three-year survey, under the sponsorship of the Office of Naval Research and with the full co-operation of the University of Arizona, a survey which now makes it possible to present long chronologies for most of the major drainage basins of the western United States and southwestern Canada. To facilitate comparisons between chronologies, these are plotted *in extenso* in Chapter II, where, also, the collection sites are briefly described; growth indices are tabulated in the Appendix. Of the 314,000 measured rings on which the charts and tables of this report are based, over one-half represent sites in the Colorado River Basin, which for many years was the only area in the West subjected to intensive study. For completeness, some diagrams and other material which have already appeared in the *Tree-Ring Bulletin* and the *University of Arizona Bulletin* are included in this survey.

One may not hope that, in this attempt to construct a macroscopic yet detailed picture of West-American climatic changes, even such obvious errors as those in computation have not crept in; much effort in checking statistical operations has, it is hoped, kept these at a minimum.

The methods of analysis have been amply reported. The procedure includes the following:

a. Searching out of suitable sites and core sampling of those types of trees which repeated field testing and laboratory analysis have shown to be specially desirable sources of dendroclimatic history.

b. Hand surfacing of the mounted cores with a razor blade along a plane inclined some 35^o-40^o to the tracheid axes.

c. Dating of the ring sequences by decadal marking, after intense intercomparison of all cores within the group and of relevant sequences from other sites in order to uniquely solve all problems of identification.

d. Measurement of ring-widths to 0.01 mm and reduction to group and regional averages and indices.

In the derivation of ring indices, general practice necessarily includes the elimination of its own age trend from each tree's record. Whether this is rapidly done by approximate eye-fitted trend lines or much more laboriously by precise arithmetic, there are included in the final results assumptions which bespeak caution in the interpretation of the longer fluctuations as climatic changes, even in the most significant indices. This problem and some other aspects of theory are developed in Chapter III.

The far-reaching variability of ring growth and of the meteorological elements makes quite unsafe any generalization of the climatic relationship found for the ring series at a given station. With the development of many highly sensitive and widely distributed series a systematic analysis of rainfall-growth correlations was carried through. The results presented in Chapter IV are a necessary preliminary to the interpretation of the derived growth sequences in terms of climatic changes.

Acknowledgments. Apart from the sponsorship already noted, perhaps the most important aid in this research has come in the ready and enthusiastic field co-operation of the National Park and Forest Services. I am indebted to the Weather Bureau, the Geological Survey, the Bureau of Reclamation, the Soil Conservation Service, and other federal and state agencies for data and other aid so freely given. To many individuals at college and private laboratories throughout the West go my deepest thanks for many stimulating discussions.

Highly responsible assistance in the field and at the Arizona Tree-Ring Laboratory throughout this three-year program has been provided by Charles W. Ferguson, Jr. I am also indebted, for significant laboratory aid, to Margaret A. Spencer, Gladys Phillips, Earl H. Kinney, Estella B. Leopold, Daniel Yuhr, and Don K. Cox. For a general review of the text I wish to thank Alsie F. Schulman.

Abbreviations. Species abbreviations are extensively used in the figures and tables; the complete identification of symbols is given in the immediately following pages. Other abbreviations:

Code symbols for tree groups, usually in three letters. These may be found in Appendix A, under the numbers corresponding to the basin stations in Table 1.

M.S.--Mean sensitivity, the average relative fluctuation in ring-width from year to year.

TRB--Tree-Ring Bulletin (a small quarterly edited at the Tree-Ring Laboratory of the University of Arizona).

II. COLLECTIONS AND CHRONOLOGIES

SAMPLED SITES

In Table 1 are briefly described those stands of trees sampled by the writer during 1939-1952 in the western United States and adjacent areas which have been measured and reduced to growth indices. The groups are in general classified according to drainage basins and arranged as closely as practicable from north to south. Unless noted otherwise, all sites are well drained slopes or ridges with thin soil.

Fraser River Basin. In the so-called "dry belt" within the basin of the lower Fraser River, in British Columbia, for at least 200 miles southward from Quesnel, Douglas-fir occurs in numerous open, moisture-deficient stands; ponderosa pine is present in the south. In view of the well-established tendency for ring sensitivity to increase at dry forest margins, it may be specially noted that these two species, fruitful sources of climatic chronology in the Colorado River Basin, reach their northern limits at about 55° (Douglas-fir) and 51° 30' (ponderosa pine) in British Columbia. No old trees were noted of the only other dry-site conifer, scopulorum juniper, found in this very limited survey.

Differences in the influence on ring chronology of Douglas-fir developed on schist (Williams Lake, Alkali Lake) as compared with basaltic lava (Tranquille) did not appear to be appreciable on these thin-soil sites.

Saskatchewan River Basin. All sites are in the mountain-prairie border zone. The collection of Douglas-fir at Jasper, a few miles from the northern limit of this species in Alberta, shows very good crossdating and sensitivity on well-drained sites, though several of the groups from the Banff area, about 175 miles southeast, are superior to it in these fundamental characters.

The older Jasper Douglas-firs, 50-75 feet tall, showed very pronounced taper as compared with trees of this species in the Colorado Basin. The Douglas-fir group at Exshaw was stunted and snag-topped, the only Canadian site currently known which supports trees apparently like those on sites of extreme aridity-stress for this species in the southern Rocky Mountains. A stand of Lyall's larch at Lake Agnes, some 1300 feet above Lake Louise, was thoroughly sampled; trees up to 500 years in age were found, and moderately good crossdating was observed in several cores, but strong distortions in chronology make many specimens difficult to date.

Test sampling of miscellaneous species of conifers yielded no reliable chronologies. Lodgepole pine (*Pinus contorta*) at Banff showed the same properties of erratic growth, non-climatic suppression and surge, and relatively short-life characteristic of this species wherever heretofore sampled. Only one relatively moist site of white spruce (*Picea glauca*) was sampled; the ring sequences were complacent.

Columbia River Basin. Douglas-fir and ponderosa pine in the Okanogan Valley of north-central Washington show good chronology characters, but no very old trees with datable ring records were found in the limited field work. Keen's excellent long chronology for eastern Oregon is to some extent applicable to this region.

Clark Fork River Basin. Only preliminary sampling has been done in this basin, principally in the Bitterroot River Valley. Both Douglas-fir and ponderosa pine are common, but no chronologies were obtained comparable in sensitivity and length to those in neighboring areas to the southeast and south, the Beaverhead River Basin (upper Missouri) of Montana and the Snake River Basin in central Idaho. For studies of climatic fluctuations in the Clark Fork Basin the regional chronologies for the comparison areas are perhaps more safe statistically.

Snake River Basin. As in other northerly basins of the West, relatively few sites have been sampled as compared with the Colorado River Basin; the most promising source areas for drought chronology lie, as expected, in the semi-arid south-central and eastern parts of Idaho. On one quite remarkable site, near Ketchum, stunted limber pines of the order of 1500 years in age yielding significant climatic chronologies have recently been discovered, and others of even greater age almost certainly await discovery in this area. Douglas-fir of high sensitivity is also present.

Missouri-Yellowstone River Basins. Field sampling shows this region to be rich in chronology trees; the longest and most sensitive records thus far found are in the southwest portion of Montana, where both Douglas-fir and limber pine provide significant chronologies. Ponderosa pine seems to be a quite secondary chronology source throughout Montana.

Although average ring-width in the older trees on adverse sites is of the order of 0.25 mm or less, annual rings are locally omitted on the cores only very rarely, consistent with the relatively high latitude.

Bighorn-Platte-Arkansas River Basins of the Missouri-Mississippi in Wyoming and Colorado. Several excellent, well-distributed groups of specimens have formed the base for a statistically sound growth index for the small and homogeneous upper basin of the South Platte River, the South Park of Colorado. In all other local basins only preliminary sampling has been done. However, North Platte and Arkansas ring series show excellent sensitivity and should represent good first approximations to the local chronologies. Douglas-fir seems to be the best source of chronology throughout this region; in the marginal stands along the eastern limits of the Rockies or in island mountains within the Great Plains ring sensitivity is characteristically higher than it is even on the most suitable chronology sites in the Colorado River Basin.

<u>Eastern Great Basin</u>. On the whole, this region has yielded relatively little chronology material. Douglas-fir, so sensitive in much of the neighboring Colorado River Basin, was found to be relatively complacent at the few sites sampled, and no areas of very long-lived trees have yet been found.

Single-leaf pinyon (*Pinus monophylla*) occurs in numerous open stands across central Nevada but seems to be characterized in general by rather erratic ring series. Scopulorum juniper reaches ages of 1000 years or more in both northern and southern Utah but is quite complacent.

A comparison of the indices for the eastern Great Basin with those in adjacent areas shows that the long and highly sensitive records in the Uintah and other sub-basins of the Colorado River system may, as expected, be used as fair first approximations to the chronology in this region.

<u>Colorado River Basin</u>. The largest number and widest distribution of good source areas for dendrochronologies are to be found in this basin. Chronologies from the southern part of the basin, particularly in the Flagstaff, Arizona, area, have been available for several decades as a result of the work of Douglass, which, apart from his sequoia studies, was largely concentrated there.

Collections by the writer, particularly in the central and northern areas, were summarized in 1945 in a first report on the tree-ring hydrology of this basin. Chronologies of specially great length were developed and reported for living trees in the areas of Mesa Verde and Bryce Canyon National Parks. The superiority of sedimentary sites, particularly limestone, as source areas for consistent records in most or all sampled trees of suitable species, the essential elimination of this soil factor as of any consequence in chronologies from the most adverse sites, and other tree selection criteria were discussed in some detail in that report and are not repeated here.

Later field work in this basin was particularly directed towards the discovery and sampling of trees of maximum longevity. Two extensive sub-regions with exceedingly old drought conifers, in and near Nine Mile Canyon in northeastern Utah and at Eagle in north-central Colorado, provided major additions to the dendrochronologies in the Colorado Basin.

Rio Grande Basin. 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: in the Sangre de Cristo range southeast of Taos and 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 wherever in the Rio Grande Basin the three chronology species noted above exist, significant drought chronologies may, in general, be obtained.

California and Western Great Basin. The analyses of the Sierra sequoia (Sequoia gigantea) by Huntington and Douglass provided, by 1919, first approximations to a climatic chronology over 3,000 years in length for the southern Sierra Nevada. Perhaps owing to the relatively moist habitat of this species, however, the climatic sensitivity of the ring-growth was soon found to be decidedly less than that obtainable in the semi-arid areas of the

Colorado Plateau and elsewhere. In recent years, the bigcone spruce of southern California has yielded 500-year rainfall histories equal to those derived from the Rocky Mountain drought conifers. Ponderosa pine seems to offer less promise in most localities of the Coast Range and on the west slopes of the Sierra Nevada, but on the drier slopes along the western margin of the Great Basin moderate ring sensitivity in this species has been observed by several investigators.

West-Central Mexico. The western Sierra Madre is largely unexplored as a source of dendrochronology. However, a survey in the high mountains west of Durango shows crossdating to exist in *Pseudotsuga*, and, to a lesser degree, in *Pinus*. Unfortunately, no long-lived trees of these genera were found; it is probable, in view of the apparently decreased life-span already noted for trees of these genera in the southern portion of their range in the Colorado Basin, that ages greater than about 300 years will only rarely be found. The ahuehuete (*Taxodium distichum*) of central and southern Mexico, which reaches ages well in excess of 1000 years, does not seem to offer much promise as a source of rainfall chronology.

Notes on Table 1

Station Number. The numerical sequence of the stations (sites) is roughly one of decreasing latitude; this has no relation to the order of collection.

Station Area. In most cases, the name of a nearby town was used; for some sites it seemed more appropriate to use a physiographic feature.

Collection Date. Month and year.

Latitude, Longitude. These coordinates have in most cases been obtained from detailed U. S. Forest Service maps and should at most stations be correct to within a mile or so. However, many collection sites extend over a considerable area, occasionally a square mile or more.

Elevation. This is an average for the site, estimated from contour maps or survey reference points.

Species. BCP -- Bristlecone pine, Pinus aristata Engelm.

BCS -- Bigcone spruce, Pseudotsuga macrocarpa (Vasey) Mayr.

CBS -- Colorado blue spruce, Picea pungens Engelm.

DF -- Douglas-fir, Pseudotsuga taxifolia (Poir) Britt.

ES -- Engelmann spruce, Picea engelmanni Parry

GS -- Giant sequoia, Sequoia gigantea (Lindl.) Deene.

JP -- Jeffrey pine, Pinus jeffreyi Grev. and Balf.

JSC -- Rocky Mountain juniper, Juniperus scopulorum Sarg.

LBP -- Limber pine, Pinus flexilis James

LL -- Alpine larch, Larix lyalli Parl.

PNN -- Pinyon, Pinus edulis Engelm.

PNNs - Single-leaf pinyon, Pinus monophylla Torr. and Frem.

PP -- Ponderosa pine, Pinus ponderosa Laws.

SCJ -- See JSC

WF -- White fir, Abies concolor (Gord. and Glend.) Hoopes

WJ -- Western juniper, Juniperus occidentalis Hook.

Measure Begin. The earliest data plotted in the growth charts or used in the tables of measures. For many localities, earlier data have been derived but were not used here because of insufficient comparable material.

(Page 12 omitted)

Table 1. Dated and Measured Increment Cores

Station No.	Station Area	Coll. Date	Lat.	Long.	Elev., ft.	Species	Trees Measured	Rings Msd. (000)	Mars. Begin, A.D.
				A. Fraser River Basin					
1	Quesnel	9-44	53°01'	122°31'	1800	DF	5	0.7	1800
2	Williams Lake	9-44	52 10	122 13	1900	DF	6	1.5	1626
3	Alkali Lake	9-44	51 48	122 14	2000	DF	7	2.1	1620
4a	Tranquille	9-44	50 42	120 31	2800	DF	14	3.4	1500
4b	Tranquille	"	"	"	"	PP	14	3.5	1420
				B. Saskatchewan River Basin					
5	Jasper	6-49	52°54'	118°04'	3600	DF	8	2.7	1537
6	Lake Agnes	6-51	51 25	116 15	7000	LL	4	0.7	1770
7a	Banff	9-44	51 10	115 38	4600	DF	10	2.7	1598
7b	Banff	6-51	"	"	"	"	8	[illegible]	1565
8	Banff	6-51	51 12	115 30	4600	DF	4	2.0	1660
9	Banff	6-51	51 11	115 36	4700	DF	7	1.1	1800
10	Exshaw	6-51	51 04	115 12	4300	DF	4	1.4	1590
				C. Columbia River Basin					
11	Vernon	9-44	50°13'	119°11'	1800	DF	4	0.5	1800
12	Penticton	8-43	49 36	119 37	1300	PP	4	0.6	1800
13	Oroville	7-43	48 59	119 44	1250	DF;PP	4	0.6	1800
14	Conconully	7-43	48 40	119 41	1800	DF;PP	8	1.1	1800
15	Republic	7-43	48 34	118 41	4800	DF;PP	5	0.7	1800
16	Republic	7-43	48 34	118 41	2800	DF;PP	4	0.6	1800
17	Winthrop	9-44	48 26	120 10	2100	DF;PP	2	0.3	1650
18	Twisp	9-44	48 26	120 04	2000	DF;PP	2	0.3	1650
				D. Clark Fork River Basin					
19a	Missoula	7-51	46°49'	114°04'	3300	DF	3	0.5	1800
19b	Missoula	"	"	"	"	PP	7	1.1	1800
20a	Sula	7-51	45 51	113 59	4500	DF	3	0.5	1800
20b	Sula	"	"	"	"	PP	8	1.2	1800
				E. Snake River Basin					
21	Salmon	7-51	45°38'	113°57'	5000	PP	6	0.9	1800
22	Salmon	7-51	45 25	114 00	4000	DF	5	0.8	1800
23	Salmon	7-51	44 58	113 57	4600	DF	6	2.0	1586
24	Ketchum	7-51	43 45	114 23	6000	DF	11	3.4	1372
25	Ketchum	7-52	43 48	114 16	7000	DF	3	0.7	1700
26a	Ketchum	7-52	43 46	114 16	6500	DF	3	[illegible]	1886
26b	Ketchum	"	"	"	"	LBP	9	10.2*	456
27	Moran	10-41	43 52	110 16	7200	DF	4	0.5	1814
28	Victor	10-41	43 32	111 00	7200	DF	4	0.6	1707
29	Hoback Canyon	10-41	43 18	110 36	7000	DF	2	0.3	1800
				F. Upper Missouri River Basin					
30	Helena	7-48	46°43'	111°48'	4300	DF	5	0.9	1553
31	Townsend	9-50	46 22	111 06	5000	DF	4	0.6	1800
32	Townsend	9-50	46 20	111 14	4200	DF	4	0.6	1800
33	Butte	9-44 6-49	45 50	112 21	5800	DF	4	1.0	1700
34	Divide	6-49	45 46	112 47	5600	DF	14	4.5	1440
35a	Springdale	6-49	45 45	110 13	4500	DF	4	1.0	1700
35b	Springdale	6-49 9-50	"	"	"	LBP	13	2.8	1574
36	Livingston	7-48	45 36	110 33	4700	DF	4	1.0	1700
37	Gardner	9-44 7-48	44 59	110 41	6000	DF	7	2.4	1443
38a	Dell	6-49	44 39	112 46	7200	DF	3	1.5	1175
38b	Dell	"	"	"	"	LBP	5	2.7	978
39a	Dell	9-50	44 33	112 48	7000	DF	3	1.2	1564
39b	Dell	"	"	"	"	LBP	3	2.0	1259
				G. Missouri-Mississippi Basins in Wyoming and Colorado					
40	Lander	10-41	42°45'	Big Horn 108°51'	8200	DF	6	1.5	1456
41	Laramie	7-46	41 07	North Platte 106 02	7600	DF	1	0.6	1370
42	Walden	7-46	40 55	106 19	8000	DF	6	2.1	1336
43	Idaho Springs	7-46	39 45	South Platte 105 27	7500	DF	2	0.8	1425
44	Mt. Evans	9-44	39 42	105 36	9200	DF	5	1.6	1500
45	Lake George	9-41	39 00	105 20	9000	DF	4	1.1	1600
46	Hartsell	[illegible]-44	38 56	105 57	9200	DF	4	1.2	1500
47	Pikes Peak	9-41	38 52	105 04	12000	ES	6	2.0	1521
48	Lake George S.	9-45	38 47	105 27	9000	DF	2	0.6	1574
49	Salida	10-41 9-50	38 29	Arkansas 105 57	7000	DF	16	4.1	1427
				H. Eastern Great Basin					
50	Logan Can.	10-41	41°57'	111°29'	7500	DF	3	0.8	1599
51	"	"	41 49	111 38	7300	DF	3	0.8	1548
52	Kamas	7-46	40 33	111 02	7800	WF;DF	3	0.7	1642
53	"	"	40 32	111 03	7500	PP	4	1.2	1511

*Four radii, KETe-5966

I. Colorado River Basin, 1939-1945

Station No.	Station Area	Coll. Date	Lat.	Long.	Elev., ft.	Species	Trees Measured	Rings Msd. (000)	Mars. Begin, A.D.	Fig12 Curve No.
				Green River Basin						
54a	Pinedale	10-41	42°55'	109°47'	8500	DF	6	1.2	1653	1
54b	Pinedale	10-41	42 55	109 47	8500	LBP	1	0.3	1674	2
55	Mid. Piney Lake	10-41	42 37	110 33	8500	DF	5	1.2	1665	3
56	Vernal	11-41	40 45	109 48	8400	DF	4	0.8	1730	4
57	Vernal	11-41	40 38	109 24	7700	PP	4	1.2	1622	5
58	Steamboat Spr.	10-41	40 44	106 54	8300	DF	6	1.4	1657	6
				Colorado-above-Gunnison River Basin						
59a	Hot Sulphur Spr.	6-42	40 03	106 06	8500	DF	6	1.4	1572	7
59b	Hot Sulphur Spr.	6-42	40 03	106 06	8500	LBP	3	0.9	1600	8
60	Redcliff	6-42;9-44	39 32	106 20	9000	DF	12	2.3	1250	9
61	Eagle East	6-42	39 43	106 45	7000	DF	4	1.1	1657	10
62	Eagle	9-45	39 38	106 51	6700	DF	9	2.7	1250	11
63a	Sopris Peak	10-41	39 18	107 14	7000	PNN	3	0.7	1600	12
63b	Sopris Peak	10-41	39 18	107 14	7000	DF	2	0.7	1441	13
				Gunnison River Basin						
64	Doyleville	9-45	38 27	106 37	8000	DF	4	1.3	1600	14
65a	Almont	9-45	38 42	106 49	8200	DF	4	1.2	1481	15
65b	Almont	9-45	38 42	106 49	8200	PP	3	0.7	1600	16
66	Sapinero	10-41	38 28	107 19	7200	DF	7	1.8	1482	17
67a	Black Can. Mon.	6-42	38 34	107 46	8300	DF	4	0.7	1700	18
67b	Black Can. Mon.	6-42	38 34	107 46	8300	PNN	2	0.6	1623	19

Station No.	Station Area	Coll. Date	Lat.	Long.	Elev., ft.	Species	Trees Measured	Rings Msd. (000)	Mars. Begin, A.D.	Curve No.
				Salt River Basin						
84	Forestdale	7-39	34°10'	110°03'	6500	PP	5	1.1	1637	38
				Gila River Basin						
85	Luna Pass	6-40	33 43	108 56	7500	DF;PP	5	1.0	1664	39
86	Sawmill	"	33 37	110 23	6000	PP	7	1.4	1711	40
87	Stray Horse Div.	"	33 29	109 21	7000	PP	3	0.5	1732	41
88	Rose Peak	"	33 27	109 22	8500	PP	4	1.2	1603	42
89	Mogollon	"	33 24	108 48	7000	DF;PP	6	1.0	1642	43
90	Mogollon Mts.	"	33 22	108 42	9200	DF;PP	5	1.0	1674	44
91	Gila Cliff Dwell. Mon.	"	33 13	108 17	6000	DF;PP	10	1.4	1680	45
92	Graham Mts.	"	32 38	109 49	8000	DF;PP	6	1.2	1713	46
				Southern Arizona Area						
93	Chiricahua Mts.	3-41	31 56	109 16	7500	DF	2	0.5	1663	47
94	"	"	31 55	109 17	8500	DF	3	0.7	1693	48
95	Santa Cat. Mts.	"	32 23	110 41	6000	DF	5	0.8	1728	49
96	"	9-40	32 27	110 47	8600	DF	6	1.6	1648	50
97	Santa Rita Mts.	2-41	31 44	110 50	6000	DF	5	1.1	1602	51
98	"	11-40;5-41	31 43	110 50	8500	DF	7	1.3	1600	52

Station No.	Station Area	Coll. Date	Lat.	Long.	Elev., ft.	Species	Trees Measured	Rings Msd. (000)	Mars. Begin, A.D.	Cur No
				Dolores River Basin						
68a	Dolores	10-41;6-42	37°35'	108°33'	7500	DF	9	2.3	1454	20
68b	"	"	"	"	"	PP	2	0.5	1633	21
68c	"	"	"	"	"	PNN	5	1.6	1250	22
68d	"	"	"	"	"	SCJ	2	0.3	1721	23
				San Juan River Basin						
69	Lime Creek	10-41	37 40	107 45	9200	DF	3	0.7	1700	24
70	Durango	7-41	37 24	107 53	9000	DF	4	0.8	1700	25
71	"	"	"	107 51	7000	DF	3	0.5	1773	26
72	Mesa Verde	8-45	37 11.8	108 30.1	6900	DF	5	1.1	1288	27
73	"	7-41	37 11.2	108 29.5	6800	DF	2	1.0	1450	"
74	"	"	37 11.1	108 29.2	"	DF	3	1.6	1390	"
75	"	"	37 09.7	108 28.7	6750	DF	2	1.0	1439	"
76	Monticello	10-41	37 44	109 24	6000	PP	2	0.5	1689	28
				Southern Utah Area						
77a	Bryce Can. N. P.	8-42;9-45	37 36	112 09	8000	DF	2	1.2	1288	29
77b	"	"	"	"	"	DF	2	0.4	1665	31
78a	Red Can.	10-41;8-42	37 45	112 18	7500	DF	2	1.1	1366	29
78b	"	"	"	"	"	DF	3	0.8	1665	31
79a	Tropic Can.	8-42	37 39	112 05	7000	DF	4	1.7	1665	30
79b	"	"	"	"	"	PP	3	1.0	1600	32
80a	Cedar City	11-41	"	112 59	6500	DF	2	1.0	1411	33
80b	"	"	"	"	"	PNN	2	0.7	1600	34
81	Zion N. P.	8-42	37 14	112 53	6000	PP	4	0.8	1727	35
82	Kaibab	7-41	36 39	112 20	5700	DF	2	0.7	1567	36
83	Jacob Lake	"	36 37	112 10	8500	DF	4	0.6	1800	37

J. Colorado River Basin, 1946-1951

Station No.	Station Area	Coll. Date	Lat.	Long.	Elev., ft.	Species	Trees Measured	Rings Msd. (000)	Mars. Begin, A.D.
				Uintah Basin					
99	Dinosaur Mon.	7-48	40°31'	108°46'	6500	PNN	1	0.6	1321
100	Uintah Mts.	6-50	40 40	109 30	7500	PP	3	2.9	1610
101	Nine Mile Can.	4-47 6-50	39 48	110 20	7200	DF	15	3.5	1092
102	Nine Mile Can.	9-46	39 46	110 29	7000	DF	6	2.3	1236
103a	Nine Mile Can.	9-46 4-47	39 45	110 32	7300	DF	6	4.3	1186
103b	Nine Mile Can.	9-46	"	"	"	PNN	2	1.3	1268
104a	Indian Can.	5-48 8-50	39 58	110 38	7200	DF	19	7.6	1131
104b	Indian Can.	8-50	"	"	"	BCP	2	0.9	1480
105	Indian Can.	5-48	39 54	110 41	7300	PNN	2	0.7	1600
106	Sunnyside	8-46	39 36	110 22	7200	DF	5	2.8	1225
107	Sunnyside	5-48	39 37	110 22	7200	PNN	1	0.6	980
108	Hill Can.	6-50	39 35	109 48	7000	PNN	4	1.4	1600
109	Hill Can.	6-50	39 33	109 45	7200	DF	6	1.4	1400
				Colorado--above Gunnison River Basin					
110	Hot Sulphur Spr.	9-50	40 04	106 06	7800	DF	3	0.5	1800
111a	Eagle West	9-50	39 40	106 59	6400	DF	6	3.4	1133
111b	Eagle West	"	"	"	"	PNN	4	0.6	1800
112	Eagle	9-46 9-50	39 37	106 51	6700	DF	31	11.2	1085
113a	Rifle	9-50	39 45	107 57	6000	DF	4	1.2	1661
113b	Rifle	"	"	"	"	PNN	2	0.3	1800
114	Redcliff	9-44	39 32	106 19	9000	DF	4	1.2	1650
115a	Aspen	9-50	39 18	106 56	7200	DF	4	0.6	1800
115b	Aspen	"	"	"	"	PP	2	0.3	1800

Station No.	Station Area	Coll. Date	Lat.	Long.	Elev., ft.	Species	Trees Meas-ured	Rings Msd. (000)	Mars. Begin, A.D.
			South Utah Area						
116a	Red Canyon	8-50	37°45'	112°18'	7500	DF	4	1.3	1310
116b	" "	"	"	"	"	PP	4	0.8	1750
116c	" "	"	"	"	"	CBS	5	1.0	1750
117a	Tropic Canyon	8-50	37 39	112 05	7000	DF	13	3.2	1150
117b	" "	"	"	"	"	PT	10	2.6	1396
118	Kaibab	8-50	36 37	112 10	8500	WF	5	0.6	1840
			San Juan and Little Colorado Basins						
119	Mancos	5-50	37 21.5	108 15.0	7400	DF	1	0.5	1404
120	Mesa Verde	5-48	37 18.5	108 25.0	6250	PNN	7	4.0	1100
123a	Mesa Verde	5-50	37 16.5	108 25.7	7700	DF	7	3.4	1670
123b	Mesa Verde	"	"	"	" "	JSC	4	0.7	1770
123c	" "	"	"	"	" "	PNN	1	[illegible]	[illegible]
121	Mesa Verde	7-47	37 17.8	108 26.5	7800	DF	3	0.6	1750
122	Mesa Verde	8-45	37 17.5	108 26.5	8000	PNN	3	0.9	1450
124	Mesa Verde	8-45	37 13.0	108 33.0	7400	PNN	4	0.6	1750
125	Mesa Verde	7-47;9-47	37 11.8	108 30.1	6900	DF	4	2.9*	1163
126	Mesa Verde	8-45	37 11.2	108 29.2	6800	DF	7	0.9	1800
127	Mesa Verde	10-51	37 10.3	108 29.3	6900	PNN	3	0.6	1750
128	Mesa Verde	5-50	37 10.0	108 27.2	6700	DF	3	1.5	1400
129	Betatakin	4-47;6-47	36 41	110 32	7100	DF	6	3.5	1273
130	[illegible]. Defiance	9-46	35 52	109 12	7500	DF	5	1.0	1708
131	[illegible]. Defiance	9-46	35 50	109 05	7000	PP	2	0.2	1850
132	Zuni Mts.	10-41	35 26	108 34	7400	DF;PP	5	0.5	1620

Station No.	Station Area	Coll. Date	Lat.	Long.	Elev., ft.	Species	Trees Meas-ured	Rings Msd. (000)	Mars. Begin, A.D.
			Flagstaff Area						
133	Grand Canyon	5-48	36 04	112 06	6900	DF	2	0.4	1747
134	Grand Canyon	5-48	35 58	111 58	7000	PP	5	1.3	1544
			Gila River Basin						
135	Reserve	6-48	33 44	108 56	7600	DF	3	0.9	1606
136a	Reserve	6-48	33 40	108 53	6200	PP	4	0.5	1597
136b	Reserve	6-48	"	"	"	PNN	7	0.6	1720
137	Point of Pines	7-46	33 21	109 42	6400	PP	6	1.1	1620
138	Point of Pines	8-48	33 18	109 43	6800	DF	4	0.6	1800

K. Rio Grande Basin

Station No.	Station Area	Coll. Date	Lat.	Long.	Elev., ft.	Spe-cies	Trees Meas-ured	Rings Msd. (000)	Mars. Begin, A.D.
139	Wagon Wheel Gap	10-41	37°48'	106°50'	9000	DF	5	0.5	1850
140	Ft. Garland	10-48	37 30	105 19	8600	DF	3	0.3	1850
141	"	7-51;10-51	37 27	105 21	8400	PNN	11	3.1	1356
142	Antonito	10-48	37 04	106 11	8500	DF	5	1.6	1490
143	Cebolla	10-48	36 21	106 32	6500	DF	3	0.9	1650
144a	Taos	7-51	36 11	105 37	7800	DF	4	0.4	1850
144b	"	"	"	"	"	PP	2	0.2	1850
144c	"	"	"	"	"	PNN	4	0.4	1850
145a	Taos Upper	10-41	36 06	105 28	9000	DF	4	1.0	1440
145b	"	7-51	"	"	8700	DF	5	1.4	1440
146	Pecos	7-46;9-51	35 35	105 46	7500	DF	4	2.0	1440
147a	Pecos South	10-41	35 28	105 41	"	DF	5	1.0	1650
147b	"	"	"	"	"	PNN	1	0.1	1850
148a	Albuquerque	7-46	35 11	106 23	8200	DF	2	0.2	1850
148b	"	"	"	"	"	PNN	1	0.1	1850
149	"	"	35 13	106 24	9000	CBS	2	0.2	1875
150	Cloudcroft	"	32 56	105 45	8800	DF	5	0.5	1850
151	"	"	32 45	105 46	9000	P	2	0.2	1850
152	Guadalupe	6-42	32 02	104 49	6500	DF	2	0.4	1750
153	"	"	32 04	104 45	8000	DF	3	0.6	1750
154a	McDonald	5-39	30 40	104 00	6800	PP	5	0.2	1903
154b	"	"	"	"	"	PNN	2	0.1	1901
155	Big Bend	11-45	29 13	103 19	6000	DF	15	2.8	1645

Station No.	Station Area	Coll. Date	Lat.	Long.	Elev., ft.	Spe-cies	Trees Meas-ured	Rings Msd. (000)	Mars. Begin, A.D.
			L. California and Western Great Basin						
156	Tahoe	6-39	39°03'	119 56	6500	JP	6	1.1	1650
157	Tioga Pass	8-42	37 57	119 1[illegible]	810[illegible]	JP	4	1.5	1757
158	" "	8-42	37 57	119 13	8300	WJ	3	0.7	1650
159	Mono Craters	8-42	37 52	119 00	7200	JP	3	1.3	1491
160	Mono Lake	8-42	37 49	118 56	7000	JP	2	0.5	1700
161	Tenaya Lake	8-42	37 50	119 28	8300	WJ	3	0.9	1650
162	Wawona Tunnel	8-42	37 43	119 42	5000	PP	7	0.6	1716
163	Wawona	8-42	37 30	119 37	5900	PP	2	0.4	1720
164	Bishop	8-42	37 31	118 59	6450	JP	5	1.[illegible]	1700
165	Las Vegas	8-42	36 16	115 34	6000	PP	7	2.9	1373
166	Antimony	5-45	34 52	119 04	6000	WF	5	0.8	1772
167	Hughes Lake	5-45	34 42	118 [illegible]	4600	BCS	6	2.5	1540
168	Mill Creek	6-45	34 24	116 05	5000	BCS	14	4.4	1474
169	Mt. Wilson	6-45	34 17	118 06	5500	BCS	5	1.0	1570
170	Big Bear Lake	6-45	34 18	116 48	6500	PNN's	7	0.4	1800
171	Big Bear Lake	6-45	34 16	116 57	6800	WJ	2	0.2	1821
172	Big Bear Lake	6-45	34 13	117 00	5500	BCS	9	[illegible]	1645
173a	San Jacinto	8-42	33 47	116 44	4700	BCS	5	1.9	1475
173b	San Jacinto	6-51 8-44	"	"	"	BCS	5	1.8	1785
173c	San Jacinto	6-45	"	"	"	BCS	9	1.7	1800
174	Palomar	12-43	33 21	116 52	5000	BCS	7	1.0	1740
175	Julian	12-47	33 05	116 35	4000	BCS	5	0.6	1770
			M. West-Central Mexico						
176	El Salto Cent.	8-43	23°46'	105°22'	8000	P	1	0.1	1640
177a	El Salto West	8-43	23.8	105.6	8500	DF	5	1.3	1640
177b	"	"	"	"	"	P	2	0.2	1640
178	El Salto SW	"	23.7	105.5	"	DF	3	0.3	1640
179a	El Salto S	"	23.6	105.4	8000	DF	5	0.5	1640
179b	"	"	"	"	"	WF	1	0.1	1640
180	Mexico City	9-43	19.3	99.5	11500	WF	2	0.2	1663

GROWTH CURVES

Ring-width measurements for almost all of the groups in Table 1, supplemented by individual growth curves for specially long-lived trees and by area and regional mean curves of various types, are collected in Figures 1 to 19. Prepared during several years, these diagrams vary somewhat in format but have a number of features in common:

Border notches permit completion of the co-ordinate grid, so that individual values may, if desired, be read off the growth curves. The vertical scale of the growth curve, in mm if unchanged measures or in per cent if standardized, is indicated at the margin; special treatment of the vertical scale is included in the figure notes below.

Figures along the group mean curves give the number of specimens on which the curve is based at various dates; in almost all cases, except as noted below, these represent the number of different trees.

Zeros below the curve denote locally-absent rings. Age trend lines or, in some cases, arithmetic mean reference lines, are superposed on a number of curves.

Smoothed curves are superposed on some of the broken-line curves. These were obtained by graphical smoothing corresponding to the weighted running mean $b' = (a + 2b + c)/4$.

Notes on Figures 1 to 19

Many of the figures contain areal or regional mean curves summarizing many or all of the other series in the chart. The composition of these mean curves is in general listed only in the notes accompanying Table 2, Appendix B, but is discussed below if the mean index was not included in that table. All the mean curves of Figures 6 to 11 and 14 to 17 are homogeneous; that is, they represent mean ring-widths for a group of trees of constant composition throughout the interval of the mean series.

Fig. 1. The short series in Douglas-fir at Vernon (50°13' N, 119°11' W) and ponderosa pine at Penticton (49°38' N, 119°37' W) were not included in Table 1-A. A sharply decreasing alternative trend line in series 8 from 1915 to 1944 seemed justifiable because of an assumed pest effect, but was found incorrect on later analysis of climatic and other data (see Table 18, footnote 3). The most sensitive records are those at Tranquille, Williams Lake, and Alkali Lake.

Fig. 2. The 1944 Banff index is the standardized mean of the measures plotted as series 8 in Fig. 1. The 1951 Banff growth curves representing trees of two age classes are for the same area. All series but that at Lake Agnes are of Douglas-fir. The Exshaw series, from the driest site in the Banff area, received double weight in the areal mean; the three Banff series, all from the same site, were given a collective weight of one in the areal mean.

Fig. 3. The ring measurements are plotted from the inner ring on the core to A.D. 950 for each of the phenomenally old Ketchum limber pines. The 4-core mean represents three trees; only in one other series, for MVR-3041 in Figure 8, does the number noted along the mean curve represent other than the number of component trees. The 28-tree Snake DF mean, 1800-1950, is based on eight groups from five stations. For description of the Clark Fork set see Table 1-D and the northern Utah set 1-H.

Fig. 4. All group means, 1440-1950, are standardized curves, plotted as per cent departures; the mean lines are at 100% and the vertical scale is 100% per border division. Two limber pines which enter the upper panel means at 1320 and 1349 are not separately plotted. The Livingston E. (1950) LBP series is not included in the basin index.

Fig. 5. The Pikes Peak Engelmann spruce series, from upper timberline, are in a different category from all other series in this figure, which are based on drought-site Douglas-fir.

Fig. 6. Each of the family of successively larger groups of Eagle trees, 1600-1950, includes all trees in the smaller groups; EAG-3339 was excluded.

Fig. 7. The specimen abbreviations NNM and NMI refer to Nine Mile and Indian Canyons, respectively. COL-6837, from Dinosaur National Monument, was collected and sent by the University of Colorado. The N.E. Utah 11 PNN mean, 1800-1945, is based on 4 Hill, 2 Indian, 2 Nine Mile, 1 Dinosaur, and 2 Sunnyside trees. The 36-tree DF mean, 1800-1945, is a weighted mean of the eight lowest series in the figure.

Fig. 11. The Kaibab North Rim series were developed by C. W. Ferguson and Don M. Black (TRB 19:12, 1952).

Fig. 12. For ease of station identification in Table 1-I, curve numbers are listed in the final column.

Fig. 13. The indices for the tributary basins represent means of the series plotted in Figure 12.

Fig. 14. All curves are means of measures, plotted on the same vertical scale of 0.25 mm per marginal scale division:

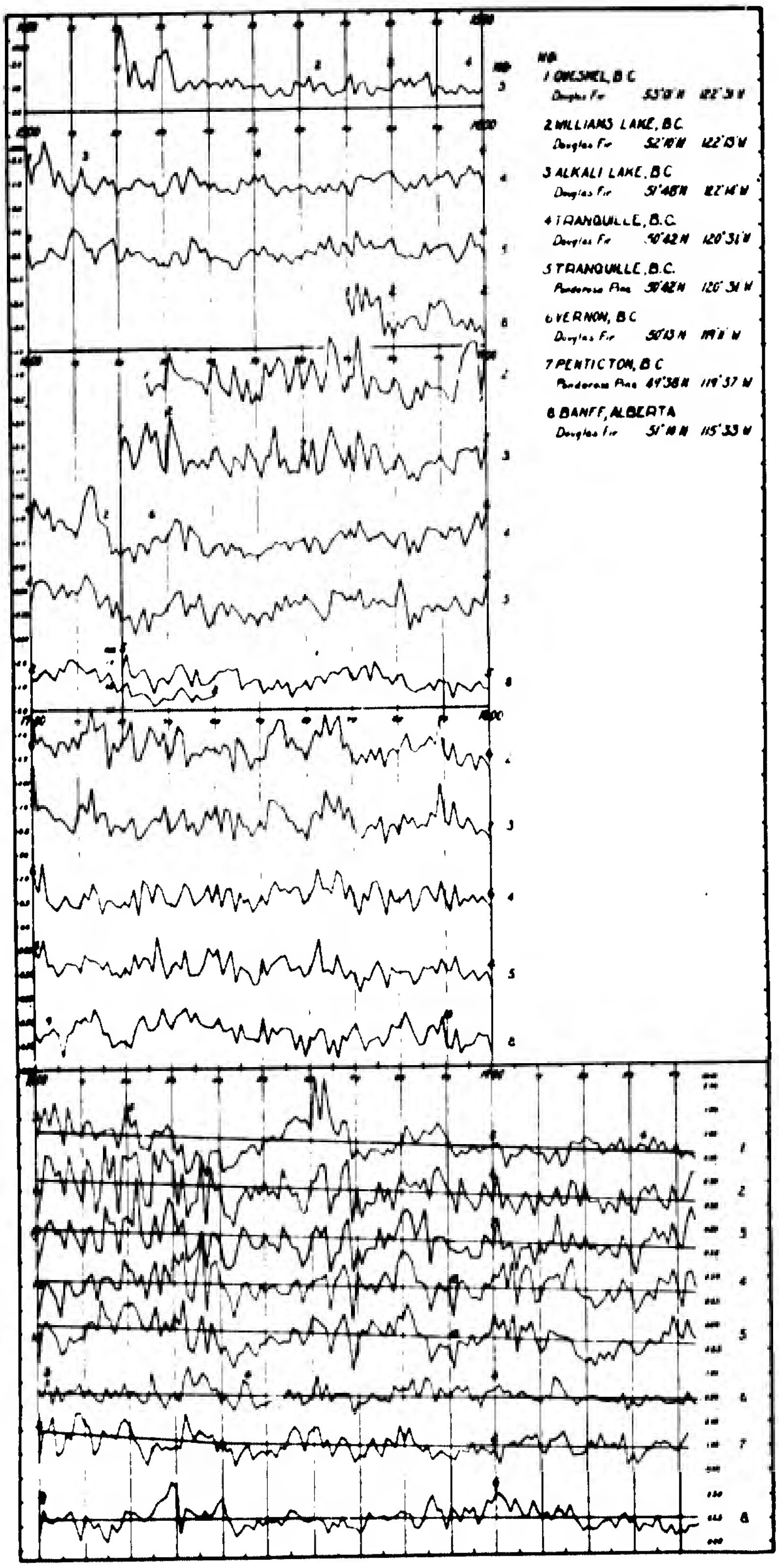
The composition of this family of curves is as follows:

3 PNN:	1 Sunnyside; 1 Dolores; 1 Mesa Verde.
8 PNN:	1 Dinosaur; 2 Nine Mile; 1 Dolores; 4 Mesa Verde.
3 DF:	1 Nine Mile; 1 Eagle; 1 Redcliff.
7 DF:	Add 1 Eagle West; 2 Eagle; 1 Bryce.
12 DF:	Add 2 Nine Mile; 1 Sunnyside; 1 Eagle; 1 Mesa Verde.
23 DF:	5 Indian; 10 Nine Mile; 4 Eagle; 4 Bryce.
60 DF:	Add 5 Indian; 4 Sunnyside; 6 Eagle West; 9 Eagle; 7 Mesa Verde; 6 Betatakin.
84 DF:	Add 4 Indian; 8 Nine Mile; 4 Rifle; 4 Redcliff; 4 Bryce.

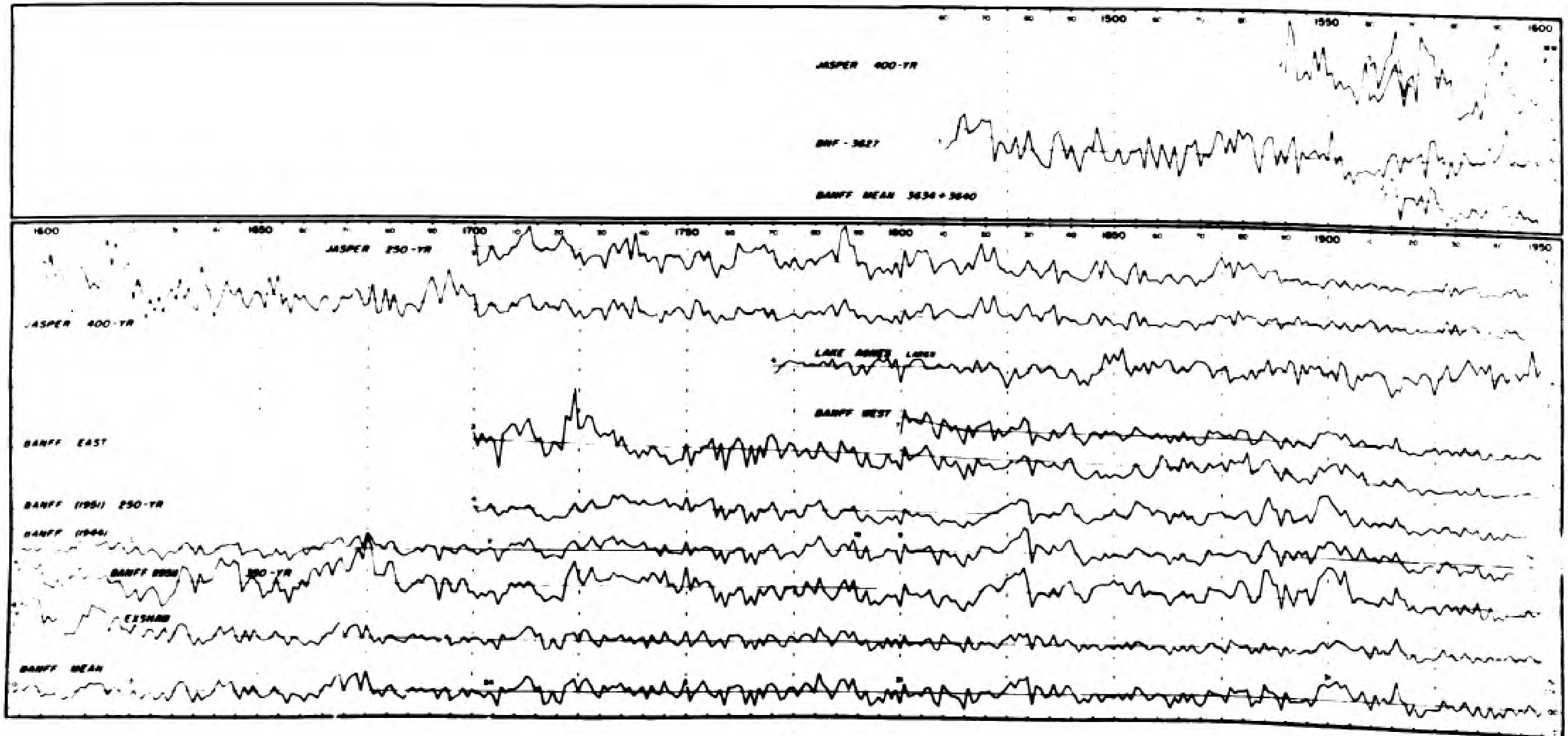
Fig. 17. The broken line trend fitted to the El Salto series, 1700-1850, was later replaced when the series was extended to 1640.

Fig. 18. All series are standardized means. The vertical scale for the station curves is 100% per margin division. The San Bernardino PP is a comparison series derived in 1932 by G. C. Dewey under the direction of A. E. Douglass.

Fig. 19. The regional means are all standardized, plotted on a scale of 50% per margin division. The upper curve is a mean of seven series plotted in this figure plus the San Bernardino PP index. To complete the transect, series were taken from the Keen, Antevs, and Hardman-Reil reports.

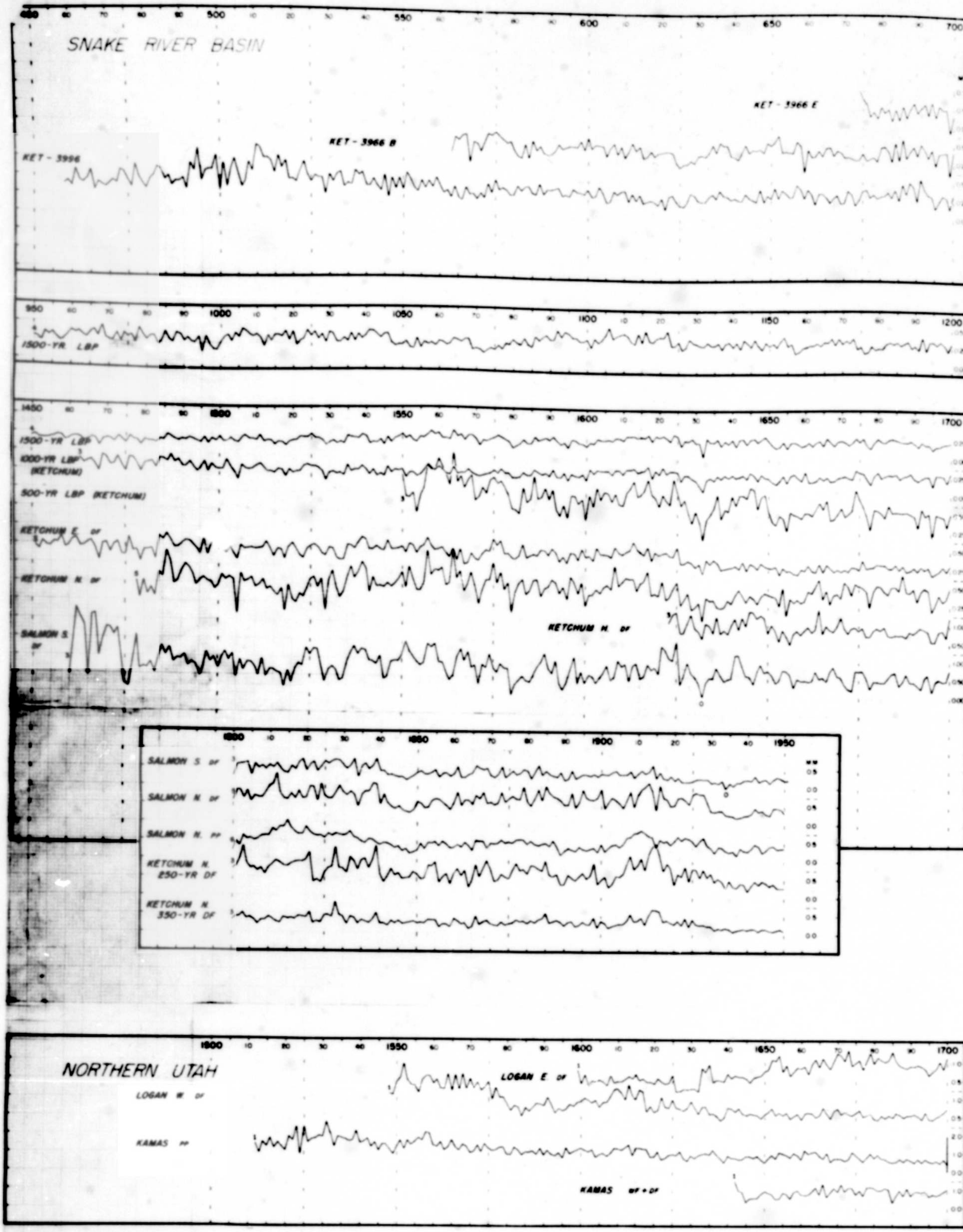

2 WILLIAMS LAKE, B.C.
Douglas Fir 52°10'N 122°13'W
3 ALKALI LAKE, B.C
Douglas Fir 51°48'N
4 TRANQUILLE, B.C.
Douglas Fir 50°42'N 120°31'W
5 TRANQUILLE, B.C.
Ponderosa Pine 50°42'N
6 VERNON, B.C
Douglas Fir 50°13'N
7 PENTICTON, B.C
Ponderosa Pine 49°38'N 119°37'W
8 BANFF, ALBERTA
Douglas Fir 115°33'W

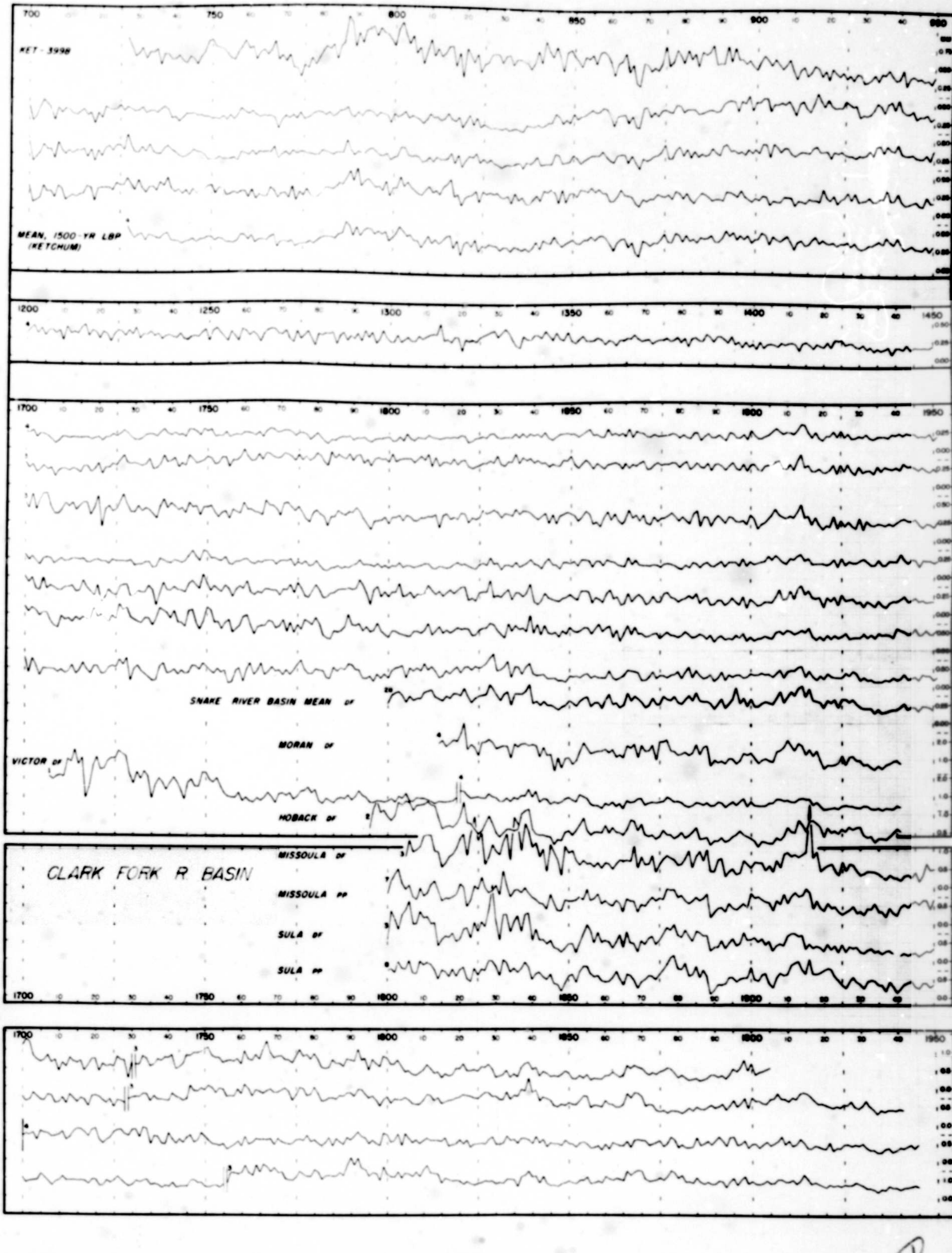
1.



JASPER 400-YR
BNF - 3627
BANFF MEAN 3634 + 3640
1500
1550
1600
1650
1700
1750
1800
1850
1900
1950
JASPER 250-YR
JASPER 400-YR
BANFF WEST
BANFF EAST
BANFF (1951) 250-YR
BANFF (1944)
EXSHAW
BANFF MEAN

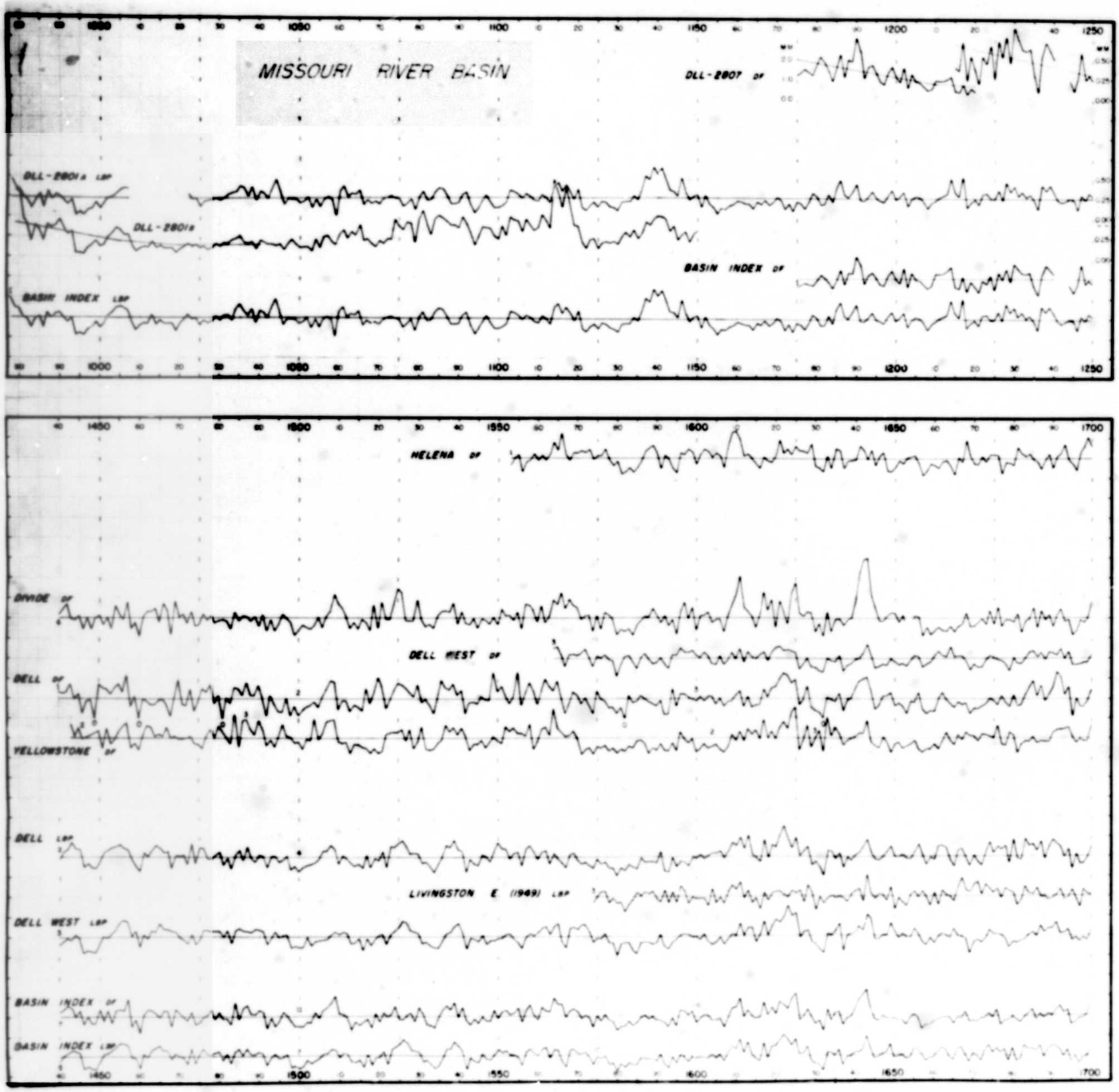
2.

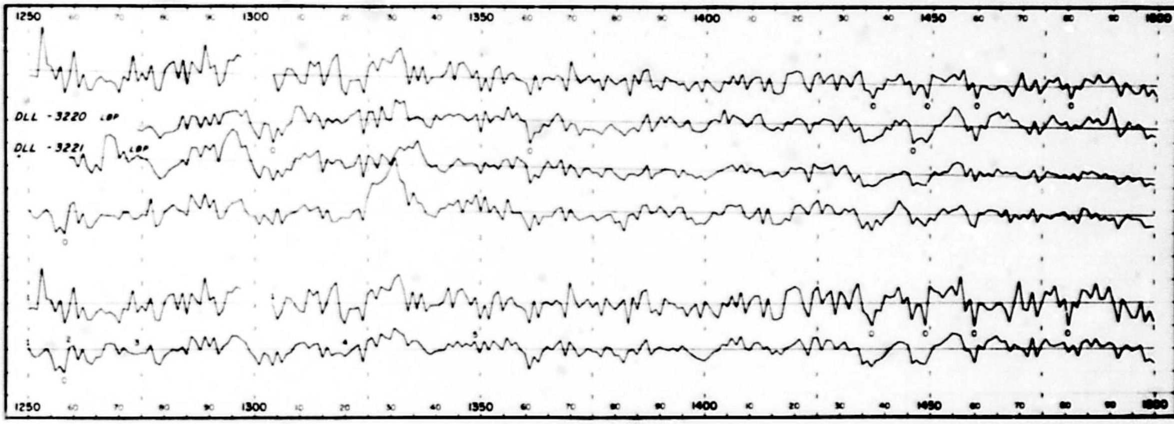

SNAKE RIVER BASIN
KET - 3996
KET - 3966 B
KET - 3966 E
1500-YR. LBP
1500-YR LBP
1000-YR LBP (KETCHUM)
500-YR LBP (KETCHUM)
KETCHUM E. DF
KETCHUM N. DF
SALMON S. DF
KETCHUM N. DF
SALMON S. DF
SALMON N. DF
SALMON N. PP
KETCHUM N. 250-YR DF
KETCHUM N. 350-YR DF
NORTHERN UTAH
LOGAN E. DF
LOGAN W. DF
KAMAS PP
KAMAS DF + DF

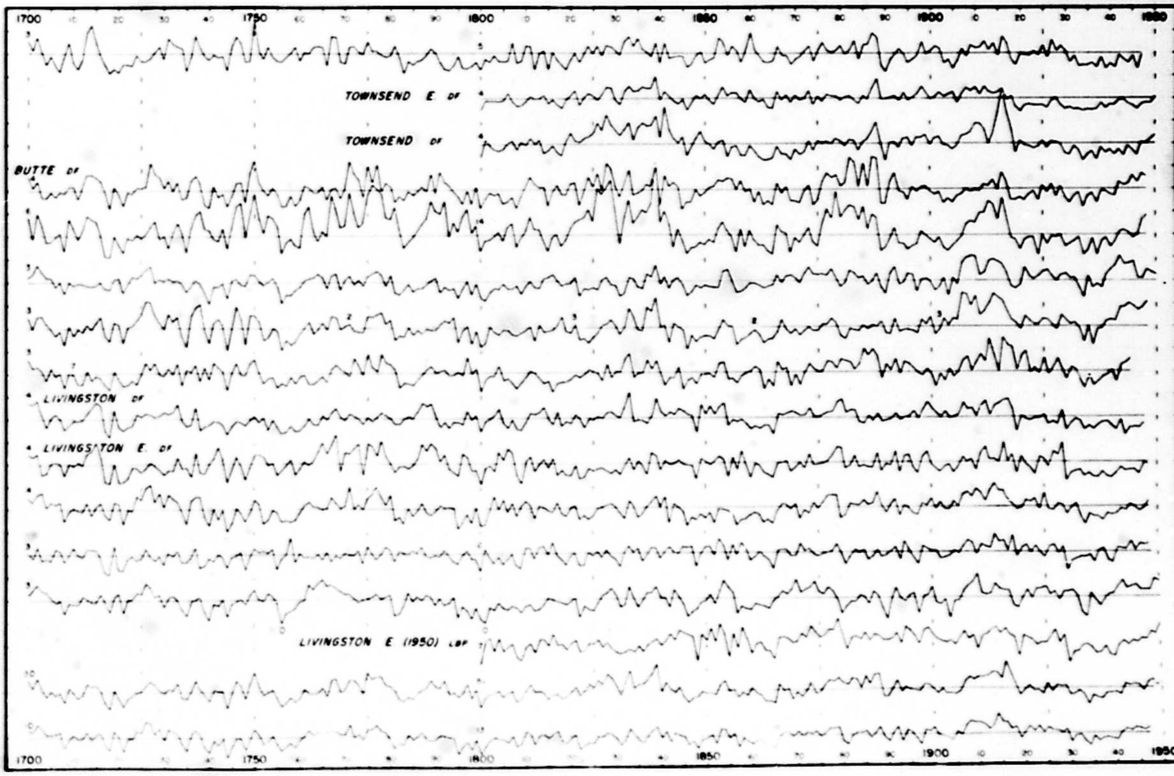


KET - 3998
MEAN, 1500-YR LBP (KETCHUM)
SNAKE RIVER BASIN MEAN DF
MORAN DF
VICTOR DF
HOBACK DF
CLARK FORK R. BASIN
MISSOULA DF
MISSOULA PP
SULA DF
SULA PP

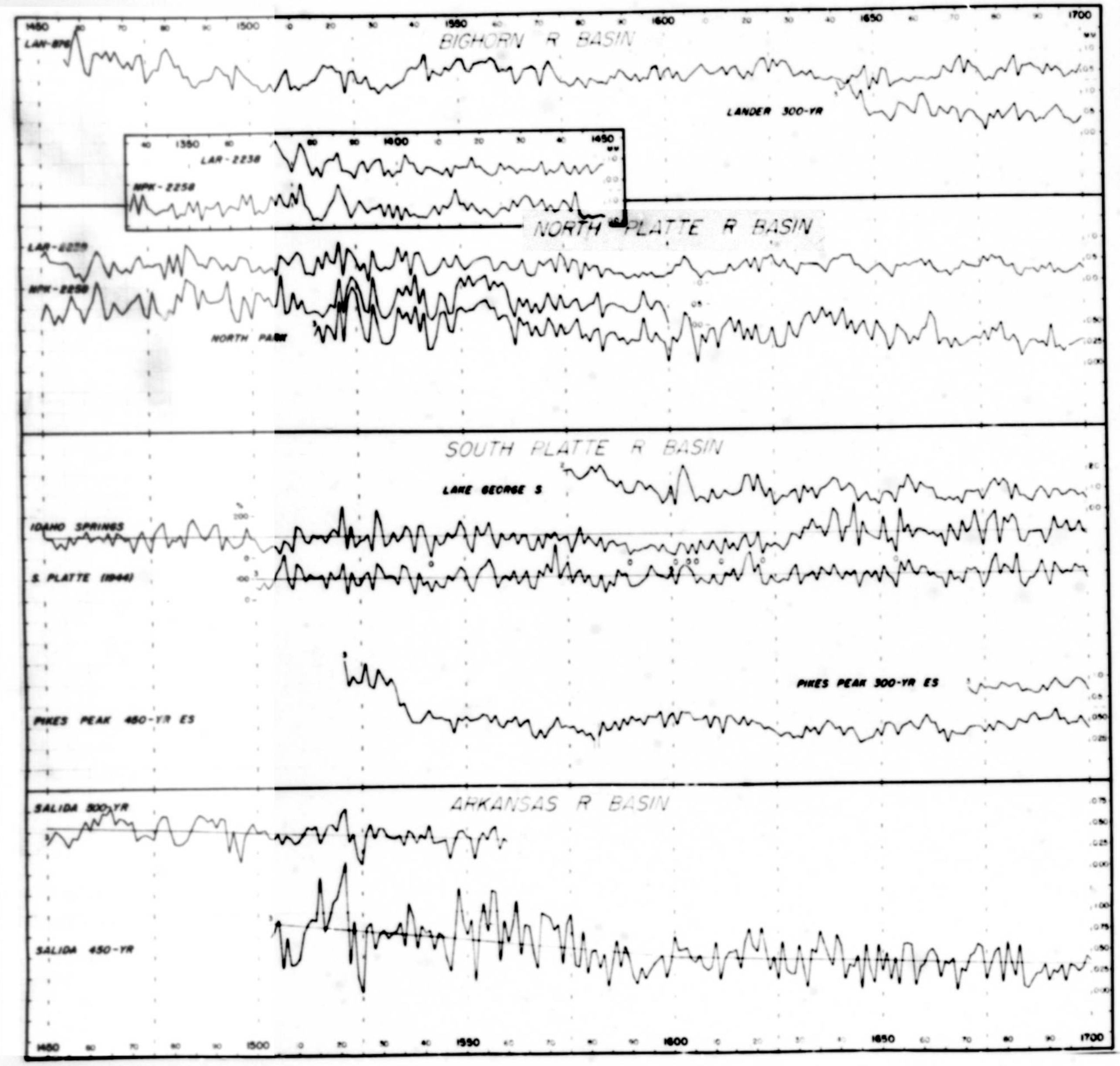
B


MISSOURI RIVER BASIN
DLL-2807 DF
DLL-2801A LDF
DLL-2801B
BASIN INDEX DF
BASIN INDEX LDF
1000
1050
1100
1150
1200
1250
HELENA DF
DIVIDE DF
DELL WEST DF
DELL DF
YELLOWSTONE DF
DELL LDF
LIVINGSTON E (1949) LDF
DELL WEST LDF
BASIN INDEX DF
BASIN INDEX LDF
1450
1500
1550
1600
1650
1700


1250
1300
1350
1400
1450
1500
DLL -3220 LBP
DLL -3221 LBP

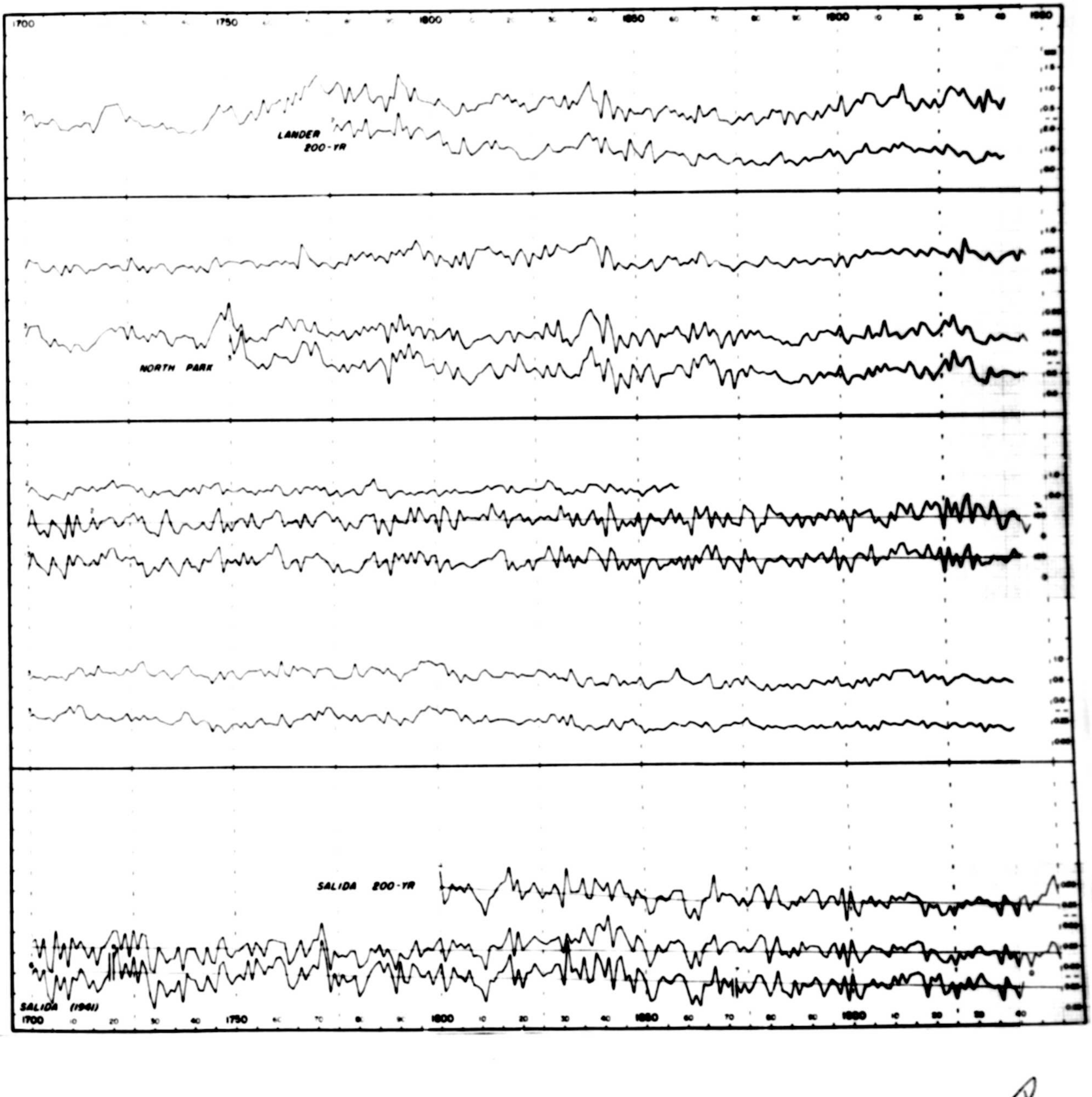

1700
1750
1800
1850
1900
1950
TOWNSEND E. DF
TOWNSEND DF
BUTTE DF
LIVINGSTON DF
LIVINGSTON E. DF
LIVINGSTON E (1950) LBP

B

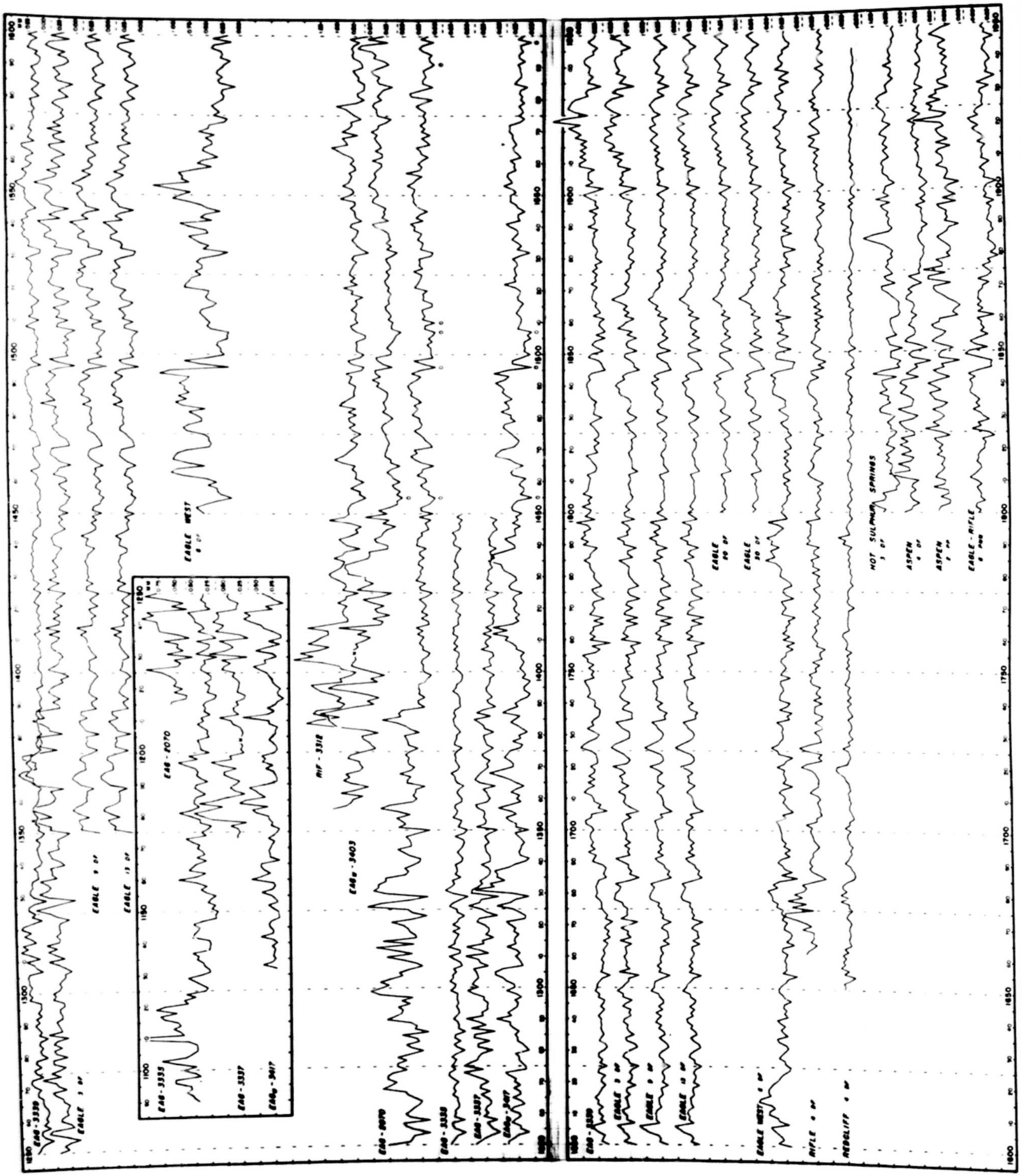


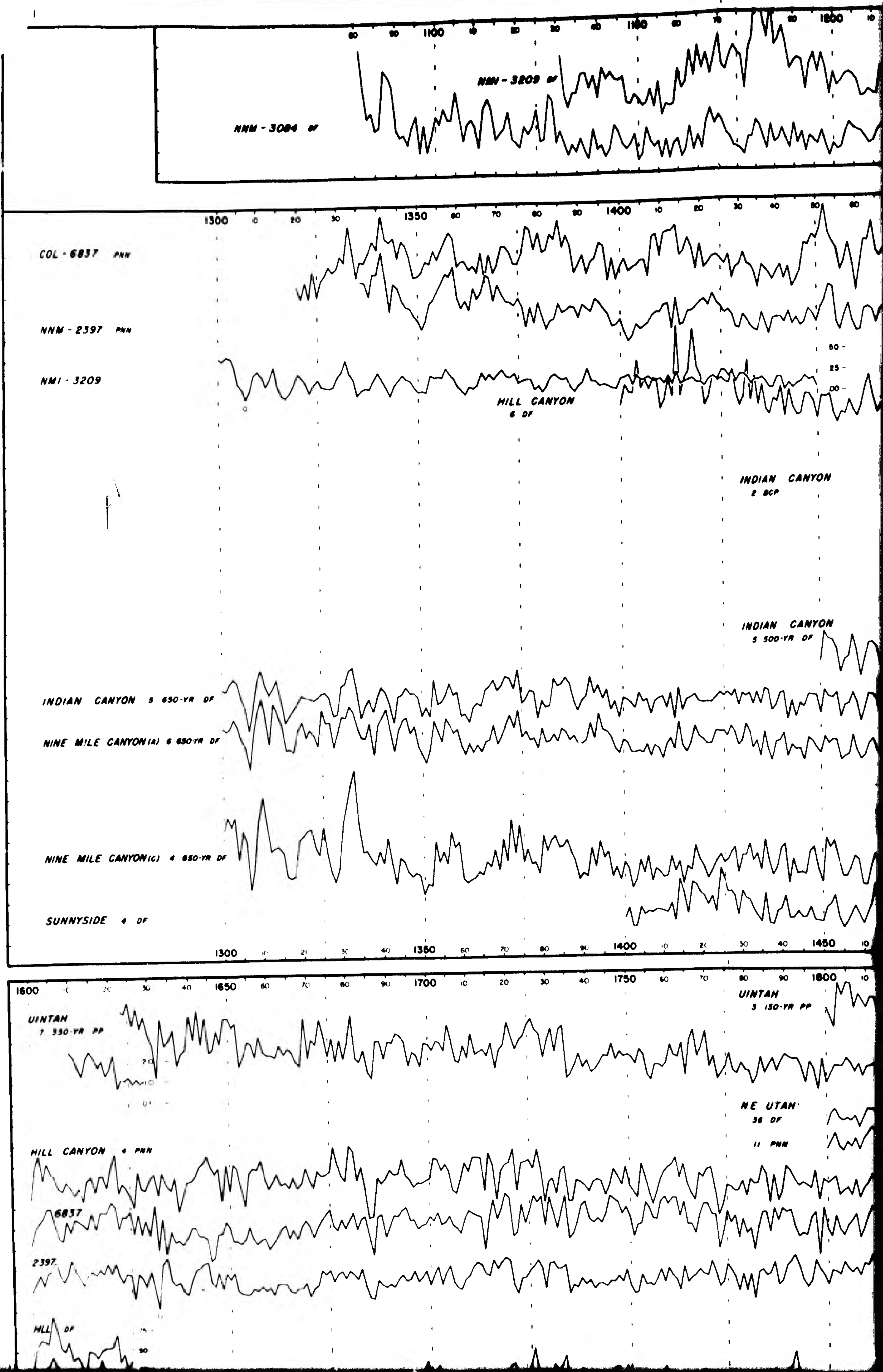
BIGHORN R BASIN
LAN-876
LANDER 300-YR
LAR-2238
NPK-2258
NORTH PLATTE R BASIN
LAR-2239
NPK-2250
NORTH PARK
SOUTH PLATTE R BASIN
LAKE GEORGE S
IDAHO SPRINGS
S. PLATTE (1944)
PIKES PEAK 300-YR ES
PIKES PEAK 460-YR ES
ARKANSAS R BASIN
SALIDA 300-YR
SALIDA 450-YR

5.

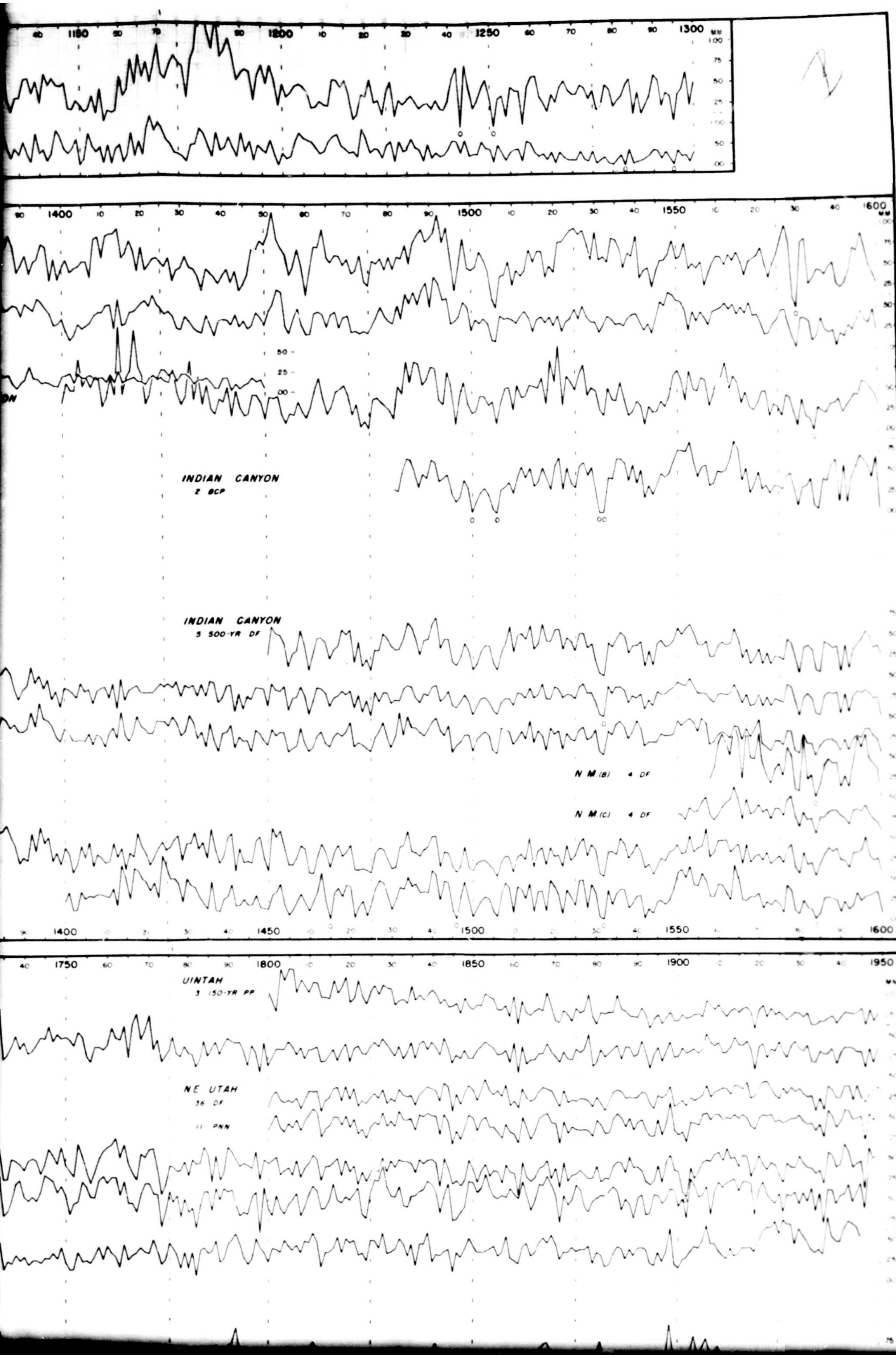


LANDER
200-YR
NORTH PARK
SALIDA 200-YR
SALIDA (1961)

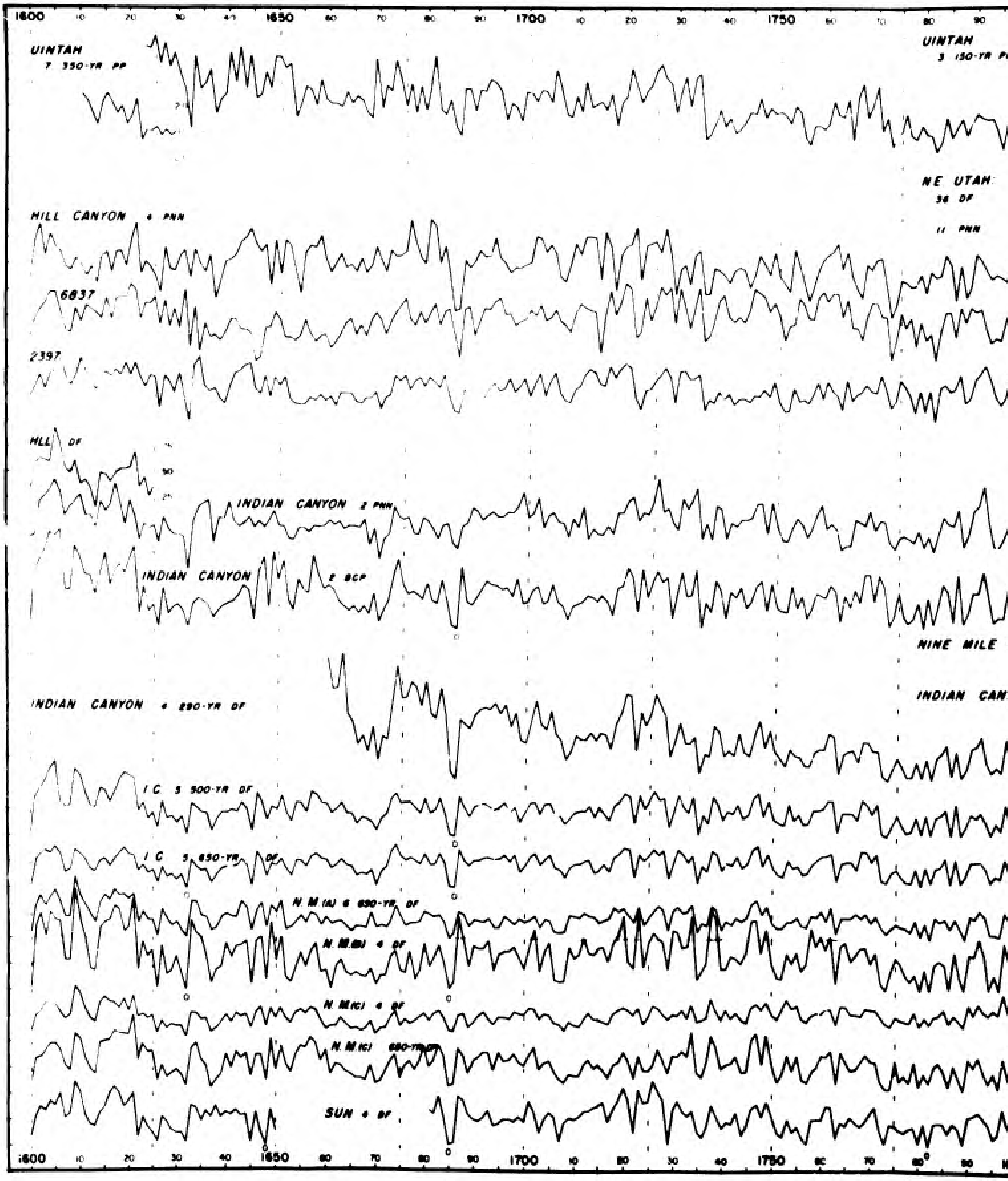

EAGLE WEST
HOT SULPHUR SPRINGS
ASPEN
EAGLE - RIFLE
REDCLIFF
RIFLE
EAGLE
EAB-2070
RIF-3318



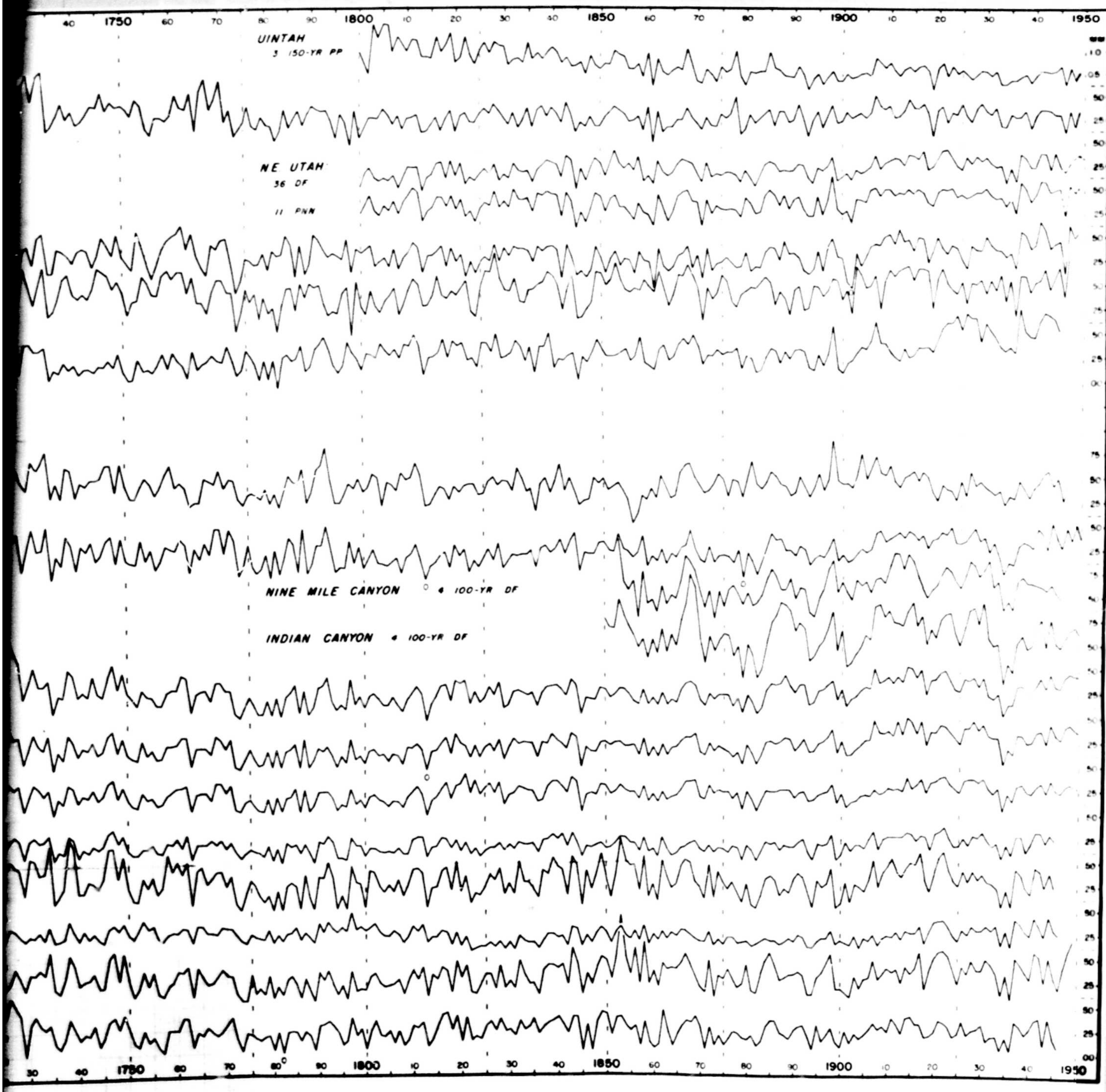
1100
1150
1200
NNM - 3209 DF
NNM - 3084 DF
1300
1350
1400
1450
COL - 6837 PNN
NNM - 2397 PNN
NMI - 3209
HILL CANYON
6 DF
INDIAN CANYON
2 BCP
INDIAN CANYON
5 500-YR DF
INDIAN CANYON 5 650-YR DF
NINE MILE CANYON (A) 6 650-YR DF
NINE MILE CANYON (C) 4 650-YR DF
SUNNYSIDE 4 DF
1600
1650
1700
1750
1800
UINTAH
7 350-YR PP
UINTAH
3 150-YR PP
N.E. UTAH:
36 DF
11 PNN
HILL CANYON 4 PNN
6837
2397
HLL DF

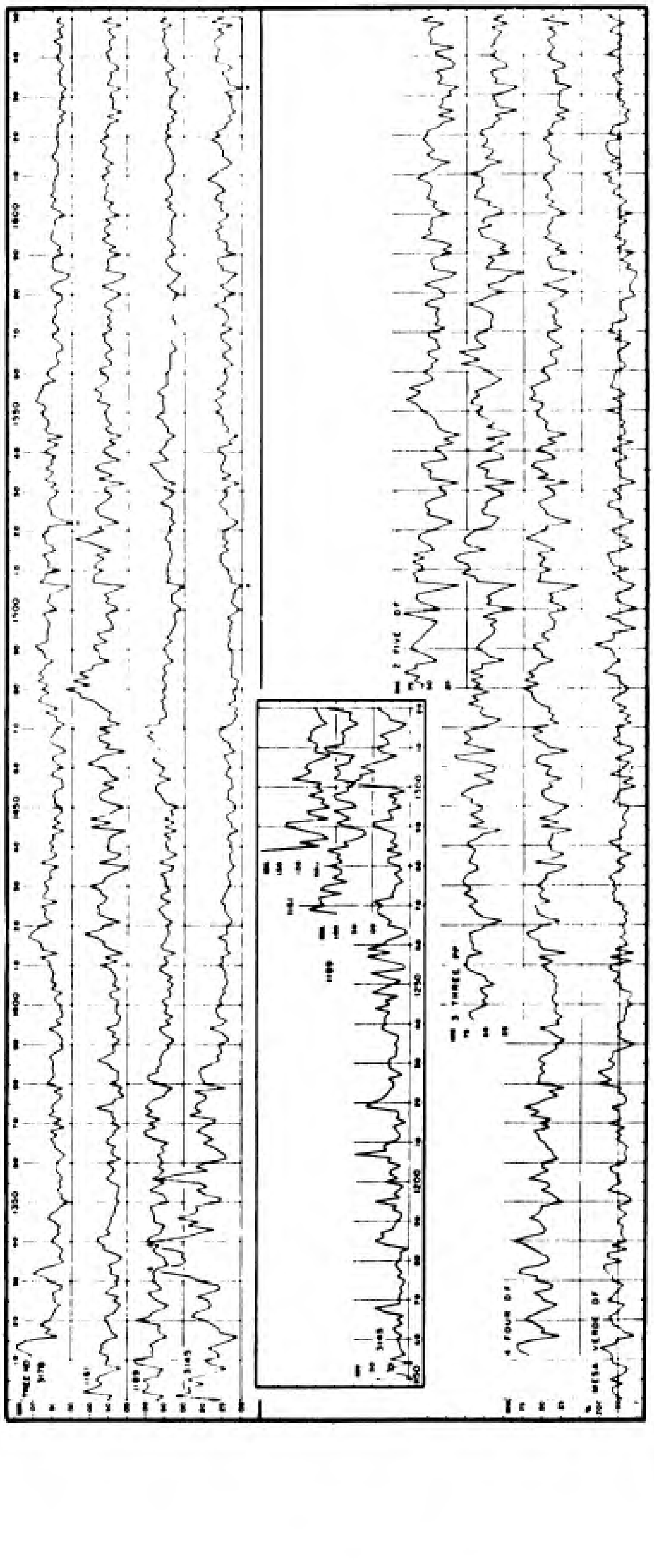


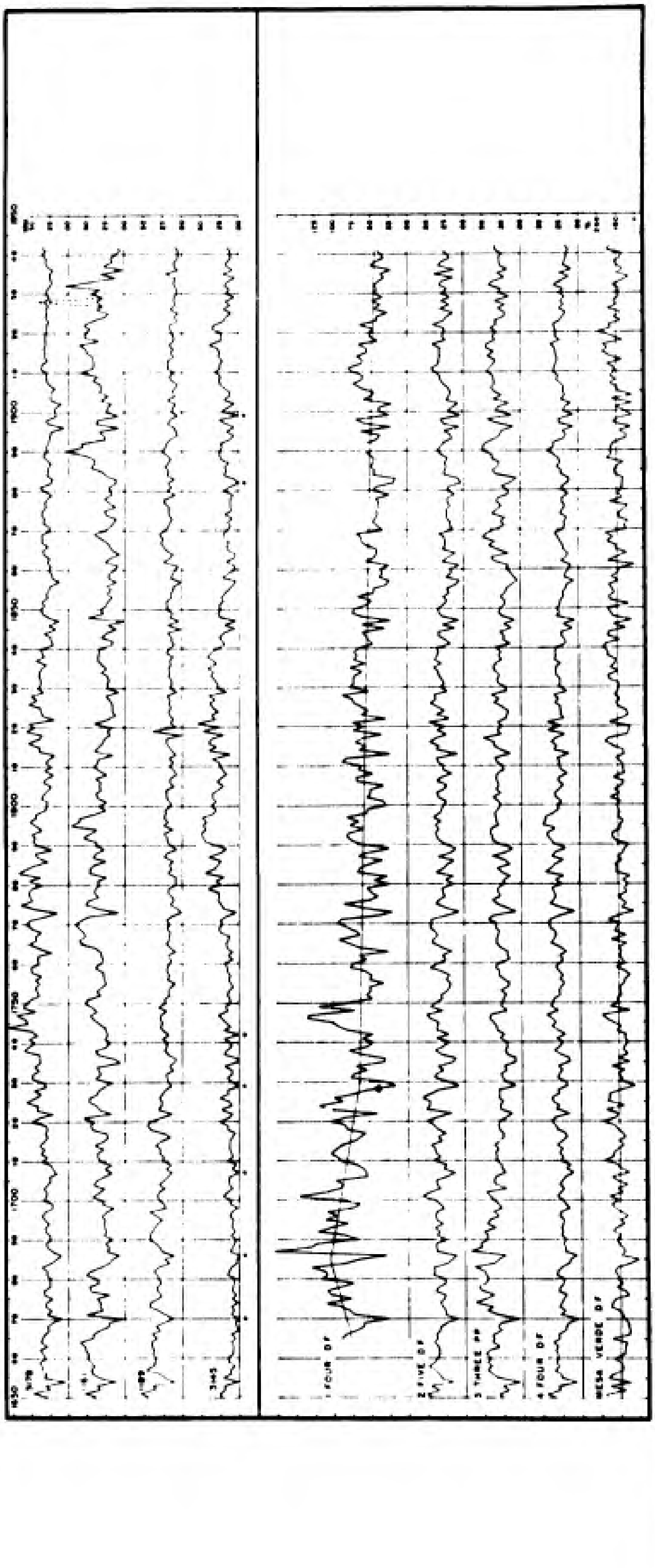
1150
1200
1250
1300
MM
1400
1450
1500
1550
1600
INDIAN CANYON
2 BCP
INDIAN CANYON
5 500-YR DF
N M (B) 4 DF
N M (C) 4 DF
1750
1800
1850
1900
1950
UINTAH
3 150-YR PP
NE UTAH
36 DF
11 PNN

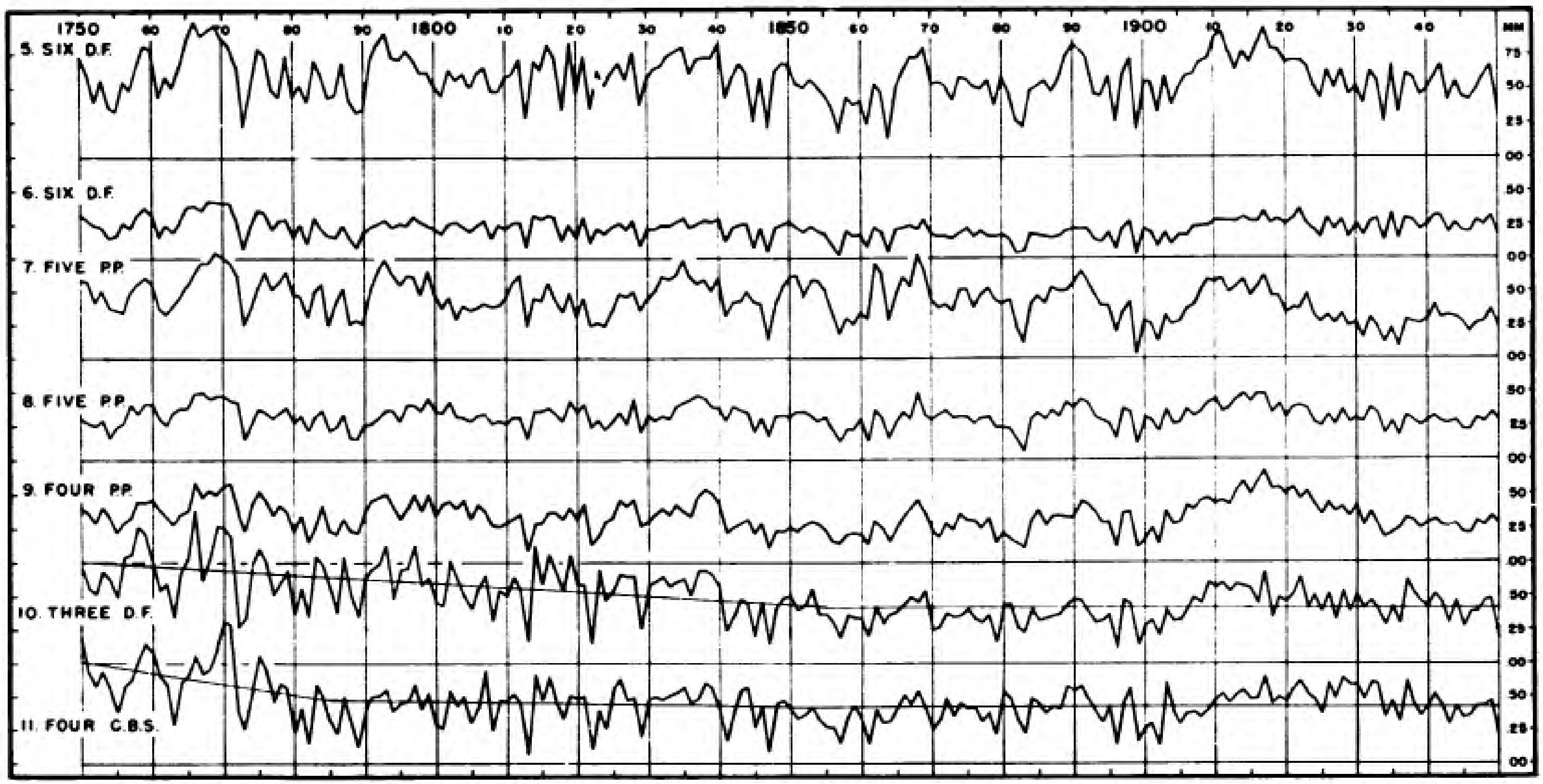


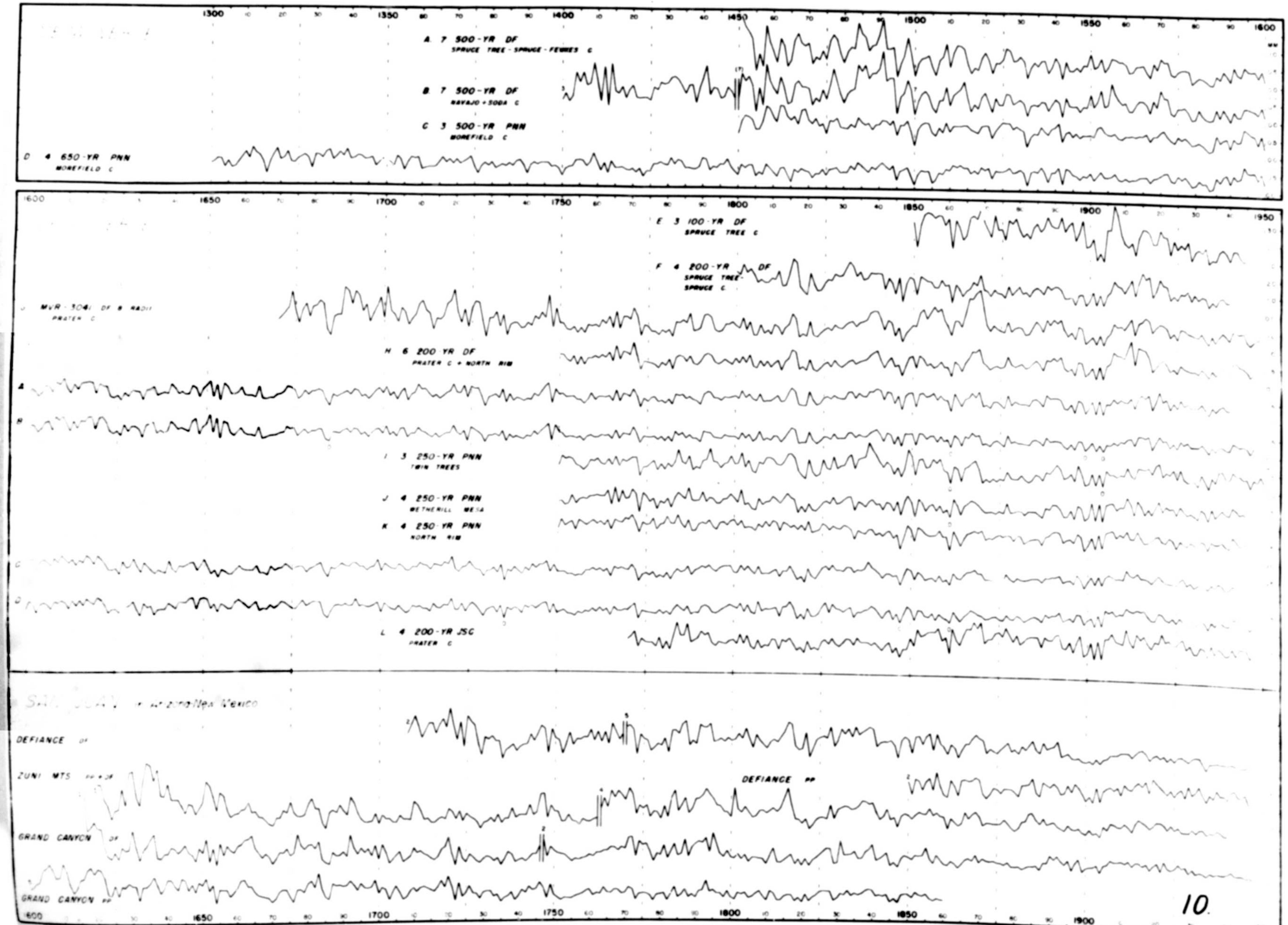
1600
1650
1700
1750
UINTAH
7 350-YR PP
UINTAH
NE UTAH
36 DF
11 PNN
HILL CANYON 4 PNN
6837
2397
HLL DF
INDIAN CANYON 2 PNN
INDIAN CANYON 2 BCP
NINE MILE
INDIAN CANYON 4 290-YR DF
I C 5 500-YR DF
I C 5 650-YR DF
N M (A) 6 650-YR DF
N M (B) 4 DF
N M (C) 4 DF
N M (C)
SUN 4 DF


40 1750 60 70 80 90 1800 10 20 30 40 1850 60 70 80 90 1900 10 20 30 40 1950
UINTAH
3 150-YR PP
N.E. UTAH
36 DF
11 PNN
NINE MILE CANYON 4 100-YR DF
INDIAN CANYON 4 100-YR DF
30 40 1750 60 70 80 90 1800 10 20 30 40 1850 60 70 80 90 1900 10 20 30 40 1950


2 FIVE DF
3 THREE PP
4 FOUR DF
MESA VERDE DF

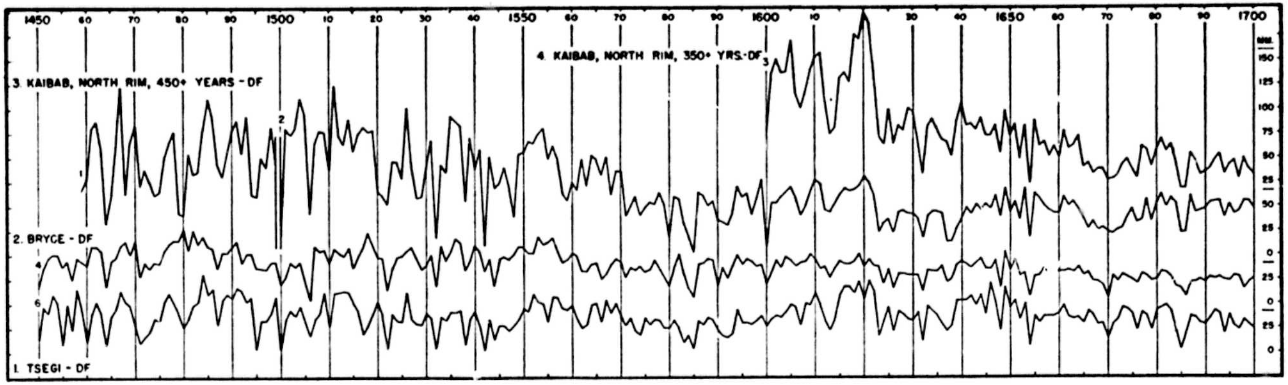

1 FOUR DF
2 FIVE DF
3 THREE PP
4 FOUR DF
MESA VERDE DF

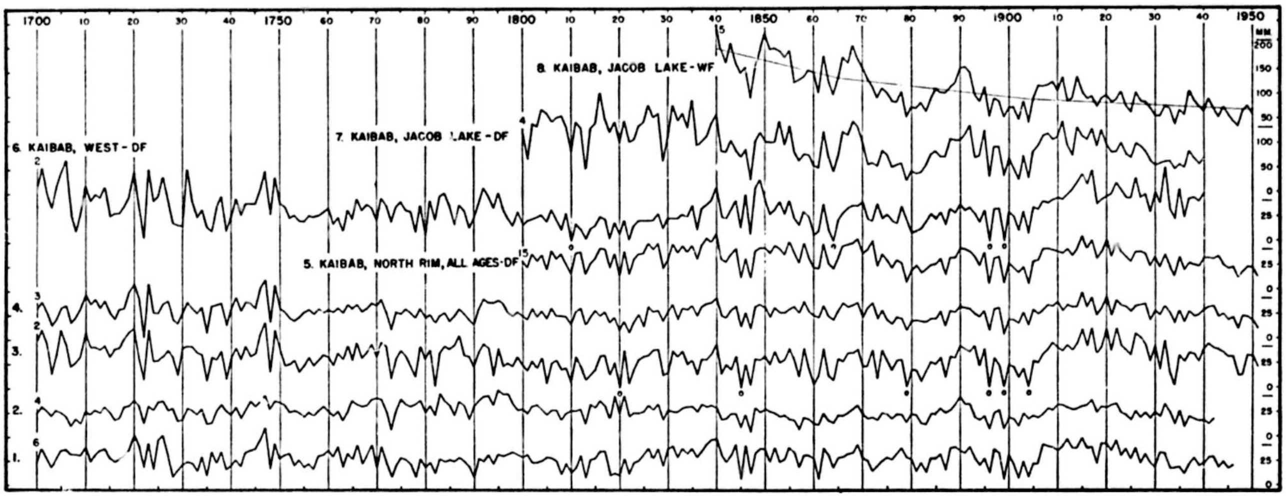

1750
1800
1850
1900
MM
5. SIX D.F.
6. SIX D.F.
7. FIVE P.P.
8. FIVE P.P.
9. FOUR P.P.
10. THREE D.F.
11. FOUR C.B.S.

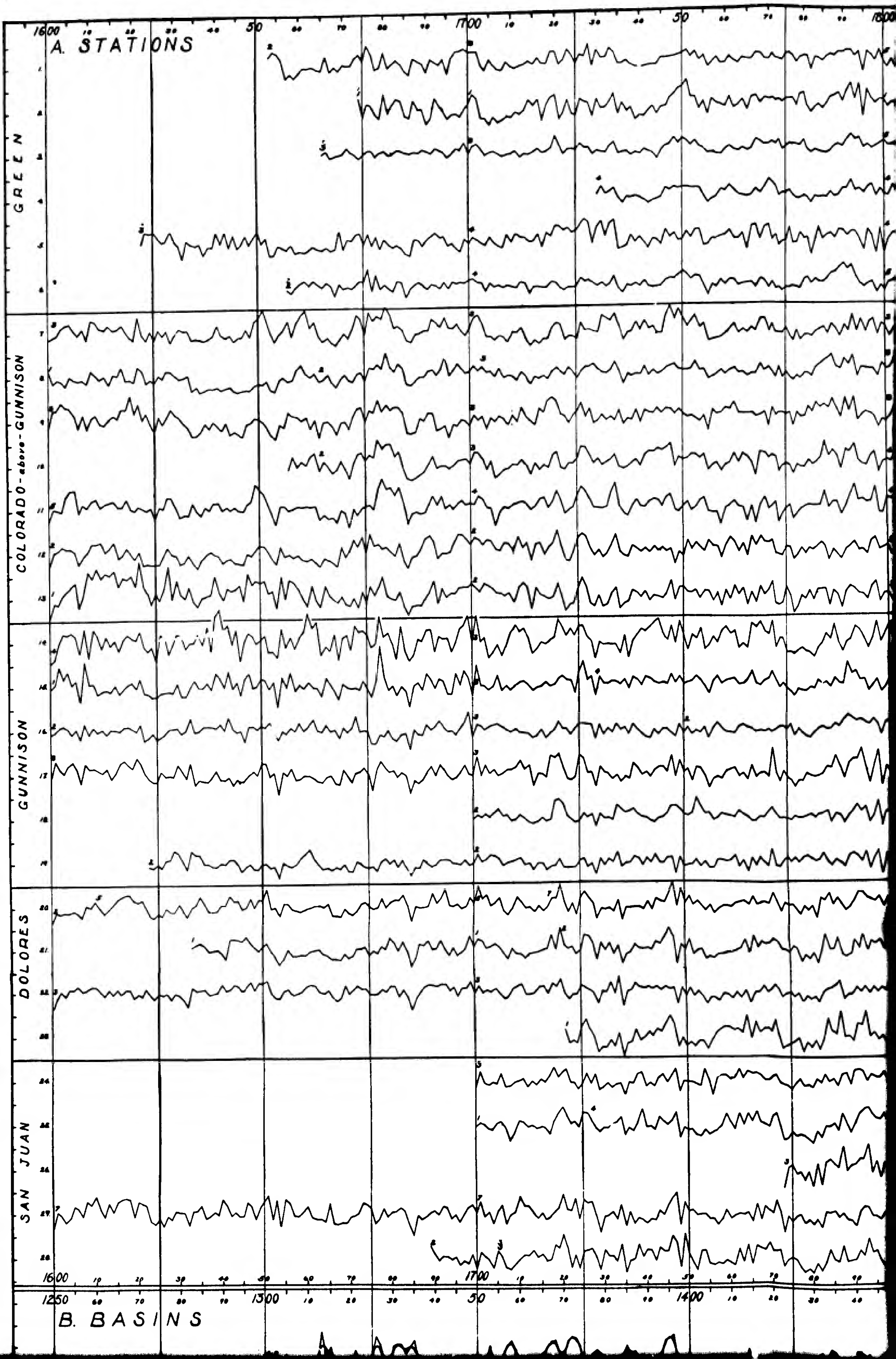


A 7 500-YR DF
SPRUCE TREE - SPRUCE - FEWKES C
B 7 500-YR DF
NAVAJO + SODA C
C 3 500-YR PNN
MOREFIELD C
D 4 650-YR PNN
MOREFIELD C
E 3 100-YR DF
SPRUCE TREE C
F 4 200-YR DF
SPRUCE TREE-
SPRUCE C
MVR-3041 DF 8 RADII
PRATER C
H 6 200 YR DF
PRATER C + NORTH RIM
I 3 250-YR PNN
TWIN TREES
J 4 250-YR PNN
WETHERILL MESA
K 4 250-YR PNN
NORTH RIM
L 4 200-YR ZSC
PRATER C
DEFIANCE
ZUNI MTS
DEFIANCE PP
GRAND CANYON
GRAND CANYON PP

10.

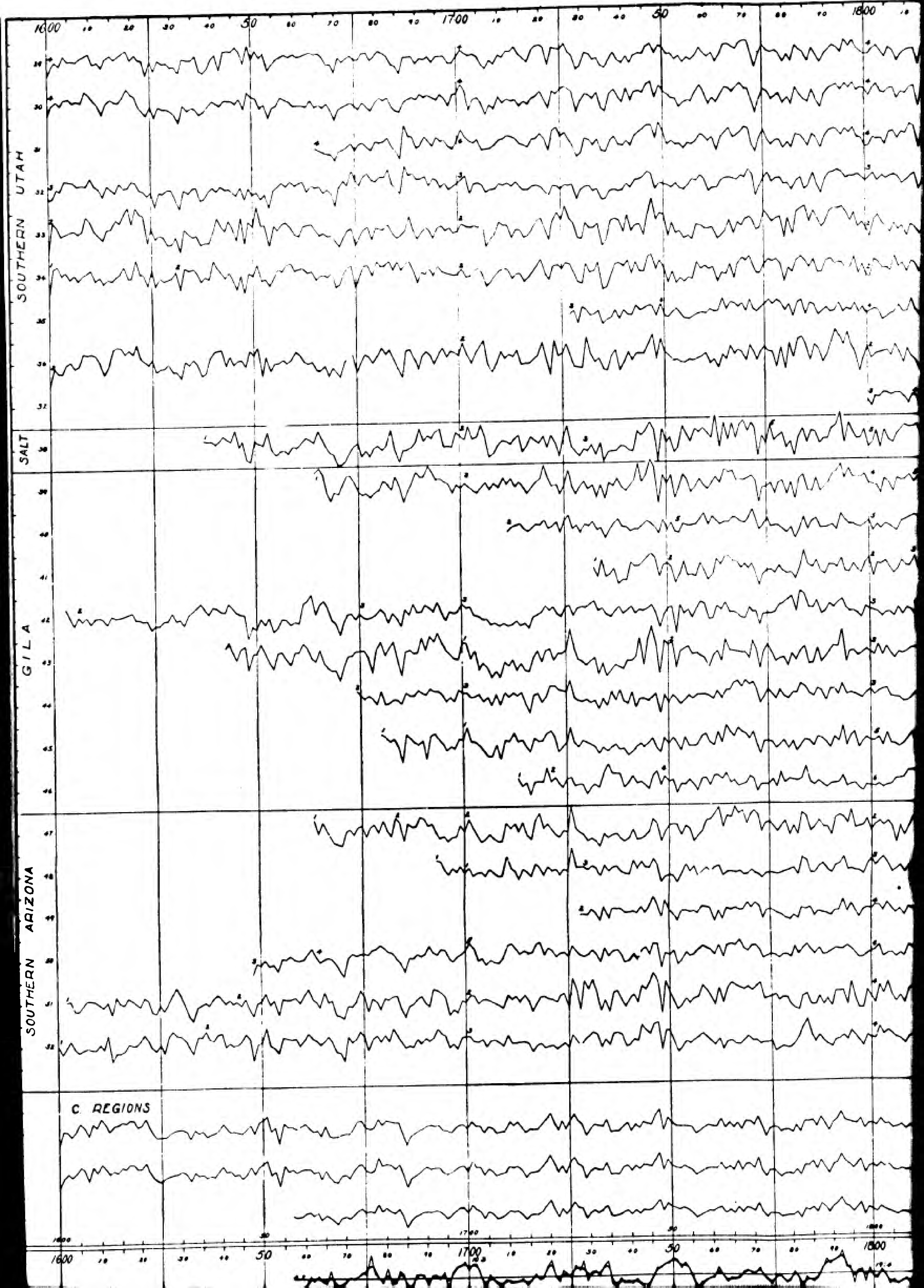

3. KAIBAB, NORTH RIM, 450+ YEARS - DF
4. KAIBAB, NORTH RIM, 350+ YRS - DF
2. BRYCE - DF
1. TSEGI - DF


8. KAIBAB, JACOB LAKE - WF
7. KAIBAB, JACOB LAKE - DF
6. KAIBAB, WEST - DF
5. KAIBAB, NORTH RIM, ALL AGES - DF

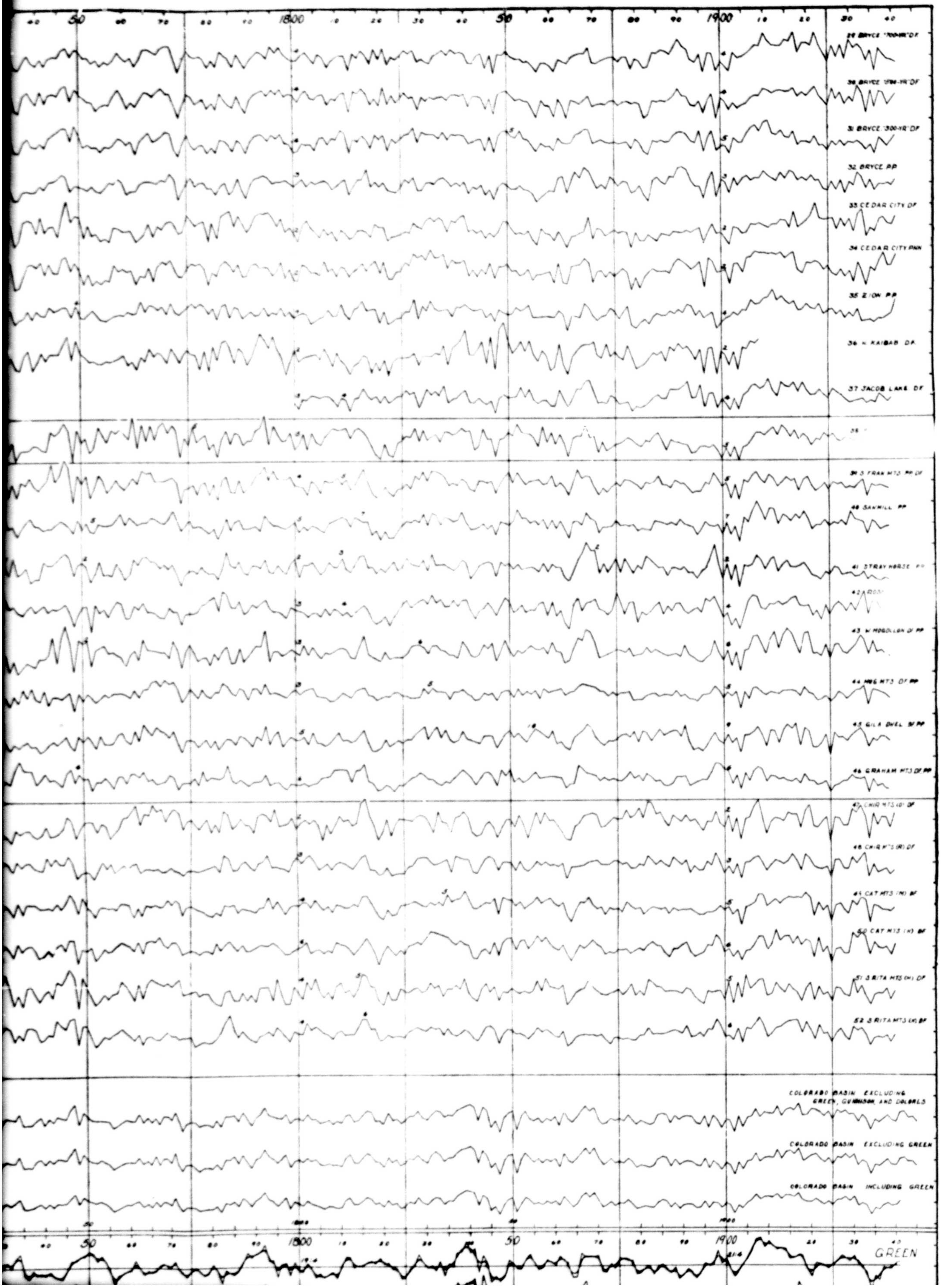


A. STATIONS
GREEN
COLORADO-above-GUNNISON
GUNNISON
DOLORES
SAN JUAN
B. BASINS
1600
50
1700
50
1800
1250
1300
1400

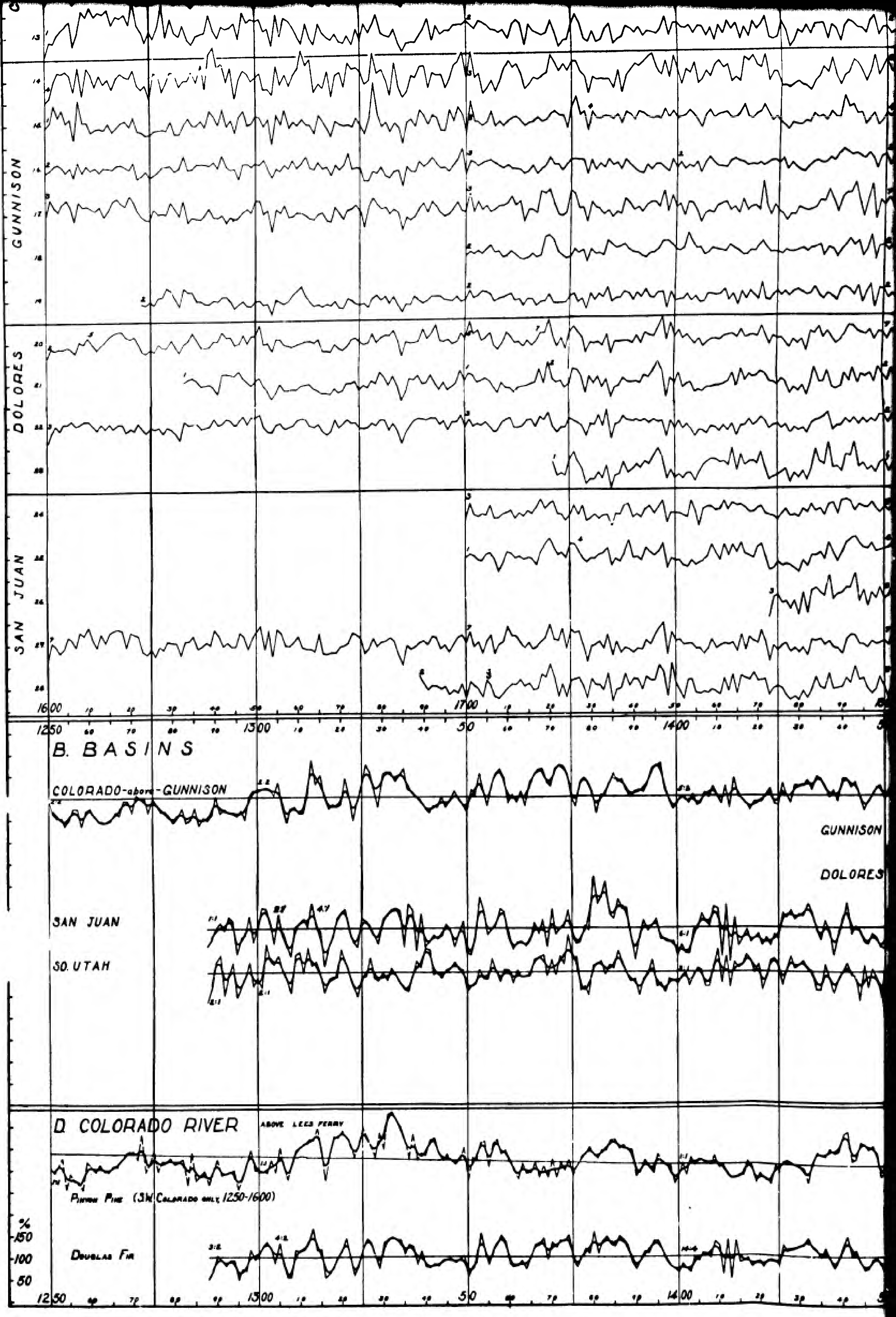
SOUTHERN UTAH
SALT
GILA
SOUTHERN ARIZONA
C. REGIONS
11 EAGLE DF
20 DOLORES DF
21 DOLORES PP
27 MESA VERDE DF
28 MONTICELLO PP

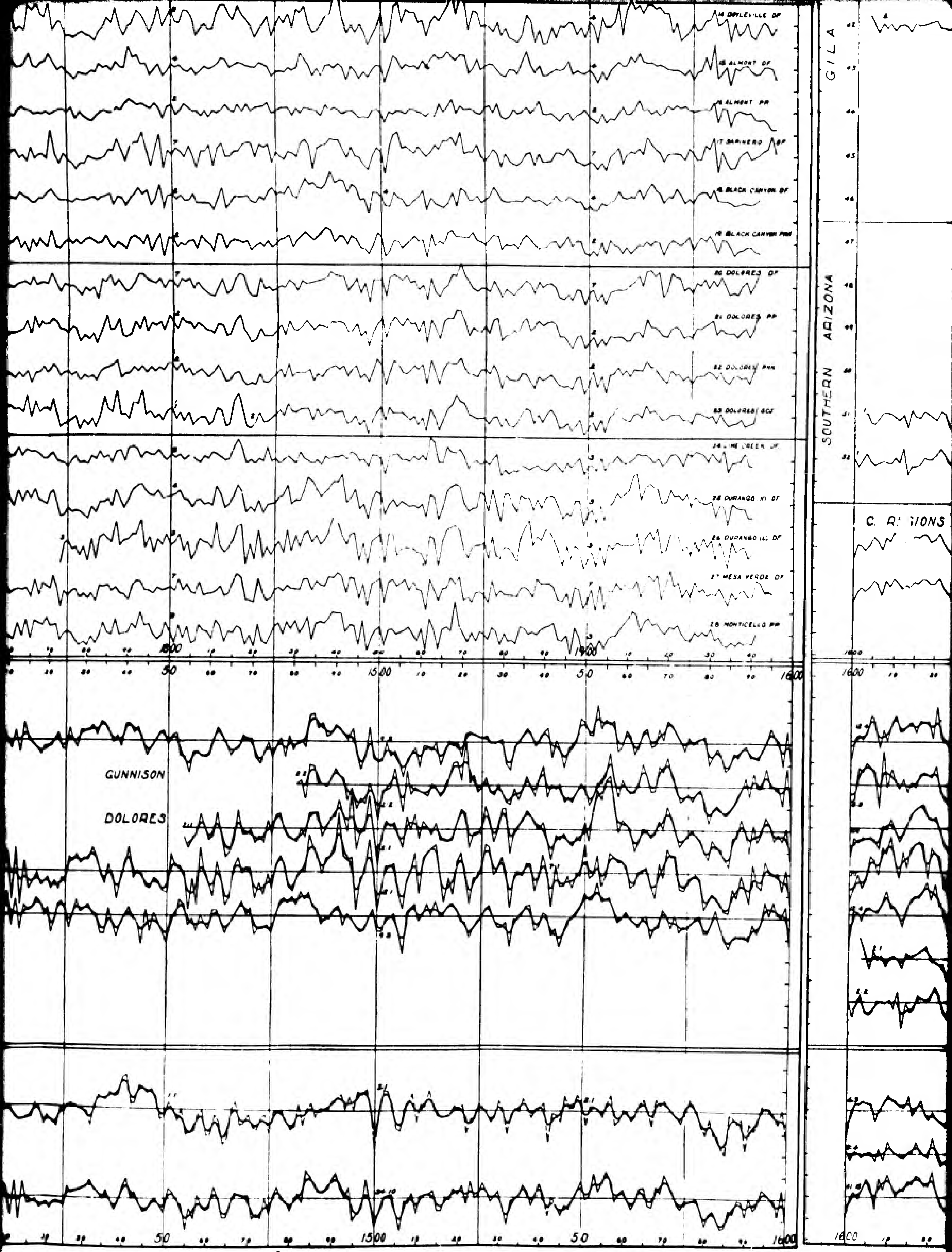


SOUTHERN UTAH
SALT
GILA
SOUTHERN ARIZONA
C. REGIONS
1600
50
1700
1800

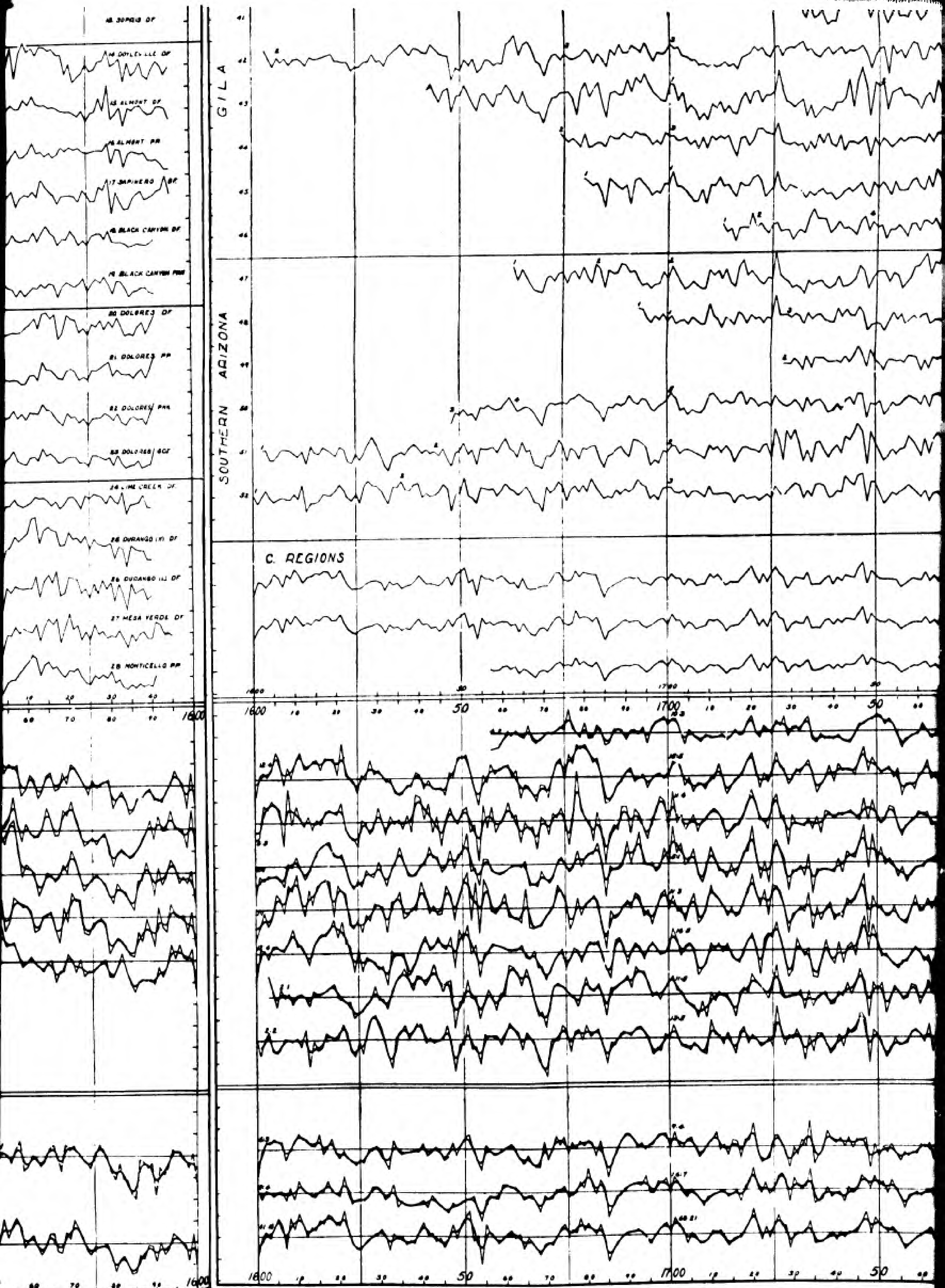


1800
1900
29 BRYCE "700-YR" DF
30 BRYCE "500-YR" DF
31 BRYCE "300-YR" DF
32 BRYCE PP
33 CEDAR CITY DF
34 CEDAR CITY PNN
35 ZION PP
36 N. KAIBAB DF
37 JACOB LAKE DF
39 S FRAN MTS PP DF
40 SAWMILL PP
41 STRAYHORSE PP
43 W MOGOLLON DF PP
44 MOG MTS DF PP
45 GILA DWEL DF PP
46 GRAHAM MTS DF PP
47 CHIR MTS (O) DF
48 CHIR MTS (R) DF
49 CAT MTS (M) DF
50 CAT MTS (H) DF
51 S RITA MTS (H) DF
52 S RITA MTS (K) DF
COLORADO BASIN EXCLUDING GREEN, GUNNISON, AND DOLORES
COLORADO BASIN EXCLUDING GREEN
COLORADO BASIN INCLUDING GREEN
GREEN

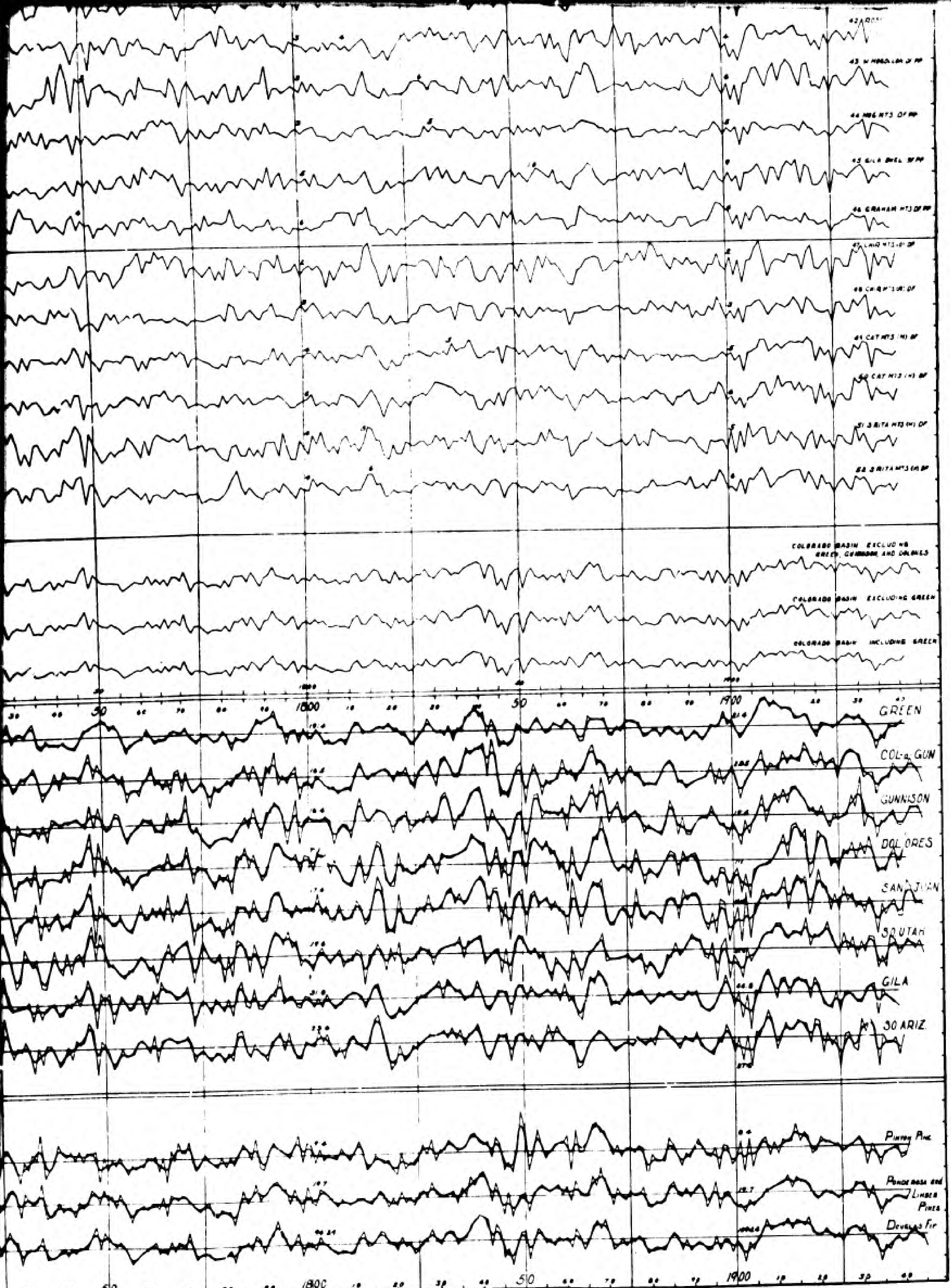

GUNNISON
DOLORES
SAN JUAN
1600
1700
1250
1300
1350
1400
B. BASINS
COLORADO-above-GUNNISON
GUNNISON
DOLORES
SAN JUAN
SO. UTAH
D COLORADO RIVER
ABOVE LEES FERRY
Pinon Pine (SW Colorado only, 1250-1600)
Douglas Fir
%
150
100
50

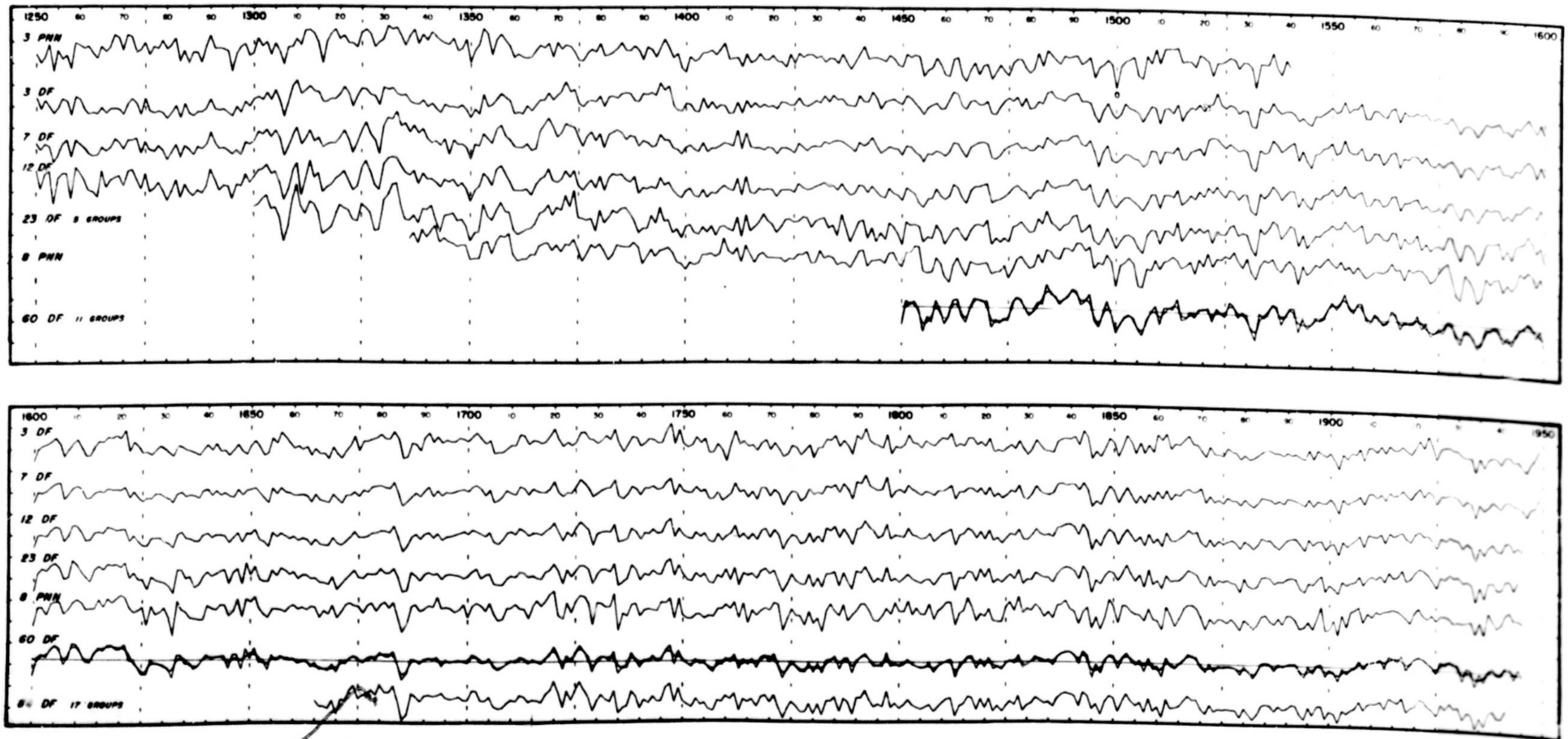


DOYLEVILLE DF
ALMONT DF
ALMONT PP
SAPINERO DF
BLACK CANYON DF
BLACK CANYON PNN
DOLORES DF
DOLORES PP
DOLORES PNN
DURANGO DF
MESA VERDE DF
MONTICELLO PP
GILA
SOUTHERN ARIZONA
GUNNISON
DOLORES
1800
1900
1500
1600



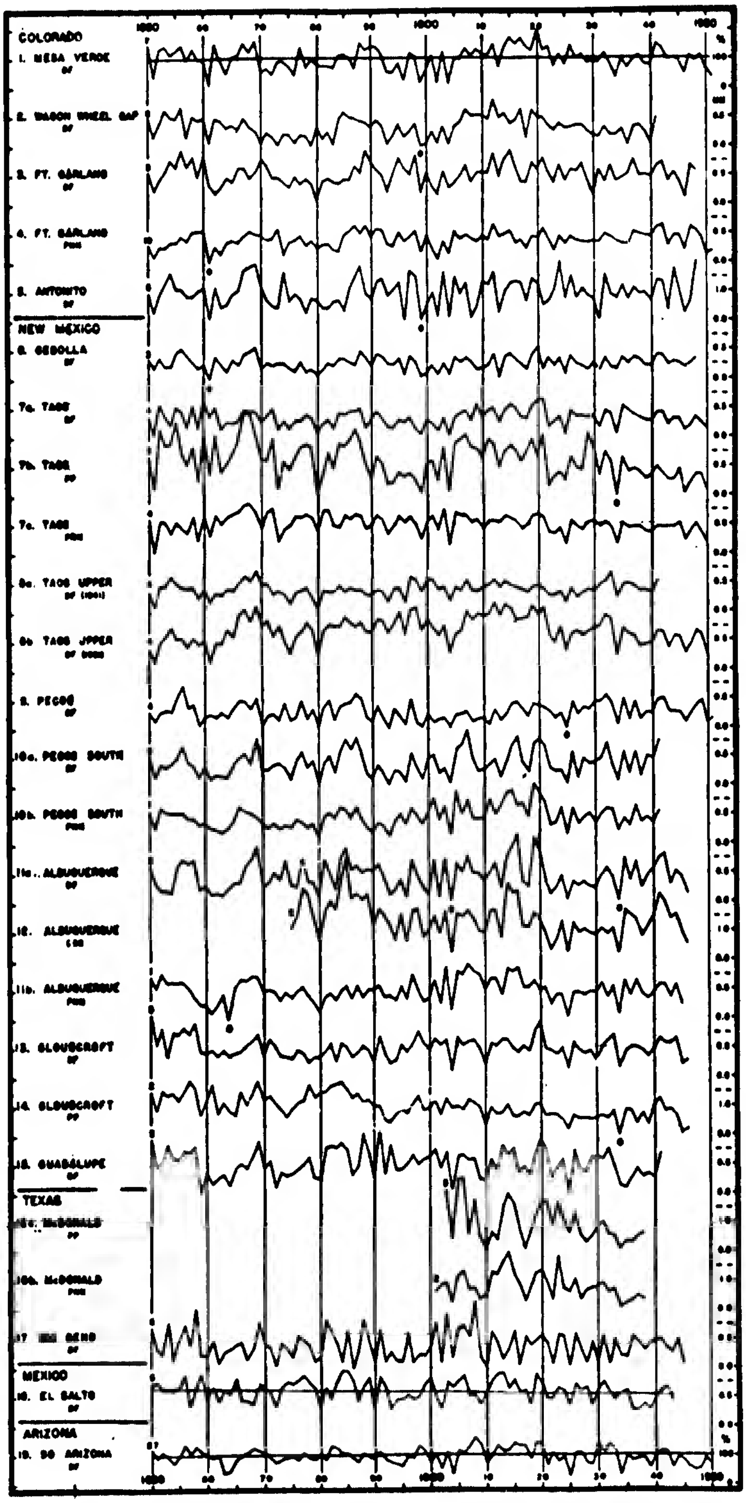
15 ALMONT DF
16 ALMONT PP
17 SAPINERO
18 BLACK CANYON DF
19 BLACK CANYON PNE
20 DOLORES DF
21 DOLORES PP
22 DOLORES PNR
24 LIME CREEK DF
25 DURANGO (1) DF
26 DURANGO (1) DF
27 MESA VERDE DF
28 MONTICELLO PP
GILA
SOUTHERN ARIZONA
C. REGIONS
1600
50
1700
50


COLORADO BASIN EXCLUDING GREEN
COLORADO BASIN INCLUDING GREEN
1800
50
1900
GREEN
GUNNISON
DOLORES
SAN JUAN
SO UTAH
GILA
SO ARIZ.
Pinyon Pine
Ponderosa and Limber Pines
Douglas Fir

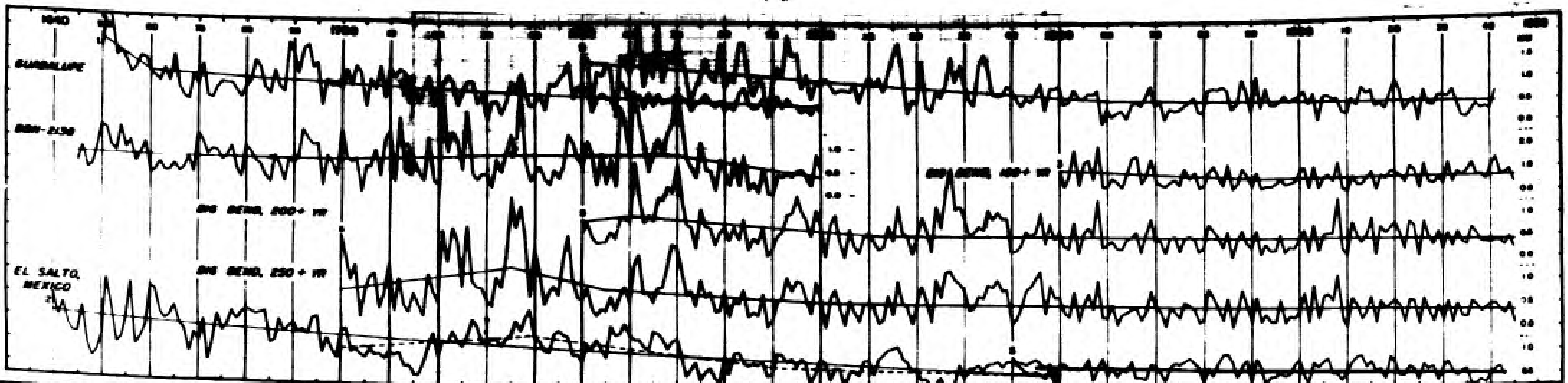

1250
1300
1350
1400
1450
1500
1550
1600
3 PHN
3 DF
7 DF
12 DF
23 DF 8 GROUPS
8 PHN
60 DF 11 GROUPS
1600
1650
1700
1750
1800
1850
1900
1950
3 DF
7 DF
12 DF
23 DF
8 PHN
60 DF
84 DF 17 GROUPS

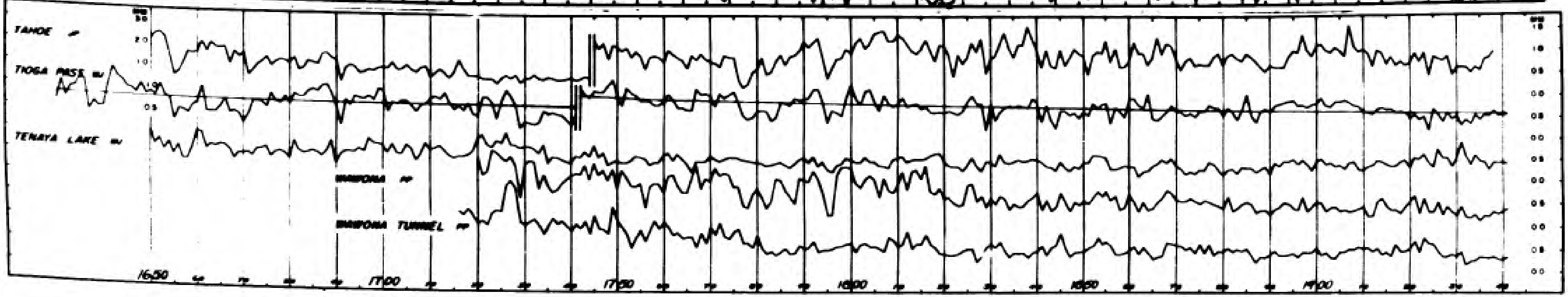
TAOS-800 DF
PEC-3921 DF
FTG-3043 PHN
FTG-3042 PHN
8. TAOS UPPER DF
9. PECOS DF
4. FT GARLAND PHN
REGIONAL MEAN, 3 AREAS DF
COMPARISON INDEX, MESA VERDE DF
4. FT GARLAND PHN
9. PECOS DF
5. ANTONITO DF
6. CEBOLLA DF
8. TAOS UPPER DF
10a PECOS SOUTH DF
REGIONAL MEANS:
5 AREAS DF
3 AREAS DF
COMPARISON INDEX, MESA VERDE DF

15.

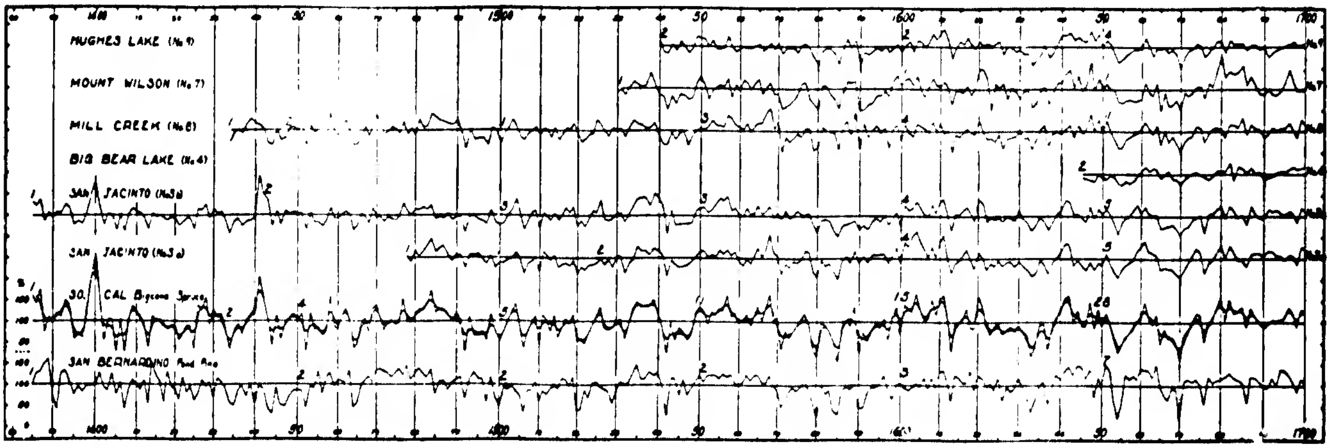

COLORADO
NEW MEXICO
TEXAS
MEXICO
ARIZONA

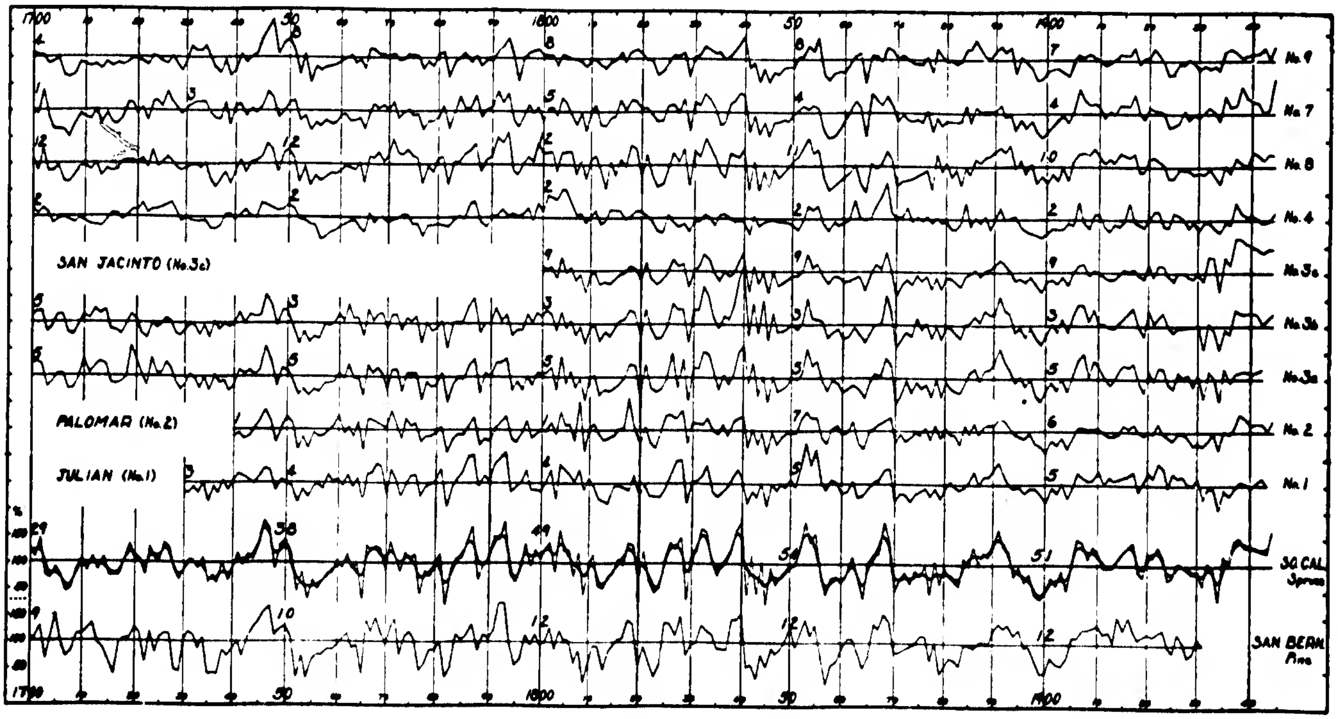
17


GUADALUPE
EL SALTO, MEXICO
BIG BEND, 200+ YR
BIG BEND, 250+ YR
1700
1800
1900

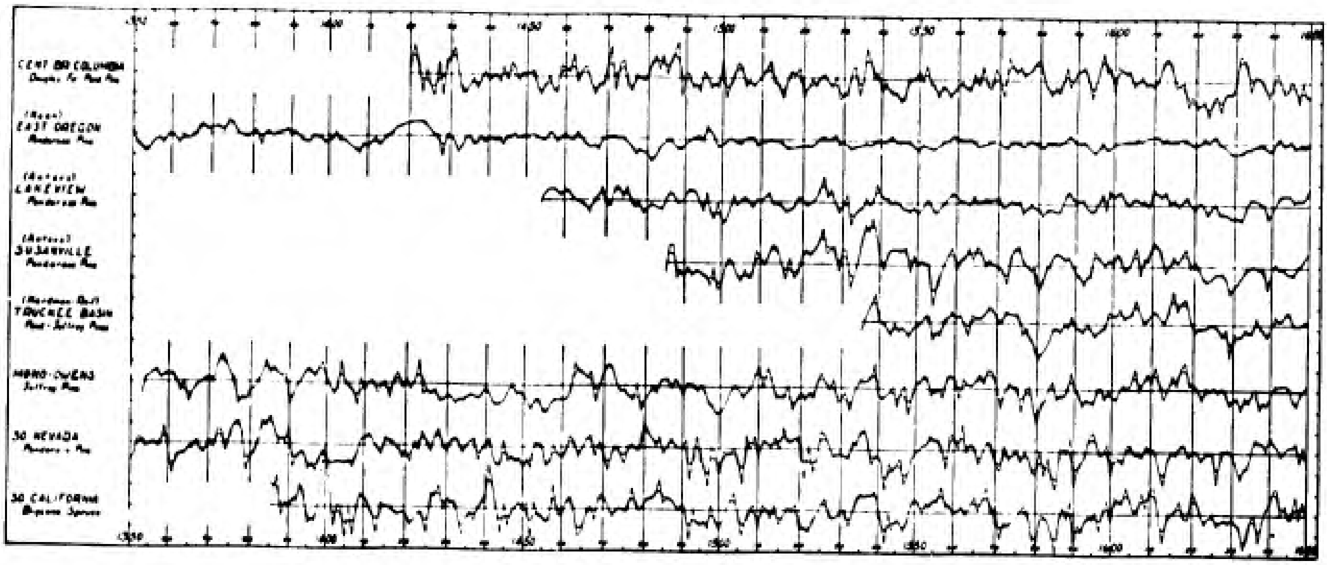

TAHOE
TIOGA PASS
TENAYA LAKE
WAWONA
WAWONA TUNNEL
1650
1700
1750
1800
1850
1900

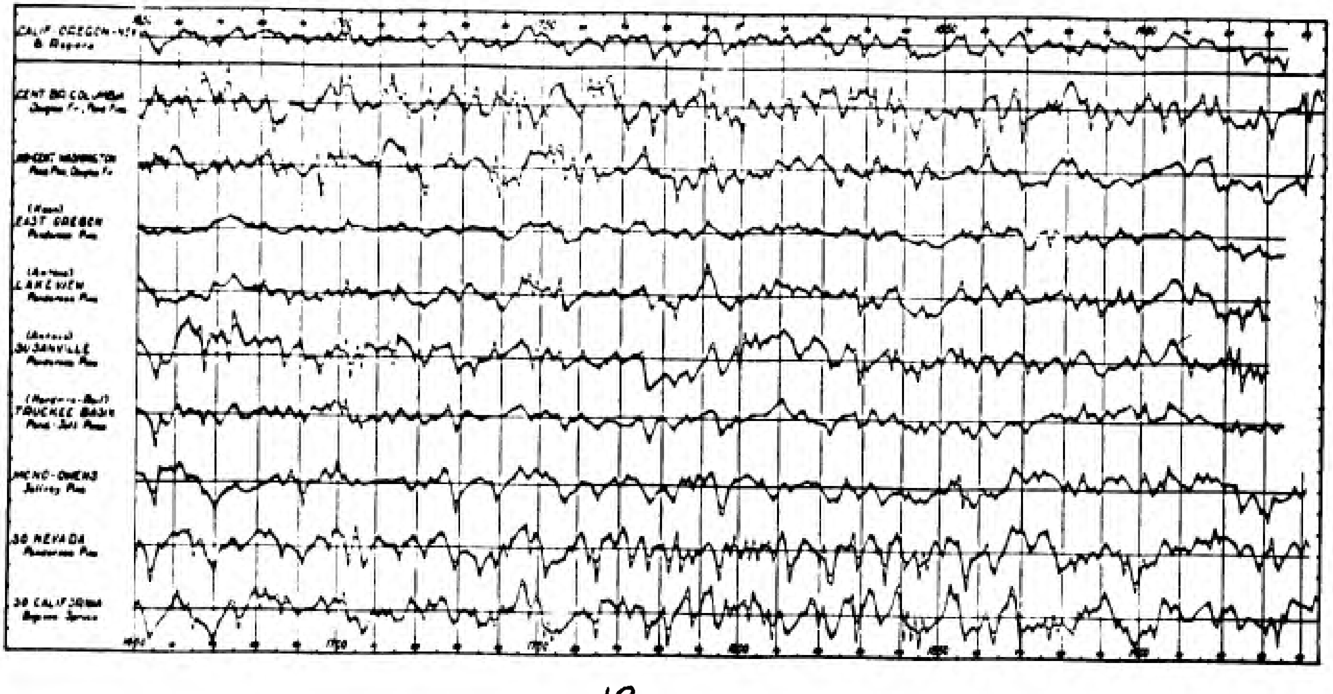
18A.


HUGHES LAKE (No. 9)
MOUNT WILSON (No. 7)
MILL CREEK (No. 8)
BIG BEAR LAKE (No. 4)
SAN JACINTO (No. 3b)
SAN JACINTO (No. 3a)
SO. CAL Bigcone Spruce
SAN BERNARDINO Pine
1500
1600
1700


1700
1800
1900
No. 9
No. 7
No. 8
No. 4
SAN JACINTO (No. 3c)
No. 3c
No. 3b
No. 3a
PALOMAR (No. 2)
No. 2
JULIAN (No. 1)
No. 1
SO. CAL Spruce
SAN BERN. Pine

18 B.


CENT BR COLUMBIA
EAST OREGON
LAKEVIEW
SUSANVILLE
TRUCKEE BASIN
MONO-OWENS
SO NEVADA
SO CALIFORNIA


CALIF OREGON
CENT BR COLUMBIA
EAST OREGON
LAKEVIEW
SUSANVILLE
TRUCKEE BASIN
MONO-OWENS
SO NEVADA
SO CALIFORNIA

III. PROBLEMS OF ANALYSIS

SUITABLE SPECIES

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 chronologies on species. Many coniferous species have been noted to yield significant ring chronologies on occasional sites but only a few are consistently useful over large areas.

Douglas-fir appears to be datable almost everywhere throughout this great region, though it may be very complacent, that is, have little change in year-to-year ring-width, on moist sites along the Pacific Slope and even in areas of low rainfall if the trees tap an underground water supply. At the other extreme, only a few apparently hypersensitive records have thus far been found--in the Rio Grande Basin--which show great variability from year to year but no apparent crossdating. Bigcone spruce of southern California, the only other American species of Pseudotsuga, is an excellent source of chronology.

In ponderosa pine, obscure chronologies, difficult to interpret in terms of climatic variations, are typical of many moist sites in the Sierra Nevada and Cascade Mountains and, less commonly, in the central and northern Rocky Mountains. In the southern Rocky Mountains and in Arizona, New Mexico, and southern California, stands of this species may be found which yield climatic histories fully as sensitive as those in Douglas-fir. Hypersensitive records are occasionally found on outlier sites of the lower forest margin in central and southern Arizona and New Mexico and in northern Mexico; the several woodland species similar to ponderosa pine in this region are quite largely undatable.

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, show such crowded and erratic ring series, with so many omitted rings, as to make increment borings and even full sections undatable; and on some sites of specially severe stress for this species, as in the Moab-Monticello area of southeastern Utah, no datable records may be found.

Limber pine tends to be complacent but usually shows very consistent, crossdatable records, so that it is commonly datable despite its characteristic slow growth on many sites. On arid sites in the southerly part of its range, as at Bryce Canyon, it often exhibits such crowded series that dating is impossible; however, on drier sites along the margins of and within the Rocky Mountain system this species yields chronologies approaching the good climatic records in Douglas-fir.

Giant sequoia provides uniquely long indices and, despite the extensive studies, already noted, of thirty to forty years ago, is far from exhausted as a source for climatic history.

Western or Sierra juniper shows promise but has as yet received only preliminary sampling.

Lodgepole pine (P.contorta) is apparently undatable everywhere. It appears, also, that all sampled species of Cupressus in the United States are characterized by such inherent cambial irregularity as to be useless for dendrochronology. The semi-desert hardwoods of the Southwest all appear to be in this category also.

Scopulorum juniper is easily datable in many areas of the central and northern Rockies; because of the relatively great resistance of very old individuals to the increment borer, however, and its scattered occurrence, it has not been widely sampled yet. It will doubtless provide valuable supplementary chronologies to those already developed for the cited regions.

In more southerly latitudes, as in New Mexico, this species tends to produce many annual-like false rings and shows much cambial irregularity in older trees, so that it is not a promising source for long chronologies; larger trees of this species on well-watered sites in New Mexico may prove useful. The other species of juniper reaching tree size in the central Rockies and the Southwest--utahensis, deppeana (pachyphloea), monosperma, flaccida--do not seem to have datable chronologies.

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.

INTERVAL OF RING GROWTH

Timber conifers sampled for ring chronologies in southern California and in the Colorado River Basin up to 40° N latitude have shown that in these regions the cambium in the lower stem tends to have the following growth characteristics:

Cell growth of mature trees begins about June 1 on most sites at the lower forest border (5000 feet to 7000 feet elevation) and sometimes as early as mid-May on the warmer and lower sites.

At higher elevations stem growth may not begin before June 15 or even later.

New ring-growth in young trees may begin a week or two earlier than that in mature trees.

Growth is most rapid during June and is substantially completed by the end of July.

Observations on conifers in higher latitudes of the Rocky Mountains form the major part of Table 3. All of these stations may be found in Table 1, but in some cases cores not measured were examined for current ring-growth. These results supplement earlier observations just cited.

Table 3. The Season of Ring Growth

Collection Date	Station	Lat.	Elev.	Species	Trees	Range of Ages, Years	Trees with Current Ring	Aver. No. Cells	Latewood: No. Trees and Cells	Aver. % Prev. Ring	Ratio % Current Ring
5-6-39	McDonald	30°40'	6800	PP	6	50-100	4	8	0	10	10
"	"	"	"	PNN	2	100±	1	5	0	5	5
6-4-49	Springdale	45 45	4500	DF	6	250-450	6	4	0	40	40
"	"	"	"	LBP	9	275-650	9	5	0	30	30
6-5-49	Divide	45 46	5600	DF	6	525-550	0	0	0	0	0
"	"	"	"	"	8	300-525	5	4	0	5	5
6-6-40	Graham Mts.*	32 37	8000	DF	3	200-210	3	4	0	15	10
"	"	"	"	PP	10	90-300	6	3	0	10	7
6-12-40	Mogollon*	33 24	6500	DF	4	120-160	4	18	0	75	60
"	"	"	"	PP	5	70-320	5	9	0	55	45
6-16-40	Gila Ruins*	33 12	6000	DF	4	50-130	4	30	0	155	75
"	"	"	"	PP	4	110-140	4	20	0	110	55
"	"	"	"	DF	5	175-500	5	8	0	70	50
"	"	"	"	PP	6	190-250	6	12	0	80	60
6-28-51	Banff	51 10	4600	DF	8	275-400	3	3	0	05	5
6-29-51	Lake Agnes	51 25	7000	LL	4	200-500	0	0	0	00	0
6-30-48	Jasper	52 54	3600	DF	8	300-420	8	6	0	120	75
7-2-51	Missoula	46 49	3300	DF	3	200-225	3	10	2;2	75	70
"	"	"	"	PP	7	200-350	7	5	0	25	25
"	Sula	45 51	4500	DF	3	250-300	3	3	0	10	10
"	"	"	"	PP	8	250-350	2	3	0	3	3
7-5-52	Ketchum	43 48	7000	DF	3	375-550	3	5	0	30	30
7-6-52	Ketchum	43 46	6500	DF	3	525-700	3	5	0	35	35
"	"	"	"	LBP	3	1350-1550	3	3	0	20	20
"	"	"	"	"	3	1000±	3	3	0	20	20
"	"	"	"	"	3	500-550	1	3	0	7	7
"	"	"	"	"	3	300-450	3	6	0	40	40
7-26-46	North Park	40 55	8000	DF	3	500-650	3	6	2?;2?	60	90
"	"	"	"	"	5	200-300	5	13	4;2	75	90
"	"	"	"	PP	2	250±	2	15	2? 2?	50	80
7-28-46	Kamas	40 33	7800	DF	2	200-250	2	15	2;3	125	90
"	"	"	"	WF	5	200-325	5	30	5;4	90	90
"	"	40 32	7500	PP	4	250-475	0	10	0	50	60
7-30-43	Oroville	48 59	1250	DF	2	250-275	2	30	2;10	100	95
"	"	"	"	PP	2	175-250	2	25	2;10	60	85
"	Conconully	48 40	1800	DF	2	250-300	2	30	2;15	100	95
"	"	"	"	PP	6	200-325	6	11	3?;2?	75	80
7-31-43	Republic	48 34	2500	DF	1	225	1	30	1;15	100	95
"	"	"	"	PP	3	200-350	3	15	0?	60	70
"	"	"	4500	DF	2	200-325	2	25	2;12	75	80
"	"	"	"	PP	3	250-350	3	12	0	40	60

* A more detailed analysis of cores from a station in ref. no. , p.19.

The set of cores on which Table 3 is based leaves much to be desired, for it was collected for an entirely different purpose. Since, with few exceptions, only one core is available from each tree, the results for any given small group of trees are probably only approximate. The observations suffer also from lack of homogeneity, for climatic and other differences must slightly alter the duration of ring growth from year to year in any tree. Nevertheless, the general limits of cambial growth seem to be consistently sketched in.

Most of the column headings need no comment; for abbreviations, see Table 1. "Average number of cells" represents only those cores in which the current ring is started. The identification of latewood when only a few cells are present is likely to be uncertain, and specially doubtful cases are noted; the number of cells is an average only for those cores which show current latewood. The "average % current ring" includes those trees in which such growth may not yet have begun and is an estimate based on the other data in the table and on the total ring-width to be expected for the given year; the expected total growth may, in many of the groups, be computed from later cores, climatic data, and evidence from other areas, but is, on the whole, little more than a working estimate.

The tendency to a later start for ring-growth in higher latitudes is borne out in Table 3. It thus seems likely that in many northerly areas of the mid-latitude Rockies growth is most rapid in July rather than in June. Despite the later start, however, even in Alberta stem growth in Douglas-fir appears to be largely completed by the end of July. At the other extreme in the latitude range here examined, young pines near the McDonald Observatory on Mt. Locke, Texas, were found in 1939 to have already begun growth in early May.

In the Ketchum limber pines, at least, cambial growth starts at about the same time even in extreme over-age as it does in middle age. Whether it ends sooner or merely proceeds more slowly to yield the characteristically thinner ring remains to be examined.

A systematic tendency for ponderosa pine to lag behind Douglas-fir both in the beginning of growth in the lower stem and in initial latewood production seems indicated in the table. All of the ten stations, from latitudes 33° to 49° where both species had been sampled, show this tendency, though in some cases the margin is small and age differences may account for it. There is some evidence, too, for a not inconsiderable cambial growth of ponderosa pine in August. Limber pine also appears to lag behind Douglas-fir in early stem growth, but cores are thus far available from only two stations.

ERRORS IN RING DATING

Locally absent rings, false rings, and other less important sources of potential error in dating a ring sequence may be completely eliminated if a sufficient degree of parallelism in year-to-year fluctuation in ring-width is present in comparative sequences. These properties of sequences--sensitivity and crossdating--are discussed in the next section; the results reported in this one are derived from groups of specimens in which such characteristics are well developed.

It now appears well established that within a given dendrochronologic species, such as Douglas-fir, the frequency of occurrence of locally-absent rings increases with increasing moisture deficit, increasing age, decreasing latitude, and decreasing elevation.

Table 4. Average Frequency of Locally Absent Rings at Selected Stations

Station	Species[1]	Lat.	Elev., ft.	Drought Stress[2]	No. Trees	Total No. Rings	No. Rings Absent	% Absent
Jasper	DF	52°54'	3600	3	6	2665	7	0.2
Banff (Bow Falls)	DF	51 10	4600	3	8	2698	0	0.0
Exshaw	DF	51 04	4300	5	8	3060	33	1.1
Divide	DF	45 46	5600	4	14	5803	43	0.7
Ketchum	DF	43 45	6000	4	6	3037	4	0.1
"	LBP	43 46	6500	5	3	4098	4	0.1
Indian Canyon	DF	39 58	7200	5	4	2870	42	1.5
Eagle	DF	39 37	6700	5	14	9939	84	0.8
Pikes Peak[3]	ES	38 52	12000	0	8	2426	0	0.0
Pecos	DF	35 38	7500	5	3	1634	41	2.5
Big Bend	DF	29 13	6000	5	5	1304	54	4.1
"	"	"	"	"	"	1040	23	2.2
"	"	"	"	"	3	380	3	0.8

1. DF - Douglas-fir; LBP - Limber pine; ES - Engelmann spruce.
2. Site scale for Rocky Mountain timber conifers: 0 - upper timberline; 1 - moist; 2 to 5 - increasing aridity (estimated).
3. An upper timberline group, no. 47 in Table 1, not an index of rainfall.

Table 5. Frequency of Locally Absent Rings in Oldest Trees at Selected Stations[1]

Station	Spec. No.	Species	Pith,[2] A.D.	Aver. Ring-Width,[3] mm.	Missing Rings Earliest	Missing Rings No.
Jasper	2571	DF	1532	0.41	----	0
"	2572	DF	1536	0.41	----	0
Banff	3634	DF	1540	0.80	----	0
"	3640	DF	1550	0.64	----	0
Exshaw	3684	DF	1508	0.22	1766	12
"	3683	DF	1553	0.21	1717	11
Divide	2786	DF	1400	0.38	1632	11
"	2789	DF	1418	0.42	1718	4
Ketchum	3755	DF	1368	0.33	1518	2
"	3757	DF	1385	0.40	----	0
"	3996	LBP	400±	0.26	1571	2
"	3966B	LBP	500±	0.25	----	0
"	3966F[4]	LBP	(4)	0.28[4]	1632	1
Pikes Peak	863	ES	1505	0.23	----	0
"	867	ES	1510	0.35	----	0
Pecos	3921	DF	1370	0.34	1415	14
"	3911	DF	1390	0.36	1516	10
Big Bend	2138	DF	1640	0.43	1703	21
"	2124	DF	1670	0.45	1730	10

1. For data on the oldest trees at the Eagle and Indian Canyon stations see Table
2. The inner ring on most cores is close to or at the pith; thus an estimate of pith date, if necessary, is rarely uncertain by more than five years.
3. Excluding inner 100 years to pith.
4. Upper radius of root; inner ring on core is A.D. 961; pith date uncertain but probably precedes A.D. 600; aver. width since 961.

The frequencies noted in Table 4 were observed on increment cores, one only from each tree, and apply only to such material. The few representative groups include the two most sensitive collections in the Rocky Mountains north of 42° latitude; these somewhat obscure the observation that locally-absent rings in general occur infrequently in the ring records of that region. The maximum frequency presently observed is found in the low-latitude Big Bend group; the data presented in TRB 18:19 show that in the six oldest trees of this group (250-300 years) the average frequency since 1870 is 8.7% and the maximum about 15%, a proportion which requires for correct ring dating nearly perfect parallelism in chronology among the trees. At the other extreme are the upper timberline chronologies, as in the Pikes Peak spruce trees, which, despite very slow growth, show no omitted rings on the cores.

Locally-absent rings in the two oldest trees from each of the stations just examined are noted in Table 5. It is evident that in the more sensitive series frequencies of the order of 5% are not at all uncommon in the outer centuries.

False annual rings are of rare occurrence in the dendrochronologic species of the northern Rocky Mountains and, when they do occur, are usually weak and quite unmistakable. Even in more southerly areas the rings of Douglas-fir and pinyon pine are, on the whole, relatively free of this difficulty; false rings tend to be very common, however, in ponderosa pine and related species. The identification of such rings is almost always possible in sensitive groups of trees by cross-comparison.

Of the collections in Table 1, the Big Bend Douglas-firs in the Rio Grande basin contained the most pronounced false rings and in the highest proportion (TRB 18:25, 1952). However, even for this station, crossdating and application of the criterion for recognition of Douglas-fir false rings (TRB 6:24, 1948)--the latewood-type coloring of all of the annual ring outside the false layer--permitted a complete solution of this dating problem.

Compression wood is a common source of distortion in ring chronology; it usually is found on the under side of conifer stems on steep slopes. Although many such slopes were sampled in a search for the most sensitive drought conifers, this factor was almost entirely eliminated from the collections by systematic sampling on the upper radius.

Fire, lightning, frost, and other injury rings are in general easily recognized and were of trivial importance in the slow-growing overage trees, which were the principal objects of study. More subtle, long-term pest and other factors do not introduce dating problems, though they may well affect the interpretation of ring chronologies and are consider in Chapter 4.

COEFFICIENTS OF MEAN SENSITIVITY AND CROSSDATING

A convenient numerical expression for the degree of variability in a given set of rings is the average first difference expressed as a ratio of the mean ring-width. As an apparent index of the climatic indicator value of the record (an assumption which is examined in a later section), this coefficient has been called the mean sensitivity.*

$$M.S. = \frac{\overline{|\Delta x|}}{\bar{x}}$$

In general, the ring-widths x on which the coefficient is based should number at least 50; however, for stability studies non-overlapping shorter intervals may be useful. The existence of a small age trend in the ring series for the interval tested does not seem to markedly affect the value of the coefficient (TRB 13:14, 1947), but, in general, if any age trend is present, it should be removed before the coefficient is computed.

Obviously, the M.S. of any group-mean curve will be less than the average M.S. of its component trees, the reduction depending on the number of trees and on the amount of variability of the individuals with respect to the group chronology. Since variability in ring chronology within any group is the result of both random fluctuations and of the physically real environmental differences at the various trees, it is evident that only groups from relatively small and climatically homogeneous areas are desirable for mean sensitivity analysis. It appears that the theoretical group M.S. for a set of n random series is less than the average M.S. of the individual components of the group in the ratio $1/\sqrt{n}$, the well-known relation for normally distributed random numbers.

On the other hand, if the individual ring records are not random but show crossdating within the group, then the M.S. coefficient should tend to remain near a constant value when trees above some critical minimum number are included in the group averages. It will be seen that with highly sensitive trees as little as three often provide a chronology reliable in most respects.

An unusually wide range in mean sensitivity for such a group is found in Table 6. An extraordinary number of stunted, overage Douglas-firs manage to eke out a living on the gypsum hills near Eagle, Colorado. It was noted during sampling that on the steep, rocky slopes with little soil the trees are limited to very slow growth even during the most favorable years, but nevertheless tend to show only slightly reduced growth during adverse years, perhaps owing to some special factor such as a slow seepage of underground water or to slower exhaustion of the tree's soil area. The average growth rate is little better on the flattish uplands but is characterized by violent fluctuations.

The means by age classes tabulated at the bottom of Table 6 suggest that sensitivity, in this group at least, is related in some degree to average ring-width. In every class, growth was greater during 1900-1950 than it was in the preceding half-century and the mean sensitivity was less.

A marked tendency for decreasing mean sensitivity with increasing ring-width also is evident in a scatter diagram of the data in the table. However, both the average growth and the mean sensitivity were less in all but one age class during 1800-1850 as compared with 1900-1950, a clear result of the differences from interval to interval in chronology characters which one would expect in non-random series.

Although all sampled trees at the Eagle site exist under a generally marginal environment for the species, the minor site differences from tree to tree which affect the sensitivity also seem to influence the crossdating quality. We may examine this effect more closely by means of the coefficient R.

This coefficient is defined as the ratio of the group M.S. to that of the average of the M.S. for the individual trees. Thus the magnitude of R must be evaluated in terms of the $1/\sqrt{n}$ ratio discussed above; e.g., for a group of four trees, R would tend to take the value 0.50 if all ring-widths were purely random.

In Table 7 the uniformly higher value of R for six sensitive as compared with six complacent series suggests that the latter type of record tends to have a greater random term in its fluctuations. Reference to Figure 6 shows the two group means, however, to be very close in chronology. It is further evident in Table 7 that the reduction of random error in groups from this site is virtually complete with as little as four datable trees.

Further light on the properties of the coefficients of sensitivity and crossdating is provided by an analysis of an unusually sensitive set of ring records from Pecos, New Mexico. Consecutive twenty-year coefficients over the interval 1500-1940 for each of four trees and for the group mean yielded 132 values, tabulated in Table 8.

Table 6. Mean Sensitivity and Ring-Widths in mm in Douglas-firs at Eagle, Colorado

EAG No.	1800 - 1850 M.S.	1800 - 1850 R.W.	1850 - 1900 M.S.	1850 - 1900 R.W.	1900 - 1950 M.S.	1900 - 1950 R.W.	Age, Yrs.[1]
3332	.195	.32	.186	.36	.195	.47	740
3333	.332	.14	.303	.15	.279	.18	600+
3335	.410	.09	.448	.12	.373	.24	860
3336	.297	.19	.444	.15	.313	.42	820
3337	.318	.19	.620	.13	.380	.20	860
3339[2]	.201	.31	.297	.24	.271	.41	890
3340	.261	.15	.347	.19	.390	.21	660
3341	.441	.13	.331	.15	.271	.29	570
3346	.218	.22	.244	.16	.218	.18	610
3347	.268	.21	.326	.20	.378	.34	580
3348	.284	.16	.336	.15	.372	.22	620
3349	.383	.19	.499	.15	.339	.26	660
3350	.309	.38	.301	.47	.320	.46	680
3352	.334	.13	.437	.12	.342	.15	730
3354	.259	.24	.250	.31	.277	.34	700
3356	.312	.24	.489	.19	.368	.25	710
3362	.278	.29	.324	.42	.348	.42	360
3365	.299	.30	.344	.23	.210	.32	430
3366	.313	.33	.480	.32	.340	.42	460
3369	.400	.25	.556	.21	.401	.32	610
3377	.375	.33	.520	.22	.397	.30	500+
3378	.504	.13	.922	.09	.625	.09	800
3379	.409	.16	.526	.17	.422	.30	730
3381	.235	.16	.303	.16	.258	.31	660
3383	.476	.37	.662	.31	.455	.45	530
3385	.186	.25	.209	.22	.232	.25	600+
3386	.251	.22	.356	.13	.345	.16	580
3387	.183	.21	.172	.21	.157	.23	650
3388	.202	.49	.211	.57	.209	.51	200+
3390	.227	.64	.206	.44	.152	.25	450
Age Class Means:							
-499 (4)	.269	.39	.339	.35	.263	.36	425
500-599 (4)	.359	.23	.419	.20	.362	.31	565
600-699 (8)	.285	.22	.3[illegible]	.21	.307	.26	649
700-799 (8)	.302	.22	.378	.23	.325	.30	722
800- (5)	.366	.18	.546	.15	.392	.27	850
Unknown (4)	.274	.30	.311	.29	.279	.31	---
All (30)	.304	.25	.389	.23	.322	.30	---

1 From 10 to 30 years (depending on early ring-widths) for height growth to boring level has been added to estimated pith date. Plus sign denotes core is incomplete and minimum age only is estimated.

2 Another radius shows .230, .273, .277.

Table 7. Sensitivity and Crossdating in Sub-Groups of Douglas-fir at Eagle, Colorado

Group	No. Trees	Interval	Tree M.S.						Aver. Tree M.S.	Group M.S.	Aver. Ring-Width, mm.	R
Complacent[1]	6	1800-1850	.195,	.218,	.186,	.183,	.202,	.227	.203	.164	.355	.794
"	"	1850-1900	.186,	.244,	.209,	.172,	.211,	.206	.205	.159	.327	.761
"	"	1900-1950	.195,	.218,	.232,	.157,	.209,	.152	.195	.166	.315	.672
Sensitive[2]	"	1800-1850	.318,	.312,	.400,	.375,	.409,	.476	.382	.340	.257	.880
"	"	1850-1900	.620,	.489,	.556,	.520,	.526,	.662	.563	.512	.205	.907
"	"	1900-1950	.380,	.368,	.401,	.397,	.422,	.455	.407	.368	.303	.907
700+ years	4	1800-1850	---	---	---	---	---	---	.276	.216	.25	.782
600+	13	"	---	---	---	---	---	---	.290	.224	.22	.772
500+	20	"	---	---	---	---	---	---	.291	.229	.22	.787
150+	30	"	---	---	---	---	---	---	.304	.243	.25	.800
700+	4	1850-1900	---	---	---	---	---	---	.364	.292	.23	.801
600+	13	"	---	---	---	---	---	---	.398	.297	.22	.746
500+	20	"	---	---	---	---	---	---	.377	.288	.20	.764
150+	30	"	---	---	---	---	---	---	.389	.314	.23	.808
700+	4	1900-1950	---	---	---	---	---	---	.300	.258	.40	.860
600+	13	"	---	---	---	---	---	---	.331	.273	.30	.825
500+	20	"	---	---	---	---	---	---	.326	.264	.28	.809
150+	30	"	---	---	---	---	---	---	.322	.267	.30	.829

1 Nos. 3332, 3346, 3385, 3387, 3388, 3390.
2 Nos. 3337, 3356, 3369, 3377, 3379, 3383.

Table 8. The Range of 20-Year Coefficients of Mean Sensitivity in Douglas-firs near Pecos, New Mexico, 1500-1940.

Tree No.	Min. M.S.	Mean Ring-Width, mm.	Max. M.S.	Mean Ring-Width, mm	Median M.S.
2208	.42	.62	.83	.39	.56
3911	.46	.56	1.22	.16	.65
3912	.27	.54	.78*	.28*	.54
3921	.43	.28	1.02	.20	.57
Average	.42	--	.89	--	.59
Group Index	.37	.42	.87	.32	.57

* Another interval of this sensitivity has a mean ring-width of 0.46 mm.

The crossdating coefficient R ranges from 0.85 to 1.00 with the median at 0.94.

Although the median sensitivity for such a short interval as 20 years is fairly stable and compares well with that for 100 years, it is evident from the foregoing tabulation that individual coefficients must be based on relatively long series to be representative. The maximum observed coefficient, signifying an average year-to-year change in ring-width of 122% of the mean annual growth during a 20-year interval, is based on a mean growth decidedly less than the overall average for the tree of 0.40 mm. In fact, as might be expected, there is a marked inverse relation of mean sensitivity to average ring-width in any single sequence.

It will perhaps suffice to examine a number of critical series--most sensitive, most complacent, longest records, obscure chronologies--to gain a quantitative view of sensitivity and crossdating in the conifers of western North America. The Mesa Verde and Ft. Garland groups in Table 9 are perhaps slightly more sensitive than the overall average of the chronologies in this survey; it appears that the M.S. of relatively few centuries-long group records exceeds 0.40 or is less than 0.25.

Table 9. Coefficients of Sensitivity and Crossdating

Station	Species	No. Trees	Interval	Tree M.S.	Aver. Tree M.S.	Group M.S.	Aver. Ring-Width, mm.	R
Exshaw	DF	4	1700-1800	.647,.411,.510,.553	.530	.482	.323	.909
"	"	"	1800-1900	.518,.456,.550,.566	.523	.469	.266	.935
Quesnel, B.C.	"	3- 5	1800-1900	--- --- --- ---	---	.22	---	---
Williams Lake, B.C.	"	6	1800-1900	--- --- --- ---	---	.40	---	---
Alkali Lake, B.C.	"	7	1800-1900	--- --- --- ---	---	.75	---	---
Tranquille, B.C.	"	13-14	1800-1900	--- --- --- ---	---	.32	---	---
Tranquille, B.C.	PP	13-14	1800-1900	--- --- --- ---	---	.27	---	---
Vernon, B.C.	DF	3- 4	1800-1900	--- --- --- ---	---	.27	---	---
Penticton, B.C.	PP	4	1800-1900	--- --- --- ---	---	.29	---	---
Ketchum (n)	DF	5	1500-1600	.305,.323,.361,.336,.352	.335	.294	.509	.678
"	"	"	1600-1700	.306,.341,.277,.366,.261	.314	.252	.409	.603
"	"	"	1700-1800	.204,.305,.226,.333,.229	.259	.209	.326	.607
"	"	"	1800-1900	.286,.299,.290,.337,.295	.302	.249	.243	.625
Ketchum (1500 yr)	LMP	4	727- 800	.147,.142,.252,.138	.170	.112	.372	.659
"	"	"	800- 900	.229,.178,.258,.199	.216	.173	.347	.802
"	"	"	900-1000	.187,.176,.263,.220	.217	.182	.323	.839
"	"	"	1000-1100	.228,.209,.240,.227	.226	.184	.314	.814
"	"	"	1100-1200	.195,.214,.265,.220	.224	.189	.311	.644
"	"	"	1200-1300	.224,.246,.281,.212	.241	.214	.311	.886
"	"	"	1300-1400	.252,.209,.299,.198	.235	.200	.268	.852
"	"	"	1400-1500	.242,.218,.291,.247	.250	.203	.163	.812
"	"	"	1500-1600	.220,.208,.326,.219	.243	.187	.215	.770
"	"	"	1600-1700	.275,.195,.306,.230	.242	.187	.226	.773
"	"	"	1700-1800	.198,.229,.203,.235	.216	.165	.183	.757
"	"	"	1800-1900	.208,.187,.263,.249	.227	.186	.190	.620
"	"	"	1900-1951	.178,.180,.251,.231	.210	.182	.225	.657
Ketchum (500 yr)	"	3	1700-1800	.223,.209,.231	.221	.180	.412	.615
"	"	"	1800-1900	.244,.214,.239	.232	.183	.323	.790
Ketchum (1000 yr)	"	"	1700-1800	.256,.223,.160	.213	.170	.324	.796
"	"	"	1800-1900	.187,.200,.209	.201	.159	.312	.791
Ketchum (500 + 1000)	"	6	1700-1800	--- --- --- ---	.217	.177	.372	.816
Ketchum (500 + 1000)	LMP	6	1800-1900	--- --- --- ---	.217	.151	.318	.696
Ketchum (500 + 1000 + 1500)	"	10	1700-1800	--- --- --- ---	.217	.162	.344[2]	.747
"	"	"	1800-1900	--- --- --- ---	.221	.155	.318[2]	.702
Ketchum (e)	DF	3	1700-1800	.200,.179,.219	.199	.165	.204	.629
"	"	"	1800-1900	.261,.197,.242	.233	.189	.180	.612
Indian Can. (500-yr)	"	5	1700-1800	.362,.484,.536,.488,.712	.516	.487	.224	.944
"	"	"	1800-1900	.323,.441,.463,.397,.418	.408	.378	.222	.927
Indian Can. (650 yr)	"	"	1700-1800	.614,.332,.413,.434,.476	.454	.406	.128	.699
"	"	"	1800-1900	.410,.239,.427,.375,.337	.356	.312	.243	.672
Indian Can. (500 + 650)	"	10	1700-1800	--- --- --- --- ---	.485	.448	.227	.924
"	"	"	1800-1900	--- --- --- --- ---	.382	.337	.233	.880
W. Tavaputs	"	36	1600-1850	--- --- --- --- ---	.414[3]	.380	.250	.918
"	"	"	1850-1900	--- --- --- --- ---	.430[3]	.363	.234	.891
"	"	"	1900-1945	--- --- --- --- ---	.343[3]	.286	.280	.834
Beale	"	30	1800-1850	(4)	.304	.242	.25	[illegible]
"	"	"	1850-1900	(4)	.289	.214	.23	[illegible]
"	"	"	1900-1950	(4)	.322	.267	.30	.629
Lake George	"	3	1720-1941	.53, .64, .56	.58	---	---	---
Pikes Peak	ES	3-	1700-1800	.160,.135,.177	.164[1]	.132	.351	[illegible]
"	"	"	1800-1900	.160,.179,.203	.181	.145	.257	.802
"	"	"	1800-1900	.196,.187,.215	.199	.172	.376	.870
"	"	6	1800-1900	--- --- --- --- ---	.190	.147	.273[1]	.774
Salida I	DF	2	1720-1941	.57, .60	.58	---	---	---
Salida II	"	"	1720-1941	.29, .19	.24	---	---	---
Mesa Verde	"	7	1800-1900	.441,.471,.401,.401,.472, .428,.449	.438	.378	.350	[illegible]
Ft. Garland	PIN	10	1650-1950	.365,.404,.297,.486,.264, .400,.339,.349,.267,.371	.370	.329	.366	[illegible]
Sangre de Cristo	DF	4	1650-1941	[illegible]	.234	.209	[illegible]	[illegible]
Pecos	"	"	1500-1600	.513,.560,.502,.582	.539	.515	.473	[illegible]
"	"	"	1600-1700	.672,.702,.555,.568	.624	.569	.554	[illegible]
"	"	"	1700-1800	.606,.717,.539,.704	.642	[illegible]	.392	[illegible]
"	"	"	1800-1900	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pecos South	"	3	1720-1941	.55, .62, .64	.60	---	---	---
Big Bend	"	5	1650-1945	[illegible]	.671	[illegible]	.364	.965
Sequoia (Ridge)	SS	4	1740-1840	.140,.163,.238,.227	.192	.164	[illegible]	[illegible]
Sequoia (Basin)	SS	4	1740-1840	.150,.114,[illegible],.172	.162	.114	.699	.704
San Jacinto	BCS	5	1650-1942	.270,.421,.427,[illegible],[illegible]	.408	.362	.734	.963
San Jacinto	PP	5	1650-1942	[illegible]	.240	.190	.750	[illegible]

1 Three fast-growth trees weighted one-half before averaging to roughly equalize with older trees.

2 1500-yr group weighted 5/3 before averaging to equalize with 500- and 1000-yr groups.

3 Average of eight group mean sensitivities: Indian Canyon (3), Nine-Mile Canyon (4), and Sunnyside (1, weighted x3).

4 See Tables 6 and 7.

The M.S. coefficients for the sensitive Pecos group indicates a small but systematic increase in ring sensitivity with increasing age. This would seem to be related to the greater incidence of microscopic and locally absent rings in older trees of high sensitivity; decreasing ring-width might also be expected to permit greater percentual growth fluctuation.

On the other hand, complacent series such as those at Ketchum show no clear influence of age on sensitivity.

No test was made of growth sensitivity in the sapling stage, since the early rings may not be representative and are of trivial importance in climatic dendrochronology.

It is noteworthy that the six groups of Douglas-firs showing the highest M.S. are <u>all</u> from sites in the general boundary zone between montane forest and prairie; the range in latitude is from 51° N to 29° N.

As an addendum to the foregoing discussion of coefficients of mean sensitivity and crossdating there are presented in Table 10 a few values of the more familiar standard deviation σ. It has already been noted that the amount of fluctuation in a mean curve is dependent on species, the sensitivity of the individual components, the degree of parallelism among the component series, and other factors. Thus, σ for the Colorado index, though it is based on sixty Douglas-firs from an area of many thousand square miles, is, nevertheless, substantially higher than that for the four Snake (Ketchum) limber pine cores from one hillside. The 50-year σ in Table 10B represent fluctuations about the long-term mean trend, not the mean for the respective shorter intervals; the pinyon series and the supersensitive Big Bend Douglas-firs show the smallest variabilities of σ with time.

Table 10A. Standard Deviation in Annual Indices, 1550-1949, Per Cent of Mean

Table 2

Set	Area	Species	No. Trees	σ
E	Snake R. Basin	DF	11	24.3
F	Snake R. Basin	LBP	4[1]	22.8
-	Snake R. Basin	LBP	3	21.6
M	Colorado R. Basin	DF	60	30.6
N	Colorado R. Basin	PNN	8	25.6[2]
Y	Rio Grande Basin	DF	8-19[3]	39.5
Z	Rio Grande Basin	PNN	3-6[4]	37.9
-	Pecos[5]	DF	4	54.5
-	Big Bend[6]	DF	5	63.0[7]

Table 10B. 50-year σ

Interval	Set: E	Snake 500-Yr.	M	N	Y	Z	Pecos	Big Bend
1550-1599	29	23	34	28	45	41	52	
1600-1649	31	26	34	24	46	42	57	
1650-1699	19	22	24	20	36	35	54	
1700-1749	22	19	30	27	41	39	55	62
1750-1799	20	20	28	26	35	33	48	58
1800-1849	26	17	30	27	37	36	68	74
1850-1899	18	19	27	27	37	41	52	57
1900-1949	26	26	36	27	37	35	50	63[8]

---

1. 4 cores from three 1500-year limber pines, unstandardized; the computed σ for this series is slightly higher than it would be if the age trend were first removed. The next group, 3 trees, represents 500-year limber pines, standardized.
2. 1549-1948.
3. 8 trees, 1550-1649; 18 trees, 1650-1669; 19 trees, 1670-1941.
4. 3 trees, 1550-1649; 6 trees, 1650-1945.
5. Included in set Y. 6. Included in set AD. 7. 1700-1945. 8. 1900-1945.

Table 11. Correlation Between Ring-Widths Along Various Radii in a Lower Stem Section of MVR-3041

Range	Radii 1 vs 5	Radii 3 vs 7	Mean of 1,3,5,7 vs Mean of 2,4,6,8
1700-1749	+.913	+.963	+.991
1750-1799	.946	.928	.989
1800-1849	.941	.946	.985
1850-1899	.934	.947	.991
1900-1949	.967	.930	.993
Mean	.940	.943	.990

It is possible for a set of data to have a markedly higher M.S. coefficient and lower σ than some other set. However, it appears that tree-ring series tend to show parallel values of the two coefficients. For example, the M.S. of the four sensitive Pecos Douglas-firs is, from Table 9, about three times that of the four complacent Ketchum limber pines for the last four centuries; from Table 10, the corresponding values of σ are roughly in the ratio of 2:1.

CHRONOLOGY DIFFERENCES

Although the crossdating coefficient R, discussed in the preceding section, enlarges the significance of the mean sensitivity analysis and provides a quick first approximation to the degree of consistency in a group of ring sequences, it is obviously rather insensitive and not intended to replace the more precise statistical measures of variation in ring chronologies. To examine more precisely the degree of such variation within a tree, group, and area we find the familiar linear correlation coefficient <u>r</u> appropriate. It is used here as a measure of covariation only and for most pairs of variates more than one interval is examined.

The rather remarkable degree of uniformity about the circuit which characterizes the more sensitive dendrochronologic trees is well shown in tree no. 3041, a 300-year Douglas-fir at Mesa Verde National Park (station 123a, Table 1). Eight equidistant radii at a typical level in the stem are analysed in Table 11. It is evident that random variations almost completely cancel out in a mean ring record for a pair of normally-oriented diameters.

The extensive collections at Mesa Verde and Bryce Canyon National Parks and at Eagle, Colorado, provide data for some estimates of the relation to chronology of the age, number, species, and location of the trees.

The various series from these have been areas plotted in full in Chapter II and described in the associated tables and notes. Correlation coefficients are collected in Table 12.

Variations at Mesa Verde from group to group and among the three species probably originate in good part in the distance effect--the common observation that neighboring groups of trees from even the most homogeneous area show systematic differences in ring chronology as a result of site and climatic differences.

The influence of tree age on chronology is obscured by many factors. The index derived from seven 500-year trees shows a much closer relation to a second index in old trees than to one from young trees; however, as shown in Table 1, the old Douglas-firs are almost all within a two-mile area in the southern part of Mesa Verde and the group of young trees some six miles to the north. On the other hand, a systematically closer relation to the older pinyon pines is shown in Table 12, though both young and old trees come from the northern part of the Park. Whether these results may be interpreted as showing a real difference in growth lag or in some other reaction of old as compared with young trees is not yet clear. However, following the extended drought which ended with 1905, young Douglas-firs at Mesa Verde, Black Canyon of the Gunnison, Bryce Canyon, and in northeastern Utah all appear to have responded more quickly than old trees to the unusually wet interval of 1905-1929. For such times, then, the climatic history in young, relatively fast-growth trees is to be sought as supplementary evidence.

The cancellation of most of the random variation in chronology in the average of even a few records from sensitive trees has already been noted. It is an accident that the coefficient in Table 12a between the seven old Douglas-firs and the single tree 3041 is higher than that between six young trees nearby and the old trees. But it is evident that a single radius in one tree may provide a good first approximation of the local chronology, for we have already noted that the 8-radii mean of 3041 is little different from any of its components.

Another good example of this effect is provided by the Eagle analysis, Table 12d. Four trees show almost as high coefficients vs the Nine Mile chronology as do the large groups. It appears from these 50-year coefficients that a half-dozen sensitive trees are quite sufficient to represent the chronology of a locality, apart from long-term fluctuations, the importance of which is discussed elsewhere.

Table 12. Sub-Group Variations in Correlation Coefficients

A. Mesa Verde[1]

	(1)DF	(2)DF	(1+2)DF	(3)DF	(4)DF	(5)JSC	(6)PPN	(7)PPN
	7-500	7-500	14-500	6-200	#7041(6)	4-200	8-200	7-500
Vs Mesa Verde DF(1), 7-500 year trees								
1750-99	---	+.915	---	+.816	+.783	---	+.636	+.713
1800-49	---	.956	---	.972	.896	+.637	.507	.774
1850-99	---	.954	---	.798	.684	.643	.823	.765
1900-45	---	.939	---	.661	.859	.629	.696	.733
Mean	---	.941	---	.812	.806	.636	.667	.736
Vs Betatakin,[2] Arizona, Douglas-fir								
1750-99	+.676	+.646	+.678	+.404	+.625	---	+.514	+.592
1800-49	.736	.748	.731	.689	.718	+.528	.370	.656
1850-99	.773	.762	.781	.729	.544	.629	.742	.665
1900-45	.714	.734	.693	.738	.773	.612	.470	.572
Mean	.725	.723	.721	.640	.665	.590	.524	.646
Vs Nine Mile Canyon,[3] Utah, Douglas-fir								
1750-99	+.501	+.471	+.492	+.349	+.539	---	+.478	+.558
1800-49	.646	.675	.657	.612	.602	+.414	.447	.521
1850-99	.679	.703	.686	.582	.576	.609	.732	.681
1900-45	.680	.686	.702	.499	.635	.477	.435	.526
Mean	.627	.634	.634	.511	.588	.500	.523	.580

B. Bryce Canyon[4] Area

	(1)DF	(2)DF	(3)DF	(4)DF	(3+4)DF	(5)PP	(6)PP	(5+6)PP	(7)PP	(8)DF	(9)CBS
	4-325	4-725	6-375	6-525	12-450	5-440	5-550	10-495	4-440	3-325	4-300
Vs Mesa Verde DF(1), 7-500 year trees											
1750-99	+.56	+.48	+.55	+.46	+.53	+.42	+.40	+.44	+.51	+.47	+.51
1800-49	.41	.42	.64	.58	.58	.59	.50	.58	.42	.34	.46
1850-99	.54	.56	.54	.47	.65	.53	.46	.49	.44	.62	.44
1900-49	.56[5]	.62[5]	.68	.65	.70	.57	.58	.59	.66	.65	.48
Mean	.52	.52	.60	.54	.615	.57	.485	.525	.51	.52	.47
Vs Nine Mile Canyon, Utah, Douglas-fir											
1750-99	---	+.45	---	---	+.53	---	---	---	---	---	---
1800-49	---	.53	---	---	.65	---	---	---	---	---	---
1850-99	---	.46	---	---	.58	---	---	---	---	---	---
1900-45	---	.57	---	---	.68	---	---	---	---	---	---
Mean	---	.50	---	---	.61	---	---	---	---	---	---
Vs Southern California Bigcone Spruce[6]											
1750-99	---	---	---	---	+.44	---	---	+.41	---	---	---
1800-49	---	---	---	---	.44	---	---	.47	---	---	---
1850-99	---	---	---	---	.59	---	---	.70	---	---	---
1900-44	---	---	---	---	.48	---	---	.41	---	---	---
Mean	---	---	---	---	.49	---	---	.50	---	---	---

C. Eagle,[7] Colorado, Douglas-fir

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	1-800	4-700	17-600	20-500	20-150	6 Compl.	6 Gens.
Vs Nine Mile Canyon, Utah, Douglas-fir							
1800-49	+.358	+.532	+.538	+.540	+.556	+.497	+.520
1850-99	.244	.437	.454	.466	.468	.454	.476
1900-49	.275	.429	.457	.462	.461	.295	.495
Mean	.292	.466	.483	.489	.495	.415	.497
Vs Eagle West,[8] Colorado, Douglas-fir							
1800-49	+.508	---	+.889	---	---	---	---
1850-99	.433	---	.810	---	---	---	---
1900-49	.548	---	.744	---	---	---	---
Mean	.496	---	.814	---	---	---	---

1. Column headings give the sub-group number and species, the number of trees (6 equidistant radii for tree No. 7041), and the approximate age class. Sub-groups (1) and (2) are in the southern part of the Park, (6) includes data for both the western and the northern part, and the rest are in the northern part. Sub-groups represent stations in Table 1 as follows: (1) - 73,74,75; (2) - 125 (3 trees), 126 (3 trees), 119; (3) - 123a (3 trees), 121; (4) - 103a (not included in preceding group; (5) - 123b; (6) - 124 (4 trees), 122, 123c, 120; (7) - 120 (6 trees), 122.

2. Station 129, Table 1.

3. Mean of groups at stations 101, 102, 103a, and 106, Table 1.

4. Column headings as in footnote 1, the age class, however, representing a computed mean. Sub-groups represent canyons in the Bryce National Park area as follows: (1) - Red and Bryce; (2) - Tropic and Red; (3) to (6) - Tropic; (7) to (9) - Red.

5. End dates of compared series in early or middle 1940's.

6. Table 2-AG, Appendix.

7. The first five sub-groups are based on trees exceeding the stated ages; see Tables 6 and 7.

8. Station 111a, Table 1.

Table 13. 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	+.466	+.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	.378	.268	.631	.485
So. Arizona (19)	.137	.261	.254	.513	.448	.533

* Mesa Verde-Wagon Wheel Gap, 99 miles; Mesa Verde-Pecos South, 196 miles; So. Arizona-Big Bend, about 400 miles.

The only slightly lower coefficients in Table 12 for comparisons between different species support visual estimates that, in the Rocky Mountain chronology conifers at any rate, the species effect is a small one. Significant differences of course exist, as the discussion of the duration of ring growth has already emphasized, and are examined further in the comparisons of growth with rainfall data.

One expects chronologies of high sensitivity to be more representative than those of low sensitivity, and at first glance the coefficients for the last two Eagle groups in Table 12d support this. It was noted in the preceding section that the crossdating coefficient R, while relatively high in both types of record, is decidely higher in the sensitive set. Examination of the growth curves in Fig. 6, however, shows a decided difference in trend during the past half-century in the two series, which is probably responsible for most of the difference in the respective coefficients. This somewhat surprising reliability in chronology for complacent series is probably true only in the presence of good cross-dating. The result is of special importance in the interpretation as climatic indices of the extraordinarily long but quite complacent limber pine series from the Ketchum area, Idaho.

The change in chronology with distance within the upper basin of the Colorado River is pleasingly consistent in the sensitive old Douglas-firs in Table 12:

Mesa Verde (1)	vs. Mesa Verde (2)	2	miles	+ 0.94
Eagle	Eagle West	5	"	+ 0.81
Betatakin	Mesa Verde	135	"	+ 0.72
Nine Mile	Mesa Verde	200	" (N-S)	+ 0.63
Nine Mile	Eagle	200	" (W-E)	+ 0.49

A somewhat less homogeneous set of records, in and near the Rio Grande basin, is examined in Table 13. 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 the less representative character of its ring record rather than 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, 1941), which seems, in fact, to be somewhat greater than for corresponding distances north-south. The contrary indications for the central latitudes of the Colorado River Basin, in the small table above, are suggestive but require supporting evidence before they may be considered significant.

The preceding discussion is based on the means of fifty-year coefficients for the past 150 or 200 years. What is the nature of the long-time relation between any pair of ring records? Such a study for the Douglas-fir indices at Mesa Verde and Tsegi and the ponderosa pine index at Flagstaff (TRB 14:10, 1947), each extended by archaeological chronologies, is given in Table 14.

Interregional comparisons in chronology are further discussed in Chapter V.

Table 24. Correlation Coefficients between Southwestern Indices

Interval A.D.	Mesa Verde vs. Tsegi	Mesa Verde vs. Flagstaff	Tsegi vs. Flagstaff
900- 949	.58	.57	.56
950- 999	.83	.59	.72
1000-1049	.65	.55	.53
1050-1099	.68	.56	.71
1100-1149	.65	.52	.60
1150-1199	.65	.66	.64
1200-1249	.78	.56	.78
1250-1299	.60	.53	.68
1300-1349	.69	.64	.55
1350-1399	.77	.46	.50
1400-1449	.70	.17	.39
1450-1499	.83	.56	.41
1500-1549	.82	.54	.58
1550-1599	.56	.41	.51
1600-1649	.64	.52	.60
1650-1699	.61	.29	.48
1700-1749	.76	.62	.72
1750-1799	.68	.46	.46
1800-1849	.74	.53	.74
1850-1899	.76	.51	.55
1900-1946	.72		
Mean, 900-1299	.68	.57	.62
Mean, 1300-1899	.71	.46	.54

AGE TREND AND ABSOLUTE VALUES

Since the absolute width of the annual ring depends in part on many non-climatic factors, such as age and species, dendroclimatic indices must be based on growth departures. Such departures from the tree's age curve or mean trend in radial growth are derived by graphic or mathematical fitting of an estimated trend line to the series of ring-widths; the ratio of the ring-width to the value of the trend or standardizing line is the standardized ring-width.

Unfortunately, the "end effect" does not permit a perfect elimination of the true age trend even by the use of the most precise methods. Applied to a tree-ring series, the "end effect" is the uncertainty in the exact position of the fitted trend or standardizing line as a result of ignorance of the data beyond either limit of the series. Thus, after averages are taken of standardized individual growth curves of different lengths to get a group mean, or of various group means for a regional mean, the run of values of the resultant index may be too high or too low near the end points of the component series by an undeterminable amount. Though this error is likely to be small, it introduces a serious uncertainty in the interpretation of long-term fluctuations in growth as an index of climatic changes.

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. The mean curve may then be standardized in the usual fashion and extended by the standardized early portions of the records in the older trees.

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, of removing 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 widely observed natural age trend in trees, a single early maximum followed by a regular decrease, should be used. The earliest decades of growth often contain a specially steep age trend and may 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.

Numerical methods involve the least-squares fitting of a polynomial, preferably of low degree, to the raw data. If trends are removed from the individual tree series, the fitted trend lines are in general different. However, when the ring-widths in a sufficient number of trees are averaged, the function applied to the means tends to assume a simple form. One such function, widely applied by the Scandinavians, is the following:

$$\frac{1}{y} = a + b\ (x - k)$$

where y is the ideal ring-width at year x, k being the mid-year of the analysed series and a and b constants. Underlying this formula is the assumption that, following the youth maximum in growth rate, the ring will tend to decrease in width with increasing age according to a hyperbolic function.

Fortunately, anticipating the discussion in the next section, we note that the age trend in specially long-lived trees is very shallow (e.g., the 1500-year Ketchum series in Table 9) and in many groups is observed to be nearly linear. The end effect is thus of importance only in the usually negligible youth rings. Since the data of this report are derived primarily from overage trees, the rapid, semi-graphical method of standardizing discussed above was found to be sufficiently precise and has been used throughout.

OVERAGE CONIFERS AND CHRONOLOGY

An intensive field search, begun by the writer in 1939, for suitable tree sources of climatic data has brought to light a remarkable category of long-lived, growth-stunted trees of high index value. These not only provide a unique kind of tree-gage record of past rainfall but exhibit very suggestive properties of growth under extreme adversity. A report on trees of this category was made in 1943, at which time forty Rocky Mountain conifers over 500 years old, the usual age limit of the Pinaceae in this region, had been located and sampled. Refined field criteria for recognition of these trees and more intensive search in succeeding years have resulted in finding so many trees over this limit that a working minimum of 700 years of age has been used in this report, 61 trees exceeding that minimum.

Rain-recording trees of great longevity are of specially high value in dendroclimatic studies not only because they provide long histories but also because, as just noted, trend lines may be more safely fitted, and thus such trees make possible a greatly improved estimate, as compared with young trees, of the absolute values of past rainfall. On the other hand, it is evident, of course, that any small secular trend in climate would be completely hidden in the fitted trend line and thus would not be determinable even in these long-lived trees.

A typical site on which such trees may be found is that at Eagle, Colorado. For many miles bordering the upper Colorado River, as at station 112 (in Table 1) just west of Eagle, stunted Douglas-firs and pinyon pines dot the steep slopes and are readily accessible from the highway. Standing dead poles are common. That this type site happens to be a gypsum formation may have no great significance, since trees of comparable age, sensitivity, and slow growth have been found on sandstone or limestone slopes nearby; however, the number of extremely old Douglas-firs per unit area is greater at this station than at any other site in the Rockies thus far sampled by the writer.

Pertinent data on trees of great longevity are assembled in Table 15. Although the picture provided by these trees is not yet complete, certain characteristics of Rocky Mountain drought conifers emerge as very probably general in nature: (a) the absolute maximum ages of Pseudotsuga and Pinus other than P. flexilis in the Rocky Mountains are of the order of 1,000 years, limber pine exceeding 1,500 years; (b) in addition to the observed tendency for maximum longevity on the most adverse sites, there seems to be a systematic relation to latitude in the age limits of various stands of a given species; (c) the median ring-width in the lower stem is about 0.30 mm*; (d) this growth rate is often approached by early maturity--two or three centuries--after which the mean growth rate decreases very slowly;

*It may be noted that Douglas-fir on locally moist sites in this generally dry region may attain growth rates comparable to those in wet-climate regions: the "Hitchcock Douglas-fir," over 100 feet in height and seven feet base diameter, a recent windfall in the Santa Catalina Mountains near Tucson, Arizona, had an average ring-width of 2.53 mm. for the 281 years of growth at the 12-foot level (5.06 mm. for the inner 50 years).

Table 15 Data on Drought Conifers over 700 Years Old

Table 1, Sta. No.	Site[2]	Specimen Number	Species[3]	Sapwood Radius, mm.	Number Sapwood Rings	Number Absent Rings	Inner Ring, A.D.	Outer Ring, A.D.	Core Length, Years	Radius, mm.	Aver. Ring-Width, mm.	Min. Century Growth, mm.
129	BTA	2452	DF	23	78	14	1272	1947	676	269	.40	24
72	MVR	2500	DF	27	91	17	1177	1947	771	267	.35	14
120	MVR	2512[4]	PNN	--	--	15	1140	1947	808	332	.41	23
120	MVR	2513	PNN	--	--	18	1098	1947	850	320	.38	22
68	DOL	957	PNN	--	--	--	1089	1941	853	232	.27	--
77	BRY	1161	DF	8	23	1	1283	1942	660	299	.45	26
77	BRY	1189	DF	6	47	0	1267	1942	676	265	.39	15
77	BRY	1190[5]	BCP	8	45	--	1234	1942	709	200	.28	--
--	BRY	2104	JSC	11	36	--	1095	1945	851	217	.26	--
--	BRY	2110	JSC	--	--	--	1170	1945	776	218	.28	--
79	BRY	4002	PP	23	130	--	1110	1952	[illegible]	354	.42	14
79	BRY	3145	DF	10	56	11	1114	1950	837	204	.24	11
67	BLK	1150	PNN	--	--	--	1200	1942	743	192	.26	--
67	BLK	1151	PNN	--	--	--	1275	1942	668	114	.17	--
107	SUN	2289	PNN	--	--	--	1125	1946	822	320	.39	--
106	SUN	2305	DF	9	45	22	1225	1946	722	166	.23	15
107	SUN	2522	PNN	--	--	4[6]	975	1947	973	416	.43	--
106	SUN	2526	DF	--	--	--	1242	1947	706	212	.30	--
102	NNM	2341	DF	28	63	--	1235	1946	712	273	.38	--
103	NNM	2351	DF	13	67	4	1199	1946	748	238	.32	20
103	NNM	2353	DF	20	85	1	1277	1946	670	158	.24	18
103	NNM	2373	DF	17	72	12	1269	1946	678	208	.31	19
103	NNM	2374	DF	14	75	4	1255	1946	692	283	.41	14
103	NNM	2375	DF	22	72	10	1180	1946	767	272	.35	19
101	NNM	2378	DF	24	53	--	1238	1946	709	194	.27	--
101	NNM	2382	DF	14	64	--	1220	1946	727	232	.32	--
103	NNM	2395	DF	6	75	24	1226	1946	721	242	.34	10
103	NNM	2396	PNN	--	--	3	1267	1946	680	320	.47	32
101	NNM	3075	DF	34	92	0	1225	1950	726	360	.50	22
101	NNM	3081	DF	20	63	9	1278	1950	673	216	.32	28
101	NNM	3082	DF	22	65	6	1242	1950	709	258	.36	20
101	NNM	3084	DF	22	79	4	1080	1950	871	313	.36	22
104	NMI	3186	DF	30	69	5	1260	1950	691	217	.31	22
104	NMI	3188	DF	24	63	--	1211	1950	740	257	.35	--
104	NMI	3202	DF	11	86	10	1224	1950	727	186	.26	12
104	NMI	3205	DF	17	107	13	1250	1950	701	182	.26	21
104	NMI	3207	DF	24	86	14[7]	1200	1950	751	257	.34	19
104	NMI	3209	DF	9	58	--	1130	1950	821	164	.20	--
112	EAG	2070	DF	14	68	8	1215	1945	731	191	.26	15
112	EAG	2275	DF	7	--	--	1240	1946	707	159	.23	--
112	EAG	2278	DF	13	54	--	1157	1946	790	221	.28	--
112	EAG	3332	DF	28	66	0[8]	1241	1950	710	270	.38	23
112	EAG	3335	DF	15	78	35	1084	1950	867	176	.20	09
112	EAG	3336	DF	20	51	7	1164	1950	787	197	.25	14
112	EAG	3337	DF	15	96	43	1141	1950	810	169	.21	11
112	EAG	3339	DF	27	78	0	1092	1950	859	206	.24	16
112	EAG	3352	DF	9	60	3	1251	1950	700	145	.21	13
112	EAG	3356	DF	15	68	6[9]	1260	1950	691	247	.36	18
112	EAG	3370	PNN	--	--	26	1266	1950	685	173	.25	--
112	EAG	3378	DF	4	42	18	1171	1950	780	230	.29	09
112	EAG	3379	DF	13	44	8	1244	1950	707	264	.37	16
111	EAGw	3417	DF	13	73	3	1132	1950	819	202	.25	15
60	RED	1120	DF	14	54	0	1091	1942	852	280	.33	21
38	DLL	2801	LBP	--	--	1[10]	977	1949	973	174	.18	--
38	DLL	2807	DF	14	77	17	1171	1949	779	215	.28	12
38	DLL	2808	LBP	--	--	--	1130	1949	820	148	.18	--
26	KET	3988	DF	23	111	0	1281	1952	672	316	.47	18
26	KET	3961	LBP	22	70	1[11]	1089	1952	864	359	.42	30
26	KET	3966B	LBP	15	83	0	563	1952	1390	352	.25	12
26	KET	3966D	LBP	37	74	1[11]	826	1952	1127	381	.34	21
26	KET	3966E	LBP	29	88	0	674	1952	1279	373	.30	17
26	KET	3966F	LBP	32	82	1[11]	961	1952	990	276	.28	18
26	KET	3996	LBP	10	53	2	458	1952	1495	402	.27	08
26	KET	3998	LBP	15	85	2	727	1952	1226	382	.31	11

Footnotes to Table 15.

1. Italicized dates were obtained by count only and represent ring sequences too crowded or uncertain to date in entirety. The reported core length in years thus represents a minimal figure. Four trees, numbers 957, 1120, 1150, and 1151, were included in a 1945 report on overage conifers (Jour. Forestry 43:422-427). All come from the lower margin of the timber forests, at elevations of approximately 6,000 feet to 9,000 feet.

2. Approximate locations of sites, tabulated in order of increasing latitude--

   BTA: Betatakin Ruin, Navajo National Monument, n. Arizona.

   MVR: Mesa Verde Nat. Park, s.w. Colorado.

   DOL: Dolores, s.w. Colorado.

   BRY: Bryce Canyon Nat. Park, s. Utah.

   BLK: Black Canyon Nat. Mon., cent. Colorado.

   SUN: Sunnyside, n.e. Utah.

   NMM: Nine Mile Canyon, n.e. Utah.

   NMI: Indian Canyon, n.e. Utah.

   EAOw: Gypsum, n. Colorado.

   RED: Redcliff, n. Colorado

   KET: Ketchum, Idaho.

   DLL: Dell, s.w. Montana.

   Specific locations of the oldest trees of special interest--

   NMM-3084 (900-year Douglas-fir): near foot of north-south ridge, east-facing slope, about 1/4 mile south of the Hanks ranch house in Nine Mile Canyon, Utah. (See University of Utah Bull., v. 28, n. 11, 1938, for description of an archaeological site, NM 10, about 200 feet above this tree.)

   DLL-2801 (1010-year limber pine): about 1,000 feet above and to southwest of the Big Sheep Ranger Station, 6 miles west of Dell, Montana.

   SUN-2522 (975-year pinyon pine): on ridge-crest northeast of the junction of Whitmore and Bear Canyons, 2 miles north of Sunnyside, Utah.

   BRY-6002 (850-year ponderosa pine): in Tropic Canyon, Bryce Canyon Nat. Park, 100 feet above and to southwest of bridge on Highway 12, about 17.5 miles east of junction with Highway 89.

3. DF: Douglas-fir (Pseudotsuga taxifolia (Poir) Britt.).

   PNN: pinyon pine (Pinus edulis Engelm.).

   BCP: bristle-cone pine (P. aristata Engelm.).

   SJ: scopulorum juniper (Juniperus scopulorum Sarg.).

   PP: ponderosa pine (P. ponderosa Laws.).

   LBP: limber pine (P. flexilis James).

4. Contributed by Don A. Spencer, U.S. Fish and Wildlife Service, who with Jack J. Wade, Mesa Verde Nat. Park, found this tree.

5. Dated 1234-1420 and 1550-1710 only.

6. In interval 975-1600 only; 1601-1830 too erratic to date.

7. Excluding undatable interval preceding A.D. 1243.

8. This total includes 30 absent rings, derived by count only, in a segment of the core 33 mm. in length representing the interval 1451-1800.

9. For the interval preceding 1700; undated 1700-1950; count only, 1500-1600, with 20 rings absent.

10. 977-1500; 1501-1949 measures 50 mm. on this core and is undated; cores obtained in 1951 from other parts of the stem show faster, datable growth in recent centuries.

11. A.D. 1632.

(e) the absolute minimum in total mean radial growth of the lower stem for an entire century is about 8 mm; (f) the number of sapwood rings in overage Douglas-fir is not significantly related to either the number of heartwood rings or the thickness of heartwood (for relatively young trees a systematic relation has been found by Stallings** when groups of five or more trees are averaged); (g) false rings are almost completely absent in all species except the scopulorum juniper, and there is a marked tendency to decreased incidence of locally absent rings in higher latitudes.

The asymmetric age distribution is most clearly noted in drought-type Douglas-fir, which has been sampled on many sites throughout its range of some 30° of latitude in the inland western cordillera from central Mexico to Jasper National Park, in Alberta. In a belt roughly defined by latitudes 39° and 40° in the Colorado River basin of eastern Utah and western Colorado literally thousands of trees may be found from 700 to 900 years old. Curiously, Douglas-fir east of the Continental Divide in these latitudes and also in the Great Basin ranges to the west of the Colorado shows much lower maximum ages. Although the distribution of such trees is, as already noted, highly dependent on local site conditions and therefore very spotty, there is a decided tendency to generally decreased maximum ages both northward and southward. Douglas-firs in the 600-year age class may be found in considerable numbers on careful search in southern Utah and southwestern Colorado, but are, in contrast, quite rare in the northern forests of Arizona and New Mexico, and in the writer's knowledge are unreported in the southern areas of these states or in Mexico, where the average maximum age seems to be about 350 years. Maximum ages are generally less than 600 years northward from the 39°-40° belt to the Canadian border (700-800 years in the rain-shadow DLI area of southwestern

**Personal communication

Montana listed in Table 15), are less than 500 years in southern British Columbia and at Banff, and may be no more than about 400 years near the northern limits for the species in central British Columbia and at Jasper Park.

Much less complete sampling of the other species listed in Table 15 does not allow more than a suggestion of the age distribution pattern. The limber pine maximum seems to occur near 44° in eastern Idaho, the pinyon pine in the 39°-40° belt like that for Douglas-fir, and ponderosa pine in the 37°-38° belt in southern Utah; all species seem to show marked decline in maximum ages southward and to a lesser degree northward of the respective belts of maximum ages.

The mean radial growth of the lower stem in overage drought conifers tends to rapidly approach a nearly constant rate, as already noted. The data in Table 16 are typical, except for the last half-century, which is affected by growth release.

The growth release, which in some trees is evident by 1890 or earlier and is apparently a result of cutting, grazing, and other modification of natural conditions, is strikingly shown in tree no. 2072. The four largest rings between 1498 and 1890, ranging from 0.59 mm to 0.66 mm, occurred in 1541, 1550, 1605, and 1841, the average growth for three centuries preceding 1900 being about 0.25 mm; following release, ring growth of 1.07 mm occurred in 1912 and 0.97 mm in 1913, the average for the interval 1911-1930 being 0.81 mm. Such latent capacity for rapid growth in a 600-year tree is notable.

Another example of release of a different nature, resulting in a reversal of the usual age trend, is that in tree no. 3350, which on the whole rather steadily increased its average ring-width for over 650 years!

Table 16. Average Ring-Widths in the Eagle Group of Overage Douglas-firs. mm

Interval	13 Trees 600+ Years	No. 2072[1]	No. 3350[2]
1351-1400	.53	---	.19[3]
1401-1500	.281	.81	.20
1501-1600	.276	.40	.21
1601-1700	.265	.28	.33
1701-1800	.255	.21	.34
1801-1900	.211	.25	.42
1901-1950	.294	.62	.46

1. Pith at A.D. 1375. 2. Pith at A. D. 1296. 3. 1301-1400.

Not necessarily typical of most of the trees in Table 15 are the oldest individuals of each species. Tree NNM-3084, a 900-year Douglas-fir, has a remarkably heavy crown and is roughly twice the height of the usual stunted and spare oldster. Most unusual, indeed, are the flourishing branches at the very top, in striking contrast to the characteristic spike-top by which the more normal overage tree is most readily recognized. Notable, too, was the luxuriant production of cones. After years of field sampling of the more characteristic, partly dead drought conifers, one is tempted to think of this tree as a genetic sport worth very special study.

Although Juniperus is widely represented in the West and some individuals reach great ages, no rainfall chronology of great length has yet been derived for any species of this genus. This is due partly to the irregular cambial habits of the southwestern junipers, which make their ring sequences unsuitable as sources of climatic chronology. The Rocky Mountain and the Sierra junipers do, however, provide very long and readable ring sequences, as earlier noted; work in progress should eventually provide significant chronologies up to a thousand years or more in length in these species. Recent reconnaissance sampling of the stands of western juniper in Yosemite National Park and to the north show some stunted trees of this species on rocky sites to attain ages of at least 2,000 years; unfortunately, it appears specially difficult to derive significant chronologies from the growth of the older trees of this species. Data on two old Rocky Mountain (scopulorum) junipers near Bryce Canyon, Utah, whose ring records have not as yet been dated, are included in Table 15 for comparative purposes.

Ages of over 3,000 years have been reported for the Bennett Juniper (Madrono, 4:21-28, 1937), a western juniper growing near Sonora Pass in the central Sierra Nevada, and the Jardine or Old Utah Juniper (Amer. Forests, 31:485, 1925), a scopulorum juniper in Logan Canyon, northern Utah.

The estimate for the Bennett tree, mean DBH (diameter at breast height) about 14 feet including bark and growing on a locally moist site, depends on an admittedly uncertain extrapolation of the growth rate on borings, which have a maximum length of only 15 inches but average over 700 rings for the outer foot of radial growth. A sampling survey by the writer, still incomplete, of the oldest trees of this species on the driest sites in the central Sierras, indicates the existence of numerous individuals in the 1,000-year class; very few of substantially greater age have, on the other hand, been located yet. The oldest of these, with some 1,100 years of growth on a 12-inch core, has a mean DBH of about 60 inches under bark, which would indicate a possible age of about 2,000 years; however, the strongly fluted stem suggests a probably large eccentricity and thus a large error in this estimate. The very slow growth is characteristic of the rain-shadow environment of this tree, at about 8,500 feet elevation on the Tioga Pass road east of Yosemite National Park. Others in the 2,000-year class may be found north of Tenaya Lake in Yosemite Park.

A re-study of the Jardine Juniper, which for many decades or more probably some centuries has been a shell only, is in progress. Cores obtained on the south and west sides of the stem, four feet above the flattish surface of the principal rock on which it grows, represent almost the entire thickness of shell. The position of the pith in the Jardine Juniper could be determined quite precisely at this level by a rot-resistant knot-cone projecting from the inner surface of the shell; the radius was thus measured as about 30 inches. Since the cores were both about 15 inches long and contained 1,030 rings (south radius) and 750 rings (west radius), and since the inner two centuries of the ring records averaged about three inches per century, it is evident that the Jardine Juniper can hardly be much over 1 500 years of age. The chronology appears to be of only secondary value as a precipitation index.

The longest actual count reported for a juniper in the Rocky Mountains seems to be that by the U. S. Geological Survey (W.S.P.774, 1938, pp. 19-23) for a tree, probably *J. utahensis*, felled in 1928 near Idaho Falls, Idaho, which carried about 1620 rings. Examination of a section from this tree by the writer suggests that the true age is, in fact, somewhat greater than this, since false rings are apparently almost non-existent and locally absent rings are common on the section. Comparison of the annual chronology with that published in the cited paper for younger juniper trees nearby indicates that non-climatic irregularities dominate in the year-to-year growth fluctuations.

INDICES IN ARCHAEOLOGICAL BEAMS

The method of dating beams from Southwestern Pueblo ruins by overlap matching with the inner rings of living trees, first reported by Douglass, in the *National Geographic Magazine* in December, 1929, made possible a long backward extension of the climatic history in the trees of that region.

During 1945-52 the writer checked and extended the dating of all the available archaeological wood in the Colorado River basin. The resultant mean growth series, published in detail in Volumes 12 to 18 of the *Tree-Ring Bulletin*, are summarized in Fig. 20.

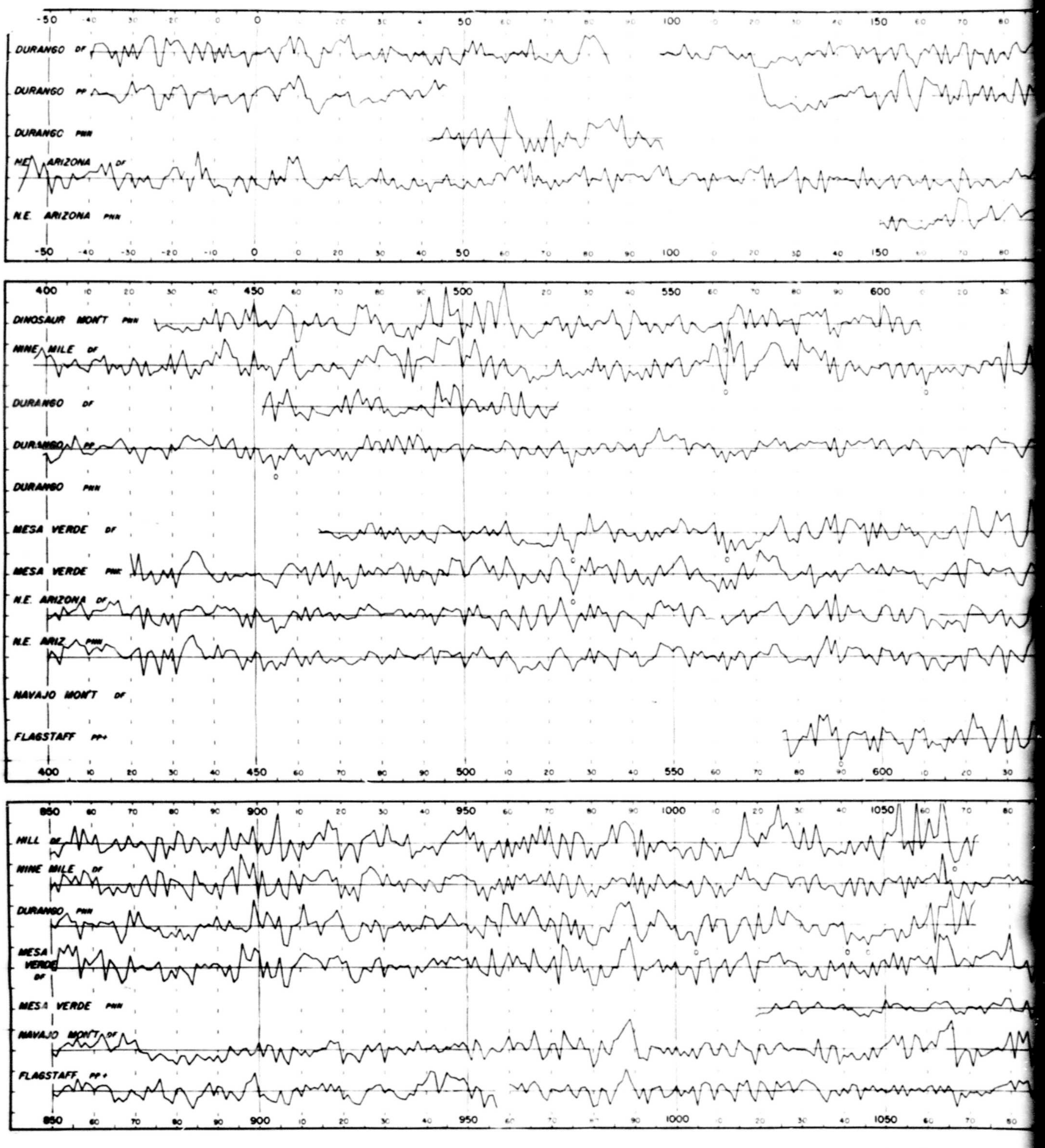
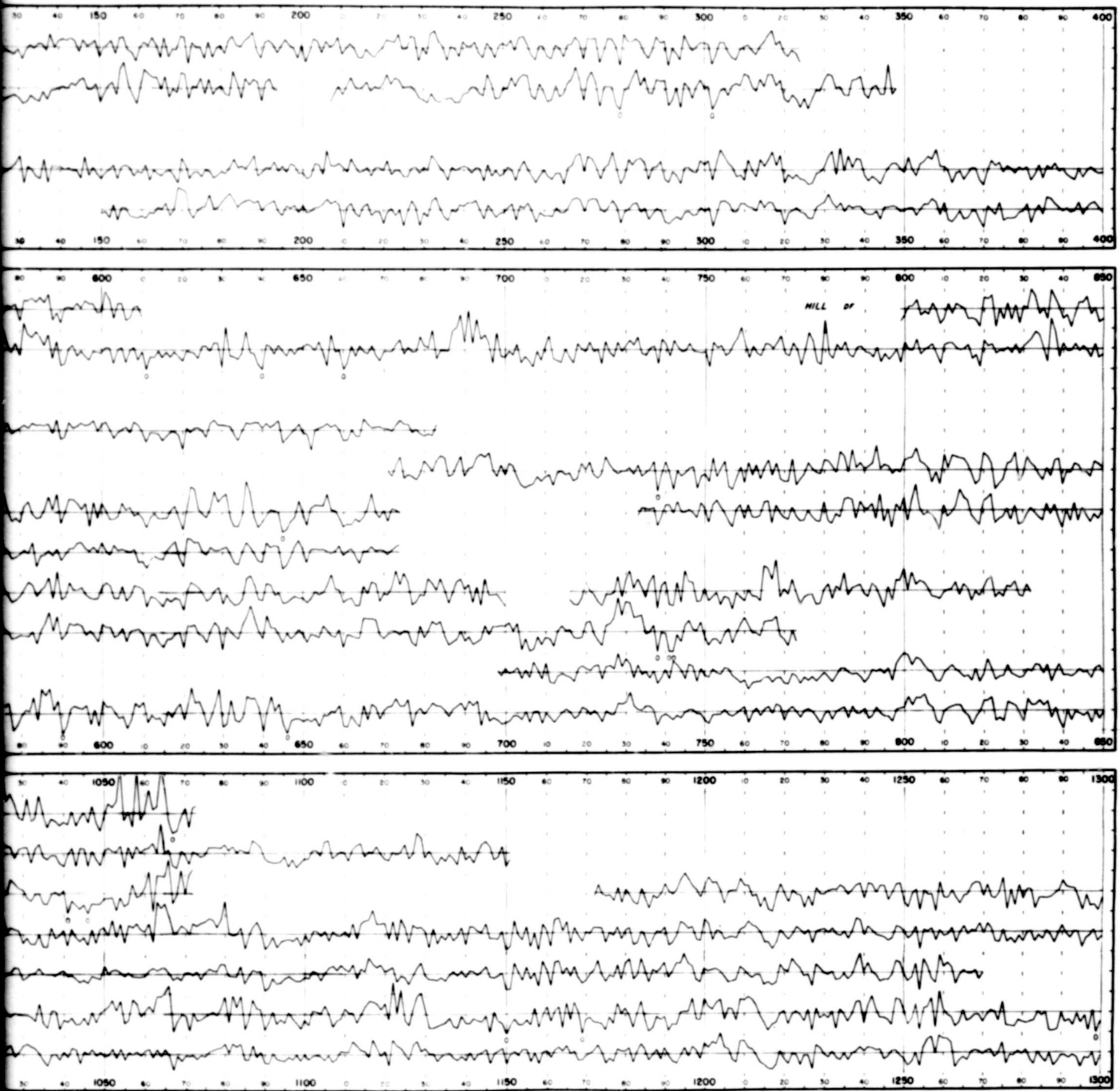


Fig. 20. Archaeological chronologies in sub-areas of the Colorado Basin



orado Basin

This diagram includes some 32,000 measured rings.*

Dated archaeological beams of the Southwest necessarily represent, on the whole, the more sensitive types of chronology, and thus the climatic interpretation of the ring records in living trees, discussed in the next chapter, apply to some extent to the archaeological chronologies also. But two special characteristics of these chronologies need to be emphasized.

First, the number of available specimens differs greatly from area to area and, in general, from decade to decade. Thus the various sequences in Fig. 20 have differing and changing weights. This defect is somewhat alleviated by the high fidelity of individual series and the tendency for the means of even two or three trees to represent well the details of short-term fluctuations.

Second, the average number of rings in the archaeological beams is relatively small, usually less than 100. Thus, the trend lines fitted to each specimen curve lead to standardized values in which long-term departures in growth are very largely eliminated. The archaeological series thus give an index of short-term variations only.

*Not included in the figure are some miscellaneous growth curves for the Colorado River Basin, principally representing single specimens, published in the Tree-Ring Bulletin as follows (species, A.D. interval, volume, and page):

Hill Canyon	DF	927-1042	17:30
S.E. Utah	DF	450- 674	16:21
S.E. Utah	PNN	1140-1250	16:21
Durango	DF	124- 196	17:30
Mesa Verde	DF	675- 700	Ms
" "	"	821- 896	13:31
Mesa Verde	PNN	463- 625	16:22
" "	"	547- 665	16:23
" "	"	710- 769	16:23
" "	"	923-1076	16:23
" "	"	1016-1074	17:30
" "	"	1142-1213	13:31
Flagstaff	PP	1047-1132	16:21
Flagstaff	CBS	1072-1255	16:21
Forestdale	PP;PNN	967-1115	16:23
Point of Pines	PP	1155-1293	15:20

The general consistency in chronology from area to area and species to species within the central portion of the Colorado River Basin, already noted in the living-tree diagrams, is very evident in the figure.

IV. THE TREE-RING AS A CLIMATIC GAGE

Abundant evidence is now at hand that ring-width in dry regions can provide a first approximation to the total rainfall of certain months and in the arctic to the mean temperature of certain summer intervals. In the western United States rainfall and the more-or-less related runoff seem to be the only variables of significance for dendrochronology. However, even for this region, tree-ring literature of the past four or five decades will show substantial differences in the rainfall interval selected or empirically deduced as most closely related to ring growth by different investigators, or by the same student at different times or for different groups of specimens.

In recent years the tendency has been to interpret the longer ring chronologies, based on mature and old trees, in terms of winter rainfall only, the summer rains being taken to have some influence only in the production of false rings and thus being of importance mainly in the growth of young trees. In the west-coast states, with little or no summer rainfall, the choice of ring-rainfall interval is, of course, much more restricted than in such regions of two-maxima rain regimes as the Rocky Mountains.

Beclouding the true mean relation between rainfall and measured growth are factors such as variation in the distribution of storms within the year, changes from year to year in the frequency of specially intense or of long-lasting storms, differences in rainfall at the tree from that at the rain-gage, special spottiness of summer rains, carry-over effects of excessive or deficient rainfall of earlier years, associated effects of temperature, and errors of observation in the rain-gage record. With respect to the ring series itself, incomplete elimination of irregular effects, ecologic and otherwise, can easily lead to an apparent rain-ring relation quite different from that which would be found in the optimum dendrochronology.

During 1951 a systematic correlation analysis was made of ring growth in relation to rainfall. The best local and areal ring sequences in the Rocky Mountains and adjacent areas, representing various tree stations from Jasper, Alberta (lat. 53° N), to the Guadalupe Mountains of southern New Mexico (lat. 32° N), were compared with the longest and best rainfall series near each station or within each area. Sixteen rainfall intervals, from three months to two years, were chosen, and a total of over 22,000 rainfall sums of the published monthly values computed.

In this test of the effectiveness of various rain intervals in the West, California and Oregon data were omitted, since in those regions the rainfall is largely concentrated in a few winter months. The computations yielded 693 linear correlation coefficients. Since the paired series ranged from 31 to 60 years in length, with a median near 45 years, and since trends in the ring series were either nonexistent or too small to affect the coefficients, it is believed that the results as a whole are fairly general. The data, summarized in Tables 17 and 18, were classified according to three regions: Montana and Southwest Canada, Colorado and Utah, and Arizona and New Mexico.

Although the rainfall season most nearly related to growth is, in general, different from series to series in Table 18, perhaps the most striking general feature is that of consistency in the regional averages. This suggests that underlying general relationships exist but that any single pair of growth-rain variates may, because of purely local effects, yield relationships which may differ substantially and which may vary for different time periods.

The consistent change in the coefficients with change in the test interval of rainfall is evident in Fig. 21.

Table 17. Mean Rainfall* at Selected Stations. Inches.

Pair No. (1)	Station (4)	Interval (7)	(9) July-June	(10) July-July	(11) Aug.-July	(12) Oct.-April	(13) Oct.-June	(14) Oct.-July	(15) Nov.-Apr.	(16) Nov.-June	(17) Nov.-July	(18) Jan.-June	(19) Jan.-June	(20) Jan.-Aug.	(21) May-July	(22) May-Aug.	(23) July-Sept.
1	Entrance, Alberta	1918-1947	18.[illegible]	21.2	18.7	6.2	11.3	13.8	5.3	10.4	12.9	8.6	11.2	13.9	7.7	10.3	7.3
2	Banff, Alberta	1918-1947	17.6	19.1	17.6	8.4	12.6	14.1	7.1	11.3	12.9	8.5	10.0	11.9	5.7	7.7	5.0
3, 4	" "	1895-1944	18.7	20.7	18.7	8.3	13.0	15.0	7.1	11.8	13.8	9.1	11.1	13.2	6.8	8.9	5.7
5, 7	Tranquille, Brit. Col.	1914-1944	8.5	9.1	8.4	4.5	6.3	7.1	4.0	[illegible].8	[illegible].5	[illegible]	[illegible].7	5.6	2.5	3.4	2.1
6, 8	Kamloops, Brit. Col.	1896-1944	10.1	[illegible]	10.0	5.1	7.3	8.2	4.4	6.6	7.6	4.7	5.6	6.7	3.2	4.3	2.8
9, 11	Agric. College, Mont.	1895-1947	17.6	18.9	17.5	8.0	13.4	14.7	6.5	11.9	13.2	10.0	11.3	12.4	6.7	7.8	4.2
10, 12	Central Division, Mont.	1896-1947	14.8	16.3	14.8	5.7	10.8	12.2	4.7	9.7	11.2	8.3	9.8	10.9	6.5	7.6	4.1
13	Denver, Colo.	1892-1944	13.9	15.4	13.9	6.5	9.8	11.4	5.3	8.7	10.3	7.4	9.0	10.4	4.9	6.2	4.0
14, 15	Colorado R. Basin, Utah	1892-1947	10.9	12.0	10.9	6.3	7.5	8.6	5.3	6.5	7.6	5.1	6.0	7.2	2.3	3.8	3.4
16, 18	Steamboat Springs, Colo.	1910-1947	23.8	25.5	23.8	15.1	18.7	20.3	13.1	16.7	18.3	12.8	14.4	16.2	5.2	7.0	5.2
17, 19	Upper Colorado R. Basin, 4 Sta. Index	1910-1947	20.4	22.4	20.4	11.9	14.9	16.8	10.8	13.3	15.2	10.3	12.3	14.1	4.8	6.7	5.5
20, 21	Durango, Colo.	1895-1947	19.1	21.1	19.0	11.0	13.0	15.0	9.2	11.0	13.2	8.4	10.3	12.7	4.0	6.2	6.2
22, 23	Colorado R. Basin, 9 Sta. Index	1895-1944	12.7	13.7	12.7	7.2	8.9	10.1	5.9	7.7	8.7	6.0	7.0	8.3	2.9	4.1	3.7
24	Colorado R. Basin, 9 Sta. Index	1895-1941	12.7	13.7	12.6	7.2	8.9	10.0	5.9	7.7	8.7	5.9	7.0	8.3	2.9	4.1	3.8
25, 39	Chacon, N. Mex.	1910-1941	20.8	24.4	20.9	7.6	11.5	15.0	6.3	10.2	13.7	8.6	12.2	15.9	7.4	11.0	9.3
26, 29, 32,40	North Rio Grande, N. Mex.	1910-1941	17.4	20.2	17.4	7.8	10.4	13.2	6.4	9.1	11.9	7.3	10.1	12.5	5.4	7.9	7.0
27, 33	Canadian R., & N. E., N. Mex.	1910-1941	16.4	19.0	16.5	5.3	9.5	12.1	4.0	8.2	10.8	7.1	9.7	12.4	6.7	9.5	7.1
28, 31,42	Santa Fe, N. Mex.	1892-1941	14.4	16.8	14.4	5.8	8.4	10.8	4.7	7.3	9.6	6.0	8.3	10.3	4.9	6.9	5.9
30,(41)	Santa Fe, N. Mex.	1910-1947	14.0	16.1	13.9	5.7	8.2	10.7	4.5	7.0	9.1	5.7	7.8	9.8	4.6	6.6	5.7
34	Cloudcroft, N. Mex.	1903-1941	24.9	29.6	25.1	9.9	12.8	17.6	8.4	11.3	16.0	8.6	13.3	18.0	7.6	12.3	12.4
35	Carlsbad, N. Mex.	1895-1941	13.3	15.5	13.3	4.6	7.4	9.6	3.2	6.0	8.2	4.9	7.1	8.8	5.0	6.7	5.9
36, 37	Tucson, Ariz.	1891-1939	11.2	13.3	11.1	5.2	5.8	7.8	4.6	5.1	7.2	3.3	5.4	7.6	2.5	4.7	5.4
38	Tucson, Ariz.	1891-1950	11.0	12.9	11.0	5.1	5.7	7.6	4.7	5.0	6.9	3.2	5.2	7.4	2.4	4.6	5.3

* These rounded-off values may, in some cases, be in error by a small fraction of an inch.

Table 18. Correlation Coefficients, Growth vs. Rainfall[1]

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Pair No.	Growth at or near	Species	[redacted]	Rainfall		Interval	July June	2-yr. July-June	July[2] July	Aug. July
1	Jasper, Alberta	DF		Entrance, Alberta		1916-1947	.56	.43	.63	.61
2	Jasper, Alberta	DF		Banff, Alberta		1918-1947	.45	.28	.51	.50
3	Jasper, Alberta	DF		Banff, Alberta		1895-1944	.36	.25	.31	.33
4	Banff,[3] Alberta	DF		Banff, Alberta		1895-1944	.72	.81	.72	.66
5	Tranquille, Brit. Col.	DF		Tranquille, Brit. Col.		1914-1944	.54	.66	.50	.45
6	Tranquille, Brit. Col.	DF		Kamloops, Brit. Col.		1896-1944	.55	.49	.49	.44
7	Tranquille, Brit. Col.	PP		Tranquille, Brit. Col.		1914-1944	.60	.71	.60	.65
8	Tranquille, Brit. Col.	PP		Kamloops, Brit. Col.		1896-1944	.46	.34	.50	.45
9	Upper Missouri R. Basin, Mont.	DF		Agric. College, Mont.		1895-1947	.59	.74	.61	.57
10	Upper Missouri R. Basin, Mont.	DF		Central Division, Mont.		1896-1947	.65	.74	.64	.57
11	Upper Missouri R. Basin, Mont.	LBP		Agric. College, Mont.		1895-1947	.53	.63	.57	.55
12	Upper Missouri R. Basin, Mont.	LBP		Central Division, Mont.		1896-1947	.55	.64	.58	.54
13	South Platte R. Basin, Colo.	DF		Denver, Colo.		1892-1944	.58	.39	.54	.54
14	Uintah Basin, Utah	DF		Colorado R. Basin in Utah		1892-1947	.77	.79	.77	.76
15	Uintah Basin, Utah	PNN		Colorado R. Basin in Utah		1892-1947	.73	.76	.72	.73
16	Upper Colorado R. Basin, Colo.	DF		Steamboat Springs, Colo.		1910-1947	.68	.62	.71	.71
17	Upper Colorado R. Basin, Colo.	DF		Upper Colorado R. Basin, 4-Sta. Index		1910-1947	.72	.67	.69	.66
18	Upper Colorado R. Basin, Colo.	PNN		Steamboat Springs, Colo.		1910-1947	.59	.46	.59	.64
19	Upper Colorado R. Basin, Colo.	PNN		Upper Colorado R. Basin, 4-Sta. Index		1910-1947	.56	.55	.57	.60
20	Mesa Verde, Colo.	DF		Durango, Colo.		1895-1947	.79	.66	.78	.77
21	Mesa Verde, Colo.	PNN		Durango, Colo.		1895-1947	.75	.68	.76	.78
22	Colorado R. Basin, Colo.-Utah	DF		Colorado R. Basin, 9-Sta. Index		1895-1944	.82	.76	.83	.82
23	Colorado R. Basin, Colo.-Utah	PNN		Colorado R. Basin, 9-Sta. Index		1895-1944	.78	.73	.79	.81
24	Colorado R. Basin, Colo.-Utah	PP		Colorado R. Basin, 9-Sta. Index		1895-1941	.64	.76	.68	.70
25	Taos, N. M.	DF		Chacon, N. M.		1910-1941	.51	.37	.49	.48
26	Taos, N. M.	DF		North Rio Grande, N. M.		1910-1941	.46	.46	.48	.46
27	Taos, N. M.	DF		Canadian River & N. E., N. M.		1910-1941	.40	.28	.36	.38
28	Santa Fe, N. M.	DF		Santa Fe, N. M.		1892-1941	.69	.53	.64	.61
29	Santa Fe, N. M.	DF		North Rio Grande, N. M.		1910-1941	.70	.51	.69	.67
30	Upper Rio Grande, N. M.	DF		Santa Fe, N. M.		1910-1947	.57	.36	.54	.50
31	Upper Rio Grande, N. M.	DF		Santa Fe, N. M.		1892-1941	.70	.44	.64	.64
32	Upper Rio Grande, N. M.	DF		North Rio Grande, N. M.		1910-1941	.80	.41	.78	.79
33	Upper Rio Grande, N. M.	DF		Canadian River & N. E., N. M.		1910-1941	.58	.41	.51	.44
34	Guadalupe Mts., N. M.	DF		Cloudcroft, N. M.		1903-1941	.56	.42	.54	.53
35	Guadalupe Mts., N. M.	DF		Carlsbad, N. M.		1895-1941	.64	.41	.58	.56

B

1 1

(6)

(7) Interval	(8) July June	(9) 2-yr. July-June	(10) July$_2$ July	(11) Aug. July	(12) Oct. April	(13) Oct. June	(14) Oct. July	(15) Nov. April	(16) Nov. June	(17) Nov. July	(18) Jan. June	(19) Jan. July	(20) Jan. Aug.	(21) May July	(22) May Aug.	(23) July Sept.
1918-1947	.56	.43	.63	.61	.24	.53	.58	.30	.57	.61	.42	.52	.52	.57	.57	.40
1918-1947	.45	.28	.51	.50	.23	.39	.46	.25	.39	.45	.17	.25	.24	.30	.23	.01
1895-1944	.36	.25	.31	.33	.35	.39	.29	.37	.36	.28	.18	.12	.09	.06	.02	-.08
1895-1944	.72	.81	.72	.66	.16	.52	.55	.20	.52	.54	.59	.61	.60	.50	.50	.36
1914-1944	.54	.66	.50	.45	.24	.52	.48	.31	.56	.54	.62	.49	.47	.35	.22	-.35
1896-1944	.55	.49	.49	.44	.25	.40	.33	.29	.41	.35	.39	.35	.28	.14	.07	-.16
1914-1944	.60	.71	.60	.65	.30	.66	.68	.22	.63	.67	.73	.69	.65	.56	.44	-.08
1896-1944	.46	.34	.50	.45	.02	.24	.3[illegible]	.07	.17	.31	.36	.44	.37	.38	.27	.05
1895-1947	.59	.74	.61	.57	.26	.49	.51	.12	.40	.40	.34	.35	.35	.35	.36	.28
1896-1947	.65	.74	.64	.57	.37	.53	.50	.26	.46	.43	.48	.46	.45	.37	.37	.26
1895-1947	.53	.63	.57	.55	.06	.46	.52	.00	.42	.45	.42	.47	.47	.52	.51	.38
1896-1947	.55	.64	.58	.54	.19	.51	.53	.10	.44	.48	.51	.54	.54	.50	.51	.37
1892-1944	.58	.39	.54	.54	.39	.49	.48	.29	.42	.39	.41	.40	.32	.27	.16	-.07
1892-1947	.77	.79	.77	.76	.65	.69	.65	.51	.56	.55	.50	.50	.43	.41	.29	.09
1892-1947	.73	.76	.72	.73	.66	.70	.65	.54	.58	.58	.51	.52	.46	.59	.44	.22
1910-1947	.68	.62	.71	.71	.42	.45	48	.32	.36	.40	.32	.37	.38	.35	.35	.40
1910-1947	.72	.67	.69	.66	.48	.49	.49	.38	.42	.38	.33	.33	.25	.22	.15	.08
1910-1947	.59	.46	.59	.64	.61	.56	.59	.54	.50	.55	.44	.50	.49	.25	.27	.30
1910-1947	.56	.55	.57	.60	.68	.60	.61	.64	.57	.53	.51	.52	.48	.11	.15	.11
1895-1947	.79	.66	.78	.77	.74	.75	.75	.62	.63	.66	.59	.61	.54	.46	.25	-.07
1895-1947	.75	.68	.76	.78	.79	.78	.80	.71	.72	.75	.71	.74	.68	.51	.29	.11
1895-1944	.82	.76	.83	.82	.72	.73	.75	.59	.63	.64	.49	.49	.46	.35	.28	-.03
1895-1944	.78	.73	.79	.81	.73	.77	.79	.68	.73	.75	.61	.63	.62	.43	.41	.06
1895-1941	.64	.76	.68	.70	.61	.59	.64	.48	.49	.56	.41	.47	.48	.39	.42	.12
1910-1941	.51	.37	.49	.48	.38	.47	.41	.27	.41	.34	.42	.34	.34	.19	.17	-.07
1910-1941	.46	.46	.48	.46	.46	.48	.48	.37	.43	.42	.43	.44	.43	.25	.23	.01
1910-1941	.40	.28	.36	.38	.24	.38	.34	.25	.37	.33	.34	.31	.39	.27	.35	.07
1892-1941	.69	.53	.64	.61	.66	.68	.59	.61	.65	.56	.59	.50	.46	.18	.14	-.07
1910-1941	.70	.51	.69	.67	.64	.67	.66	.61	.68	.64	.66	.63	.62	.28	.30	.00
1910-1947	.57	.36	.54	.50	.50	.46	.41	.37	.36	.32	.29	.25	.20	.09	.03	-.08
1892-1941	.70	.44	.64	.64	.68	.70	.59	.59	.63	.52	.56	.45	.40	.14	.11	-.20
1910-1941	.80	.41	.78	.79	.77	.74	.70	.67	.71	.63	.61	.56	.50	.20	.17	-.16
1910-1941	.58	.41	.51	.44	.42	.49	.41	.45	.48	.38	.49	.39	.40	.20	.20	.10
1903-1941	.56	.42	.54	.53	.49	.50	.45	.47	.47	.42	.41	.36	.25	.08	-.03	.03
1895-1941	.64	.41	.58	.56	.60	.58	.52	.50	.49	.44	.40	.35	.25	.17	.03	.03
1891-1939	.52	.48	.64	.61	.52	.53	.67	.48	.49	.63	.32	.50	.48	.37	.30	.23
1891-1939	.63	.50	.71	.68	.56	.59	.71	.54	.57	.68	.44	.59	.52	.36	.25	.09

14	Uintah Basin, Utah	DF	Colorado R. Basin in Utah	1892-1947	.77	[illegible]	.77	.76
15	Uintah Basin, Utah	PNN	Colorado R. Basin in Utah	1892-1947	.73	.76	.72	.73
16	Upper Colorado R. Basin, Colo.	DF	Steamboat Springs, Colo.	1910-1947	.68	.62	.71	.71
17	Upper Colorado R. Basin, Colo.	DF	Upper Colorado R. Basin, 4-Sta. Index	1910-1947	.72	.67	.69	.66
18	Upper Colorado R. Basin, Colo.	PNN	Steamboat Springs, Colo.	1910-1947	.59	.46	.59	.64
19	Upper Colorado R. Basin, Colo.	PNN	Upper Colorado R. Basin, 4-Sta. Index	1910-1947	[illegible]	.55	.57	.60
20	Mesa Verde, Colo.	DF	Durango, Colo.	1895-1947	.79	.66	.78	.77
21	Mesa Verde, Colo.	PNN	Durango, Colo.	1895-1947	.75	.68	.76	.78
22	Colorado R. Basin, Colo.-Utah	DF	Colorado R. Basin, 9-Sta. Index	1895-1944	.82	.76	.83	.82
23	Colorado R. Basin, Colo.-Utah	PNN	Colorado R. Basin, 9-Sta. Index	1895-1944	.78	.73	.79	.81
24	Colorado R. Basin, Colo.-Utah	PP	Colorado R. Basin, 9-Sta. Index	1895-1941	.64	.76	.68	.70
25	Taos, N. M.	DF	Chacon, N. M.	1910-1941	.51	.37	.49	.48
26	Taos, N. M.	DF	North Rio Grande, N. M.	1910-1941	.46	.46	.48	.46
27	Taos, N. M.	DF	Canadian River & N. E., N. M.	1910-1941	.40	.28	.36	.38
28	Santa Fe, N. M.	DF	Santa Fe, N. M.	1892-1941	.69	.53	.64	.61
29	Santa Fe, N. M.	DF	North Rio Grande, N. M.	1910-1941	.70	.51	.69	.67
30	Upper Rio Grande, N. M.	DF	Santa Fe, N. M.	1910-1947	.57	.36	.54	.50
31	Upper Rio Grande, N. M.	DF	Santa Fe, N. M.	1892-1941	.70	.44	.64	.64
32	Upper Rio Grande, N. M.	DF	North Rio Grande, N. M.	1910-1941	.80	.41	.78	.79
33	Upper Rio Grande, N. M.	DF	Canadian River & N. E., N. M.	1910-1941	.58	.41	.51	.44
34	Guadalupe Mts., N. M.	DF	Cloudcroft, N. M.	1903-1941	.56	.42	.54	.53
35	Guadalupe Mts., N. M.	DF	Carlsbad, N. M.	1895-1941	.64	.41	.58	.56
36	Upper Gila R. Basin, Ariz.-N. M.	PP	Tucson, Arizona	1891-1939	.52	.48	.64	.61
37	So. Ariz.	DF	Tucson, Arizona	1891-1939	.63	.50	.71	.68
38	So. Ariz.	DF	Tucson, Arizona	1891-1950	.64	.51	.71	.68
39	Holman Pass[4], N. M.	PP	Chacon, N. M.	1910-1941	.45	.51	.55	.61
40	Holman Pass, N. M.	PP	North Rio Grande	1910-1941	.35	.27	.47	.55
41	Holman Pass, N. M.	PP	Santa Fe, N. M.	1910-1941	.26	.19	.39	.45
42	Holman Pass, N. M.	PP	Santa Fe, N. M.	1892-1941	.41	.37	.46	.52

Means, Pairs 1 to 38:

Montana:S.W. Canada	DF	8 pairs	.55	.55	.55	.52
	PP-LPP	4 "	.54	.58	.56	.50
Colorado:Utah	DF	6 "	.73	.65	.72	.71
	PP	1 "	.64	.76	.68	.70
	PNN	5 "	.68	.64	.69	.71
Arizona:New Mexico	DF	13 "	.61	.43	.59	.5[illegible]
	PP	1 "	.52	.48	.64	.61
All Pairs	DF	27 "	.62	.52	.61	.5[illegible]
" "	PP-LPP	6 "	.55	.59	.60	.56
" "	PNN	5 "	.68	.64	.69	.71
" "	All	38 "	.615	.544	.616	.6[illegible]

Regional Means	All	10 "	.702	.681	.705	.6[illegible]

1892-1947	.77	.79	.77	.76	.65	.69	.65	.51	.56	.55	.50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1892-1947	.73	.76	.72	.73	.66	.70	.65	.54	.58	.58	.51	.52	.46	.59	.44	.22
1910-1947	.68	.62	.71	.71	.42	.45	48	.32	.36	.40	.32	.37	.38	.35	.35	.40
1910-1947	.72	.67	.69	.66	.48	.49	.49	.36	.42	.38	.33	.33	.25	.22	.15	.08
1910-1947	.59	.46	.59	.64	.61	.56	.59	.54	.50	.55	.44	.50	.49	.25	.27	.30
1910-1947	.56	.55	.57	.60	.68	.60	.61	.64	.57	.53	.51	.52	.48	.11	.15	.11
1895-1947	.79	.66	.78	.77	.74	.75	.75	.62	.63	.66	.59	.61	.54	.46	.25	-.07
1895-1947	.75	.68	.76	.78	.79	.78	.80	.71	.72	.75	.71	.74	.66	.51	.29	.11
1895-1944	.82	.76	.83	.82	.72	.73	.75	.59	.63	.64	.49	.49	.46	.35	.29	-.03
1895-1944	.78	.73	.79	.81	.73	.77	.79	.68	.73	.75	.61	.63	.62	.43	.41	.06
1895-1941	.64	.76	.68	.70	.61	.59	.64	.48	.49	.56	.41	.47	.48	.39	.42	.12
1910-1941	.51	.37	.49	.48	.38	.47	.41	.27	.41	.34	.42	.34	.34	.19	.17	-.07
1910-1941	.46	.46	.48	.46	.46	.48	.48	.37	.43	.42	.43	.44	.43	.25	.23	.01
1910-1941	.40	.28	.36	.38	.24	.38	.34	.25	.37	.33	.34	.31	.39	.27	.35	.07
1892-1941	.69	.53	.64	.61	.66	.68	.59	.61	.65	.56	.59	.50	.46	.18	.14	-.07
1910-1941	.70	.51	.69	.67	.64	.67	.66	.61	.68	.64	.66	.63	.62	.28	.30	.00
1910-1947	.57	.36	.54	.50	.50	.46	.41	.37	.36	.32	.29	.25	.20	.09	.03	-.08
1892-1941	.70	.44	.64	.64	.68	.70	.59	.59	.63	.52	.56	.45	.40	.14	.11	-.20
1910-1941	.80	.41	.78	.79	.77	.74	.70	.67	.71	.63	.61	.56	.50	.20	.17	-.16
1910-1941	.58	.41	.51	.44	.42	.49	.41	.45	.48	.38	.49	.39	.40	.20	.20	.10
1903-1941	.56	.42	.54	.53	.49	.50	.45	.47	.47	.42	.41	.36	.25	.08	-.03	.03
1895-1941	.64	.41	.58	.56	.60	.58	.52	.50	.49	.44	.40	.35	.25	.17	.03	.03
1891-1939	.52	.48	.64	.61	.52	.53	.67	.48	.49	.63	.32	.50	.48	.37	.30	.23
1891-1939	.63	.50	.71	.68	.56	.59	.71	.54	.57	.68	.44	.59	.52	.36	.25	.09
1891-1950	.64	.51	.71	.68	.58	.61	.70	.59	.60	.69	.48	.59	.51	.32	.23	.08
1910-1941	.45	.51	.55	.61	.45	.66	.72	.43	.66	.72	.73	.75	.68	.55	.43	.10
1910-1941	.35	.27	.47	.55	.55	.59	.71	.52	.59	.70	.56	.75	.67	.49	.41	.12
1910-1941	.26	.19	.39	.45	.39	.48	.55	.51	.51	.58	.49	.58	.51	.46	.41	.10
1892-1941	.41	.37	.46	.52	.48	.57	.58	.44	.56	.58	.49	.53	.50	.34	.30	-.09

8 pairs	.55	.55	.55	.52	.26	.47	.46	[illegible]	.46	.45	.40	.39	.36	.33	.29
4 "	.54	.58	.56	.50	.14	.47	.51	.10	.42	.48	.51	.54	.51	.49	.43
6 "	.73	.65	.72	.71	.57	.60	.60	.45	.50	.50	.44	.45	.40	.34	.25
1 "	.64	.76	.68	.70	.61	.59	.64	.48	.49	.53	.41	.47	.48	.39	.42
5 "	.68	.64	.69	.71	.69	.66	.69	.62	.62	.63	.56	.58	.55	.36	.31
13 "	.61	.43	.59	.57	.54	.57	.54	.48	.53	.49	.47	.44	.40	.21	.16
1 "	.52	.48	.64	.61	.52	.53	.67	.48	.49	.63	.32	.50	.48	.37	.30
27 "	.62	.52	.61	.59	.46	.55	.53	.42	.50	.48	.44	.43	.39	.28	.22
6 "	.55	.59	.60	.58	.28	.50	.56	.23	.44	.52	.46	.52	.50	.45	.41
5 "	.68	.64	.69	.71	.69	.68	.69	.62	.62	.63	.56	.58	.55	.36	.31
38 "	.615	.544	.616	.602	.465	.556	.554	.415	.506	.507	.460	.464	.431	.314	.263
10 "	.702	.681	.705	.693	.586	.635	.671	.485	.559	.553	.495	.502	.467	.347	.319

Footnotes to Table 1C.

1. Unless otherwise noted, all correlations are positive. Some of the growth indices used in these correlations were later extended, the principal final indices (Table 2) being analysed further in Table 21. All sub-regional indices are plotted in the figures of Chapter II. A few coefficients were computed for the March-July rainfall interval, not listed in the table. These are: pair no. 25, +.38; 28, +.44; 30, +.27; 31, +.39; 39, +.75; 41, +.59; 42, +.52.

2. 13 months.

3. The first Banff index, based on specimens from one site only (TRB 13:1C, 1947). The trees, sampled in 1945, seemed to be dying and the rings in the outer decades were very crowded. On the assumption that a pest effect was present, a trend line with steep downward slope in the outer decades was fitted to the growth curve and a complete set of 16 coefficients computed for the resulting departures. However, the coefficients for the series of unstandardized measures yielded systematically higher values and are used in the table. This analysis emphasizes the danger in making apparently reasonable assumptions abo t the causes of growth departures.

4. This is the only series in this table which was not derived by the writer. The growth data were read off plotted curves in W.S.Glock, Smiths. Misc. Coll. 111 (18), 1950; the resulting inaccuracies appear to be small and to have only a negligible effect on the coefficients. The results for pairs 39 to 42 support Glock's analysis of his data by trend coefficients, which show spring and foresummer rainfall to parallel growth in this special group somewhat more closely than other, longer rainfall intervals.

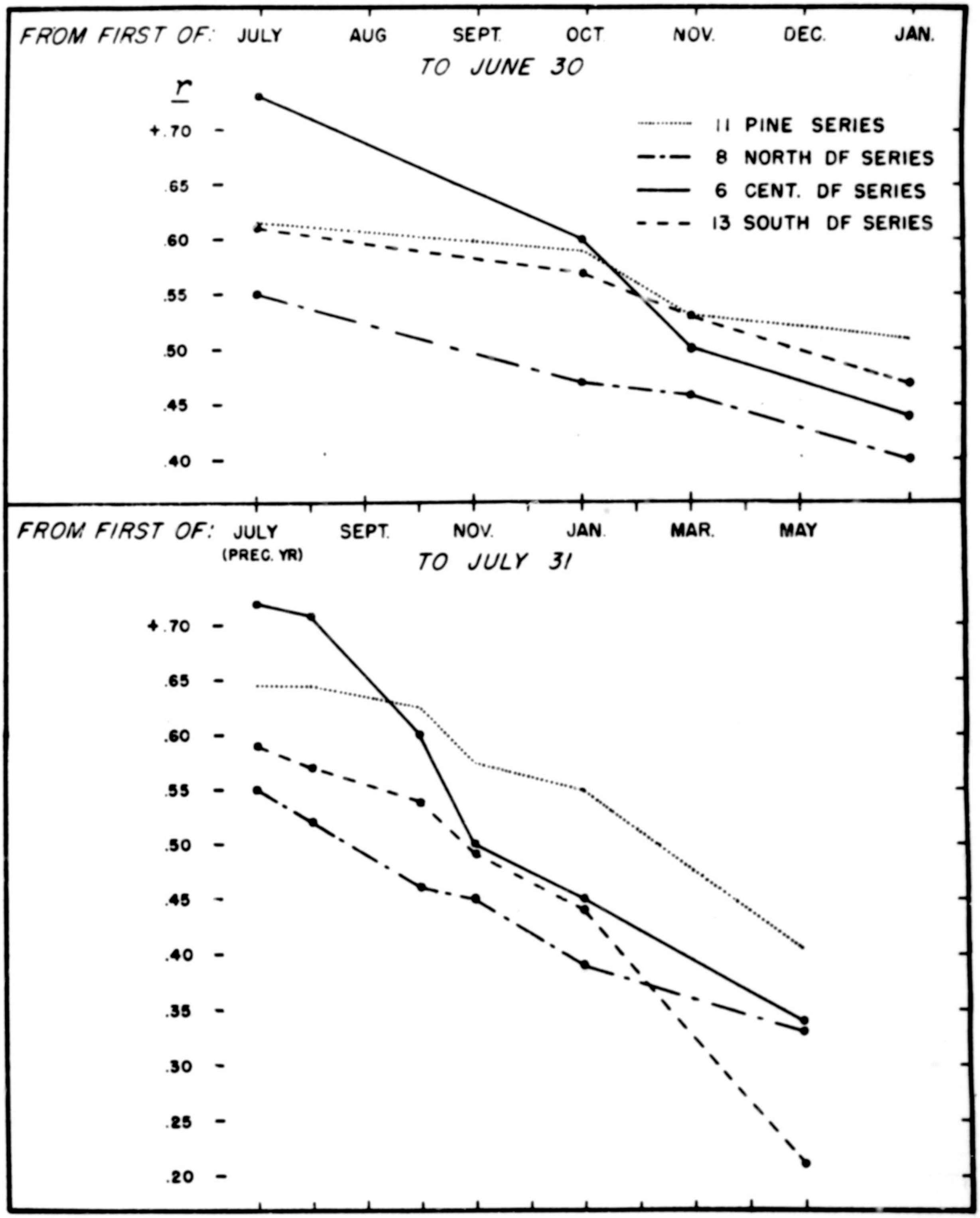


Fig. 21. The coefficient of correlation of growth compared with various rainfall intervals

In Douglas-fir, the effect of shortening the October-June test interval at either limit is to systematically reduce the coefficients in all areas. The October-July rainfall yields on the whole slightly lower coefficients than for October-June, but since July is a relatively rainy month some small influence on the tree-ring chronology must be present.

In ponderosa pine, on the other hand, there is in all areas an improvement in the coefficients when the test interval of rainfall is extended to include July. This is also true for limber pine in Montana and pinyon pine in the Colorado-Utah area, the only areas with coefficients for these species. However, though consistent, the analysis is based on too few series to be conclusive.

The most unexpected result of this analysis was the evidence that the relative width of the annual ring in Douglas-fir is significantly dependent on rainfall which occurred as much as a year preceding growth. In all areas the coefficient for the year July-June is substantially higher than for October-June. The three pine species showed a parallel relation, but the thirteen-month July-July interval represents perhaps a slightly closer approach to the true mean effective rain interval for these species.

Lag effects in ponderosa and limber pine of the central and northern Rockies, though not in Douglas-fir anywhere, are indicated by the coefficients based on a two-year rain interval ending in June of the growth year.

One would expect the averaging of the ring records from a large area and of the rainfall records from many stations to result in some cancellation of random error and thus in higher growth-rain coefficients for all rain intervals of any consequence. This is clearly the case in Table 18. The most representative ring index in this table is that for Douglas-fir in the Colorado River Basin (above the Grand Canyon) based on 84 highly sensitive trees in 17 well distributed groups. The highest coefficients are found in the correlation with a rainfall index for this region based on nine

Weather Bureau stations with the longest and most complete records. It seems probable that most of the possible cancellation of error has been effected in these two indices and that the coefficients are very near the absolute maximum possible between these two variables. The bottom line in Table 18 presents an average of the coefficients for the ten pairs of variates which include only regional growth indices.

Since some of the more sensitive single-core records have been found to show coefficients of about +0.7 with rainfall records 50 or more years in length, as at Mesa Verde, the great labor required to derive general indices like that for the Colorado River Basin might seem to show little yield. Unfortunately, only relatively few single-tree cores have the noted high reliability in chronology, and there is, of course, strong need for statistical stability in the data if climatic interpretation of the ring indices is to be relied upon as an extension into earlier centuries of the rain-gage data.

To summarize this analysis of the growth-effective rain interval: sensitive drought conifers on selected sites from southern Arizona to southwestern Alberta provide an index of rainfall for a year ending in June or July with a growth-rain coefficient of correlation averaging about +0.70 and in some cases exceeding +0.80; the true rain interval recorded by tree-rings may be slightly different in different species.

Upon the subsequent completion of a number of additional regional indices, the results of the foregoing analysis were applied to the principal chronologies presented in Table 2 of this report. Rainfall and river flow series representative of the main areas of study were selected (Tables 19 and 20). In addition to the usual coefficient $\underline{r}$ between these data and the growth indices of Table 2, coefficients of the smoothed data were derived.

Table 19A. Rainfall for Year Ending June 30. Inches

Year	Spokane, Wash.	Denver, Colo.	Santa Fe, N. Mex.	Tucson, Arizona[1]	So. Coast Range, Cal.[2] % of Mean	Cent. Sierra Nevada[3] % of Mean	Year	Spokane, Wash.	Denver, Colo.	Santa Fe, N. Mex.	Tucson, Arizona[1]	So. Coast Range, Cal.[2] % of Mean	Cent. Sierra Nevada[3] % of Mean
1851	---	---	10.06	---	62	39	1901	19.79	8.87	15.61	6.93	102	126
1852	---	---	17.30	---	101	91	1902	16.41	12.70	15.53	7.27	76	97
1853	---	---	16.60	---	114	164	1903	16.05	9.86	15.77	10.60	116	95
1854	---	---	23.37	---	106	102	1904	19.68	14.84	5.49	7.23	61	130
1855	---	---	23.42	---	122	88	1905	15.13	16.18	19.34	20.33	143	98
1856	---	---	28.83	---	91	75	1906	14.98	15.90	14.06	11.76	134	170
1857	---	---	17.29	---	55	73	1907	17.76	14.10	19.42	12.98	144	161
1858	---	---	8.91	---	83	77	1908	13.70	11.67	13.23	13.62	95	70
1859	---	---	10.02	---	69	93	1909	14.75	24.97	9.71	12.43	135	125
1860	---	---	11.59	---	101	99	1910	14.00	14.07	12.54	9.80	95	98
1861	---	---	15.11	---	92	85	1911	14.08	7.79	10.66	11.37	129	145
1862	---	---	8.00	---	196	215	1912	15.75	16.69	17.78	12.00	66	56
1863	---	---	12.14	---	44	63	1913	19.83	14.88	12.72	9.70	73	70
1864	---	---	9.68	---	50	48	1914	13.93	22.30	12.75	9.41	152	129
1865	---	---	24.06	---	93	109	1915	15.99	19.78	20.36	20.25	131	94
1866	---	---	13.28	---	115	105	1916	18.20	10.68	16.16	13.05	142	114
1867	---	---	10.50	---	137	149	1917	12.44	11.20	10.98	11.10	105	93
1868	---	---	9.72	---	134	192	1918	9.55	16.79	9.58	10.63	96	73
1869	---	---	10.42	---	107	99	1919	13.02	13.95	17.92	9.58	72	101
1870	---	---	6.79	---	54	85	1920	10.38	10.79	18.56	20.19	97	76
1871	---	---	15.60	---	61	66	1921	13.83	13.87	14.37	6.32	91	114
1872	---	---	11.16	---	73	118	1922	11.26	12.15	13.67	16.11	155	113
1873	---	13.68	10.08	---	76	68	1923	15.69	19.61	10.75	7.14	82	108
1874	---	13.00	13.77	---	139	110	1924	10.51	13.24	13.63	15.69	57	49
1875	---	12.24	16.78	---	87	77	1925	16.27	8.83	8.14	4.31	67	92
1876	---	24.13	19.23	---	128	125	1926	11.47	14.48	15.83	13.24	113	77
1877	---	17.81	14.79	---	42	59	1927	16.82	16.69	13.20	10.35	131	116
1878	---	13.79	15.11	---	139	93	1928	19.61	12.23	14.70	7.62	72	87
1879	---	15.42	15.82	---	66	96	1929	9.76	16.39	13.60	6.67	73	61
1880	---	6.32	11.52	---	116	119	1930	9.79	9.61	17.14	15.10	89	85
1881	---	11.42	11.84	---	77	99	1931	10.17	14.07	15.47	10.39	61	64
1882	25.71	17.78	21.15	---	73	101	1932	17.62	9.30	16.90	13.05	127	106
1883	27.08	15.37	10.69	---	65	72	1933	11.38	13.13	14.23	9.35	94	63
1884	14.74	19.65	17.20	---	235	118	1934	15.73	6.66	12.88	9.71	67	75
1885	20.44	13.51	18.33	---	72	75	1935	13.31	16.25	13.71	12.46	127	105
1886	15.76	14.93	12.76	---	130	110	1936	13.24	16.06	12.32	13.05	101	123
1887	19.39	11.25	16.07	---	80	81	1937	15.12	11.69	19.48	12.41	178	101
1888	21.07	13.76	12.93	---	116	65	1938	15.55	19.35	11.49	9.91	162	147
1889	12.48	11.48	11.19	---	127	73	1939	10.73	8.43	15.00	7.35	94	65
1890	20.13	11.99	8.70	---	178	186	1940	17.21	11.66	15.62	6.15	116	---
1891	13.11	18.37	17.14	15.60	115	91	1941	---	15.44	17.96	17.21	207	---
1892	16.23	12.07	14.64	9.27	86	91	1942	---	15.92	12.63	13.33	78	---
1893	21.51	12.42	8.12	7.03	176	155	1943	---	12.32	12.00	5.90	145	---
1894	20.53	15.73	16.12	12.49	55	104	1944	---	13.40	6.79	11.64	125	---
1895	13.10	15.81	15.03	5.45	125	125	1945	---	12.98	13.03	11.56	102	---
1896	15.23	12.00	16.06	11.59	64	118	1946	---	9.12	11.30	8.81	109	---
1897	23.08	14.11	20.81	12.20	119	112	1947	---	17.90	14.17	11.38	114	---
1898	19.99	12.60	15.61	11.75	52	69	1948	---	13.46	16.06	7.22	65	---
1899	14.70	10.49	10.45	13.17	53	91	1949	---	15.54	15.41	7.16	87	---
1900	19.08	15.90	14.50	7.43	66	111	1950	---	11.77	12.31	7.66	76	---
							Mean	15.75	13.97	14.27	10.97	102.5	98.5

Footnotes to Table 19.

1. Data by months in H. V. Smith, Climate of Arizona, Univ. Ariz. Agr. Expt. Sta. Tech. Bull. 197, 1945, for the University station. Supplemented by recent data, U. S. W. B.
2. Indices of rainfall for four key areas in south coastal California have been derived by Lynch, Metropolitan Water District of So. California Publ., 1931, from Weather Bureau data to 1930. An average of these indices was taken. To extend the curve beyond 1930 an approximate index was derived by averaging the records for Mt. Wilson and Cuyamaca, two mountain stations with long records and high mean rainfall, and adjusting these to the mean of the Lynch indices by a coefficient based on the comparative values during the interval 1905-1930.
3. An index derived by Hardman and Venstrom, Trans. Amer. Geoph. Union, 71-90, 1941, which is based on thirteen stations in the Truckee River Basin and adjacent areas.
4. Missing data for occasional months in some of the single-station records, as at Banff, were estimated from neighboring stations.
5. Mean of October-June rainfall only, at five Washington stations: Omak, Conconully, Irene Mountain, Lemansky Lake, Republic.
6. Nine of the longer, more complete rainfall series within or just beyond the western or northern borders of the Colorado River Basin above Grand Canyon: Collbran, Delta, Durango, Meeker, Montrose, and Paonia in Colorado, Ft. Duchesne and Moab in Utah, and Evanston in Wyoming.
7. Crested Butte, Fraser, Meeker, and Steamboat Springs, all in north-central Colorado.

Table 19B. Rainfall for Year Ending June 30. Inches

Year	Entrance, Alta.	Banff, Alta.[4]	Kamloops B.C.	E. Washington[5]	Cent. Div., Montana	S.W. Div., Idaho	S.E. Div., Idaho	3-Sta. Colo, R.B.[6]	4-Sta. Upper, Colo.[7]
1895	---	15.15	---	---	---	12.62	11.66	11.43	---
1896	---	17.10	8.46	---	13.24	17.39	12.45	10.12	---
1897	---	20.50	9.86	---	16.82	20.09	12.96	15.26	---
1898	---	22.66	13.90	---	18.40	13.44	13.47	13.19	---
1899	---	23.07	8.80	---	14.12	16.47	10.62	10.44	---
1900	---	25.59	12.13	---	12.80	15.48	10.50	10.34	---
1901	---	22.83	9.86	---	14.61	12.61	9.32	9.26	---
1902	---	25.34	10.19	---	13.47	13.00	10.23	7.93	---
1903	---	22.96	7.71	---	12.27	15.90	11.14	11.35	---
1904	---	24.42	15.85	---	14.25	18.43	14.45	10.27	---
1905	---	15.14	5.64	---	11.26	13.36	10.82	13.21	---
1906	---	13.26	9.87	---	16.01	15.94	16.31	15.04	---
1907	---	19.52	9.81	---	19.27	16.45	17.83	15.16	---
1908	---	24.17	9.63	---	19.26	13.35	14.30	12.06	---
1909	---	15.75	7.58	---	16.39	16.06	14.39	15.15	---
1910	---	19.82	8.90	10.13	18.60	19.74	14.59	11.80	---
1911	---	17.38	6.87	13.55	18.73	19.48	14.74	13.63	19.67
1912	---	16.43	10.99	12.19	17.12	17.44	13.73	15.41	24.00
1913	---	21.89	14.21	13.00	17.78	15.86	16.82	11.59	19.03
1914	---	18.52	10.80	12.23	15.59	18.06	16.73	15.64	24.20
1915	---	20.20	10.72	14.65	15.29	14.15	13.35	14.38	19.31
1916	---	26.52	12.42	13.53	20.48	19.56	13.49	12.93	20.61
1917	---	19.82	9.78	10.24	16.17	16.50	14.99	17.33	27.04
1918	14.21	18.44	8.84	7.69	11.27	15.65	11.71	10.26	19.83
1919	9.75	18.55	11.14	11.02	11.50	15.30	11.77	12.93	18.13
1920	20.17	16.74	8.29	7.45	14.16	13.50	11.25	15.37	24.68
1921	17.17	15.84	8.07	14.26	12.35	20.64	15.10	12.77	23.30
1922	12.29	14.64	6.66	9.42	14.27	15.68	13.17	14.79	19.69
1923	12.95	18.15	11.20	13.45	17.35	16.07	13.38	11.50	21.43
1924	11.46	18.62	10.11	7.51	14.03	10.69	9.70	13.02	18.00
1925	16.08	18.56	13.75	11.34	14.74	18.00	13.53	11.73	17.60
1926	20.90	15.23	9.88	9.50	13.88	12.88	12.14	15.76	20.33
1927	22.93	17.29	12.55	12.51	18.89	19.53	12.98	14.52	22.86
1928	24.01	22.85	14.90	10.00	15.75	16.64	12.38	14.09	26.53
1929	19.18	13.96	8.31	8.15	13.62	11.94	10.94	13.60	18.51
1930	17.49	19.23	7.72	8.18	11.56	13.20	10.03	13.71	22.40
1931	19.48	14.74	7.29	8.34	10.68	11.43	11.51	10.31	19.64
1932	17.84	18.61	7.24	12.63	14.96	17.43	13.47	12.42	20.25
1933	22.19	18.63	8.31	11.59	13.43	13.54	10.02	10.33	18.72
1934	24.47	19.69	9.04	8.98	14.09	11.54	7.03	9.97	14.47
1935	33.03	17.16	7.42	11.00	10.76	13.63	10.97	11.13	19.21
1936	20.68	14.30	12.36	11.71	10.44	14.81	10.81	9.23	20.57
1937	11.81	12.47	13.14	12.04	11.38	11.77	11.32	11.81	17.99
1938	17.25	23.15	8.24	13.59	16.62	19.29	14.59	14.64	24.28
1939	18.44	14.75	14.89	9.75	13.92	12.05	11.93	10.07	16.86
1940	15.21	15.51	8.34	13.52	12.47	16.46	11.13	10.61	15.73
1941	16.84	15.12	9.59	20.35	15.06	18.24	15.23	16.45	18.22
1942	18.80	17.62	12.72	15.90	18.16	17.11	14.81	15.09	18.94
1943	26.30	18.96	10.96	---	15.96	19.34	12.90	11.21	21.51
1944	23.09	16.60	8.39	---	14.40	13.29	13.56	13.60	19.63
1945	18.86	20.14	---	---	13.68	16.54	13.47	11.07	18.97
1946	18.13	21.52	---	---	12.27	16.41	13.13	10.67	15.46
1947	16.19	21.71	---	---	16.89	16.75	12.97	13.12	23.07
1948	19.63	20.70	---	---	17.96	14.79	12.31	14.86	22.15
1949	---	16.91	---	---	12.82	13.46	13.43	13.47	22.07
1950	---	28.23	---	---	14.02	14.70	12.65	10.20	18.87
1951	---	---	---	---	---	16.25	11.58	---	---
Mean	18.61	18.96	10.05	11.49	14.83	15.62	12.74	12.64	20.48

Table 20. Runoff[1] for Water-Year Ending Sept. 30. Millions of Acre-Feet

Year	Spray R. at Banff	Missouri at Ft. Benton[2]	Snake nr Heise[3]	Colorado at Lee Ferry[4]	Rio Grande nr Del Norte	Kings R. at Piedra	San Gabriel nr Azusa[5]
1882	---	6.92	---	---	---	---	---
1883	---	6.75	---	---	---	---	---
1884	---	6.54	---	---	---	---	---
1885	---	8.97	---	---	---	---	---
1886	---	5.29	---	---	---	---	---
1887	---	7.52	---	---	---	---	---
1888	---	6.69	---	---	---	---	---
1889	---	3.92	---	---	---	---	---
1890	---	4.84	---	---	.81	---	---
1891	---	5.97	---	---	.83	---	---
1892	---	7.14	---	---	.59	---	---
1893	---	6.47	---	---	.39	---	---
1894	---	8.58	---	---	.41	---	---
1895	---	5.43	---	13.70	.64	---	---
1896	---	6.23	---	13.30	.49	1.54	.027
1897	---	6.13	---	18.43	.73	1.95	.091
1898	---	6.93	---	10.85	.91	0.88	.023
1899	---	7.70	---	18.22	.37	1.26	.010
1900	---	5.59	---	13.46	.52	1.31	.012
1901	---	5.04	---	14.35	.49	2.96	.096
1902	---	4.72	---	9.60	.26	1.50	.024
1903	---	5.19	---	13.74	.82	1.64	.108
1904	---	6.05	---	13.09	.34	1.69	.029
1905	---	3.68	---	14.81	.93	1.45	.160
1906	---	4.33	---	18.83	.90	3.90	.232
1907	---	7.53	---	22.74	1.19	2.73	.350
1908	---	8.34	---	12.41	.58	1.00	.078
1909	---	7.57	---	23.14	.87	2.80	.180
1910	---	5.99	---	14.01	.69	1.78	.139
1911	.42	5.46	5.72	16.42	.92	2.83	.273
1912	.37	6.67	5.99	19.44	.97	0.97	.077
1913	.42	7.64	6.40	14.37	.53	0.94	.050
1914	.45	6.32	5.85	20.74	.63	2.55	.296
1915	.40	6.54	3.86	13.64	.69	1.82	.132
1916	.51	8.21	5.97	19.14	.83	3.04	.279
1917	.37	8.22	6.53	23.75	1.00	1.89	.092
1918	.37	5.57	6.45	16.09	.53	1.36	.132
1919	.37	3.67	3.70	12.60	.78	1.20	.039
1920	.34	5.46	5.25	21.50	1.00	1.40	.117
1921	.38	5.70	5.72	23.08	1.02	1.53	.070
1922	.30	6.01	5.21	18.71	.98	2.20	.410
1923	.39	5.55	5.03	18.71	.78	1.56	.076
1924	.32	4.69	3.62	14.54	.83	0.39	.028
1925	.40	5.64	5.92	13.46	.65	1.29	.024
1926	.27	5.29	3.91	16.18	.71	1.04	.111
1927	.43	7.83	6.30	19.06	.90	1.96	.129
1928	.46	7.20	6.27	17.63	.74	0.97	.033
1929	.32	4.98	4.31	21.88	.86	0.85	.036
1930	.38	3.98	4.27	15.21	.60	0.86	.046
1931	.32	3.01	2.99	8.07	.36	0.47	.032
1932	.41	3.88	4.70	17.60	.89	2.08	.129
1933	.44	4.27	4.15	11.67	.50	1.18	.047
1934	.37	3.59	2.78	5.92	.34	0.66	.052
1935	.37	3.12	4.11	11.92	.68	1.62	.127
1936	.28	3.31	5.35	14.12	.48	1.88	.054
1937	.29	2.62	3.81	14.10	.57	2.34	.218
1938	.37	4.35	5.16	17.96	.79	3.28	.353
1939	.29	3.95	4.32	11.44	.56	0.97	.067
1940	.31	3.14	3.42	9.08	.30	1.79	.059
1941	.26	2.96	3.70	18.93	.95	2.54	.325
1942	.35	5.78	4.31	19.66	.93	2.01	.081
1943	.33	[illegible]	6.51	13.61	.51	2.03	.283
1944	.24	4.96	3.97	15.52	.85	1.17	.193
1945	.29	4.35	4.89	13.72	.55	2.06	.096
1946	.37	4.30	5.30	10.69	.42	1.61	.101
1947	.40	6.41	5.29	15.83	.62	1.11	.109
1948	---	7.78	4.79	16.03	.93	1.00	.029
1949	---	4.86	4.88	16.75	.91	0.96	.025
1950	---	6.40	---	13.23	.49	1.28	.028
1951	---	6.23	---	---	.31	---	---
Mean	.361	5.668	4.885	15.659	.687	1.687	.118

Footnotes to Table 20

1. Data taken from or based on U.S.G.S. Water-Supply Papers. Unless otherwise noted, upstream depletions minor.
2. Measured flow; depletions considerable.
3. Measured flow plus storage change in Moran Lake; depletions considerable.
4. Flow corrected for depletions, estimated by the U.S. Bur. of Reclamation for 1897-1943; other years similarly estimated.
5. Includes Azusa Canal; flow adjusted for storage and evaporation in reservoirs (Metropolitan Water District of So. California data).

As may be theoretically demonstrated, the most efficient smoothing with respect to reduction of random fluctuations is that by unweighted running means; a rather limited test of this in growth-climate correlations bears this out. Practical considerations such as those in reservoir management suggested three years as an appropriate conservation interval. Thus the smoothing formula, applied to both sets of variates, has the form
$c' = (a + b + c)/3$.

Tables 21 and 22 contain coefficients approaching +0.9, the highest thus far obtained in such studies; these, in the light of earlier analyses of necessarily more crude material, emphasize the importance of the process of successive refinement of the data, which it is possible to apply to dendroclimatic material. The compared series are plotted in Figs. 22 and 23.

Table 21. Correlation of Data in Table 2 vs July-June Rainfall

Table 2, Set	Area	Species[1]	Interval	Rainfall Data[2]	r	r Smoothed[3]
A	Fraser R. Basin	DF;PP	1896-1944	Kamloops, B.C.	+.45	+.43
B	Jasper	DF	1916-1947	Entrance, Alta.	.56	.80
C	Banff, Alta.	DF	1895-1950	Banff, Alta.	.58	.80
D	Mid. Columbia R. B.	DF;PP	1910-1942	E. Washington	.67	.74
D	Mid. Columbia R. B.	DF;PP	1882-1940	Spokane, Wash.	.43	.44
E	Snake River B.	DF	1895-1950	SW Idaho	.33	.55
E	Snake River B.	DF	1895-1950	SE Idaho	.62	.74
F	Snake River B.	LBP	1895-1950	SW Idaho	.26	.42
F	Snake River B.	LBP	1895-1950	SE Idaho	.56	.75
G	Missouri R. B.	DF	1896-1950	Cent. Montana	.67	.78
H	Missouri R. B.	LBP	1896-1950	Cent. Montana	.45	.74
I	N. Platte R. B.	DF	1911-1946	Upper Colorado	.35	.58
J	S. Platte R. B.	DF	1873-1944	Denver, Colo.	.56	.51
K	Arkansas R. B.	DF	1873-1944	Denver, Colo.	.47	.42
M	Colorado R. B.	DF	1895-1950	Colorado R. B.	.81	.87
U[4]	Colorado R. B.	PNN	1895-1944	Colorado R. B.	.77	.89
W	Gila R. B.	PP	1891-1939	Tucson, Ariz.	.52	.56
X	S. Arizona	DF	1891-1950	Tucson, Ariz.	.64	.68
Y	Rio Grande Basin	DF	1851-1891	Santa Fe, N. M.	.29	.23
Y	Rio Grande Basin	DF	1892-1950	Santa Fe, N. M.	.69	.58[5]
AF	E. Cent. California	JP	1851-1894	Cent. Sierra Nevada	.12	.23
AF	E. Cent. California	JP	1895-1939	Cent. Sierra Nevada	.55	.65
AG	S. California	BCS	1851-1895	S. Coast	.60	.65
AG	S. California	BCS	1896-1950	S. Coast	.72	.87

1. DF - Douglas-fir; PP - ponderosa pine; LBP - limber pine; PNN - pinyon pine; JP - Jeffrey pine; BCS - bigcone spruce.

2. Data for the listed stations and some others are given in Table 19.

3. By formula $c' = (a + b + c)/3$.

4. A 32-tree regional mean. For set N, the 8-tree group of 650-year pinyons, 1895-1948, the corresponding coefficients are +.65 and +.85.

5. For the interval 1900-1950 the unsmoothed and smoothed coefficients are roughly equal.

Table 22. Correlation of Some Regional Growth Indices with Water-Year Runoff

Table Set	Area	Species	Interval	Runoff Station	r	r, Smoothed
C	Banff	DF	1911-1947	Spray at Banff	+.43	+.60
E	Snake R. B.	DF	1911-1949	Snake nr Heise	.44	.68
F	Snake R. B.	LBP	"	"	.34	.47
G	Missouri R. B.	DF	1882-1950	Missouri at Ft. Benton	.77	.81
H	Missouri R. B.	LBP	"	"	.52	.71
M	Colorado R. B.	DF	1895-1950	Colorado at Lee Ferry	.73	.84
N	Colorado R. B.	PNN	1895-1948	"	.51	.69
Y	Rio Grande	DF	1890-1950	Rio Grande nr Del Norte	.60	.43
AF	S. California	BCS	1896-1950	San Gabriel nr Azusa	.67	.88

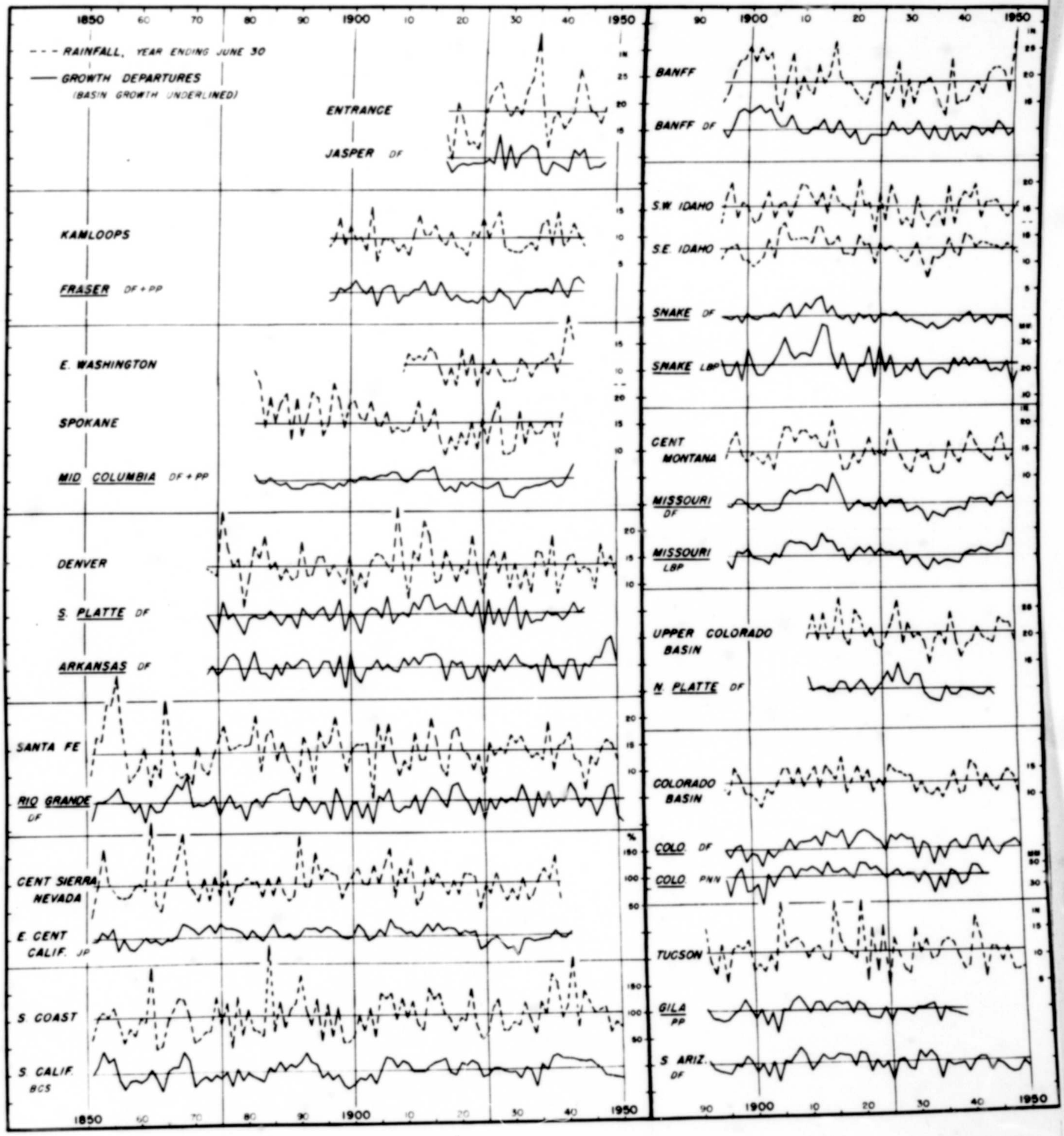
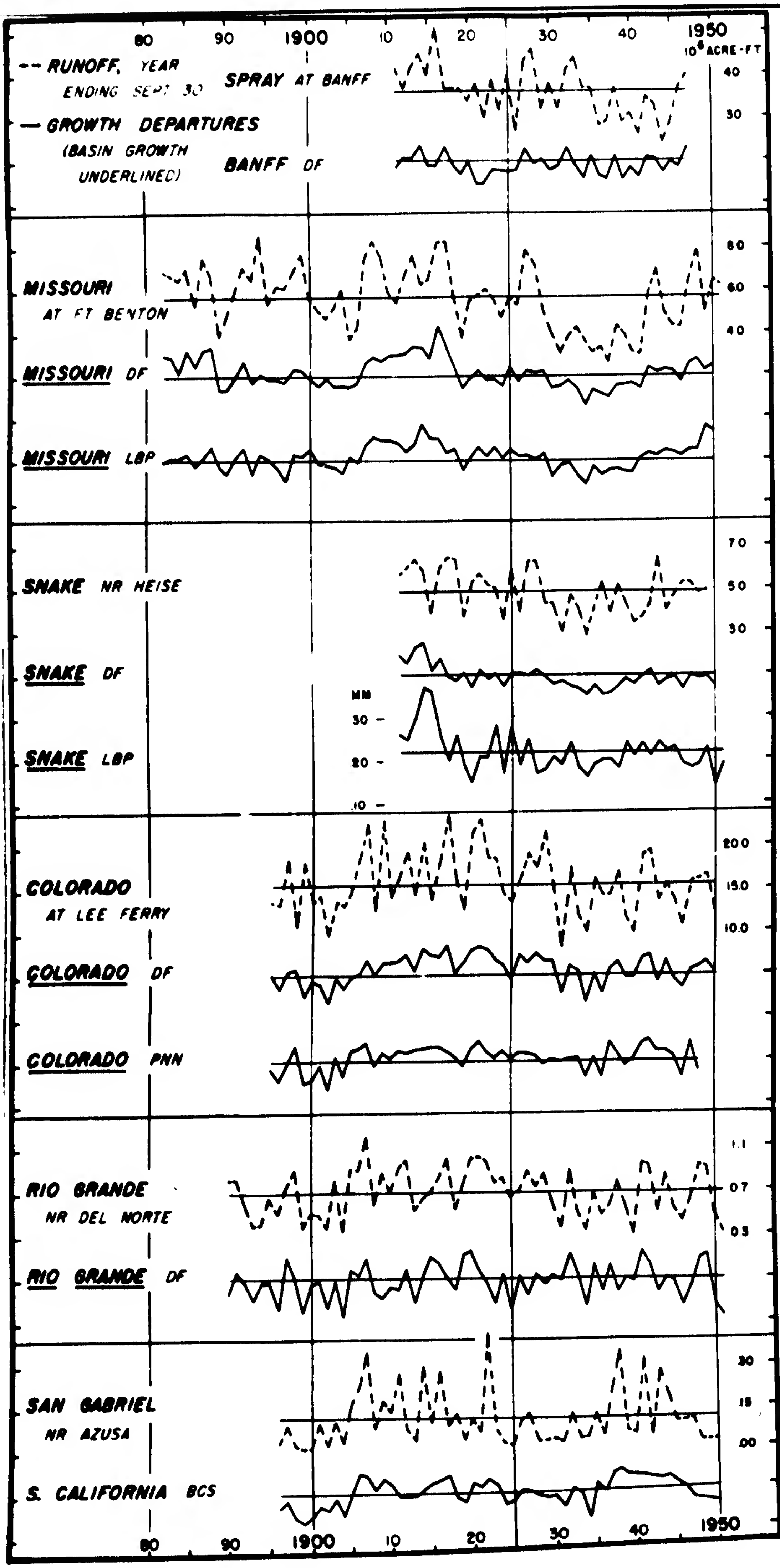


Fig. 22. Rainfall and corresponding growth



80
90
1900
10
20
30
40
1950
10⁶ ACRE-FT
-- RUNOFF, YEAR ENDING SEPT 30
— GROWTH DEPARTURES (BASIN GROWTH UNDERLINED)
SPRAY AT BANFF
BANFF DF
40
30
MISSOURI AT FT BENTON
MISSOURI DF
MISSOURI LBP
80
60
40
SNAKE NR HEISE
SNAKE DF
SNAKE LBP
70
50
30
MM
30
20
10
COLORADO AT LEE FERRY
COLORADO DF
COLORADO PNN
20.0
15.0
10.0
RIO GRANDE NR DEL NORTE
RIO GRANDE DF
1.1
0.7
0.3
SAN GABRIEL NR AZUSA
S. CALIFORNIA BCS
30
15
.00
80
90
1900
10
20
30
40
1950

V. GROWTH INDICES AND CLIMATIC CHANGES

Among the possible long-term climatic properties susceptible to direct test on a network of centuries-long rainfall indices are: (1) the nature of the frequency distribution of the annual departures, (2) significant changes with time in the type of fluctuation in each index, (3) systematic displacement from one area to the next in phase and amplitude of maxima and minima, and (4) cyclic recurrences.

FREQUENCY DISTRIBUTIONS

To examine the frequency of various ring-widths, regional mean series are obviously more desirable than single-tree sequences, since random fluctuations in chronology have in part been eliminated. The distribution of values in some critical indices included in the growth tables is presented in Table 23, in terms of their own standard deviations as shown in Table 10.

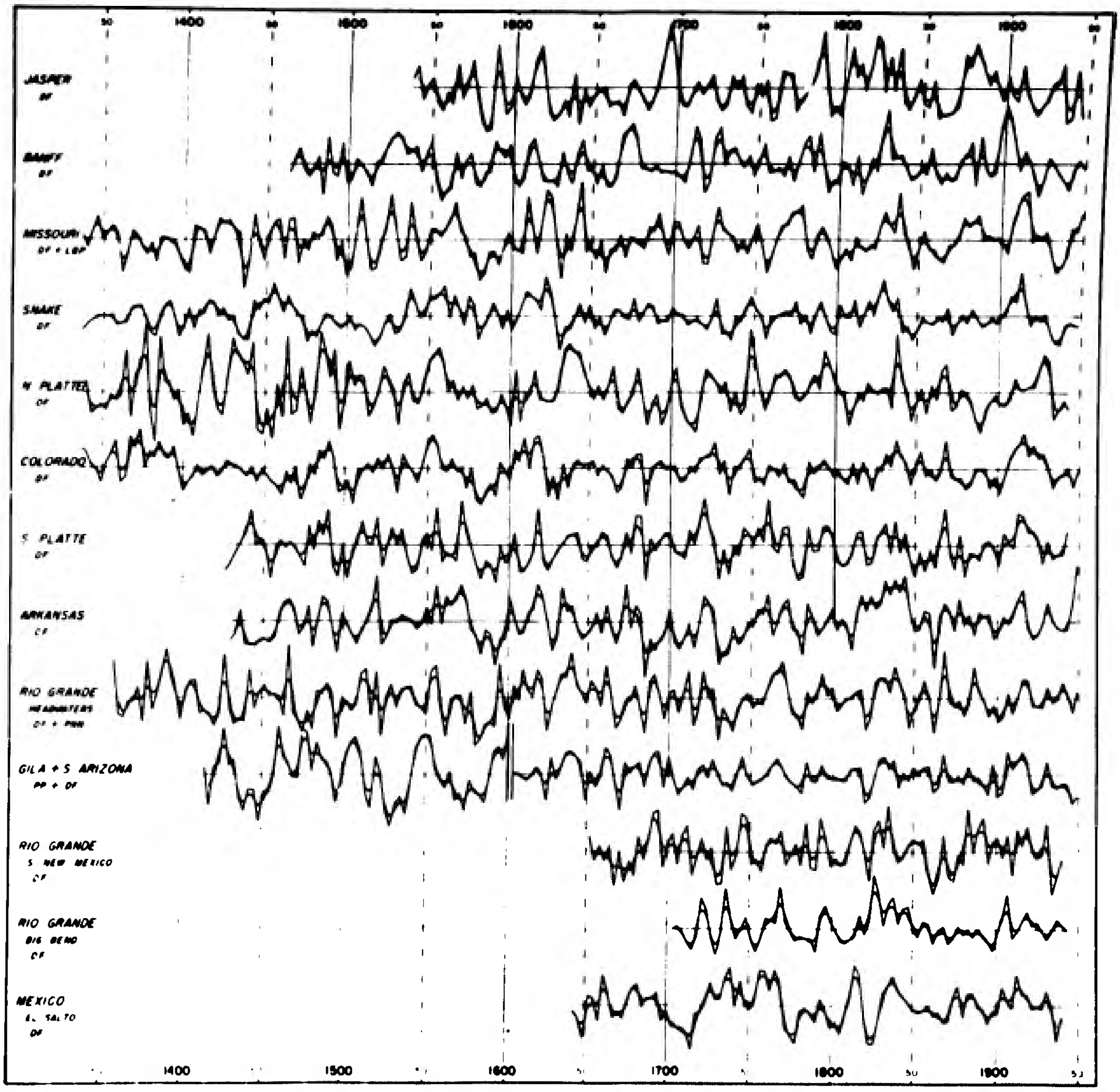
Although the analysed sets of data represent very different types of ring records, it appears that all tend to show the same scatter of values. It also appears that this scatter tends to assume the typical distribution in a normal error function, as shown in the last two columns of Table 23. It does not necessarily follow that these sequences of tree-ring widths, and, as shown above, their related variables rainfall and runoff, occur at random!

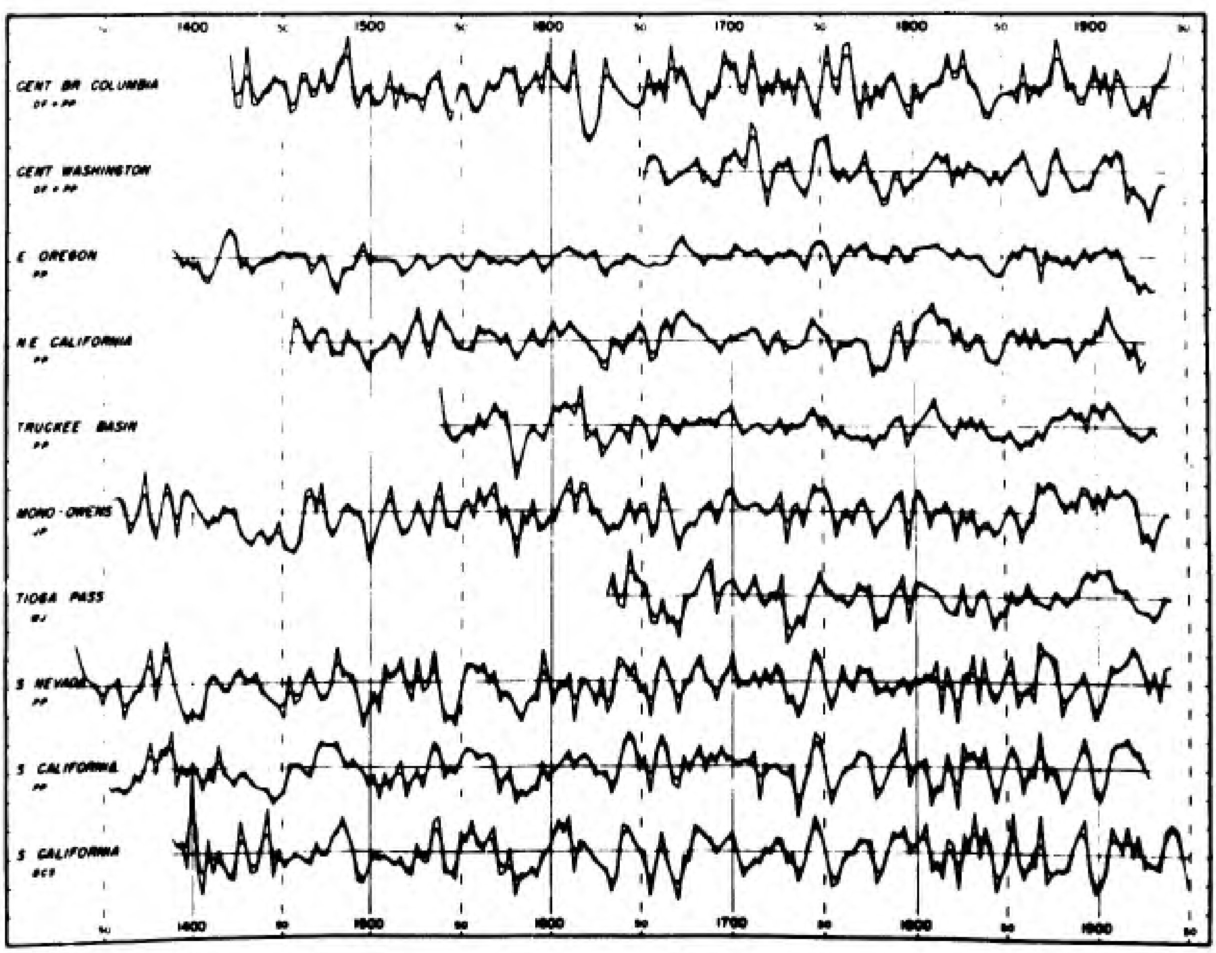
REGIONAL TRANSECTS

A rough visual examination of changes from index to index is afforded by the Rocky Mountain and Pacific Slope transects, Figures 24 and 25. These represent 3-year nonoverlapping means of the best indices presently available for these regions. Unfortunately, it is not yet possible to construct such transects with fully comparable series--e.g., in the Rocky Mountain transect, the Colorado Basin index represents many areas and seasons of field work, but

Table 23. Frequency of Departures in Annual Indices, 1550-1949, in Per Cent

Class	Snake DF	Snake LBP	Colorado DF	Colorado PNN	Rio Grande DF	Rio Grande PNN	Mean	Normal Mean
$< -2\sigma$	1.0	3.0	3.0	3.7	1.3	3.8	2.6	2.3
-2σ to $-\sigma$	13.7	12.0	11.2	14.8	17.0	14.5	13.9	13.6
$-\sigma$ to 0	35.0	34.5	34.8	29.2	32.0	31.2	32.8	34.1
0 to σ	34.0	36.0	33.5	38.0	32.7	35.5	34.9	34.1
σ to 2σ	13.0	12.7	15.7	13.5	14.7	14.5	14.0	13.6
$> 2\sigma$	3.3	1.8	1.8	0.8	2.3	0.5	1.8	2.3


1400
1500
1600
1700
1800
1900
JASPER
DF
BANFF
DF
MISSOURI
DF + LBP
SNAKE
DF
N PLATTE
DF
COLORADO
DF
S PLATTE
DF
ARKANSAS
RIO GRANDE
GILA + S ARIZONA
PP + DF
RIO GRANDE
S NEW MEXICO
RIO GRANDE
BIG BEND
MEXICO
DF


1400
1500
1600
1700
1800
1900
CENT BR COLUMBIA
CENT WASHINGTON
E OREGON
PP
N E CALIFORNIA
PP
TRUCKEE BASIN
PP
MONO - OWENS
TIOGA PASS
S NEVADA
PP
S CALIFORNIA
PP
S CALIFORNIA

in the N. Platte only one locality. Nevertheless, all plotted series are based on sensitive ring records; as the previous discussion has indicated, the average of only a few trees of this type can yield fairly reliable indices.

Perhaps the most striking change in the march of tree-growth and, by inference, in the associated rainfall and river flow, is that exhibited by the Southern California indices. Both the bigcone spruce and ponderosa pine series suggest that in the seventeenth century, perhaps about A.D. 1635-40, the tendency for long-term swings to one or the other side of the mean gave way to fluctuations of shorter wave-length, which have persisted to the present time.

The tendency just discussed may also be noted in the Colorado River Basin indices in Douglas-fir and pinyon pine. This change cannot be merely the statistical result of an increasing number of trees and groups entering the mean curve with advancing time, for the fully homogeneous 1946-51 indices of Figure 26, each representing a fixed number of long-lived trees, show the same phenomenon.

In this connection, the extremely long-lived Colorado Basin trees show that a major minimum, characterizing much of the 1200's, was followed by a major maximum which persisted with very few interruptions for almost the entire 1300's. This great 200-year fluctuation seems to be the first and longest of the series of extended "waves" in growth and rainfall which preceded the relatively rapid fluctuations of the past three centuries. If longer waves preceded the 200-year fluctuation, the early 1250 years of Southwestern Pueblo chronology (Fig. 20) would fail to show them for, as already noted, such major trends would be hidden by the short individual sequences in that overlapping chain; the observations on variation in ring sensitivity in archaeological beams from century to century provide somewhat uncertain evidence against the existence of such long waves.

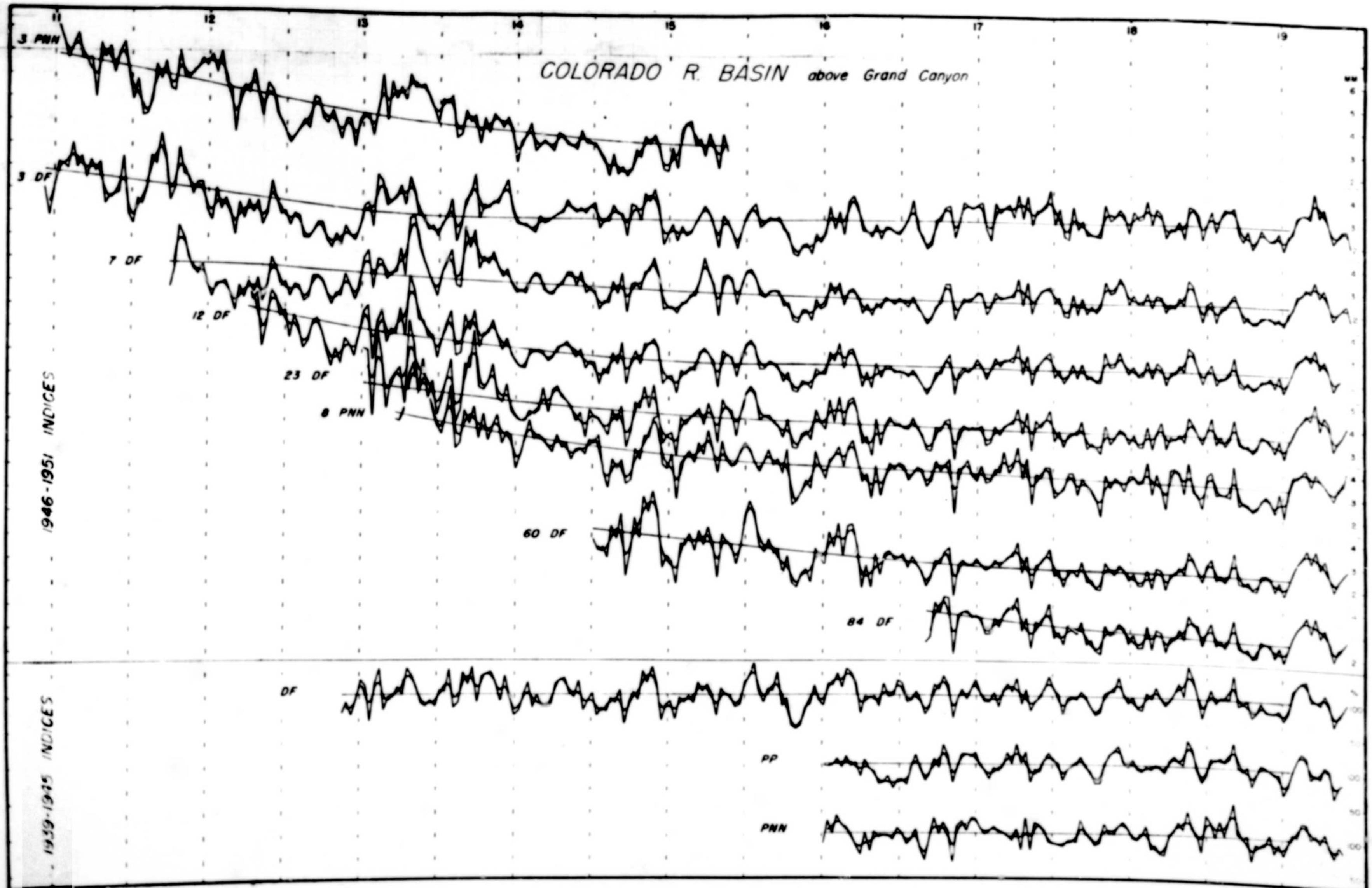


Fig. 26. Upper: A family of homogeneous growth curves in the Colorado Basin
Lower: Mean departures based on a varying number of trees

Inspection of Figures 24 and 25 shows the above-noted change in wave character to be weakly evident in other southerly series; there is some evidence for a reversal in the northerly Missouri Basin index, shorter variations being more characteristic preceding 1650.

In Table 24 is presented a more exact analysis of the characteristics of the maxima and minima in four of the best regional indices in the transects. The standard deviations of the nonoverlapping three-year means during the past four centuries for each of these series is in the 20%-25% range. The end dates for the maxima and minima, read off the plotted curves where these significantly cross the mean line, apply to these condensed data, are to some small extent arbitrary, and may be slightly different from those for annual data. For each set of n three-year values the net cumulative deviation D from the general mean, the average net deviation $\bar{D}$, and the average net deviation in terms of the standard deviation are tabulated. Some of the longer intervals were subdivided to determine the values for the more pronounced portions. It is probable that some of the intervals of three or six years in these tables are of little significance.

It appears that for the intervals 15 or more years in length ($n \geq 5$), the average net deviation is rarely much more than one standard deviation. Such pronounced deviations as the Banff maximum of 1897-1917 are worthy of special note.

MILLENIA-LONG CHRONOLOGIES

Ring indices of unusual length have thus far been derived for four areas of the western United States and are presented in highly condensed form in Figure 27.

Table 24. General Maxima and Minima in Regional Smoothed Growth Indices

A. Banff Area Douglas-fir $\sigma = 25.1$

Max.	n	D	$\bar{D}$	$\bar{D}/\sigma$	Min.	n	D	$\bar{D}$	$\bar{D}/\sigma$
1588-1599	4	81	20.2	0.81	1552-1587	12	204	17.0	0.68
1609-1617	3	60	20.0	.80	1600-1608	3	68	22.7	.90
1639-1644	2	45	22.5	.90	1618-1638	7	118	16.9	.67
1666-1677	4	168	42.0	1.67	1645-1665	7	116	16.6	.66
1708-1716	3	83	27.7	1.10	1678-1707	10	110	11.0	.44
1723-1755	11	147	13.4	.53	1717-1722	2	62	31.0	1.23
1774-1788	5	97	19.4	.77	1756-1773	6	56	9.3	.37
1825-1839	5	138	27.6	1.10	1789-1824	12	166	13.8	.55
1873-1887	5	49	9.8	.39	1840-1872	11	139	13.5	.54
1897-1917	7	219	31.3	1.25	1888-1896	3	38	12.7	.51
					1918-(1950)	11	159	14.5	.58

B. Missouri River Basin Douglas-fir and Limber Pine. $\sigma = 25.33$

Max.	n	D	$\bar{D}$	$\bar{D}/\sigma$	Min.	n	D	$\bar{D}$	$\bar{D}/\sigma$
1186-1206	7	77	11.0	0.44	1207-1209	1	34	34.0	1.34
1210-1215	2	48	24.0	0.95	1216-1221	2	36	18.0	.71
1222-1239	6	116	19.3	0.76	1240-1281	14	221	15.8	.63
1282-1299	6	75	12.5	0.49	1300-1308	3	97	32.3	1.28
1309-1314	2	33	16.5	.65	1315-1323	3	37	12.3	.49
1324-1359	12	238	19.8	.78	1360-1365	2	62	31.0	1.23
1366-1371	2	18	9.0	.36	1372-1404	11	165	15.0	.59
1405-1434	10	130	13.0	.51	1435-1440	2	91	45.5	1.80
1441-1443	1	35	35.0	1.38	1444-1449	2	32	16.0	.63
1450-1467	6	90	15.0	.59	1468-1476	3	45	15.0	.59
1477-1491	5	72	14.4	.57	1492-1503	4	113	28.2	1.11
1504-1512	3	68	22.7	.90	1513-1516	2	76	38.0	1.50
1519-1530	4	91	22.8	.90	1531-1536	2	48	24.0	.95
1537-1542	2	54	27.0	1.07	1543-1548	2	42	21.0	.83
1549-1572	8	145	18.1	.72	1577-1608	12	205	17.1	.68
1609-1629	7	205	29.3	1.16	1630-1638	3	58	19.3	.76
1639-1644	2	101	50.5	2.00	1645-1683	13	146	11.2	.44
1684-1692	3	60	20.0	.79	1693-1698	2	21	10.5	.42
1699-1716	6	57	9.5	.38	1717-1722	2	63	31.5	1.25
1723-1737	5	75	15.0	.59	1738-1746	3	35	11.7	.46
1747-1752	2	25	12.5	.49	1753-1761	3	69	13.0	.51
1762-1779	6	158	26.3	1.04	1780-1785	2	37	18.5	.73
1786-1794	3	28	9.3	.37	1795-1824	10	150	15.0	.59
1825-1842	6	149	24.8	.98	1843-1872	10	135	13.5	.53
1873-1899	9	112	12.4	.49	1900-1905	2	24	12.0	.48
1906-1929	8	203	25.4	1.00	1930-1941	4	122	30.5	1.21
1942-(1950)	3	58	19.3	0.76					

C. Colorado River Basin Douglas-fir. $\sigma = 20.0$

Max.	n	D	$\bar{D}$	$\bar{D}/\sigma$	Min.	n	D	D	$\bar{D}/\sigma$
1081-1089	13	247	19.0	.95	1090-1110	7	142	20.3	1.02
(1081-1085)	5	146	29.2	1.46	1132-1161	10	177	17.7	.88
(1072-1089)	6	115	19.2	.96	1174-1179	2	28	14.0	.70
1111-1131	7	130	18.6	.93	1213-1299	29	572	19.7	.98
1162-1173	4	51	12.8	0.64	(1213-1236)	8	129	18.1	.90
1180-1212	11	[illegible]	4.7	0.24	(1246-1299)	18	365	20.3	1.02
1300-1398	33	572	5.8	.29	1399-1476	26	251	9.6	.48
(1300-1344)	15	311	20.7	1.04	(1435-1476)	14	194	13.9	.70
(1366-1398)	11	250	22.7	1.14	1495-1512	6	125	20.8	1.04
1477-1494	6	87	14.5	.73	1531-1533	1	33	33.0	1.65
1512-1530	6	36	6.0	.30	1540-1545	2	21	10.5	.52
1534-1539	2	24	12.0	.60	1573-1602	10	213	21.3	1.06
1566-1572	9	118	13.1	.66	1624-1638	3	106	35.3	1.76
1603-1623	8	172	21.5	1.08	1654-1671	6	72	12.0	.60
1650-1653	5	34	6.8	.34	1684-1686	1	49	49.0	2.45
1672-1683	4	51	12.8	.64	1705-1716	4	37	9.2	.46
1687-1704	6	20	3.3	.16	1735-1737	1	34	34.0	1.70
1717-1734	6	83	13.8	.69	1750-1782	11	151	13.7	.68
1738-1749	4	44	11.0	.55	17[illegible]-1830	11	83	7.6	.38
1783-1797	5	21	4.2	.21	1846-1848	1	21	21.0	1.05
1831-1845	5	86	17.2	.86	1855-1866	4	30	7.5	.38
1849-1854	2	30	15.0	.75	1846-1848	1	21	21.0	1.05
1867-1869	1	37	37.0	1.85	1855-1866	4	30	7.5	.38
1906-1932	9	199	22.1	1.10	1870-1905	12	163	13.6	.68
					(1870-1884)	5	83	16.6	.83
					(1894-1905)	4	80	20.0	1.00
					1973-(1950)	6	68	11.4	.57

D. So. California Bigcone Spruce $\sigma = 24.6$

Max.	N	D	$\bar{D}$	$\bar{D}/\sigma$	Min.	n	D	$\bar{D}$	$\bar{D}/\sigma$
1549-1569	7	134	19.1	0.78	1570-1596	9	207	23.0	0.94
1597-1620	8	113	14.1	.57	1621-1638	6	131	21.8	.89
1639-1650	4	75	18.8	.77	1651-1677	9	166	18.4	.75
1678-1701	8	123	15.4	.63	1702-1716	5	74	14.8	.60
1717-1728	4	30	7.5	.30	1729-1740	4	68	17.0	.69
1741-1749	3	75	25.0	1.02	1750-1767	6	92	15.3	.62
1768-1776	3	39	13.0	.53	1777-1782	2	61	30.5	1.24
1783-1806	8	128	16.0	.65	1807-1824	6	84	14.0	.57
1825-1842	6	106	17.7	.72	1843-1851	3	78	26.0	1.06
1852-1854	1	48	48.0	1.95	1855-1866	4	64	16.0	.65
1867-1869	1	46	46.0	1.87	1870-1884	5	114	22.8	.93
1885-1893	3	76	25.3	1.03	1894-1905	4	125	31.2	1.27
1906-1923	6	105	17.5	.71	1924-1935	4	54	13.5	.55
1936-1944	3	94	31.3	1.27	1945-(1950)	2	41	20.5	.83

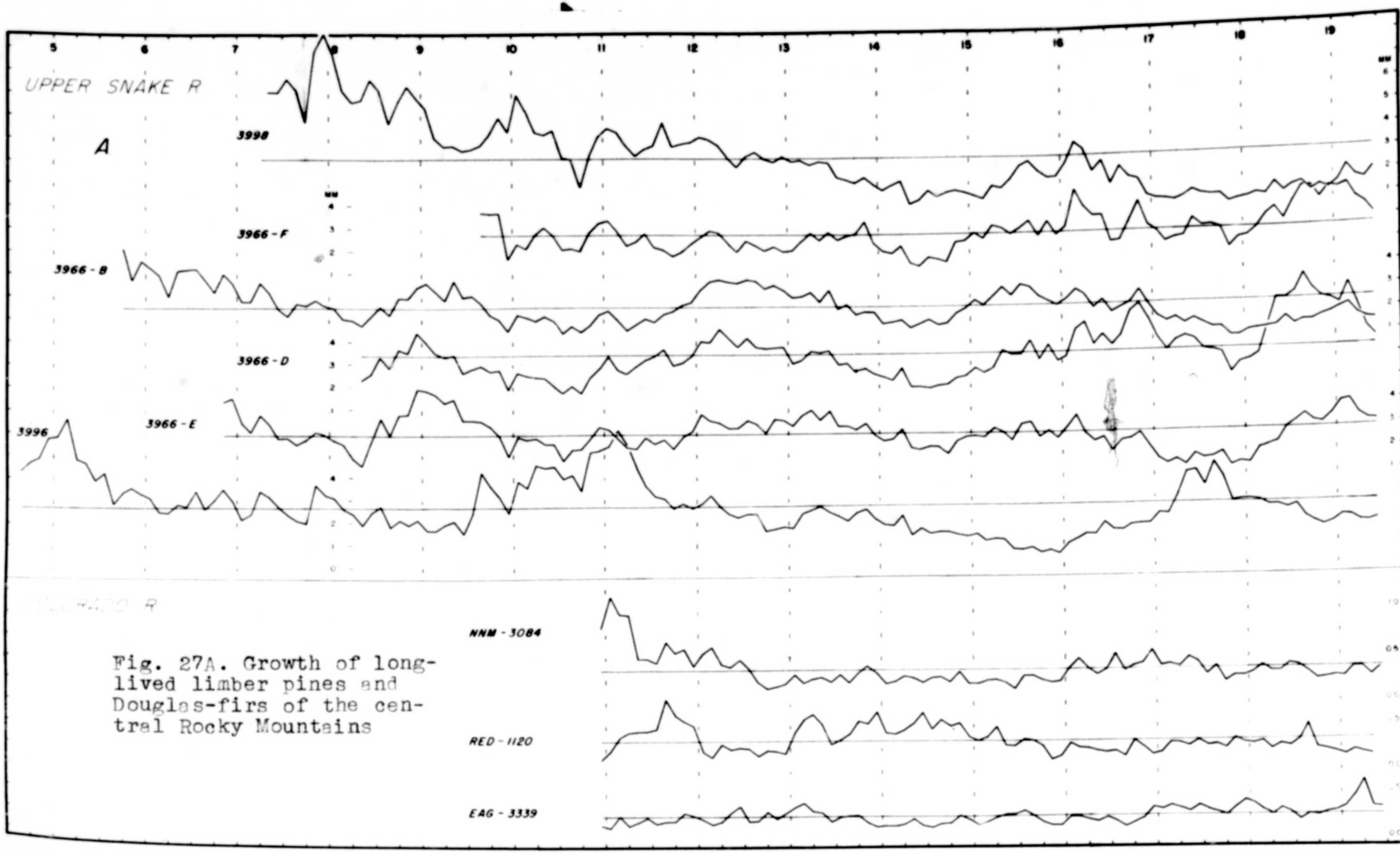
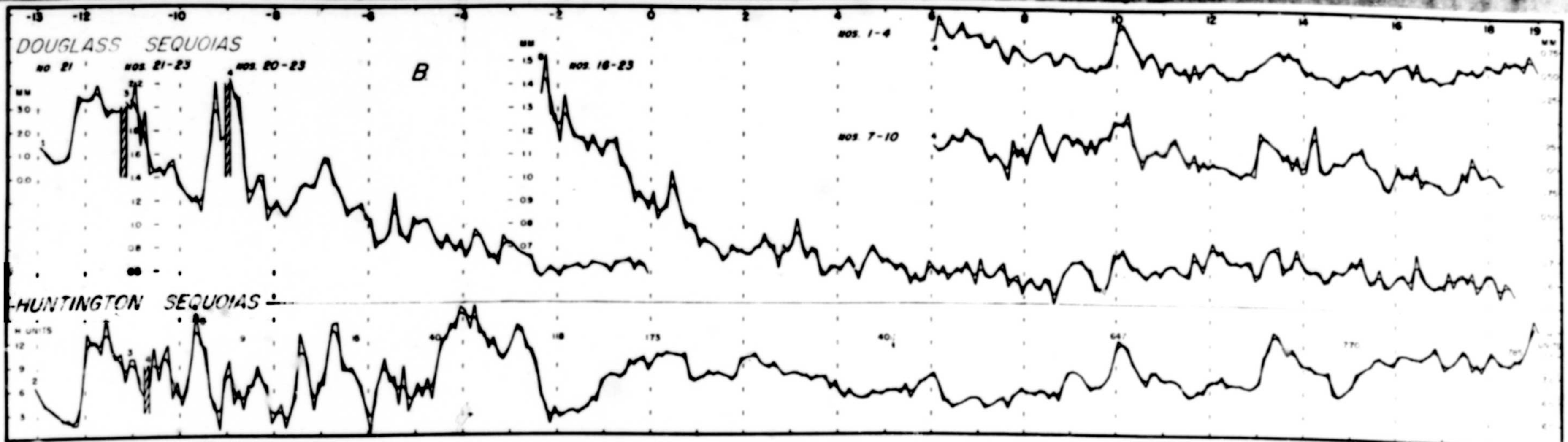


Fig. 27A. Growth of long-lived limber pines and Douglas-firs of the central Rocky Mountains



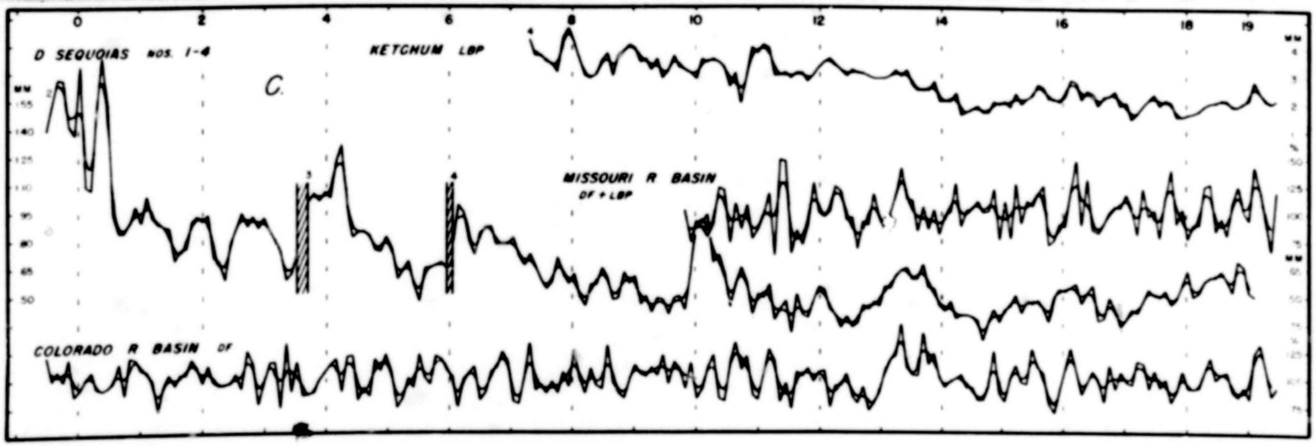


Fig. 27B. Decadal growth in various groups of giant sequoias
Fig. 27C. 9-year mean ring-widths in millenium-long chronologies

It is evident from panel A, in which the decade means of measured ring-widths along individual cores are plotted, that even in highly sensitive trees, such as that at Nine Mile Canyon (NNM-3084), single sequences contain centuries-long swings which are not necessarily representative of a general climatic fluctuation.

Within a single tree the case is different. The three radii from the stem and the single root radius (F) of the 1500-year Ketchum limber pine 3966 show fair parallelism in most details, the upward trend in the outer centuries of growth of cores D and F being the result of locally-favored growth, in one case near the edge of a wind-killed sector, in the other along the upper above-ground radius of a root. Core B, from a radius laterally centered within the vertical band of living cambium, perhaps is most representative of long-term growth trends in this tree.

The longest known growth records are those in Sequoia gigantea. Huntington's series, developed forty years ago on the basis of vast numbers of growth measures by decade sums on stump tops, has been severely criticized for inclusion of many insensitive trees and for lack of precision, the statistical corrections made by Huntington for the probable differences between gross count and true age being considered inadequate.

In Figure 27B, the principal old sequoia records individually analysed by Douglass, with all anomalous rings solved and dating precisely done to the year, are separated according to type: 1 to 4--ridges or upper slopes; 7 to 10--swampy basin near site of preceding set; 16 to 23--drier basin or intermediate slopes, mostly from sites at some distance from the first two groups, and containing three 3000-year trees.

The striking differences in ring sensitivity between sequoias from the most arid as compared with the most moist sites is much less evident in the highly compressed group mean curves of the diagram. Indeed, many of the major characters, such as the maxima in the 1000's and 1300's and the minimum between, appear in both swampy basin and dry ridge and are present in modified form in the longest set.

It is notable that the much-maligned, crudely developed Huntington series, based on hundreds of trees, presents much the same major features as the highly sensitive Douglass group 1-4, with one exception, a pronounced upward trend in the former for the past twelve centuries. Huntington ascribed this to basal flare; probably playing a part also are factors such as the natural tendency to select for measurement the stump radius most open in the outer centuries, and incomplete elimination of the incoming effect of a large number of fast-growing younger trees on the average. The first factor is in slight evidence in the D 1-4 series also.

The close relation of the D 1-4 index to the rain-sensitive bigcone spruce chronology for Southern California, and the relation evident in Figure 27C to the more distant Colorado Basin index during the past eight centuries lend confidence in the climatic significance of the better sequoia chronologies during the past millenium. Descreased correlation with the Colorado Basin index suggests that the longer climatic fluctuations in sequoia growth of earlier centuries are increasingly less reliable, though it should be recalled that the archaeological portion of the Colorado Basin chronology may not report longer fluctuations.

Although the Snake River (Ketchum) index in Fig. 27C is based on only 4 cores from 3 trees at one site, it tends to parallel in many details the Missouri Basin index based on a large number of relatively short-lived trees from a number of areas. It would appear that much new information on centuries-long climatic fluctuations in the northern Rocky Mountain area would become available with extensive collection and analysis of the recently discovered Ketchum-type trees. The preliminary suggestion in

Fig. 27C is that these long-period changes at times are in phase and at other times out of phase with those in the southern Rocky Mountains and in southern California.

INTER-AREA VARIATIONS

Although the transect figures above show in some cases a more-or-less steady change from minimum to maximum or the reverse along the transect, there is no obvious indication in these figures of any systematic, progressive displacement. Thus, synoptic long-term forecasting, after the fashion of the daily forecasting of weather, is not possible, unless hidden characteristics of this kind are shown to exist.

The different extent of the affected area in one very dry year as compared with another is a well-known climatic observation. The fluctuating range of general maxima and minima as a function of time is seen in the transect figures to be characteristic of all documented centuries. Occasional droughts are present in pronounced form over very extensive areas, such as those for the late 1500's and the late 1800's. The latter, which ended with an extremely pronounced minimum in 1900-04 in the Colorado River Basin, is of special interest. It is well developed in southern California and throughout the southern Rocky Mountains. It is much less emphatic in the upper Missouri Basin, and at Banff, Alberta, is replaced by perhaps the most extreme maximum in the past four centuries.

The foregoing leads to a numerical examination of the possibility of significant correlation in rainfall indices between selected distant areas. In Table 12 sub-group correlations were presented, almost all between various areas of the Colorado River Basin. The analysis is extended in Table 25 to some of the major basin indices. It is evident that the strong negative correlation between Banff and Southern California for several decades near 1900 is an unusual occurrence: the next earlier half-century

Table 25. Interregional Correlation Coefficients

A. 25-Year Intervals

Interval	SCL-S: CCL	SCL-S: LVO	SCL-S: BC	SCL-S: MO	SCL-S: BNF	BC: BNF
1550-1574	+.36	+.05	-.29	+.32	+.00	+.20
1575-1599	+.41	+.23	-.03	+.52	+.16	+.18
1600-1624	+.28	+.09	+.04	-.02	-.00	+.50
1625-1649	+.43	+.28	-.21	+.44	+.37	+.39
1650-1674	+.75	+.07	-.37	+.03	-.41	+.52
1675-1699	+.28	-.05	-.27	-.20	-.30	+.33
1700-1724	+.24	-.02	+.12	+.30	+.08	+.33
1725-1749	+.57	+.67	+.01	+.32	+.01	+.52
1750-1774	+.38	+.07	-.20	+.51	-.08	+.13
1775-1799	+.66	+.48	+.16	+.03	-.04	+.45
1800-1824	+.58	-.13	-.07	-.17	+.27	+.06
1825-1849	+.69	+.44	+.29	+.44	+.37	+.70
1850-1874	+.42	+.46	+.13	+.33	+.15	+.03
1875-1899	+.10	-.11	-.40	-.18	-.37	+.21
1900-1924	+.32	+.29	-.17	+.43	-.49	+.66
1925-1944	----	----	+.47	+.02	+.04	-.17
Mean	+.43	+.19	-.05	+.20	-.015	+.315

A. 50-Year Intervals

Interval	SCL-S: CRB-1	SCL-P: CRB-1	SCL-S: CRB-2	SCL-P: CRB-2	SCL-S: CRB-8	SCL-P: CRB-8
1800-1849	+.40	+.42	+.39	+.41	+.32	+.38
1850-1899	.43	.44	.48	.47	.57	.42
1900-1944	.47	.62	.59	.75	.54	.85
Mean	.43	.49	.49	.54	.48	.55

C. 100-Year Intervals

Pairs	1550-1649	1650-1749	1750-1849	1850-1944	Mean
SCL-S:CCL	+.47	+.53	+.49	+.30[1]	+.45
SCL-S:LVO	+.24	+.20	+.24	+.21[1]	+.22
SCL-S:BC	-.17	-.19	+.04	-.03	-.09
SCL-S:CRB-3	+.49	+.46	+.28	+.33	+.39
SCL-S:CRB-4	+.52	+.49	+.43	+.40	+.46
SCL-S:CRB-5	+.58	+.52	+.46	+.49	+.51
SCL-S:CRB-6	+.59	+.52	+.42	+.54	+.51
SCL-S:CRB-7	+.59	+.51	+.45	+.57	+.53
SCL-S:CRB-8	----	----	+.42	+.58	----
SCL-S:CRB-9	----	+.49	+.45	+.47	----
SCL-S:MO	+.40	+.23	+.27	+.13	+.26
SCL-S:BNF	+.09	-.17	+.15	-.20	-.03
CRB-7:MO	+.31	+.09	+.18	+.21	+.20
CRB(1+2):ORE	----	+.22	+.16	+.25[2]	----
CRB-9:ORE	----	+.24	+.08	+.20[2]	----
CRB-9:BC	----	-.15	+.05	-.03[2]	----
BNF:BC	+.32	+.42	+.32	+.26	+.33

1. 1850-1924   2. 1850-1935

BC----Brit. Columbia DF+PP; Table 2-A
BNF---Banff Area DF, Table 2-C
CCL---Cent. Calif. (Mono-Owens) Jeff.pine; Table 2-AF
LVO---Antev's SE Oregon; 2-AE
MO----Missouri River DF; 2-G

ORE-- Keen's E.Oregon PP; Fig. 19
SCL-S So.California BCS; Table 2-AG
SCL-P So.California PP; Table 2-AH
CRB Colorado River Basin series: 1--1945 PP,Fig.13; 2--PNN,2-V;3--8 DF, Fig.14;4--7 DF, Fig.14; 5--12 DF, F.14; 6--25 DF,Table 2-O;7--60 DF,2-M; 8--84 DF,Fig.14; 9--1945 DF,Fig.13

of similar character is that for 1650-1699. Each was preceded by relatively strong positive correlation. The correlation for the past 400 years as a whole is that for random series.

A preliminary general analysis of the march of differences in chronology is developed in Figure 28. Since the standard deviations of the series which were paired and differenced for this figure are all roughly of the same order of magnitude, no corrections were made for this critical characteristic except for the extremely variable Big Bend index; more precise analysis would require the adjustment of all series.

The subtraction of one series from another with which it is negatively correlated would result in an increase in the amplitude of at least some of the maxima and minima; the opposite effect would follow for positively correlated series. Comparison with the component series in the transect figures shows that these effects, if present in any part of Figure 28, are quite weak.

The rainfall coefficient of correlation for the pair of series southern California: Colorado River Basin, 1896-1950, is +.40; for southern California: Missouri River Basin (central division, Montana), same interval, it is +.11. These are somewhat less than the corresponding growth coefficients of Table 25C. After the rainfall series are smoothed by three-year running means, as in Chapter IV, the respective coefficients are +.28 and +.16. The corresponding smoothed growth coefficients are +.52 and +.19. The smoothed rainfall correlations are, thus, also less than the corresponding growth coefficients. Although the analysed interval is relatively short, these consistent results suggest, at least tentatively, the following possibilities: (1) growth is dependent on some factor other than rainfall,with which the latter is also correlated, (2) growth fluctuations depend in part on some factor, such as ultra-violet

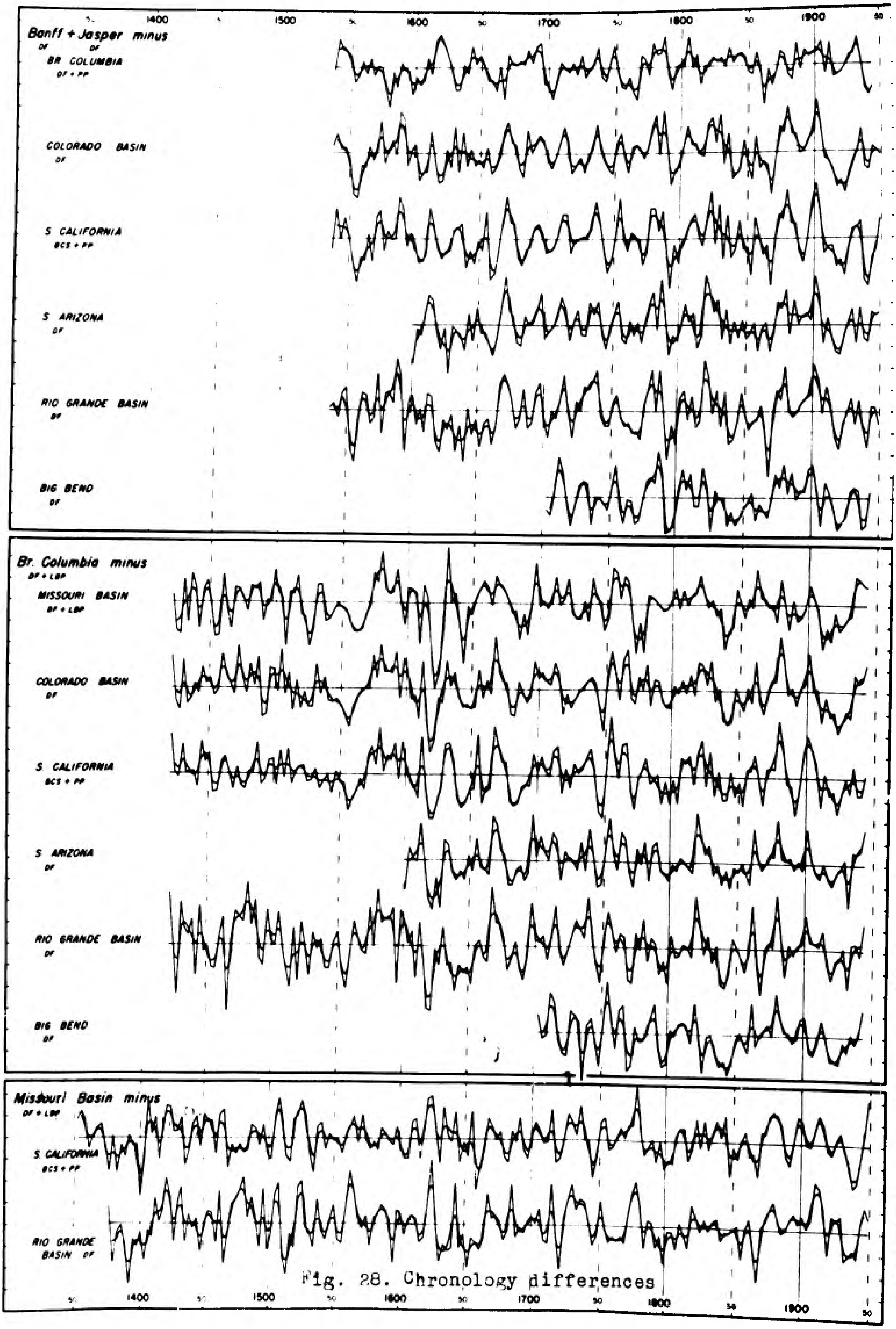


Fig. 28. Chronology differences

radiation, which fluctuates similarly in geographically distant areas, and (3) the growth series are more representative of the rainfall in montane forests than the gage records.

CYCLIC VARIATIONS

Preliminary optical analyses of the cycles in the data of this report were made with the cycloscope (Douglass, C.I.W. Pub. 289. III). Only 3-year or longer means of the data were analysed for cycles in the range 15 to 100 years. In no data were cycles found of such regularity and strength as to assure physical reality. Of those cycles having more pronounced amplitude, the following approximate wave-lengths in years seem worthy of note for future reference:

Banff: 21 to 24, 60, since 1450.

Colorado River Basin: 21 to 23, 60+ , 100, since 50 B.C.; 80, roughly during first 900 and last 550 years.

Snake: 20, 24, and 40, since 1650.

So. Platte: 21 and 38 to 43, since 1350.

Rio Grande: 21 to 23, since 1450.

Banff + Jasper minus Colorado River Basin: 24, 40, 47, 60, since 1550.

Banff + Jasper minus So. California: 20, since 1550.

Brit. Columbia minus Missouri: 21, since 1425.

Brit. Columbia minus So. California: 20+ , since 1440.

Missouri minus So. California: 45 to 50, since 1350.

These persistent wave-lengths are average values, the maximum-to-maximum interval varying greatly, as do the wave-form and amplitude; in some cases a change of phase within the analysed range seems indicated. More precise analysis at these and other, almost equally promising, settings of the cycloscope are postponed for the time being.

VI. SUMMARY AND CONCLUSIONS

Based on about one-third million annual rings in selected, drought-sensitive trees from semi-arid sites, regional indices have been derived for the upper basins of all the major streams of the western United States. Almost all indices are statistically well-based for about 500 years; the Colorado and Missouri indices are well documented for about 800 years. Three series of maximum length are: Colorado, 2,009 years, including the extension in archaeological beams; Snake, 1494 years; Missouri, 973 years.

Fundamental studies. A major element in the construction of these indices was the discovery and extensive sampling of a category of drought-recording, stunted conifers growing with extreme slowness on the most adverse sites and attaining ages twice or more the normal for the species on optimum growth sites. The oldest tree thus far discovered in each of the principal species is: limber pine, 1510 years; pinyon pine, 975 years; Rocky Mountain Douglas-fir, 880 years; ponderosa pine, 850 years. The much longer-lived *Sequoia*, growing in a relatively moist environment, were not sampled for this report; a brief re-examination of th published records is noted below.

In confirmation and extension of earlier work, the ring growth in the lower stems of dry site Rocky Mountain conifers at or near the lower forest border was found to be most rapid during June and essentially completed, as far as total ring thickness is concerned, by the end of July throughout the sampled range of over 20° of latitude. Earlier initiation of the growth season in young trees on south-facing slopes, growth-lag in pines as compared with Douglas-firs, differences from year to year as a function of climate, and similar effects apparently seldom extend the season at either limit by more than a week or two. Initiation of cambial growth in extremely overage trees is apparently not greatly delayed as compared with young trees of the same species on the same site.

As much as 4% of the rings may be omitted on cores from dry-site mature conifers of the Southwest; in higher latitudes, as in Idaho and Montana, thousand-year ring sequences from the dry lower forest border may show only one such omitted ring on the core.

The mean sensitivity--the fluctuation in ring-width from year to year relative to the mean trend in ring-width--remains essentially constant during the life of centuries-old conifers, the real tendency for higher sensitivity with slower growth being relatively slight. The mean sensitivity in trees of good rain-recording quality may range from less than 20% to over 80%. The standard deviations of the regional mean curves show a corresponding range from about 20% to over 60%.

Correlation analysis of a typical, sensitive Douglas-fir yielded a mean coefficient $\underline{r}$ of +0.94 between the ring-widths along any two stem radii, and +0.99 between the means for four equidistant radii as compared with that for the intermediate ones.

Correlation coefficients between typical ring chronologies show that most of the local variations are eliminated in averages of five to ten well selected cores. The coefficients decrease with increasing distance between the groups, as one would expect in rainfall-related indices.

A systematic correlation analysis indicates that the rainfall interval most closely represented in the principal local and regional chronologies of this report is the year ending in June for Douglas-fir and June or July for the pines. Slight further differences with species and site are apparently of no permanent significance, being a function of the partly accidental form and sequence of rainfall distributions during the small number of years of gage records. Growth and rainfall series smoothed by three-year running means yield systematically higher coefficients than unsmoothed data, in some cases closely approaching +0.90. It should be noted, however, that these apply only to the few decades of gage records; the interpretation of the indices of this report in terms of absolute rainfall, as distinguished from relative rainfall, becomes increasingly approximate with extension into the past.

Centuries-long characters in west-American rainfall. Despite limitations in amount of material and uncertainties inherent in the data of this report, some conclusions of fair reliability may be drawn regarding long-term rainfall variations in the West.

Evidence is strong for the existence of a great 200-year wave in rainfall in the Colorado River Basin, the 1200's extraordinarily dry, the 1300's extraordinarily wet (more precisely, perhaps, 1215-1299 and 1300-1396). The droughts of the first interval and the floods of the second appear to have far exceeded in duration and intensity those recorded by modern gages.

The rainfall and growth maximum at Banff, 1897-1904, appears to have exceeded that for any like interval in the past four centuries. During this maximum and for several earlier years, however, deficient growth and such intensity of drought as have been rarely approached in the centuries of growth records prevailed in both the Colorado River Basin and southern California. This negative correlation is, however, not systematic, as will be noted.

Noteworthy among other climatic events is the pronounced and extensive drought of 1573-1593, which seems to have been as severe in southwestern Montana as it was in the southern Rocky Mountains and southern California, though it apparently did not extend into Alberta. The total flow of the Colorado River during the two years 1584-85 may not have exceeded the record for low runoff recorded in 1934.

When many centuries of data are examined, the frequency distribution of growth departures in the widely based regional indices of this report tends to assume that of the normal error function.

Some of the indices suggest the possibility of a peculiar change in the characteristic march of rainfall some three centuries ago. In southern California the tendency for long-term swings to one side of the growth-mean or the other, which had been typical for some centuries preceding the mid-1600's, gave way to cycles of much shorter average duration. This tendency is very pronounced in the Colorado River Basin. On the other hand, a reverse tendency seems to be indicated in the Missouri River Basin indices, in which shorter variations are more characteristic preceding 1650. It is perhaps no more than a coincidence that about 1645 to 1715 occurred the well-known great dearth in sunspots, for some of the representative growth indices in this report, from regions other than those just noted, apparently do not record such a change.

The 3200-year Sequoia chronologies developed by Douglass and Huntington for the relatively moist southern Sierra Nevada have been re-examined in light of the highly sensitive southern California and Colorado River Basin chronologies. The better Sequoia series show a fairly good relation to these chronologies and thus can be taken to provide a fair first approximation to southern Sierra rainfall for the past 1500 to 2000 years. Too few good records in earlier years of the Douglass collections and cumulative errors in the Huntington series lead to the conclusion that at least the 1300 years of Sequoia chronology in B.C. have at present very limited climatic value.

Mapped sequences of chronologies along the Pacific Slope and the Rocky Mountains exhibit no evident systematic time displacement in either short-term or long-term fluctuations, which would permit long-range synoptic forecasting after the fashion of the daily forecasting of weather.

Pairs of regional indices from widely separated latitudes, such as Banff and southern California, show that decades-long intervals of strong negative correlation may be succeeded by similar intervals of strongly positive or of no correlation. The reasons for the inferred long-term, massive changes in certain details of the general circulation of the atmosphere may perhaps be clarified with the aid of more dendrochronologic data.

Appendix A. Location Guide to Sampled Stations, Table 1

1 -- CQV. 4 mi N of Quesnel, B.C., on Prince George road.

2 -- CWL. About 5 mi N of Williams Lake on Quesnel road.

3.-- CAL. N and W of Alkali Lake, B.C.

4 -- CKM. 4-5 mi by winding road WNW of Tranquille Sanatorium, B.C.

5 -- JSP. About 2 mi. along Pyramid Lake road from Jasper, Alta.

6 -- AGN. Slopes above Lake Agnes, Banff National Park, Alta.

7 -- BNP. Tunnel Mountain at Banff, Alta.

8 -- BNP. Near Power House about 2 mi. from Banff, Alta.

9 -- BNP. At milepost 2 on Banff-Jasper highway.

10 -- EXH. Limestone quarry near Exshaw, Alta.

11 -- CVR. 2-3 mi. SW of Vernon, B.C.; granite.

12 -- OPN. W--facing slopes above Okanagan Lake about 10 mi. N. of Penticton, B.C.

13 -- ORO. 0.2 mi. S of Chopaka, Washington.

14 -- OKN. Toats Coulee, 10 mi. N of Conconully, Washington.

15 -- REPh. Quartz Mountain Lookout, 10 mi. SE of Republic, Washington.

16 -- REPl. Near junction Quartz Mountain and Republic-Grand Coulee road.

17 -- MWTn. Boulder Creek near Winthrop, Washington.

18 -- MWTe. Pipestone Canyon near Twisp, Washington.

19 -- MSS. 6 mi. S of Missoula, Mont., on Hwy 93.

20 -- SUL. At jcn Hwy 93 and Bitterroot East Fork Road near Sula, Mont.

21 -- SMNs. About 10 mi N of N.Fork, Idaho, on Hwy 93.

22 -- SMNn. At N. Fork, Idaho.

23 -- SMNs. 16.5 mi S of Salmon, Idaho, on Hwy 93.

24 -- KETn. Near boundary Sawtooth National Forest, 4 mi N of Ketchum, Idaho.

25 -- KETh. 12.2 mi NE of Ketchum on Sun Valley (Trail Creek) road.

26 -- KETe. 9.2 mi NE of Ketchum on Sun Valley road.

27 -- TWTe. 16.6 mi E of Moran Lake, Wyoming, on Hwy 287.

28 -- TWTw. 9.6 mi E of Victor, Idaho, on Hwy 22.

29 -- TWTs. 19.5 mi S of Jackson, Wyoming, on Hwy 189.

30 -- HEL. Near entrance to Helena Nat. Forest, on Hauser Lake Road NE of Helena, Mont.

31 -- TOWe. 12 mi. W of Hwy 89 on Hwy 6 to Townsend, Mont.

32 -- TOW. 0.2 mi. E of entrance to Helena Nat. Forest on Hwy 6 from Townsend.

33 -- BTT. About 21 mi. SE of Butte, Mont., on Hwy 105.

34 -- DIV. 3 mi. W of Divide, Mont., on Hwy 43.

35 -- LIVe. Overlooking Springdale, Mont; 1950 group of 7 trees 0.2 mi W of 1949 group

36 -- LIV. 5 mi. S of Livingston, Mont., on Hwy 89.

37 -- GRD. 3 mi. N of Mammoth Hot Springs, Yellowstone Nat. Park.

38 -- DLL. Above Big Sheep Ranger Station 6 mi. SW of Dell, Mont.

39 -- DLLw. 10 mi. by road SW of Big Sheep Ranger Station.

40 -- LAN. N of Popo Agie River above Middle Fork Ranger Station and SW of station on switchback road.

41 -- LAR. Near entrance to Medicine Bow Nat. For. on Hwy 230 SW of Laramie.

42 -- NPK. 2 mi NW on Hwy 125 from junction with Hwy 127 in North Park, Colorado.

43 -- IDS. About 2.5 mi E of Idaho Springs, Colorado, on Hwy 40.

44 -- EVN. 7 mi S of Idaho Springs on Mt. Evans road.

45 -- PIKw. 1 mi E of Lake George, Colorado.

46 -- HRT. 0.5 mi on Hwy 24 E of boundary of Cochetope N.F., S of Antero Junction, Colorado.

47 -- PIKh. At upper timberline on Pikes Peak road.

48 -- SPLs. 2 mi S of Lake George, Colorado, on Eleven-Mile Canyon road.

49 -- SAL. 6 mi E of Salida, Colorado.

50 -- LOGe. 29 mi NE of Logan, Utah, on Hwy 89.

51 -- LOGw. 13.4 mi NE of Utah State Agr.Coll., Logan, on Hwy 89.

52 -- SLC. Near Soapstone Ranger Station, about 16 mi E of Kamas, Utah, on Hwy 150.

53 -- SLC. About 1 mi NW of station 52.

54 -- WND. About 9 mi. NE of Pinedale, Wyoming, on Fremont Lake road.

55 -- BGP. 0.5 mi. E of Middle Piney Lake, Wyoming.

56 -- VER. S 10, T 1S, R 19E, N of Vernal, Utah.

57 -- VER. S 18, T 2S, R 22E, N of Vernal, Utah.

58 -- STM. 3.5 mi. E of Clark on Summer Camp (Seedhouse) road. Location in error in ref. , Table 1.

59 -- HSS. Above Spring Creek about 1.5 mi. S of Hot Sulphur Springs, Colo.

60 -- RED. Kiln Creek about 1.5 mi. E of Redcliff, Colorado.

61 -- EAGe. 6 mi. E of Eagle, Colo.; cliffs N of Hwy 6.

62 -- EAG. 1.1 mi. W. of Eagle, Colo. Gypsum cliffs S of hwy.

63 -- SOP. At White River N. F. boundary on Hwy 133 S of Carbondale, Colo.

64 -- GUNe. 26.6 mi. E of Gunnison, Colo., on Hwy 50.

65 -- GUNn. 1.0 mi. NE of Almont, Colo.

66 -- GUNl. 1.3 mi. W of Lake Fork bridge on Hwy 50.

67 -- BLK. Warner's Point, Black Canyon of the Gunnison Nat. Mon., Colorado.

68 -- DOL. Dry Can., about 5 mi. N of McPee, Colo., on Hwy 145.

69 -- NDU. About 30 mi. N of Durango, Colo., on Hwy 550.

70 -- DURh. Dyke Canyon above Trimble Springs, Colo.

71 -- DURl. Earl Morris' Talus Village Ruin near Trimble Springs, Colo.

72 -- MVR. E wall near mouth of Navajo Canyon, Mesa Verde Nat. Park, Colo.

73 -- MVR. Spruce (Campfire) Canyon, W of Hq. area, M.V.N.P.

74 -- MVR. Spruce Tree Canyon, at Hq., M.V.N.P.

75 -- MVR. Fewkes Canyon, M.V.N.P.

76 -- MOAs. 11.8 mi. S of Monticello, Utah, on Hwy 47.

77 -- BRYs. Bryce Point, Bryce Canyon Nat. Park, Utah.

78 -- PRTw. 0.5 mi. E of entrance, Powell N. F., on Hwy 12 E of Bryce Jct., Utah.

79 -- BRYe. Near lower forest limit Tropic Canyon road, Bryce Canyon N. P., Utah.

80 -- CED. 3.5 mi. SE of Cedar City, Utah, on Hwy 14.

81 -- ZIO. 0.5 mi. W of E Checking Station, Zion Nat. Park, Utah.

82 -- KBBl. Near Oak Canyon Ranger Sta., about 6 mi. on E road from Jacob Lake Ranger Sta., Arizona.

83 -- KBBh. About 6 mi. S of Jacob Lake, Arizona.

84 -- FOR. Low cliffs E and S of Forestdale Ruin, Forestdale Creek, Ariz.

85 -- MGN. San Francisco Mts., W of Luna, N. Mex., and E side of pass on Hwy 260.

86 -- HTP. About 30 mi. N of San Carlos, Arizona, in sawmill area.

87 -- BRL. S of Mogollon Rim on Hwy 666.

88 -- ROZ. N of Clifton, Ariz., on Hwy 666.

89 -- MOL. Ridge west of Mogollon, N. Mex.

90 -- MGH. Just E of old sawmill at crest on mountain road E of Mogollon, N. Mex.

91 -- GCF. Near Gila Cliff Dwellings Nat. Mon. N of Silver City, N. Mex.

92 -- PTO. Swift Trail road to Heliograph Peak, Graham Mts., Ariz. Pine near Ladybug Saddle, Douglas-fir at Turkey Flat.

93 -- CHR. Onion Saddle, Chiricahua Mts., Arizona.

94 -- CHR. Above Rustler Park, Chiricahua Mts., Arizona.

95 -- SCM. Head of Bear Canyon, Santa Catalina Mts., Arizona.

96 -- SCH. Near top of Mt. Lemmon trail above Summerhaven, Arizona.

97 -- SRM. Near lower limit of Douglas-fir along Florida Canyon trail above Santa Rita Exp't. Sta., Arizona.

98 -- SRH. Head of Florida Canyon, Santa Rita Mts., Arizona.

99 -- DIN. S 1/2 S 17, T 6N, R 101W, Dinosaur Nat. Monument, Colorado-Utah; COL-6877, submitted by the University of Colorado Museum.

100 -- UIN. 21 mi. N of Vernal, Utah, on Menilo road.

101 -- NMMe. Nine Mile Canyon, Utah, about one mi. E of junction Argyle and Minnie Maud Creeks.

102 -- NMMc. 5 mi. westerly on road from 48.

103 -- NMMw. 15 mi. W and S on road from 48.

104 -- NMI. About 4 mi. NE of Indian Canyon Ranger Station, Utah.

105 -- NMI. Near Indian Canyon Ranger Station, Utah.

106 -- SUN. One mi. N of Sunnyside, Utah.

107 -- SUN. NE of junction Whitmore and Bear Canyons N of Sunnyside, Utah.

108 -- HLL. Near Rain gage #3, Ute Indian Agency, Utah.

109 -- HLL. School Section Canyon, head of Hill Creek, Utah.

110 -- HSS. Hills to S above Hot Sulphur Springs, Colo.

111 -- EAGw. 22 mi. E of Glenwood Springs, Colo., on Hwy 6.

112 -- EAG. See Site No. 62.

113 -- RIF. Near Rio Blanco N of Rifle, Colo.

114 -- RED. About one mi. E of Site No. 7.

115 -- ASP. 11.5 mi. NW of Aspen on Hwy 82.

116 -- BRYw. See Site No. 78.

117 -- BRYe. See Site No. 79.

118 -- KBB. About 7 mi. S of Jacob Lake, Arizona.

119 -- MAN. 3 mi. E of Mancos, Colo., on Hwy 160.

120 -- MVRm. Head of Morefield Canyon, Mesa Verde Nat. Park, Colo.

123 -- MVRn. Near head of Prater Canyon, M.V.N.P.

121 -- MVRn. North Rim W of Knife-Edge, M.V.N.P.

122 -- MVRn. Near Hill's Cabin, Point Lookout, M.V.N.P.

124 -- MVRw. Wetherill Mesa N of Mug House, M.V.N.P.

125 -- MVRs. See Site No. 72.

126 -- MVRs. See Site No. 74.

127 -- MVRs. Twin Trees Area, M.V.N.P.

128 -- MVRs. E side of Soda Canyon opp. Balcony House, M.V.N.P.

129 -- BTA. Near Betatakin Ruin, Arizona.

130 -- DFI. Near Fluted Rock SE of Chinle, Arizona.

131 -- DFI. About 8 mi. N of Ft. Defiance, Arizona, on Sawmill road.

132 -- ZUN. 7 mi. S of Hwy 66 on Ft. Wingate road, N. Mex.

133 -- GRN. Near Bright Angel L. O., Grand Canyon Nat. Park, Arizona.

134 -- GRN. Buggeln Hill, G. C. N. P.

135 -- SUw. Luna Pass W of Luna, N. Mex.

136 -- SU. Chicago Nat. History Museum SU site, N. Mex.

137 -- POP. About 4 mi. E and S on Nantack Ridge road from the Univ. of Arizona Museum summer camp at Point of Pines.

138 -- POP. Near crest of Nantack Ridge road 8.0 mi. from U.A. camp.

139 -- WWG. Spring Gulch Canyon, Colo.

140 -- FTG. About 5 mi. NE on Hwy 160a.

141 -- FTG. Rolling hills N. of Ft. Garland, Colo.

142 -- ANT. 12 mi. W on Hwy 17.

143 -- CEB. Echo Cliffs Amphitheatre, about 15 mi. S of Cebolla, N. Mex., on Hwy 84.

144 -- TAO. Above Rio Pueblo, N. Mex., about 15 mi. W of divide (Holman Pass) on Hwy. 3 from Las Vegus to Taos.

145 -- TAOh. About one mi. W of Holman Pass, Sangre de Cristo Mts., N. Mex. 7a is SFEe group in Tree-Ring Bulletin 8(4), 1942; 7b site extends the 7a area for about a mile westward along the road.

146 -- PEC. Nr Glorieta Pass on Hwy 85 S.W. of Pecos, N. Mex.

147 -- PECs. Shallow canyon in mesa about one mi. W of Hwy 85 and 5 mi. S of Pecos Ruin, N. Mex. This is SFEs group in Tree-Ring Bulletin 8(4), 1942.

148 -- ALB. Sandia Mts., N. Mex., 2-3 mi. NW of Sandia Park on Hwy 44.

149 -- ALBn. La Madera Winter Sports area, Sandia Mts. N. Mex.

150 -- CCR. About one mi. S. of Cloudcroft, N. Mex. Two specimens in this group from site 13.

151 -- CCR. Sacramento Lookout, Lincoln Nat. Forest, N. Mex. One P. ponderosa, one P. strobiformis.

152 -- GUA. Guadalupe Mts., N. Mex. Nr. mouth of Devils Den Canyon S. of El Paso Gap.

153 -- GUA. About 0.5 mi. S. of Dark Canyon Lookout, Guadalupe Mts., N. Mex.

154 -- MCD. Mt. Locke, Texas, site of McDonald Observatory.

155 -- BBN. Boot Springs Area, S. of Hq., Big Bend Nat. Park, Texas.

156 --- TAH. 2 mi S of Glenbrook Inn, Nevada, facing Lake Tahoe.

157 -- MONh. Tioga Pass road E of Yosemite National Park, 1.5 mi E of crest.

158 -- MONh. Tioga Pass road, 1.0 mi E of crest.

159 -- MONl. SE of Mono Craters, about one mi N of old sawmill.

160 -- MONs. Northern area of Mono Craters, California.

161 -- YOSh. N and E of Tenaya Lake, Yosemite N.P.

162 -- YOSw. 0.8 mi above Wawona Road Tunnel, Y.N.P.

163 -- YOSs. Ridge N of Wawona Ranger Station, Y.N.P.

164 -- OWVn. Sherwin Summit, about 20 mi NW of Bishop on Hwy 395.

165 -- CHA. 0.3 mi E of Charleston Mt. Lodge, Spring Mts., Nevada. Several cores contributed by G. C. Baldwin.

166 -- ANGw. Antimony Peak, about 5 mi WNW of Chuchupate Ranger Station, W of Gorman, California.

167 -- ANGn. Lower Shake Canyon and Sawmill Mt. About 7 mi W of Lake Hughes, California.

168 -- ANGe. Mill Creek Divide, about 10 mi S of Vincent, Cal.

169 -- ANGs. Los Angeles Crest Hwy near Mt. Lawlor.

170 -- BRNn. N of Baldwin Lake and 8 mi E of Big Bear Ranger Station, San Bernardino Mts., Cal.

171 -- BRNn. 0.2 to 2.5 mi E of Big Bear Ranger Station; N of road.

172 -- BRNs. Near head of Siberia Creek, SW of Big Bear Lake.

173 -- JAC. 0.5 to 1.0 mi E of Keen Camp Summit, Hwy 74 E of San Jacinto, Cal.

174 -- PAL. 2 mi on Palomar Mt. road above junction with Highway 15 mi SE of Palo, Cal.

175 -- JUL. 2.5 mi E of Julian, Cal., on Hwy 78.

176 -- MXDa. Ridges near lumber camp at El Salto, Durango State, Mexico.

177 -- MXDc. Quebrada de la Huizache, about 15 mi. W of El Salto and several miles WSW of side camp at Campana; lat., long., and elevation of groups 2 to 5 represent rough estimates.

178 -- MXDb. Logs sampled in lumber yard at El Salto.

179 -- MXDe. Quebrada Chapultepec, about 8 mi. S of El Salto.

180 -- MXM. Cueva Grande, about 5 mi. westerly from Desierto de Los Leones Monastery.

APPENDIX B. GROWTH TABLES

The growth indices in Table 2 are of two types. For almost all basins standardized growth departures are tabulated in per cent of the mean trend (e.g., the value 100 represents the mean of all measures after removal of age trend); unless otherwise stated, the index is of this type. For some localities and regions, also, year-by-year averages of the ring-widths in mm are tabulated. The important property of statistical homogeneity is characteristic of the latter type of series, which is based on continuous records from the same trees throughout the entire length of the index, except for minor adjustments at the extreme dates in some cases. Reference should be made to the location data of Table 1 to judge what portions of the various river basins are representated in the indices: in all cases the upper basin, in some only the headwaters areas.

A. A mean of Williams Lake, Alkali Lake, and the two Tranquille groups. Homogeneous 1702--. Fig. 1.

B. Homogeneous 1560--. Fig. 2.

C. A mean of four Douglas-fir stations in the immediate vicinity of Banff. See note on Fig. 2, above. Homogeneous 1800--.

D. The N. Central Washington index of Fig. 19. See note on that figure.

E. One tree at Ketchum East preceding 1372, two (KETe and KETn) 1372-1387, three (one from SANs), 1388-1477; means of three 500-year DF groups averaged, then standardized, 1478-1950, for a homogeneous series in that interval, based on 11 trees.

G. A mean of the individually standardized series of Fig. 4.

H. A mean of the individually standardized series of Fig. 4.

I. 1 tree, 1336-1369; two, 1370-1514; three, 1515-1749; the average growth of six trees, 1750-1946, was standardized for a homogeneous series in that interval.

J. One tree at Idaho Springs 1427-1499; a weighted average of the two standardized series of Fig. 5, 1500-1699; the homogeneous 1944 index only for 1700-1944.

K. A mean of the individually standardized series of Fig. 5.

L. To derive this index, consecutive three-year means were derived for each of the archeological series plotted in Fig. 20 and an unweighted average taken; a weighted average of the living-tree series in Fig.14 was similarly obtained; in the region of overlap of these two sub-indices varying weights were applied to derive the final mean. A zero year has been introduced for continuity; thus the first value in the table is at -55 A.D. or 56 B.C.

O to U. For composition see note in Fig. 14 above.

V. 11 trees in N.E. Utah, 6 in the Upper Colorado River Basin, 15 at Mesa Verde.

W, X. Means of the individually standardized series of Fig. 12.

Y. The three-area mean of Fig. 15, 1440-1649, the five-area mean 1650-1951.

Z. The Ft. Garland series of Fig. 15.

AA, AB. Fig. 15.

AC, AD. Fig. 17.

AE. Fig. 19. This series is a mean of 18 trees collected by Antevs and individually standardized by the writer in 1932.

AF. Fig. 19.

AG, AH. Fig. 18

AI. The El Salto groups of Table 1-M. See TRB 10:16, 1944.

Table 2. Growth Indices

2-A. Fraser River Basin (Central British Columbia) Douglas-fir and Ponderosa Pine

A.D.	0	1	2	3	4	5	6	7	8	9
1420	116	174	130	54	112	67	48	133	50	138
1430	140	166	121	59	59	78	93	69	90	110
1440	89	94	103	85	123	87	132	120	89	107
1450	107	106	112	71	56	82	98	65	60	126
1460	119	105	154	82	116	124	85	56	83	75
1470	115	174	64	130	140	73	66	103	99	91
1480	98	135	152	119	155	107	142	151	189	55
1490	109	108	75	86	64	117	103	76	89	72
1500	146	50	88	100	137	127	76	98	78	91
1510	104	116	142	86	88	46	97	118	104	125
1520	51	72	98	78	103	106	88	78	107	49
1530	62	61	120	131	59	97	175	142	100	120
1540	66	96	75	66	70	44	50	103	100	101
1550	121	95	135	88	86	53	86	79	55	77
1560	81	95	78	73	114	81	134	82	76	130
1570	90	59	154	131	114	131	107	118	125	142
1580	146	90	85	62	87	67	93	134	81	106
1590	122	125	137	98	55	100	123	171	120	134
1600	75	136	125	117	125	83	99	111	87	96
1610	81	104	142	153	141	82	88	95	36	64
1620	32	43	51	10	52	67	24	68	71	66
1630	82	167	156	140	75	114	108	107	83	54
1640	99	123	99	71	77	105	83	48	99	65
1650	62	53	105	89	140	102	120	69	95	107
1660	110	89	134	87	59	99	171	152	125	89
1670	126	95	183	117	74	119	114	96	75	75
1680	89	120	86	26	59	50	72	101	92	95
1690	93	78	83	78	111	107	123	146	158	80
1700	104	116	170	111	104	77	98	108	84	95
1710	96	138	120	174	117	108	128	62	80	77
1720	93	90	139	58	97	111	106	147	110	110
1730	75	87	119	143	72	77	71	89	133	108
1740	136	72	123	131	41	121	91	84	41	63
1750	97	71	136	147	150	150	102	115	98	78
1760	69	123	168	114	160	122	164	169	87	134
1770	77	39	77	67	108	105	105	27	101	90
1780	78	110	116	74	76	108	110	124	99	134
1790	96	68	149	69	69	89	94	58	80	75
1800	38	83	119	112	91	75	75	115	88	81
1810	73	119	118	67	104	139	114	114	88	144
1820	138	136	151	108	72	90	150	93	144	138
1830	150	104	151	54	63	95	154	41	135	110
1840	87	62	46	27	89	95	101	74	77	88
1850	100	90	92	75	110	93	88	99	55	78
1860	116	127	127	134	43	96	104	150	138	18
1870	101	76	88	100	91	120	99	122	87	140
1880	164	168	150	113	118	130	51	105	119	184
1890	94	54	79	108	90	88	67	73	119	106
1900	118	143	115	98	124	47	108	121	121	99
1910	88	86	110	110	142	91	91	139	94	89
1920	91	72	61	67	59	88	61	67	114	98
1930	77	35	75	98	96	107	104	110	93	130
1940	102	77	142	154	130	---	---	---	---	---

2-B. Jasper, Alberta, Douglas-fir

A.D.	0	1	2	3	4	5	6	7	8	9
1530	---	---	---	---	---	---	---	122	131	86
1540	82	101	141	76	61	94	83	129	97	141
1550	95	102	74	90	76	65	74	51	80	138
1560	66	82	66	85	114	122	157	108	62	86
1570	96	55	157	144	132	131	79	112	67	96
1580	51	28	40	44	42	65	33	73	146	150
1590	175	115	146	67	86	50	61	72	79	70
1600	97	143	104	117	103	56	31	74	128	113
1610	79	94	62	137	190	135	186	146	128	146
1620	60	110	77	16	62	37	69	32	74	90
1630	66	117	69	95	49	41	156	109	94	24
1640	55	80	122	92	84	108	66	52	81	103
1650	91	53	147	95	151	65	87	39	101	83
1660	101	77	64	52	89	106	78	47	68	106
1670	99	105	136	119	74	82	153	50	55	146
1680	59	120	58	33	87	89	79	56	105	159
1690	196	156	94	154	229	172	127	175	146	126
1700	134	46	54	70	107	84	67	74	74	105
1710	98	129	136	156	100	90	86	113	97	101
1720	92	136	120	97	63	89	51	66	91	96
1730	93	46	106	140	101	127	113	59	168	89
1740	91	72	76	85	30	94	78	96	114	108
1750	60	57	146	148	78	113	62	28	80	57
1760	62	61	145	116	103	105	130	123	139	87
1770	130	63	62	81	79	95	80	65	104	110
1780	95	115	104	135	157	99	174	219	132	148
1790	75	97	84	33	71	93	62	75	55	100
1800	38	152	75	99	145	137	180	165	70	107
1810	122	141	133	109	88	90	120	95	164	157
1820	132	142	246	127	105	103	112	72	98	148
1830	184	110	112	67	128	142	191	38	107	105
1840	81	79	56	56	66	139	142	88	142	108
1850	59	69	63	20	141	166	41	135	85	65
1860	62	40	83	74	56	46	95	102	78	85
1870	74	66	92	85	166	184	138	160	78	173
1880	135	168	166	154	102	81	146	139	156	81
1890	105	109	103	158	95	120	85	102	86	60
1900	98	140	107	67	133	73	83	111	88	114
1910	150	128	62	96	111	62	93	76	84	41
1920	65	77	71	78	77	79	94	78	105	81
1930	148	59	110	122	144	130	45	37	88	77
1940	62	47	129	108	135	54	64	88	---	---

5

2-C. Banff, Alberta, Douglas-fir

A.D.	0	1	2	3	4	5	6	7	8	9
1460	80	61	74	77	115	126	94	101	110	126
1470	127	131	58	98	94	76	80	119	68	90
1480	149	97	85	65	87	87	135	150	119	76
1490	115	74	44	93	112	104	163	117	75	74
1500	76	106	66	72	104	104	115	56	141	90
1510	85	125	89	56	119	37	68	122	118	136
1520	66	99	90	115	166	156	102	145	107	173
1530	146	165	154	86	52	134	155	155	75	119
1540	80	131	160	55	117	96	112	124	103	115
1550	94	151	82	110	41	66	27	62	64	69
1560	62	57	76	71	105	129	114	47	99	97
1570	105	91	114	80	143	136	88	93	41	74
1580	84	81	87	81	96	92	77	96	140	126
1590	127	129	151	69	100	118	108	126	125	125

6

A.D.	0	1	2	3	4	5	6	7	8	9
1600	73	87	79	90	69	59	73	69	100	117
1610	114	138	132	138	133	78	111	124	86	79
1620	71	97	71	59	89	91	57	64	94	50
1630	78	125	146	137	85	44	95	56	74	78
1640	107	154	116	131	150	93	58	121	77	127
1650	89	65	74	81	124	86	84	58	89	82
1660	74	50	85	82	66	105	133	117	163	184
1670	101	148	173	181	103	195	128	78	98	68
1680	115	128	84	73	61	94	112	95	108	95
1690	98	107	58	103	114	56	69	79	114	65
1700	107	91	89	66	95	79	26	121	94	113
1710	112	122	146	175	158	106	124	37	46	102
1720	54	42	131	140	165	97	151	164	130	91
1730	71	132	109	123	117	142	102	120	86	99
1740	125	63	131	96	84	153	97	90	70	90
1750	162	54	98	116	154	113	82	72	110	36
1760	117	116	131	118	36	106	32	114	61	133
1770	136	106	58	68	114	118	74	114	141	124
1780	93	187	133	112	59	97	155	158	112	158
1790	84	60	103	32	50	76	46	115	63	112
1800	43	145	78	84	99	79	119	122	56	35
1810	138	114	82	81	74	20	125	53	64	108
1820	102	111	82	80	107	130	158	128	172	167
1830	177	46	141	131	84	90	152	88	102	145

7

A.D.	0	1	2	3	4	5	6	7	8	9
1840	133	94	54	80	60	97	98	60	89	92
1850	86	102	75	107	75	136	129	99	75	82
1860	104	100	84	37	90	61	113	65	107	60
1870	47	67	127	111	107	100	68	141	115	126
1880	123	134	86	84	73	162	127	122	108	40
1890	151	81	84	82	88	104	69	108	165	178
1900	162	177	193	162	179	135	108	113	154	103
1910	84	85	106	106	136	87	87	133	92	66
1920	96	44	45	79	79	77	79	129	95	101
1930	79	89	128	87	59	110	63	57	108	55
1940	81	60	105	108	74	96	85	129	109	73
1950	95	---	---	---	---	---	---	---	---	---

8

2-D. Middle Columbia River Basin Douglas-fir and Ponderosa Pine

A.D.	0	1	2	3	4	5	6	7	8	9
1650	102	84	107	75	128	108	121	86	129	144
1660	136	105	98	90	103	61	93	76	91	110
1670	77	99	121	90	79	114	99	92	93	126
1680	99	130	134	86	69	117	72	106	96	83
1690	75	77	96	96	129	25	94	133	124	104
1700	142	93	137	116	128	110	110	108	104	128
1710	75	142	164	167	153	138	148	88	83	109
1720	70	27	77	97	102	100	106	135	93	106
1730	91	111	116	121	118	104	98	66	132	27
1740	81	52	74	79	58	107	110	144	132	138
1750	136	122	159	119	154	158	71	98	129	74
1760	67	122	136	110	68	92	84	84	95	103
1770	88	90	100	115	124	156	96	85	98	75
1780	87	77	102	22	72	86	76	52	60	103
1790	102	84	133	104	61	46	88	79	106	73
1800	90	110	126	73	121	93	108	75	106	168
1810	137	132	132	177	146	141	108	134	155	170
1820	122	103	109	70	64	114	115	93	92	83
1830	99	77	125	135	94	117	101	102	107	101
1840	88	111	89	54	80	116	125	82	96	82
1850	86	85	91	99	100	100	115	112	96	110
1860	122	166	106	106	100	91	110	99	106	57
1870	76	69	72	77	77	66	99	116	125	136
1880	116	134	122	93	89	111	92	81	91	70
1890	70	69	84	83	89	86	77	70	87	79
1900	101	89	107	110	102	113	118	116	128	125
1910	99	93	108	132	135	131	146	82	57	75
1920	54	92	73	87	78	69	65	77	87	37
1930	35	32	56	64	65	75	78	81	94	67
1940	78	109	153							

2-E. Snake River Basin Douglas-fir

A.D.	0	1	2	3	4	5	6	7	8	9
1280	---	---	129	101	97	88	112	113	66	96
1290	94	118	71	100	97	118	86	115	121	123
1300	101	85	106	88	68	113	101	81	112	88
1310	92	110	99	124	128	91	87	79	77	93
1320	64	85	98	86	79	92	102	121	112	132
1330	119	117	132	115	107	117	67	81	92	85
1340	82	97	87	95	101	97	99	96	86	117
1350	100	86	98	112	105	92	107	103	76	85
1360	91	91	89	85	90	98	95	112	124	106
1370	135	97	109	116	114	94	110	80	99	70
1380	65	80	53	86	113	108	90	136	107	99
1390	116	127	114	93	99	103	95	60	82	97
1400	90	82	113	98	119	109	88	71	112	96
1410	114	108	101	98	121	117	124	99	173	122
1420	111	106	82	102	114	115	108	93	77	116
1430	85	96	74	76	76	71	76	59	68	56
1440	79	103	126	133	109	114	103	125	106	139
1450	115	126	109	137	146	153	129	152	94	128
1460	81	104	130	138	113	88	144	102	73	100
1470	128	108	89	103	74	56	68	74	112	54
1480	74	66	76	53	100	111	118	118	75	90
1490	99	109	94	93	82	67	90	96	90	95
1500	81	97	102	96	100	43	106	80	94	96
1510	81	74	100	73	81	73	72	74	34	84

A.D.	0	1	2	3	4	5	6	7	8	9
1520	59	73	83	77	115	86	125	116	93	47
1530	93	105	81	55	62	110	132	132	129	150
1540	142	102	112	104	114	76	90	106	111	115
1550	131	136	144	125	108	101	114	174	145	152
1560	123	126	93	77	119	119	147	100	119	114
1570	101	54	106	112	132	125	105	134	102	106
1580	32	67	84	106	73	78	101	115	113	125
1590	106	111	129	70	68	66	118	139	71	116
1600	65	94	86	91	91	108	122	90	127	176
1610	126	136	105	144	129	106	111	149	103	118
1620	101	173	150	133	138	108	64	93	124	84
1630	78	71	16	83	85	90	102	79	68	82
1640	80	137	142	122	85	99	79	95	123	110
1650	110	98	62	71	118	85	95	82	81	81
1660	84	96	92	116	117	93	100	103	120	103
1670	96	97	82	72	132	125	137	108	85	101
1680	111	106	102	105	125	131	93	124	116	96
1690	104	78	86	113	123	47	82	101	96	96
1700	141	91	137	102	70	110	97	100	92	82
1710	90	82	88	110	80	88	122	95	76	95
1720	109	65	73	96	102	94	125	114	131	60
1730	86	101	84	76	78	56	41	105	123	85
1740	89	106	83	92	83	105	135	123	102	151
1750	130	100	97	104	92	107	62	52	96	108
1760	71	119	119	76	97	116	92	101	114	95
1770	109	93	106	103	93	132	133	101	78	91
1780	121	101	82	62	69	102	99	106	106	123

A.D.	0	1	2	3	4	5	6	7	8	9
1790	123	113	131	87	74	67	71	101	68	91
1800	66	102	109	130	110	75	110	89	107	97
1810	128	121	115	94	80	80	101	95	109	113
1820	106	127	106	96	103	114	125	129	179	156
1830	108	97	119	145	72	127	120	91	124	158
1840	88	74	74	100	85	74	74	56	74	71
1850	93	89	79	105	109	113	68	94	67	76
1860	103	129	87	80	89	76	134	104	116	106
1870	77	66	81	109	77	85	105	101	98	98
1880	98	78	106	126	94	126	83	87	95	91
1890	71	87	112	68	96	100	96	88	104	73
1900	112	93	89	101	101	113	97	136	150	93
1910	114	147	127	103	176	111	139	98	86	103
1920	70	107	91	103	74	103	103	99	112	95
1930	78	83	74	66	54	74	54	58	74	87
1940	78	99	112	74	87	95	66	99	91	95
1950	74	---	---	---	---	---	---	---	---	---

2-F. Snake River Basin Limber Pine

A.D.	0	1	2	3	4	5	6	7	8	9
				1 Tree, Unit .01 mm						
450	---	---	---	---	---	---	---	---	38	42
460	35	56	43	40	45	57	30	41	37	35
470	39	44	40	58	55	44	35	65	48	40
480	33	45	50	62	58	45	50	37	43	43
490	47	32	67	57	87	44	57	59	59	78
500	30	67	35	56	74	54	35	42	68	56
510	91	88	74	74	70	54	77	60	70	45
520	45	41	56	69	50	41	50	47	47	25
530	51	42	52	55	35	40	38	57	51	55
540	37	37	46	36	30	51	22	46	34	48
550	33	55	46	35	30	45	35	45	36	50
560	39	29	32	23	38	23	20	37	27	28
				Mean of 2 Trees, Unit .01 mm						
560	---	---	---	29	46	37	39	48	24	36
570	34	32	36	50	44	54	46	44	41	38
580	32	34	30	42	34	40	34	44	32	34
590	34	37	43	34	36	36	41	38	42	35
600	46	34	38	44	40	26	32	42	33	40
610	34	30	42	32	38	36	28	32	28	28
620	32	26	35	35	24	18	20	23	31	28
630	29	28	27	34	40	32	44	39	38	30
640	29	26	30	40	32	33	32	40	30	40
650	37	46	44	38	36	32	32	48	44	19
660	40	32	26	36	32	36	32	30	35	28
670	26	34	30	22	26	36	33	29	32	26

A.D.	0	1	2	3	4	5	6	7	8	9
680	37	38	38	26	44	24	50	32	44	44
690	28	52	40	32	34	17	30	35	34	12
700	34	12	16	20	34	28	28	18	36	20
710	20	24	23	24	26	27	27	33	14	30
720	26	32	33	26	37	36	33	48	36	28

Mean of 4 Cores, 3 Trees. Unit .01 mm

A.D.	0	1	2	3	4	5	6	7	8	9
720	---	---	---	---	---	---	---	55	46	37
730	41	44	35	42	40	38	37	42	45	35
740	34	33	30	32	34	36	31	35	36	39
750	39	34	36	36	31	31	30	32	40	41
760	35	40	30	34	34	33	37	40	24	31
770	31	30	32	25	27	28	29	31	29	32
780	36	38	38	37	35	41	42	58	53	39
790	51	40	47	50	50	42	45	42	45	34
800	38	43	53	47	41	42	35	35	26	33
810	41	32	37	31	35	41	43	26	35	16
820	33	35	29	37	21	30	28	31	30	29
830	24	28	28	23	29	26	24	26	23	27
840	35	26	37	34	33	42	34	29	32	35
850	39	33	32	37	37	42	37	41	43	40
860	31	22	34	37	38	26	33	17	13	34
870	32	28	32	32	36	45	33	33	45	43
880	34	43	35	37	32	40	38	39	42	34
890	34	39	49	42	46	37	43	37	42	33
900	37	38	46	44	31	41	38	35	38	41
910	34	24	34	36	30	31	37	41	33	37
920	34	33	34	30	34	33	35	30	34	28
930	26	27	31	31	34	37	33	43	36	33
940	41	34	26	29	31	27	27	25	31	24
950	30	29	25	36	31	35	29	24	28	34
960	39	36	38	33	30	37	40	32	46	30

A.D.	0	1	2	3	4	5	6	7	8	9
970	27	27	37	25	38	32	35	25	45	36
980	29	34	35	23	28	40	30	26	39	37
990	28	33	27	27	34	14	34	23	17	16
1000	25	34	36	28	39	34	45	41	37	35
1010	37	32	21	36	28	36	37	35	41	29
1020	41	23	29	31	42	35	41	31	37	27
1030	40	38	28	28	32	29	36	29	37	31
1040	36	43	42	38	33	38	39	26	22	24
1050	24	29	20	19	33	19	28	25	27	23
1060	29	26	25	26	33	31	29	32	33	19
1070	20	19	14	18	20	19	24	20	28	26
1080	33	28	26	35	26	23	37	32	37	40
1090	34	34	47	37	45	43	37	37	32	33
1100	35	25	35	31	35	41	51	37	40	42
1110	44	41	33	30	44	32	48	34	33	37
1120	39	39	47	27	28	32	22	25	36	32
1130	30	27	27	31	28	29	31	24	31	32
1140	27	31	24	36	32	27	35	28	22	33
1150	28	31	26	34	40	28	31	17	19	25
1160	26	28	29	31	28	33	32	37	29	37
1170	30	35	32	40	24	26	17	19	27	23
1180	25	24	31	32	30	33	28	31	33	25
1190	26	23	39	21	33	34	30	34	30	21
1200	31	37	42	32	39	30	36	37	33	36
1210	23	41	33	35	33	41	44	30	37	35
1220	26	35	32	22	32	37	36	30	37	32
1230	41	27	33	32	36	30	33	25	30	31

A.D.	0	1	2	3	4	5	6	7	8	9
1240	29	27	32	26	25	28	29	26	34	37
1250	23	35	39	34	27	22	35	29	21	38
1260	35	29	34	30	20	31	36	38	37	31
1270	30	35	24	19	34	24	29	34	25	15
1280	31	30	33	32	33	19	30	34	22	30
1290	25	33	24	36	28	35	20	25	37	28
1300	25	22	32	23	25	30	24	25	31	27
1310	30	33	35	33	48	26	27	26	30	30
1320	11	27	25	27	24	30	32	35	37	39
1330	30	36	41	36	28	19	15	32	28	26
1340	33	33	29	39	32	26	36	27	25	36
1350	24	21	26	31	25	24	25	28	26	19
1360	25	23	17	25	24	27	26	31	26	23
1370	24	25	19	22	24	24	27	22	25	26
1380	21	26	15	26	28	24	22	33	29	22
1390	30	29	26	21	30	19	23	15	23	16
1400	20	13	23	15	20	20	20	17	22	20
1410	21	23	21	13	23	25	20	16	22	19
1420	18	25	17	26	27	28	21	23	23	19
1430	17	22	14	18	12	15	13	15	16	08
1440	18	16	15	20	14	17	16	16	16	16
1450	19	21	17	16	16	18	19	21	20	14
1460	16	20	20	19	14	15	19	17	08	16
1470	19	17	14	21	17	12	22	17	17	10
1480	18	16	16	14	19	19	26	23	19	17
1490	20	19	21	20	18	15	23	15	21	16
1500	24	17	18	22	16	16	23	26	21	22

A.D.	0	1	2	3	4	5	6	7	8	9
1510	20	26	16	20	20	14	18	17	13	18
1520	20	20	25	25	25	29	24	24	20	14
1530	17	20	16	19	16	26	25	24	23	28
1540	26	16	18	17	21	14	24	17	23	25
1550	28	22	26	20	15	25	24	27	32	27
1560	30	23	23	21	34	26	28	21	27	27
1570	23	15	21	20	23	25	28	25	22	20
1580	11	14	17	22	17	17	26	21	24	25
1590	22	27	21	16	19	13	23	23	19	18
1600	15	20	19	25	24	24	24	22	27	26
1610	24	30	29	30	27	28	28	32	24	30
1620	29	30	28	24	32	30	17	25	24	27
1630	21	21	C2	27	25	23	26	18	25	20
1640	26	17	26	27	20	26	28	23	26	30
1650	24	18	15	16	22	14	21	22	20	16
1660	18	22	17	22	24	17	28	22	17	24
1670	25	22	19	21	28	23	27	17	14	22
1680	27	23	22	25	27	25	24	23	23	25
1690	21	16	23	20	19	13	17	18	21	21
1700	22	21	25	16	21	20	17	13	08	11
1710	17	16	15	16	16	15	16	16	14	16
1720	17	12	16	17	20	19	21	26	23	16
1730	13	13	15	20	21	20	18	24	27	21
1740	19	22	19	20	16	26	26	24	19	27
1750	24	26	16	18	17	22	16	18	19	18
1760	22	21	20	17	21	15	23	26	25	21
1770	22	25	25	22	17	21	22	19	12	17

A.D.	0	1	2	3	4	5	6	7	8	9
1780	21	16	10	08	13	13	16	17	17	19
1790	13	16	15	16	13	11	15	16	16	17
1800	18	12	13	19	13	22	15	13	18	16
1810	16	20	17	17	15	16	18	17	18	17
1820	20	20	11	12	16	17	19	16	22	24
1830	18	16	17	18	17	22	17	23	18	23
1840	20	22	18	24	16	19	17	21	22	22
1850	21	21	18	20	25	27	19	20	17	16
1860	28	20	21	20	21	18	27	16	25	22
1870	22	17	17	20	18	19	19	20	22	21
1880	16	20	18	16	23	24	14	20	23	18
1890	18	21	18	14	25	24	18	18	23	16
1900	28	22	18	18	21	23	27	32	27	24
1910	26	26	25	30	37	36	26	20	26	19
1920	15	21	21	28	17	28	19	25	17	18
1930	21	19	24	18	16	19	20	20	18	24
1940	21	24	21	24	22	23	19	20	19	23
1950	14	19	---	---	---	---	---	---	---	---

2-G. Missouri River Basin Douglas-fir

A.D.	0	1	2	3	4	5	6	7	8	9
1170	---	---	---	---	---	[illegible]	67	76	71	[illegible]
1180	90	118	104	82	55	95	141	68	129	[illegible]
1190	208	168	74	118	128	102	90	63	118	[illegible]
1200	96	78	101	86	127	95	91	72	[illegible]	[illegible]
1210	125	123	125	139	157	87	88	107	[illegible]	[illegible]
1220	59	31	87	73	114	45	129	94	148	[illegible]
1230	171	147	126	122	131	60	50	151	160	[illegible]
1240	122	---	---	---	65	31	71	179	75	[illegible]
1250	75	60	73	226	120	113	65	118	13	[illegible]
1260	70	34	86	27	27	61	70	88	61	[illegible]
1270	17	79	62	150	88	60	67	125	[illegible]	[illegible]
1280	102	156	145	71	146	80	142	112	90	[illegible]
1290	113	127	44	69	149	165	171	109	—	—
1300	---	---	---	---	96	87	88	123	110	[illegible]
1310	65	89	157	138	155	51	98	161	180	[illegible]
1320	12	76	76	80	20	136	160	116	172	[illegible]
1330	186	204	225	164	61	147	74	145	[illegible]	[illegible]
1340	94	95	106	167	79	154	162	129	[illegible]	[illegible]
1350	30	91	86	130	152	65	[illegible]	126	[illegible]	[illegible]
1360	71	13	113	36	100	105	91	116	179	[illegible]
1370	190	119	61	100	119	61	105	[illegible]	[illegible]	[illegible]
1380	75	95	115	10	130	75	150	100	[illegible]	[illegible]
1390	46	123	102	100	79	84	42	79	[illegible]	[illegible]
1400	111	61	54	38	102	86	125	61	150	[illegible]

19

A.D.	0	1	2	3	4	5	6	7	8	9
1410	111	134	134	39	122	33	28	39	154	160
1420	171	160	80	40	147	171	100	138	153	48
1430	151	127	73	145	182	63	50	00	69	63
1440	122	135	154	142	99	130	61	100	83	85
1450	136	76	130	69	132	136	128	185	50	84
1460	19	107	136	131	117	97	131	131	80	137
1470	119	100	81	124	61	70	97	108	135	87
1480	121	89	94	62	170	86	142	156	113	112
1490	131	123	42	95	53	77	122	103	76	49
1500	50	50	72	68	120	92	133	144	167	202
1510	111	110	94	38	73	57	68	82	40	112
1520	72	116	97	108	147	184	181	102	116	75
1530	144	116	60	55	43	95	130	152	134	166
1540	97	141	77	58	84	64	97	76	77	188
1550	89	120	130	106	116	140	72	129	157	104
1560	82	143	126	121	188	159	159	96	124	136
1570	121	86	102	93	43	100	75	105	80	72
1580	27	46	48	75	51	66	94	104	85	97
1590	80	79	70	50	95	52	132	129	105	124
1600	65	92	106	102	79	80	87	45	95	141
1610	143	187	100	130	101	89	95	169	108	141
1620	108	172	186	136	165	209	78	97	134	88
1630	58	72	80	134	76	111	115	52	83	93
1640	128	179	202	226	135	78	70	94	82	81
1650	82	76	74	53	83	102	88	32	49	49
1660	66	77	85	90	92	60	93	86	117	69

A.D.	0	1	2	3	4	5	6	7	8	9
1670	74	69	88	38	113	95	125	86	76	[illegible]
1680	96	61	67	95	113	132	82	111	90	[illegible]
1690	102	133	146	117	[illegible]	80	62	88	88	[illegible]
1700	155	116	161	115	79	102	86	95	89	[illegible]
1710	97	74	88	137	125	131	110	84	88	[illegible]
1720	75	40	75	88	100	105	131	146	137	[illegible]
1730	99	116	107	139	75	70	105	133	112	81
1740	63	113	105	104	88	97	152	130	75	141
1750	164	120	84	95	106	75	87	88	75	[illegible]
1760	69	113	96	91	95	118	75	122	155	97
1770	111	153	149	129	92	162	157	160	186	139
1780	124	106	66	89	77	70	90	111	119	131
1790	120	116	146	85	95	70	91	136	70	166
1800	30	71	83	84	100	75	92	96	81	[illegible]
1810	100	126	92	100	90	62	81	84	85	75
1820	96	118	81	100	127	112	165	120	175	150
1830	121	81	136	106	111	126	128	147	176	212
1840	95	137	105	91	115	73	45	65	72	98
1850	86	90	80	124	142	96	102	70	90	77
1860	106	90	79	80	53	45	125	97	104	87
1870	87	68	98	130	82	91	120	141	137	162
1880	130	120	150	144	107	109	122	165	167	65
1890	68	100	136	85	105	95	98	97	117	116
1900	96	79	97	77	70	76	84	132	148	150
1910	147	150	155	169	164	141	215	167	120	71
1920	94	112	90	94	77	120	84	112	108	116
1930	69	75	85	68	80	64	86	45	76	76
1940	80	71	118	108	115	111	84	125	(137)	(110)
1950	(121)									

2-H. Missouri River Basin Limber Pine

A.D.	0	1	2	3	4	5	6	7	8	9
970	---	---	---	---	---	---	---	---	204	156
980	148	104	96	49	97	107	53	128	100	121
990	127	102	79	101	14	22	11	41	52	80
1000	80	73	109	126	153	160	150	140	77	38
1010	62	78	71	114	68	87	70	72	73	34
1020	70	90	122	94	102	65	96	75	83	106
1030	90	111	116	86	147	170	137	110	142	75
1040	136	126	100	156	196	127	63	96	94	94
1050	72	81	102	47	94	50	91	104	91	04
1060	133	158	104	121	116	137	62	87	71	61
1070	67	96	104	108	100	96	54	71	96	37
1080	104	133	87	92	129	150	146	112	71	71
1090	75	116	129	62	21	46	63	1'2	79	50
1100	49	57	74	138	130	119	98	119	106	65
1110	81	114	102	74	159	176	128	160	128	92
1120	140	48	36	60	76	52	80	76	56	48
1130	36	76	80	60	108	92	140	208	188	252
1140	220	248	196	140	132	108	200	124	68	108
1150	116	56	112	68	52	20	48	44	60	68
1160	84	80	72	72	48	80	72	92	68	80
1170	104	92	44	72	36	80	72	48	80	124
1180	108	68	72	120	80	112	168	116	104	172
1190	132	92	88	108	136	100	88	60	112	120
1200	96	116	132	60	100	108	104	84	48	76
1210	88	104	112	124	200	172	108	104	56	60

A.D.	0	1	2	3	4	5	6	7	8	9
1220	96	68	120	124	100	100	140	92	180	212
1230	160	112	132	104	120	92	44	104	140	164
1240	132	92	80	88	100	96	44	116	96	128
1250	112	76	68	88	108	80	68	72	60	110
1260	117	88	101	48	38	67	69	125	127	122
1270	81	107	90	82	80	86	86	121	44	36
1280	72	87	99	93	110	77	155	136	98	157
1290	110	152	78	109	123	159	159	143	127	87
1300	67	32	84	72	27	91	40	77	88	117
1310	124	129	103	120	124	63	109	74	82	83
1320	69	68	104	120	42	137	149	107	164	148
1330	143	194	174	161	116	136	137	114	87	76
1340	91	96	96	124	110	134	109	121	112	134
1350	82	136	96	135	118	99	150	117	127	98
1360	80	12	65	43	69	109	97	117	139	70
1370	131	104	69	82	102	93	92	66	110	104
1380	75	74	40	93	98	77	114	141	75	99
1390	106	100	94	103	91	114	95	79	63	57
1400	49	64	89	96	121	117	149	119	155	102
1410	98	125	127	101	107	78	93	75	103	110
1420	123	141	110	67	149	151	94	139	136	101
1430	115	130	94	101	103	35	47	22	48	56
1440	74	101	117	130	127	118	36	49	38	34
1450	73	112	116	131	144	166	163	156	94	92
1460	39	115	97	134	142	155	130	133	86	117
1470	102	96	63	141	64	115	140	114	111	119

Table 2-H (continued)

A.D.	0	1	2	3	4	5	6	7	8	9
1480	126	81	114	65	123	138	106	140	108	109
1490	122	115	86	96	113	88	96	110	41	53
1500	37	47	79	61	76	86	108	112	135	134
1510	90	116	107	68	64	78	41	102	54	90
1520	93	121	56	134	141	159	180	162	123	122
1530	117	63	75	56	34	51	90	136	135	168
1540	150	125	31	91	75	66	108	82	79	105
1550	131	117	123	102	103	95	49	119	136	114
1560	104	134	140	87	134	127	72	43	125	132
1570	109	112	116	91	56	94	85	98	56	61
1580	22	56	40	63	53	54	92	85	64	84
1590	76	106	59	40	95	63	103	98	70	98
1600	93	95	92	88	107	92	109	78	117	151
1610	139	181	118	170	107	87	76	164	93	147
1620	151	179	204	183	155	182	106	112	145	76
1630	60	56	22	115	116	99	123	49	92	94
1640	112	115	126	195	134	84	89	102	109	154
1650	90	94	99	82	86	128	131	101	68	83
1660	88	115	137	124	87	78	128	140	103	63
1670	108	99	72	124	154	115	138	116	133	73
1680	138	75	81	151	131	137	125	151	97	130
1690	149	149	135	98	124	71	97	60	88	95
1700	132	124	156	143	110	113	116	122	52	94
1710	108	94	99	124	92	114	121	69	45	132
1720	103	39	98	98	133	125	175	169	118	142
1730	89	139	128	122	77	44	116	136	117	59

Table 2-H (continued)

A.D.	0	1	2	3	4	5	6	7	8	9
1740	38	91	72	99	18	62	101	95	51	98
1750	138	114	71	85	109	72	42	60	77	58
1760	92	105	130	111	122	116	119	133	125	113
1770	114	155	100	112	86	135	137	150	126	120
1780	89	48	69	63	109	86	101	120	94	84
1790	88	106	101	98	96	25	61	78	41	86
1800	23	58	83	96	90	89	74	101	56	66
1810	120	110	64	106	109	94	112	122	76	67
1820	95	105	42	58	72	69	100	98	115	110
1830	94	61		134	105	83	70	101	123	139
1840	93	120	74	114	102	97	60	79	44	84
1850	87	104	63	127	126	87	108	50	90	76
1860	61	78	82	58	56	42	98	116	112	96
1870	115	99	113	105	118	95	108	128	128	134
1880	67	57	97	106	105	116	85	106	133	86
1890	67	107	132	70	118	104	83	53	117	111
1900	126	95	90	84	71	108	96	138	156	148
1910	149	141	120	137	184	153	153	119	125	76
1920	104	130	107	131	102	124	107	111	101	117
1930	61	90	95	62	44	84	63	70	79	74
1940	71	104	116	112	122	119	110	123	(125)	(180)
1950	(166)	---	---	---	---	---	---	---	---	---

B-I. North Platte River Basin Douglas-fir

A.D.	0	1	2	3	4	5	6	7	8	9
1330	---	---	---	---	---	---	77	188	59	165
1340	96	88	61	71	82	81	117	39	62	57
1350	130	70	136	84	104	91	97	136	47	86
1360	105	96	88	174	116	171	87	81	65	89
1370	168	110	179	118	101	190	120	259	115	89
1380	23	33	18	53	109	155	256	180	120	35
1390	86	147	107	66	99	102	129	47	132	31
1400	118	82	105	49	61	42	44	38	77	122
1410	98	124	110	148	248	136	145	90	148	96,
1420	65	99	72	34	65	106	113	89	170	127
1430	176	208	198	114	137	187	100	139	84	103
1440	178	150	86	261	69	33	53	36	44	55
1450	40	114	82	82	66	31	87	149	96	89
1460	25	89	127	236	156	40	56	116	82	64
1470	85	113	127	156	66	51	164	75	60	40
1480	86	64	155	118	218	202	191	105	169	124
1490	113	118	122	131	213	87	34	31	142	105
1500	38	155	151	116	134	93	98	231	64	73
1510	153	82	122	66	66	73	95	58	97	88
1520	64	150	61	156	184	168	112	67	60	147
1530	100	59	57	59	78	142	115	129	102	145
1540	88	130	47	47	77	130	136	89	87	139
1550	148	137	141	143	156	163	167	145	149	129
1560	140	140	106	58	127	107	115	82	105	80

A.D.	0	1	2	3	4	5	6	7	8	9
1570	88	129	109	78	112	87	91	109	129	77
1580	88	69	98	108	45	88	95	96	75	79
1590	61	77	73	73	136	81	70	95	77	70
1600	16	85	71	93	188	141	79	12	94	70
1610	110	112	54	111	126	147	100	138	78	114
1620	79	128	72	70	80	120	63	60	66	140
1630	100	90	130	160	171	134	151	186	188	178
1640	126	158	189	120	149	100	129	149	101	81
1650	146	124	102	48	71	137	118	104	69	95
1660	84	119	128	181	158	65	89	89	58	89
1670	63	66	79	92	95	89	117	81	128	116
1680	153	88	82	110	80	29	61	86	91	78
1690	81	62	147	59	66	47	67	71	85	92
1700	100	145	148	152	100	87	59	94	[illegible]	69
1710	59	35	69	69	45	42	59	73	101	118
1720	129	140	122	143	138	87	147	102	91	105
1730	77	113	99	127	116	70	57	96	99	106
1740	96	96	46	71	50	89	135	171	206	171
1750	190	118	114	147	78	87	77	70	85	71
1760	99	118	120	114	138	116	104	140	153	128
1770	109	150	116	99	87	101	93	85	107	74
1780	93	104	89	124	96	115	113	137	119	53
1790	148	113	175	126	162	114	149	148	97	121
1800	123	86	91	120	118	70	117	74	50	45
1810	67	85	88	102	112	84	65	82	117	115
1820	83	139	116	93	95	113	105	76	138	94
1830	85	151	84	83	61	88	86	147	175	206

A.D.	0	1	2	3	4	5	6	7	8	9
1840	148	141	58	177	119	11	96	57	35	119
1850	97	47	105	129	86	36	93	89	100	100
1860	131	112	94	64	153	95	133	162	110	135
1870	101	38	105	112	36	97	116	76	120	99
1880	104	92	88	89	88	74	55	58	46	51
1890	48	86	91	57	69	104	88	104	97	85
1900	130	72	47	83	84	82	71	126	74	110
1910	91	149	95	104	111	92	93	127	125	65
1920	111	135	108	74	100	123	162	122	196	129
1930	113	153	151	81	60	55	48	106	75	76
1940	97	93	85	76	74	98	72	---	---	---

B-J. South Platte River Basin Douglas-fir

A.D.	0	1	2	3	4	5	6	7	8	9
1420	---	---	---	---	---	20	73	48	79	47
1430	105	61	96	67	88	116	95	97	63	109
1440	153	67	152	198	95	59	145	126	101	96
1450	108	94	95	48	77	43	106	69	111	102
1460	134	81	100	108	61	126	62	124	117	87
1470	95	30	97	133	72	34	120	150	174	52
1480	88	82	110	52	158	166	151	103	84	117
1490	158	160	40	102	76	47	55	73	144	69
1500	70	50	69	50	68	100	111	164	60	45
1510	165	147	84	107	102	100	113	61	127	107
1520	110	192	29	130	59	69	105	123	79	163
1530	147	69	100	108	68	145	150	98	21	131
1540	83	80	25	89	57	58	110	87	116	156
1550	131	61	27	116	170	144	176	126	45	91
1560	97	82	124	62	93	120	45	37	120	60
1570	146	108	220	63	121	148	51	104	173	64
1580	99	58	48	97	30	72	55	109	89	98
1590	35	41	45	64	78	125	96	77	63	69
1600	91	46	115	130	112	104	48	65	63	57
1610	93	53	46	102	62	115	59	102	171	172
1620	101	141	46	52	85	60	56	65	65	115
1630	132	51	99	98	123	60	121	104	101	158
1640	117	68	112	94	142	35	99	110	60	99
1650	58	144	81	75	24	167	105	157	99	94
1660	126	122	86	96	76	78	26	114	69	72

A.D.	0	1	2	3	4	5	6	7	8	9
1670	48	114	111	136	100	29	64	151	191	61
1680	142	123	110	179	52	30	74	77	101	145
1690	88	48	147	115	91	110	96	126	122	114
1700	69	189	111	86	73	42	140	67	73	35
1710	145	94	142	123	95	69	121	95	154	122
1720	175	181	126	114	135	121	173	89	101	37
1730	48	81	60	96	127	88	61	36	91	125
1740	79	63	85	120	105	111	151	160	47	118
1750	100	119	84	151	88	132	85	107	120	146
1760	140	194	150	70	70	106	116	48	126	133
1770	120	143	120	111	82	46	92	46	56	60
1780	53	50	73	113	113	147	70	94	114	30
1790	142	106	139	69	143	69	151	124	79	124
1800	131	42	87	108	59	77	84	88	74	67
1810	76	92	103	114	107	129	154	147	54	94
1820	54	76	76	105	51	102	110	114	169	118
1830	63	170	89	127	60	120	90	86	161	150
1840	132	99	42	160	137	50	92	50	100	70
1850	104	04	70	105	101	51	74	75	95	75
1860	115	48	120	44	120	60	137	174	101	170
1870	100	50	113	100	71	34	151	64	105	68
1880	25	85	98	85	89	115	90	60	95	95
1890	52	125	100	62	113	126	78	96	157	39
1900	113	78	30	104	122	117	83	105	61	96
1910	104	91	143	117	165	170	117	126	179	109
1920	104	161	104	91	148	26	152	57	117	52
1930	117	161	39	109	61	74	70	104	91	96
1940	74	96	129	100	117	---	---	---	---	---

2-K. Arkansas River Basin Douglas-fir

A.D.	0	1	2	3	4	5	6	7	8	9
1420	---	---	---	---	---	---	---	182	132	68
1430	87	70	56	88	108	128	125	90	73	58
1440	82	80	67	67	70	60	72	73	70	63
1450	64	77	93	66	76	57	80	58	99	118
1460	96	124	106	134	133	149	111	125	123	110
1470	118	74	84	86	84	77	116	131	131	98
1480	86	64	69	79	104	128	179	133	124	133
1490	110	134	132	48	105	68	23	88	109	123
1500	100	104	107	65	89	102	56	89	66	59
1510	67	94	111	113	116	64	98	121	133	129
1520	143	188	65	110	32	12	105	124	65	110
1530	114	98	99	100	111	77	135	122	60	111
1540	101	124	80	96	96	79	39	96	156	128
1550	107	120	30	111	146	106	164	169	74	124
1560	92	136	185	79	179	137	86	53	168	164
1570	160	135	148	64	151	174	64	61	139	47
1580	96	99	59	93	20	75	127	64	117	90
1590	43	25	67	40	60	78	89	101	44	63
1600	156	119	121	136	97	88	106	77	67	75
1610	143	40	99	118	116	136	71	146	157	174
1620	120	191	136	66	107	39	150	69	57	57
1630	141	77	17	128	120	166	147	111	81	176
1640	143	41	86	77	114	10	148	73	29	150
1650	66	194	40	109	24	140	156	151	24	79
1660	92	128	140	118	50	100	95	111	06	78

A.D.	0	1	2	3	4	5	6	7	8	9
1670	70	124	130	162	154	43	92	136	150	35
1680	174	105	56	165	21	15	42	66	66	99
1690	42	76	67	95	37	95	93	74	84	131
1700	97	116	70	114	35	16	117	55	99	29
1710	105	85	114	93	60	89	45	76	94	110
1720	145	104	86	136	62	151	82	142	122	32
1730	09	91	75	42	61	57	92	22	99	90
1740	89	57	51	100	63	47	124	139	66	70
1750	92	95	92	132	77	137	113	89	126	125
1760	141	140	125	60	58	89	128	79	100	173
1770	127	201	146	40	103	70	95	78	89	98
1780	37	51	61	114	119	136	98	129	90	36
1790	127	79	75	127	67	93	101	117	87	121
1800	146	56	83	125	105	113	94	122	82	77
1810	66	25	97	98	115	120	142	130	63	146
1820	81	114	123	149	128	111	116	123	145	145
1830	78	204	123	175	115	179	112	103	186	173
1840	134	196	65	166	188	125	121	74	146	129
1850	100	33	52	109	110	102	113	128	136	127
1860	66	23	71	22	101	109	111	177	73	122
1870	108	122	112	77	110	76	97	140	155	127
1880	53	102	163	80	80	59	118	66	122	100
1890	113	134	122	63	84	122	121	65	145	34
1900	152	67	42	98	97	126	91	112	90	61
1910	136	106	138	108	141	143	147	172	45	121
1920	107	119	54	60	103	40	107	60	125	84
1930	119	145	112	104	93	105	39	143	95	96
1940	49	122	123	43	107	98	133	130	195	211
1950	115	---	---	---	---	---	---	---	---	---

2-L. Colorado River Basin Mixed Species, Three-Year Means on Middle Year

A.D.	0	+3	+6	+9	+12	+15	+18	+21	+24	+27
-70	---	---	---	---	---	177	146	81	70	108
-40	124	125	86	114	105	103	90	140	89	128
-10	89	74	94	74	101	101	144	110	80	93
+20	128	99	82	94	99	94	91	85	109	90
50	81	109	66	98	124	135	82	74	83	101
80	148	125	83	115	120	115	126	87	110	99
110	102	117	88	108	97	70	80	70	75	96
140	109	109	113	88	105	113	65	119	100	91
170	137	72	100	95	130	125	133	100	98	103
200	76	109	123	101	113	93	85	109	102	111
230	65	122	70	89	112	92	80	113	117	82
260	83	81	106	132	151	91	86	120	133	91
290	80	61	102	112	74	126	94	118	112	146
320	83	67	45	110	144	117	133	71	72	122
350	106	93	143	128	57	68	79	79	98	78
380	103	79	111	109	76	94	123	97	100	135
410	102	127	125	98	91	95	78	97	141	120
440	127	138	95	96	76	68	112	75	86	86
470	86	79	121	121	108	103	106	111	116	136
500	106	114	101	100	72	75	74	74	104	64
530	97	117	85	97	70	106	132	136	94	112

A.D.	0	3	6	9	12	15	18	21	24	27
560	109	80	108	66	114	152	87	130	117	140
590	91	124	99	99	106	85	111	73	64	85
620	81	124	88	109	96	106	121	108	92	71
650	86	85	111	82	69	103	112	100	133	84
680	109	137	96	136	133	117	93	97	78	65
710	70	71	80	105	100	96	131	149	113	86
740	94	86	118	84	81	86	86	88	94	127
770	71	85	93	80	84	118	111	94	96	90
800	128	144	106	69	118	114	56	146	55	115
830	86	122	101	94	86	99	80	91	133	130
860	128	106	85	101	100	90	68	86	61	93
890	86	100	114	131	122	79	80	110	118	134
920	99	71	112	108	108	86	89	121	105	136
950	118	91	82	110	114	128	99	96	121	107
980	38	85	146	171	60	109	94	82	67	119
1010	88	67	134	94	99	143	120	97	95	60
1040	60	70	81	78	112	106	120	122	166	67
1070	99	108	120	147	117	94	135	60	61	69
1100	67	105	99	97	111	124	134	116	120	113
1130	112	74	81	[illegible]	92	105	90	69	87	61
1160	88	110	116	111	114	79	93	121	109	93
1190	97	97	115	96	105	105	97	117	84	48
1220	88	87	88	101	97	78	104	116	102	91
1250	87	70	93	86	71	71	93	95	67	60
1280	67	74	62	80	60	64	66	112	120	76
1310	124	134	98	117	113	137	109	168	153	126

A.D.	0	3	6	9	12	15	18	21	24	27
1340	122	108	100	81	107	119	156	80	88	141
1370	127	131	100	122	115	135	117	113	128	101
1400	71	61	89	104	91	98	103	90	96	111
1430	106	104	96	90	102	82	98	92	82	76
1460	65	94	80	102	57	76	106	92	124	113
1490	136	116	66	74	84	53	96	98	107	94
1520	114	99	120	102	67	120	104	98	61	101
1550	133	145	132	100	96	113	96	102	74	100
1580	58	53	71	79	64	108	95	85	125	110
1610	140	101	139	142	115	63	90	59	106	74
1640	104	111	103	106	110	91	105	98	90	60
1670	76	113	101	116	119	81	101	105	110	99
1700	102	103	82	84	103	94	114	115	116	135
1730	92	111	66	104	100	113	[illegible]	61	69	76
1760	105	100	69	108	81	85	71	62	110	94
1790	101	112	104	90	97	85	80	106	[illegible]	130
1820	96	71	102	97	120	102	156	117	109	79
1850	108	122	91	98	64	97	137	91	66	80
1880	74	78	100	100	100	75	90	67	88	113
1910	125	131	146	117	130	114	130	103	75	69
1940	92	101	78	97	---	---	---	---	---	---

S-W. Colorado River Basin Douglas-fir
80 Trees

A.D.	0	1	2	3	4	5	6	7	8	9
1450	48	117	106	115	91	29	72	55	116	91
1460	81	72	116	121	75	56	98	122	120	116
1470	118	42	64	54	69	59	112	129	124	97
1480	78	90	118	111	172	141	137	112	127	137
1490	158	163	113	123	144	67	46	82	124	86
1500	38	57	78	86	78	42	24	71	97	116
1510	88	111	111	106	141	74	80	102	63	110
1520	109	116	70	116	101	90	136	126	90	107
1530	96	40	16	108	91	106	136	131	72	101
1540	128	126	48	95	62	73	96	66	111	158
1550	124	131	149	164	175	121	153	154	99	90
1560	128	109	85	91	135	126	74	101	92	92
1570	125	77	99	57	66	81	64	108	106	58
1580	36	82	76	58	18	37	92	83	96	93
1590	43	68	37	78	97	101	122	111	73	98
1600	38	105	114	109	136	151	142	81	110	159
1610	156	123	98	88	124	144	175	155	155	141
1620	142	159	96	94	73	47	47	100	84	84
1630	74	67	30	118	118	84	88	65	75	103
1640	120	103	110	110	117	66	121	121	63	142
1650	108	146	67	98	45	119	95	116	106	99
1660	106	86	92	96	71	89	64	64	61	63
1670	80	101	66	109	120	101	91	109	117	106
1680	131	121	118	140	85	19	48	107	104	90
1690	108	112	104	117	79	105	94	102	106	98

A.D.	0	1	2	3	4	5	6	7	8	9
1700	95	[illegible]	121	95	95	[illegible]	76	61	[illegible]	[illegible]
1710	103	95	118	115	92	[illegible]	96	[illegible]	115	[illegible]
1720	165	127	65	126	97	140	171	144	[illegible]	84
1730	101	120	116	105	144	47	[illegible]	74	[illegible]	[illegible]
1740	74	105	98	[illegible]	98	110	114	[illegible]	[illegible]	[illegible]
1750	102	67	75	106	67	95	[illegible]	[illegible]	95	[illegible]
1760	115	95	[illegible]	64	107	[illegible]	[illegible]	72	120	[illegible]
1770	100	176	60	[illegible]	72	101	61	56	56	97
1780	56	93	[illegible]	109	109	[illegible]	89	122	[illegible]	[illegible]
1790	110	122	[illegible]	114	91	65	[illegible]	148	102	94
1800	82	90	115	95	[illegible]	74	76	94	[illegible]	[illegible]
1810	94	107	116	[illegible]	[illegible]	99	[illegible]	[illegible]	70	[illegible]
1820	79	[illegible]	66	[illegible]	[illegible]	95	[illegible]	95	136	[illegible]
1830	91	99	128	113	104	117	86	[illegible]	[illegible]	[illegible]
1840	154	136	96	[illegible]	[illegible]	[illegible]	96	50	117	[illegible]
1850	138	75	129	150	117	92	121	[illegible]	[illegible]	[illegible]
1860	92	42	135	92	63	104	122	151	[illegible]	[illegible]
1870	92	67	105	71	97	[illegible]	92	92	[illegible]	[illegible]
1880	97	76	42	71	114	116	114	[illegible]	[illegible]	[illegible]
1890	109	114	114	76	55	101	71	109	[illegible]	[illegible]
1900	86	60	38	97	71	97	101	[illegible]	101	[illegible]
1910	130	134	147	109	164	151	143	172	105	[illegible]
1920	160	168	100	139	[illegible]	92	147	[illegible]	101	[illegible]
1930	134	59	122	109	76	101	59	114	[illegible]	97
1940	97	139	143	84	174	92	(71)	(109)	(116)	(130)
1950	(105)	---	---	---	---	---	---	---	---	---

2-N. Colorado River Basin Pinyon Pine
8 Trees

A.D.	0	1	2	3	4	5	6	7	8	9
1320	96	92	109	80	90	96	103	116	102	92
1330	122	138	136	164	145	102	121	127	110	138
1340	117	145	134	109	121	106	115	101	102	100
1350	76	80	84	110	119	88	116	132	122	129
1360	86	79	81	76	92	89	115	103	125	93
1370	116	106	115	112	119	101	84	105	113	110
1380	125	95	64	97	87	120	102	115	115	101
1390	76	95	101	97	107	113	111	87	89	69
1400	70	84	67	78	98	100	100	86	113	136
1410	101	109	114	83	125	92	84	104	102	79
1420	105	83	97	87	94	90	102	108	100	91
1430	89	121	91	101	98	75	96	85	73	90
1440	118	120	73	96	84	96	90	121	111	95
1450	79	113	124	120	125	67	54	71	108	83
1460	45	51	98	104	87	47	90	92	88	86
1470	96	58	69	76	76	52	87	104	111	59
1480	83	79	120	90	138	116	117	108	134	126
1490	126	148	155	113	144	69	85	102	134	87
1500	34	94	106	108	93	27	29	86	82	109
1510	84	105	109	118	109	89	99	106	78	115
1520	97	131	76	118	116	127	121	140	114	96
1530	124	86	68	106	120	115	125	99	90	111
1540	121	106	57	109	86	96	115	96	122	134
1550	118	106	125	104	113	94	111	96	82	90
1560	99	99	97	107	127	107	110	80	113	103

A.D.	0	1	2	3	4	5	6	7	8	9
1570	110	110	98	76	84	108	123	135	94	40
1580	27	161	89	67	25	37	97	80	94	98
1590	40	80	65	80	117	108	120	113	83	105
1600	80	104	104	83	116	121	121	86	99	117
1610	127	122	99	101	101	127	107	130	120	130
1620	140	136	102	90	95	105	54	108	82	90
1630	103	75	21	121	98	90	72	70	67	67
1640	109	101	98	112	112	81	94	128	76	128
1650	120	133	78	81	71	97	97	74	89	102
1660	110	97	102	95	105	102	71	71	82	108
1670	71	90	111	116	109	106	88	109	117	93
1680	112	120	104	120	72	29	54	107	113	94
1690	99	110	108	138	103	105	103	92	98	117
1700	76	109	119	90	96	120	85	63	68	104
1710	104	115	101	101	71	110	127	110	127	149
1720	160	80	69	122	89	125	144	139	123	50
1730	123	120	109	109	152	34	87	79	115	118
1740	79	99	132	99	96	124	121	135	71	136
1750	82	71	71	85	85	71	80	77	103	103
1760	117	103	126	74	123	57	100	83	98	106
1770	100	126	121	32	72	107	84	84	52	99
1780	58	76	29	99	125	102	84	123	67	88
1790	102	126	136	102	71	68	85	112	91	132
1800	100	100	135	88	112	92	92	127	71	103
1810	115	133	133	53	95	104	149	119	68	92
1820	83	110	68	65	65	116	135	105	152	96
1830	114	105	129	111	84	102	78	123	126	141

A.D.	0	1	2	3	4	5	6	7	8	9
1840	111	102	60	102	117	45	84	39	87	147
1850	126	63	126	123	105	96	93	75	117	79
1860	76	45	127	97	58	82	121	133	133	121
1870	91	48	88	70	88	82	73	68	73	49
1880	85	73	55	67	98	104	79	70	95	73
1890	104	104	88	58	64	82	58	98	138	52
1900	58	92	37	110	67	123	129	141	89	120
1910	107	126	120	126	129	135	133	123	108	90
1920	126	145	120	108	123	105	120	120	114	96
1930	102	99	102	106	62	106	62	143	118	90
1940	102	140	(149)	(121)	(121)	(112)	(62)	(143)	(78)	---

2-O. Colorado River Basin Douglas-fir.
5 Stations, 23-650+ year Trees. Unit .01 mm

A.D.	0	1	2	3	4	5	6	7	8	9
1300	57	59	66	70	54	56	44	16	34	67
1310	63	57	48	63	60	50	25	29	33	48
1320	59	55	53	42	40	61	56	50	29	30
1330	64	71	84	85	60	43	42	48	38	55
1340	54	59	43	28	47	48	50	41	43	35
1350	17	27	28	60	46	42	54	63	52	52
1360	32	25	28	31	33	38	50	52	64'	47
1370	56	53	71	57	77	45	44	42	44	29
1380	54	39	45	54	50	55	56	50	42	27
1390	32	32	47	38	57	40	42	27	31	21
1400	34	36	27	25	34	27	35	24	34	35
1410	31	29	45	22	48	29	34	40	49	41
1420	37	27	34	43	44	40	41	46	45	34
1430	41	44	45	33	36	24	49	33	17	30
1440	40	43	21	34	18	28	20	40	35	27
1450	14	41	37	38	35	17	23	21	37	30
1460	15	24	37	39	25	19	31	37	38	36
1470	43	15	22	17	22	17	35	37	41	35
1480	29	30	45	39	54	40	37	31	37	39
1490	47	49	29	33	39	20	15	23	35	24
1500	11	20	26	27	24	13	06	27	34	33
1510	18	33	33	28	44	21	30	38	31	37
1520	32	36	20	34	30	30	40	42	30	33
1530	31	15	06	39	32	38	48	44	27	34

Table 2-O. (continued)

A.D.	0	1	2	3	4	5	6	7	8	9
1540	[illegible]	[illegible]	19	[illegible]	17	[illegible]	[illegible]	31	37	40
1550	[illegible]	[illegible]	41	[illegible]	44	[illegible]	42	46	[illegible]	[illegible]
1560	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19	[illegible]	[illegible]	[illegible]
1570	[illegible]	[illegible]	[illegible]	19	24	24	21	36	36	19
1580	[illegible]	[illegible]	[illegible]	21	06	13	[illegible]	30	30	32
1590	14	[illegible]	13	[illegible]	30	32	41	34	[illegible]	[illegible]
1600	10	31	[illegible]	34	40	43	[illegible]	24	[illegible]	44
1610	41	[illegible]	[illegible]	21	36	39	36	41	40	41
1620	[illegible]	45	[illegible]	31	[illegible]	24	12	[illegible]	22	21
1630	[illegible]	16	07	34	34	24	[illegible]	14	17	26
1640	31	[illegible]	29	32	34	18	31	35	17	41
1650	27	37	22	[illegible]	20	32	[illegible]	35	32	27
1660	30	[illegible]	[illegible]	[illegible]	22	23	18	18	16	24
1670	10	16	22	27	32	24	25	[illegible]	27	23
1680	34	[illegible]	29	34	34	07	09	30	[illegible]	20
1690	27	30	27	29	22	27	28	27	26	25
1700	25	31	34	25	[illegible]	28	16	15	15	22
1710	25	24	30	29	24	25	23	22	30	32
1720	39	31	16	32	24	31	37	37	33	16
1730	[illegible]	32	35	30	39	14	18	21	38	33
1740	30	27	25	31	[illegible]	26	40	44	25	37
1750	26	20	19	[illegible]	23	27	17	16	25	22
1760	32	20	34	14	[illegible]	25	27	22	31	34
1770	27	31	18	06	16	27	20	16	15	27
1780	13	[illegible]	13	[illegible]	[illegible]	30	14	29	19	10

Table 2-O. (continued)

A.D.	0	1	2	3	4	5	6	7	8	9
1790	31	[illegible]	[illegible]	[illegible]	18	[illegible]	19	[illegible]	20	[illegible]
1800	19	25	[illegible]	[illegible]	20	18	21	22	15	22
1810	[illegible]	[illegible]	30	09	24	[illegible]	31	30	19	34
1820	24	34	17	[illegible]	18	[illegible]	[illegible]	22	35	16
1830	21	21	30	[illegible]	24	24	18	29	34	36
1840	36	32	22	38	30	06	[illegible]	17	[illegible]	32
1850	30	21	29	40	30	21	29	15	35	19
1860	22	13	29	21	22	[illegible]	[illegible]	35	33	30
1870	21	16	29	17	24	[illegible]	24	21	20	11
1880	[illegible]	18	15	18	[illegible]	[illegible]	[illegible]	21	24	24
1890	27	[illegible]	27	16	13	23	21	27	32	14
1900	21	17	11	25	21	24	25	37	22	30
1910	33	30	34	27	38	32	34		[illegible]	32
1920	39	44	42	38	31	23	35	[illegible]	39	35
1930	36	30	32	29	09	26	13	31	32	24
1940	24	34	35	(25)	(34)	(25)	---	---	---	---

2-P. Colorado River Basin Douglas-fir.
6 Stations, 37-500+ year Trees. Unit .01 mm

A.D.	0	1	2	3	4	5	6	7	8	9
1450	26	56	50	55	40	09	35	25	58	44
1460	25	36	58	58	37	26	49	61	58	58
1470	52	19	29	26	33	30	54	65	58	43
1480	32	41	50	46	79	69	69	55	61	64
1490	74	56	56	60	70	30	20	40	58	41
1500	10	24	34	38	36	19	11	27	40	54
1510	25	49	50	50	60	34	30	38	31	44
1520	46	50	31	50	42	35	57	49	35	44
1530	36	21	06	39	33	40	49	50	25	37
1540	47	49	15	40	26	27	35	32	40	49
1550	61	50	61	75	50	46	61	58	42	36
1560	45	36	29	34	52	48	30	34	36	32
1570	46	31	37	19	20	29	24	37	35	19
1580	13	28	23	17	06	11	32	24	31	28
1590	13	22	12	21	32	31	37	36	23	37
1600	14	35	36	35	44	51	49	27	41	51
1610	54	42	30	33	41	48	46	52	52	44
1620	48	51	33	26	21	23	16	33	28	28
1630	24	23	11	37	37	26	26	24	26	33
1640	39	34	38	32	34	21	39	35	20	41
1650	34	45	26	34	12	35	28	31	28	29
1660	31	26	26	27	18	27	18	19	18	22
1670	17	38	25	33	34	31	27	31	36	30
1680	38	37	35	41	23	03	16	29	29	27

Table 2-P. (continued)

A.D.	0	1	2	3	4	5	6	7	8	9
1690	31	30	29	33	21	28	24	26	30	28
1700	26	37	31	26	24	32	24	18	23	25
1710	30	27	31	30	24	30	26	24	29	33
1720	47	34	18	34	25	41	49	38	19	17
1730	25	30	28	25	36	11	22	16	32	24
1740	17	27	24	32	24	29	38	45	18	36
1750	27	23	20	26	22	21	17	11	24	20
1760	27	27	33	17	25	18	29	15	30	30
1770	26	35	22	08	19	23	21	14	12	22
1780	14	24	12	27	27	33	19	31	27	16
1790	24	31	38	29	22	20	21	37	20	23
1800	20	22	27	20	21	18	17	23	12	21
1810	18	24	26	08	19	25	31	33	15	27
1820	14	26	14	19	15	23	25	23	37	18
1830	23	27	31	28	25	29	24	32	35	30
1840	39	34	25	38	35	06.	24	08	30	35
1850	34	15	33	32	24	24	29	16	29	20
1860	22	08	34	24	19	27	30	37	35	36
1870	23	17	21	18	22	19	20	22	22	17
1880	21	17	11	16	26	28	27	16	26	22
1890	28	27	27	19	13	25	14	25	25	[illegible]
1900	21	21	07	22	14	23	24	34	26	31
1910	30	33	38	25	40	39	34	39	22	31
1920	37	36	35	28	28	21	35	29	34	29
1930	30	17	27	23	09	22	14	24	30	[illegible]
1940	22	32	33	17	30	20	14			

2-4. Colorado River Basin Douglas-fir.
6 Stations, 24-200+ year Trees. Unit .01mm

A.D.	0	1	2	3	4	5	6	7	8	9
1660	---	---	---	---	---	41	34	35	32	45
1670	17	40	45	65	73	42	50	57	65	50
1680	71	52	54	66	45	17	17	57	52	42
1690	48	50	51	49	41	45	47	46	47	42
1700	41	56	59	40	40	43	31	30	27	34
1710	37	39	49	44	39	40	41	37	51	59
1720	72	53	30	54	39	52	66	52	42	24
1730	38	47	36	34	40	23	24	34	53	47
1740	26	37	30	41	37	35	56	50	40	54
1750	36	31	28	41	31	33	26	27	41	39
1760	45	46	46	23	40	40	38	32	39	44
1770	34	40	26	19	26	37	32	21	24	29
1780	17	32	18	35	35	36	20	36	28	19
1790	46	42	55	36	28	35	29	50	27	33
1800	28	31	37	30	24	26	31	36	24	27
1810	39	45	43	22	31	30	42	39	27	40
1820	27	27	23	30	20	26	33	29	39	21
1830	27	29	39	34	28	31	24	38	40	44
1840	40	30	23	44	41	12	31	17	30	41
1850	35	19	31	45	38	31	29	20	34	20
1860	28	17	36	22	29	25	34	48	33	34
1870	26	19	34	26	25	23	26	22	25	14
1880	24	16	12	19	29	31	29	25	28	24
1890	25	31	30	19	14	29	19	30	31	16
1900	25	22	13	28	25	26	28	40	26	34
1910	36	36	36	30	42	39	35	46	24	28
1920	38	42	42	31	29	23	36	30	40	29
1930	34	29	25	25	11	20	11	30	31	20
1940	21	31	(28)	(19)	(32)					

2-5. Colorado River Basin Douglas-fir.*
5 Stations, 26-200+ year Trees. Unit .01 mm

A.D.	0	1	2	3	4	5	6	7	8	9
1750	70	61	45	50	52	32	50	45	57	65
1760	66	51	65	46	66	61	59	72	71	61
1770	76	59	75	54	69	71	67	44	38	51
1780	36	56	22	65	70	68	49	60	38	45
1790	54	72	76	79	56	72	62	56	45	52
1800	43	35	54	41	55	32	36	53	34	45
1810	31	46	56	21	47	50	66	65	25	39
1820	25	50	14	32	36	51	59	54	59	28
1830	37	71	56	58	55	65	52	55	68	72
1840	78	36	42	52	56	26	40	06	46	56
1850	54	36	55	56	46	59	42	27	53	42
1860	32	17	45	35	18	36	55	58	59	69
1870	45	51	41	39	44	38	39	46	45	30
1880	40	43	30	28	43	47	39	32	50	52
1890	63	56	69	38	32	43	17	43	51	13
1900	26	32	18	42	17	36	41	56	52	53
1910	64	58	64	44	60	59	58	61	36	47
1920	61	44	55	39	38	31	51	41	47	34
1930	45	31	42	35	18	38	25	40	37	29
1940	35	46	42	31	36	29	26	---	---	---

* Four Pinus pungens at one station included in this index.

2-6. Colorado River Basin Douglas-fir.
6 Stations, 31-150+ year Trees. Unit .01 mm

A.D.	0	1	2	3	4	5	6	7	8	9
1800	73	61	78	67	71	61	56	53	51	48
1810	44	60	74	48	54	70	79	74	65	46
1820	44	71	45	57	45	49	64	67	62	50
1830	47	78	66	73	59	67	62	79	80	77
1840	66	73	46	77	61	32	43	15	53	65
1850	61	18	56	67	56	44	53	39	59	51
1860	51	25	49	41	36	44	57	69	65	72
1870	61	41	46	51	37	39	44	42	42	38
1880	40	32	37	39	56	62	52	34	42	33
1890	44	46	44	36	36	47	26	41	31	30
1900	37	34	16	38	32	42	43	51	45	50
1910	46	50	60	40	59	56	60	71	53	52
1920	54	66	56	46	57	45	60	58	60	49
1930	51	37	49	40	19	37	32	33	46	31
1940	38	(38)	(43)	(38)	(33)	(28)	(26)			

2-7. Colorado River Basin Pinyon Pine.
3 Stations, 3-850+ year Trees. Unit .01 mm

A.D.	0	1	2	3	4	5	6	7	8	9
1100	68	76	78	79	85	80	75	68	66	66
1110	69	69	78	69	86	69	78	90	52	58
1120	66	68	65	64	69	68	45	57	48	79
1130	74	67	63	63	76	61	74	81	64	59
1140	58	73	68	66	75	77	70	63	56	64
1150	37	46	65	58	41	74	45	52	39	55
1160	45	27	50	51	43	66	51	75	68	59
1170	47	57	66	74	61	46	55	55	53	50
1180	82	84	46	50	73	55	46	69	56	50
1190	79	55	58	66	65	69	57	74	60	52
1200	79	70	66	69	67	63	52	69	63	76
1210	54	59	56	56	53	54	43	30	32	56
1220	45	55	63	54	50	55	65	35	74	59
1230	53	55	56	41	42	48	36	30	62	57
1240	43	59	59	46	44	41	32	36	50	45
1250	36	25	31	46	15	29	29	34	16	48
1260	46	42	44	37	30	44	36	43	57	54
1270	39	57	55	37	40	48	34	44	41	50
1280	41	45	53	26	39	24	37	37	25	44
1290	56	41	42	41	39	15	35	43	46	33
1300	36	53	44	46	34	47	38	22	42	43
1310	52	45	62	63	59	49	25	50	59	64
1320	52	56	48	48	43	60	64	59	43	49
1330	52	68	64	66	56	45	57	64	47	59
1340	51	61	56	52	49	47	54	40	42	33

A.D.	0	1	2	3	4	5	6	7	8	9
1350	26	40	46	65	59	35	52	59	52	45
1360	32	36	33	32	33	40	46	43	48	32
1370	49	41	46	45	39	29	28	37	41	38
1380	48	34	35	38	42	49	40	40	45	40
1390	29	44	41	32	43	52	43	31	36	20
1400	15	33	28	30	37	38	40	35	41	48
1410	30	31	32	21	36	26	29	37	30	30
1420	35	26	28	21	36	26	38	33	36	36
1430	32	35	28	32	32	26	37	28	20	29
1440	37	46	31	33	33	32	29	36	32	25
1450	23	37	34	36	35	12	19	21	33	25
1460	14	12	32	34	13	06	20	27	14	24
1470	25	08	17	25	18	13	28	32	32	22
1480	16	21	39	24	42	37	31	26	36	34
1490	35	36	26	30	35	11	23	26	32	26
1500	00	25	31	33	36	15	11	38	29	45
1510	29	46	46	46	47	31	33	33	26	40
1520	38	33	16	31	31	34	38	36	25	33
1530	35	27	03	32	31	31	45	28	20	37
1540	29	---	---	---	---	---	---	---	---	---

2-U. Colorado River Basin Pinyon Pine.
4 Stations, 8-650+ year Trees. Unit .01 mm

A.D.	0	1	2	3	4	5	6	7	8	9
1320	62	58	68	50	56	60	64	72	63	57
1330	75	83	83	100	88	62	77	77	66	83
1340	70	87	80	65	72	63	68	60	60	59
1350	46	47	49	64	69	51	66	76	70	74
1360	49	45	48	44	52	50	65	58	70	52
1370	65	59	64	62	66	56	46	56	62	55
1380	68	52	46	53	47	65	55	62	62	54
1390	42	51	54	52	57	60	59	46	47	36
1400	37	44	35	41	51	52	52	45	59	70
1410	52	56	59	43	64	47	43	53	52	40
1420	53	42	49	44	47	45	51	54	50	45
1430	44	60	45	50	48	37	47	42	36	44
1440	56	59	36	47	41	47	[illegible]	59	54	46
1450	38	57	60	58	60	72	26	34	52	39
1460	21	24	46	49	41	22	42	47	41	40
1470	45	27	32	36	35	24	40	46	51	41
1480	38	36	55	41	63	53	53	49	61	57
1490	57	67	70	51	65	31	36	46	60	39
1500	15	42	47	48	41	12	13	36	36	48
1510	37	46	48	52	48	29	43	47	34	50
1520	42	57	33	51	50	55	52	60	49	41
1530	53	37	29	45	51	49	53	42	38	47
1540	51	45	24	46	36	40	48	40	51	56
1550	49	45	52	43	47	39	46	40	24	37

A.D.	0	1	2	3	4	5	6	7	8	9
1560	41	41	40	44	52	44	45	33	46	42
1570	45	45	40	31	34	44	50	54	38	16
1580	11	41	36	27	10	15	39	32	38	39
1590	16	32	26	32	47	43	48	45	33	42
1600	20	41	41	33	46	48	48	34	39	46
1610	50	48	39	40	40	50	42	51	47	51
1620	55	53	40	35	37	41	21	42	32	35
1630	40	29	08	47	38	35	28	27	26	26
1640	42	39	38	43	43	31	36	49	29	49
1650	46	51	30	31	27	37	37	28	34	39
1660	42	37	39	36	40	39	27	27	31	41
1670	27	34	42	44	41	40	33	41	44	35
1680	42	45	39	45	27	11	20	40	42	35
1690	37	41	40	51	38	39	38	34	36	43
1700	28	40	44	33	35	44	31	23	25	38
1710	38	42	37	37	26	40	46	40	46	54
1720	58	29	25	44	32	45	52	50	44	18
1730	44	43	39	39	54	12	31	28	41	42
1740	28	35	36	35	34	44	43	48	25	48
1750	29	25	25	30	30	25	28	27	36	36
1760	41	36	44	26	43	20	35	29	34	37
1770	35	44	42	11	25	37	29	29	18	34
1780	20	26	10	34	43	35	29	42	23	30
1790	35	43	43	35	24	23	29	38	31	45
1800	34	34	46	30	38	31	31	43	24	35
1810	39	45	45	18	32	35	50	40	23	31

A.D.	0	1	2	3	4	5	6	7	8	9
1820	28	37	23	22	22	39	45	35	51	32
1830	38	35	43	37	28	34	26	41	42	47
1840	37	34	20	34	39	15	28	13	29	49
1850	42	21	42	41	35	32	31	25	39	26
1860	25	15	42	32	19	27	40	44	44	40
1870	30	16	29	23	29	27	24	29	24	16
1880	28	24	18	22	32	34	26	23	31	24
1890	34	34	29	19	21	27	19	32	45	17
1900	19	30	12	36	22	40	42	46	29	39
1910	35	41	39	41	42	44	43	40	35	29
1920	41	47	39	35	40	34	39	39	37	31
1930	33	32	33	34	20	34	20	46	38	29
1940	33	45	(48)	(39)	(39)	(36)	(20)	(46)	(25)	

2-V. Colorado River Basin Pinyon Pine.
11 Stations, 32-150+ year Trees. Unit .01mm

A.D.	0	1	2	3	4	5	6	7	8	9
1800	45	44	57	42	39	42	38	50	41	46
1810	50	60	55	35	45	46	55	50	39	46
1820	33	47	31	35	27	40	53	42	55	39
1830	46	44	57	48	45	47	42	52	55	56
1840	51	51	38	54	45	21	33	18	39	60
1850	55	28	50	52	36	34	36	28	41	32
1860	34	15	49	35	28	35	46	50	50	41
1870	40	22	40	29	31	31	32	33	31	21
1880	36	30	23	26	37	39	37	26	38	30
1890	39	40	34	24	24	37	21	[illegible]	48	26
1900	27	33	14	42	30	41	49	49	38	46
1910	45	49	46	41	53	44	44	46	41	39
1920	52	51	45	48	45	37	41	45	39	41
1930	41	33	42	36	23	68	27	44	41	30
1940	34	49	48	40	40	---	---	---	---	---

2-W. Gila River Basin Ponderosa Pine

A.D.	0	1	2	3	4	5	6	7	8	9
1600	---	---	---	149	113	79	118	98	106	80
1610	108	109	100	79	114	104	107	112	120	124
1620	98	94	88	87	80	64	66	86	90	124
1630	90	94	70	114	136	143	164	140	111	146
1640	144	126	140	172	140	110	138	136	26	86
1650	85	136	96	98	46	88	114	96	68	106
1660	102	170	166	152	124	164	170	93	53	64
1670	29	63	123	127	122	112	102	99	75	101
1680	140	114	109	126	102	54	116	114	124	131
1690	142	115	165	152	155	128	97	106	68	115
1700	120	142	109	107	82	79	77	49	82	47
1710	103	83	106	95	97	77	80	102	115	102
1720	145	129	118	104	88	119	168	93	89	93
1730	94	93	105	61	105	68	90	98	102	73
1740	77	101	91	122	95	120	151	127	43	125
1750	104	122	52	86	113	104	84	89	119	116
1760	74	95	127	99	147	124	126	120	107	112
1770	114	135	96	41	86	101	94	74	106	95
1780	77	103	64	123	145	66	84	125	61	80
1790	100	114	108	156	90	103	105	84	81	109
1800	104	80	101	80	110	90	76	90	95	105
1810	114	113	107	77	105	128	147	96	68	54
1820	57	80	80	70	82	88	107	99	115	118
1830	126	99	141	127	111	115	94	102	101	126
1840	115	79	70	89	112	110	111	56	110	125

A.D.	0	1	2	3	4	5	6	7	8	9
1850	124	90	121	101	98	126	113	102	116	88
1860	125	87	100	56	46	102	141	126	156	142
1870	125	75	88	77	91	112	95	104	110	95
1880	79	85	104	94	103	107	90	87	69	105
1890	96	106	73	66	60	67	91	104	142	110
1900	[illegible]	103	44	94	16	106	100	127	155	126
1910	88	120	133	93	121	132	122	126	65	131
1920	116	74	69	65	101	55	96	96	93	77
1930	104	104	114	119	46	103	86	61	76	68

2-Z. Southern Arizona Douglas-fir

A.D.	0	1	2	3	4	5	6	7	8	9
1410	---	---	---	---	137	113	82	39	47	94
1420	110	134	96	69	139	126	157	173	150	95
1430	130	114	111	136	109	76	74	59	57	48
1440	51	74	80	66	94	60	67	44	31	43
1450	48	95	93	95	64	51	80	96	134	125
1460	142	178	150	120	96	67	123	140	65	109
1470	116	51	96	141	155	173	155	190	150	122
1480	83	117	114	140	144	141	171	146	80	127
1490	126	106	98	101	105	41	91	57	47	65
1500	140	136	136	100	126	153	146	173	135	141
1510	133	120	131	94	76	56	53	35	61	129
1520	133	110	114	103	66	35	70	56	12	39
1530	46	39	76	76	56	69	89	60	15	66
1540	124	116	91	137	153	109	164	134	106	161
1550	168	106	145	144	159	140	101	63	103	81
1560	93	67	73	67	139	78	94	99	43	56
1570	63	66	75	39	63	68	64	90	102	50
1580	74	106	74	72	76	20	105	67	110	69
1590	80	112	137	178	162	114	134	110	104	142
1600	103	62	104	120	78	72	84	104	99	97
1610	105	83	198	78	97	79	63	114	109	101
1620	102	136	122	74	61	96	66	120	152	156
1630	138	106	65	35	108	113	137	103	119	140
1640	136	97	105	94	99	96	171	96	26	90
1650	90	175	79	84	47	111	107	109	109	89

A.D.	0	1	2	3	4	5	6	7	8	9
1660	110	158	134	118	78	116	103	91	47	36
1670	13	96	97	97	130	180	71	116	121	99
1680	131	105	115	122	89	41	93	87	107	116
1690	112	106	125	129	118	104	61	78	71	110
1700	100	131	106	81	84	71	88	79	67	64
1710	136	108	107	86	110	86	61	111	124	86
1720	105	94	79	82	98	77	170	112	80	104
1730	96	115	95	48	102	66	106	109	46	60
1740	72	104	77	119	106	112	159	141	38	114
1750	103	87	52	68	97	80	83	85	111	117
1760	105	86	126	68	113	116	120	119	109	111
1770	112	121	110	67	87	92	79	68	81	81
1780	62	83	65	129	132	65	74	104	84	81
1790	65	107	111	126	88	138	88	70	69	108
1800	98	93	128	103	120	91	70	93	64	107
1810	117	98	97	81	102	153	161	110	91	38
1820	53	95	58	67	91	85	101	106	118	114
1830	118	128	109	132	107	126	90	119	120	139
1840	114	64	56	86	114	107	117	53	106	116
1850	117	88	112	95	72	98	137	102	131	110
1860	100	89	100	38	43	81	97	105	120	114
1870	104	89	73	81	93	95	84	105	92	85
1880	103	82	130	123	105	106	86	77	105	96
1890	91	112	81	75	69	61	98	89	129	109
1900	69	100	49	105	32	112	102	130	158	134
1910	71	97	132	113	116	175	130	129	84	139
1920	134	61	106	76	96	99	103	106	74	66
1930	139	109	137	115	71	99	80	84	92	57
1940	96	113	113	59	94	81	60	49	55	91
1950	72	---	---	---	---	---	---	---	---	---

2-Y. Upper Rio Grande Basin Douglas-fir

A.D.	0	1	2	3	4	5	6	7	8	9
1370	---	---	---	---	---	64	25	76	152	205
1380	109	122	18	111	74	129	115	137	120	136
1390	87	218	267	82	125	154	132	93	106	21
1400	66	140	93	56	186	130	173	86	128	159
1410	116	63	114	39	141	16	80	63	121	40
1420	40	77	56	61	62	113	133	149	179	35
1430	99	111	41	64	75	135	25	34	14	61
1440	80	126	107	191	102	24	135	142	162	40
1450	64	171	98	95	173	45	62	98	173	111
1460	122	76	82	60	85	149	233	195	98	73
1470	80	18	138	58	42	24	62	53	66	66
1480	11	55	31	46	122	126	133	57	71	96
1490	113	126	113	84	124	75	33	67	129	115
1500	40	60	98	82	82	88	25	80	116	82
1510	146	166	132	152	155	109	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	125	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	68	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	136	52	176	180	91

A.D.	0	1	2	3	4	5	6	7	8	9
1620	154	158	114	135	58	29	73	130	31	13?
1630	152	97	72	105	139	174	121	160	78	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	66	195
1690	151	107	154	121	68	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	62	136	125	65	21
1730	55	77	93	64	93	78	90	29	19	71
1740	50	89	68	125	60	114	144	167	36	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	61	92	58
1780	45	56	71	104	128	91	61	136	70	77
1790	110	144	142	156	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	61	163	36	93	69	116	82	119	100	73
1830	120	117	130	128	135	105	62	144	164	135
1840	198	135	45	136	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	149
1870	83	94	89	100	125	54	95	126	78	93

A.D.	0	1	2	3	4	5	6	7	8	9
1880	33	97	114	81	120	131	134	146	155	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	152	48	108	151	136	103	76	158
1920	162	119	89	43	111	31	106	62	109	68
1930	107	98	158	104	38	137	73	131	71	100
1940	94	161	(134)	(69)	(101)	(94)	(38)	(84)	(147)	(155)
1950	(39)	(15)	---	---	---	---	---	---	---	---

2-Z. Upper Rio Grande Basin Pinon Pine

A.D.	0	1	2	3	4	5	6	7	8	9
1350	---	---	---	---	---	---	104	109	167	148
1360	63	112	60	69	47	86	80	109	95	54
1370	125	106	117	67	156	95	95	132	116	65
1380	160	107	65	87	79	117	118	163	155	110
1390	61	73	111	177	141	136	121	103	78	06
1400	78	95	89	80	136	86	142	62	81	72
1410	111	95	129	79	137	80	80	104	86	39
1420	94	71	83	22	81	165	171	150	172	67
1430	125	123	97	85	126	68	115	92	92	112
1440	102	140	121	120	96	51	95	95	84	84
1450	104	143	147	122	86	76	120	75	63	99
1460	86	98	76	83	69	63	106	106	94	51
1470	64	10	85	98	67	65	99	133	155	147
1480	126	124	152	105	150	160	176	127	145	116
1490	150	152	95	100	140	51	29	77	117	143
1500	61	139	144	159	171	176	61	102	82	75
1510	54	116	116	116	142	141	107	46	55	115
1520	113	152	75	112	93	69	135	160	69	116
1530	117	117	80	88	108	61	116	127	102	127
1540	125	159	59	107	96	29	96	123	105	21
1550	118	37	116	100	130	157	133	149	107	78
1560	43	97	46	54	43	114	101	107	63	124
1570	72	39	99	28	66	92	88	73	67	22
1580	36	35	76	56	25	57	119	105	114	125
1590	11	39	95	58	126	112	130	121	35	108
1600	73	12	108	126	153	177	156	150	163	121
1610	137	83	96	116	123	96	45	99	139	94

A.D.	0	1	2	3	4	5	6	7	8	9
1620	136	88	103	70	112	52	46	30	79	107
1630	107	128	122	82	95	143	152	146	85	156
1640	195	91	140	125	140	40	116	58	12	67
1650	64	67	93	102	39	119	104	107	40	157
1660	64	169	175	104	112	129	64	94	47	86
1670	96	77	116	125	127	61	104	119	128	102
1680	100	61	29	92	79	07	75	93	64	116
1690	107	92	116	134	61	79	68	66	72	104
1700	59	112	73	128	39	80	101	94	101	42
1710	127	165	135	152	115	117	47	61	87	87
1720	140	142	100	100	140	176	134	139	125	07
1730	29	65	109	65	119	65	126	76	63	96
1740	71	64	57	72	55	05	105	95	22	98
1750	107	115	70	95	93	116	121	63	154	141
1760	166	145	165	137	142	126	151	103	162	139
1770	147	147	114	44	65	50	61	64	94	76
1780	06	36	71	103	118	100	87	101	69	50
1790	90	93	122	110	123	113	131	102	59	119
1800	132	70	87	68	114	76	60	109	90	49
1810	106	96	118	129	143	94	135	103	31	06
1820	83	83	61	67	93	104	123	123	149	139
1830	113	113	107	167	96	151	129	174	69	114
1840	115	146	54	109	98	106	72	40	09	118
1850	78	17	58	58	92	84	110	92	115	138
1860	145	00	75	29	78	87	61	124	142	130
1870	128	99	107	140	12	84	93	113	61	87

A.D.	0	1	2	3	4	5	6	7	8	9
1880	61	93	73	53	53	177	154	169	147	160
1890	102	160	149	64	61	114	67	105	119	32
1900	119	53	03	87	17	125	102	119	96	96
1910	125	90	152	99	131	137	87	106	64	106
1920	119	160	111	55	137	82	119	105	99	79
1930	70	82	131	119	99	85	85	152	128	117
1940	105	154	163	73	126	125	50	157	157	114
1950	32	50	---	---	---	---	---	---	---	---

2-AA. Upper Rio Grande Basin Douglas-fir.
7 Stations, 8-500+ year Trees. Unit .01 mm

A.D.	0	1	2	3	4	5	6	7	8	9
1440	44	69	59	105	56	13	74	78	89	22
1450	38	94	54	52	95	25	34	54	95	61
1460	67	45	45	35	47	82	128	107	54	40
1470	44	10	76	32	23	13	45	29	36	36
1480	08	30	17	25	67	69	73	37	39	53
1490	62	69	62	46	68	19	18	37	71	63
1500	22	33	54	45	45	45	14	44	64	45
1510	80	102	72	83	85	59	08	47	76	70
1520	78	77	26	47	22	36	50	62	52	81
1530	61	47	39	50	87	42	56	73	39	67
1540	76	75	31	75	48	29	29	48	52	32
1550	72	31	56	81	82	70	79	70	41	65
1560	32	30	13	27	41	66	48	33	60	68
1570	87	26	63	14	38	51	51	70	59	10
1580	13	36	23	18	23	14	41	28	43	36
1590	16	23	46	23	78	77	72	73	27	30
1600	30	27	52	49	32	52	29	42	42	62
1610	72	75	48	76	34	67	25	66	87	44
1620	74	76	55	65	28	14	35	62	15	63
1630	72	44	34	50	66	82	57	85	36	90
1640	92	48	46	67	45	18	80	71	26	79
1650	43	92	62	72	36	80	58	52	41	37
1660	70	61	79	80	36	67	27	38	29	32
1670	34	34	34	49	46	49	28	74	54	53

Table 2AA (continued)

A.D.	0	1	2	3	4	5	6	7	8	9
1680	65	39	52	51	18	07	45	52	34	51
1690	76	45	74	50	48	56	20	41	44	43
1700	25	63	35	54	39	12	44	29	44	23
1710	66	51	59	64	23	45	11	47	46	22
1720	65	72	[illegible]	51	42	35	54	56	25	10
1730	17	33	39	20	42	35	32	08	02	27
1740	30	38	25	49	29	44	45	69	09	49
1750	13	48	22	22	36	33	31	19	48	46
1760	34	48	66	22	56	42	59	41	71	46
1770	61	61	50	15	36	35	45	35	40	28
1780	25	29	33	42	53	40	33	55	26	27
1790	36	62	57	39	39	35	33	31	36	33
1800	37	25	43	30	56	34	13	55	30	51
1810	31	46	46	44	22	41	56	46	13	17
1820	25	61	10	26	32	44	26	39	64	33
1830	31	44	40	50	56	44	28	50	66	68
1840	71	52	16	48	43	25	37	12	36	50
1850	39	14	36	41	44	49	56	36	37	21
1860	31	13	36	27	26	40	53	62	52	57
1870	21	27	27	26	54	22	33	41	25	32
1880	13	31	37	24	32	31	45	49	47	24
1890	19	36	26	12	29	25	07	44	20	04
1900	23	17	12	25	02	26	24	31	13	17
1910	24	16	35	18	29	37	41	34	25	42
1920	40	34	30	23	26	09	41	25	35	32
1930	37	32	46	37	10	39	22	36	29	27
1940	23	43	39	20	29	27	11	24	41	44
1950	11	15	---	---	---	---	---	---	---	---

* Five trees, 1680-81; six, 1682-89; seven, 1942-48; five, 1949-50; four, 1951. The mean ring-widths for the foregoing intervals have been adjusted to the eight-tree mean.

2-AB. Upper Rio Grande Basin Douglas-fir. 5 Stations, 19-300+ year Trees. Unit .01 mm

A.D.	0	1	2	3	4	5	6	7	8	9
1650	70	105	86	102	88	114	79	69	50	55
1660	81	87	88	91	41	78	37	47	32	35
1670	44	50	50	60	61	61	36	86	72	61
1680	87	56	60	62	24	07	68	66	52	118
1690	91	64	92	72	52	74	24	54	54	62
1700	38	92	60	87	62	30	62	40	69	31
1710	89	65	76	77	30	48	14	54	56	36
1720	80	91	53	56	49	44	66	67	38	11
1730	29	41	49	34	49	41	47	15	10	37
1740	26	46	35	64	41	58	73	95	14	71
1750	29	65	32	26	68	47	41	26	52	53
1760	42	49	78	33	73	80	76	59	79	54
1770	76	84	62	20	40	32	47	36	43	27
1780	21	26	33	48	59	42	37	62	32	38
1790	50	65	64	71	50	49	39	46	57	46
1800	55	33	44	37	63	42	19	57	38	43
1810	36	46	45	47	32	52	70	55	25	19
1820	34	69	15	39	37	48	84	49	74	30
1830	49	48	55	52	55	42	25	56	66	54
1840	79	54	18	51	42	29	36	12	33	49
1850	44	14	41	40	44	51	61	40	39	84
1860	37	09	36	25	26	41	50	64	55	74
1870	31	35	33	37	46	20	35	46	38	34
1880	12	35	41	29	43	47	48	52	54	26
1890	25	42	33	19	33	33	11	52	36	09
1900	30	33	13	33	06	41	36	30	23	20
1910	27	26	41	16	36	50	45	34	25	58
1920	53	39	29	14	36	10	44	20	35	26
1930	34	31	50	33	12	42	25	41	22	31
1940	29	50	---	---	---	---	---	---	---	---

2-AC. Middle Rio Grande (Guadalupe) Douglas-fir

A.D.	0	1	2	3	4	5	6	7	8	9
1650	89	163	131	89	101	90	75	89	115	118
1660	94	91	80	108	81	136	71	53	44	101
1670	77	123	56	51	74	88	86	64	70	54
1680	80	92	139	125	79	66	121	65	72	168
1690	162	114	174	164	173	144	42	105	91	94
1700	87	133	95	146	129	44	116	86	148	66
1710	147	120	144	136	56	95	58	100	134	49
1720	96	112	139	122	54	91	127	126	62	91
1730	13	69	72	31	73	134	103	160	96	59
1740	71	105	47	136	127	151	170	209	86	137
1750	109	114	70	88	82	100	94	14	116	115
1760	88	123	167	67	119	83	168	76	119	110
1770	184	116	90	44	71	91	1[illegible]5	92	83	155
1780	72	94	64	158	151	94	60	93	86	21
1790	82	121	100	166	147	153	62	113	57	96
1800	91	106	93	75	82	83	80	103	55	96
1810	121	96	119	65	134	162	210	141	30	69
1820	59	174	53	42	94	80	113	195	126	174
1830	122	78	57	161	213	171	96	92	96	127
1840	114	87	61	93	77	109	140	82	132	132
1850	145	75	90	137	162	100	125	122	140	04
1860	70	32	48	59	29	61	96	41	120	165
1870	80	105	90	68	57	63	78	94	118	54
1880	50	149	153	149	166	145	64	69	194	137
1890	53	206	69	156	79	79	98	129	96	116
1900	122	147	64	139	12	125	131	114	118	52
1910	44	116	80	166	179	153	77	95	63	141
1920	194	153	37	93	130	06	150	65	78	127
1930	127	125	150	43	25	19	55	86	62	65
1940	57	147	---	---	---	---	---	---	---	---

2-AD. Middle Rio Grande (Big Bend) Douglas-fir

A.D.	0	1	2	3	4	5	6	7	8	9
1640	---	---	---	---	---	73	117	51	63	116
1650	190	182	126	109	187	117	144	74	103	141
1660	47	54	81	59	56	76	34	66	99	30
1670	173	152	110	126	121	93	108	1[illegible]7	69	39
1680	134	120	93	81	46	27	111	79	29	100
1690	86	109	193	163	144	130	17	113	89	80
1700	247	181	120	136	18	87	117	130	43	93
1710	134	34	130	49	34	75	48	25	119	67
1720	43	213	128	194	164	72	201	79	68	67
1730	48	46	110	86	151	296	222	273	202	64
1740	175	127	48	77	89	69	180	208	109	63
1750	68	95	52	34	48	43	77	47	91	104
1760	80	200	177	90	108	81	132	131	181	211
1770	238	167	94	100	48	141	91	190	43	64
1780	107	42	92	68	123	31	56	48	112	06
1790	29	83	96	164	143	191	168	121	66	173
1800	118	06	124	157	74	12	115	62	28	94
1810	106	79	33	44	136	68	208	110	90	22
1820	108	125	118	30	212	134	264	318	208	206
1830	163	88	100	141	126	196	174	207	167	174
1840	26	38	77	144	143	168	230	63	179	106
1850	131	63	45	168	25	111	181	93	241	49
1860	56	96	34	53	80	94	111	34	90	183
1870	86	62	16	97	80	40	111	109	95	29
1880	51	177	143	104	48	141	04	88	168	93
1890	37	149	25	69	33	34	132	26	57	49
1900	91	167	25	200	43	140	133	131	292	47
1910	06	171	117	62	101	188	14	158	119	148
1920	168	121	38	174	160	08	179	104	47	138
1930	34	141	40	139	78	63	160	128	88	101
1940	109	119	97	71	131	34	---	---	---	---

Table 2-AE. Southeastern Oregon Ponderosa Pine

A.D.	0	1	2	3	4	5	6	7	8	9
1450	---	---	---	51	90	115	129	130	127	110
1460	134	125	106	98	97	90	69	103	104	134
1470	86	86	130	132	106	133	99	82	97	70
1480	78	94	89	82	78	107	124	118	96	98
1490	108	130	128	123	102	74	126	75	59	99
1500	47	51	79	118	90	106	111	104	81	108
1510	100	110	123	92	93	91	74	80	85	111
1520	103	90	99	105	122	162	110	131	93	73
1530	96	120	45	72	84	86	111	92	108	141
1540	124	109	112	97	106	95	87	86	80	90
1550	75	84	105	107	78	77	92	103	114	126
1560	117	107	107	94	118	98	108	113	108	110
1570	114	89	92	107	96	108	76	88	98	97
1580	86	70	87	86	81	78	67	120	131	112
1590	110	107	110	88	81	82	104	129	82	135
1600	116	125	130	108	97	111	112	104	110	93
1610	135	127	116	134	100	111	91	109	118	97
1620	86	104	100	72	93	101	77	76	77	65
1630	68	68	62	98	112	115	111	102	103	64
1640	81	102	121	125	121	123	107	117	110	117
1650	141	125	111	97	106	60	85	75	81	77
1660	72	86	77	93	93	83	92	75	81	121
1670	115	110	113	126	141	125	107	107	104	117
1680	95	129	95	89	104	101	97	68	93	96
1690	101	85	81	87	95	77	93	107	91	100

A.D.	0	1	2	3	4	5	6	7	8	9
1700	106	87	135	90	105	116	99	112	84	94
1710	99	104	103	110	81	119	106	84	75	72
1720	78	61	74	86	79	107	115	103	102	72
1730	98	122	122	106	101	94	87	89	105	65
1740	60	71	89	103	95	145	121	152	95	134
1750	94	112	120	94	93	145	66	65	82	87
1760	93	108	107	105	96	110	99	99	116	101
1770	90	96	98	110	108	125	92	63	79	92
1780	93	71	87	46	97	95	104	89	95	122
1790	119	179	148	132	95	84	85	68	74	105
1800	80	97	101	108	95	110	131	103	110	146
1810	127	125	131	104	123	117	115	98	127	122
1820	102	116	101	101	101	120	101	104	124	52
1830	92	79	104	77	77	100	120	115	132	88
1840	79	74	67	55	69	87	52	65	57	61
1850	73	91	95	96	114	144	96	108	90	87
1860	115	137	115	107	80	87	123	101	131	116
1870	96	86	94	93	92	117	93	110	110	122
1880	89	117	89	75	108	113	88	94	109	61
1890	66	102	85	90	132	91	100	124	94	72
1900	96	97	93	107	116	111	124	147	149	145
1910	116	94	91	142	112	114	118	95	58	71
1920	50	84	68	85	34	79	64	88	112	52
1930	66	53								

2-AF. East-Central California (Mono-Owens) Jeffrey Pine

A.D.	0	1	2	3	4	5	6	7	8	9
1350	---	---	---	68	111	118	126	131	108	123
1360	117	124	104	75	106	50	79	94	98	110
1370	112	96	142	167	147	125	103	43	66	57
1380	84	84	101	123	156	121	139	126	119	122
1390	44	69	100	105	124	136	130	115	140	151
1400	110	98	75	86	153	99	97	87	47	113
1410	83	103	108	78	98	106	64	110	129	88
1420	113	84	107	160	73	85	74	90	58	61
1430	73	70	51	68	62	70	78	73	68	73
1440	98	77	55	52	56	68	88	106	78	82
1450	79	54	40	65	66	37	33	55	69	65
1460	67	65	84	158	134	132	117	136	59	109
1470	127	156	146	102	84	93	75	65	107	39
1480	69	82	100	80	114	114	119	93	119	106
1490	72	110	107	105	85	108	92	57	56	34
1500	35	48	66	97	107	92	71	90	93	134
1510	152	94	147	121	72	79	72	101	42	70
1520	87	66	90	71	112	138	110	95	122	63
1530	76	89	41	78	104	121	114	117	126	160
1540	90	74	81	90	103	55	93	107	34	87
1550	119	115	133	125	83	97	101	78	130	137
1560	121	76	123	112	106	119	137	112	147	142
1570	106	51	90	116	102	107	42	99	106	52
1580	15	66	72	102	121	73	89	86	96	144
1590	100	91	59	79	72	64	102	106	76	98

A.D.	0	1	2	3	4	5	6	7	8	9
1600	88	76	99	115	102	116	152	97	121	141
1610	117	158	114	77	102	137	109	154	170	110
1620	115	102	72	108	98	110	97	106	100	62
1630	80	85	50	89	70	95	104	53	77	64
1640	92	115	114	111	116	110	75	64	98	102
1650	121	115	118	93	78	41	86	79	75	86
1660	116	147	139	103	115	109	110	68	78	62
1670	31	65	72	85	79	102	80	75	75	84
1680	83	93	95	103	112	118	87	102	129	102
1690	108	43	99	106	100	100	125	136	109	117
1700	154	106	122	99	93	109	103	98	101	103
1710	105	108	107	108	102	109	110	116	85	82
1720	108	98	88	116	104	101	178	132	96	26
1730	74	82	94	108	108	115	107	102	108	56
1740	80	94	109	112	116	145	[illegible]	112	120	137
1750	132	114	136	112	115	105	66	56	82	82
1760	91	110	108	102	93	61	94	94	108	119
1770	94	105	125	112	117	99	83	53	65	85
1780	91	97	72	57	93	121	104	123	67	128
1790	123	104	131	134	103	38	33	92	102	119
1800	116	120	130	127	116	100	122	93	78	68
1810	90	110	108	88	104	104	111	116	108	112
1820	99	83	62	72	63	91	125	95	99	71
1830	87	90	115	102	79	60	68	85	89	84
1840	100	70	92	70	64	79	68	71	90	86
1850	103	90	92	124	106	136	53	99	61	57
1860	76	102	82	92	78	95	93	109	153	142

A.D.	0	1	2	3	4	5	6	7	8	9
1870	129	111	128	148	118	147	134	124	127	118
1880	92	124	101	86	115	143	102	98	110	91
1890	101	131	128	132	116	137	129	118	90	95
1900	100	144	125	86	98	134	102	162	131	129
1910	109	116	98	116	145	118	144	120	131	126
1920	104	119	111	116	49	61	84	96	85	49
1930	89	94	86	88	78	82	87	89	116	94
1940	88	111	---	---	---	---	---	---	---	---

8-AG.Southern California Bigcone Spruce

A.D.	0	1	2	3	4	5	6	7	8	9
1380	---	---	---	---	---	163	143	178	75	112
1390	98	119	113	153	138	59	71	61	116	204
1400	259	141	53	102	101	24	104	28	104	135
1410	119	109	87	38	111	100	101	89	81	89
1420	86	56	72	88	87	35	136	127	156	92
1430	127	111	117	80	32	78	93	69	101	116
1440	113	210	154	106	40	113	58	94	107	117
1450	101	117	29	118	81	85	66	73	160	89
1460	82	115	131	103	33	46	93	106	72	131
1470	137	110	80	97	101	94	96	152	105	98
1480	115	128	126	137	173	117	130	126	115	97
1490	117	98	87	105	69	66	75	53	114	73
1500	55	77	101	125	141	93	79	79	100	113
1510	52	116	102	77	113	64	85	107	93	118
1520	55	60	48	79	93	115	173	83	82	86
1530	99	106	61	100	129	147	136	137	178	152
1540	119	85	24	96	56	82	75	53	75	121
1550	133	125	98	125	115	130	125	163	112	119
1560	98	101	119	93	115	138	103	131	161	98
1570	111	35	76	64	76	88	102	118	99	32
1580	15	97	91	81	57	05	89	117	89	132
1590	27	74	54	81	96	85	107	58	112	134
1600	78	140	130	124	166	130	105	107	154	114
1610	154	163	109	27	92	98	106	132	66	65
1620	157	135	91	71	91	100	72	61	[illegible]	79

A.D.	0	1	2	3	4	5	6	7	8	9
1630	92	77	71	19	44	93	97	33	84	113
1640	127	160	164	97	128	94	92	149	68	133
1650	94	124	101	70	27	47	67	75	65	104
1660	111	149	111	96	118	51	63	64	64	52
1670	14	63	76	93	120	115	52	97	104	136
1680	154	103	153	123	124	136	86	134	114	100
1690	88	99	103	102	107	110	135	121	90	131
1700	125	114	146	80	72	91	75	43	55	90
1710	105	84	108	87	108	75	76	79	103	135
1720	110	106	76	130	109	110	134	125	87	68
1730	87	104	101	87	110	61	73	65	101	64
1740	88	120	97	112	108	136	182	165	82	172
1750	140	115	41	82	31	67	51	66	79	81
1760	103	93	113	86	100	37	152	124	130	124
1770	90	141	114	63	120	110	113	36	83	73
1780	92	118	19	89	109	111	139	167	68	99
1790	102	152	146	172	77	65	91	140	93	127
1800	109	127	137	63	163	123	123	75	118	41
1810	100	112	59	54	73	82	108	98	141	135
1820	72	125	70	44	56	104	141	128	152	30
1830	125	122	166	158	106	79	97	105	127	165
1840	179	39	118	41	100	23	96	62	76	82
1850	97	96	127	182	140	158	76	41	72	76
1860	66	80	114	78	33	104	120	121	177	143
1870	46	72	82	65	89	77	98	44	109	64
1880	95	80	73	61	115	99	134	104	124	117

A.D.	0	1	2	3	4	5	6	7	8	9
1890	134	168	135	124	77	95	67	84	45	76
1900	47	74	63	90	55	102	149	141	112	136
1910	123	95	86	97	115	126	134	142	90	60
1920	124	116	135	120	74	60	104	103	93	66
1930	91	63	106	96	34	116	97	143	152	136
1940	137	136	128	124	131	(104)	(99)	(92)	(69)	(68)
1950	(60)									

2-AH. Southern California (San Bernardino Mts.) Ponderosa Pine

A.D.	0	1	2	3	4	5	6	7	8	9
1350	145	89	77	80	44	85	102	107	38	97
1360	56	61	102	96	94	41	95	106	91	98
1370	83	77	85	102	119	113	157	128	133	49
1380	101	149	106	117	118	99	127	129	149	159
1390	71	39	125	132	107	75	95	81	97	97
1400	95	127	91	84	123	75	103	41	86	110
1410	98	68	109	52	150	122	108	57	128	94
1420	87	62	113	80	96	61	77	109	95	105
1430	67	113	105	88	54	49	83	97	71	101
1440	54	96	87	42	29	90	50	48	70	83
1450	83	82	43	93	90	130	75	113	123	95
1460	109	107	104	130	45	56	96	109	118	106
1470	132	133	129	124	115	126	135	121	143	110
1480	123	136	127	115	132	77	107	107	84	102
1490	110	115	64	110	127	111	111	56	115	69
1500	51	93	89	95	83	73	32	86	86	107
1510	60	82	77	91	96	90	115	111	96	116
1520	38	42	87	68	104	107	94	91	85	54
1530	87	106	100	105	126	147	113	115	131	121
1540	129	100	28	114	112	76	113	74	90	108
1550	122	107	122	123	122	114	126	119	124	102
1560	100	107	122	110	122	122	104	107	124	99
1570	88	48	67	85	93	87	93	110	90	49
1580	22	101	77	86	55	14	87	95	89	100
1590	43	45	79	92	94	102	122	85	65	96

A.D.	0	1	2	3	4	5	6	7	8	9
1600	103	94	89	96	101	98	117	91	115	94
1610	129	134	105	62	123	120	106	107	133	88
1620	122	118	99	104	89	113	63	96	86	93
1630	116	94	71	37	67	101	108	54	97	126
1640	114	135	146	124	149	144	117	139	72	118
1650	92	147	132	60	22	57	127	115	124	115
1660	138	138	137	119	146	97	76	68	96	92
1670	21	110	114	110	114	102	56	120	108	112
1680	114	121	131	120	112	108	60	120	118	107
1690	98	94	118	98	138	137	123	108	83	116
1700	105	107	128	66	105	151	101	70	83	112
1710	115	124	133	97	86	59	36	101	104	105
1720	125	113	56	119	78	108	115	113	48	43
1730	104	119	112	87	107	38	41	40	83	73
1740	87	100	73	108	125	137	157	166	112	122
1750	128	107	33	72	30	64	74	76	83	83
1760	96	102	114	88	91	42	141	118	144	116
1770	95	125	139	77	110	118	102	45	57	83
1780	84	97	36	55	114	103	113	132	81	114
1790	106	122	174	170	94	54	63	110	94	113
1800	96	101	128	86	122	103	102	59	83	21
1810	57	90	89	46	79	92	103	107	141	135
1820	57	92	59	36	56	137	136	112	149	78
1830	98	100	133	124	117	90	89	87	144	144
1840	155	54	58	34	81	56	88	80	88	103
1850	129	93	119	146	114	135	73	20	59	62
1860	88	107	106	85	53	75	140	129	156	144

A.D.	0	1	2	3	4	5	6	7	8	9
1870	83	83	88	93	98	115	115	67	103	46
1880	61	74	71	60	99	101	92	102	107	102
1890	129	140	131	137	117	130	93	93	68	43
1900	45	77	65	59	73	115	112	127	128	131
1910	136	120	124	103	153	126	151	125	111	118
1920	121	116	123	123	98	83	122	106	79	85
1930	114	99	---	---	---	---	---	---	---	---

2-AI. West-Central Mexico Douglas-fir

A.D.	0	1	2	3	4	5	6	7	8	9
1640	127	94	115	85	76	76	112	62	43	54
1650	76	156	116	66	74	102	155	66	78	95
1660	154	148	116	105	112	127	101	93	60	69
1670	77	109	48	79	121	95	105	126	113	124
1680	130	128	125	127	130	79	85	119	99	109
1690	115	102	106	98	126	128	68	96	76	61
1700	107	113	72	60	70	65	61	70	72	64
1710	79	72	77	51	54	39	35	30	93	115
1720	70	103	99	122	102	94	114	147	133	106
1730	102	113	112	98	114	122	151	131	156	175
1740	119	115	94	91	131	137	128	126	88	90
1750	73	111	103	127	107	86	157	136	142	165
1760	139	129	132	116	109	153	149	135	115	133
1770	139	99	47	68	85	39	61	73	46	34
1780	103	58	114	117	93	81	89	88	92	56
1790	62	119	116	97	108	86	110	95	37	68
1800	110	100	49	85	87	25	75	84	69	115
1810	117	73	126	139	155	162	170	131	120	92
1820	97	60	65	42	45	70	36	47	50	122
1830	72	114	115	124	106	130	135	144	123	146
1840	132	114	112	104	114	121	106	95	109	68
1850	106	109	91	93	90	97	129	54	100	132
1860	70	103	65	94	85	124	66	66	59	112
1870	101	88	52	101	119	113	134	136	117	105
1880	48	105	74	122	151	153	126	69	112	133
1890	50	137	108	45	70	74	86	76	83	119
1900	138	85	48	127	111	132	144	87	87	63
1910	95	134	154	157	109	138	99	107	59	156
1920	129	84	84	119	107	63	129	108	121	61
1930	114	139	105	81	102	112	49	49	68	53
1940	91	114	115	84	---	---	---	---	---	---

BIBLIOGRAPHY

Aandstad, S., "Die Jahresbestimmung der Kiefer und die Zeitbestimmungen älterer Gebäude in Solör im östlichen Norwegen." Nyt Mag. Naturv., 78: 201-268 (1938).

Antevs, E., "Die Jahresringe der Holzgewächse und die Bedeutung derselben als klimatischer Indikator." Progr. Rei Bot., 5: 285-386 (1917).

..."Rainfall and Tree Growth in the Great Basin." Spec. Publ. Amer. Geogr. Soc., No. 21; Carnegie Instn. Wash. Publ. 469 (1938).

Douglass, A.E., "Climatic Cycles and Tree-Growth." Carnegie Instn. Wash. Publ. 289: I (1919); II (1928); III (1936).

..."Notes on the Technique of Tree-Ring Analysis." Tree-Ring Bull., 7: 2-8 (1940); 7: 28-34 (1941); 8: 10-16 (1941); 10: 2-8 (1943); 10: 10-16 (1943).

Eidem, P., "Über Schwankungen im Dickenwachstum der Fichte (Picea Abies) in Selbu, Norwegen." Nyt Mag. Naturv., 83: 145-189 (1943).

Eklund, B., "Ett försök att numeriskt fastställa klimatets inflytande på tallens och granens radietillväxt." Norrlands SkogsvFörb. Tidskr., 3: 193-226 (1944).

Erlandsson, S., "Dendrochronological Studies." Stockholms Högskolas Geokronol. Inst., Data 23 (1936).

Giddings, J. L., "Dendrochronology in Northern Alaska." Bull. Univ. Ariz., Vol. 12, No. 4; Publ. Univ. Alaska, No. 4 (1941).

..."Chronology of the Kobuk-Kotzebue Sites." Tree-Ring Bull., 14: 26-32 (1948).

..."Mackenzie River Delta Chronology." Tree-Ring Bull., 13: 26-29 (1947).

Glock, W. S., "Growth Rings and Climate." Bot. Rev., 7: 649-713 (1941).

Hardman, G., and Reil, O. E., "Relationship between Tree Growth and Stream Runoff in the Truckee River Basin, California-Nevada." Bull. Nevada Agric. Exp. Sta., No. 141 (1936).

Huber, B., "Die Jahresringe der Bäume als Hilfsmittel der Klimatologie und Chronologie." Die Naturw., 35: 151-154 (1948).

Huber, B., und von Jazewitsch, W., "Aus der Praxis der Jahrring-Analyse." Allgem. Forstzeitschrift, No. 49 (1950).

Huntington, E., "The Climatic Factor as Illustrated in Arid America." Carnegie Instn. Wash. Publ. 192 (1914).

Hustich, I., "The Scotch Pine in Northernmost Finland and its Dependence on the Climate in the Last Decades." Acta Bot. Fenn., 42 (1948).

..."On the Correlation between Growth and the Recent Climatic Fluctuation." Geog. Annaler, 90-105 (1949).

Kapteyn, J. C., "Tree Growth and Meteorological Factors." Rec. Trav. Bot. Neerland., 11: 71-93 (1914).

Keen, F. P., "Climatic Cycles in Eastern Oregon as Indicated by Tree-Rings." Mon. Wea. Rev. Wash., 65: 175-188 (1937).

Lyon, C. J., "Water Supply and the Growth Rates of Conifers around Boston." Ecology, 24: 329-344 (1943).

..."Hemlock Chronology in New England." Tree-Ring Bull., 13: 2-4 (1946).

Mikola, P., "On Variations in Tree Growth and their Significance to Growth Studies." Comm. Inst. Forestalis Fenniae, 38.5 (1950).

Ording, Å., "Årringanalyser på Gran og Furu." Medd. Norske Skogsforsøksv., 7: 105-354 (1941).

Schulman, E., "Precipitation Records in California Tree-Rings." Proc. Sixth Pacific Sci. Congress (1939), 3: 707-717 (1941). See also Carnegie Instn. Wash. Yearbook, 32: 208 (1933).

..."Tree-Ring Hydrology of the Colorado River Basin." Bull. Univ. Ariz., Vol. 16, No. 4 (1945).

..."Tree-Ring Hydrology in Southern California." Bull. Univ. Ariz., Vol. 18, No. 3 (1947).

...(Reports on Climatic-Archaeological Indices in the Southwest). Tree-Ring Bull., 12: 18-24 (1946); 14: 2-8 (1947); 14: 18-24 (1948); 15: 2-14 (1948); 15: 24-32 (1949); 16: 10-14 (1949); 17: 2-16 (1950); 18: 10-27 (1952); 18: 30-36 (1952).

Schumacher, F. X., and Meyer, H. A., "Effect of Climate on Timber-Growth Fluctuations." Jour. Agric. Research, 54: 79-107 (1937).

Stallings, W. S., "A Tree-Ring Chronology for the Rio Grande Drainage in Northern New Mexico." Proc. Nat. Acad. Sci., 19: 803-806 (1933).