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EXTENSION OF THE SAN JUAN CHRONOLOGY TO B.C. TIMES

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The addition of climatically significant ring records in archaeological beams which amplify and extend further into antiquity the master sequence for the upper San Juan is perhaps of as much interest for climatology as it is for archaeology, since this sequence gives us decidedly the longest sensitive year-by-year index of rainfall presently available. The new data reported here now permit fairly reliable estimates of the occurrence of dry and wet years and intervals in this region for the first century A.D. and for some five or six decades in B.C.[1]

It was recognized in 1934, when the remarkable collection of beams obtained by Earl H. Morris in northeastern Arizona was dated,[2] that the ring record during the early two centuries following A.D. 11 was very weak, and especially so for the years preceding A.D. 94, which were represented by only one rather insensitive specimen, MLK-152. Subsequent collections, particularly from the Durango sites also excavated by Morris, have given us excellent climatic data for the 100's A.D.[3] A number of specimens from one of these sites, the Durango Rock Shelters (North and South Caves at Falls Creek), showed excellent internal crossdating but reduced only to so-called floating chronologies which could not be dated. Two of these undated chronologies, from the ADE[4] and AFE areas of the North Shelter, were highly significant, for each, over 80 years in length, represented many sensitive specimens of two or more species; with errors in chronology thus essentially eliminated, failure to match the master chronology for the region indicated with high probability that dates for these floating chronologies largely, if not entirely, preceded the 100's A.D.

In June, 1951, through the courtesy of H. S. Gladwin, the writer received a quarter section of Douglas-fir from a beam, GP-2997, carrying some three and a half centuries of ring record, which had been found to have an outside date near A.D. 295.[5] In a letter dated March 6, 1952, he states:

"GP-2997 came from the west part of Mummy Cave, but it was embedded in the talus, rather than a part of an actual wall. I think that it was intended to serve as a sort of retaining device to hold the talus from sliding, but I may be wrong. It was certainly not a part of a house.

"The rings are so narrow that it was obvious some rings would be incomplete. I therefore marked out four traverses on one side of a cross-section, then turned it

[1]This analysis was done in part under contract between the University of Arizona and the Office of Naval Research (NR089-020).

[2]A. E. Douglass, The Central Pueblo Chronology, *Tree-Ring Bull.* 2:29-34, 1936.

[3]E. Schulman, Early Chronologies in the San Juan Basin, *Tree-Ring Bull.* 15:24-32, 1949. The substantial contribution of I. F. Flora in supplying specimens carrying early records in the Durango area is noted in that report. It may be added here that Flora, who examined the Rock Shelter collection (see below) shortly after its excavation, recognized a strong set of "signature rings," which he called the "Z" dating, in many specimens of the ADE series. This collection consisted almost entirely of small charcoal fragments, many with extremely crowded series of rings.

[4]It is expected that the detailed locations of the dated sub-groups in the collections from the Rock Shelters and the Talus Village, reported in this and earlier issues of the *Bulletin*, will be given by Dr. Morris in a forthcoming monograph.

[5]The sequence was mentioned by Gladwin in *Medallion Papers* 32, 1944, p. 25.

over and measured four more radii. The composite of the eight traverses agreed well enough with the early records from Obelisk and Mummy Caves to make it fairly certain that #2997 covered the range from 54 B.C. to A.D. 295.. . .

"The beam was collected by Deric O'Bryan in 1939 and I obtained a date of A.D. 295 sometime early in 1940."

Deric O'Bryan notes in a letter dated March 17, 1952:

"The log was laid horizontally, stabilized by several large sandstone blocks, apparently to hold fill. The log is about on a level with the base of the central tower and in the smaller alcove, which is on the up-canyon side of the tower."

Analysis of the quarter-section fully verified the suggested placement in time. The ring sequence was brilliantly clear and completely free of ambiguous false rings; however, locally absent rings were numerous and, in the crowded outer decades, very difficult (see below).

In order to derive the most general climatic index of the extremely sensitive record in GP-2997, two sections were then obtained[6] from opposite ends of the main piece, a foot-long beam.

The growth records for the interval preceding A.D. 160 along eight radii of GP-2997 are presented in Figure 1. At level I, the lowest available in the stem, with pith date 59 B.C., the diameter least distorted by branches and other influences was chosen for measurement. At level II, some twelve inches higher and with pith date 56 B.C., two diameters at right angles to each other could be selected. The quarter section of the beam first received, with pith date of 52 B.C., is represented by the two series at level III in the figure; its original position in the tree must have been about a foot above level II. The orientation of the measured levels with each other has not yet been determined: e.g., I-A is not necessarily vertically below III-A. The specially thin layer of sapwood, characteristic of Douglas-fir in the most arid environments, begins near A.D. 240 at all levels.

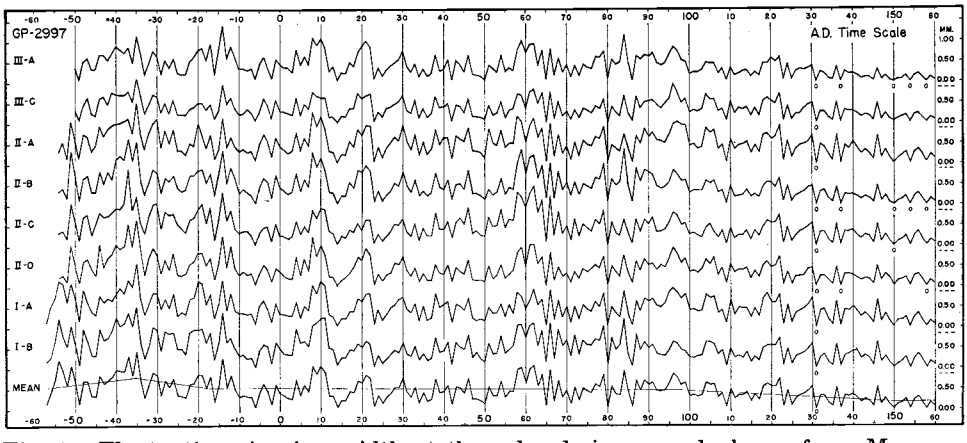

Fig. 1. Fluctuations in ring-width at three levels in an early beam from Mummy Cave, Canyon del Muerto, Arizona. Zeros below the curves indicate missing rings.

The mean growth curve for GP-2997, given in part in Figure 1, represents the two radii of level I from 58 B.C. to 51 B.C., all eight radii from 50 B.C. to A.D. 174, seven (omitting II-C) from A.D. 175 to 255, and three (I-B, II-D, III-A) from A.D. 256 to 304. The outer portion of the growth record indicated many locally absent rings but could be clearly read on the three measured radii. *Nowhere* on the available specimens were the rings found present for A.D. 131, 236, 258, 279, and 302; the gratifying consistency in chronology, however, as shown in Figure 1, permits a very

[6]Through the courtesy of H. S. Gladwin and with the co-operation of Don Yost and Harrison Brown of the California Institute of Technology. The measurement and reduction to charts of the specimens in this report have been ably carried out by C. W. Ferguson, Jr.

secure placement of these omitted rings. Since the complete ring for A.D. 304 was found at many widely separated places and since the outer part of the growth curve does not seem to have the characteristics of a dying tree,[7] it seems highly probable that this is very near the actual cutting date of the tree. The rings beyond A.D. 295 were observed at various points on intensive examination of the entire outer faces of the sections.

In the course of the analysis it was noted that the *smallest* radius showed 17 microscopic rings which were locally absent on longer radii. This phenomenon, now observed with sufficient frequency to justify a generalization for sensitive over-age conifers on slopes, is perhaps a biological reaction of the cambium to dry years obverse to that which results in the formation of excess compression wood on the *longer* radii in wet years.

Presentation of the ring sequences in this report, crossing in date from B.C. to A.D., seems to require two time scales. Mathematically, the year 0 A.D., included by Douglass in the sequoia chronology,[8] is desirable for continuity of sequence; it has been used in this report in the plots and tabulated ring measures, where dates in the pre-A.D. range are denoted by —A.D. Since, however, we are for the first time dealing with precise archaeological tree-ring dates in the Southwest in B.C. times, it will perhaps avoid a source of confusion to use the classical historian's B.C. scale in the text and tables describing dated specimens, as is done here. Thus, the earliest pith date of GP-2997 is B.C. 59 or —58 A.D.

Reserving for the moment the detailed comparison of the record in GP-2997 with that in other early series, we next consider the floating chronologies from the Durango Rock Shelters noted above. Comparison with the Mummy Cave Douglas-fir resulted almost at once in the decisive dating of the ADE series completely within but very near the early limit of the record in the former. One of the Durango specimens with several mm. of bark attached was found to carry an outside date of A.D. 46, which may be considered the actual "cutting" date as evidenced in the associated dated specimens.

The newly dated specimens are described in Table 1, and the more critical records plotted in Figure 2. The mean growth curve for ponderosa pine

[7] *Tree-Ring Bull.* v. 17, 1950, p. 4.
[8] *Carnegie Inst. Wash.* Publ. 289, I, 1919, p. 120.

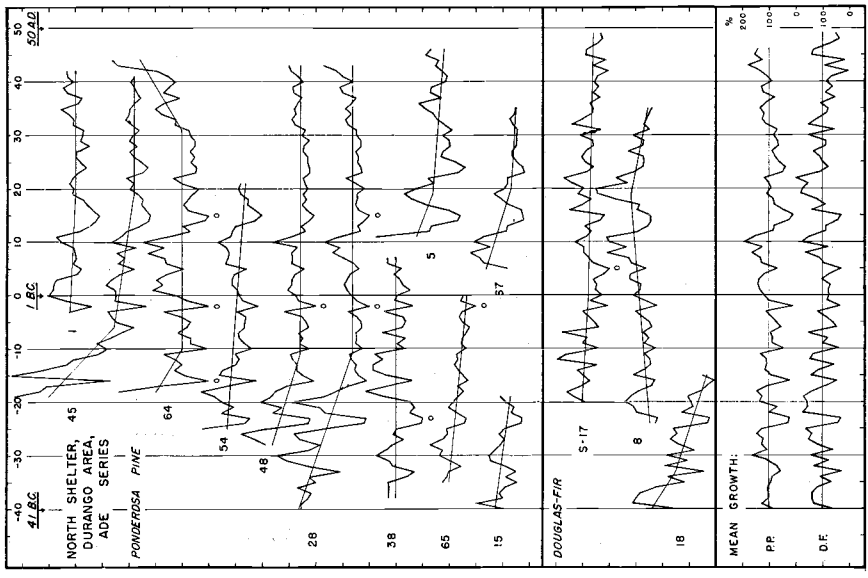

Fig. 2. Representative growth curves in charcoal fragments from a Basket Maker II site in s.w. Colorado. Estimated trend lines are superposed.

Table 1. Recently Dated Specimens from the San Juan Basin

Field No.	G.P. No.	Form[1]	Species[2]	Ring-Width, mm.	Plot Scale[3]	Inner Ring,[4] B.C. or A.D.	Outer Ring,[5] B.C. or A.D.
			Mummy Cave, Northeastern Arizona				
	2997	sec.	DF		....	**59** p	304
			Durango Rock Shelters, Southwestern Colorado				
ADE- 1	3844	¼ sec.	PP	0.51	1	**04**	42
2	3947	¼ sec.	PP	0.80	....	**24** p	41
4	3846	½ sec.	PP	0.79	....	**27** p	31
5	3847	frag.	PP	0.74	1	10	46
6	3848	¼ sec.	PP	1.29	....	04 p	35
7	3849	frag.	PP	0.68	....	**04**	34
8	3850	frag.	DF	0.45	1	**27** p	35
10	3852	frag.	PP	0.93	....	**20**	39
11	3853	frag.	PP	0.67	....	09	35
12	3854	frag.	PP	1.29	....	04 p	28
15	3857	frag.	PP	1.10	½	**41**	**20**
16	3858	¼ sec.	PP	1.67	....	05 p	20
17	3859	frag.	PP	1.15	....	**18**	02
18	3860	frag.	DF	1.32	½	**42** p	**16**
19	3861	frag.	PP	1.09	....	06	27
20	3862	frag.	PP	0.79	....	**17**	21
28	3870	¼ sec.	PP	0.51	1	**42** p	43
38	3880	¼ sec.	PP	0.21	2	**39**	34+
45	3887	frag.	PP	0.70	1	**21** p	41
48	3890	frag.	PP	0.38	1	**30**	44
49	3891	frag.	PP	0.53	....	09	41
54	3896	frag.	PP	0.48	1	**26**	21
55	3897	frag.	PP	0.44	....	**12**	36
62	3903	frag.	PP	0.40	....	07	39+
64	3905	frag.	PP	0.30	2	**19**	45
65	3906	½ sec.	PP	0.70	½	**39** p	**01**
67	3908	frag.	PP	0.86	½	05	36
68	3909	frag.	PP	0.47	....	11	42
70[6]	3911	frag.	PP	0.39	....	**10**	46
72	3913	frag.	DF	0.77	....	**09**	22
74	3915	frag.	PP	0.33	....	**17**	25
85	3926	frag.	PP	0.60	....	**27**	08
90	3930	frag.	PP	0.30	....	**15**	18
102	3939	sec.	PP	1.00	....	07 p	19
103	3940	frag.	PP	0.91	....	05	25
105	3942	frag.	PP	1.08	....	**34**	**10**
ADES-14	3961	frag.	PP	0.38	....	**14**	28
17	3964	frag.	DF	0.20	2	**22**	54
21	3968	frag.	PP	0.47	....	**08**	26
22	3969	¼ sec.	DF	0.88	....	**31**	**15**
32[7]	3979	frag.	PP	0.41	....	**01**	46
			Durango Talus Village, Southwestern Colorado				
II-X[8]	.....	frag.	DF	0.21	2	**30** p	85

[1]All specimens are charcoal; sec.—section; frag.—fragment.

[2]DF—Douglas-fir; PP—ponderosa pine. Many of the pine charcoal fragments look much like Douglas-fir, but have been easily differentiated under the microscope on the usual basis of spiral thickening of DF tracheid walls.

[3]In Figure 2. 1—standard vertical scale of 0.50 mm. ring-width per scale division on the figure margins; ½—1.00 mm. per scale division; 2—0.25 mm.

[4]p—pith ring.

[5]The usual symbols (see previous *Bulletins*) denoting the probable number of rings lost from the outside of the specimen, useful in estimating the "cutting" date, have been omitted, since almost all specimens are charcoal fragments with indeterminate loss. Outer ring dates definitely at or near true final growth ring are: ADE-5, bark; ADE-28 and ADE-70 (ADES-32) at or near bark.

[6]Apparently not from the same tree as ADE-5.

[7]From the same tree as ADE-70.

[8]Plotted in Figure 3. Average ring-width in selected portions of the specimen: 0.31 mm., B.C. 29 to A.D. 11; 0.16 mm., A.D. 12 to A.D. 85. The outer ring on this specimen may easily be a century earlier than the bark date, in view of the extremely small average ring-width.

compares well with that for Douglas-fir, despite the small number of specimens in the latter. Many of the specimens in Table 1 seem to represent a single tree though they carry different numbers; however, growth rates and other characteristics suggest at least a half-dozen trees in the dated ADE series.

The tendency for decided dominance of Douglas-fir in one sub-group and ponderosa pine in another has already been noted in earlier reports in this Bulletin on the Durango chronologies. That this tendency is not an accident but represents some important changes in forest composition—and perhaps also in culture preferences—is now more strongly indicated.

On review of those series from the Durango Talus Village[9] (Ignacio 7:101) which failed to date in earlier analyses, a small charcoal fragment from Floor 2 of that site was found to carry a record very nearly parallel to that in the ADE series and to extend it for 36 years, to A.D. 85. Thus the gap in the early Durango chronology is reduced to the eleven years from A.D. 86 to 96, on the assumption that during the still sparsely documented second half of the first century A.D. no year is unrepresented in at least one of the dated specimens.

To examine the possibility of such unrecorded years, which would, of course, affect all earlier dates, we turn to Figure 3. We conclude:

(1) With a number of areally different, rapid-growth specimens of differing species entering the chronology after A.D. 93,[9] no real likelihood of error exists after this date;

[9]*Tree-Ring Bull.* 16:12-16, 1949.

Table 2. Tree-Ring Indices for Douglas-Fir in Northeastern Arizona: Ring-Widths in Per Cent of the Growth Trend

A.D.	9	8	7	6	5	4	3	2	1	0
—50	....	....	31	75	127	209	161	100	176	111
—40	22	109	105	52	52	122	92	100	111	133
—30	128	127	171	109	178	93	39	82	125	120
—20	54	105	81	116	57	55	50	105	114	154
—10	157	98	149	37	108	233	101	155	94	58
—00	68	60	58	13	79	117	91	27	116	....
	0	1	2	3	4	5	6	7	8	9
00	76	67	55	50	142	67	115	83	206	170
10	206	144	83	75	55	54	75	113	88	123
20	109	144	168	64	81	59	67	91	106	85
30	156	85	70	107	54	75	54	52	108	67
40	71	82	36	82	84	81	123	68	78	60
50	56	91	68	59	109	72	80	75	132	132
60	101	150	164	130	176	75	191	60	119	81
70	90	50	99	64	95	83	113	132	115	168
80	64	107	101	95	159	87	36	127	94	125
90	125	127	113	119	94	114	146	171	117	164
100	83	76	72	85	117	131	128	94	107	40
110	131	94	107	107	117	90	99	76	132	151
120	137	130	167	52	132	59	89	91	105	125
130	164	28	114	98	65	52	148	33	115	101
140	112	99	103	95	95	58	163	69	109	80
150	55	82	99	121	55	115	120	109	69	94
160	80	122	45	97	79	69	90	97	71	35
170	155	116	50	83	84	61	97	86	55	70
180	90	79	109	150	108	115	104	129	170	64
190	83	110	104	139	93	117	84	129	119	81
200	83	57	64	133	125	79	197	119	118	134
210	113	87	156	116	86	94	112	69	106	112
220	97	143	76	99	96	64	61	106	115	81
230	113	97	170	144	112	89	46	110	98	106
240	118	112	81	106	104	45	124	66	97	69
250	82	115	100	46	106	142	103	70	36	71
260	99	66	53	81	82	32	111	121	173	181
270	93	168	156	116	57	107	123	188	114	30
280	64	153	122	150	158	135	50	110	112	140
290	54	37	92	70	33	107	113	91	87	146
300	125	146	45	127	200					

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—20	54	105	81	116	57	55	50	105	114	154
—10	157	98	149	37	108	233	101	155	94	58
—00	68	60	58	13	79	117	91	27	116	....
	0	1	2	3	4	5	6	7	8	9
00	76	67	55	50	142	67	115	83	206	170
10	206	144	83	75	55	54	75	113	88	123
20	109	144	168	64	81	59	67	91	106	85
30	156	85	70	107	54	75	54	52	108	67
40	71	82	36	82	84	81	123	68	78	60
50	56	91	68	59	109	72	80	75	132	132
60	101	150	164	130	176	75	191	60	119	81
70	90	50	99	64	95	83	113	132	115	168
80	64	107	101	95	159	87	36	127	94	125
90	125	127	113	119	94	114	146	171	117	164
100	83	76	72	85	117	131	128	94	107	40
110	131	94	107	107	117	90	99	76	132	151
120	137	130	167	52	132	59	89	91	105	125
130	164	28	114	98	65	52	148	33	115	101
140	112	99	103	95	95	58	163	69	109	80
150	55	82	99	121	55	115	120	109	69	94
160	80	122	45	97	79	69	90	97	71	35
170	155	116	50	83	84	61	97	86	55	70
180	90	79	109	150	108	115	104	129	170	64
190	83	110	104	139	93	117	84	129	119	81
200	83	57	64	133	125	79	197	119	118	134
210	113	87	156	116	86	94	112	69	106	112
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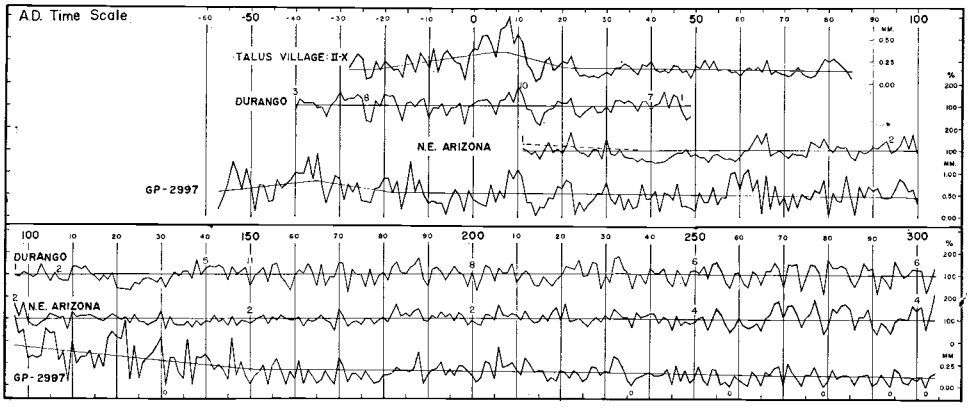

Fig. 3. Comparative early chronologies in the San Juan Basin.

(2) From 58 B.C. to about A.D. 100 the growth rings for GP-2997 are relatively open; in MLK-152 the record is of the characteristic "bound" type, in which rings are very crowded yet complacent and with rare or no omitted rings. Thus, since each beam has been minutely analysed at several levels, an unrecorded year in this interval would be most unexpected. The evidence in the newly dated Durango charcoal supports this conclusion.

Thus it appears that the early chronology is well established, a change of even one year in the Durango dates given in Table 1 being highly improbable.

There is evidence in Figure 3 for a severe and extended drought following A.D. 11, which may have lasted for four or even five decades. In this connection, the uncertainties in estimating the age trend in growth near the curve limits[10] are well illustrated in this figure. The trend line estimated for the long record in GP-2997 is probably a fair approximation after the first few decades of growth. Judging by that series, however, the trend line estimated by the writer[11] in 1949 for MLK-152, on which the early decades of the northeastern Arizona index are based, was evidently too low. A revised line for the first three decades, linearly decreasing from 30% higher at A.D. 10 to identity at A.D. 40, is indicated in Figure 3. The adjusted index for MLK-152 and the chronology in GP-2997 have been used in the northeastern Arizona index in Table 2, which now extends and in part replaces Table 2a of the 1949 report. Tables of measures for the Durango area are reserved pending further extensions; the plotted curves will perhaps suffice for the time being.

Further, Figure 3 suggests that the trend lines estimated for the Talus Village specimen and for the North Shelter sequences in Figure 2 of this paper are all somewhat low for some decades after A.D. 11. However, in the absence of more evidence from the Durango area itself we have not adjusted these trend lines at this time.

It is worth recalling that there remains undated, among miscellaneous specimens, the already noted AFE series from the North Shelter. Although peculiarities in chronology have often greatly delayed or even made impossible the recognition of a true date well within an established and appropriate master chronology, it seems much more probable that the AFE series will be found to antedate substantially the ADE series when further backward extensions of the master chronology for the upper San Juan basin become available.

[10] *Tree-Ring Bull.* v. 17, 1950, p. 11.
[11] *Tree-Ring Bull.* v. 15, no. 4, 1949, fig. 1.