

Annual Subscription, \$1.50

Single Copy, 50c

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PHOTOGRAPHIC TREE-RING CHRONOLOGIES AND THE FLAGSTAFF SEQUENCE*

A. E. DOUGLASS

Prehistoric tree-ring specimens, precisely dated, are the foundation stones on which are built the prehistoric chronologies that contribute to the history of early peoples, to long records of climatic change, and to determination of dates of pests and fire injuries and even of land ownership. For these purposes the preservation of the better specimens is of the first importance. But the examination of such specimens by all persons interested is limited and usually can be offered only in the laboratory. It becomes, therefore, in a way an obligation to show the essential facts revealed in the preferred specimens. This should be done by the best possible photographs.

The need for photographs and other methods of representation was recognized at a very early date. "Rubblings" were made of some of the Flagstaff specimens about 1905. In 1911 Mr. R. H. Weiteknecht contributed rubblings from stump tops which were good enough to be dated and measured (*Climatic Cycles and Tree Growth*, Vol. I, 1919, p. 42). In the next ten years some photographs were made of potentially valuable prehistoric specimens not yet dated. Early photographs of ring detail were published in 1919 (Vol. I, plate 2) and 1920 (*Ecology* 1:26). As the centuries-long sequences developed, the pressing need for a more formal photographic ring chronology became evident. In 1934 a group of tree-ring workers organized the Tree-Ring Society which passed this resolution: When the date of a ruin is published, it should be accompanied by a photograph of a type specimen (*Tree-Ring Bulletin* 1 (1):6, July, 1934) whose rings show the date.

In the late 1920's a special box for the illumination of specimens was equipped with a ten-inch focus lens at the front and used to take a great number of ring photographs in the darkroom. This work was done largely by Mr. Philip C. Keenan in 1927 to 1930 and included some 569 negatives. The prehistoric floating chronology began in RD-113 (A. D. 700) and was kept separate from the historic sequence.

After that attempts were made to photograph rings by a Leica camera such as used for microfilms. These were easy to take, but the quality was not satisfactory. That effort showed that the making of satisfactory ring photographs is a highly technical process and requires continued individual effort.

In 1933 Mr. H. Faurest Davis began for us some five years of photographic work on tree-rings. He developed great skill in preparing specimens and in doing very satisfactory photography as to definition, proper exposures, and strength of image and in using a personal artistic sense. Results of the work of 1933-35 are called the E series of negatives and number up to 185.

* The tables and charts of this paper were derived and constructed by Terah L. Smiley under the direction of Edmund Schulman. Identification of the individual ring records was checked by the writer. I am greatly indebted to the Museum of Northern Arizona for a large part of the set of archaeological specimens.

These were used in the first formal publication of a series of ring photographs in 1935 by the National Geographic Society (Dating Pueblo Bonito and Other Ruins of the Southwest, Tech. Papers, Pueblo Bonito Series No. 1, pp. 57-72). This gives a good representation of the rings from A.D. 698 to 1929. No charcoal is included.

In the special collaboration between the University of Arizona and the Carnegie Institution in 1935-37, the Carnegie series CN was begun by the writer with one or two dozen negatives, then carried on by Mr. Davis through 1937, with a few additional negatives by the writer ending in No. 286. These large groups by Davis form the basis of long, continuous, mounted photographic ring records extending back to A.D. 698 as in the earlier series. One such composite record was constructed for Dr. H. F. Osborn and is placed in the American Museum of Natural History in New York. Another was photographed in moving pictures and was shown in various lectures.

TABLE 1. PHOTOGRAPHED SPECIMENS OF THE FLAGSTAFF AREA

Specimen No.	Site	Form ¹	Species ²	Mean Ring-Width, mm ³	Inner Ring ⁴	Outer Ring ⁵	Photo-graphed Range ⁶	Record Quality
F-3992	N.A. 2798	Ch frag	PP	.47	575	794+vv	576- 778	B
F-4012	N.A. 2798	Ch frag	PP	.47	647	758 vv	649- 748	AB
F-4053	N.A. 2800	Ch frag	PP	1.19	644	697 vv	652- 694	AB
F-3993	N.A. 2798	Ch frag	PP	1.73	670	771 vv	670- 754	B
F-3995	N.A. 2798	Ch frag	PP	.75	693	828 vv	694- 826	B
F-1355	N.A. 1625-C	1/2 sec	PP	1.38	714	771 vv	715- 769	BC
F-4089	N.A. 2798	Ch frag	PP	1.14	715	803 vv	716- 802	B
F-4003	N.A. 2798	Ch frag	PP	.41	727	927 vv	728- 927	B
F-2361	N.A. 1959	Ch frag	PP	1.80	737	780 vv	738- 779	BC
Y	N.A. 2001-A	Ch frag	PP	.77	747	844 vv	749- 841	AB
F-4097	N.A. 2551	Ch frag	PP	1.07	842	888 vv	844- 887	A
F-745	N.A. 192-B	Ch frag	PP	1.19	844	923 vv	845- 922	AB
F-1941	N.A. 2002-A (?)	Ch frag	PP	.54	871	972 vv	871- 971	A
F-1832	N.A. 2002	Ch frag	PP	1.21	890	938 vv	891- 938	AB
F-3061-2	N.A. 1531	Ch 1/2 sec	DF	.72	900	963 v	902- 958	AA
F-1615	N.A. 1625-B	Ch frag	PP	.63	916	1044 vv	917-1042	AB
F-1935	N.A. 2002-A	Ch frag	PP	.63	960	997 vv	972-1097	B
F-209	N.A. 862	Ch frag	PP	.93	972	1034 vv	972-1033	AA
F-1934	N.A. 2002-A	Ch frag	PP	.45	954+	1118 vv	982-1116	AB
WPT-133	Wupatki	1/2 sec	DF	.95	987	1106+v	990-1064	A
F-4471	N.A. 2134-E	Ch frag	PNN	.47	987	1086 vv	996-1075	A
F-406	N.A. 1238	Ch frag	PP	1.28	997	1067 v	999-1066	AA
F-3683	N.A. 333	F sec	DF	.46	1018	1187 vv	1019-1185	AB
WPT-9	Wupatki	Core	PP	1.20	1022	1127 vv	1033-1089	AA
F-4753	N.A. 3673	Sketch			1042	1075		
WPT-87	Wupatki	F sec	DF	.59	1045	1135+c	1051-1132	A
GP-353	Tusayan Ruin	Ch frag	PNN	.70	1119	1182 vv	1119-1181	B
WPT-76	Wupatki	1/2 sec	DF	.92	1118	1159 vv	1120-1146	A
E. P.	Elden Pueblo	1/2 sec	DF	.77	1122	1160 vv	1122-1159	A
WPT-7	Wupatki	F sec	PP	1.26	1129	1170 c	1132-1169	A
WPT-15	Wupatki	V-cut	PP	.79	1129	1183 vv	1131-1180	B
CIT-1	Citadel	F sec	JUN	.56	1144	1192 v	1145-1191	BC
THP-7	Turkey Hill Pueblo	Ch frag	PP	.80	1149	1204 vv	1155-1203	AB
F-2648	Near Winona	Frag	PP	.91	1162	1244 vv	1162-1244	B
THP-1	Turkey Hill Pueblo	1/4 sec	DF	.84	1233	1279 vv	1234-1277	AB
KNK-1	Kinnikinnick	Ch frag	PP	.68	1253	1293 vv	1253-1289	A
KNK-4	Kinnikinnick	Ch frag	PP	.31	1275	1311 vv	1276-1311	B
JMcG-X	Flag. Area	V-cut	PP	.42	1308	1929	1309-1929	AB ⁷
FL-13	Flag. Area	V-cut	PP	.55	1397	1906	1397-1906	B
FL-17	Flag. Area	V-cut	PP	.53	1505	1906	1513-1906	A
FL-9	Flag. Area	V-cut	PP	.51	1577	1906 c	1588-1906	AB

¹Ch—charcoal; specimens not so labeled are of wood.
 frag—fragment.
 F sec—full section.
 core—1" tubular boring.

²PP—ponderosa pine (*Pinus ponderosa*)
 DF—Douglas fir (*Pseudotsuga taxifolia*)
 PNN—pinon pine (*P. edulis*)
 JUN—juniper

³Applies to the photographed range.

⁴p—pith present.

⁵c—outside ring constant along outer face of specimen—probably very few or no rings broken or worn off.
 v—outside ring variable, possibly 5 or more rings lost.
 vv—outside ring very variable, probably many rings lost.
 +—locally-absent rings near the outside.

⁶Poor parts of the chronology and outside rings which were difficult or impossible to photograph are omitted.

⁷1309-1450.

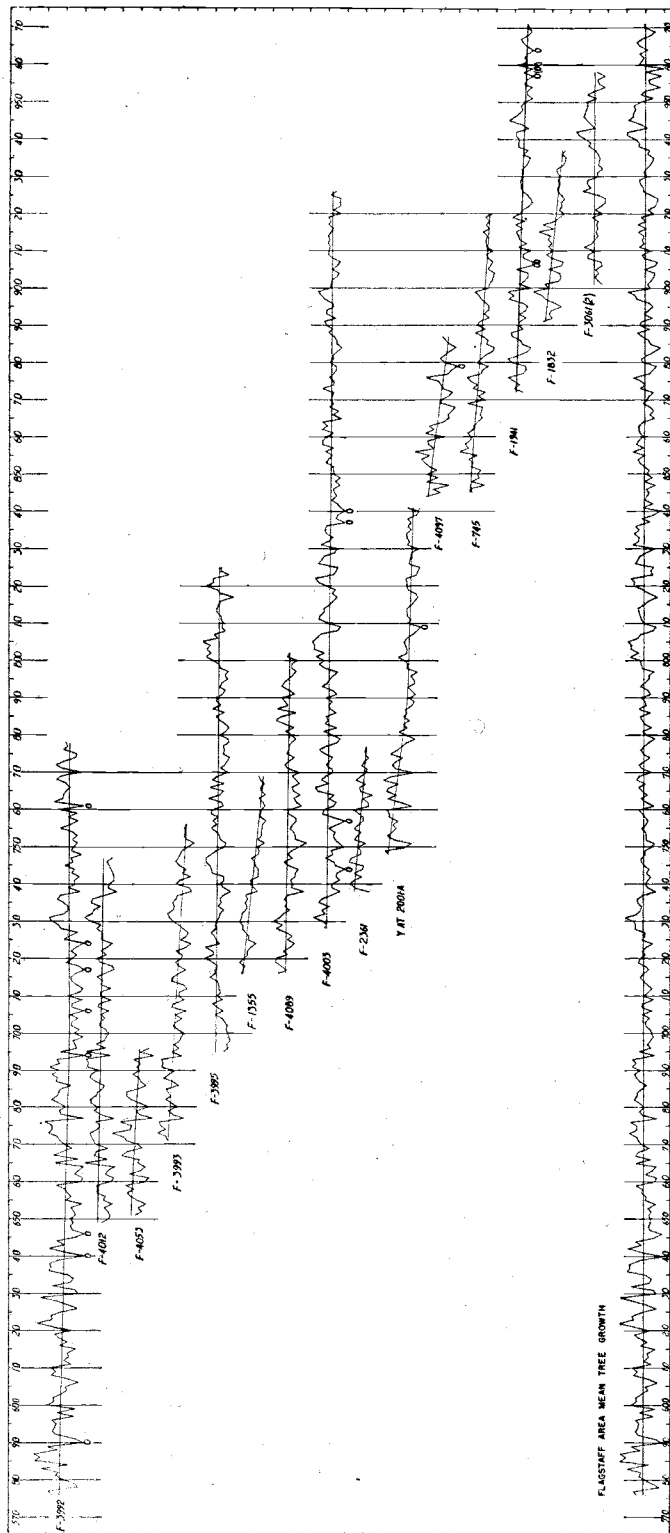


Figure 1-A. Measured ring-widths in specimens from the Flagstaff area, A.D. 576-971. Zeros below the curves give the locally-absent rings in each sequence. The vertical scale of each curve has been adjusted to give approximately the same spread about the line of trend; the base lines are given by the border division at or just below the absolute minimum in each curve.

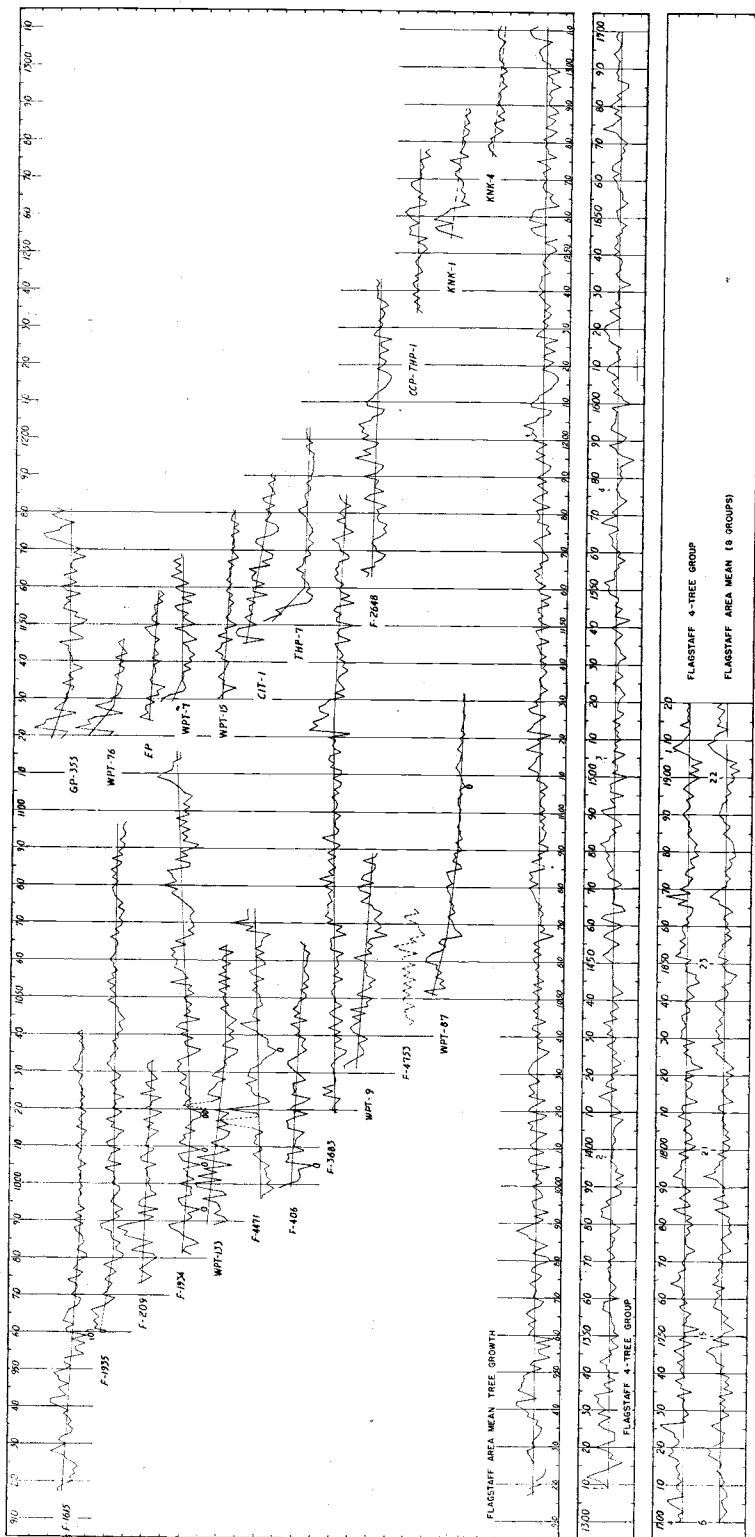


Figure 1-B. Measured ring-widths in specimens from the Flagstaff area, A.D. 917-1311. The broken-line curve F-4753 represents the measures of a sketch of the original specimen and is not included in the mean growth curve. Figures above the mean curves give the number of trees on which the data are based.

TABLE 2. TREE-RING INDICES FOR THE FLAGSTAFF AREA: RING-WIDTHS
IN PER CENT OF THE GROWTH TREND*

A.D.	0	1	2	3	4	5	6	7	8	9
570							137	150	16	44
580	88	120	111	182	71	222	192	222	116	162
590	00	37	122	139	127	123	140	46	119	37
600	162	134	138	102	77	84	24	69	154	132
610	156	56	92	71	77	38	112	78	120	145
620	66	149	229	150	159	110	30	82	148	220
630	29	44	166	63	56	83	182	171	175	125
640	00	110	183	108	144	45	00	62	72	72
650	60	69	58	75	34	87	83	107	105	137
660	37	32	85	54	31	138	62	142	126	67
670	110	128	136	173	135	136	165	30	103	121
680	95	119	147	135	133	112	80	117	133	145
690	113	159	138	157	38	115	59	76	63	43
700	52	59	83	83	64	104	50	104	104	45
710	99	75	51	77	98	115	100	67	81	123
720	115	86	105	85	52	104	91	89	143	140
730	151	199	132	113	109	128	129	108	34	78
740	88	78	60	80	68	98	110	110	89	92
750	59	40	82	84	84	107	84	77	89	103
760	122	44	88	116	79	109	123	88	136	122
770	55	103	121	99	67	101	113	99	74	40
780	82	102	59	97	109	119	65	123	87	92
790	111	61	77	117	91	76	74	47	108	114
800	119	171	129	166	162	182	134	119	49	37
810	99	113	121	127	129	95	77	28	74	100
820	153	152	166	51	63	47	143	135	122	84
830	43	159	127	127	152	126	144	63	114	52
840	13	102	52	96	85	75	90	40	98	59
850	92	77	100	123	131	100	161	105	141	133
860	106	123	130	127	110	47	72	51	65	110
870	88	79	57	123	96	119	161	73	60	40
880	111	118	88	45	16	67	79	114	143	78
890	126	119	60	103	83	55	80	140	152	192
900	75	86	62	52	46	102	42	35	101	117
910	72	131	108	117	109	138	95	134	96	122
920	58	82	47	38	34	72	109	112	127	132
930	91	109	98	74	60	58	87	78	133	126
940	154	197	192	86	128	189	164	162	151	160
950	125	59	121	103	18	76	80	15	(100)	(00)
960	134	122	107	137	92	127	145	120	69	50
970	108	103	92	101	131	82	62	113	117	85
980	20	32	114	96	32	83	131	146	205	147
990	102	57	112	33	105	110	119	64	69	84
1000	120	68	99	86	122	27	129	142	128	53
1010	119	133	103	90	42	137	120	148	76	44
1020	145	134	98	53	144	114	129	143	86	108
1030	140	148	137	125	100	65	40	96	100	72
1040	112	83	128	123	50	112	99	122	88	111
1050	92	95	126	78	126	70	109	99	114	92
1060	118	126	81	123	89	123	95	19	88	63
1070	92	87	93	74	94	86	108	119	125	133
1080	151	103	152	136	151	72	73	142	83	109
1090	55	53	101	76	68	63	84	74	97	66
1100	99	73	91	95	91	69	94	58	78	115
1110	109	111	161	142	120	116	85	173	134	95
1120	116	42	171	142	132	102	73	144	163	114
1130	130	101	102	64	91	102	106	81	69	91
1140	70	108	72	100	107	123	53	104	116	127
1150	48	98	114	92	119	119	59	101	48	104
1160	112	78	118	132	110	139	99	112	65	69
1170	94	100	116	142	108	54	78	61	124	116
1180	116	132	59	115	151	122	71	99	124	77
1190	130	94	62	57	93	134	87	137	119	75
1200	151	133	159	149	202	133	123	69	57	160
1210	163	130	121	91	56	42	23	20	46	110
1220	74	47	96	94	42	87	90	20	140	125
1230	95	80	106	76	66	98	63	98	107	130
1240	107	128	124	117	119	69	81	109	113	87

A.D.	0	1	2	3	4	5	6	7	8	9
1250	75	36	56	102	37	127	167	180	97	184
1260	173	172	154	29	61	79	63	104	114	108
1270	95	108	116	78	96	149	44	91	86	108
1280	95	117	66	42	102	76	54	95	36	57
1290	85	87	75	85	77	28	75	70	96	31
1300	83	82	132	133	142	140	107	77	172	142
1310	158	151	216	171	115	74	25	92	74	100
1320	168	112	63	63	65	126	158	134	84	159
1330	116	142	161	153	180	75	112	126	64	105
1340	97	113	112	148	111	84	97	47	79	92
1350	47	79	72	79	90	89	98	137	129	128
1360	59	102	88	63	85	109	98	102	114	94
1370	110	76	86	118	90	88	72	105	73	47
1380	89	92	150	141	153	107	126	93	44	42
1390	81	35	74	33	78	65	78	100	89	93
1400	84	96	79	79	93	89	82	61	38	115
1410	50	76	105	112	172	131	73	134	123	86
1420	107	65	92	50	71	101	76	102	129	86
1430	81	130	105	109	151	75	105	112	66	80
1440	100	92	42	68	98	98	100	99	100	104
1450	99	130	154	121	105	69	106	152	134	85
1460	53	112	165	145	37	51	106	98	93	96
1470	107	58	84	127	133	104	118	126	139	122
1480	145	145	175	123	121	89	115	59	77	111
1490	152	173	95	101	124	50	121	118	124	77
1500	30	115	85	85	115	83	47	107	86	101
1510	69	92	81	105	71	115	73	56	91	87
1520	82	71	45	63	74	113	95	60	87	82
1530	89	78	44	72	77	87	109	89	62	92
1540	123	81	22	109	87	69	107	86	89	134
1550	141	135	164	110	108	114	81	93	56	93
1560	80	102	124	120	124	145	92	100	183	148
1570	105	127	99	75	48	83	90	104	98	91
1580	73	87	79	89	56	13	73	102	110	142
1590	75	55	89	135	134	117	112	113	106	131
1600	35	77	82	127	101	117	138	103	126	161
1610	153	121	92	100	113	87	128	155	148	161
1620	181	168	128	95	112	153	86	124	102	101
1630	106	100	39	86	107	119	93	99	85	93
1640	132	102	131	116	110	120	86	89	62	104
1650	111	113	119	80	58	89	86	90	115	115
1660	124	141	104	146	142	118	92	100	80	90
1670	62	90	112	127	198	149	125	100	138	110
1680	160	137	106	124	93	65	66	123	119	128
1690	118	119	115	127	141	121	108	103	129	131
1700	71	99	76	61	77	87	90	62	60	73
1710	93	78	88	95	114	99	95	122	163	148
1720	164	115	85	88	76	118	149	102	96	54
1730	91	74	103	77	104	33	81	57	74	54
1740	101	101	81	129	127	141	180	155	58	149
1750	99	86	33	67	93	73	99	103	146	131
1760	133	104	132	82	151	119	130	112	119	99
1770	97	120	107	53	76	90	108	90	55	66
1780	59	70	61	100	140	69	85	142	88	95
1790	89	118	135	202	142	142	118	119	85	129
1800	74	65	102	64	89	74	98	93	108	105
1810	93	125	123	49	83	102	110	97	75	85
1820	48	89	47	68	97	114	141	132	161	104
1830	131	125	141	139	111	129	106	102	122	151
1840	142	91	80	86	115	65	57	36	89	102
1850	115	81	135	126	111	117	97	65	99	71
1860	95	84	108	102	60	93	134	135	183	156
1870	128	91	93	74	95	103	75	65	80	49
1880	55	55	60	70	85	119	90	80	113	113
1890	135	132	124	122	97	106	76	95	99	63
1900	59	77	34	84	47	103	134	166	185	205
1910	164	166	141	95	149	133	144	128	116	156
1920	130									

* The number of specimens on which the table is based at any date may be found in Figure 1. For the interval A.D. 1700-1920 the table represents the 8-group FAM series plotted in that figure.

The records preceding A.D. 700 and extending in good form back to A.D. 176 and in an inferior record back to A.D. 11 were worked out by 1935. Prints were made of the entire record, and a continuous series of ring photographs was available for a lecture in Denver in 1937. The set exhibited in the Arizona State Museum was thus extended back to A.D. 11.

Prints of the Davis photographs made in 1935-37 were mounted on cards in 1939 and the better ones selected with great care for showing a photographic chronology. The latewood of each ring was marked. Micro-rings were indicated by the letter *m* or two very small parallel lines outside the edge of the photograph. Decade dates were all inserted, the number of the specimen was given with its mean date for each photograph and its species, and its ring type in terms of A, B, C, and D, A being superb sensitivity and D very complacent. Then followed the number of the negative, the amount of enlargement from the original to the print, and the location from which it came.

For immediate attainment of some of the needed publication, microfilm reproductions were made. Some seven hundred of the best photographs of Southwestern chronology and twenty or more photos of one giant sequoia were sent on for this purpose. This was done by the Bibliofilm Service of the Library of the Department of Agriculture in Washington, and a very good reproduction was made. This is available at a cost under \$5, as Document No. 1298, titled "Southwestern Photographic Ring Sequences, 1939," American Documentation Institute, Science Service, Washington, D.C.

This microfilm had very few specimens from the Flagstaff area, west of the Little Colorado River. This was done, however, with a plan for a later special publication of the Flagstaff ring records. The Flagstaff sequences have special value because of the part they have played in the development of tree-ring records and as exemplifying the almost exclusive use of ponderosa pine.

In 1942 a "Grant-in-Aid" of \$150 was given by the Sigma Xi Society for the purpose of photographing Flagstaff ring records. Because of the war it was not until January 1, 1946 that Mr. Frederick H. Scantling, with additional aid from the University of Arizona, began work on the photography of specimens of the Flagstaff area. In six months he produced a series extending without break from A.D. 576 to the present time. The location farthest to the north for specimens in this set is fifty miles, the Wayside Museum near the Grand Canyon, and the farthest to the south is Chaves Pass, a similar distance southeast of Flagstaff. The Little Colorado River on the east is the boundary of this area. It is hoped that this newly photographed set may be published in entirety soon.

The photographed Flagstaff specimens, plotted in the figure, represent a selection of the better records in the available archaeological collections. These records are both sensitive and free of difficult false rings. The chronology in recent centuries is based on three of the 1906 group of stump sections (Climatic Cycles and Tree Growth, Vol. I, 1919, pp. 23-4), plus a 600-year tree found by J. C. McGregor about 1930. The growth curve for the interval A.D. 1309-1699 will probably be substantially improved after certain living tree collections are made and analyzed. In Table 1, data for the interval A.D. 1700-1920 represent the Flagstaff Area Mean based on eight groups (Vol. II, 1928, p. 120).

It is planned to devote a future issue of the Bulletin to photographs of Flagstaff ring records of special interest.