

FINAL REPORT

Preparation and Analysis of Tree-Ring Specimens

From Washington State, USA

for

University of California

Lawrence Livermore National Laboratory

Attention: Dr. James Kercher

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November 9, 1981

## INTRODUCTION

The purpose of this project has been to produce tree-ring chronologies from increment cores of Pinus ponderosa collected from an area in Washington State south of the Trail, British Columbia copper smelter. The cores were collected by Carl Fox, now of Southern California Edison, Rosemead, California, in 1977 and delivered to the Laboratory of Tree-Ring Research in 1980. We began work on the project in July, 1981 when funding became available from the Lawrence Livermore Laboratory.

According to Carl Fox, the cores were collected from seven sites, three control sites and four pollution sites. We successfully dated cores from all the control sites, but from only two of the pollution sites. We have produced five site chronologies from the dated cores. However, we suggest that because of the nature of the chronologies, the individual core and tree chronologies comprising the site chronologies may provide more meaningful information than the site chronologies for subsequent analyses of the data.

## METHODS

The cores arrived encased in the paper straws in which they had been put during collection in 1977, along with rudimentary field notes for each tree from each site. In general, these notes included only the field identification number assigned to each core, the diameter at breast height (DBH) of each tree, and the species of the tree collected. No description of microsite characteristics was included in the field notes. We have no site information other than the location of the sites on maps of the collection area.

We segregated the cores into their respective sites and eliminated those for which 1) the notation on the straws was either obscure or non-existent, and 2) there were no field notes identifying to which site the cores belonged. The remaining cores were mounted in grooved sticks and sanded along a cross-sectional surface.

Variations in ring width from one year to the next are produced by changes in regional climatic factors which affect tree growth. The resulting patterns of wide and narrow rings may be sufficiently characteristic of certain time periods in the ring-width series from trees in one region to be identified in all cores (Ferguson, 1970). The procedure of crossdating involves matching the common patterns of wide and narrow rings among all cores from a site, correcting for missing or false rings in individual cores, and then assigning the exact calendar year to each ring in each core (Stokes and Smiley, 1968).

The crossdating of cores from each site in this study was accomplished first and then the sites themselves were crossdated. All dating was checked by workers who had not done the original dating. The dated ring widths were measured to the nearest 0.01 mm, the measurements were checked by another worker, and then entered on magnetic tape.

In general, the widths of rings and the year-to-year variance in ring width decrease with tree age and with the increasing circumference of the tree. This produces a downward trend in ring width and variance, but the degree of the downward trend is slightly different for each tree in a site (Fritts, 1976). This growth trend for each core was removed in order to amplify the common variations in ring width due to regional climate, pollution or other growth-limiting factors on a site. The computer program INDEX (Fritts et al., 1969; Graybill, 1979a) was used

to fit a straight line of zero or negative slope or an exponential curve to the ring-width measurements for each core from each site. Each ring-width value was divided by the value of the estimated curve for the particular year to produce a ring-width index, and the index values for individual cores were then averaged by year to produce index series for each tree. The tree index series were averaged to produce a yearly index series or site chronology for each site.

The six character ID number assigned to each index series identifies the series as either a core index series, a tree index series, or a site chronology. The first three characters of the ID indicate the site from which the series was produced. A core series from site BMV, for example, from tree 9, would have the ID of BMV092, signifying that the core series is from the second core from tree 9. The tree index series ID would be BMV090. The final chronology ID includes the first three characters signifying the site and the fourth and fifth characters signifying the species from which the chronology was derived. The species code for Pinus ponderosa is 64. The sixth character in the site chronology ID indicates the nature of the chronology. A "9" indicates that all cores comprising the site chronology have been included in the series. The chronology is referred to as the statistical chronology. A "0" indicates that a selected group of cores from the site have been included in the series. The chronology is referred to as the climatic chronology.

We produced two final index series for each of the five sites; the index series comprised of all dated cores from the site (statistical chronologies) and index series comprised of ten trees (with two cores per tree) which shared a common period from 1915 to 1974 (climatic chronologies). The latter series were used for analyses of variance

and cross-correlation. (See Appendix A for identification of which trees from each site were included in the climatic chronologies).

The essential characteristics of each site chronology are listed in Table I. The three chronology statistics listed in Table I indicate the relative amounts of low-frequency and high-frequency variance present in each site chronology. Mean sensitivity is a measure of the relative difference between successive pairs of index values in a chronology, and thus estimates the relative amount of high-frequency, or year-to-year, variability within a chronology. First-order autocorrelation measures the correlation of each value in a chronology with the value preceding it, and thus estimates the similarity in ring width from year to year, or the low-frequency variance present in a chronology. Standard deviation is a measure of the variance at both low and high frequencies. High mean sensitivity, low first-order autocorrelation, and high standard deviation indicate the presence of a large amount of high-frequency climatic information in a chronology (Fritts and Shatz, 1975). Conversely, low mean sensitivity, high first-order autocorrelation and low standard deviation indicate the presence of less high-frequency climatic information.

To further assess the amount of climatic information in each chronology, we performed analyses of variance and cross-correlation on the cores comprising each climatic chronology using the computer program SUMAC (Graybill, 1979a). In addition to such analyses, a simple visual inspection of core, tree and final index plots was helpful in interpreting the results of the various statistical analyses.

TABLE I  
Site identification, location, and basic characteristics of site tree-ring chronologies

Site Name	Chronology ID	Latitude and Longitude	Elevation	Number of Cores	Length of Chronology	COMMON PERIOD		CHRONOLOGY STATISTICS		
						First Year	Last Year	Mean Sensitivity	First-order autocorrelation	Standard Deviation
Bang's Mtn. Vista	BMV649	48°32'N 118°12'W	3600 ft.	56	1633-1976	1915	1974	.197	.564	.260
	BMV640			20	1633-1976			.221	.533	.283
St. Paul's Mission	SPM649	48°37'N 118°07'W	1400 ft.	37	1845-1976	1915	1974	.133	.850	.282
	SPM640			20	1846-1976			.139	.836	.282
Moses Spring	MSP649	49°40'N 117°50'W	1800 ft.	34	1808-1976	1915	1974	.163	.728	.279
	MSP640			20	1808-1976			.174	.732	.301
Sheep Creek Flat	SCF649	48°57'N 117°55'W	1340 ft.	38	1806-1976	1915	1974	.230	.753	.361
	SCF640			20	1806-1976			.231	.771	.390
Northport South	NPS649	48°55'N 117°52'W	1440 ft.	22	1819-1976	1915	1974	.249	.821	.432
	NPS640			20	1819-1976			.246	.825	.430

## RESULTS

### Crossdating

We successfully crossdated cores and trees from five of the seven sites originally sampled by Carl Fox. The two sites that could not be dated, Northport and Sheep Creek South, are two of the sites designed as pollution sites.

The ring-width patterns on cores from the datable sites were characterized by periods of sensitivity, where groups of rings exhibited variability in width, and periods of complacency, where groups of rings were fairly uniform in width. The dating of these cores depended primarily on the periods of sensitivity where characteristic patterns of wide and narrow rings could be discerned and cross-matched among most of the cores from a site. It became apparent when comparing cores within a site that the periods of sensitivity and complacency occurred at the same time on most of the cores. The coincidence of these patterns in time was also present among the core series from all five sites.

The problems in dating encountered with the Northport and Sheep Creek South sites derived primarily from the fact that the periods of sensitivity and complacency in each core did not correspond in time with periods of sensitivity and complacency in other cores. Frequently the lack of correspondence occurred in two cores from the same tree, and, certainly, the patterns did not correspond from one tree to the next on these sites.

### Chronology Statistics

The chronology statistics listed in Table I were compared with those compiled for Pinus ponderosa in the western United States. Fritts and Shatz (1975) selected 21 Pinus ponderosa tree-ring chronologies from sites throughout the western United States for the purpose of characteriz-

ing them for dendroclimatic analysis. In Table II the chronology statistics for the five Washington chronologies are compared with those for the 21 western grid chronologies. Fritts and Shatz established criteria by which to assess a chronology for the amount of information on climatic variability it might contain. According to these criteria, it would be unusual for a western Pinus ponderosa chronology to be characterized as a good climatic chronology if it had a value for mean sensitivity lower than the 95% limit of 0.086, a value for first-order autocorrelation higher than the 95% limit of 0.685, and a value for standard deviation lower than the 95% limit of 0.156.

The values for mean sensitivity for the five site chronologies from Washington all fall between the lower 50% and 95% limits for mean sensitivity. The values for first-order autocorrelation for two of the control chronologies (SPM640 and MSP640) and the two pollution chronologies (SCF640 and NPS640) are higher than the upper 95% limit for western Pinus ponderosa. However, the value for first-order autocorrelation in the control chronology BMV640 falls within the upper 50% limit for first-order autocorrelation in western Pinus ponderosa chronologies. The values for standard deviation for the Washington chronologies fall within the limits for western Pinus ponderosa chronologies. The value for the pollution chronology SCF640 is actually within the upper 50% for standard deviation for the western grid chronologies.

#### Analyses of variance and cross-correlation

Table III summarizes the results of the analysis of variance on the five Washington chronologies. All chronologies contain a high percentage of variance in common among the cores and trees comprising each chronology. In the case of one pollution chronology (SCF640) the majority of the re-



TABLE II  
 Comparison of chronology statistics for 21 western U. S. Pinus ponderosa tree-ring  
 chronologies and five Washington State Pinus ponderosa tree-ring chronologies

MEAN SENSITIVITY		FIRST-ORDER AUTOCORRELATION		STANDARD DEVIATION	
Upper 95% limit	.611	Upper 95% limit	.685	Upper 95% limit	.575
Upper 50% limit	.437	Upper 50% limit	.531	Upper 50% limit	.436
MEAN for <u>Pinus ponderosa</u>	.348	MEAN for <u>Pinus ponderosa</u>	.452	MEAN for <u>Pinus ponderosa</u>	.366
Lower 50% limit	.260	Lower 50% limit	.374	Lower 50% limit	.295
Lower 95% limit	.086	Lower 95% limit	.220	Lower 95% limit	.156
<u>Control Sites</u>		<u>Control Sites</u>		<u>Control Sites</u>	
BMV640	.221	BMV640	.533	BMV640	.285
SPM640	.139	SPM640	.836	SPM640	.282
MSP640	.174	MSP640	.732	MSP640	.301
<u>Pollution Sites</u>		<u>Pollution Sites</u>		<u>Pollution Sites</u>	
SCF640	.231	SCF640	.771	SCF640	.390
NPS640	.246	NPS640	.825	NPS640	.361

Table III

Analysis of variance results for the Washington state Pinus ponderosa tree-ring chronologies

<u>Chronology ID</u>	<u>% variance in common</u>	<u>% variance due to trees</u>	<u>% variance in core class</u>	<u>% variance due to cores</u>
BMV640	40.486	23.943	.711	34.860
SPM640	51.677	14.367	1.445	32.511
MSP640	46.279	24.706	.400	28.616
SCF640	55.107	4.741	-.975	41.127
NPS640	49.397	22.446	.710	27.447

maining variance is due to variation among the cores. Among the other sites the remaining variance is fairly evenly split between variance due to among-tree variance and variance due to among-core variance.

The correlation among the cores and trees on each site was computed for the common period 1915 - 1974 and for 20-year periods with 10-year overlaps within the common period (see Table IV). A decrease in the correlation among cores on each site occurs in all chronologies from roughly 1935 to 1974. Specifically, the correlation among elements in the control chronologies decreases from 1935-1974 for BMV640, from 1945-1974 for SPM640, and from 1935-1974 for MSP640. The correlation among elements in the pollution chronologies decreases very slightly from 1935-1964 for SCF640 and more markedly for NPS640 from 1935-1974.

Table IV  
 Correlation among trees on five Washington state Pinus ponderosa tree-ring sites (n=180)

<u>Period</u>	<u>BMV640</u>	<u>SPM640</u>	<u>MSP640</u>	<u>SCF640</u>	<u>NPS640</u>
1915-1964	.440	.524	.479	.630	.538
1915-1934	.522	.562	.446	.461	.672
1925-1944	.626	.476	.602	.692	.683
1935-1954	.403	.602	.312	.421	.420
1945-1964	.234	.352	.230	.452	.319
1955-1974	.324	.297	.606	.541	.386

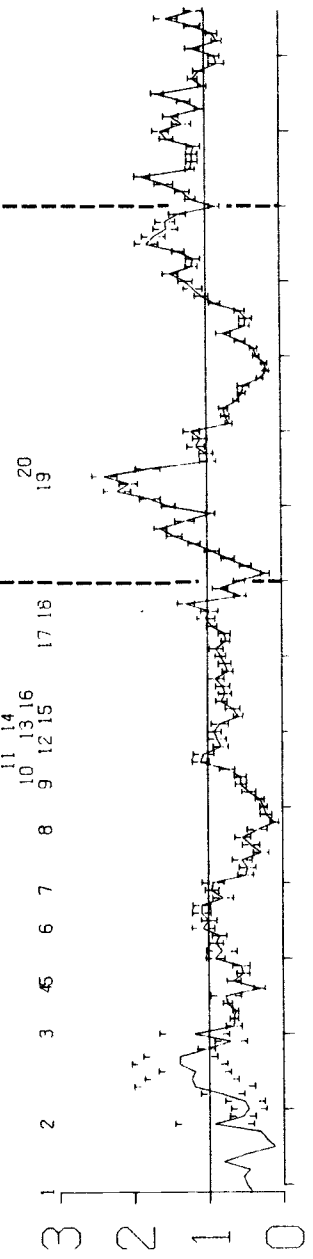
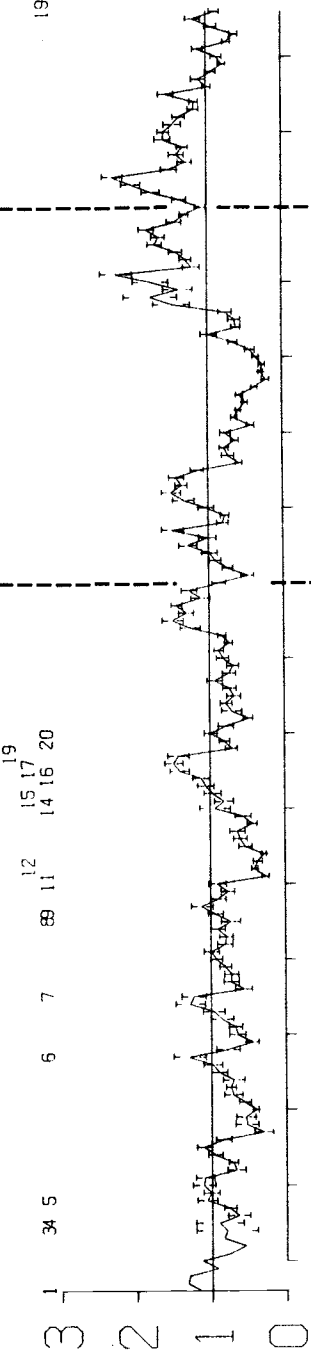
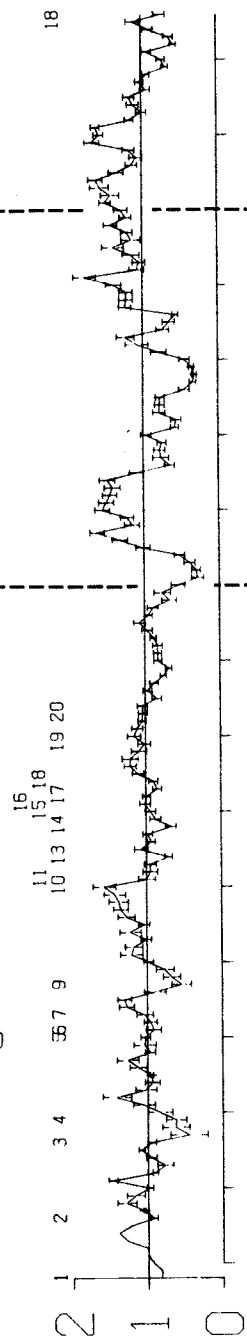
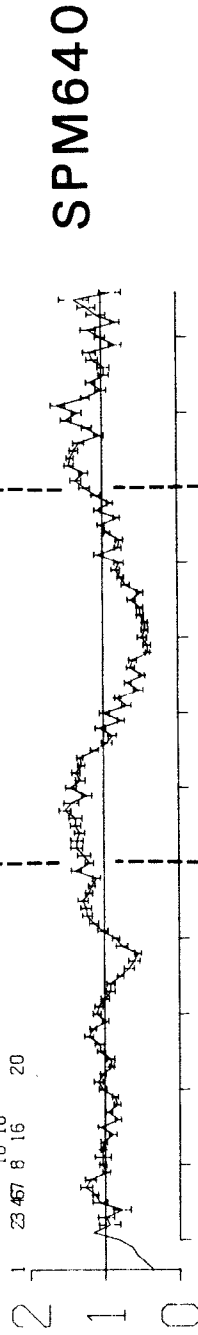
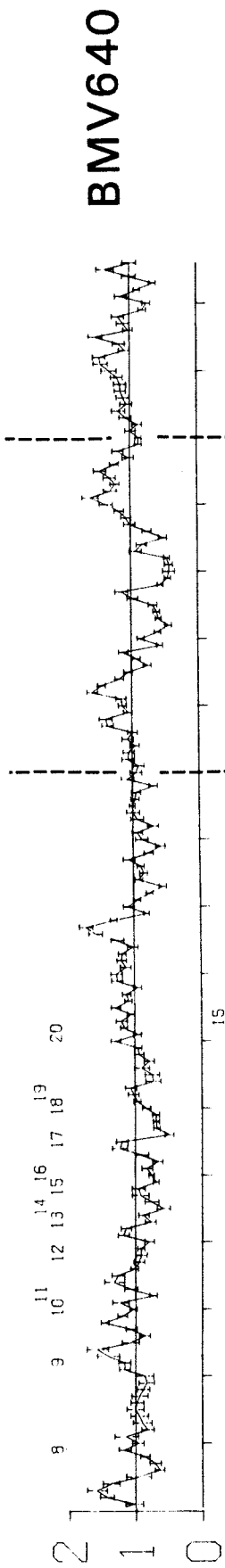
DISCUSSION

It became apparent during the process of dating the cores that the ring-width series from all five sites were generally complacent and that verification of crossdating depended upon the few periods of compressed, sensitive ring widths. The expectation before doing any analyses was that the high-frequency climatic signal in the series would not be strong.

The existence of a large degree of trend in ring width and little year-to-year variability is evident in the chronology statistics for the final site chronologies (low values for mean sensitivity and high values for autocorrelation). However, the analysis of variance results at first seem to be contrary to the indications of the chronology statistics. Ordinarily, when an analysis of variance shows that there is a high percentage of variance in common, there is a correspondingly high value for mean sensitivity in the chronology and a low value for first-order autocorrelation. The assumption in this case is that tree growth on a site is commonly limited by yearly fluctuations in regional climatic factors and that this common response is reflected in a high percentage of variance in common in the ring-width series from these trees. This, however, is not the case for the five Washington state chronologies. The high percentage of variance in common is probably not due to commonality of high-frequency variance but commonality of low-frequency variance.

The final chronologies plotted with 50% standard error bars (Fig. 1) provide visual evidence for the existence of low-frequency trends in the site chronologies. All site chronologies contain a marked long-term trend in the common period 1915-1974. The analysis of variance results probably reflect this common trend rather than variance due to marked year-to-year variation.

INDEX VALUES



1850 1900 1950

YEAR

The decrease in correlation among cores on each site from 1935-1974 is difficult to interpret without either site information or climatic data. The decrease in correlation among cores from each site is inversely related to the increase in the standard error of the mean index values in the final chronologies during the period 1935-1974.

No attempt has been made to assess differences between control and pollution site chronologies. Nonetheless, any differences between the two types of sites are not readily apparent in the analyses performed thus far. There does seem to be a more marked increase in mean index value in the pollution chronologies from roughly 1935 to 1960, and this is especially noticeable in the plot of the SCF640 chronology (Fig. 1).

#### SUGGESTIONS

The magnetic tape being sent with this report (see Appendix B) contains raw ring-width data and standardized core, tree and final chronologies. The standardizing procedure we used was very conservative. If a ring-width series did not contain an exponential growth curve, a straight line was fit to the series. If this standardization scheme is not satisfactory to your purposes, the ring-width data have been provided so that you may use them as you see fit.

An analysis of variance that might better reflect the amount of common variance due to climate in each chronology might be performed for each final index chronology after first-differencing the component core indices or filtering out the low-frequency variance in each chronology. In any case, some efforts to remove the low-frequency variance seem to be necessary to identify the climatic signal in the chronologies, and before assessing the chronologies for indications of air pollution effects on ring width.

It was apparent in both the dating process and in the results of the analyses of variance and cross-correlation that a large amount of variability exists among trees on a site and even among the cores. The among-core variability is more pronounced on the control sites Bangs Mtn. Vista (BMV) and St. Paul's Mission (SPM), and the pollution site Sheep Creek Flat (SCF). On all sites there is enough intra-site variability that any use of the tree-ring data should probably be preceded by an analysis of possible sources of intra-site variability, using the core and tree indices and any site information which may be available.



## REFERENCES

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- Fritts, H.C. (1976). Tree rings and climate. London, Academic Press.
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- Graybill, D.A. (1979b). Program operating manual for RWLIST, INDEX and SUMAC. Unpub. MS., Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona.
- Stokes, M.A. and Smiley, T.L. (1968). An introduction to tree-ring dating. Chicago, University of Chicago Press.

## Appendix A

Core series included in the climatic chronologies for  
the five Washington Pinus ponderosa sites.

Control Site ChronologiesBangs Mtn. Vista (BMV)

BMV011	BMV121
BMV012	BMV122
BMV041	BMV151
BMV042	BMV152
BMV051	BMV201
BMV052	BMV202
BMV061	BMV311
BMV062	BMV312
BMV091	BMV381
BMV092	BMV382

St. Paul's Mission (SPM)

SPM031	SPM251
SPM032	SPM252
SPM041	SPM261
SPM042	SPM262
SPM051	SPM341
SPM052	SPM342
SPM101	SPM371
SPM102	SPM372
SPM121	SPM421
SPM122	SPM422

Moses Spring (MSP)

MSP031	MSP141
MSP032	MSP142
MSP041	MSP181
MSP042	MSP182
MSP051	MSP191
MSP052	MSP192
MSP081	MSP381
MSP082	MSP382
MSP091	MSP411
MSP092	MSP412

Pollution Site ChronologiesSheep Creek Flat (SCF)

SCF011	SCF201
SCF012	SCF202
SCF021	SCF221
SCF022	SCF222
SCF031	SCF251
SCF032	SCF252
SCF091	SCF281
SCF092	SCF283
SCF181	SCF291
SCF182	SCF292

Northport South (NPS)

SPS011	NPS072
NPS012	NPS073
NPS021	NPS081
NPS022	NPS082
NPS031	NPS101
NPS032	NPS102
NPS041	NPS111
NPS042	NPS112
NPS051	NPS121
NPS052	NPS122

## Appendix B

## Contents of magnetic tape

Included in this appendix are a form describing how data were written on the magnetic tape and what type of data are contained in each file, a list of the first line in each file on the tape, and a description of the format in which ring-width and index data are written. The description of format was written by Don Graybill (Graybill, 1979b).

Each core index series and tree summary is followed by one ANOVA card. The final summaries (XXX649 and XXX640) are followed by one ANOVA card and by sums of squares cards which each contain 11 values. The format for the sums of squares cards is (A6, I4, 11(I6), 2X, 'SQ').



# Magnetic Tape Information Form

Date Written November 4, 1981

From Marna Ares Thompson  
Laboratory of Tree Ring Research  
University of Arizona  
Tucson, Arizona 85721

To Dr. James Kercher, L-524  
Lawrence Livermore National Laboratory  
P.O. Box 808 - 7000 East Ave.  
Livermore, California 94550

**Recording Mode**

- 7-track  
 556 bpi (HI)  
 800 bpi (HY)  
 Odd parity (binary)  
 Even parity (coded)  
 9-track  
 800 bpi (HD)  
 1600 bpi (PE)  
 6250 bpi (GE)  
 ASCII (US)  
 EBCDIG (EB)

**Data Format**

- Unlabeled  
 Labeled VSN= \_\_\_\_\_  
Label= \_\_\_\_\_  
SCOPE internal (NCS/PE internal)(F=SI for NOS or KRONOS)  
 Stranger tape (interchange format)  
blocking factor 40 records per block  
record length 80 characters per record  
block length 3200 characters per block (equals blocking factor x record length)

**Contents**File 1 Ring widths for BMV coresFile 2 Ring widths for SPM coresFile 3 Ring widths for MSP coresFile 4 Ring widths for SCF coresFile 5 Ring widths for NPS coresFile 6 Core indices for BMVFile 7 Tree summaries, final chronologies, BMVFile 8 Core indices for SPMFile 9 Tree summaries, final chronologies, SPMFile 10 Core indices for MSP

This tape was recorded or will be read on the Control Data CYBEF 175 computer at the University of Arizona, under the NOS/BE 1.4 (level 508) operating system.

The operating system uses the 63-character set option. If you have questions about reading or writing the tape, contact the Computing Center Consulting Office at (602) 626-3651.



## Magnetic Tape Information Form

From Marna Ares Thompson  
Laboratory of Tree Ring Research  
University of Arizona  
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Date Written November 4, 1981  
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## Recording Mode

- 7-track  
 556 bpi (HI)  
 800 bpi (HY)  
 Odd parity (binary)  
 Even parity (coded)  
 9-track  
 800 bpi (HD)  
 1600 bpi (PE)  
 6250 bpi (GE)  
 ASCII (US)  
 EBCDIC (EB)

## Data Format

- Unlabeled  
 Labeled VSN= \_\_\_\_\_  
 Label= \_\_\_\_\_  
 SCOPE internal (NCS/PE internal)(F=SI for NOS or KRONOS)  
 Stranger tape (interchange format)  
 blocking factor 40 records per block  
 record length 80 characters per record  
 block length 3200 characters per block (equals blocking factor x record length)

## Contents

File 11 Tree summaries, final chronologies, MSP  
 File 12 Core indices for SCF  
 File 13 Tree summaries, final chronologies, SCF  
 File 14 Core indices for NPS  
 File 15 Tree summaries, final chronologies, NPS  
 File 6 \_\_\_\_\_  
 File 7 \_\_\_\_\_  
 File 8 \_\_\_\_\_  
 File 9 \_\_\_\_\_  
 File 10 \_\_\_\_\_

This tape was recorded or will be read on the Control Data CYBER 175 computer at the University of Arizona, under the NOS/BE 1.4 (level 508) operating system.

The operating system uses the 63-character set option. If you have questions about reading or writing the tape, contact the Computing Center Consulting Office at (602) 626-3651.

REF V2.3 08.23.15. 11/04/81 SEQUENTIAL PROCESSING PAGE 1  
LOGICAL FILE NAME = TRL284

FILE NO.	NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	WORDS
BMV011	1850	496	456	505	426	375	317													0
SPM021	1859	468	445	402	461	503	471													0
MSCF011	1890	488	445	402	130	162	150													0
SCF011	1814	78	122	98	133	88	764													0
NPS011	1846	70	190	105	992	88	888													0
BMV011	1850	1025	1155	1155	1892	550	814													0
SPM031	1853	1974	9990	9990	1796	550	814													0
370	1853	1974	9990	9990	1796	550	814													0
MSP031	1871	787	721	721	1597	550	814													0
340	1871	1974	9990	9990	1597	550	814													0
SCF011	1813	1974	9990	9990	1597	550	814													0
380	1813	1974	9990	9990	1597	550	814													0
NPS011	1846	9990	9990	9990	1597	550	814													0
220	1846	1974	9990	9990	1597	550	814													0

END OF INFORMATION DETERMINED FROM TAPE MARK COUNT.



## Formats for ring-width and index records

Ring-width and index records are used and/or produced by numerous programs. Their format has been standardized and is described below.

### Ring-Widths

Ring-width records are used as input for RWLIST, INDEX and other programs not described here. The generalized format for these records is: (A6, 2X, I4, 10I6). In order to avoid problems with machines with small word size, the use of the A6 field is often treated as 2A3 or A3, A2, A1. In order to avoid the use of actual decimal points on punched output the ring-width measurements are converted to integers before being punched. They are actually read and stored as real numbers (10F6.2), i.e., expressed in 100ths of a millimeter.

Ring-widths are obtained from dated measurements along a single radius of a tree. Each radius or core sample is usually assigned a unique identification number and is assumed to be accurately dated before punched (or before it is placed in a data collection). One 80 column card will normally contain a 6 digit identification number in the first 6 columns, the decade year in columns 9-12, and ten ring-width values which follow including values of zero for locally absent rings (Fig. 1). All cards for a given radius must contain the same ID number and the decade years must appear in sequential order. In cases where B.C. dates are used a constant, e.g., 8000, should be added so that the year 1 A.D. is assigned a date 8001.

Exceptions may occur in the first and last decades. These may contain from one to ten ring-width values (as well as the usual identification number and year). The first card contains only enough ring-width values to complete the first decade (Fig. 1a). For example, in Fig. 1a the year is

not an even decade but rather the year 1742. Any card bearing this date must contain values for the eight years, 1742 through 1749, the remaining 2 data fields on the right are blank. All ring-width values on the first card are left justified to fill up the left-most spaces. The date in columns 9-12 in this first card must correspond to the date of the first ring-width value. All following cards begin with an even decade, 1750, 1760, etc. (Fig. 1b), and must contain 10 ring-width values ranging from 0 to 9.98 mm except for the last card. Decimal points are never entered on the cards.

The last card contains a 999 or larger number after the last valid ring width (Fig. 1c). That is, if the last measured tree ring is for 1967, the ring-width value will appear in the eighth position on the last card (1960 is the first position and 1967 the eighth position (Fig. 1a) and the ninth position will contain a number of "999" or larger. This "999" is never processed as data. It is read and used as a signal to the computer that the last decade has been encountered and the next card, if there is one, contains ring widths for another radius or sample, or is a control card. If the last value is in the tenth position, the following card contains the identification number, the next decade date, and 999 in the first data position. All other positions to the right of a 999 are ignored. This feature limits the use of our program to ring-width series where no value is larger than 9.98 mm. If a ring-width exceeds this value, it can be reduced to proper scale along with other measurements by multiplying all values for that radius by an appropriate constant. While this scaling affects ring widths, it will not affect the index values as they are expressed as percentages.

Figure 1 Ring Widths

190161 1742 101 218 132 162 254 250 059 212

A

00 00000000000000 00 800 00000000000000000000000000000000  
 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80  
 190161 1750 069 104 039 052 054 042 038 034 067 071

B

00 00000000 000 000000 0000 000000 000000 000000 000000 000000 000000 000000 000000000000  
 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80  
 190161 1960 046 041 033 015 042 046 056 032 999

C

00 00000000 000 000000 000000 000000 000000 000000 000000 000000 000000 00000000000000000000  
 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

Figure 2 Indices Without N

79218218099990 9990 9990 9990 9990 9990 9990 9990 9990 9990 1024

A

00000000 0000 000000 000000 000000 009000 000000 000000 000000 000000 0000 000000  
 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80  
 79218219500776 0870 0965 1129 1176 1129 0706 0612 1059 0941

B

0000000000 000000 00 0000 000000000000000000000000000000000000 00 0000 00000000 000000 000000  
 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80  
 79218219601202 1034 1443 1611 1659 1226 1130 9990 9990 9990

C

0000000000 00 00000 00 000000 0000000 0000000 000000 0000  
 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

Figure 3 Indices With N

52301015059990 09990 09990 09990 01367 10946 10525 11314 21645 21003 2

A

000 0 00 0000 00 000 00 000 00 000 00 0000000 000000 00000000000000000000000000000000 0000  
 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80  
 52301015100857 20682 50721 50876 50799 70584 90993 101149 100896 101149 10

B

000 0 900 000000 000000 000000 000000 000000 000000 000000 000000 000000 000000 000000 000000 000000  
 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80  
 52301015201424 101353 41595 41555 49990 09990 09990 09990 09990 09990 09990 0

C

000 0 900 000000 000 00 000 00 000 00 000 00 000 00  
 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

## Indices

The generalized format for index records is: (A6, I4, 10(I4, I3). The A6 field is for identification and the next field (I4) contains a decadal value. The remaining I4 fields contain index values that have been converted from real numbers (F4.3) to integers. The I3 fields are either blank or contain the frequency of specimens that were used in developing the index value in the previous field.

Indices (or index cards) are punched as output by programs INDEX and SUMAC--if the punch options are used. They may be punched by hand when standardization has been accomplished by other than computer means. There are two types of index cards--one not showing the number of observations (N), the other showing this number. Both types will have an identification number punched in columns 1-6, and the date of the first index on the card punched in columns 7-10 (Fig. 2). With the possible exception of the first and last cards, there will be ten indices to a card. The first and last index cards should have 9990 punched for all positions at the beginning or ending where there are no index values (Fig. 2a). The computer tests for values of 9990 to distinguish absence of data from values of zero. The values for indices on the first card are right justified.

The first type of index cards not showing number of observations (N) contains values of indices in columns: 11-14, 18-21, 25-28, 32-35, 39-42, 46-49, 53-56, 60-63, 67-70, and 74-77 (Fig. 2). This type of card should be used only for single radii with one observation per index value.

The second type contains all the information as the first type plus the sample size or the number of radii (N) that were averaged together to obtain each index value. These numbers are punched in the columns following the respective indices, 15-17, 22-24, 29-31, 36-38, 43-45, 50-52, 57-59, 64-66,

71-73, and 78-80 (Fig. 3). The computer programs are written to interpret a zero or blank value in the numbers position as a value of 1. When several master chronologies are averaged, they are weighted according to the value of N. The data on cards without this N value will be read as having an N number of 1.