WESTERN U.S. TREE-RING INDEX CHRONOLOGY DATA FOR DETECTION OF ARBOREAL RESPONSE TO INCREASING CARBON DIOXIDE

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INTRODUCTION

This report summarizes tree-ring chronologies recently developed by the University of Arizona Laboratory of Tree-Ring Research that can be used for the purpose of examining tree-ring growth response to increasing atmospheric carbon dioxide. Portions of this research were accomplished under contract with the Oak Ridge National Laboratory project "Detection of forest response to increased atmospheric carbon dioxide" (Darrell C. West, P.I.).

Background

It was recently hypothesized that " -- subalpine vegetation generally, and upper treeline conifers in particular could now be exhibiting enhanced growth due directly to rising levels of atmospheric CO_2." (LaMarche, Graybill, Fritts and Rose 1984). The basis for this hypothesis is the idea that CO_2 is normally limiting to photosynthesis at relatively high elevations because the concentration of CO_2 per unit volume is decreased from that nearer sea level. With substantially increasing CO_2 since the mid 1800's one might then expect to see improved photosynthetic performance in trees at high elevations over that period.

At the time the paper was written in late 1983 and early 1984 the available data that had been processed and appeared to demonstrate this effect into the 1980's were ring widths of limber pine (Pinus flexilis James) from 3325 m. altitude on Mt. Jefferson, central Nevada and of Great Basin bristlecone pine (Pinus longaeva D.K. Bailey) from 3400-3500 m. altitude in the White Mountains of eastern California. As the paper was going to press a data set of 50 bristlecone pine cores that had been collected in 1983 from upper treeline (3415 m.) on Mt. Washington in east-central Nevada was dated and measured. Inspection of the ring-width plots of several individual series suggested that growth trends were similar to those seen in the sites mentioned above. A comparison of plots of the final index chronologies recently developed for all of these sites supports that observation. They are presented in later sections that describe each site chronology.

While the similarity in growth patterns of trees at 3300-3500 m. across a transect of ca. 400 km. is of considerable interest, the data are limited to two species of pine and to the central Great Basin. Therefore further research undertaken in 1984 was broadly directed at increasing the number as well as the elevational and geographic distribution of sites.

Research Design and Collections

An exhaustive survey of numerous chronologies in our tree-ring data banks, of others in process and consideration of the biological-environmental interactions that might be occurring has shaped the research design in specific directions.

One of the primary goals that orients all collection efforts is to obtain chronologies that are as old and climatically sensitive as possible. This is basically a strategy of obtaining the best and longest possible sample of paleoclimatic variability the trees might record.

Climatic sensitivity is important because the detection of a CO_2 signal in a tree-ring chronology will in part depend on how much other variance can be controlled or accounted for. Age is important for several reasons. The old series provide a control, a record of climatic variation prior to 'contamination' by increased atmospheric CO_2 of the past 100 or so years. They can potentially provide a better description of the nature and range of climatic variation than can be derived from the relatively short modern instrumented records. Additionally, many of the chronologies have substantial autocorrelation to several lags. For various analytical purposes it may be desirable to develop time series models and work with white noise residuals of the index chronologies (Box and Jenkins 1976). Relatively long series with substantial specimen depth are desirable in order to obtain reliable estimates of the autocorrelation structure.

Given these concerns and one of increased geographic coverage it was deemed appropriate and useful to expand collections at relatively high elevations into other areas. Rocky Mountain bristlecone pine (*Pinus aristata* Engel.) appeared particularly promising based on earlier work by LaMarche and Stockton (1974). Those collections are limited in numbers of series per site and all end prior to 1971. Three sites in Colorado previously studied by LaMarche were recollected in 1984 - Mt. Goliath, Almagre Mtn. and Hermit Lake (see figure 1).

The same species of bristlecone pine is present at elevations near 3550 m. in the San Francisco Mountains of N. Arizona but had not received professional attention so substantial exploration and effort was expended there. Trees from several localities were sampled. This resulted in a provisional chronology that is acceptable for current purposes but which could be considerably enhanced in length and series depth with further work.

All series described above have been fully processed since collection. In addition, upper treeline chronologies were finalized for three sites that had been collected in 1983: Sheep and Campito Mountains, California and Mt. Washington, Nevada.

Given the mid summer beginning of this project in 1984 the new collections of upper treeline data were limited. The field collection season

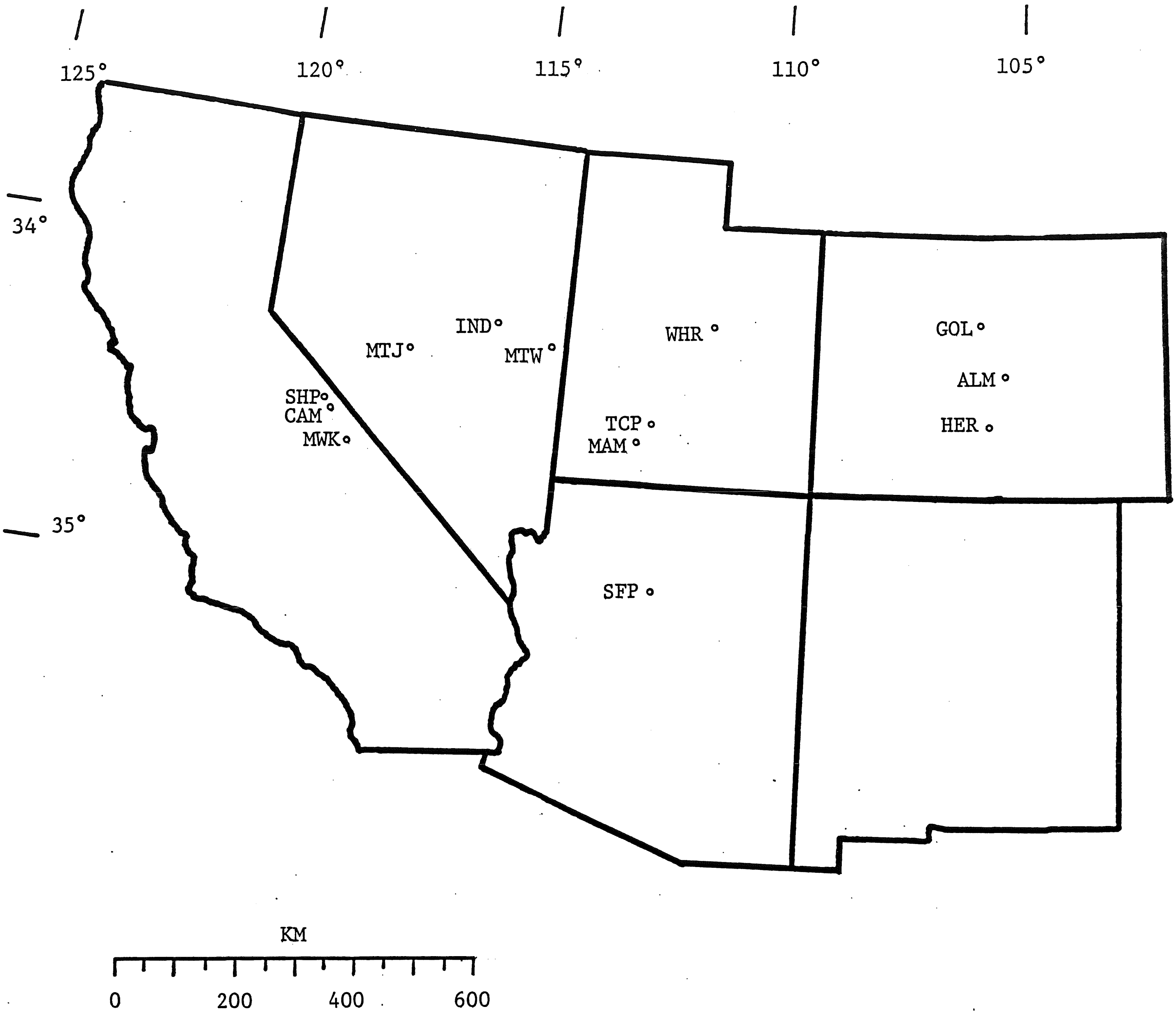


Figure 1. Site collections.

ABBREVIATION	SITE NAME	STATE	ID	ALTITUDE	SPECIES
ALM	Almagre Mountain	CO	64251C	3535 m	P. aristata
CAM	Campito Mountain	CA	90251C	3505 m	P. longaeva
GOL	Mt. Goliath	CO	64351C	3535 m	P. aristata
HER	Hermit Lake	CO	64151C	3660 m	P. aristata
IND	Indian Garden	NEV	28751L	2805 m	P. longaeva
MAM	Mammoth Creek	UT	993519	2590 m	P. longaeva
MTJ	Mount Jefferson	NEV	793599	3300 m	P. flexilis
MTW	Mount Washington	NEV	80151C	3415 m	P. longaeva
MWK	Methuselah Walk	CA	99651L	2900 m	P. longaeva
SFP	San Francisco Peaks	AZ	86451T	3535 m	P. aristata
SHP	Sheep Mountain	CA	90151C	3450 m	P. longaeva
TCP	Table Cliffs Plateau	UT	------	3110 m	P. longaeva
WHR	Wild Horse Ridge	UT	------	2805 m	P. longaeva

above 3000 m. is usually restricted to the period of June 15 - September 15 by weather conditions. Other locations in the Southwest that are targeted for sampling in 1985 to provide reasonable geographic coverage for higher elevations include the Sangre de Cristo Mountains of northern New Mexico, the San Juan Mountains of southern Colorado and the Sawatch Range of west-central Colorado. P. aristata and P. flexilis provide the best potential for long chronologies in those areas.

Field reconnaissance and review of a very large number of older data records suggest that some conspicuous voids in the Great Basin might be filled. In the northern sector the Ruby Mountains near Elko, Nevada and in the southern sector the Spring Mountains near Las Vegas have the potential for providing both upper and lower forest border chronologies of P. longaeva. There appears to be no bristlecone pine above 3200 m. in Utah with the possible exception of Haystack Peak in the Deep Creek Range along the Nevada border near latitude 40°. Access to all of these remaining Great Basin sites is rather difficult and may restrict the number collected in the near future.

One further aspect of the research concerns the issue of detection of a changing level or nature of tree growth response to increasing CO_2 that covaries with altitudinal and latitudinal change. It is apparent from previous work in the Southwest (Fritts, Smith, Cardis and Budelsky 1965) with several species and with Great Basin bristlecone pine (LaMarche 1974a) that tree-growth characteristics in the frequency domain vary substantially along altitudinal gradients. From these studies and a host of others in the arid western U.S., it can be generalized that trees growing near their lower elevational limit are strongly limited in growth by available moisture and tend to provide relatively good records of that variation. However it is uncommon to find much more than 60-70% variance in common for a lower forest border tree-ring series and an instrumented precipitation (or Palmer Drought Severity Index) record. The 'unexplained' variance is expectably due in part to various uncontrolled factors leading to random errors such as slight differences in individual series both within and between trees, limited or too far distant climatic records, etc. The hypothesis that some of the variability in arid site lower forest border tree-ring series can be attributed to variation in CO_2 has not yet been seriously entertained so at the present time it cannot be rejected. In the arid western U.S. the lower forest border for many coniferous species commonly used in dendroclimatology is near 1500-1800 m. The lower forest border for P. longaeva ranges from about 2500-2900 m.

For the current project it may be feasible in a few cases to begin to examine the differences in growth response over altitudinal transects holding species and latitude as constants. Several collections of lower forest border P. longaeva have been made in the past few years. Some remain in process but three of sufficient length and specimen depth are currently available. A series from Methuselah Walk, California provides a lower forest border bristlecone counterpart to the upper treeline series from Sheep and Campito Mountains, about 17 km. distant but 600 m. higher. A series from Indian Garden, Nevada provides a generalized lower forest border series (2805 m.) for the area that might be considered in relation to the upper treeline sites at Mt. Jefferson (3300 m.) and Mt. Washington (3415 m.).

In southwestern Utah the final Mammoth Creek chronology at 2590 m. may be usefully seen in contrast to a chronology in process from Table Cliffs Plateau at a somewhat intermediate elevation for the species at 3110 m. The Wild Horse Ridge site in central Utah at 2805 m., also in process, has no upper treeline counterpart but is currently the northernmost site with substantial age potential (2000 years) for the species that I have yet sampled.

When tree-ring series from their mid-elevational range and generally more mesic forest interior settings are examined they appear to have substantially less variance in common than their lower or upper forest border counterparts (Fritts et al. 1965; LaMarche 1974a). The trees' physiological processes are not so consistently stressed by temperature or precipitation and tend not to provide good records of those variables. The ring-width series often have non-climatic surges or are erratic to the point of being almost non-stationary in mean value function and variance. Individual biotic factors, tree or stand disturbance or intra-stand competition can all be operating to produce these non-climatic variations. This makes series from this kind of setting undesirable for current purposes.

Moving into upper treeline sites the individuals are more widely spaced like their lower forest border counterparts. The chances for stand disturbance due to fire are relatively low and competition between individuals is relatively low or nonexistent. The ring-width or ring-width index series from the upper and lower forest border sites are however substantially different. A visual comparison of any of the plots of indices from upper versus lower treeline settings in the succeeding site and chronology descriptions suggests that the former are characterized by extensive low frequency variance while the latter have extensive high frequency variance. This is supported by the accompanying plot of the variance spectrum for each series.

The physiological and ecological reasons for these kinds of differences and interpretations of them as different responses to temperature and precipitation have been treated at length by Fritts (1969) and LaMarche (1974a,b). The lower forest border series are primarily responsive to effective or available moisture which is of course controlled both by precipitation and temperature. The upper treeline series have been characterized primarily as temperature responsive with the role of precipitation being somewhat less clear in terms of its impact on the variance structure.

One direction of the current project then will be to attempt to isolate the relative contributions of temperature and precipitation in order to control or remove them so that potential variability due to increasing CO_2 might be recognized. Since there is substantial autocorrelation in most chronologies, and to a significant but lesser extent in the instrumented temperature records, a variety of time series and transfer function modeling procedures will be required (Box and Jenkins 1976; Meko 1981).

In addition to the possibility that some of the change in growth of high elevation conifers is a direct response to increasing CO_2 via increased net photosynthesis, one further process could be operating. With increasing CO_2 the water use efficiency of the trees might also be increasing due to increased closure of stomatal apertures and decreased rate of transpiration (Lemon 1983). If this is occurring then increases in growth may be scaled to some degree by the aridity of the sites in question. The Great Basin sites are all somewhat more arid than those that have been collected in Colorado. A comparison of the ring-width index plots for all of those upper treeline collections indicates that all sites have some upward growth trend since the mid 1800's but the rate of increase in the last 30 or so years appears greatest in the Great Basin area.

Detailed analysis of this data and of that projected for collection in 1985 will aid in clarification of the various issues that have been raised here.

Collection Procedures

All tree-ring series treated here were collected from living trees or in a few cases from dead standing individuals with increment borers. In many cases only one core per tree was obtained because the living cambial sector on the main trunk was restricted to a single strip of bark. Limited evaluation of each sample was made in the field by examination for distortions, branch scars, etc. and trees were recored as necessary. Trees selected for coring were in environmentally similar settings within each site. Sites were generally less than 1-2 hectares in size. Documentation of site locations, descriptions and chronology characteristics follows in succeeding pages. All tree-ring series are maintained at The Laboratory of Tree-Ring Research.

Chronology Development

Dating and Measurement

Each site collection was dated independently by a senior research technician according to standard cross-dating procedures (Stokes and Smiley 1968). The only difficulties encountered were some areas of major growth compression which led to an inability either to see the rings distinctly or to determine which might be locally absent. Not surprisingly these episodes were most common in the mid 1400's, mid 1600's and mid 1800's where various sites were severely limited in growth. The dating was independently checked by the principal investigator and a final selection of series to be measured was made. The few series rejected were normally too short, complacent or distorted to be useful. Ring-widths were measured to the nearest .01 mm. with a Henson stage under a Bausch and Lomb stereoscopic microscope. Data transmission from there to mainframe computers followed the procedures described by Robinson and Evans (1980).

Standardization

Dated ring-width series are time series that generally may have four different kinds of signals in the frequency domain.

> "For any individual specimen let
>
> $$R(t) = C + B + D + E$$
>
> where R(t) is the measured ring width in year t; C is the macroclimatic signal common to trees at a site; B is the biological growth curve as a function of increasing tree age; D is the tree disturbance signal that may be: D1, unique to a single specimen or tree and due to random events that affected its growth or D2, common to most or all specimens due to fire, insect damage, or other disturbance that affected an entire site; and E is the random growth signal unique to each specimen."
> Graybill (1982)

Our goal in chronology development is to maximize the macroclimatic signal and remove or minimize the others. In most cases the disturbance factors were initially minimized at the sample collection stage by site selection and avoidance of trees with obvious injury.

The ring-width measurements were processed with a standardized suite of programs (Graybill 1979). Recognition of the shape of the biological growth curve and disturbance signals not previously discerned was aided by output from program RWLIST. Inspection of a limited number of descriptive statistics and a printer plot of each individual series led to the deletion of some with anomalous growth characteristics. All series were then standardized with program INDEX by fitting negative exponential curves or straight lines of negative or zero slope. A new time series resulted as follows

$$\text{Index}(t) = R(t)/Y(t)$$

where Y(t) is the expected annual growth determined from curve-fitting. This scales the mean of each series to about 1.0, reduces autocorrelation due to growth trend and scales the variance so that it is more homogeneous throughout the series than it was in the original ring widths (Fritts 1976). The index series for each site were then averaged to form a final chronology. This has the effect of emphasizing the common macroclimatic signal and minimizing the error variance due to tree and core variations.

Chronology Statistics

Three sets of descriptive statistics are provided for each final chronology. The first two are used for general evalutive purposes while the third was developed for analytical purposes of the current project.

The first set of statistics is provided for comparison of various characteristics of all chronologies across a common time period. The beginning date of A.D. 1660 was selected as the earliest date for all chronologies where a substantial number of series per site were continuous up to date of collection. The final date in most cases is 1983 although a few sites were collected in the preceding five years. Most of the statistics are widely used and require no comment. "Mean sens." is an abbreviation for mean sensitivity. This is an older statistic (Douglass 1936) widely used in dendrochronology. It is the mean percentage change of each value to the next over a series. In essence it is a special measure of high frequency variance.

The correlation analysis provides insight regarding the similarities in high frequency variation among the component chronology series. The mean correlation between tree value multiplied by 100. is essentially equivalent to the amount of variance common to those trees or %Y of Fritts' analysis of variance (1976:294). The signal to noise ratio is commonly used to compare the relative power of the common variance signal across different chronologies. The succeeding variance agreement values provide a notion of the useful length of a chronology for climatic reconstruction (Wigley, Briffa, and Jones 1984). Tree-ring-climate calibrations are made with the recent portion of chronologies where sample depth is relatively high. As the number of series declines toward the early portion of a chronology the results of applying the reconstruction equation become less certain.

The second set of statistics is for the full length of each chronology and simply provides a descriptive overview. It should be noted that two of the chronologies, Methuselah Walk and Indian Garden, extend respectively back into the seventh and fourth millenia B.C. (Ferguson and Graybill 1983) but only the recent portion for time series analysis is included here.

Time Series Analysis

The time series model developed for each of the chronologies may be a useful control for various regression and response function analyses that attempt to isolate the relative contributions of temperature, precipitation and CO_2 to recent growth. Since the time period used precedes major anthropogenic CO_2 increases the models derived should best reflect the long term persistence structure of the chronologies. The models can then be used to remove persistence in the series since 1859.

The period of A.D. 1380-1859 was selected as the longest period common to all chronologies that both predates the major increases in CO_2 over the past 100 or so years and includes substantial numbers of component series for all chronologies. The average sample depth at 1380 is 20 and at 1859 is 29.

The models were computed with software from the BMDP package (Dixon 1981). For each series the range of models considered were AR(1) through AR(6), MA(1), MA(2) and ARMA(1,1). Most arid site coniferous chronologies fall in the range of those processes. The most parisimonious model was selected after evaluating the significance of model parameters and the independence and distribution of model residuals. The various statistics provided are discussed with respect to the evaluation process in a number of sources (Hoff 1983; McCleary and Hay 1980).

Climatic Data

The laboratory maintains a large file of monthly records of temperature and precipitation data. A number of stations in the vicinity of each tree-ring site that have records extending into the 1800's or near the turn of the last century are being examined for use in analysis. Those selected normally have only a limited amount of missing data that requires estimation and do not evidence major nonclimatic trends due to station moves, urbanization or other factors.

CO_2 Data

Atmospheric CO_2 concentrations from Mauna Loa Observatory, Hawaii, 1958-1983 will be used in some of the analyses.

SITE AND CHRONOLOGY INFORMATION

Site name *Mount Washington*

State *Nevada* County *White Pine*

Latitude *38° 54'* Longitude *114° 18'* Altitude *3415 m*

Collectors *D. A. Graybill, M. R. Rose, 1983. V. C. LaMarche, 1966*

Species collected *Pinus longaeva*

Associated arboreal species

Parent mineral of soil *Limestone*

Slope direction *South*

Slope angle *20°*

COMMON PERIOD CHRONOLOGY STATISTICS FOR ID 80151C

INTERVAL	1660-1978	N. OF TREES	18	N. OF RADII	28
MEDIAN	1.093	MEAN	1.076	STD. DEV.	.260
SKEWNESS	-.138	KURTOSIS	3.132	MEAN SENS.	.177

AUTOCORRELATION TO LAG 10

LAG	1	2	3	4	5	6	7	8	9	10
VALUE	.618	.618	.560	.545	.471	.468	.427	.377	.354	.315

CORRELATION ANALYSIS

	MEAN R	95 PCT LIMITS		N
AMONG ALL RADII	.438	.345	.523	378
BETWEEN TREES	.431	.337	.516	368
WITHIN TREES	.661	.594	.719	10
RADII VS MEAN	.671	.606	.727	28

SIGNAL TO NOISE RATIO 13.626

VARIANCE AGREEMENT BETWEEN FULLY REPLICATED CHRONOLOGY
OF ONE RADIUS PER TREE AND REDUCED SAMPLE SIZE CHRONOLOGY

N. OF TREES	1	2	3	4	5	6	7	8	9	10
VARIANCE	.462	.646	.745	.807	.849	.880	.903	.921	.936	.948
N. OF TREES	11	12	13	14	15	16	17	18	19	20
VARIANCE	.958	.967	.974	.981	.987	.992	.996	1.000		

FULL CHRONOLOGY STATISTICS FOR ID 80151C

INTERVAL	700-1983	N. OF TREES	25	N. OF RADII	42
MEDIAN	1.033	MEAN	1.044	STD. DEV.	.314
SKEWNESS	.792	KURTOSIS	5.921	MEAN SENS.	.192

AUTOCORRELATION TO LAG 10

LAG	1	2	3	4	5	6	7	8	9	10
VALUE	.690	.666	.643	.608	.552	.553	.518	.484	.490	.466

AVERAGE R OF RADII WITH MEAN OF ALL OTHERS .612

TIME SERIES MODEL FOR A.D. 1380 - 1859

MODEL SELECTED ARMA(1,1)

PARAMETERS	TYPE	ORDER	VALUE	95 PCT LIMITS	
	AR	1	.9370	.8954	.9786
	MA	1	.5927	.4975	.6879

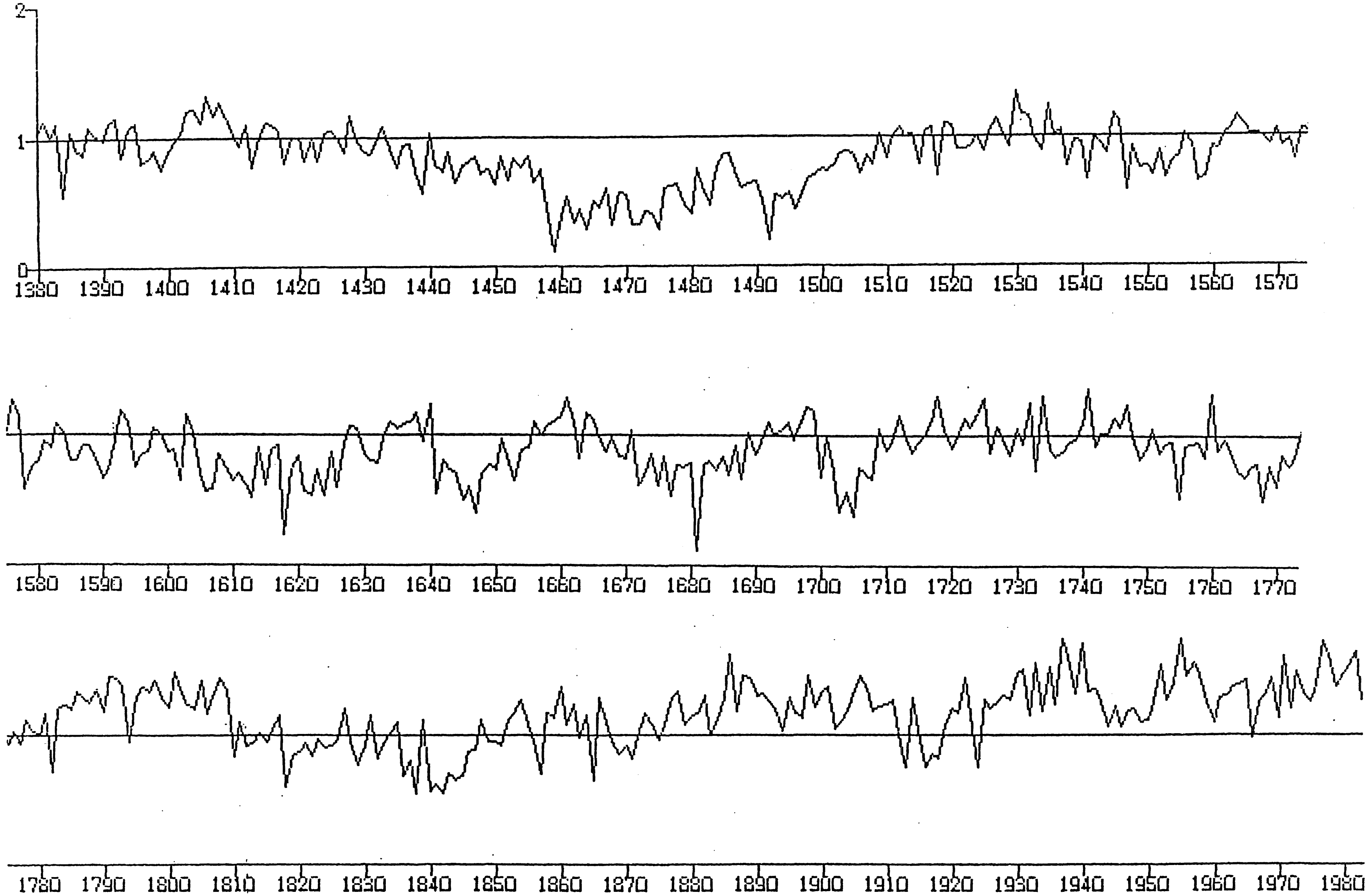
RESIDUAL SUM OF SQUARES	13.758930	RESIDUAL MEAN SQUARE	.028845
DEGREES OF FREEDOM	477	RESIDUAL STANDARD ERROR	.1698
INDEX OF DETERMINATION	48.97	AKAIKE INFO. CRITER.	1262.41
Q STATISTIC, 20 LAGS	11.00	CHI-SQ.,5 PCT, 19 D.F.	30.14

MAJOR COMPETING MODEL AR(4)

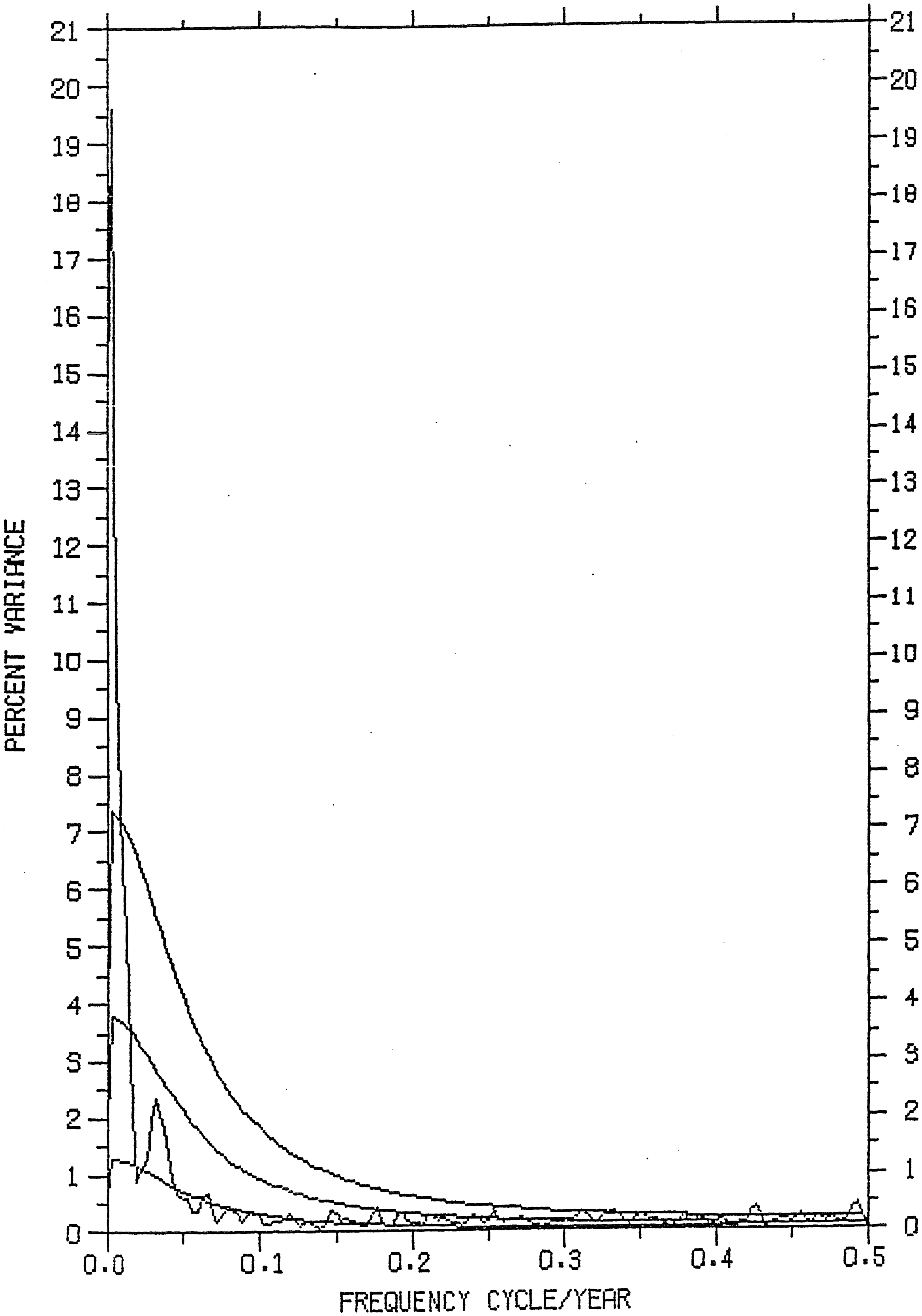
PARAMETERS	TYPE	ORDER	VALUE	95 PCT LIMITS	
	AR	1	.3201	.2287	.4115
	AR	2	.2237	.1287	.3187
	AR	3	.1657	.0705	.2609
	AR	4	.1201	.0283	.2119

RESIDUAL SUM OF SQUARES	13.669216	RESIDUAL MEAN SQUARE	.028960
DEGREES OF FREEDOM	472	RESIDUAL STANDARD ERROR	.1702
INDEX OF DETERMINATION	49.30	AKAIKE INFO. CRITER.	1263.27
Q STATISTIC, 20 LAGS	8.60	CHI-SQ.,5 PCT, 19 D.F.	30.14

ID = 80151C
TREE-RING INDICES



SPECTRUM FOR 80151C
SERIES : MT. WASHINGTON, NEV.
PERIOD 1380 TO 1983 WITH 150 LAGS



SITE AND CHRONOLOGY INFORMATION

Site name *Mount Jefferson*

State *Nevada* County *Nye*

Latitude *38° 47'* Longitude *116° 57'W* Altitude *3300 m*

Collectors *D. A. Graybill, M. R. Rose, 1981*

Species collected *Pinus flexilis*

Associated arboreal species

Parent mineral of soil *Sandstone*

Slope direction *South, West*

Slope angle *30°*

COMMON PERIOD CHRONOLOGY STATISTICS FOR ID 793599

INTERVAL	1660-1978	N. OF TREES	18	N. OF RADII	22
MEDIAN	1.021	MEAN	1.019	STD. DEV.	.253
SKEWNESS	.245	KURTOSIS	4.402	MEAN SENS.	.162

AUTOCORRELATION TO LAG 10

LAG	1	2	3	4	5	6	7	8	9	10
VALUE	.635	.588	.503	.446	.376	.321	.314	.256	.207	.154

CORRELATION ANALYSIS

	MEAN R	95 PCT LIMITS		N
AMONG ALL RADII	.322	.220	.417	231
BETWEEN TREES	.315	.212	.411	227
WITHIN TREES	.639	.569	.700	4
RADII VS MEAN	.587	.510	.655	22

SIGNAL TO NOISE RATIO 8.273

VARIANCE AGREEMENT BETWEEN FULLY REPLICATED CHRONOLOGY
OF ONE RADIUS PER TREE AND REDUCED SAMPLE SIZE CHRONOLOGY

N. OF TREES	1	2	3	4	5	6	7	8	9	10
VARIANCE	.353	.537	.650	.726	.781	.823	.855	.881	.903	.921
N. OF TREES	11	12	13	14	15	16	17	18	19	20
VARIANCE	.936	.949	.960	.970	.979	.987	.994	1.000		

FULL CHRONOLOGY STATISTICS FOR ID 793599

INTERVAL	1120-1981	N. OF TREES	26	N. OF RADII	35
MEDIAN	.979	MEAN	.979	STD. DEV.	.237
SKEWNESS	.158	KURTOSIS	4.037	MEAN SENS.	.148

AUTOCORRELATION TO LAG 10

LAG	1	2	3	4	5	6	7	8	9	10
VALUE	.689	.618	.528	.470	.415	.364	.334	.291	.266	.224

AVERAGE R OF RADII WITH MEAN OF ALL OTHERS .512

TIME SERIES MODEL FOR A.D. 1380 - 1859

MODEL SELECTED AR(2)

PARAMETERS	TYPE	ORDER	VALUE	95 PCT LIMITS	
	AR	1	.4717	.3839	.5595
	AR	2	.2680	.2002	.3758

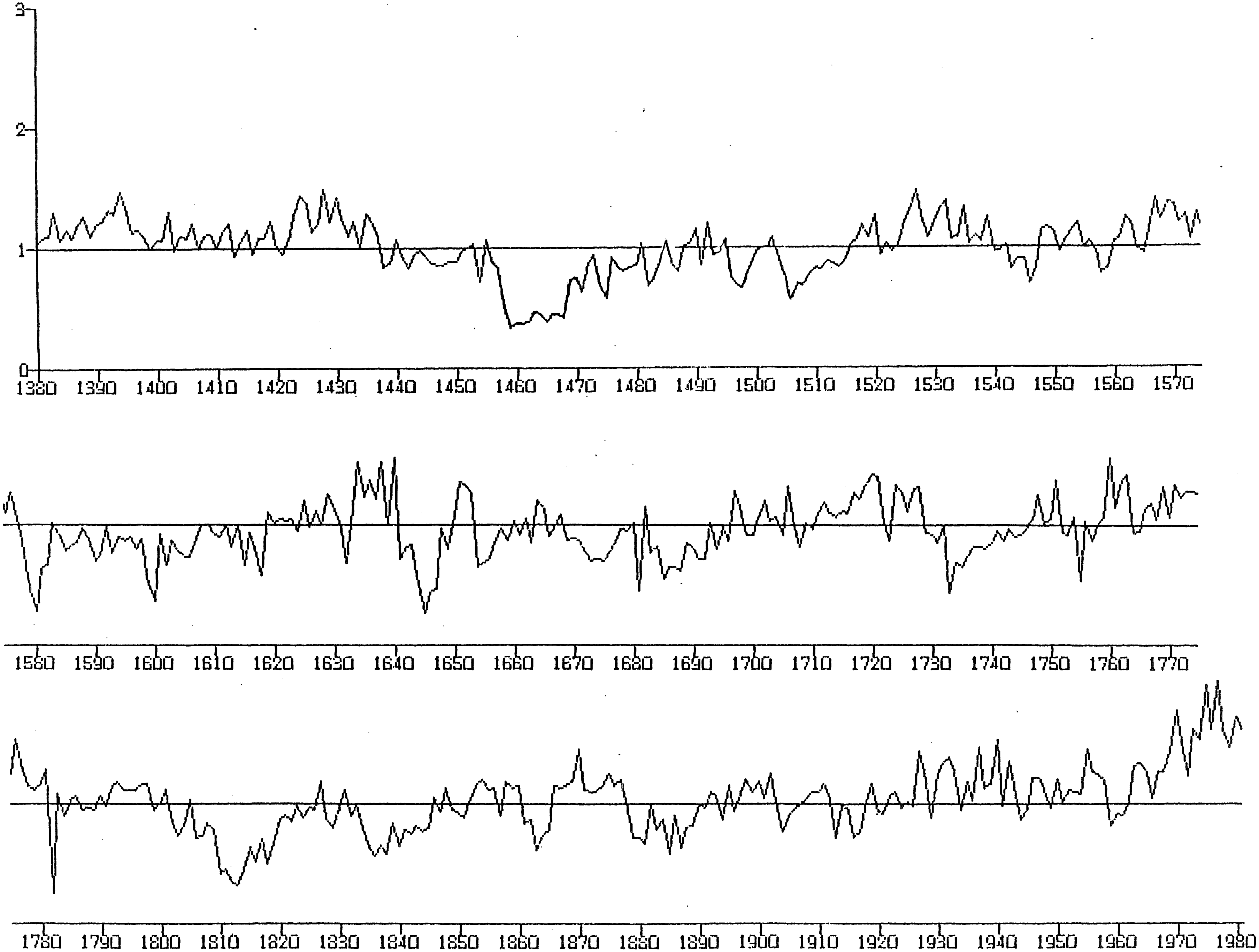
RESIDUAL SUM OF SQUARES	14.420768	RESIDUAL MEAN SQUARE	.030296
DEGREES OF FREEDOM	476	RESIDUAL STANDARD ERROR	.1741
INDEX OF DETERMINATION	48.70	AKAIKE INFO. CRITER.	1284.96
Q STATISTIC, 20 LAGS	15.00	CHI-SQ.,5 PCT, 19 D.F.	30.14

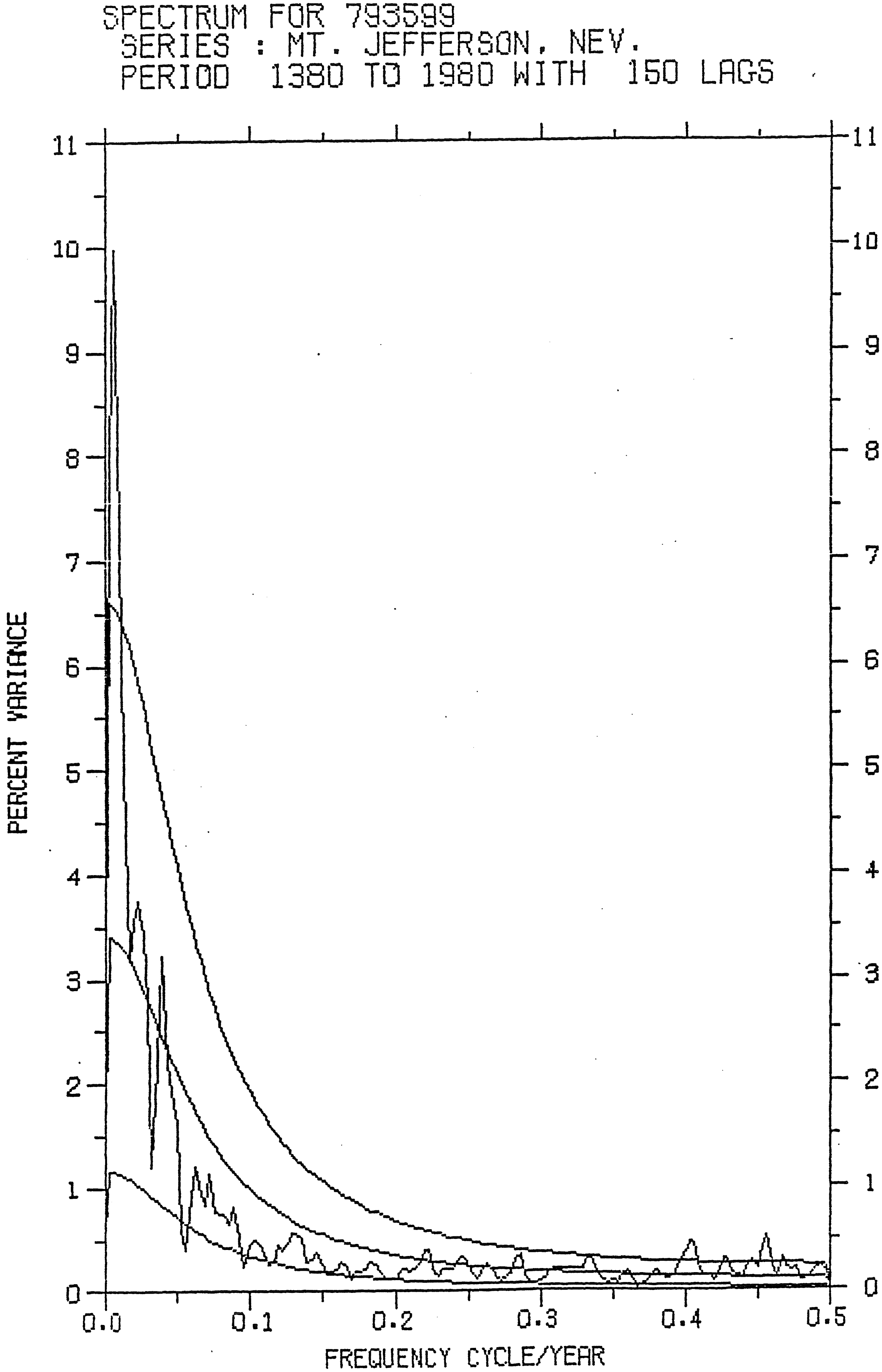
MAJOR COMPETING MODEL ARMA(1,1)

PARAMETERS	TYPE	ORDER	VALUE	95 PCT LIMITS	
	AR	1	.8722	.8102	.9342
	MA	1	.3975	.2815	.5135

RESIDUAL SUM OF SQUARES	14.439701	RESIDUAL MEAN SQUARE	.030272
DEGREES OF FREEDOM	477	RESIDUAL STANDARD ERROR	.1740
INDEX OF DETERMINATION	48.63	AKAIKE INFO. CRITER.	1285.59
Q STATISTIC, 20 LAGS	17.00	CHI-SQ.,5 PCT, 19 D.F.	30.14

ID = 793599
TREE-RING INDICES





SPECTRUM FOR 793599
SERIES : MT. JEFFERSON, NEV.
PERIOD 1380 TO 1980 WITH 150 LAGS
PERCENT VARIANCE
0
1
2
3
4
5
6
7
8
9
10
11
0.0
0.1
0.2
0.3
0.4
0.5
FREQUENCY CYCLE/YEAR

SITE AND CHRONOLOGY INFORMATION

Site name *Sheep Mountain*

State *California* County *Mono*

Latitude *37° 32'* Longitude *118° 13'* Altitude *3450 m*

Collectors *D. A. Graybill, M. S. McCarthy, M. R. Rose, 1983*
V. C. LaMarche, 1971

Species collected *Pinus longaeva*

Associated arboreal species *Pinus flexilis*

Parent mineral of soil *Dolomite*

Slope direction *South*

Slope angle *15°*

COMMON PERIOD CHRONOLOGY STATISTICS FOR ID 90151C

INTERVAL	1660-1978	N. OF TREES	12	N. OF RADII	19
MEDIAN	1.121	MEAN	1.147	STD. DEV.	.337
SKEWNESS	.435	KURTOSIS	3.228	MEAN SENS.	.170

AUTOCORRELATION TO LAG 10

LAG	1	2	3	4	5	6	7	8	9	10
VALUE	.766	.741	.717	.719	.683	.672	.635	.618	.604	.556

CORRELATION ANALYSIS

	MEAN R	95 PCT LIMITS		N
AMONG ALL RADII	.536	.452	.610	171
BETWEEN TREES	.524	.440	.600	164
WITHIN TREES	.744	.691	.790	7
RADII VS MEAN	.744	.690	.789	19

SIGNAL TO NOISE RATIO 13.234

VARIANCE AGREEMENT BETWEEN FULLY REPLICATED CHRONOLOGY
OF ONE RADIUS PER TREE AND REDUCED SAMPLE SIZE CHRONOLOGY

N. OF TREES	1	2	3	4	5	6	7	8	9	10
VARIANCE	.564	.740	.826	.877	.910	.934	.952	.966	.977	.986

N. OF TREES	11	12	13	14	15	16	17	18	19	20
VARIANCE	.994	1.000								

FULL CHRONOLOGY STATISTICS FOR ID 90151C

INTERVAL	470-1983	N. OF TREES	22	N. OF RADII	33
MEDIAN	.965	MEAN	.994	STD. DEV.	.303
SKEWNESS	.664	KURTOSIS	3.732	MEAN SENS.	.182

AUTOCORRELATION TO LAG 10

LAG	1	2	3	4	5	6	7	8	9	10
VALUE	.732	.703	.682	.658	.640	.616	.597	.580	.566	.553

AVERAGE R OF RADII WITH MEAN OF ALL OTHERS .632

TIME SERIES MODEL FOR A.D. 1380 - 1859

MODEL SELECTED ARMA(1,1)

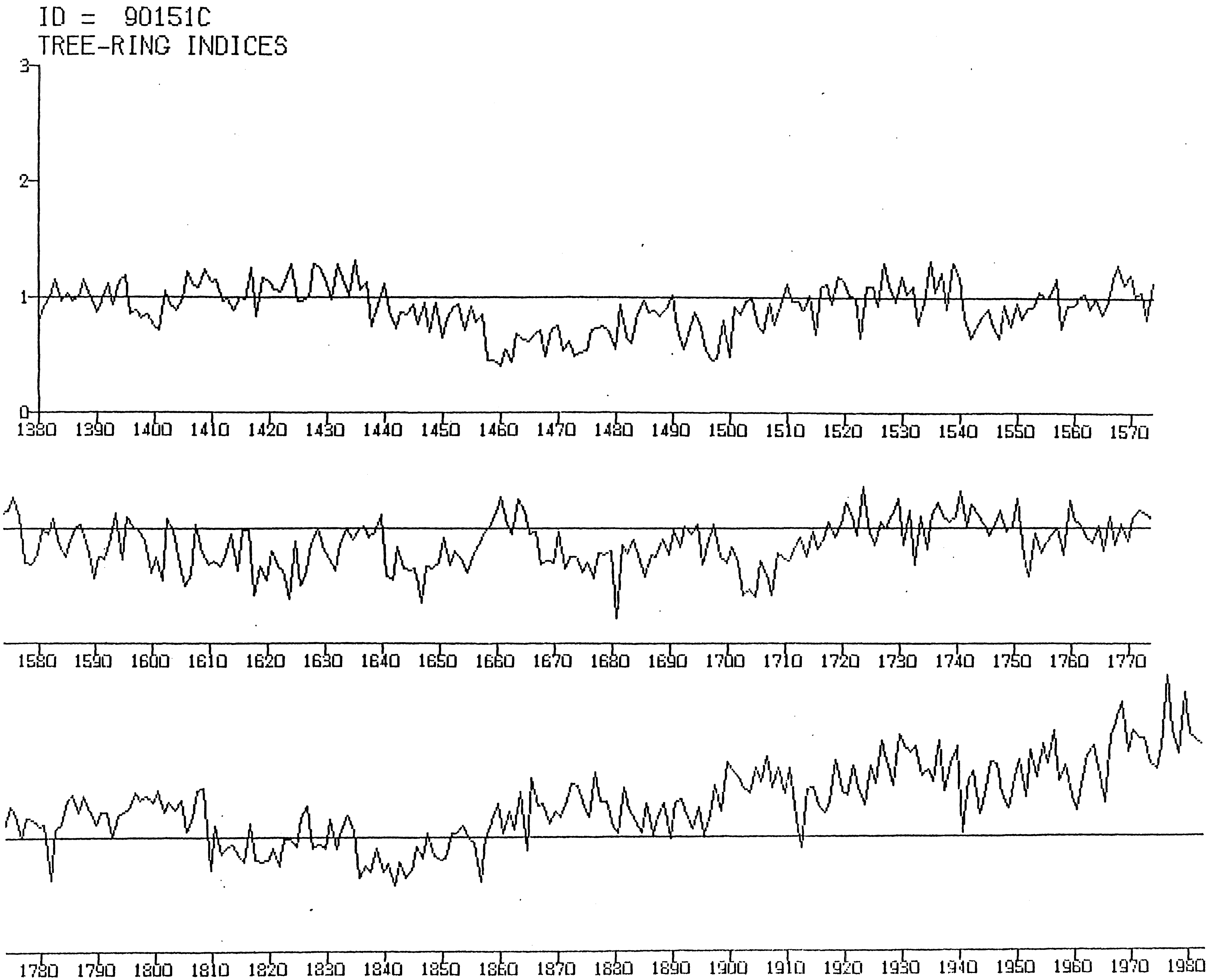
PARAMETERS	TYPE	ORDER	VALUE	95 PCT LIMITS	
	AR	1	.9280	.8812	.9748
	MA	1	.6087	.5097	.7077

RESIDUAL SUM OF SQUARES	13.173989	RESIDUAL MEAN SQUARE	.027618
DEGREES OF FREEDOM	477	RESIDUAL STANDARD ERROR	.1662
INDEX OF DETERMINATION	30.69	AKAIKE INFO. CRITER.	1241.56
Q STATISTIC, 20 LAGS	21.00	CHI-SQ.,5 PCT, 19 D.F.	30.14

MAJOR COMPETING MODEL AR(4)

PARAMETERS	TYPE	ORDER	VALUE	95 PCT LIMITS	
	AR	1	.3372	.2462	.4282
	AR	2	.2019	.1061	.2977
	AR	3	.1127	.0165	.2089
	AR	4	.1328	.0414	.2242

RESIDUAL SUM OF SQUARES	13.190000	RESIDUAL MEAN SQUARE	.027945
DEGREES OF FREEDOM	472	RESIDUAL STANDARD ERROR	.1672
INDEX OF DETERMINATION	30.61	AKAIKE INFO. CRITER.	1246.14
Q STATISTIC, 20 LAGS	25.00	CHI-SQ.,5 PCT, 19 D.F.	30.14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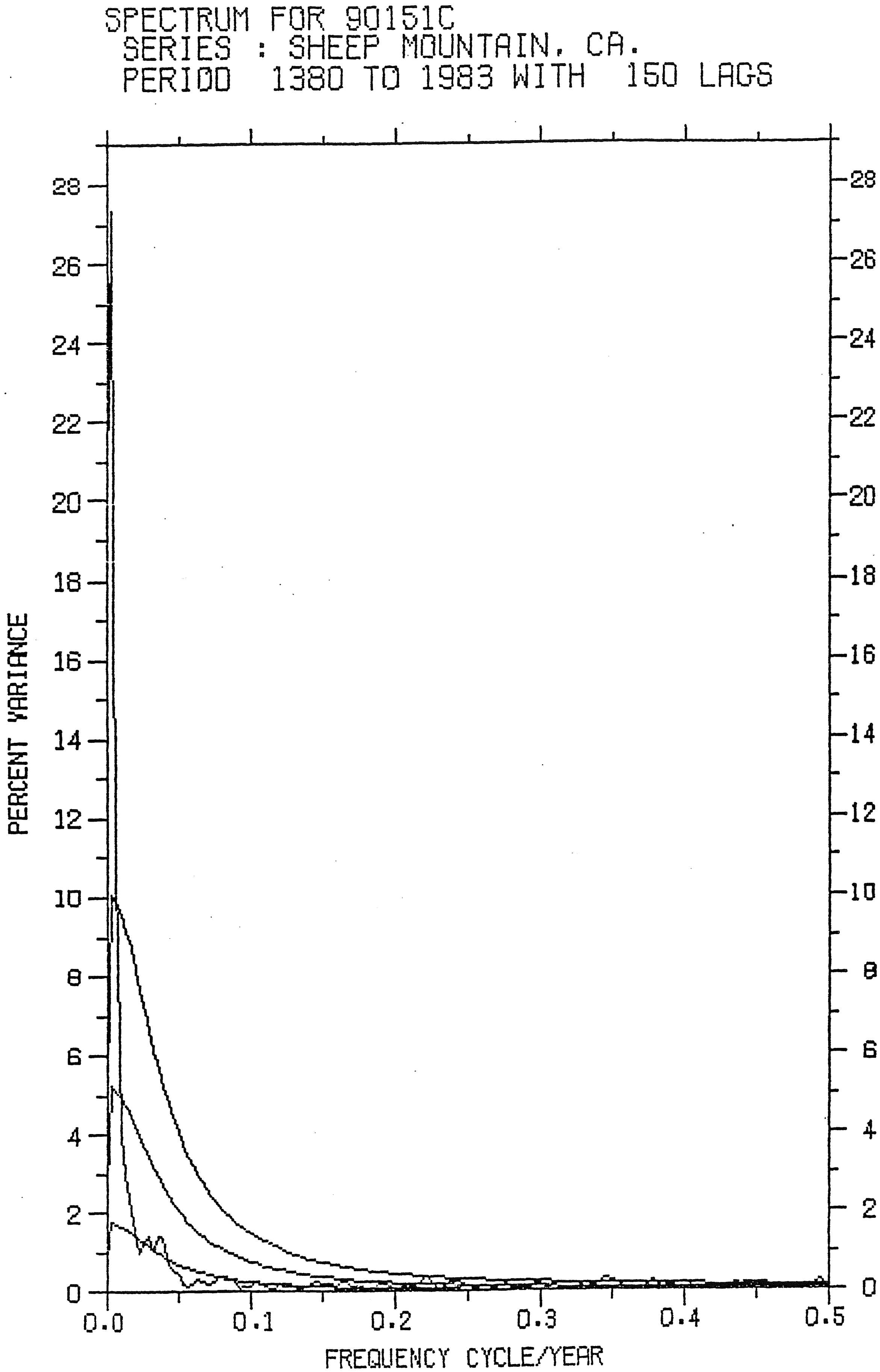

SPECTRUM FOR 90151C
SERIES : SHEEP MOUNTAIN, CA.
PERIOD 1380 TO 1983 WITH 150 LAGS
PERCENT VARIANCE
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
0.0 0.1 0.2 0.3 0.4 0.5
FREQUENCY CYCLE/YEAR

SITE AND CHRONOLOGY INFORMATION

Site name *Campito Mountain*

State *California* County *Mono*

Latitude *37° 30'* Longitude *118° 13'* Altitude *3505 m*

Collectors *D. A. Graybill, M. S. McCarthy, M. R. Rose, 1983*
V. C. LaMarche, Jr., 1971

Species collected *Pinus longaeva*

Associated arboreal species

Parent mineral of soil *Dolomite*

Slope direction *West*

Slope angle *30°*

COMMON PERIOD CHRONOLOGY STATISTICS FOR ID 90251C

INTERVAL	1660-1978	N. OF TREES	11	N. OF RADII	20
MEDIAN	1.070	MEAN	1.048	STD. DEV.	.301
SKEWNESS	-.321	KURTOSIS	2.802	MEAN SENS.	.222

AUTOCORRELATION TO LAG 10

LAG	1	2	3	4	5	6	7	8	9	10
VALUE	.602	.469	.380	.378	.366	.348	.331	.275	.307	.244

CORRELATION ANALYSIS

	MEAN R	95 PCT LIMITS		N
AMONG ALL RADII	.431	.337	.517	190
BETWEEN TREES	.419	.324	.506	181
WITHIN TREES	.641	.571	.701	9
RADII VS MEAN	.665	.599	.722	20

SIGNAL TO NOISE RATIO 7.937

VARIANCE AGREEMENT BETWEEN FULLY REPLICATED CHRONOLOGY
OF ONE RADIUS PER TREE AND REDUCED SAMPLE SIZE CHRONOLOGY

N. OF TREES	1	2	3	4	5	6	7	8	9	10
VARIANCE	.472	.665	.770	.836	.882	.915	.940	.960	.976	.989
N. OF TREES	11	12	13	14	15	16	17	18	19	20
VARIANCE	1.000									

FULL CHRONOLOGY STATISTICS FOR ID 90251C

INTERVAL	626-1983	N. OF TREES	22	N. OF RADII	39
MEDIAN	1.024	MEAN	1.024	STD. DEV.	.296
SKEWNESS	.449	KURTOSIS	5.571	MEAN SENS.	.206

AUTOCORRELATION TO LAG 10

LAG	1	2	3	4	5	6	7	8	9	10
VALUE	.634	.489	.435	.394	.353	.314	.290	.269	.257	.249

AVERAGE R OF RADII WITH MEAN OF ALL OTHERS .583

TIME SERIES MODEL FOR A.D. 1380 - 1859

MODEL SELECTED ARMA(1,1)

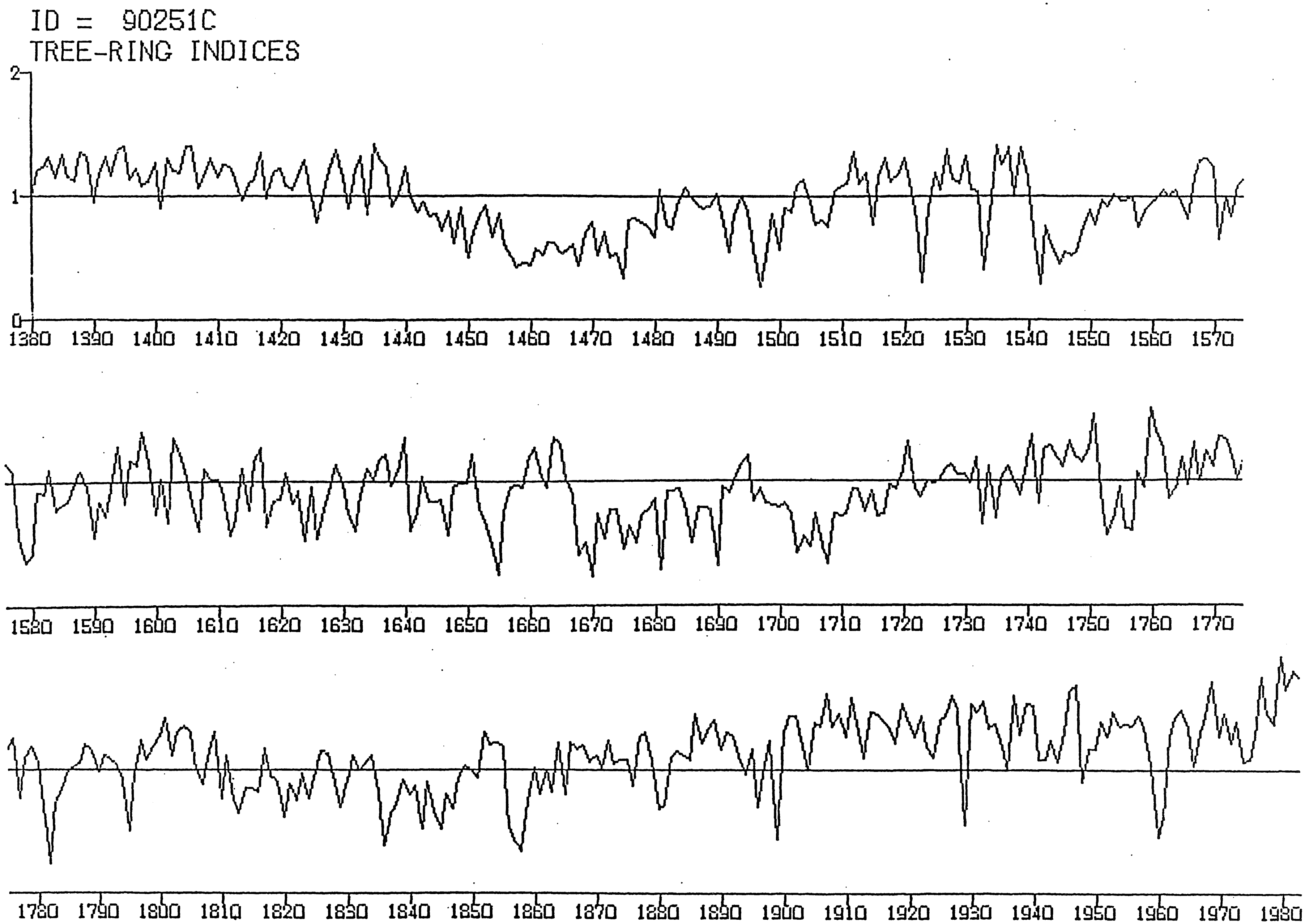
PARAMETERS	TYPE	ORDER	VALUE	95 PCT LIMITS	
	AR	1	.7552	.6538	.8566
	MA	1	.2791	.1315	.4267

RESIDUAL SUM OF SQUARES	22.299227	RESIDUAL MEAN SQUARE	.046749
DEGREES OF FREEDOM	477	RESIDUAL STANDARD ERROR	.2162
INDEX OF DETERMINATION	34.34	AKAIKE INFO. CRITER.	1494.18
Q STATISTIC, 20 LAGS	22.00	CHI-SQ.,5 PCT, 19 D.F.	30.14

MAJOR COMPETING MODEL AR(2)

PARAMETERS	TYPE	ORDER	VALUE	95 PCT LIMITS	
	AR	1	.4989	.4081	.5897
	AR	2	.1326	.0414	.2238

RESIDUAL SUM OF SQUARES	22.325873	RESIDUAL MEAN SQUARE	.046903
DEGREES OF FREEDOM	476	RESIDUAL STANDARD ERROR	.2166
INDEX OF DETERMINATION	34.26	AKAIKE INFO. CRITER.	1494.76
Q STATISTIC, 20 LAGS	25.00	CHI-SQ.,5 PCT, 19 D.F.	30.14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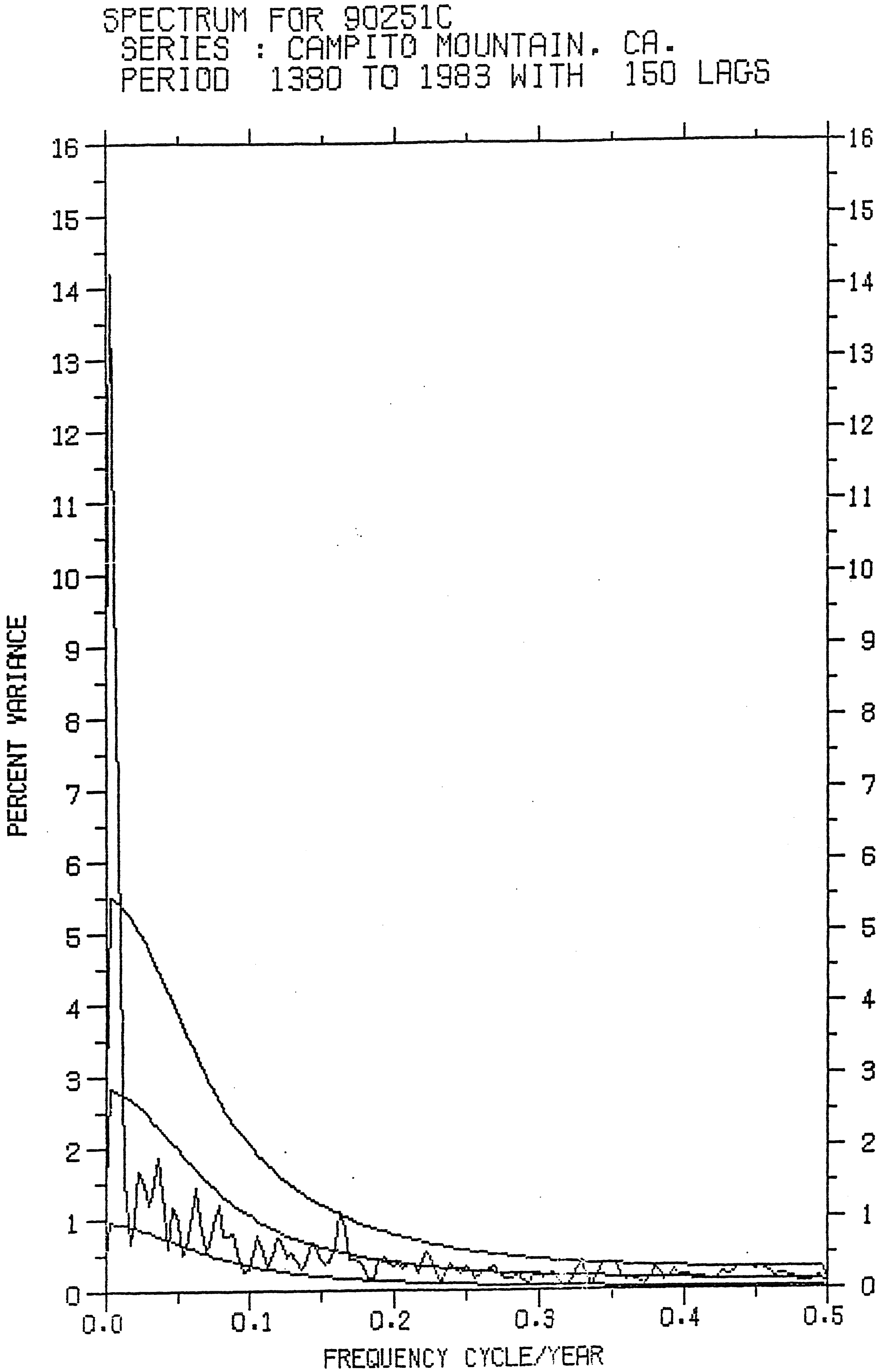
SPECTRUM FOR 90251C
SERIES : CAMPITO MOUNTAIN, CA.
PERIOD 1380 TO 1983 WITH 150 LAGS
PERCENT VARIANCE
FREQUENCY CYCLE/YEAR
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0.0 0.1 0.2 0.3 0.4 0.5

SITE AND CHRONOLOGY INFORMATION

Site name *San Francisco Peaks*

State *Arizona* County *Coconino*

Latitude *35° 20'* Longitude *111° 40'* Altitude *3535 m*

Collectors *D. A. Graybill, M. R. Rose, 1984*

Species collected *Pinus aristata*

Associated arboreal species *Picea engelmanii*

Parent mineral of soil *Misc. volcanics*

Slope direction *Southeast to southwest*

Slope angle *45°-75°*

COMMON PERIOD CHRONOLOGY STATISTICS FOR ID 86451T

INTERVAL	1660-1978	N. OF TREES	16	N. OF RADII	19
MEDIAN	1.008	MEAN	1.014	STD. DEV.	.195
SKEWNESS	.325	KURTOSIS	3.463	MEAN SENS.	.114

AUTOCORRELATION TO LAG 10

LAG	1	2	3	4	5	6	7	8	9	10
VALUE	.744	.594	.489	.400	.301	.233	.165	.109	.067	.035

CORRELATION ANALYSIS

	MEAN R	95 PCT LIMITS		N
AMONG ALL RADII	.290	.186	.388	171
BETWEEN TREES	.281	.177	.379	168
WITHIN TREES	.695	.633	.748	3
RADII VS MEAN	.560	.480	.631	19

SIGNAL TO NOISE RATIO 6.250

VARIANCE AGREEMENT BETWEEN FULLY REPLICATED CHRONOLOGY
OF ONE RADIUS PER TREE AND REDUCED SAMPLE SIZE CHRONOLOGY

N. OF TREES	1	2	3	4	5	6	7	8	9	10
VARIANCE	.326	.509	.626	.707	.767	.813	.849	.879	.903	.924
N. OF TREES	11	12	13	14	15	16	17	18	19	20
VARIANCE	.941	.956	.969	.981	.999	1.000				

FULL CHRONOLOGY STATISTICS FOR ID 86451T

INTERVAL	548-1983	N. OF TREES	24	N. OF RADII	32
MEDIAN	1.004	MEAN	1.001	STD. DEV.	.221
SKEWNESS	.169	KURTOSIS	3.664	MEAN SENS.	.126

AUTOCORRELATION TO LAG 10

LAG	1	2	3	4	5	6	7	8	9	10
VALUE	.721	.611	.576	.543	.491	.432	.375	.354	.324	.304

AVERAGE R OF RADII WITH MEAN OF ALL OTHERS .503

TIME SERIES MODEL FOR A.D. 1380 - 1859

MODEL SELECTED ARMA(1,1)

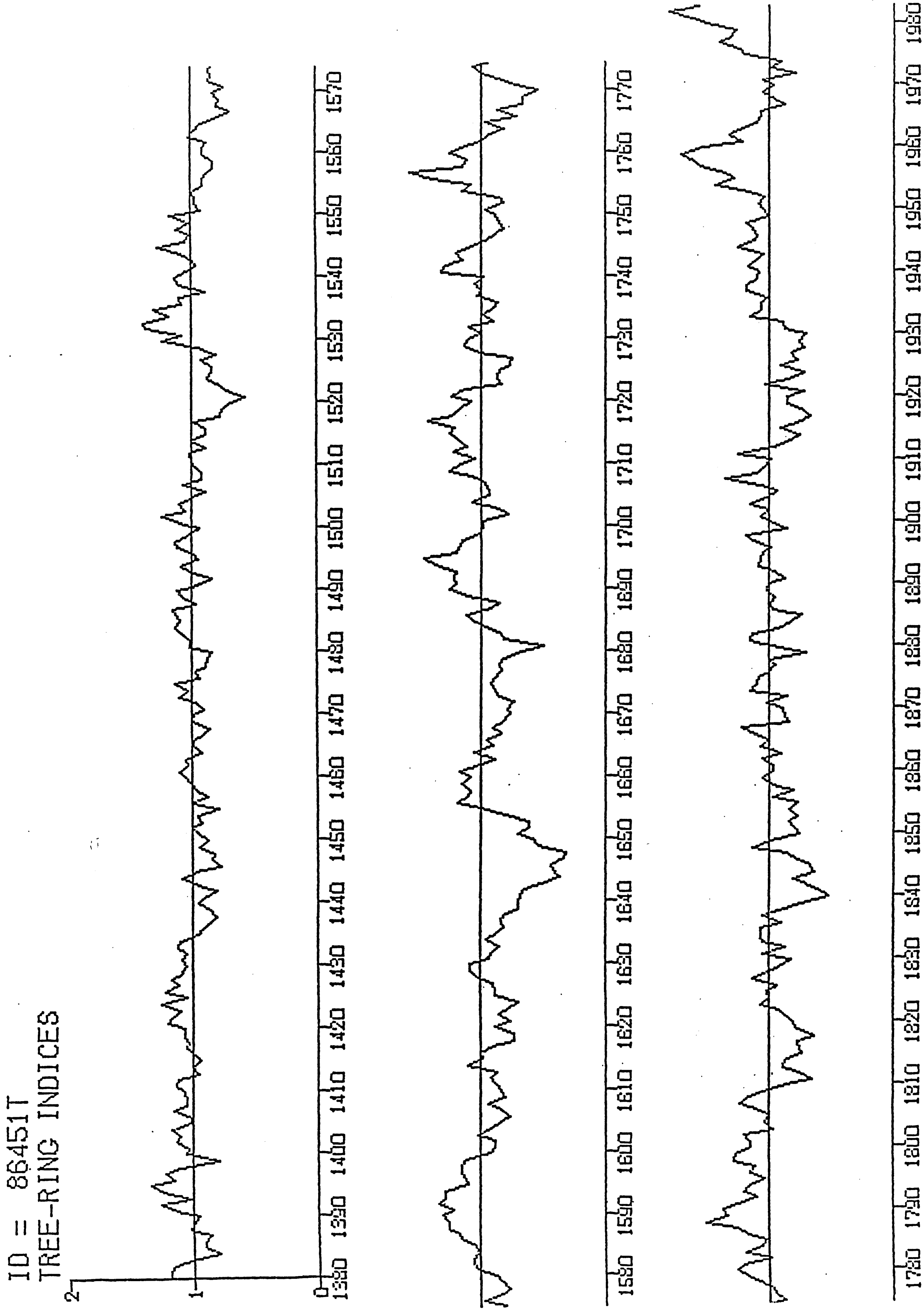
PARAMETERS	TYPE	ORDER	VALUE	95 PCT LIMITS	
	AR	1	.8401	.7775	.9027
	MA	1	.1415	.0273	.2557

RESIDUAL SUM OF SQUARES	6.056924	RESIDUAL MEAN SQUARE	.01269
DEGREES OF FREEDOM	477	RESIDUAL STANDARD ERROR	.1127
INDEX OF DETERMINATION	62.73	AKAIKE INFO. CRITER.	868.58
Q STATISTIC, 20 LAGS	14.00	CHI-SQ.,5 PCT, 19 D.F.	30.14

MAJOR COMPETING MODEL AR(2)

PARAMETERS	TYPE	ORDER	VALUE	95 PCT LIMITS	
	AR	1	.7033	.6123	.7943
	AR	2	.1081	.0173	.1989

RESIDUAL SUM OF SQUARES	6.057278	RESIDUAL MEAN SQUARE	.01272
DEGREES OF FREEDOM	476	RESIDUAL STANDARD ERROR	.1128
INDEX OF DETERMINATION	62.73	AKAIKE INFO. CRITER.	868.61
Q STATISTIC, 20 LAGS	14.00	CHI-SQ.,5 PCT, 19 D.F.	30.14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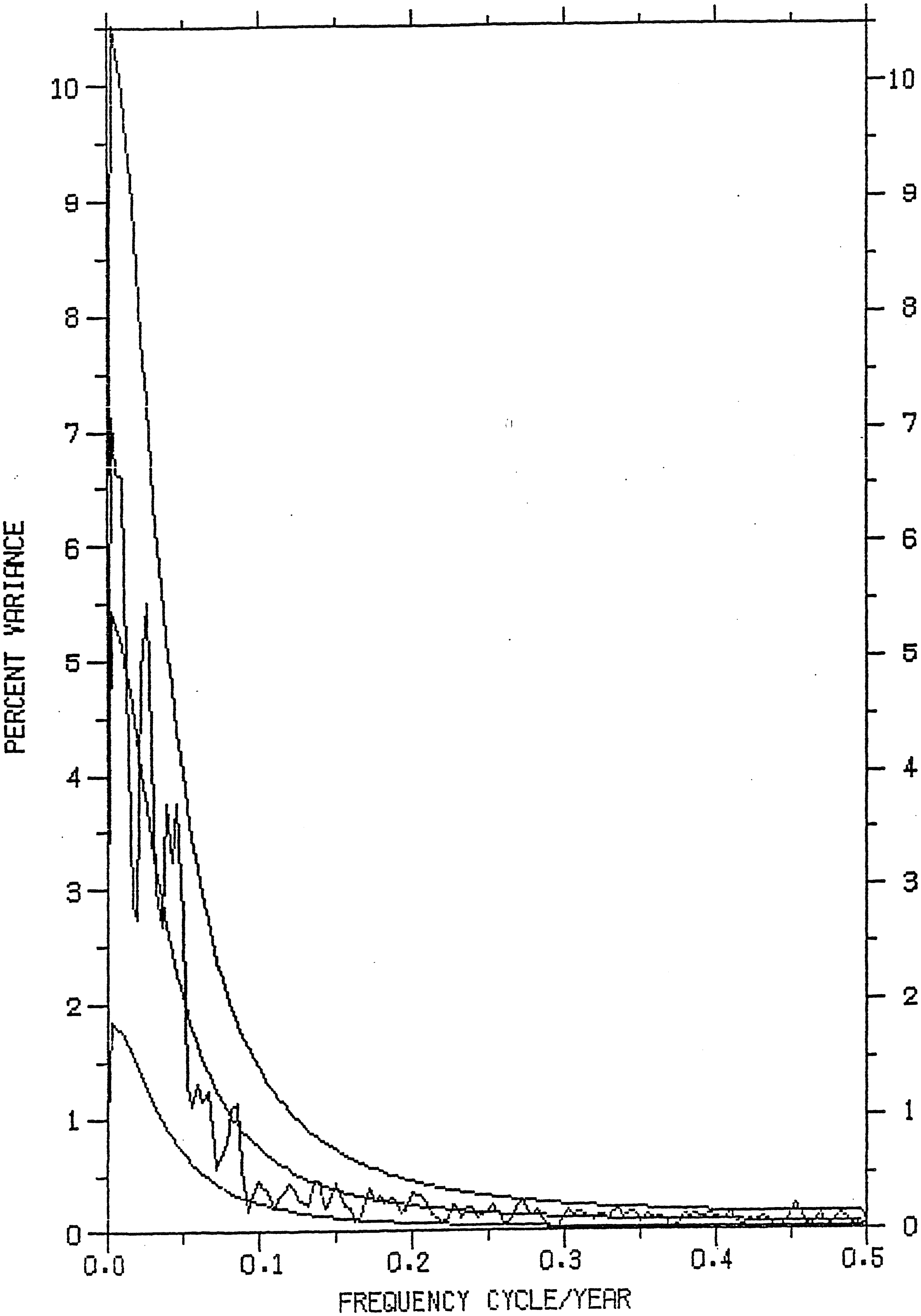
1780 1790 1800 1810 1820 1830 1840 1850 1860 1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980

SPECTRUM FOR 86451T
SERIES : SAN FRANCISCO PEAKS, AZ.
PERIOD 1380 TO 1983 WITH 150 LAGS



SITE AND CHRONOLOGY INFORMATION

Site name *Hermit Lake*

State *Colorado* County *Custer*

Latitude *38° 06'* Longitude *105° 38'* Altitude *3660 m*

Collectors *D. A. Graybill, C. W. Shaw, Wu Xiang-ding, 1984*
V. C. LaMarche, T. P. Harlan, 1969

Species collected *Pinus aristata*

Associated arboreal species *Picea engelmanii*

Parent mineral of soil *Sandstone*

Slope direction *South*

Slope angle *25°-40°*

COMMON PERIOD CHRONOLOGY STATISTICS FOR ID 64151C

INTERVAL	1660-1978	N. OF TREES	20	N. OF RADII	21
MEDIAN	.998	MEAN	1.005	STD. DEV.	.267
SKEWNESS	-.229	KURTOSIS	3.416	MEAN SENS.	.144

AUTOCORRELATION TO LAG 10

LAG	1	2	3	4	5	6	7	8	9	10
VALUE	.783	.729	.676	.650	.582	.575	.558	.525	.466	.428

CORRELATION ANALYSIS

	MEAN R	95 PCT LIMITS		N
AMONG ALL RADII	.322	.220	.417	210
BETWEEN TREES	.322	.220	.417	209
WITHIN TREES	.280	.175	.378	1
RADII VS MEAN	.585	.508	.653	21

SIGNAL TO NOISE RATIO 9.492

VARIANCE AGREEMENT BETWEEN FULLY REPLICATED CHRONOLOGY
OF ONE RADIUS PER TREE AND REDUCED SAMPLE SIZE CHRONOLOGY

N. OF TREES	1	2	3	4	5	6	7	8	9	10
VARIANCE	.356	.538	.649	.724	.778	.818	.850	.875	.896	.913
N. OF TREES	11	12	13	14	15	16	17	18	19	20
VARIANCE	.928	.940	.951	.961	.969	.977	.983	.990	.995	1.000

FULL CHRONOLOGY STATISTICS FOR ID 64151C

INTERVAL	1035-1983	N. OF TREES	26	N. OF RADII	33
MEDIAN	.979	MEAN	.987	STD. DEV.	.233
SKEWNESS	.060	KURTOSIS	3.732	MEAN SENS.	.129

AUTOCORRELATION TO LAG 10

LAG	1	2	3	4	5	6	7	8	9	10
VALUE	.767	.672	.619	.558	.491	.471	.431	.381	.335	.304

AVERAGE R OF RADII WITH MEAN OF ALL OTHERS .480

TIME SERIES MODEL FOR A.D. 1380 - 1859

MODEL SELECTED ARMA(1,1)

PARAMETERS	TYPE	ORDER	VALUE	95 PCT LIMITS	
	AR	1	.8937	.8413	.9461
	MA	1	.3671	.2587	.4755

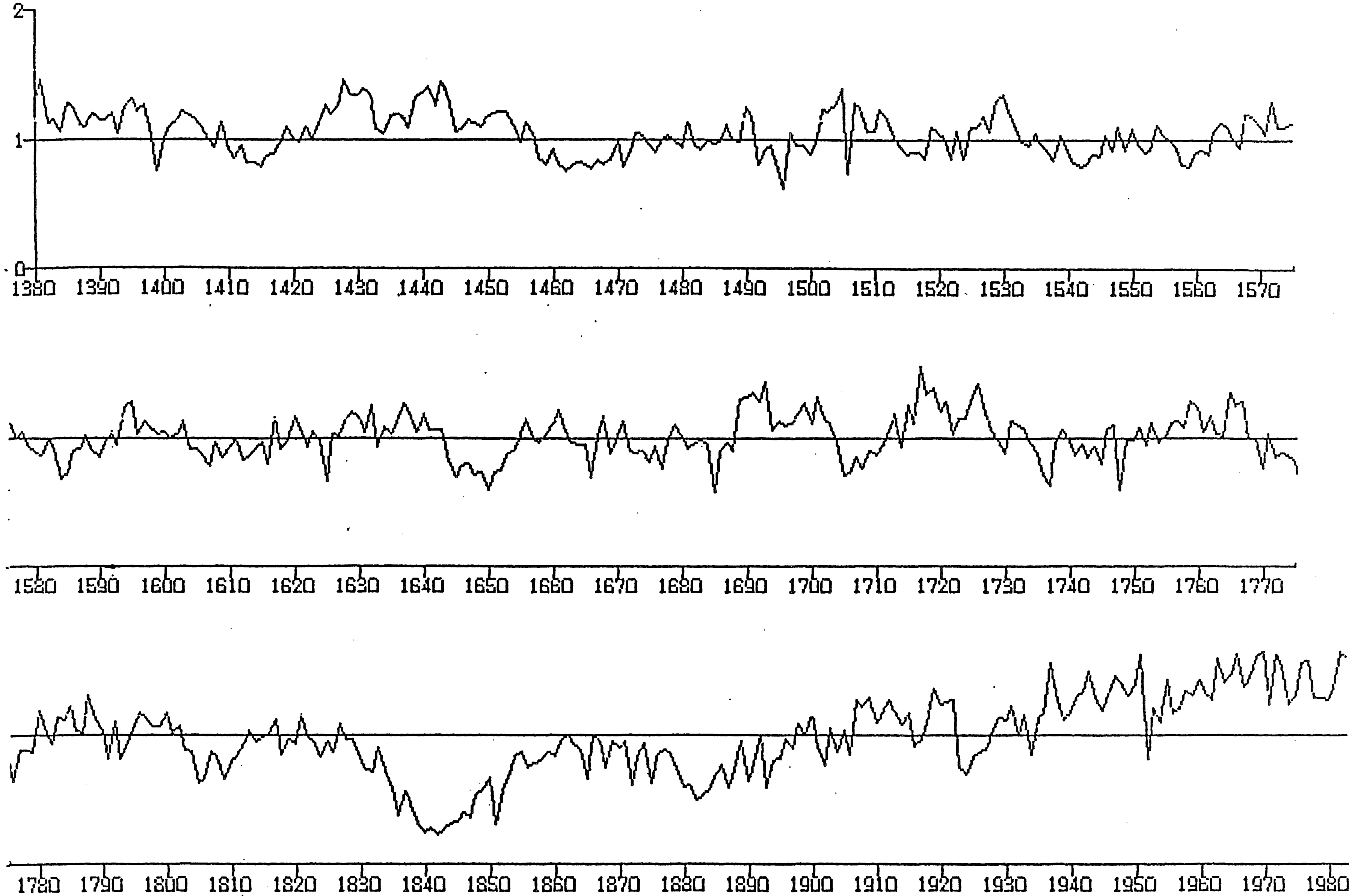
RESIDUAL SUM OF SQUARES	8.519456	RESIDUAL MEAN SQUARE	.017860
DEGREES OF FREEDOM	477	RESIDUAL STANDARD ERROR	.1336
INDEX OF DETERMINATION	58.17	AKAIKE INFO. CRITER.	1032.33
Q STATISTIC, 20 LAGS	23.00	CHI-SQ.,5 PCT, 19 D.F.	30.14

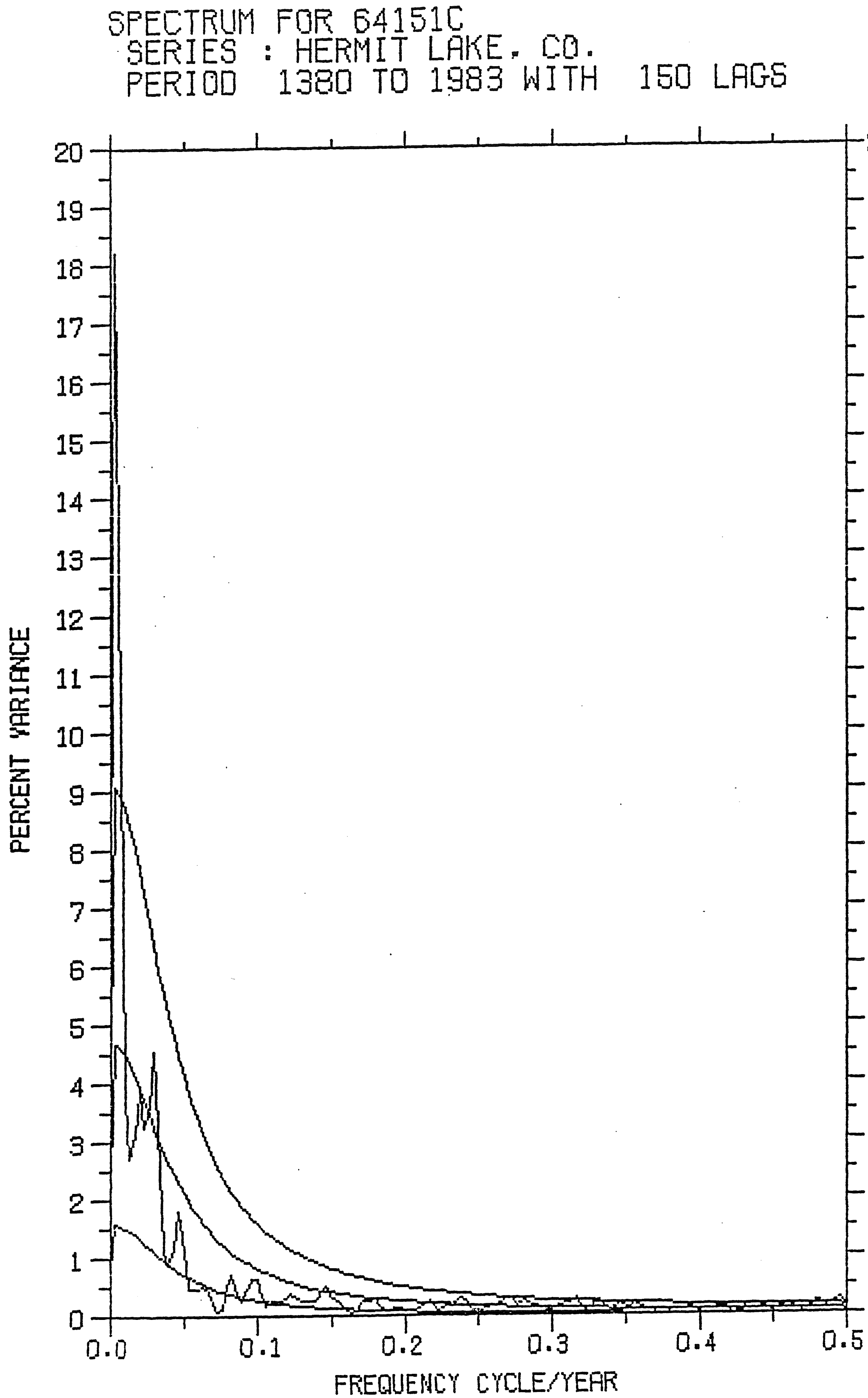
MAJOR COMPETING MODEL AR(3)

PARAMETERS	TYPE	ORDER	VALUE	95 PCT LIMITS	
	AR	1	.5309	.4405	.6213
	AR	2	.1737	.0731	.2743
	AR	3	.1276	.0380	.2172

RESIDUAL SUM OF SQUARES	8.382533	RESIDUAL MEAN SQUARE	.017685
DEGREES OF FREEDOM	474	RESIDUAL STANDARD ERROR	.1330
INDEX OF DETERMINATION	58.85	AKAIKE INFO. CRITER.	1026.55
Q STATISTIC, 20 LAGS	24.00	CHI-SQ.,5 PCT, 19 D.F.	30.14

ID = 64151C
TREE-RING INDICES





SPECTRUM FOR 64151C
SERIES : HERMIT LAKE, CO.
PERIOD 1380 TO 1983 WITH 150 LAGS
PERCENT VARIANCE
FREQUENCY CYCLE/YEAR
0.0
0.1
0.2
0.3
0.4
0.5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

SITE AND CHRONOLOGY INFORMATION

Site name *Almagre Mountain*

State *Colorado* County *Teller*

Latitude *38° 46'* Longitude *104° 59'* Altitude *3535 m*

Collectors *D. A. Graybill, C. Shaw, Wu Xiang-ding, 1984*
V. C. LaMarche, T. P. Harlan, 1969

Species collected *Pinus aristata*

Associated arboreal species *Picea engelmanii*

Parent mineral of soil *Granite*

Slope direction *Northwest to Northeast*

Slope angle *15°-45°*

COMMON PERIOD CHRONOLOGY STATISTICS FOR ID 64251C

INTERVAL	1660-1978	N. OF TREES	17	N. OF RADII	19
MEDIAN	1.016	MEAN	1.029	STD. DEV.	.287
SKEWNESS	-.216	KURTOSIS	2.985	MEAN SENS.	.134

AUTOCORRELATION TO LAG 10

LAG	1	2	3	4	5	6	7	8	9	10
VALUE	.827	.784	.702	.644	.582	.534	.504	.477	.453	.439

CORRELATION ANALYSIS

	MEAN R	95 PCT LIMITS		N
AMONG ALL RADII	.406	.311	.494	171
BETWEEN TREES	.400	.304	.489	169
WITHIN TREES	.782	.735	.821	2
RADII VS MEAN	.643	.574	.703	19

SIGNAL TO NOISE RATIO 11.350

VARIANCE AGREEMENT BETWEEN FULLY REPLICATED CHRONOLOGY
OF ONE RADIUS PER TREE AND REDUCED SAMPLE SIZE CHRONOLOGY

N. OF TREES	1	2	3	4	5	6	7	8	9	10
VARIANCE	.436	.622	.726	.792	.837	.871	.896	.917	.933	.946
N. OF TREES	11	12	13	14	15	16	17	18	19	20
VARIANCE	.958	.967	.976	.983	.989	.995	1.000			

FULL CHRONOLOGY STATISTICS FOR ID 64251C

INTERVAL	560-1983	N. OF TREES	27	N. OF RADII	36
MEDIAN	.969	MEAN	.985	STD. DEV.	.233
SKEWNESS	.225	KURTOSIS	3.478	MEAN SENS.	.147

AUTOCORRELATION TO LAG 10

LAG	1	2	3	4	5	6	7	8	9	10
VALUE	.688	.580	.522	.473	.447	.419	.381	.363	.330	.320

AVERAGE R OF RADII WITH MEAN OF ALL OTHERS .522

TIME SERIES MODEL FOR A.D. 1380 - 1859

MODEL SELECTED AR(2)

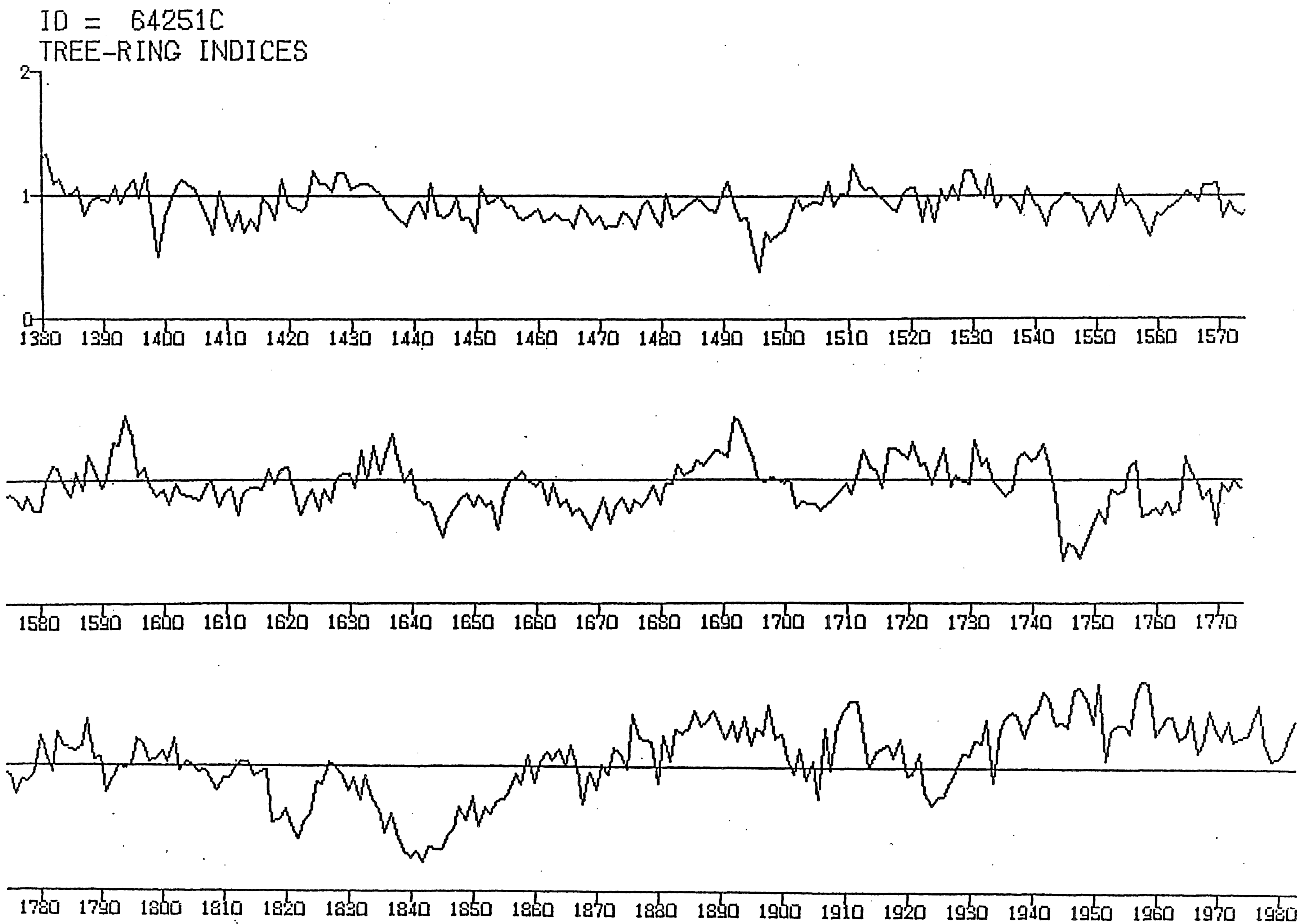
PARAMETERS	TYPE	ORDER	VALUE	95 PCT LIMITS	
	AR	1	.5837	.4945	.6729
	AR	2	.2133	.1249	.3017

RESIDUAL SUM OF SQUARES	8.012175	RESIDUAL MEAN SQUARE	.016832
DEGREES OF FREEDOM	476	RESIDUAL STANDARD ERROR	.1297
INDEX OF DETERMINATION	57.42	AKAIKE INFO. CRITER.	1002.86
Q STATISTIC, 20 LAGS	17.00	CHI-SQ.,5 PCT, 19 D.F.	30.14

MAJOR COMPETING MODEL ARMA(1,1)

PARAMETERS	TYPE	ORDER	VALUE	95 PCT LIMITS	
	AR	1	.8503	.7873	.9133
	MA	1	.2546	.1390	.3702

RESIDUAL SUM OF SQUARES	8.064549	RESIDUAL MEAN SQUARE	.016907
DEGREES OF FREEDOM	477	RESIDUAL STANDARD ERROR	.1300
INDEX OF DETERMINATION	57.14	AKAIKE INFO. CRITER.	1005.99
Q STATISTIC, 20 LAGS	19.00	CHI-SQ.,5 PCT, 19 D.F.	30.14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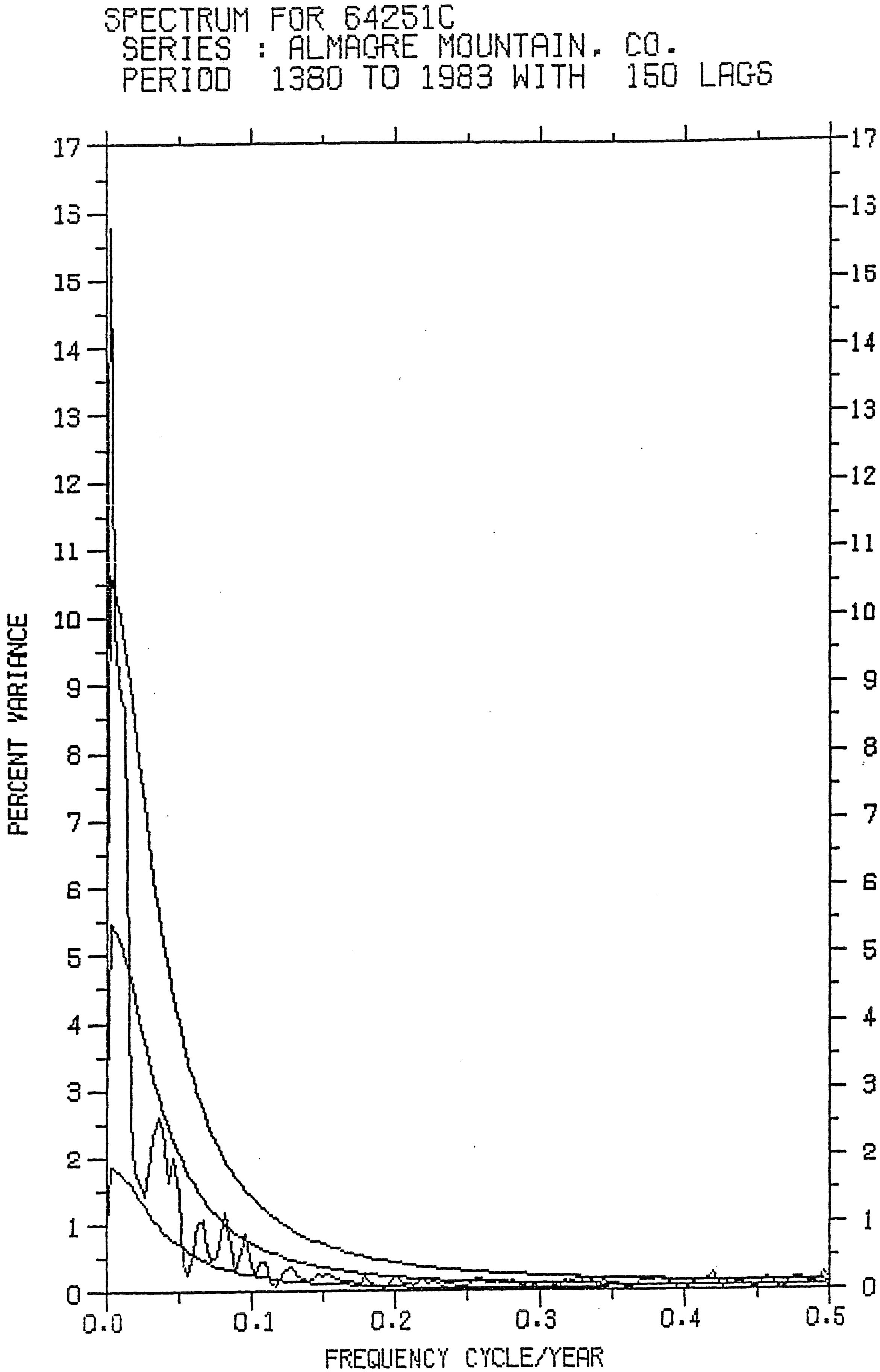

SPECTRUM FOR 64251C
SERIES : ALMAGRE MOUNTAIN, CO.
PERIOD 1380 TO 1983 WITH 150 LAGS
PERCENT VARIANCE
FREQUENCY CYCLE/YEAR
0.0
0.1
0.2
0.3
0.4
0.5

SITE AND CHRONOLOGY INFORMATION

Site name *Mount Goliath*

State *Colorado* County *Clear Creek*

Latitude *39° 38'* Longitude *105° 35'* Altitude *3535 m*

Collectors *D. A. Graybill, C. W. Shaw, Wu Xiang-ding, 1984*
V. C. LaMarche, T. P. Harlan, 1969

Species collected *Pinus aristata*

Associated arboreal species *Picea engelmanii*

Parent mineral of soil *Granite*

Slope direction *South*

Slope angle *20°-30°*

COMMON PERIOD CHRONOLOGY STATISTICS FOR ID 64351C

INTERVAL	1660-1978	N. OF TREES	21	N. OF RADII	25
MEDIAN	1.075	MEAN	1.064	STD. DEV.	.210
SKEWNESS	-.061	KURTOSIS	3.198	MEAN SENS.	.137

AUTOCORRELATION TO LAG 10

LAG	1	2	3	4	5	6	7	8	9	10
VALUE	.630	.597	.536	.503	.440	.393	.338	.269	.234	.188

CORRELATION ANALYSIS

	MEAN R	95 PCT LIMITS		N
AMONG ALL RADII	.306	.203	.402	300
BETWEEN TREES	.299	.195	.396	295
WITHIN TREES	.657	.589	.715	5
RADII VS MEAN	.573	.495	.643	25

SIGNAL TO NOISE RATIO 8.951

VARIANCE AGREEMENT BETWEEN FULLY REPLICATED CHRONOLOGY
OF ONE RADIUS PER TREE AND REDUCED SAMPLE SIZE CHRONOLOGY

N. OF TREES	1	2	3	4	5	6	7	8	9	10
VARIANCE	.332	.512	.624	.701	.757	.799	.833	.860	.882	.900
N. OF TREES	11	12	13	14	15	16	17	18	19	20
VARIANCE	.916	.930	.942	.952	.961	.970	.977	.984	.990	.995
N. OF TREES	21	22	23	24	25	26	27	28	29	30
VARIANCE	1.000									

FULL CHRONOLOGY STATISTICS FOR ID 64351C

INTERVAL	587-1983	N. OF TREES	26	N. OF RADII	34
MEDIAN	.944	MEAN	.980	STD. DEV.	.321
SKEWNESS	1.757	KURTOSIS	9.142	MEAN SENS.	.143

AUTOCORRELATION TO LAG 10

LAG	1	2	3	4	5	6	7	8	9	10
VALUE	.835	.789	.752	.721	.696	.673	.644	.633	.610	.580

AVERAGE R OF RADII WITH MEAN OF ALL OTHERS .508

TIME SERIES MODEL FOR A.D. 1380 - 1859

MODEL SELECTED ARMA(1,1)

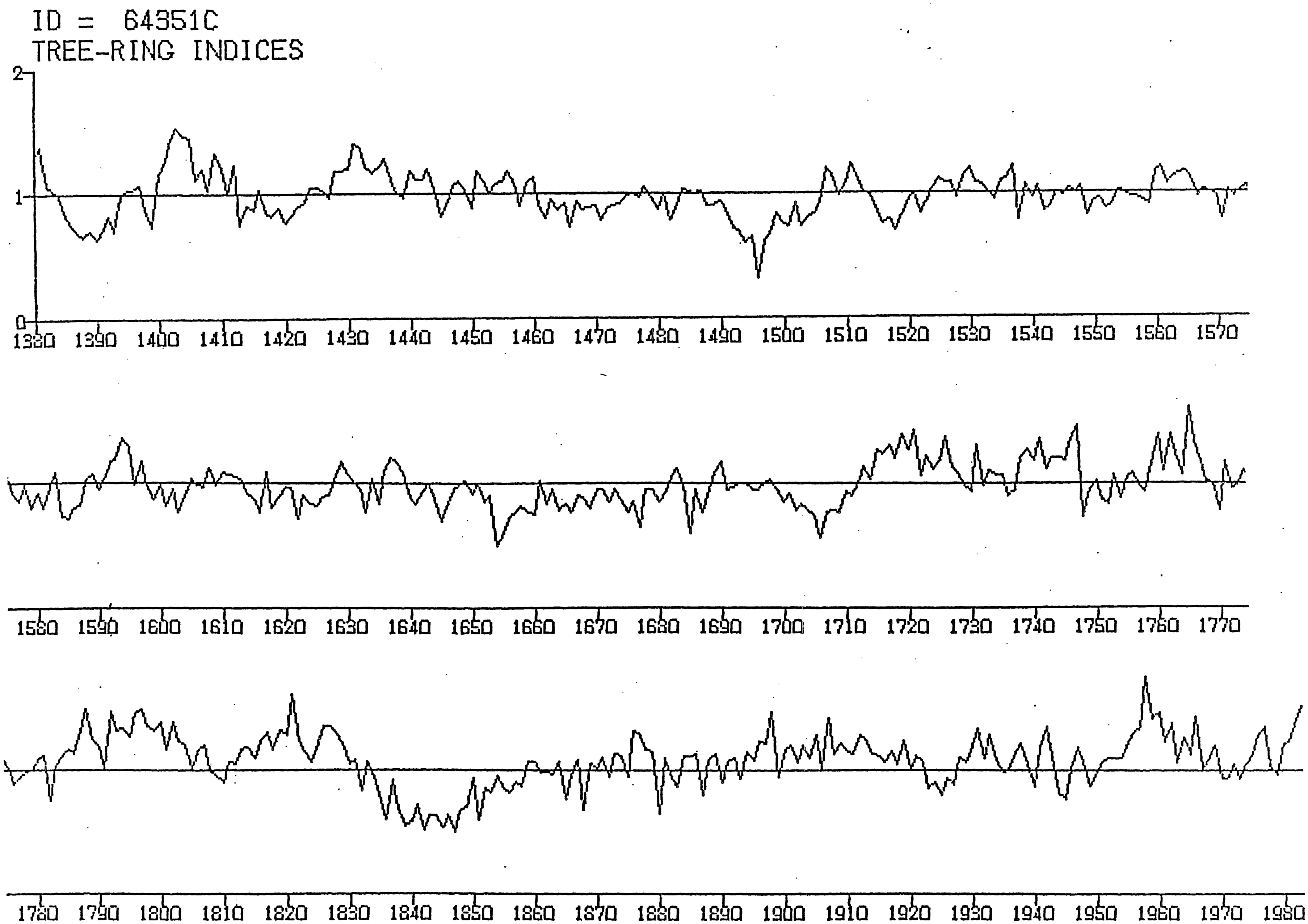
PARAMETERS	TYPE	ORDER	VALUE	95 PCT LIMITS	
	AR	1	.8803	.8229	.9377
	MA	1	.3739	.2617	.4861

RESIDUAL SUM OF SQUARES	8.751729	RESIDUAL MEAN SQUARE	.018347
DEGREES OF FREEDOM	477	RESIDUAL STANDARD ERROR	.1355
INDEX OF DETERMINATION	53.96	AKAIKE INFO. CRITER.	1045.24
Q STATISTIC, 20 LAGS	31.00	CHI-SQ.,5 PCT, 19 D.F.	30.14

MAJOR COMPETING MODEL AR(2)

PARAMETERS	TYPE	ORDER	VALUE	95 PCT LIMITS	
	AR	1	.5214	.4334	.6094
	AR	2	.2631	.1755	.3507

RESIDUAL SUM OF SQUARES	8.771165	RESIDUAL MEAN SQUARE	.018427
DEGREES OF FREEDOM	476	RESIDUAL STANDARD ERROR	.1357
INDEX OF DETERMINATION	53.86	AKAIKE INFO. CRITER.	1046.31
Q STATISTIC, 20 LAGS	36.00	CHI-SQ.,5 PCT, 19 D.F.	30.14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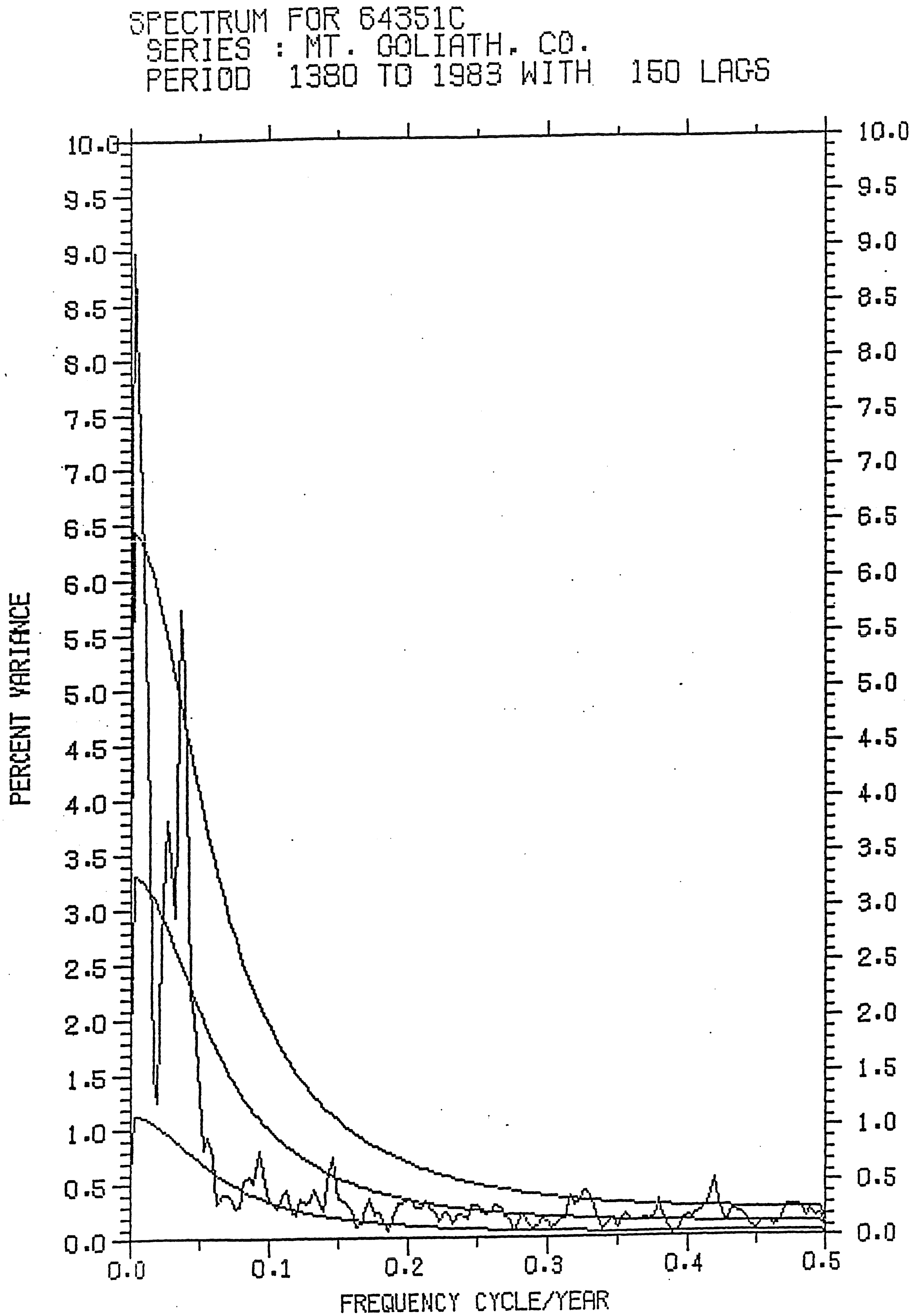


SPECTRUM FOR 64351C
SERIES : MT. GOLIATH. CO.
PERIOD 1380 TO 1983 WITH 150 LAGS
PERCENT VARIANCE
FREQUENCY CYCLE/YEAR
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.1
0.2
0.3
0.4
0.5

SITE AND CHRONOLOGY INFORMATION

Site name *Mammoth Creek*

State *Utah* County *Iron*

Latitude *37° 39'* Longitude *112° 40'* Altitude *2590 m*

Collectors *D. A. Graybill, M. R. Rose, M. S. McCarthy, 1978-1981*

Species collected *Pinus longaeva*

Associated arboreal species *P. ponderosa, P. flexilis, Jun. scopulorum*

Parent mineral of soil *Sandstone, limestone*

Slope direction *South to East*

Slope angle *20°*

COMMON PERIOD CHRONOLOGY STATISTICS FOR ID 993519

INTERVAL	1660-1978	N. OF TREES	17	N. OF RADII	26
MEDIAN	1.079	MEAN	1.042	STD. DEV.	.384
SKEWNESS	-.188	KURTOSIS	2.502	MEAN SENS.	.432

AUTOCORRELATION TO LAG 10

LAG	1	2	3	4	5	6	7	8	9	10
VALUE	.115	.053	.146	.098	.101	.075	.094	.013	.093	.018

CORRELATION ANALYSIS

	MEAN R	95 PCT LIMITS		N
AMONG ALL RADII	.412	.316	.499	325
BETWEEN TREES	.401	.305	.489	313
WITHIN TREES	.651	.583	.710	12
RADII VS MEAN	.658	.591	.716	26

SIGNAL TO NOISE RATIO 11.382

VARIANCE AGREEMENT BETWEEN FULLY REPLICATED CHRONOLOGY
OF ONE RADIUS PER TREE AND REDUCED SAMPLE SIZE CHRONOLOGY

N. OF TREES	1	2	3	4	5	6	7	8	9	10
VARIANCE	.436	.623	.726	.792	.838	.871	.897	.917	.933	.946
N. OF TREES	11	12	13	14	15	16	17	18	19	20
VARIANCE	.958	.967	.976	.983	.989	.995	1.000			

FULL CHRONOLOGY STATISTICS FOR ID 993519

INTERVAL	364-1980	N. OF TREES	20	N. OF RADII	32
MEDIAN	1.016	MEAN	1.005	STD. DEV.	.361
SKEWNESS	.077	KURTOSIS	3.498	MEAN SENS.	.382

AUTOCORRELATION TO LAG 10

LAG	1	2	3	4	5	6	7	8	9	10
VALUE	.262	.218	.211	.198	.118	.162	.159	.126	.131	.122

AVERAGE R OF RADII WITH MEAN OF ALL OTHERS .602

TIME SERIES MODEL FOR A.D. 1380 - 1859

MODEL SELECTED ARMA(1,1)

PARAMETERS	TYPE	ORDER	VALUE	95 PCT LIMITS	
	AR	1	.9277	.8447	1.0107
	MA	1	.8249	.7025	.9473

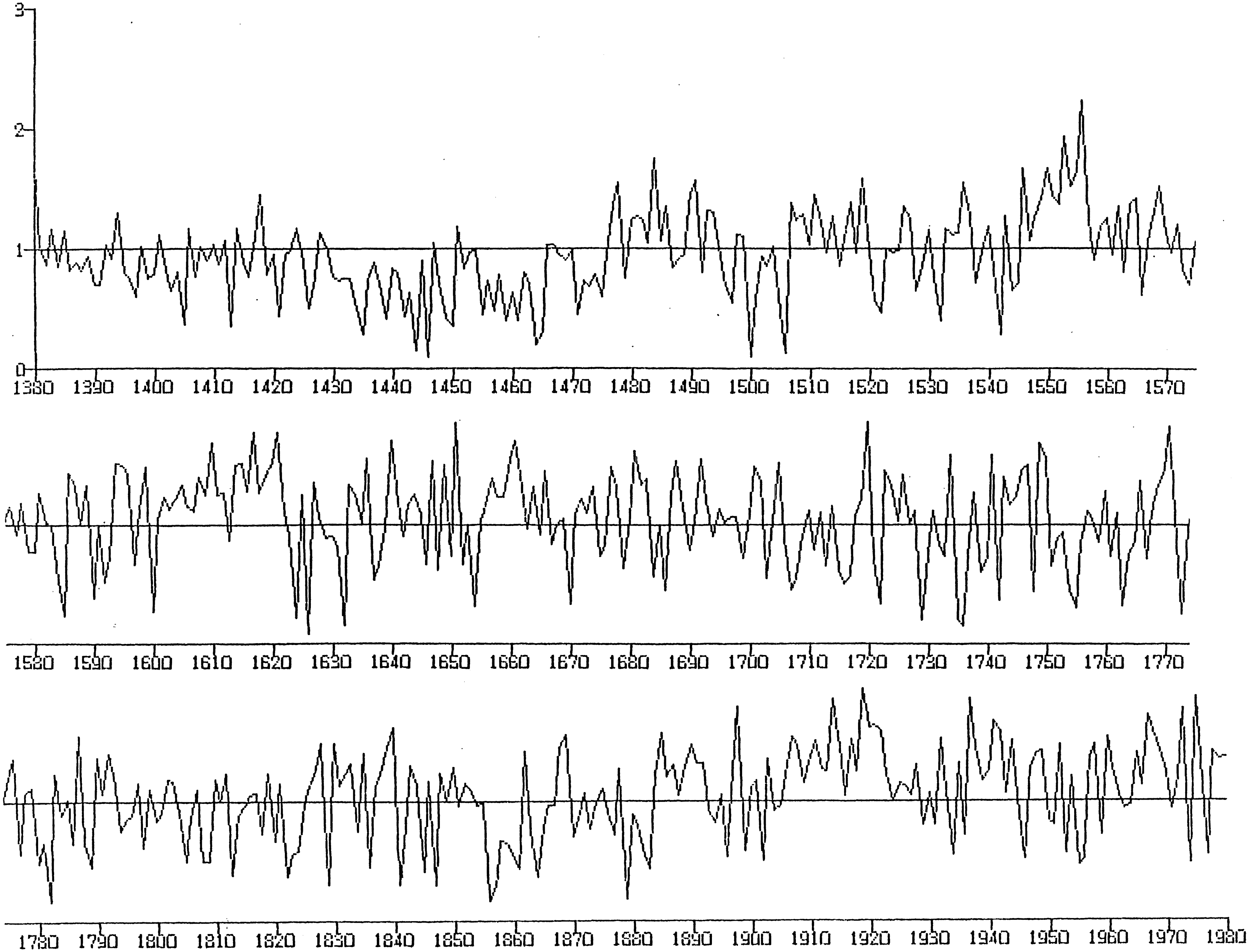
RESIDUAL SUM OF SQUARES	62.089949	RESIDUAL MEAN SQUARE	.130166
DEGREES OF FREEDOM	477	RESIDUAL STANDARD ERROR	.3608
INDEX OF DETERMINATION	8.01	AKAIKE INFO. CRITER.	1985.72
Q STATISTIC, 20 LAGS	12.00	CHI-SQ.,5 PCT, 19 D.F.	30.14

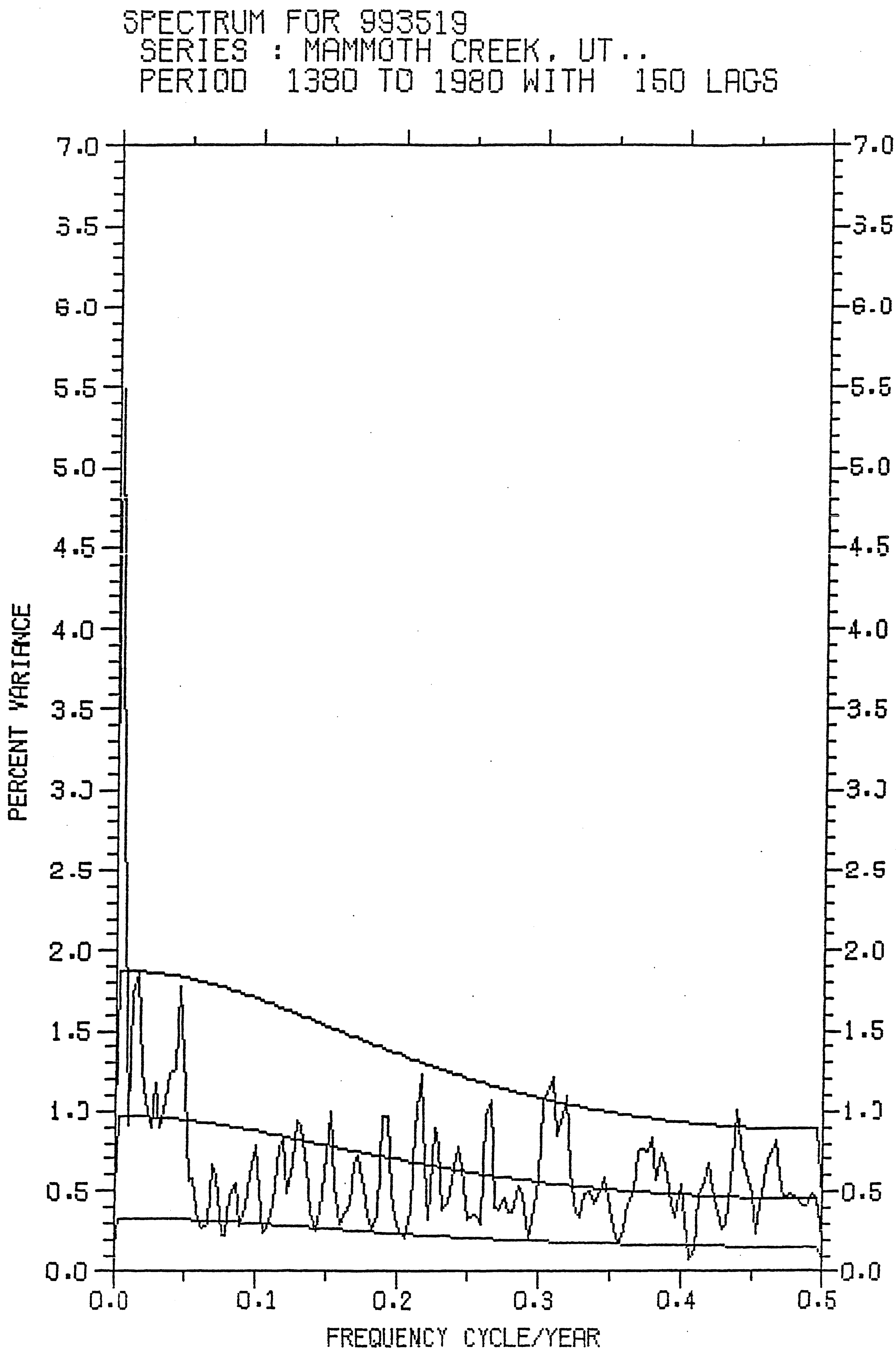
MAJOR COMPETING MODEL AR(2)

PARAMETERS	TYPE	ORDER	VALUE	95 PCT LIMITS	
	AR	1	.1516	.0612	.2420
	AR	2	.1021	.0115	.1927

RESIDUAL SUM OF SQUARES	64.131777	RESIDUAL MEAN SQUARE	.134731
DEGREES OF FREEDOM	476	RESIDUAL STANDARD ERROR	.3671
INDEX OF DETERMINATION	4.99	AKAIKE INFO. CRITER.	2001.25
Q STATISTIC, 20 LAGS	31.00	CHI-SQ.,5 PCT, 19 D.F.	30.14

ID = 993519
TREE-RING INDICES




SPECTRUM FOR 993519
SERIES : MAMMOTH CREEK, UT..
PERIOD 1380 TO 1980 WITH 150 LAGS
PERCENT VARIANCE
FREQUENCY CYCLE/YEAR
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
0.1
0.2
0.3
0.4

SITE AND CHRONOLOGY INFORMATION

Site name *Indian Garden*

State *Nevada* County *White Pine*

Latitude *39° 5'* Longitude *115° 26'* Altitude *2805 m*

Collectors *D. A. Graybill, M. S. McCarthy, R. N. Ahlstrom, B. J. Davis-Ortiz C. W. Ferguson, 1981*

Species collected *Pinus longaeva*

Associated arboreal species *Pinus flexilis*

Parent mineral of soil *Limestone*

Slope direction *East, West*

Slope angle *30°-40°*

COMMON PERIOD CHRONOLOGY STATISTICS FOR ID 28751L

INTERVAL	1660-1978	N. OF TREES	15	N. OF RADII	23
MEDIAN	.964	MEAN	1.007	STD. DEV.	.312
SKEWNESS	.549	KURTOSIS	3.518	MEAN SENS.	.291

AUTOCORRELATION TO LAG 10

LAG	1	2	3	4	5	6	7	8	9	10
VALUE	.373	.180	.148	.119	.098	.172	.099	.013	-.011	.040

CORRELATION ANALYSIS

	MEAN R	95 PCT LIMITS		N
AMONG ALL RADII	.335	.234	.429	253
BETWEEN TREES	.331	.230	.425	244
WITHIN TREES	.445	.352	.529	9
RADII VS MEAN	.603	.528	.669	23

SIGNAL TO NOISE RATIO 7.426

VARIANCE AGREEMENT BETWEEN FULLY REPLICATED CHRONOLOGY
OF ONE RADIUS PER TREE AND REDUCED SAMPLE SIZE CHRONOLOGY

N. OF TREES	1	2	3	4	5	6	7	8	9	10
VARIANCE	.376	.565	.678	.754	.808	.849	.881	.906	.927	.944

N. OF TREES	11	12	13	14	15	16	17	18	19	20
VARIANCE	.959	.971	.982	.992	1.000					

FULL CHRONOLOGY STATISTICS FOR ID 28751L

INTERVAL	1380-1980	N. OF TREES	25	N. OF RADII	37
MEDIAN	.943	MEAN	.991	STD. DEV.	.316
SKEWNESS	.501	KURTOSIS	3.427	MEAN SENS.	.266

AUTOCORRELATION TO LAG 10

LAG	1	2	3	4	5	6	7	8	9	10
VALUE	.418	.238	.233	.250	.200	.177	.139	.060	.034	.069

AVERAGE R OF RADII WITH MEAN OF ALL OTHERS .555

TIME SERIES MODEL FOR A.D. 1380 - 1859

MODEL SELECTED ARMA(1,1)

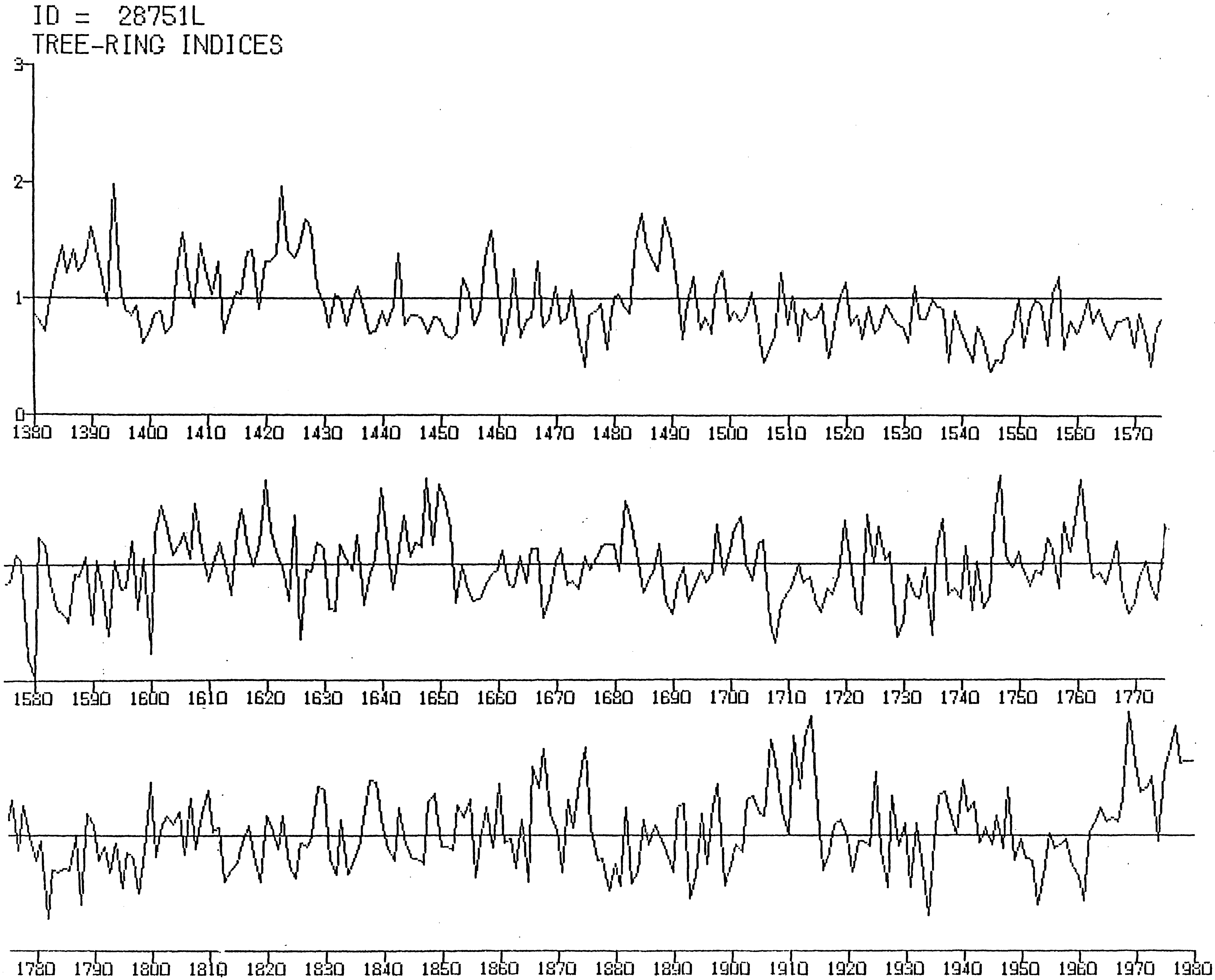
PARAMETERS	TYPE	ORDER	VALUE	95 PCT LIMITS	
	AR	1	.7839	.6545	.9133
	MA	1	.5115	.3341	.6889

RESIDUAL SUM OF SQUARES	35.042188	RESIDUAL MEAN SQUARE	.073464
DEGREES OF FREEDOM	477	RESIDUAL STANDARD ERROR	.2710
INDEX OF DETERMINATION	16.11	AKAIKE INFO. CRITER.	1711.15
Q STATISTIC, 20 LAGS	33.00	CHI-SQ.,5 PCT, 19 D.F.	30.14

MAJOR COMPETING MODEL AR(1)

PARAMETERS	TYPE	ORDER	VALUE	95 PCT LIMITS	
	AR	1	.3887	.3045	.4729

RESIDUAL SUM OF SQUARES	35.469578	RESIDUAL MEAN SQUARE	.074204
DEGREES OF FREEDOM	478	RESIDUAL STANDARD ERROR	.2724
INDEX OF DETERMINATION	15.09	AKAIKE INFO. CRITER.	1714.96
Q STATISTIC, 20 LAGS	34.00	CHI-SQ.,5 PCT, 19 D.F.	30.14



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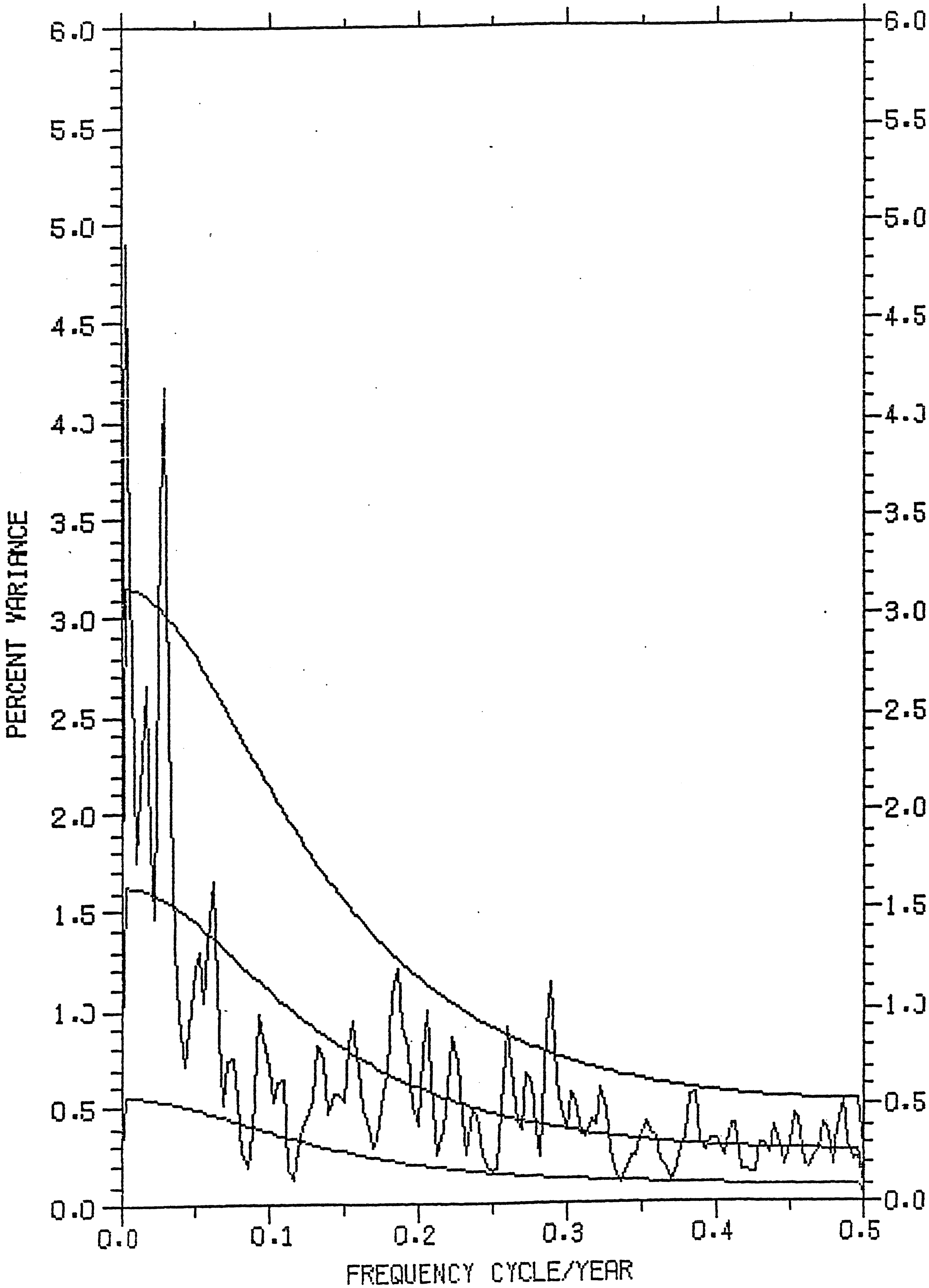
1780 1790 1800 1810 1820 1830 1840 1850 1860 1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980

SPECTRUM FOR 28751L
SERIES : INDIAN GARDEN, NEV.
PERIOD 1380 TO 1980 WITH 150 LAGS



SITE AND CHRONOLOGY INFORMATION

Site name *Methuselah Walk*

State *California* County *Inyo*

Latitude *37° 26'* Longitude *118° 10'* Altitude *2900 m*

Collectors *D. A. Graybill, 1978-1981*

Species collected *Pinus longaeva*

Associated arboreal species *Pinus flexilis*

Parent mineral of soil *Dolomite*

Slope direction *West to northwest*

Slope angle *20°-30°*

COMMON PERIOD CHRONOLOGY STATISTICS FOR ID 99651L

INTERVAL	1660-1978	N. OF TREES	25	N. OF RADII	30
MEDIAN	1.024	MEAN	1.007	STD. DEV.	.259
SKEWNESS	-.618	KURTOSIS	3.546	MEAN SENS.	.271

AUTOCORRELATION TO LAG 10

LAG	1	2	3	4	5	6	7	8	9	10
VALUE	.222	.231	.065	.086	.112	.088	.026	-.041	-.052	-.019

CORRELATION ANALYSIS

	MEAN R	95 PCT LIMITS		N
AMONG ALL RADII	.354	.254	.447	435
BETWEEN TREES	.352	.251	.444	430
WITHIN TREES	.565	.485	.635	5
RADII VS MEAN	.619	.546	.682	30

SIGNAL TO NOISE RATIO 13.556

VARIANCE AGREEMENT BETWEEN FULLY REPLICATED CHRONOLOGY
OF ONE RADIUS PER TREE AND REDUCED SAMPLE SIZE CHRONOLOGY

N. OF TREES	1	2	3	4	5	6	7	8	9	10
VARIANCE	.378	.559	.665	.735	.784	.821	.850	.873	.891	.907
N. OF TREES	11	12	13	14	15	16	17	18	19	20
VARIANCE	.920	.931	.940	.949	.956	.963	.969	.974	.979	.983
N. OF TREES	21	22	23	24	25	26	27	28	29	30
VARIANCE	.987	.991	.994	.997	1.000					

FULL CHRONOLOGY STATISTICS FOR ID 99651L

INTERVAL	1380-1980	N. OF TREES	25	N. OF RADII	30
MEDIAN	1.047	MEAN	1.026	STD. DEV.	.264
SKEWNESS	-.581	KURTOSIS	3.733	MEAN SENS.	.272

AUTOCORRELATION TO LAG 10

LAG	1	2	3	4	5	6	7	8	9	10
VALUE	.219	.185	.112	.078	.120	.072	.048	.021	-.017	-.014

AVERAGE R OF RADII WITH MEAN OF ALL OTHERS .575

TIME SERIES MODEL FOR A.D. 1380 - 1859

MODEL SELECTED ARMA(1,1)

PARAMETERS	TYPE	ORDER	VALUE	95 PCT LIMITS	
	AR	1	.7010	.4706	.9314
	MA	1	.5121	.2369	.7873

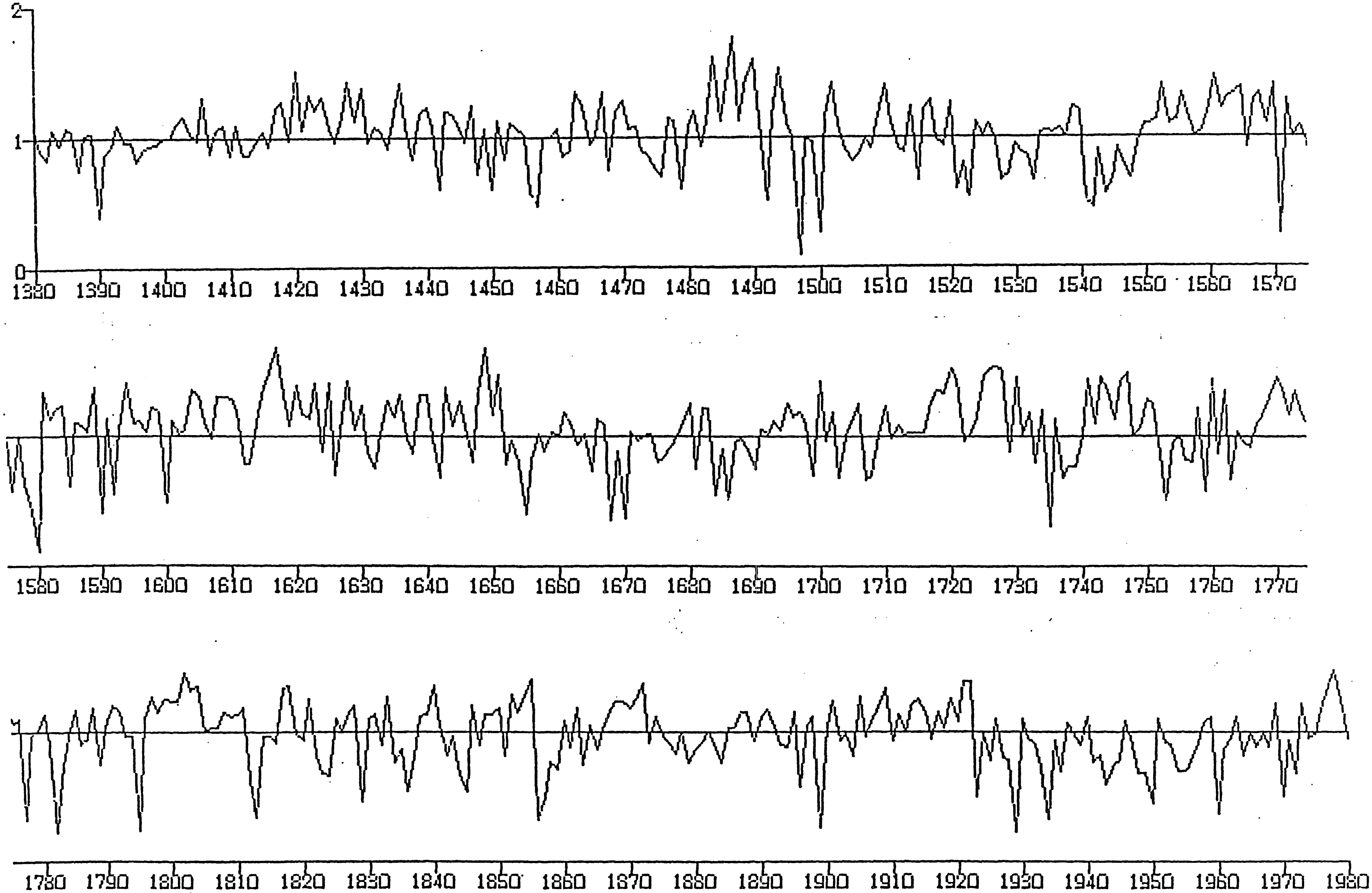
RESIDUAL SUM OF SQUARES	32.635521	RESIDUAL MEAN SQUARE	.068418
DEGREES OF FREEDOM	477	RESIDUAL STANDARD ERROR	.2616
INDEX OF DETERMINATION	6.73	AKAIKE INFO. CRITER.	1676.99
Q STATISTIC, 20 LAGS	6.80	CHI-SQ.,5 PCT, 19 D.F.	30.14

MAJOR COMPETING MODEL AR(2)

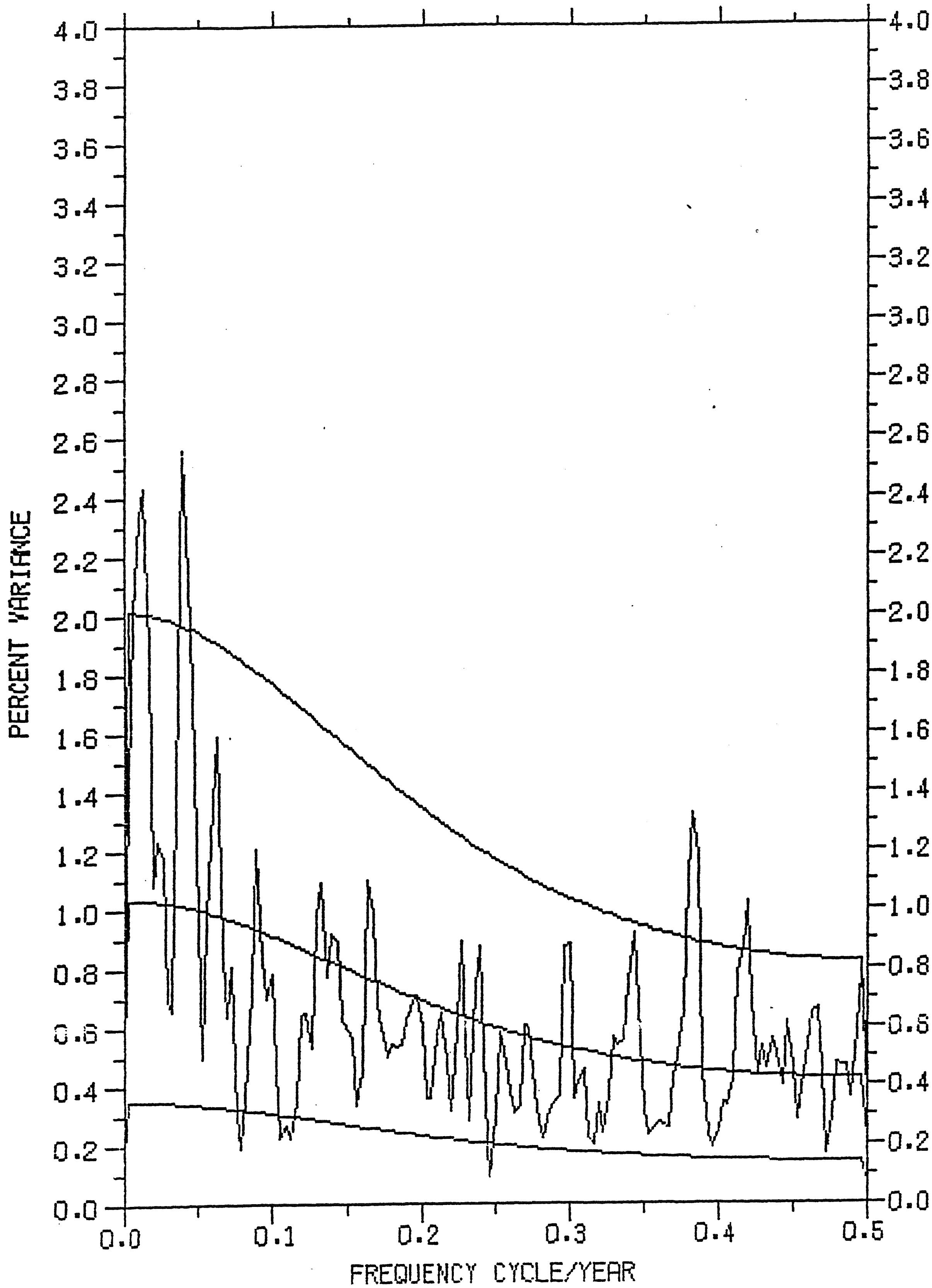
PARAMETERS	TYPE	ORDER	VALUE	95 PCT LIMITS	
	AR	1	.1912	.1000	.2824
	AR	2	.1239	.0327	.2151

RESIDUAL SUM OF SQUARES	32.714675	RESIDUAL MEAN SQUARE	.068726
DEGREES OF FREEDOM	476	RESIDUAL STANDARD ERROR	.2622
INDEX OF DETERMINATION	6.51	AKAIKE INFO. CRITER.	1678.16
Q STATISTIC, 20 LAGS	7.80	CHI-SQ.,5 PCT, 19 D.F.	30.14

ID = 99651L
TREE-RING INDICES



SPECTRUM FOR 99651L
SERIES : METHUSELAH WALK, CA..
PERIOD 1380 TO 1980 WITH 150 LAGS



SITE AND CHRONOLOGY INFORMATION

Site name *Table Cliffs Plateau*

State *Utah* County *Garfield*

Latitude *37° 41'* Longitude *111° 54'* Altitude *3110 m*

Collectors *D. A. Graybill, M. R. Rose, 1983*

Species collected *Pinus longaeva*

Associated arboreal species *Picea engelmanii*

Parent mineral of soil *Limestone*

Slope direction *East to West*

Slope angle *60°-80°*

Six of the 25 series from this site are dated to near A.D. 800. Several cores reach further back in time but the dating is difficult. Further collection is required.

SITE AND CHRONOLOGY INFORMATION

Site name *Wild Horse Ridge*

State *Utah* County *Emery*

Latitude *39° 25'* Longitude *111° 04'* Altitude *2805 m*

Collectors *D. A. Graybill and M. R. Rose, 1984*

Species collected *Pinus longaeva*

Associated arboreal species *Pinus flexilis, Picea engelmanii*

Parent mineral of soil *Limestone*

Slope direction *South*

Slope angle *40°-60°*

The data from this site remain in process. It appears that the site chronology will exceed 2000 years in length. Further collection is warranted to develop adequate numbers of series.

Acknowledgments

William J. Robinson, director of the Laboratory of Tree-Ring Research, provided a broad range of resources that allowed this project to flourish. H. C. Fritts' depth of perspective on tree-ring research has been a positive contribution. V. C. LaMarche, Jr. shared site collection data that strengthened several chronologies. M. R. Rose and M. S. McCarthy provided invaluable assistance in most phases of the project ranging from data collection to analysis. Preparation of this report was greatly aided by C. W. Shaw, L. Kervin and A. Allen.

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