

0313

002980

OCCURRENCE OF FALSE RINGS IN APACHE PINE

(Pinus engelmannii) IN CHIRICAHUA NATIONAL MONUMENT, ARIZONA,

AND CORRELATION WITH CLIMATIC VARIABLES

William B. Gillespie

Geos. 564B

May 11, 1990

INTRODUCTION

The phenomenon of intra-annual bands, or false rings, is one that has received little attention from dendrochronologists. In part this is a result of their characteristic scarcity in most tree-ring series, but in addition, dendrochronologists have often avoided sampling trees that show high frequencies of false rings. Because intra-annual bands can make crossdating more difficult and often tenuous, researchers developing tree-ring chronologies have tended to avoid them. Alternatively, intra-annual rings can be viewed not as a nuisance, but as a data source that may embody information not manifest in annual ring-width series.

In the 1960s, Fritts (1976) made detailed observations of ring development and correlative environmental variability for a few years on growth for a ponderosa pine in the Santa Catalina Mountains. Fritts (1976) showed that intra-annual bands of latewood within the early wood portion of the annual ring are attributable to variations in growth rate during the growing season. The specimen showed false ring formation in four of the five years it was monitored. Fritts also indicated that the intra-annual latewood tended to form during the persistent June drought that characterizes southern Arizona climate, while renewed earlywood growth was correlated with the onset of the intense July-August rainy season.

Fritts' data on false-ring development suggest that the pines are responding rapidly to summer moisture conditions, resulting in same-year ring response to the summer conditions. This is potentially useful, in that most dendroclimatic investigations have found that summer climate typically is only poorly reflected in the ring widths of the same year;

effects of summer rain are often observed only in the subsequent year's ring structure (Fritts and Swetnam n.d.). As a result, dendroclimatic reconstructions (e.g., Rose et al. 1981) have found it difficult to isolate and predict the main summer rainfall event. Examining a direct response, rather than one obscured by a one-year lag could provide a means for better estimation of warm-season precipitation variability.

One geographic region where intra-annual rings are relatively common is in the mountains of southeastern Arizona where the summer "monsoonal" influx of moist air, following a prevalent spring drought, gives a very strong precipitation maximum. False rings show up in several conifer taxa, particularly Arizona cypress and species of pine, especially those growing near the lower woodland margin (Pinus ponderosa, P. leiophylla, and P. engelmannii). Pinus engelmannii Carr. (Apache pine; formerly known as P. latifolia or P. apachea), is one of the species that shows strong false ring development. It is also one of the least studied species of pine in the United States, in part because its distribution is so limited. In the United States, this Madrean species occurs only in the Chiricahua, Huachuca, Dragoon, Santa Rita, and Santa Catalina Mountains of southeastern Arizona, and in the extreme southwest corner of New Mexico (Fig. 1). It has received little attention from dendrochronologists for three reasons: 1) its relative rarity, 2) its tendency to be short-lived, and 3) the high incidence of false rings. Schulman (1956), for example, dismissed P. engelmannii as undatable.

The present study is an exploratory investigation of the occurrence of intra-annual bands in a set of Apache pines from the Chiricahua Mountains. The objective is to examine false rings on crossdated

specimens, develop a chronology of their presence and absence, assess the importance of age and interstand differences, and make preliminary correlations of their occurrence with climatic data. Observations on the placement of false rings along the radial axis within each annual ring are also made.

MATERIALS AND METHODS

Specimens examined

Two stands of Apache pine were sampled from Rhyolite Canyon in Chiricahua National Monument on the west side of the Chiricahua Mountains, Cochise County, Arizona. An initial collection was made from a small stand (designated LRC for Lower Rhyolite Canyon) from near the lower end of the canyon at an elevation of 5400 feet. This stand is from 300-500 m east of the Monument Visitor Center, location of the Chiricahua N. M. weather station (Fig. 2). After the initial sample of 8 trees made in October, 1989, proved to contain only a few usable cores, a second sample of 10 additional trees was made in March, 1990. Two cores from each tree were taken at breast height from opposite sides of the tree (perpendicular to the direction of lean or slope).

Sampled trees from the LRC stand are all from a restricted area on the inner terrace of the main Rhyolite Canyon stream channel. Dates from these trees cluster around A.D. 1900, however an earliest date of ca. 1840 provide a minimum age for this young-looking geomorphic surface. Associated trees include Quercus arizonica, Q. hypoleucoides, Juniperus deppeana, Pinus cembroides, P. leiophylla, and scattered P. ponderosa.

The second examined sample includes 12 cores from 7 trees from the floor of Rhyolite Canyon ca. 2 km upstream to the east near the mouth of Sarah Deming Canyon. This is from a coller, more mesic setting at an elevation of ca. 5850 feet. These specimens, designated by the prefix RFL, were collected, prepared, and dated Laboratory for Tree-Ring Research personnel (the generous assistance and advice of Chris Basin and Alex McCord are greatly appreciated). Included are three cores from two Chihuahua pines (*P. leiophylla*) in addition to *P. engelmannii*. Trees from this higher stand are in generally better condition than those from the LRC stand, with greater mean ring-widths, fewer missing rings, easier crossdating, and more readily observable false-ring development.

A large proportion of laboratory time was directed toward attempting accurate crossdating of the LRC specimens. This was found to be difficult and, with some cores, unachievable. Ring characteristics vary greatly, particularly as a function of tree age. The outer decades of older trees characteristically are dominated by narrow, indistinct rings with numerous missing years. Skeleton-plotting of ring-width patterns and comparison with specimens and ring-width series from nearby stands (Onion Saddle, the RFL specimens, and skeleton plots prepared by Alex McCord), approximately one-half of the LRC specimens were crossdated and found appropriate for false-ring analysis. A combined sample of 22 crossdated cores from 14 trees were examined for false ring development. These include 10 cores (6 trees) from the RFL collection and 12 cores (8 trees) from the LRC stand.

False-ring Data

The analysis of false-ring occurrence presented here is based on the coded presence on a four-point ordinal scale of false ring distinctiveness for each annual ring. Designations for this coding system, modified from one developed by Alex McCord, are: 0 - no evidence of an intra-annual ring or band is visible; 1 - subtle latewood development evident within the early portion is discernable; 2 - an extra latewood band is present but clearly false; 3 - distinct false ring is well developed, in some cases to the extent that it can be distinguished from true annual rings only with difficulty.

In addition, four types of anomalous placements of the intra-annual banding along the radial width of the ring were noted whenever they occurred: 1) "Early" placement was designated where false band development occurred in inner 50 percent of the total ring width (the modal position is between ca. 55 and 75 percent of the total width); 2) "Late" placement was marked where a distinct intra-annual band is in the outer 20 percent of the ring, and 3) "Extra Late Wood" was noted in cases where the primary, late-season latewood includes a perceptible irregularity (a thin band of wider cells with thinner walls, but too weak to constitute a false band); and 4) "Double False Rings" where a plurality of intra-annual bands are present.

RESULTS

False-ring Indices

Based on the recorded distinctiveness, a mean-value index was calculated for each stand and for the combined assemblage. This index, with values ranging from 0 to +3, is the simple arithmetic mean of the coded values for all cores in each year. Index values were calculated

for the period 1900 to 1988, with sample depths ranging from 7 cores at the early end of the scale, to the full 22 specimens. Figure 3 shows the unmodified index for the combined sample and Figure 4 the indices for the two stands. Raw values are presented in Table 1. For only one year (1935) were distinctive false rings (code 3) recorded for every core, and in only two years, 1971 and 1974, both years with characteristically very narrow ring-widths, were no false rings observed in the analyzed sample. In not only the combined sample, but each of the stands, the overall mean ring index is 1.8, or slightly above the central position (indicating presence in more than half of the years).

Inter-tree and Inter-stand Comparisons

Figure 4 shows that there is general agreement in false ring patterning between the two stands, though there are are notable differences in many years. A parametric correlation coefficient between the two series is $r = 0.48$, but it should be noted tht the index values of both sets have markedly non-normal distirbutions and are not appropriate for parametric correlation analysis.

To achieve a more appropriate measure of correspondence between cores and both between and among the two stand samples, percentage agreement measure of false ring presence/absence was applied. The data set was reduced slightly in size for this analysis to allow for more comprehensive comparison. To control for variable core length and to avoid small sample sizes at the early end of the series, an optimum common period was defined from 1912 to 1988 for which observations were available for all years in 17 of the 22 cores (Table 2). For this analysis, the four-point false-ring distinctiveness scale was reduced to

a binary, presence/absence code (A includes codes 0 and 1; P includes 2 and 3). A matrix of percent similarity was generated using a dissimilarity measure (Manhattan Metric Distance) between each pair of cores.

These core-to-core comparisons allow insight into the contribution of different variance components in the false ring patterning. As expected, similarities are highest between multiple cores from single trees. However, the similarity is not as high as anticipated prior to the examination. Mean percent similarity between same-tree cores is 82 percent (see bottom, Table 2), indicating that nearly 20 percent of the time, a false ring on one side of a bole will not be apparent on the opposite side. Values ranged from 75 to 92 percent, with the lowest intra-tree similarity occurring in the single matched Chihuahua pine sample (RFL 6). One of the cores from this tree had consistently lower similarity with all other cores in the combined sample, suggesting that Chihuahua pine may manifest false ring development somewhat differently from Apache pine.

Within-stand similarity is slightly greater than between stand similarity, with both the stands having comparable average values (Table 2). Mean intra-stand similarity is 70 percent for the RFL sample, and 71 percent for LRC cores. Mean inter-stand similarity is 62 percent. Figure 5 graphically represents the mean percent similarity of each core with the other cores in the two stand groups. I find the degree of inter-stand similarity noteworthy; it is not greatly less than the mean intra-stand values, nor those of paired cores from single trees. This suggests that there is a signal, most likely climatic, affecting false-ring development throughout the area. There is an appreciable "noise"

component including physiological and other factors, but this unshared variance is substantial within each tree, and rather than simply between trees and stands.

Age_trend

The unstandardized false ring index curve shown in Figures 3 and 4 show a general decline in values in recent decades. The major factor contributing to this trend is undoubtedly the effect of an age trend and the occurrence in the sample of many trees of nearly the same age. Just as there is a growth trend in reduced ring widths, the frequency of false rings declines as trees age and rings become more narrow. Figure 6 shows false ring index calculated by years from the inner most ring (an indication, if not always precise, of minimum age) rather than by calendar year. This curve, and the 11-year weighted running mean shown with it, show a marked drop off in average false ring frequency between ca. 35 and 65 years. The curve also shows a short positive trend in the first 20 years, much as in ring-width series. Variance increases in the later years, but this may be largely an artifact of smaller sample sizes.

Standardized_False-ring_index

Although a number of trial efforts to analyze the association of the unmodified false ring indices with various climatic data, the unstandardized series was found wanting for several reasons. Of primary importance are the effects of the observed age-related trend. Reliable parametric correlation with ring-width or climatic series is largely

precluded by the presence of the age trend and the questionable normality of the index data.

As described below, the primary means of examining association with climatic variables used here is to compare subsamples of high-index and low-index years, a modification of decile comparison technique. However, as is apparent from the plot of unstandardized indices, low-index years are concentrated in the latter part of the studies period, while high indices are most prevalent in the early part. Initial numerical tests of comparison of false ring indices and climatic data produced variable and often contradictory results.

To correct for the effects of the observed growth trend, attempts were made to provide a standardized index for use in comparison with climatic data. Figure 7 shows a fairly flexible curve generated using a 21-year weighted moving average filter and Figure 8 gives a standardized index series given by the differences between the raw index values and the fitted curve. This standardized series is given by subtracting the fitted curve values, rather than dividing by them, the technique used more commonly in standardizing ring-width series. Dividing index values to generate standardized values was found (in this and other trials) to give distinctly non-stationary variance structure with many of the highest and lowest values in the most recent decades. The subtraction technique, imparts a vertically asymmetrical structure to the variance (positive peaks have lower amplitude than negative ones), but this is not deemed a drawback for the sorting techniques employed here. Since the objective is to isolate peaks throughout the length of the series, stability through time is considered more important than the normality of the data spread around the line of central tendency.

Another attribute of the unstandardized false-ring index series was the tendency for low-index years to be years with very narrow ring widths. Accordingly, initial attempts to correlate low-index years with climatic data showed the same characteristics that give narrow rings, primarily subnormal cool-season precipitation. In many cases, the absence of false rings in narrow rings was one of visibility in very narrow rings; cores with wider and better preserved ring structure often had false rings, but in more stressed trees, the entire ring is minimal or missing. In other words, the low index values in some of the narrow rings is in part of function of using many highly stressed low elevation trees. Attempts were made to use residuals from regression with the Onion Saddle, alone and in conjunction with standardization from fitted curves. Division of index values exacerbated the tendency for rings to have low false ring indices, whether or not regression residual were used. The simple subtraction method used here gave more satisfactory stabilization of minimal values.

False ring occurrence and Palmer Drought Severity Index

A number of attempts were made to make assessments of the correlation between false ring presence in the annual series, as indicated by the indices, and climatic variables, including monthly precipitation values from long-term meteorological stations in the area, and monthly Palmer Drought Severity Indices for the Southeastern Arizona climatic division (on computer file at the Laboratory for tree-ring Research). Given the ordinal nature of the false ring observations, parametric statistical techniques have been largely avoided in deference

to non-parametric methods. As noted above, a primary technique adopted here is to compare a set of high-index years (that those where false rings are characteristically present) with a set of low-index years. Intermediate years tend to be those with ambiguous false-ring representation -- many cores show them while many do not.

Figure 9 shows the association between the two sets (high- and low-index years) and monthly PDSI values averaged for each set. The sets include the 14 highest and lowest values in the standardized series shown on Figure 8. Fourteen is an admittedly odd number, but was selected for three reasons; 1) to give a large sample than from the highest and lowest deciles, 2) because this number is closest to distinguishing the high and low peaks from the intermediate frequencies, and 3) because it approximates the portion of the index values that lie more than one standard deviation from the mean (they do not directly correspond to z-scores greater than one because of the asymmetry of the index value distribution noted above.

Figure 9 shows a marked difference between the set of years where false rings are characteristically absent from those where they are present. Specifically, spring and early summer moisture conditions tend to be subnormal in years lacking false ring development, and above normal in years having high false-ring index values. The discrepancy is greatest in March, April, May, and June. Statistical significance of these differences was made by applying the Mann-Whitney test, comparing each sample to the entire 89 year series. This shows that the difference of the mean values for the subset in comparison with the entire population is significant at the .05 level in three cases, the low-index set for March, April, and May (Figure 9). In other words, years in which

false rings are most often absent are those with marked spring droughts. Using the Mann-Whitney test to compare the two samples with each other, rather than to the entire data set may show more statistically significant differences.

False-ring Placement

Another attribute examined is the climatic characteristics of the a set of years showing characteristically early placement of a false ring along the radial axis versus a set of years when the false ring is typically near the end of the latewood. Figure 10 shows the pattern of differences in mean monthly PDSI for these two sets (significance testing has not been applied). This patterning suggests that early false-ring placement is associated spring and early summer drought, conditions which presumably inhibit rapid earlywood development. In contrast, years with late false-ring placement are characterized by above normal moisture conditions not only in the spring but into the summer.

Figure 11 shows the same data set discrimination applied to monthly precipitation data (standardized to restructure the variance) for Bowie. This again shows early placement associated with low moisture values (subnormal winter precipitation), and late placement with higher than normal winter-spring precipitation.

SUMMARY

This exercise has pointed out a number of characteristics of the occurrence of intra-annual rings and their correspondence with climatic conditions. Percent similarity measures between sets of cores from Rhyolite Canyon shows that the pattern of presence or absence of false rings is shared between separate stands, and is not greatly lower than the similarity shared between paired cores from single trees (mean values are 62 and 83 percent respectively).

There is an observable age-related trend showing a decline in the abundance of false ring occurrences with increasing age. Greatest decline in the Rhyolite Canyon sample occurs between approximately 35 and 65 years from the innermost ring.

Preliminary tests of association between sets of high- and low-index years and climatic data indicates that years characteristically lacking false rings have subnormal spring and early summer moisture conditions. Mean PDSI values were found to be significantly below normal for March, April, and May in the set of years most often lacking false rings. False ring presence is more likely in years with above normal early season moisture conditions. These findings may appear to be in conflict with the information presented by Fritts (1976) for ponderosa pine in the Catalina Mountains. Fritts presented evidence that the false rings formed during the common June drought when temperatures were rising and moisture amounts were low. The present study, focussing on a different set of data at a different level, suggests that year-to-year variability in false-ring frequency has different climatic determinants; false ring presence is favored by above-normal moisture conditions, rather than sub-normal. These two are not as contradictory as it may appear at first glance Fritts was looking at conditions within a given

year that corresponded to the formation of a false ring and found June aridity to be the apparent cause. The information presented here adds the observation that the years in which this is most likely to occur are ones in which higher than normal springtime moisture conditions have resulted in substantial early wood development. The results here do suggest that the presumption of an association of false ring presence with drought conditions in the spring and early summer is overly simplistic and inaccurate.

The final attribute examined, the placement of false rings with an annual ring, suggests that early placement is associated with subnormal early season moisture conditions. Years with characteristically late placement tend to have above normal spring and early summer moisture.

REFERENCES CITED:

- Fritts, H.C. 1976. Tree rings and climate. Academic Press, New York.
- Fritts, H.C. and T.W. Swetnam. n.d. Dendroecology: a tool for evaluating variations in past and present forest environments. In press, in Advances in Ecological Research, Vol. 19.
- Little, E.L., Jr. 1974. Atlas of United States trees. Vol. 1. Conifers and important hardwoods. USDA Forest Service Misc. Publ. 1146.
- Rose, M.R., J.S. Dean, and W.J. Robinson. 1981. The past climate of Arroyo Hondo, New Mexico, reconstructed from tree rings. School of American Research Press, Santa Fe.
- Schulman, E. 1956. Dendroclimatic changes in semiarid America. University of Arizona Press, Tucson.

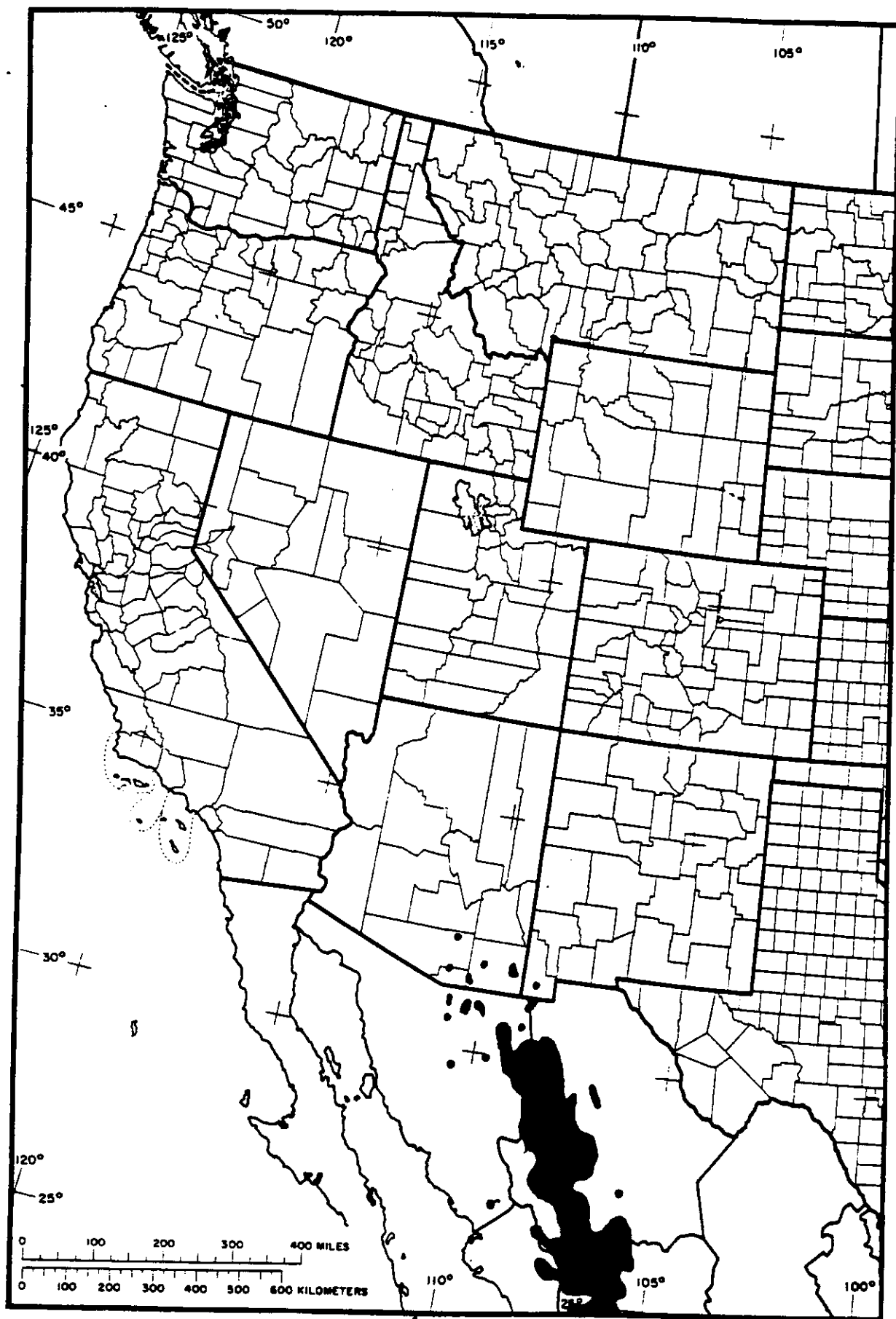
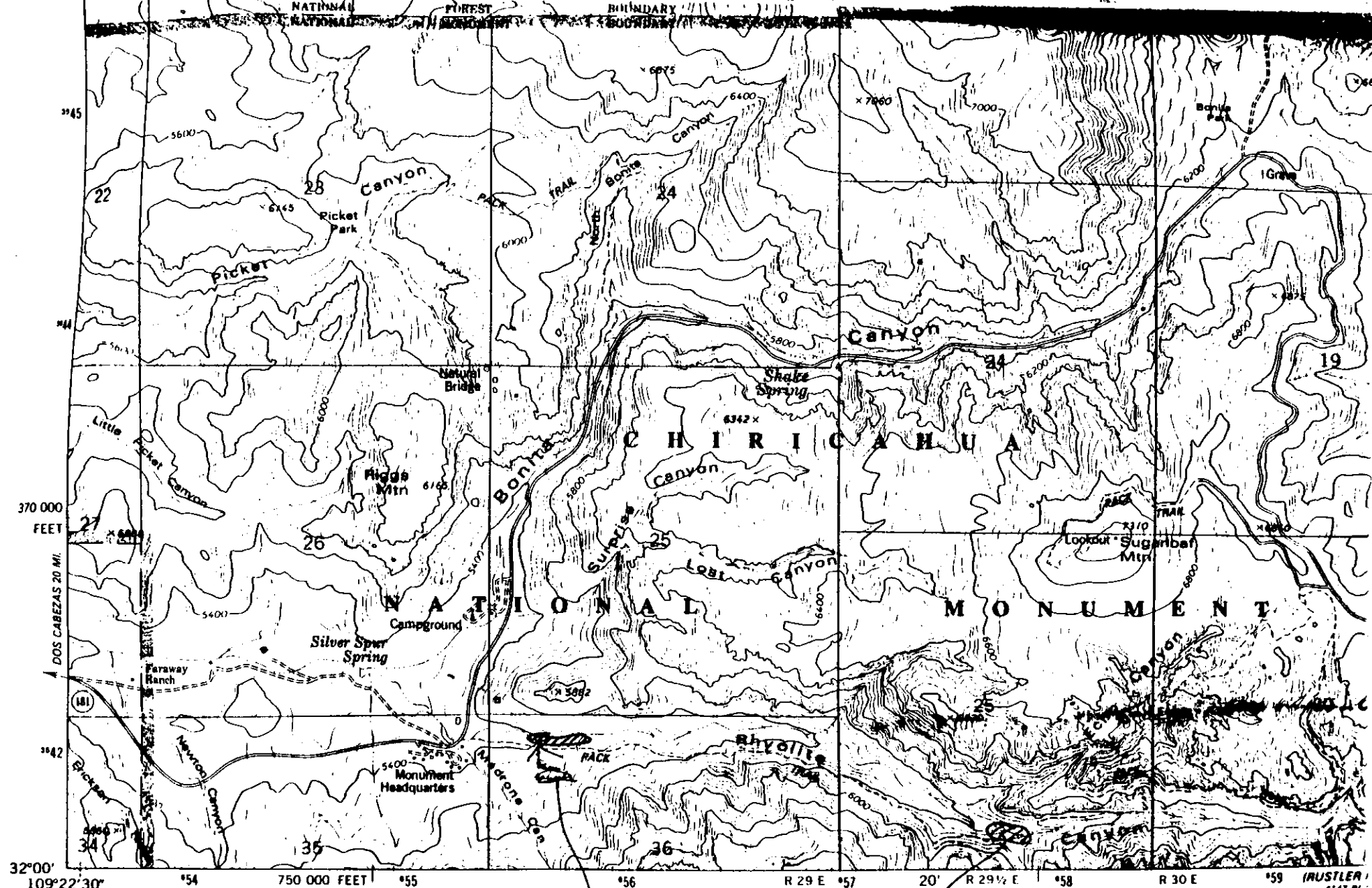


Fig. 1

Map 55-W. Apache pine, *Pinus engelmannii* Carr. (Little 1974)

Figure 1. Location of two sampled stands in Rhyolite Camp.



Mapped, edited, and published by the Geological Survey

Control by USGS and NOS/NOAA

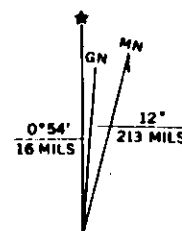
Topography by photogrammetric methods from aerial photographs taken 1973. Field checked 1974. Map edited 1979

Projection and 10,000-foot grid ticks: Arizona coordinate system, east zone (transverse Mercator)

1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue. 1927 North American datum

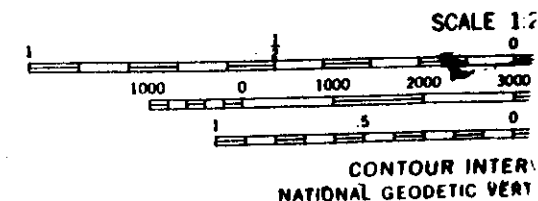
To place on the predicted North American Datum 1983 move the projection lines 8 meters south and

LRC
SAMPLE
AREA

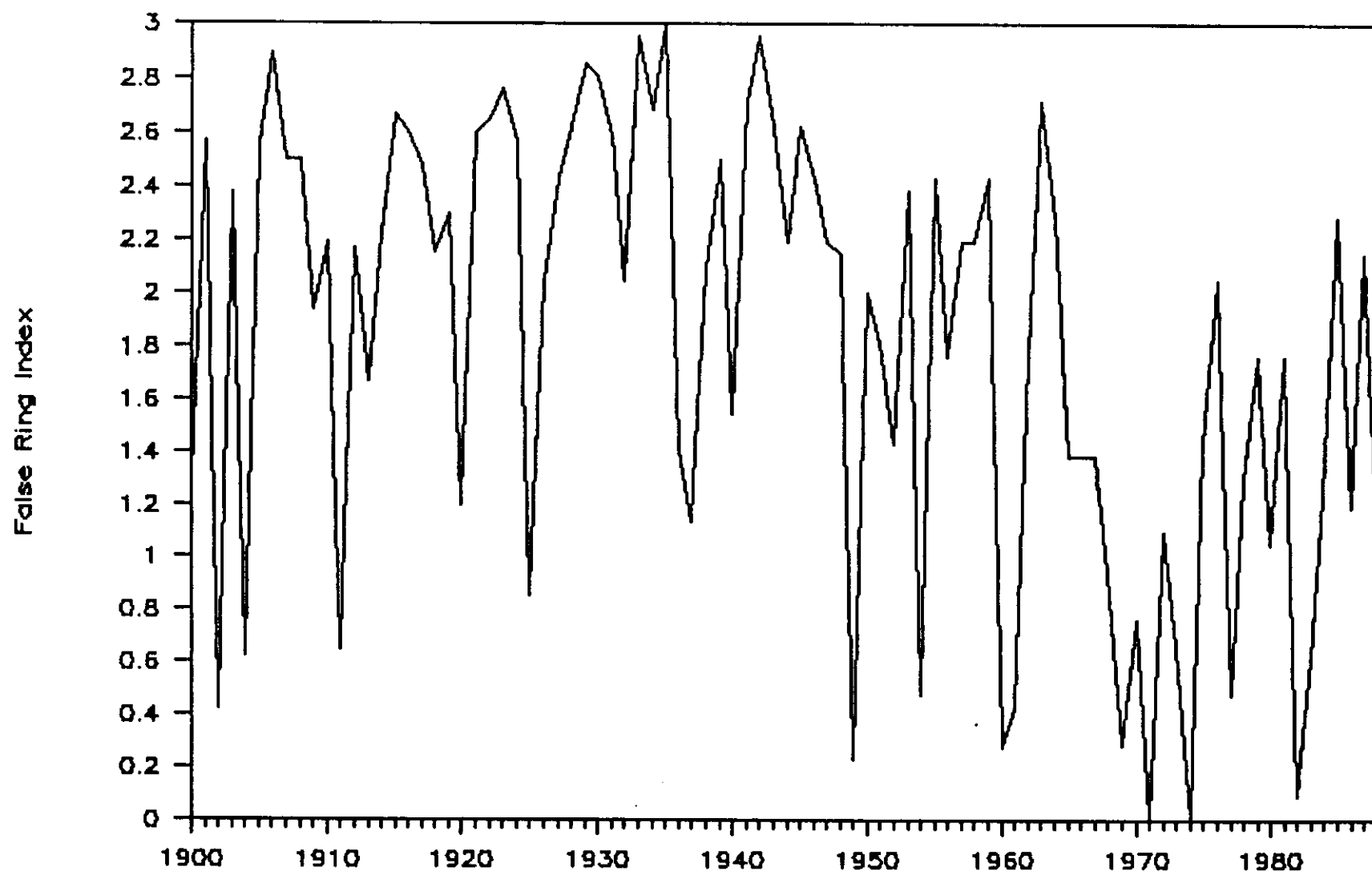


UTM GRID AND 1979 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

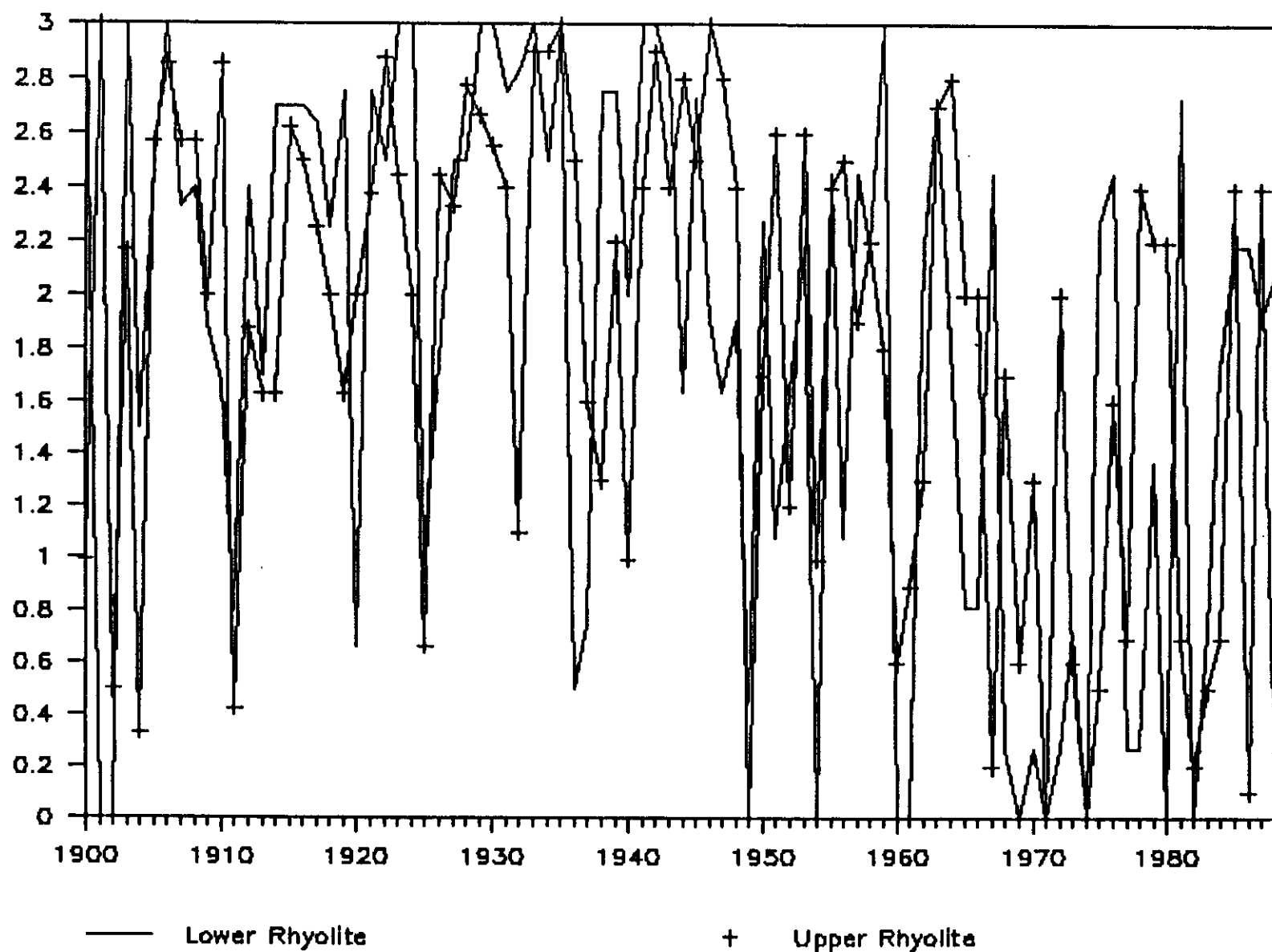
RPL
SAMPLE
AREA



Rhyolite Canyon False Rings

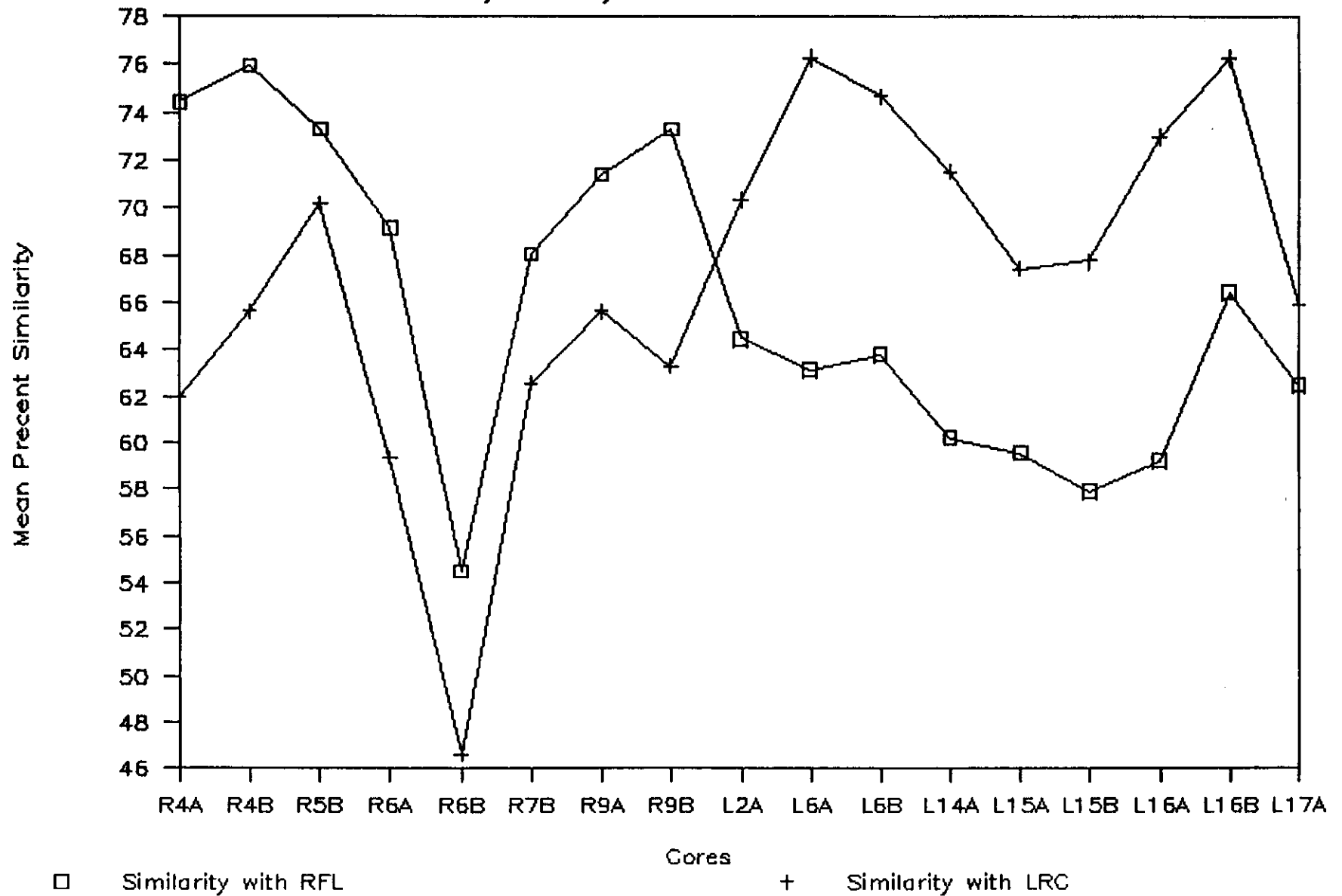


Rhyolite Canyon False Ring Indices

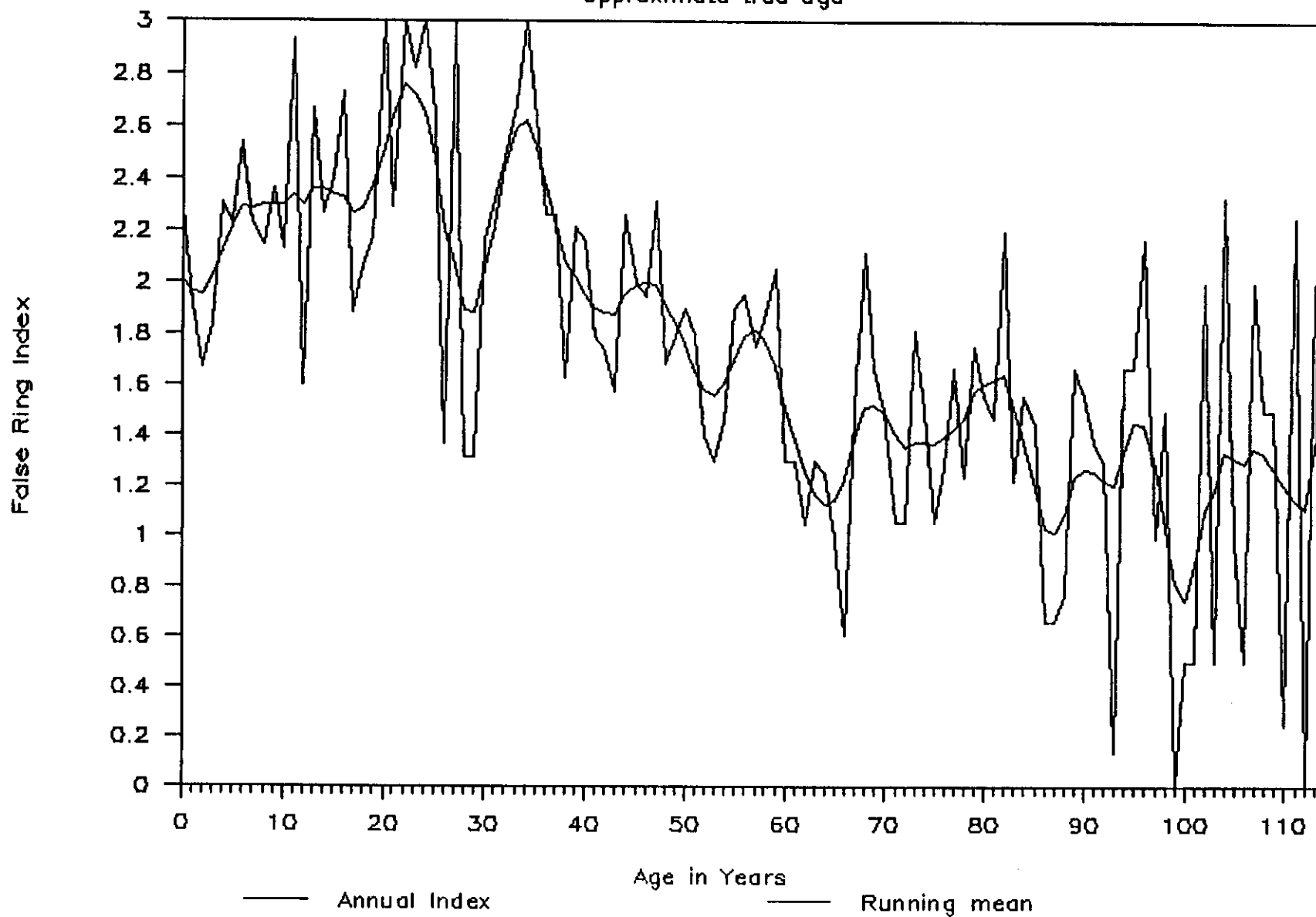


Percent Similarity of cores from two

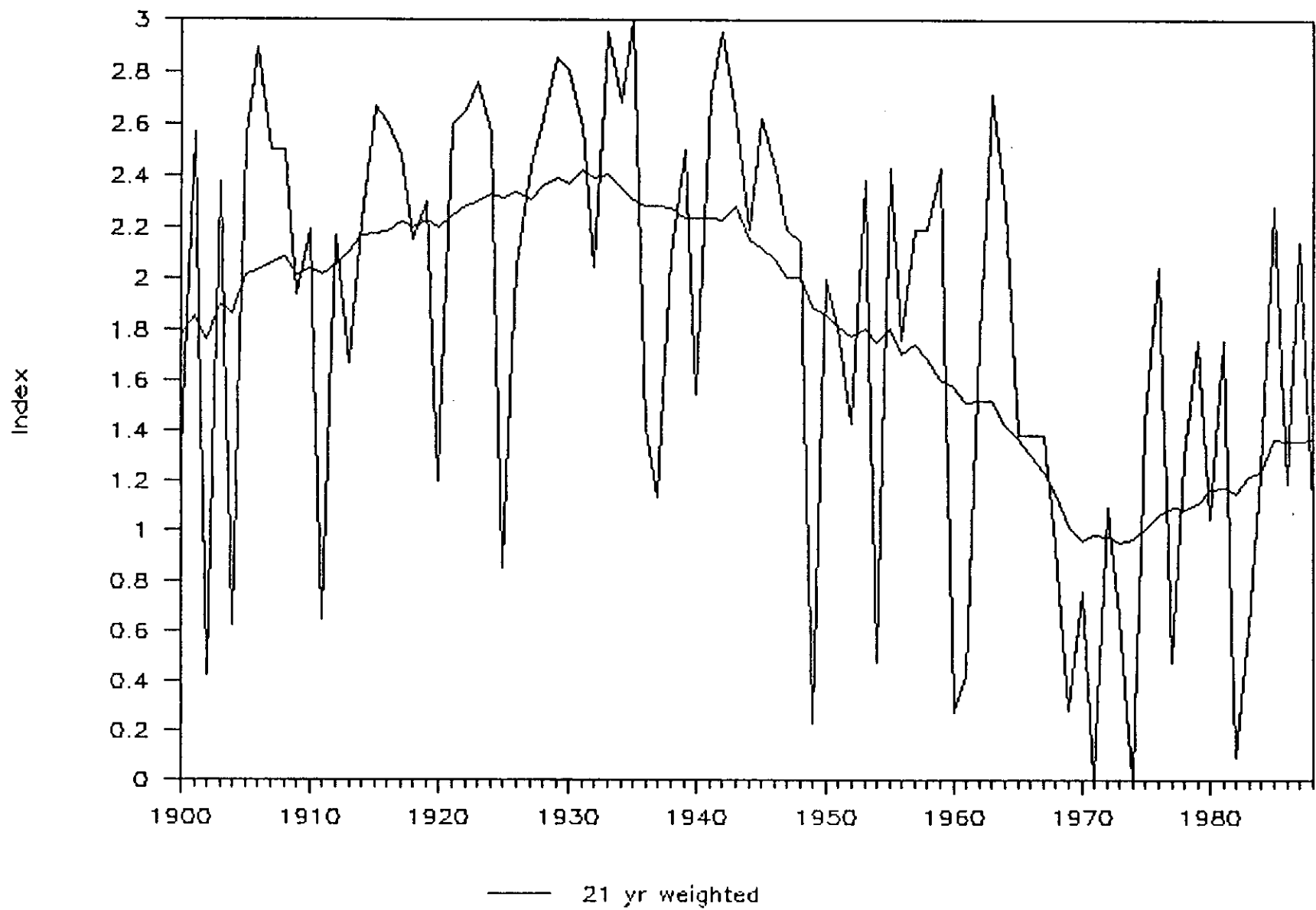
Rhyolite Canyon stands with other cores



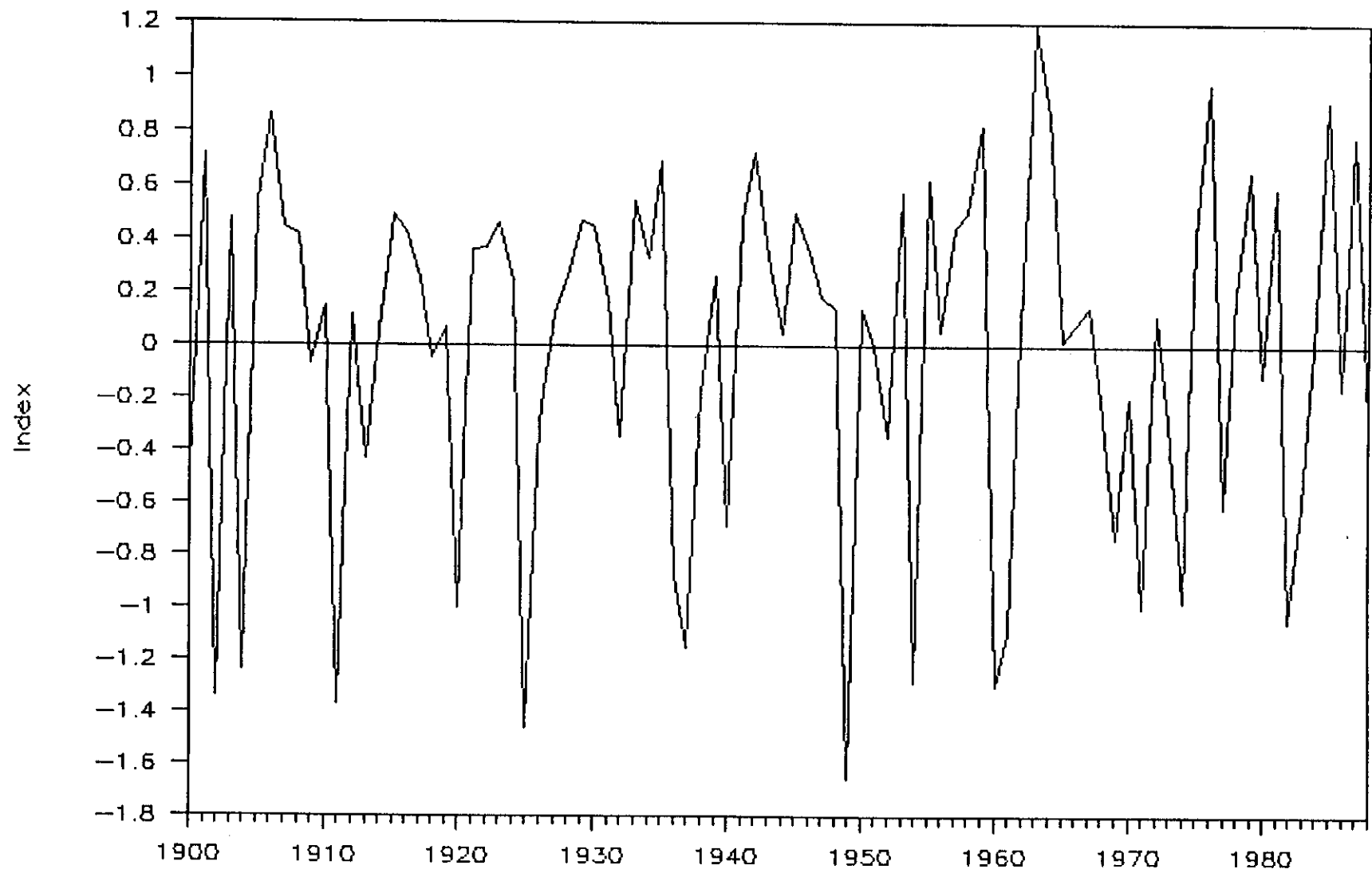
False Ring Index and approximate tree age



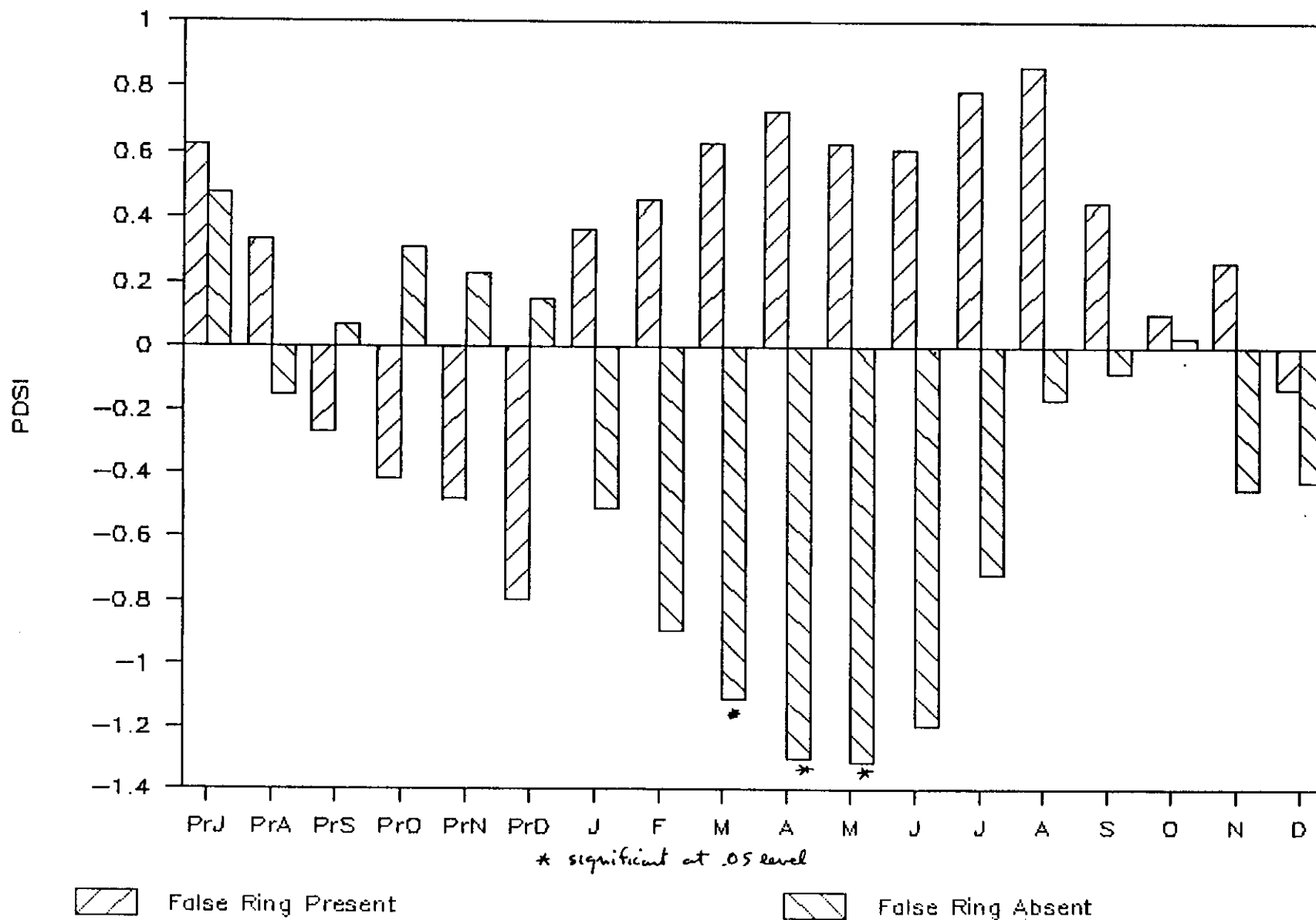
False Ring Index



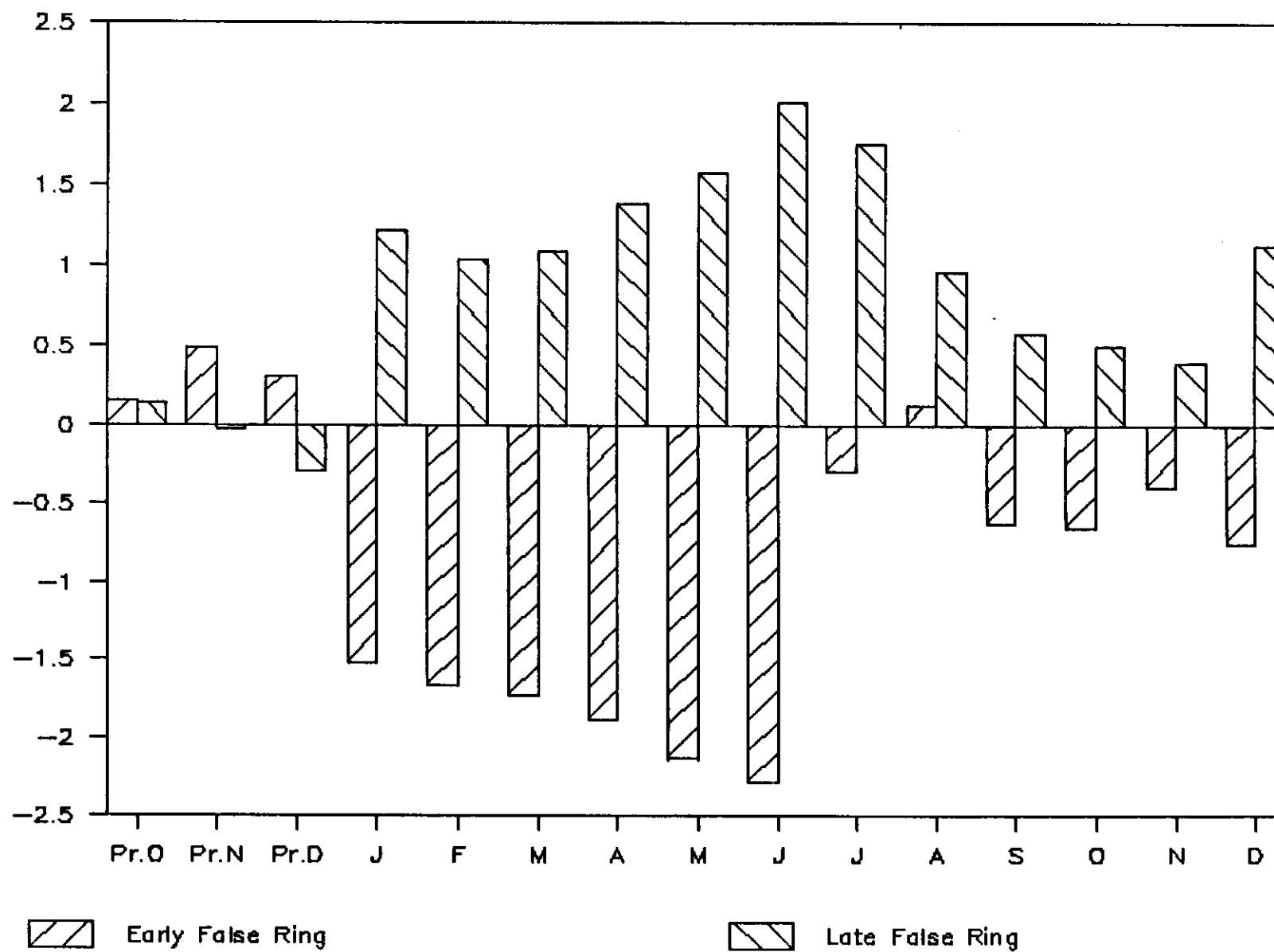
Standardized False Ring Index



Mean Monthly PDSI



False Ring Placement & Monthly PDSI



Bowie Precip. & False Ring Placement

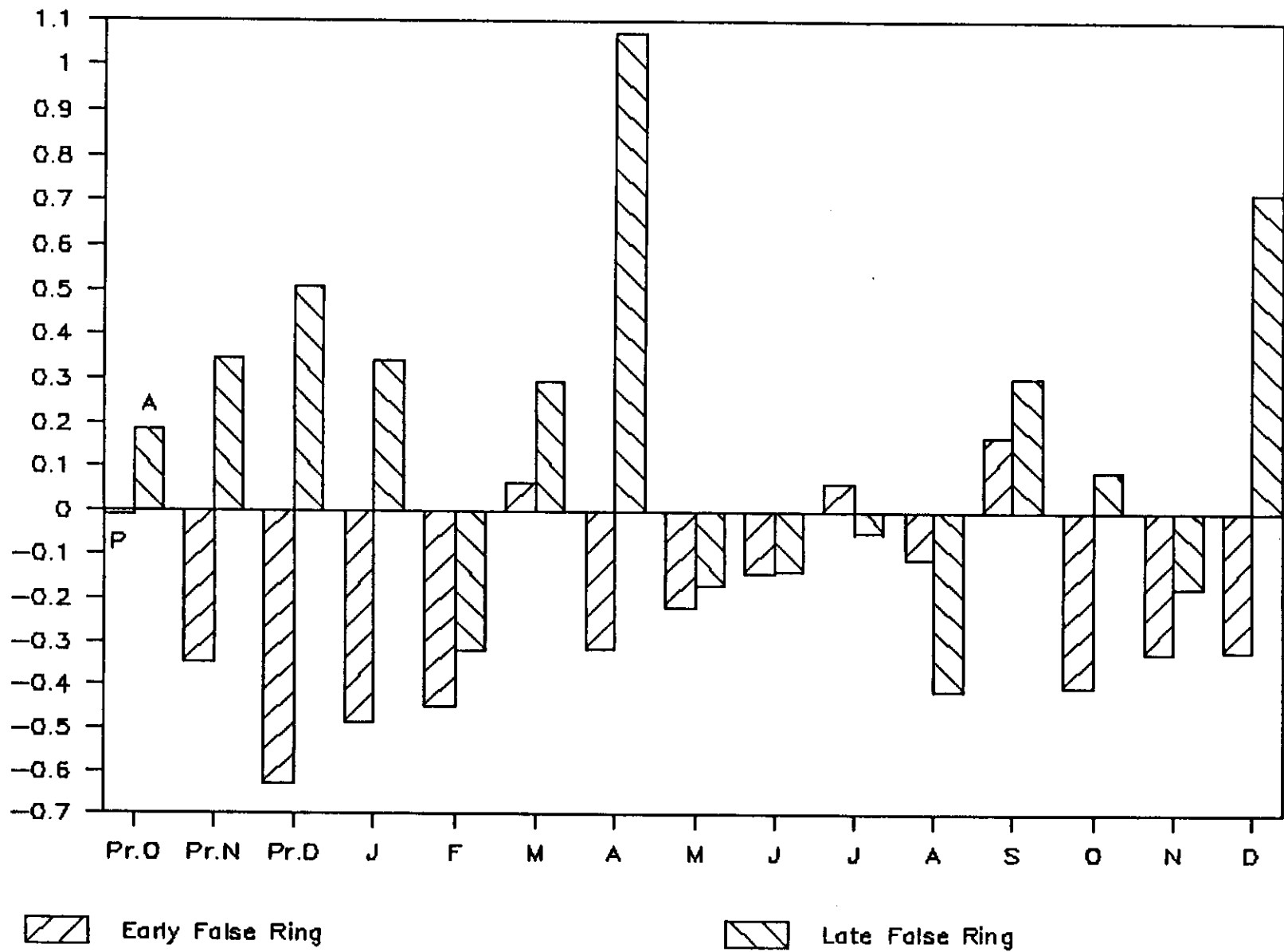


Table 1. Rhyolite Canyon False Ring Observations.

Coded values range from 0 (false ring absent) to 3 (distinct false ring).

	RFL stand								LRC stand													
	RFL 4A	RFL 4B	RFL 5A	RFL 6A	RFL 6B	RFL 7B	RFL 9A	RFL 9B	RFL 16AA	RFL 16BB	LRC 2A	LRC 5B	LRC 6A	LRC 6B	LRC 14A	LRC 15A	LRC 15B	LRC 16A	LRC 16B	LRC 17B	LRC 19A	LRC 19B
inner	Chihuahua pine																					
Year ring	1882	1892	1904	1825	1846	1910	1873	1893	1922	1930	1906	1848	1907	1907	1898	1907	1907	1907	1907	1910	1917	1917
1900	0	0		3	3		0	0					3									
1901	3	3		3	3		3	3					0									
1902	0	1		0	2		0	0					0									
1903	3	3		3	3		1	0					3			3						
1904	0	0		1	1		0	0					0			3						
1905	3	3	3	3	0		3	3					3			2						
1906	3	3	3	3	2		3	3					3			3						
1907	3	3	3	3	0		3	3			1	3				3						
1908	3	3	3	3	0		3	3			1	3	2	3		3						
1909	3	2	3	0	0		3	3			0	3	2	3	3	0	0	3	3			
1910	3	3	3	2	3		3	3			3	0	3	3	3	3	0	0	0			
1911	0	1	1	0	0		1	0			0	1	3	1	0	0	0	1	1	1		
1912	3	1	3	0	0	2	2	3			3	3	3	3	3	2	1	3	3	0		
1913	3	1	3	0	0	2	2	2			3	3	3	1	2	1	0	2	2	0		
1914	1	1	3	0	0	2	2	3			3	3	3	3	3	3	2	3	3	1		
1915	3	3	3	3	0	3	3	3			3	3	3	3	3	3	3	3	3	0		
1916	3	3	3	3	0	2	3	3			3	3	3	3	3	3	3	0	3	3		
1917	3	3	3	2	0	2	2	3			2	3	3	3	3	3	3	3	3	0	3	
1918	2	2	3	2	0	2	2	3			2	3	3	3	3	1	0	3	3	0	3	3
1919	2	2	3	0	0	1	2	3			3	3	3	3	3	3	3	3	3	0	3	3
1920	3	3	0	3	3	0	1	3			0	0	0	0	0	0	0	0	0	2	3	3
1921	3	2	3	3	1	2	2	3			3	0	3	3	3	3	3	3	3	3	3	3
1922	3	2	3	3	3	3	3	3			3	3	3	3	0	3	3	0	3	3	3	3
1923	3	3	3	0	1	3	3	3	3		3	3	3	3	3	3	3	3	3	3	3	3
1924	3	2	3	0	0	1	3	3	3		3	3	3	3	3	3	3	3	3	3	3	3
1925	0	0	0	0	0	3	0	0	3		3	0	0	0	0	3	3	0	3	0	0	0
1926	3	2	3	3	0	2	3	3	3		3	0	0	3	3	3	0	0	3	0	3	3
1927	3	3	3	0	0	3	3	3	3		3	3	3	3	3	3	0	0	3	3	3	3
1928	3	3	3	2	2	3	3	3	3		3	3	3	3	3	3	3	3	3	0	0	0
1929	3	3	3	2	1	3	3	3	3		3	3	3	3	3	3	3	3	3	3	3	3
1930	3	3	3	2	0	3	3	3	3		3	3	3	3	3	3	3	3	3	3	3	3
1931	3	3	3	2	3	3	3	2	1	1	3	3	3	3	0	3	3	3	3	2	3	3
1932	1	0	3	0	0	1	2	3	0	1	3	3	3	3	3	3	3	3	3	2	3	3
1933	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
1934	3	3	3	3	3	2	2	3	3	3	3	3	3	3	0	0	3	3	3	3	3	3
1935	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
1936	3	3	3	1	0	3	3	3	3	3	3	0	0	0	0	0	0	0	3	0	0	0
1937	1	1	1	3	3	0	1	3	0	3	3	3	0	0	0	0	0	0	0	0	0	0
1938	1	1	3	0	0	3	1	3	0	1	3	3	3	3	3	0	3	3	3	3	3	3
1939	1	3	3	2	3	1	2	3	1	3	3	3	3	3	3	0	3	3	3	3	3	3
1940	3	3	0	0	0	1	1	0	2	0	3	3		0	0	0	3	3	3	0	3	3
1941	3	3	3	3	3	2	1	1	3	2	3		3	3	3	3	3	3	3	3	3	3
1942	3	3	3	3	3	3	2	3	3	3	3		3	3	3	3	3	3	3	3	3	3
1943	3	2	3	2	0	3	2	3	3	3	3		3	3	3	1	3	3	3	3	3	3
1944	3	3	3	3	3	3	1	3	3	3	3		3	3	3	0	0	3	3	0	0	0
1945	3	2	3	3	1	3	1	3	3	3	3		3	3	3	0	3	3	3	3	3	3
1946	3	3	3	3	3	3	3	3	3	3	3		3	3	3	0	0	0	3	3	3	3
1947	3	3	3	2	2	3	3	3	3	3	0		0	0	0	3	0	3	3	3	3	3
1948	3	3	3	0	0	3	3	3	3	3	3		0	3	3	0	0	0	3	3	3	3
1949	0	0	0	0	0	0	0	0	0	0	0		2	3	0	0	0	0	0	0	0	0
1950	1	1	3	2	1	2	1	0	3	3	3		2	3	3	0	0	3	3	3	2	3

Table 1 (cont.)

	RFL 4A	RFL 4B	RFL 5A	RFL 6A	RFL 6B	RFL 7B	RFL 9A	RFL 9B	RFL 16AA	RFL 16BB	LRC 2A	LRC 5B	LRC 6A	LRC 6B	LRC 14A	LRC 15A	LRC 15B	LRC 16A	LRC 16B	LRC 17B	LRC 19A	LRC 19B
1951	3	3	3	3	0	3	3	3	2	3	3		0	0	0	0	0	0	3	3	3	0
1952	3	1	0	3	1	0	0	1	2	1	0		3	3	3	0	0	0	3	0	3	3
1953	3	3	3	3	1	3	3	2	2	3	3		3	3	3	0	0	0	3	3	3	3
1954	2	0	0	0	0	2	0	0	3	3	0		0	0	0	0	0	0	0	0	0	0
1955	2	3	3	2	1	3	3	1	3	3	3		3	3	0	3	3	3	3	3	3	0
1956	3	2	3	2	1	3	3	2	3	3	0		3	3	3	0	0	0	3	0	0	0
1957	3	2	3	0	0	3	2	0	3	3	3		0	0	3	3	3	3	3	3	3	3
1958	3	2	3	3	2	0	2	1	3	3	3		3	3	3	3	0	0	3	0	3	3
1959	3	3	3	0	0	2	1	0	3	3	3		3	3	3	3	3	3	3	3	3	3
1960	0	0	0	0	0	0	0	0	3	3	0		0	0	0	0	0	0	0	0	0	0
1961	0	0	3	0	0	0	0	0	3	3	0		0	0	0	0	0	0	0	0	0	0
1962	1	1	1	3	2	0	0	1	2	2	3		3	3	3	3	0	0	3	0	3	3
1963	3	3	3	2	1	3	3	3	3	3	3		3	3	3	3	0	3	3	3	3	3
1964	3	3	3	3	3	2	2	3	3	3	3		3	3	0	2	0	0	3	0	3	3
1965	3	2	2	0	0	1	3	3	3	3	3		0	3	0	0	0	0	0	0	3	0
1966	3	3	2	2	2	0	1	1	3	3	3		3	3	0	0	0	0	0	0	0	3
1967	0	0	0	0	0	0	0	0	1	1	3		3	3	0	3	3	3	3	3	3	0
1968	0	3	0	3	3	0	0	2	3	3	0		0	0	3	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	0	3	3	0		0	0	0	0	0	0	0	0	0	0
1970	3	0	0	0	0	3	0	1	3	3	0		0	0	0	0	0	0	0	0	3	0
1971	0	0	0	0	0	0	0	0	0	0	0		M	M	0	0	0	0	0	0	0	0
1972	0	0	0	3	2	3	3	3	3	3	3		0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	3	3	2		0	0	3	0	0	0	0	0	3	0
1974	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	M	0	0	M	0	M
1975	1	1	0	0	0	0	2	0	0	1	3		3	3	3	2	2	0	3	0	3	3
1976	0	1	3	1	2	0	2	1	3	3	3		3	3	3	0	0	3	3	3	0	3
1977	1	1	3	0	0	0	0	0	1	1	3		0	0	0	0	0	0	0	0	0	0
1978	3	3	0	3	3	0	3	3	3	3	3		0	0	0	0	0	0	0	0	0	0
1979	3	3	3	3	3	0	0	1	3	3	3		0	3	0	0	0	0	3	0	3	3
1980	3	2	3	1	2	3	2	0	3	3	0		0	0	0	0	0	0	0	0	3	0
1981	1	2	0	0	0	0	1	1	1	1	3		3	3	3	3	0	3	3	3	3	3
1982	0	0	0	0	0	2	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	1	0	0	0	3	1	0		0	3	0	0	0	0	2	3	0	0
1984	0	1	0	2	2	0	0	0	0	2	3		3	3	3	0	0	3	2	0	2	0
1985	3	2	3	3	3	1	1	2	3	3	3		3	3	3	0	0	3	3	0	3	3
1986	0	0	0	0	0	0	0	0	1	0	3		3	3	3	0	0	3	3	0	3	3
1987	3	3	3	3	3	0	1	2	3	3	0		3	3	3	0	0	3	3	0	3	3
1988	0	0	0	0	0	0	0	0	0	0	3		3	3	3	0	0	3	2	0	3	3
1989											0		0	0	0	0	0	0		0	0	0
Count	89	89	84	89	89	77	89	89	66	58	83	41	82	82	87	81	81	81	80	79	73	72
Mean	2.02	1.87	2.08	1.55	1.12	1.63	1.64	1.78	2.28	2.27	2.19	2.29	1.92	2.10	1.87	1.29	1.09	1.51	2.17	1.32	2.10	1.75

Table 2. Percent similarity in false ring presence/absence between 17 cores from two Rhyolite Canyon stands.
Data are for the period 1912 to 1988 and are based on Manhattan Metric Distance.

PERCENTAGE SIMILARITY

	R4A	R4B	R5B	R6A	R6B	R7B	R9A	R9B	L2A	L6A	L6B	L14A	L15A	L15B	L16A	L16B	L17A
R4A		90.7	81.5	71.0	51.3	76.3	75	75	65.7	63.1	65.7	59.2	60.5	55.2	57.8	71.0	59.2
R4B	90.7		82.8	75	57.8	69.7	76.3	78.9	69.7	64.4	69.7	63.1	64.4	59.2	61.8	72.3	65.7
R5B	81.5	82.8		65.7	48.6	76.3	80.2	77.6	76.3	73.6	76.3	69.7	60.5	60.5	68.4	78.9	67.1
R6A	71.0	75	65.7		75	63.1	61.8	72.3	60.5	65.7	65.7	59.2	52.6	52.6	55.2	63.1	59.2
R6B	51.3	57.8	48.6	75		43.4	50	55.2	43.4	48.6	46.0	42.1	48.6	48.6	48.6	40.7	52.6
R7B	76.3	69.7	76.3	63.1	43.4		75	72.3	63.1	60.5	57.8	59.2	63.1	63.1	60.5	68.4	67.1
R9A	75	76.3	80.2	61.8	50	75		81.5	69.7	64.4	64.4	65.7	56.5	64.4	59.2	69.7	65.7
R9B	75	78.9	77.6	72.3	55.2	72.3	81.5		67.1	64.4	64.4	63.1	69.7	59.2	61.8	67.1	63.1
L2A	65.7	69.7	76.3	60.5	43.4	63.1	69.7	67.1		76.3	78.9	72.3	63.1	60.5	68.4	84.2	59.2
L6A	63.1	64.4	73.6	65.7	48.6	60.5	64.4	64.4	76.3		92.1	82.8	65.7	65.7	78.9	84.2	64.4
L6B	65.7	69.7	76.3	65.7	46.0	57.8	64.4	64.4	78.9	92.1		80.2	63.1	60.5	71.0	86.8	64.4
L14A	59.2	63.1	69.7	59.2	42.1	59.2	63.1	65.7	72.3	82.8	80.2		61.8	59.2	75	80.2	60.5
L15A	60.5	64.4	60.5	52.6	48.6	63.1	69.7	56.5	63.1	65.7	63.1	61.8		81.5	68.4	68.4	67.1
L15B	55.2	59.2	60.5	52.6	48.6	63.1	64.4	59.2	60.5	65.7	60.5	59.2	81.5		76.3	63.1	75
L16A	57.8	61.8	68.4	55.2	48.6	60.5	59.2	61.8	68.4	78.9	71.0	75	68.4	76.3		76.3	69.7
L16B	71.0	72.3	78.9	63.1	40.7	68.4	69.7	67.1	84.2	84.2	86.8	80.2	68.4	63.1	76.3		67.1
L17A	59.2	65.7	67.1	59.2	52.6	67.1	65.7	63.1	59.2	64.4	64.4	60.5	67.1	75	69.7	67.1	

Percent similarity with all other cores.

	R4A	R4B	R5B	R6A	R6B	R7B	R9A	R9B	L2A	L6A	L6B	L14A	L15A	L15B	L16A	L16B	L17A
	67.4	70.1	71.5	63.8	50.0	64.9	66.1	67.6	67.4	69.7	69.2	65.8	63.4	62.8	66.1	71.3	64.2
	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16

Percent similarity with other cores in RFL (upper) stand.

	RFL cores								LRC cores								
	74.4	75.9	73.3	69.1	54.5	68.0	71.4	73.3	64.4	63.1	63.8	60.1	59.5	57.8	59.2	66.4	62.5
	7	7	7	7	7	7	7	7	8	8	8	8	8	8	8	8	8

Percent similarity with other cores in LRC (lower) stand.

	RFL cores								LRC cores								
	61.9	65.6	70.1	59.3	46.6	62.5	65.6	63.3	70.3	76.3	74.6	71.5	67.4	67.7	73.0	76.3	65.9
	9	9	9	9	9	9	9	9	8	8	8	8	8	8	8	8	8

Mean percent similarity of:

Each LRC core with each RFL core	61.9
Each LRC core with each LRC core	71.4
Each RFL core with each RFL core	70.0

Percent similarity between cores from single trees. (Mean is 82.8)

RFL4	RFL6	RFL9	LRC6	LRC15	LRC16
90.7	75.0	81.5	92.1	81.5	76.3