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# Cooperative National Park Resources Studies Unit

## ARIZONA

TECHNICAL REPORT NO. 32

Fire History of Rhyolite Canyon, Chiricahua National Monument

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COOPERATIVE NATIONAL PARK RESOURCES STUDIES UNIT
University of Arizona/Tucson - National Park Service

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# FIRE HISTORY

# OF

# RHYOLITE CANYON,

# CHIRICAHUA NATIONAL MONUMENT

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## ABSTRACT

Fire scar samples collected from areas along the length of Rhyolite Canyon were dendrochronologically analyzed to reconstruct three centuries of fire history. During the 17th to 19th centuries large surface fires often burned through most or all of the canyon at intervals of 9 to 22 years. Before 1801 mean fire intervals were 14.6 years for fires scarring more than 25% of sampled trees and 6.2 years for fires scarring any sampled tree. Shorter interval fires (2 years minimum interval) were recorded in sub-areas of the canyon during periods in the 1700's in the upper canyon and after 1851 in the lower canyon. There was an unusual gap in fire occurrence in the middle and upper portion of the canyon from 1801 to 1851. After this hiatus fires apparently no longer spread between the upper and lower canyon. The episodic fire regime of the 17th, 18th and 19th centuries ended around the beginning of the 20th century, although a fire in 1924 was recorded in several areas of the canyon.

# INTRODUCTION

Knowledge of fire regimes, including the frequency, areal extent, and intensity of past fires, is needed to evaluate and plan prescribed burning programs in wilderness and parks. There is widespread agreement among most forest scientists and land managers that fire is essential for the healthy functioning of forest and woodland ecosystems, and that this process should be reintroduced in wilderness and parks where it has been artificially excluded by humans. Fire regimes are, however, highly variable both spatially and temporally, even within forest types. Documentation of past fire regimes is therefore one of the first and most basic scientific inventories that is necessary to improve understanding of the fire process within specific management units.

The objective of this study was to reconstruct a long-term history of fire within the Rhyolite Canyon watershed of Chiricahua National Monument. This history was developed through collection and analysis of tree-ring samples from fire-scarred trees within the canyon, and from written fire records kept by the National Park Service. This report contains a complete description of the results of dendrochronological dating of 33 sampled trees. Interpretations and questions regarding the 380-year history contained in the tree-ring records are discussed, and potential future investigations designed to answer some of the questions are broadly outlined.

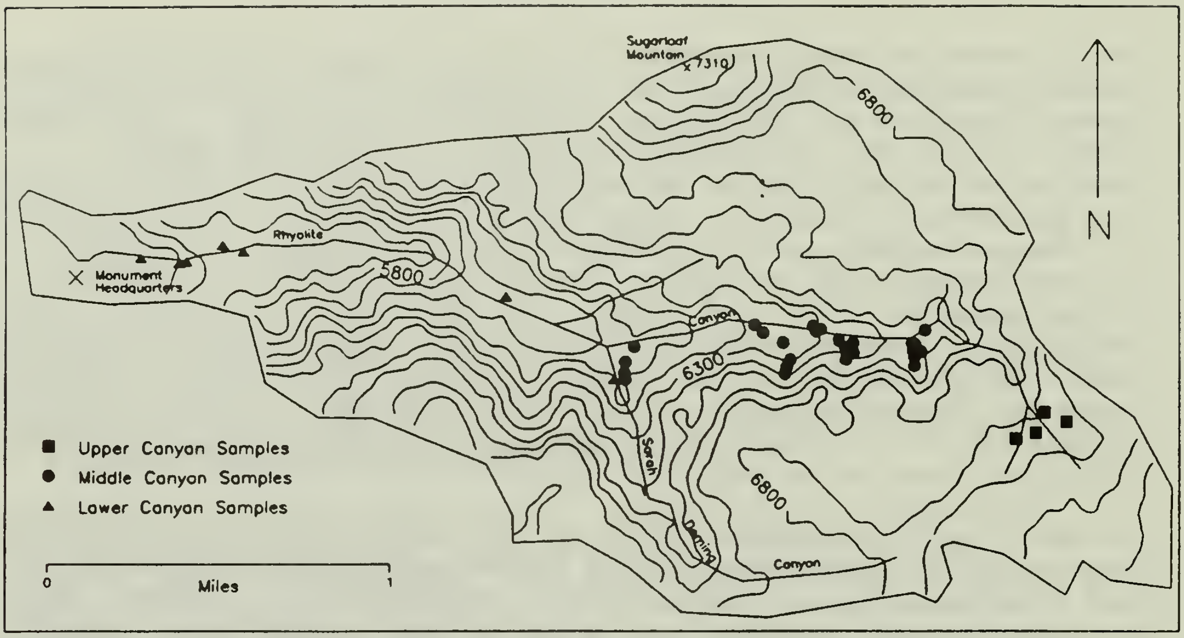
Rhyolite Canyon fire history is particularly unique and insightful. This is the first fire history from a stand of this southwestern type. The Rhyolite plant community is a mixed-conifer and oak woodland forest that is restricted to the canyon bottom and north-facing slopes along its length. South facing slopes are generally occupied by xerophytic plants, such as evergreen sclerophyll shrubs, i.e., interior chaparral. The forest extends below the usual elevational limits for most of the primary conifer trees that are present. Cold air drainage and presence of sub-surface water in the canyon are responsible for this strip-like forest. Fire and vegetation histories from ecosystems such as Rhyolite are also interesting because these are communities that may be especially sensitive to other climate related disturbances, such as flood events. Rhyolite offers a special opportunity for study of the interactions of these environmental variables.

## DESCRIPTION OF STUDY AREA

Chiricahua National Monument is located in southeastern Arizona approximately 76 km (47 miles) north of the Mexican border and 156 km (97 miles) southeast of Tucson. The monument lies on the northwestern flank of the Chiricahua Mountains which rise to an elevation of 2,985 m (9,793 feet). The monument occupies a relatively low area at the north end of the main range and is prominently dissected by several westward draining canyons. Elevations within the monument range between 1,579 and 2,229 m (5,180 and 7,313 feet). The Chiricahua Mountains are part of a southern extension of the Basin and Range province located between the Colorado Plateau and the Sierra Madre to the south in Mexico. They are a component of the Mountain Plateau or southeast high section of this province which extends eastward into western Texas.

Climate of southeastern Arizona is semi-arid, characterized by low rainfall, relatively high temperatures and evaporation, and low humidity. Precipitation is distinctly bimodal with wet winters and summers and a pronounced foresummer drought (April-June) and a less predictable fall drought. Summer rains in the form of thunderstorms occur from July to September with moist air usually flowing from the southeast. Winter storms from December to March are usually derived from frontal systems from the northwest (Sellers et al. 1985). Average temperatures for oak woodland stations in southeast Arizona are highest in late June and early July and lowest during January. Average minimum temperature for January is -0.2°C (31 °F) while average maximum is 14.7°C (56 °F). In July the average minimum and maximum temperatures are 17.4 and 32.8°C respectively (63 and 91 °F).

The study area is within Rhyolite Canyon drainage east of the monument headquarters (Figure 1). Rhyolite is the largest canyon within the monument (Reeves 1976) and drains westward into the Sulfur Springs Valley. Its headwaters lie on the divide with East White-tail Canyon. Streamflow within Rhyolite is intermittent. The stream channel is well developed with a relatively broad, gravelly, boulder-strewn bottom at the monument headquarters. Elevations range between 1,640 m (5,381 feet) at the headquarters to 2,229 m (7,313 feet) at the summit of Sugarloaf Mountain. The study area includes most of the Sarah Deming drainage, the mesa-like area to the west of Sarah Deming and north of Jesse James Canyon, and the monument's eastern boundary along the divide with White-tail Canyon. The southern flank of Sugarloaf Mountain and Echo Canyon make up the northern half. Major tributaries to Rhyolite are Sarah Deming, Echo, Totem and Hunt Canyons.



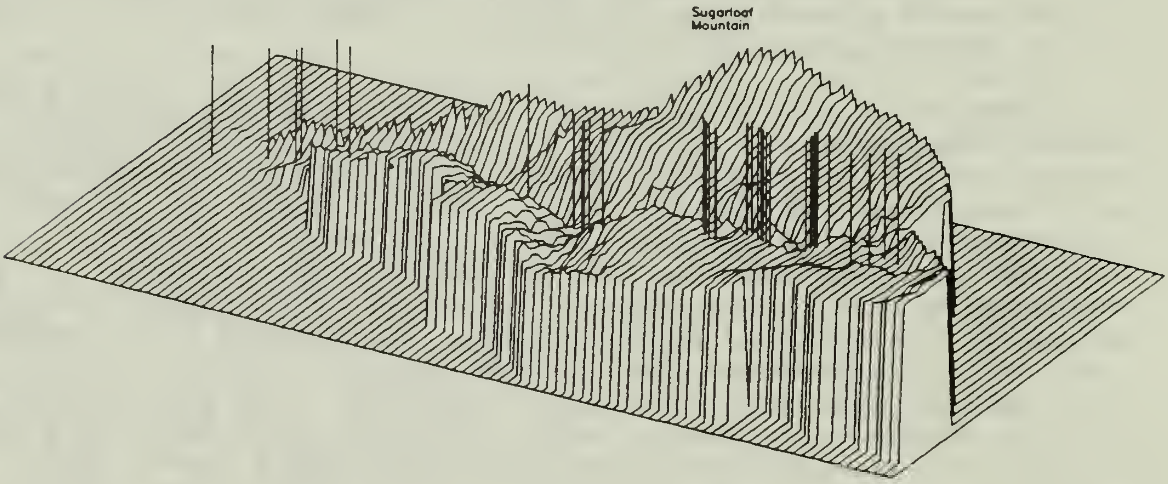




Figure 1. Fire scar sample locations, Rhyolite Canyon, Chiricahua National Monument, Arizona.

Geologically the area is predominately rhyolitic tuff created by volcanic activity 28 million years ago. The fracturing, faulting, and erosion of this material has resulted in the rugged, dissected topography, which is one of principal public attractions in the monument (Reeves 1976; Murray 1982). Soils are shallow on the uplands, but relatively deep and stable in canyon bottoms, and generally gravelly to moderately coarse (Reeves 1976). Slopes are of varying degree and exposure, but slope aspects are predominately north or south. Slope aspects are especially important in determining species composition through the effects of insolation and evapotranspiration.

Vegetation of the study area is diverse, and is a consequence of a broad range of elevation, precipitation, temperature, topography, soil, and fire regimes. Plant species composition is strongly influenced by distinct regional plant communities located to the north, east and south, leading to a high degree of biotic complexity not found at higher latitudes (Whittaker and Niering 1965). Higher elevation, mesic montane conifer forests found within protected habitats in Chiricahua National Monument have northern affinities while lower elevation semi-desert grasslands have affinities to the east. Madrean evergreen oak woodland, making up 60% to 65% of the vegetation cover in the monument (Reeves 1976; Murray 1982), is strongly influenced by the Sierra Madre, where the distributional center of oak woodland is located, but the type within Rhyolite also has some affinities with more northern and western interior chaparral.

Detailed descriptions of the vegetation within the monument can be found in Roseberry and Dole (1939), Moir (1974, 1975), Reeves (1976), and Murray (1982). Major plant associations are interior chaparral, semi-desert grassland, montane conifer forest, relict conifer forest, and Madrean evergreen woodland. Sampling for this study was carried out in the montane conifer forest and Madrean evergreen woodland.

Montane conifer forest is found on mesic, north-facing slopes and canyon bottoms above 1,600 m (5,249 feet) (Murray 1982). This type is common in Totem and Hunt Canyons with an overstory of pine and Douglas-fir, *Pseudotsuga menziesii*, and an understory of oak, *Quercus* spp. In a review of historic fire records Murray (1982) states that fire in this community is rare to non-existent, with some exceptions such as in Totem Canyon where low intensity ground fires seem to have occurred. In upper Hunt Canyon a nearly pure pine community exists consisting of ponderosa pine, *Pinus ponderosa*, with an open understory (Reeves 1976). Fire is believed to have frequently occurred in the pine type (Murray 1982).

Relict conifer forest dominated by *Cupressus arizonica* (Arizona cypress) can be found on canyon bottoms at low to mid-elevations (Reeves 1976). This type replaces *Pseudotsuga menziesii* and *Pinus ponderosa* at lower elevations in Rhyolite Canyon. Murray (1982) states that the fire regime in the Arizona cypress community type varies greatly in frequency and severity. He felt the community in Rhyolite Canyon was comparatively isolated from the fire regimes of surrounding community types.

Madrean evergreen woodland within the study area can be subdivided into Mexican oak-pine woodland, open oak woodland and riparian oak woodland. The Mexican oak-pine woodland is found throughout the monument, and is especially common on upland slopes, and mesas. *Pinus ponderosa, P. leiophylla* var *chihuahuana* (Chihuahua pine), *P. engelmanii* (Apache pine) and *P. cembroides* (piñon pine) are common. This is probably a fire tolerant and fire maintained community and although the fire regime is poorly understood (Marshall 1957), Murray (1982) suggests it may be similar to other pine communities.

Open oak woodland is restricted to south-facing slopes in the lower portions of canyons in the study area. *Quercus emoryi* (Emory oak) dominates at lower elevations while *Q. arizonica* (Arizona white oak) is more common at higher elevations. Fire frequency is considered very important in determining structure of this woodland (Murray 1982). Riparian oak woodland is found in the canyon bottom in the lower sections of Rhyolite Canyon.

Interior chaparral composed of evergreen sclerophyll species such as *Arctostaphylos pungens* (point-leaf manzanita), *Q. toumeyi* (Toumey oak), *Q. arizonica, P. cembroides* and *Juniperus deppeana* (alligator juniper) is found in a mosaic pattern throughout the Mexican oak-pine woodland (Reeves 1976; Murray 1982). *P. cembroides* and *Juniperus deppeana* are considered to be recent invaders of chaparral since the inception of fire control (Murray 1982).

An open grassland is found on the north side of Sugarloaf Mountain and may be attributed to a severe fire in the late 19th-century (Reeves 1976). Prior to fire control, it is believed that some of the present mixed grass-scrub stands were open grassland kept free of shrub invasion by fire (Murray 1982).

Major tree species occurring in the study area are: *Pseudotsuga menziesii, Pinus ponderosa, P. leiophylla* var *chihuahuana, P. engelmanii, P. cembroides, Cupressus arizonica, Quercus chrysolepis* var *palmeri* (canyon live oak), *Q. rugosa* (netleaf oak), *Q. hypoleucoides* (silver-leaf oak), *Q. emoryi, Q. arizonica, Arbutus arizonica* (Arizona madrone), and *Juniperus deppeana*. Species from which good fire scar records were obtained were *Pinus* *ponderosa* at the higher elevations and *P. engelmanii* in the lower canyon area. Some evidence of scarring was also observed on *Cupressus arizonica, Quercus* spp. and *Arbutus arizonica*.

## Fire in Southeastern Arizona

The fire season in southeastern Arizona occurs mainly in the late spring and early summer, prior to the inception of the "Arizona monsoon", but often extends throughout the summer into October. The pre-monsoon season is a period of high temperature, low humidity, and dry vegetation. Weak storm cells sometimes develop in which virga and lightning are common. Lightning during this period often results in isolated or clusters of ignitions that are associated with specific storm systems (Bock et al. 1976; Murray 1982; Pyne 1984).

Fires ignited by lightning are possible in southern Arizona from April through November, with peak occurrence in a several week period before the height of the monsoon at the end of July. By August, when thunderstorm activity is often very high, soils and woody fuels at upper elevations are typically saturated with moisture and fire activity is limited. When drier conditions return toward the end of September, few thunderstorms occur and fire activity remains low. Almost 60% of the annual area burned by lightning fires within the National Forests of Arizona and New Mexico originate from June fires. By contrast, May accounts for 17.1%, July for 18.1% and August for only 2.5% of the annual area burned per fire (Barrows 1978). The Coronado National Forest, which borders portions of Chiricahua National Monument, leads the Southwest in annual area burned per million protected acres (3,401 acres/million acres protected [Barrows 1978]).

The maximum level of lightning-fire occurrence in southern Arizona is within the elevation range of 1,700 to 2,300 m (5,580 - 7,550 feet), with 53.2% of the total occurrence. Barrows' study concluded that lightning-fire occurrence in southern Arizona was distributed randomly by aspect and was weighted heavily to the ponderosa pine habitat types (48%), followed by grass (26.5%), brush (13.8%), mixed-conifer (5.8%) and woodland (5.8%).

Few studies of fire history or fire effects in Madrean evergreen woodland have been conducted, but the presence and importance of fire within the various woodland community types has been noted (Leopold 1924; LeSueur 1945; Wallmo 1955; Marshall 1957, 1963; Niering and Lowe 1984). Marshall (1963), surveying birds in the Mexican pine-oak woodlands, compared woodlands of Mexico to those in the United States and felt fire played a different role due to the differences in fire suppression policies at the time of his study. In Mexico, where fire suppression was minimal, he found the woodlands to be open with a dense grass understory. Across the border in the United States where fire suppression was sophisticated and generally effective, Marshall observed that woodlands were stunted, have heavy fuel accumulations, and little grass understory. Fires that do occur are often severe and may kill most of the overstory trees and understory plants.

Moir (1982) studied the fire history of Boot Canyon, in the high Chisos Mountains in Big Bend National Park, which may be classified as Madrean evergreen woodland with Arizona cypress. Ring counts from scars on *Pinus cembroides* indicate at least 10 fires between 1770 and 1940. He suggests a 50-year return interval and that the fire frequency was the same in 1880 as today. He also emphasized that fire effects and history in one canyon woodland may not be comparable to another canyon (Moir 1980). Vegetation differences between southwestern canyons are often great and have not yet been classified to a sufficient degree. Additionally, he considers fire in canyon bottoms to have likely been very local with little influence from surrounding upland areas. However, a recently completed fire history study of Frijoles Canyon in Bandelier National Monument indicates fires generally burned in the canyon bottom (riparian, cottonwood and ponderosa pine) during the same years major fires burned on the surrounding mesa tops (ponderosa pine and mixed conifer) (Caprio et al. 1988).

## METHODS

### Modern Fire Records

Chiricahua National Monument has maintained records of fire occurrence within the monument boundaries since the 1920's. These records include date, size, location, and fuel type. A report by Jandrey (1975) includes fire occurrence information from the early 1920's through 1975. Fire records and other sources were reviewed to aid in interpretation of fire-scar data.

### Dendrochronology

Rhyolite Canyon and adjacent areas were surveyed in the fall of 1987 to locate potential sample sites and fire-scarred material. Following initial reconnaissance, cross sections or partial sections of snags, stumps, downed logs, and living trees were collected. Criteria used to select samples were:

1) number of visible scars as evidenced by the number of healing ridges observed on the scarred stem and 2) state of preservation, i.e., degree of decay present (Swetnam 1983a). Occasionally two or more cross sections were cut from the same tree when it appeared that all of the scars visible within the wound would not be represented on a single section (Dieterich and Swetnam 1984). The samples were collected in clusters where possible in order to maximize the information obtained for each collection site, since individual trees rarely record every fire which burns within their vicinity (Arno and Sneck 1977; Kilgore and Taylor 1979).

Many tree species respond to injury through a process of sealing off injured areas from healthy tissue by including pathogen resistant compounds in woody tissue around the site of the wound (Shigo and Marx 1977). Conifers appear to concentrate resins at the injury site and dendrochronologists have observed that the entire stem around the site of a wound, such as a fire scar, may become impregnated with resin over time. This resinous portion resists decay and may persist for long periods of time in a remarkable state of preservation (Dieterich and Hibbert 1988). These old fragmented pieces of wood are referred to in this report as "remnants". Remnants were sought out as potential samples through which the fire record might be extended back in time, and also as a means of gathering useful fire history information without relying exclusively on samples from living trees.

A chain saw was used to fell snags, section logs and stumps, and remove samples from living trees. Where possible, as an alternative to felling snags, wedge sections were removed from the face of the scar as described by Arno and Sneck (1977). Thirty-five cross sections or wedges were collected in this manner. Twenty-four of these samples were from remnants and eleven were from living trees. One additional sample, which had been previously collected, was obtained from Chiricahua National Monument.

Although the tree-ring sampling must be considered partially destructive, the overall impact on the Monument's resources is considered to be very low. All samples were out of sight of main trails, and in some instances were in quite remote areas. Living trees from which partial wedges were taken should not succumb immediately from the sampling. However, these stems may be more susceptible to wind throw and invasion by decay organisms. Sampling of limited numbers of living trees (including removal of partial wedges and felling) has been deemed scientifically justifiable and appropriate for meeting management information needs in many other National Parks and Forest Service wilderness areas (Kilgore 1987). The sampling of snags and downed logs might be considered a "salvage" of scientific information, since this material is continually decaying, and thus information on past forest ecosystems is becoming less available. Much of this dead woody material is present only because of fire suppression activity during the current century; under pre-settlement fire regimes it would have burned up long ago. As prescribed burning activity becomes more common place within parks and monuments this material will be consumed and historic information lost.

The samples were sectioned with a band saw and sanded with a series of progressively finer grit sanding belts to prepare the surface. Grit sizes down to 400 were used for this purpose. The cross sections were examined with a binocular microscope, and crossdated as described by Stokes and Smiley (1968). Once the specimens had been successfully crossdated, the fire dates (determined from the fire scars) were recorded. The position of the scars within the rings, where it was possible to discern, was also noted in order to provide an estimate of the season of occurrence (Barrett 1981; Dieterich and Swetnam 1984).

In conjunction with the collection of fire scarred samples, an increment borer was used to extract cores from living trees at selected sites within the study area. These cores were mounted, surfaced, crossdated and a chronology developed to aid in dating the remnant material for which the outside or "bark" date was unknown (Douglass 1941; Stokes and Smiley 1968). All tree-ring and fire-scar dating was checked by a second dendrochronologist to ensure accuracy.

Increment cores from unscarred ponderosa pine used to develop the local chronology were commonly missing 10 to 15 annual growth rings between 1940 and 1986 and were essentially undatable for this period. Other specimens showed stem growth for all years during this interval. Growth anomalies associated with fire scarring exacerbate this problem in scarred specimens. The growth decline phenomena is poorly understood at this time. It does not seem to be due to senescence in the older trees, as some very old trees do not show it, while some relatively young trees do. Other dating problems were associated with the formation of false rings[1] in *Pinus* spp. growing at low elevations, and extensive networks of insect galleries in many of the cross section samples. Due to

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[1]False rings are bands of latewood cells formed within an annual growth ring. The longer growing season and more pronounced early summer drought present at lower elevations and on exposed slopes below 2,300 m (7,550 feet) may be responsible for this common phenomenon as drought stress has been linked to the formation of latewood bands during the growing season (Fritts 1976).

these obstacles the use of simple ring counting methods, as opposed to dendrochronological crossdating, would rarely have yielded accurate dates. A record of fire occurrence so derived would be indecipherable because of the variability encountered. The use of remnant material would, of course, have been impossible without crossdating since exact dates of ring formation in these old fragments of wood can only be determined with these procedures.

An index of the extent of past fires was computed as a proportion of the number of trees scarred for a particular year relative to the number of fire-scar susceptible trees for that year. A fire-scar susceptible tree is defined as one that has already sustained a scar and is therefore more likely to scar during subsequent fires (Romme 1980). The fire-scar index was plotted by different elevation groups to compare fire occurrence at different sites in the canyon.

### Seasonal Occurrence of Past Fires

Individual fire scars were examined in an attempt to determine the season of occurrence (Ahlstrand 1980; Barrett 1981). This involved observing the relative position of each fire scar within the annual ring in which it occurred. Inferences on the seasonal or monthly timing of past fires based on their position within annual rings depends upon our current knowledge of cambial phenology. These inferences and their limitations will be explored in the discussion section.

The fire scars were identified as one of the following types based on observations of relative positions within annual rings:

D - Dormant season. The fire scar occurred on the boundary of two rings, with latewood cells of the prior year on one side of the scar and earlywood cells of the next year on the other side of the scar. By convention, for southwestern U.S. fire scar material, dormant season scars are dated to the year of formation of the adjacent earlywood cells. Technically, this type of fire scar could be formed by fires occurring between approximately mid-September of one year and late April or May of the next year. Dating these scars to the year of the adjacent earlywood assumes that the fire was a spring or early summer fire, rather than a late summer or early fall fire of the previous year. Justifications for this assumption are described in the discussion section.

E - Earlywood. The fire scar occurred within earlywood cells of one annual ring. These types of scars were further sub-classified where possible into categories of EE, early-earlywood, occurring within the first one-third of the earlywood portion of the ring; ME, mid-earlywood, occurring in the second one-third of the earlywood; LE, late-earlywood, occurring in the last one-third of the earlywood. Earlywood scars that could not be sub-classified were simply given the generic classification of E, earlywood. Earlywood type scars were probably formed by fires occurring between May and late July or August.

L - Latewood. The fire scar occurred within the latewood cells of the ring. Latewood type fire scars were probably formed by fires occurring between August and mid-September.

Identification of fire scar position, and attendant interpretation of seasonal timing of past fires, is somewhat imprecise and subjective because: 1) it necessarily involves the judgment of the observer; 2) ring widths at the site of the injury are often so small that the exact position of the scar within the ring is impossible to determine; and 3) the initiation and cessation of cambial growth may vary from year-to-year, from micro-site to micro-site, and from one tree species to another. However, despite these uncertainties, after examining hundreds of scars from an area the pattern of scarring usually emerges and exceptions to this pattern become noticeable. Additional insight can be gained by examining scars resulting from fires of known calendar date.

## RESULTS

### Modern Lightning Fire Data

Fire records are available from Chiricahua National Monument starting in the mid 1920's, however, prior to 1946 it is possible that not all fires were reported (Jandrey 1975). Lightning was responsible for 80% of the reported fires in the monument between 1946 and 1975 (Jandrey 1975). Most ignitions occurred during July, with the earliest reported being May 3 and the latest on October 25. An average of 1.5 lightning fires occurred per year between 1946 and 1975. Murray (1982) estimated the number of these fires with potential for spread was 0.8 per year. The month with the highest average spread index was June, which coincides with the warmest and driest period in the year. With the start of summer rains fuel moisture increases and greenup of herbaceous vegetation occurs reducing the spread potential. This greenup has the greatest effect on vegetation types where grass is the primary fuel.

Murray (1982) found that most ignitions and intense fires were within interior chaparral and Mexican pine-oak woodland types, particularly in areas with *Arctostaphylos pungens* and grasses.

Distribution of fires by elevation was bimodal with peaks at lower and upper elevations in the monument. Most spreading fires were at low elevations around 1,700 m (5,580 feet), and ignitions above 2,070 m (6,800 feet) were usually single tree, or snag fires (Murray 1982).

The modern record suggests a scattered ignition pattern and rather low overall ignition rate, of which perhaps 50% would have resulted in spreading fires. This pattern and rate may not be sufficient to explain the mean fire interval calculated for the canyon bottom. Of the recorded fires approximately 26% occurred within the Rhyolite drainage or on associated ridges. It is not clear at this time where the source areas for ignitions affecting the canyon were located. Almost no ignitions recorded in the modern record occurred within the canyon proper leading to the conclusion that the majority of historic fires were ignited elsewhere and were able to spread into and within the drainage.

It should be noted that comparison of recent versus past fire regimes and ignition sites must be interpreted in light of associated vegetation changes which may have occurred in the last 100 years. Changes have been noted in most vegetation types of southeast Arizona (Leopold 1924; Marshall 1957, 1963; Hastings and Turner 1965; Reeves 1976) and are very apparent in oak woodlands, desert grasslands, and pine forest. These changes include an increase in dominance of woody plants and a corresponding decrease in dominance of herb species. Alteration in the fuel matrix would certainly affect ignitions and spread of fire through the various vegetation types. Identifying potential source areas for past fires that may spread into Rhyolite Canyon is therefore not a simple task. However, additional fire scar sampling and other studies may help to resolve some of these questions.

## Fire Scar Record

The fire-scar record from Rhyolite Canyon is summarized in a master fire chronology presented in Figure 2. Thirty-three samples from living and remnant material were dated and form the basis for the record.[2] Horizontal lines represent individual trees and are arranged by groups in order of decreasing elevation within the drainage. Arrows along the lines mark locations of fire scars observed within the ring

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[2]Three additional samples were collected from Arizona cypress located near the middle of the canyon. Ring formation in this species is not well understood and the samples were only tentatively crossdated. Results from these samples were therefore not included in this report.

series. Arrows on both sides of a line indicate that scars for that year occurred in more than one place on the ring circumference. A total of 418 fire scars from Rhyolite Canyon were dated and are listed by individual tree in Appendix B.

Fire-scar indices for Rhyolite Canyon are plotted by elevation group and for the entire canyon in Figure 3. Prior to 1801, fire-scarred trees recorded fairly regular canyon-wide events. With few exceptions, trees at the canyon mouth recorded fires with the same frequency as those at the canyon head. Table 1 lists fire interval data for selected periods of the chronology. The periods were logically divided by the depth of sample coverage through time and obvious changes in the record, such as the period after 1801 and after 1851. Table 2 lists the same descriptive statistics for fire years when 25% or more of the fire-scar susceptible trees were scarred. Thus, the values in Table 1 describe the occurrence of all recorded fires within the canyon, while values in Table 2 are descriptive of larger fires.

The mean fire interval (MFI) for large fires that burned through most or all of Rhyolite Canyon (See Table 2) is 14.6 years with a range of 9 to 22 years. In general, for the 1655 to 1801 period, the MFI estimates do not differ appreciably from the upper to the lower reaches of the canyon. After 1801, however, this pattern of episodic, canyon-wide fire changes dramatically. At this point a fifty-year gap in the fire record is visible in the upper and middle part of the canyon. Only a single fire in 1818 was recorded by one tree (RHY 16, See Figure 3) above Sarah Deming Canyon. Trees in the lower canyon continued to sustain fire scars, with a MFI similar to the period prior to 1801 (See Tables 1 and 2).

After 1851, fires were recorded again by trees in the upper and middle portions of the canyon until 1886 when the last wide-spread fire was recorded (sample RHY 7 recorded a fire in 1894 which was not recorded by other samples). The lower canyon during this period was still under a largely separate fire regime characterized by a pronounced increase in fire frequency. Lower canyon trees recorded fires in 1852, 1856, 1859, 1867, 1873, and 1882 for a much reduced MFI of 6.0 years. Of these fires only the fire of 1873 was recorded by sampled trees in other areas of the canyon. After the late 1880's only two fires were recorded anywhere in the drainage: 1) a fire in 1924 recorded by trees in both the upper and lower parts of the drainage; and 2) fires recorded by two different trees in 1980 and 1983 (RHY 7 and RHY 22 respectively). These latter two fire events may have been prescribed burns conducted by NPS, although we have not yet confirmed this possibility.

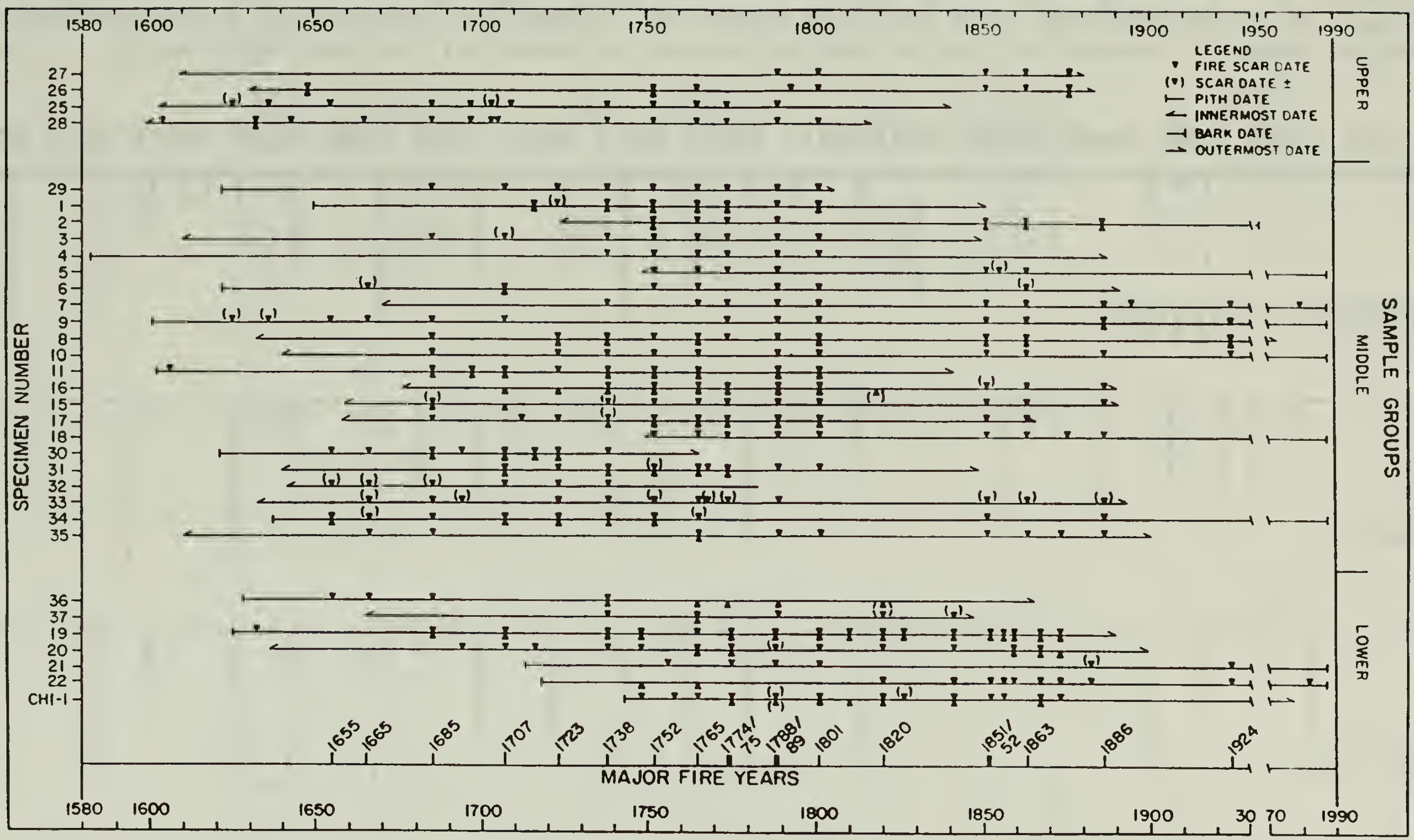


Figure 2. Master fire chronology for Rhyolite Canyon, Chiricahua National Monument.

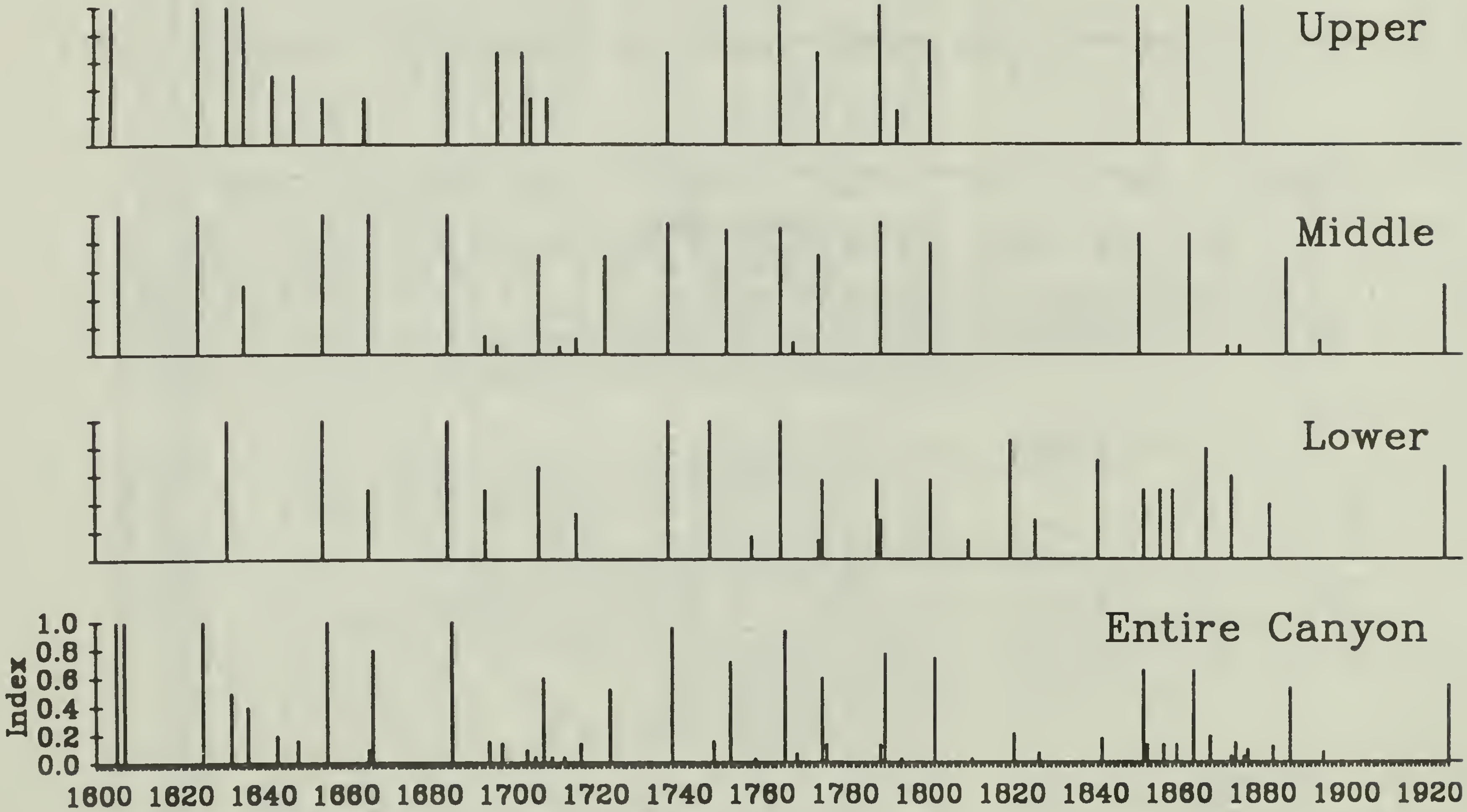


Figure 3. Fire-scar indices for sample groups within Rhyolite Canyon. Index values were computed as a proportion of number of trees scarred per year relative to the number of fire-scar susceptible trees in each year. Canyon-wide fires are visible as bars that are common to all three groups. The 50-year fire interval in the early 1800's is obvious in the Upper and Middle plots.

Table 1. Mean Fire Intervals (MFI) for Rhyolite Canyon using all fires (see Figure 2). MFIs, standard deviations, and ranges are reported in years.

| LOCATION | PERIOD | NO. OF FIRES | MFI | STD. DEV. | RANGE |
|---|---|---|---|---|---|
| Upper | | | | | |
| | 1604 to 1801 | 20 | 10.4 | 6.7 | 2 to 28 |
| | 1801 to 1851 | 0 | 50.0 | - | - |
| | 1851 to 1876 | 3 | 12.5 | - | 12,13 |
| | 1604 to 1876 | 23 | 12.4 | 10.3 | 2 to 50 |
| Middle | | | | | |
| | 1606 to 1801 | 19 | 10.8 | 5.3 | 3 to 19 |
| | 1801 to 1851 | 1 | 25.0 | - | 17,33 |
| | 1851 to 1894 | 6 | 8.6 | 3.1 | 3 to 12 |
| | 1851 to 1924 | 7 | 12.2 | 8.6 | 3 to 30 |
| | 1606 to 1894 | 26 | 11.5 | 6.6 | 3 to 33 |
| | 1606 to 1924 | 27 | 12.2 | 7.5 | 3 to 33 |
| Lower | | | | | |
| | 1632 to 1801 | 16 | 11.3 | 6.0 | 1 to 23 |
| | 1801 to 1852 | 4 | 10.2 | 2.3 | 6 to 15 |
| | 1852 to 1882 | 6 | 6.0 | 2.3 | 3 to 9 |
| | 1852 to 1924 | 7 | 12.0 | 13.6 | 3 to 42 |
| | 1632 to 1882 | 26 | 10.0 | 5.4 | 1 to 23 |
| | 1632 to 1924 | 27 | 11.3 | 8.1 | 1 to 42 |
| Entire | | | | | |
| | 1604 to 1801 | 32 | 6.2 | 4.6 | 1 to 19 |
| | 1801 to 1851 | 5 | 8.3 | 3.9 | 2 to 15 |
| | 1851 to 1894 | 13 | 3.6 | 2.1 | 1 to 8 |
| | 1851 to 1924 | 14 | 5.6 | 7.3 | 1 to 30 |
| | 1604 to 1894 | 50 | 5.8 | 4.3 | 1 to 19 |
| | 1604 to 1924 | 51 | 6.3 | 5.4 | 1 to 30 |

Table 2. Mean Fire Intervals (MFI) for Rhyolite Canyon using fire events recorded on at least 25% of the fire-scar susceptible trees. MFIs, standard deviations, and ranges are reported in years. 1655 was the earliest fire date used for computations; before this date tree-ring sample depth was too low to accurately estimate fire-scar indices. Note that MFIs for the middle canyon trees are the same as for the entire canyon.

| LOCATION | PERIOD | NO. OF FIRES | MFI | STD. DEV. | RANGE |
|---|---|---|---|---|---|
| Upper | | | | | |
| | 1655 to 1801 | 13 | 11.8 | 6.9 | 2 to 28 |
| | 1801 to 1851 | 0 | 50.0 | - | - |
| | 1851 to 1876 | 3 | 12.5 | 0.5 | 12,13 |
| | 1655 to 1876 | 16 | 14.5 | 11.3 | 2 to 50 |
| Middle | | | | | |
| | 1655 to 1801 | 11 | 14.6 | 3.6 | 9 to 22 |
| | 1801 to 1851 | 0 | 50.0 | - | - |
| | 1851 to 1924 | 4 | 24.3 | 10.7 | 12 to 38 |
| | 1655 to 1924 | 15 | 19.2 | 11.1 | 9 to 50 |
| Lower | | | | | |
| | 1655 to 1801 | 13 | 12.6 | 5.0 | 1 to 21 |
| | 1801 to 1852 | 4 | 12.8 | 4.8 | 6 to 19 |
| | 1852 to 1924 | 6 | 6.0 | 2.3 | 3 to 9 |
| | 1655 to 1924 | 23 | 12.5 | 8.3 | 1 to 42 |
| Entire | | | | | |
| | 1655 to 1801 | 11 | 14.6 | 3.6 | 9 to 22 |
| | 1801 to 1851 | 0 | 50.0 | - | - |
| | 1851 to 1924 | 4 | 24.3 | 10.7 | 12 to 38 |
| | 1655 to 1924 | 15 | 19.2 | 11.1 | 9 to 50 |

The fire recorded in 1886 by trees in the mid-canyon groups may represent the fire referred to by Roseberry and Dole (1939) and others. This fire reportedly burned from the area of Sugarloaf Peak south to Pinery Canyon. Sugarloaf itself does not support the growth of ponderosa pine or other species which record fire events and can be dated by dendrochronological methods. Collection of additional samples in other areas such as Bonita Canyon or within the possible boundaries of this burn might confirm the timing and extent of the fire.

**Seasonal Occurrence of Past Fires**

Of a total 418 dated fire scars it was possible to confidently assign relative positions within annual rings to only 251. It was not possible to identify position of the fire scars in other cases because the annual rings were too small, or decay and insect galleries prevented making these observations. The distribution of relative positions of fire scars is shown in Table 3.

These data were sorted by fire date and a series of histograms constructed for ten major fire years between 1685 and 1886 (See Figure 4). Most fires (80%) occurred within some portion of the earlywood, indicating that growing season fires from approximately May to August would be most typical of pre-settlement fires. In spite of expected differences in cambial phenology between individual trees and species, certain patterns revealing specific seasonal timing of past fires are evident in the data.

The fires of 1685, 1707, 1765, and 1801 appear to have occurred early in the growing season, perhaps during the month of May or June. The fires of 1738, 1789, 1851, 1867, and 1886 appear to have occurred well into the growing season, possibly as late as August or September.

Prescribed natural fires in wilderness areas of the southwest often continue to burn for a month or longer after ignition, with periods of inactivity punctuated by brief intervals of relatively rapid spread under favorable conditions. The range of values for the fire of 1752 may represent this type of behavior (See Figure 4). Another possibility is that the range of scar position was a result of separate fires occurring at different times during the same year.

Our inferences of monthly timing of these fires is based on studies of intra-annual growth of ponderosa pine in the Santa Catalina Mountains of southern Arizona over the five-year period 1963-1967 (Fritts 1976). The trees studied were

Table 3. Relative positions of fire scars within annual rings of specimens from Chiricahua National Monument, Arizona.

| Relative Position | Number of Fire Scars | Percent of Total |
|---|---|---|
| D | 42 | 17 |
| E | 64 | 26 |
| EE | 33 | 13 |
| ME | 71 | 28 |
| LE | 33 | 13 |
| L | 8 | 3 |
| Total | 251 | 100 |

growing at an elevation of 2,590 m (8,500 feet) on an arid site. Fritts found cambial activity began in late April, increased steadily through May and June, was most rapid during July and early August, and had generally ceased by mid-September. This indicates a fire during May could be recorded within the earlywood. A scar occurring between the latewood of one year's growth and the earlywood formed the subsequent year, or dormant season scar, would indicate a fire having occurred between mid-September and late April. However, during 1967, Fritts observed that mature xylem cells were not formed until June, so that under some conditions a fire resulting in what might appear to be a dormant season scar could possibly occur as late as the month of May. A scar within the latewood cells would probably indicate a fire occurring in late August or early September. Since southern Arizona's lightning season begins in late April or early May and there is little lightning activity in the fall, dormant season scars are dated by convention to the spring of the coming year (adjacent earlywood cells) unless there is some contraindication, such as a latewood scar on one tree associated with dormant season scars on others (Swetnam 1983b).

There is an obvious difference in elevation between Fritts' Santa Catalina Mountain study area and Rhyolite Canyon (2,590 m versus about 2,000 m respectively). Because of elevation differences, the growing season in Rhyolite may be a month or more longer. This introduces some uncertainty into interpreting fire-scar position based on Fritts' results. A fire scar specimen collected in late May 1988 had some recently developed earlywood cells. Increment cores collected in Rhyolite Canyon on September 1, 1987 showed no evidence of latewood formation, but cores collected in late October of the

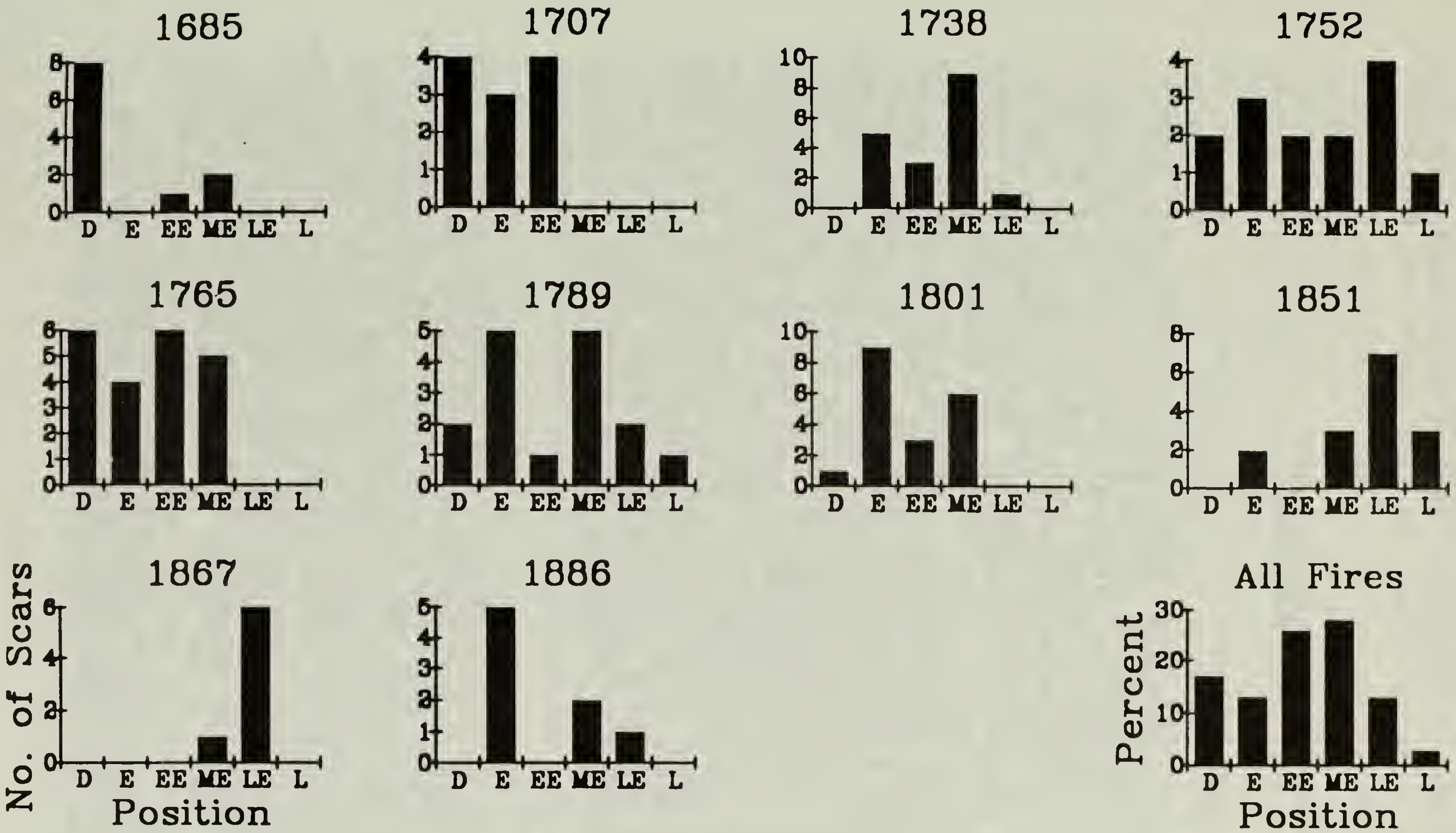


Figure 4. Distribution of fire-scar positions within annual rings for ten different major fire years in Rhyolite Canyon. Scar positions were: D = dormant season, E = earlywood, EE = early-earlywood, ME = mid-earlywood, LE = late earlywood, L = latewood (see text for explanation). The E classification was given to those fire scars clearly within the earlywood, but further classification as to the portions of the earlywood (e.g. EE, ME, or LE) was not possible.

same year appeared to have a complete ring. The latewood and late-earlywood type scars, which were fairly common, may represent fire activity during the late summer and fall.

# DISCUSSION

### The Fire Scar Record

The fire regime of Rhyolite Canyon seems to have been fairly constant from the beginning of the fire-scar record up to 1801. The distribution of fire-scar dates within the canyon suggests that regardless of where a fire began, once in the canyon bottom it tended to spread throughout most or all of the drainage. It is possible that some scars were caused by fires ignited separately at different points along the canyon, although the low ignition rate during the historic period suggests that this was unlikely. Modern records indicate the ridges above Hunt Canyon as well as the Heart of Rocks areas have been a source of lightning ignition in the recent past. It is probable that lightning fires from the higher elevations occasionally were able to burn downslope to where fire could continue to travel through the continuous fuel bed of the canyon bottom. Another probable source for ignition may have been fires burning up from the grassland at the base of the mountains. Slightly higher fire frequencies recorded in both the upper and lower groups of trees as compared to the middle group suggest these were closer to areas of ignition and that not all fires were able to travel the length of the canyon system. Wherever fire began, it would conceivably be able to burn unimpeded provided that conditions, i.e., fuels and fuel moistures, in the usually mesic canyon bottom were conducive to fire spread.

After 1801 this pattern changed. The subsequent 50-year long break in the scar record for trees in the upper and middle groups has not been observed in any other fire chronology from the southwest during the pre-1900 period. Other sites for which fire-scar histories have been compiled show relatively long fire-free intervals during the late 1820's to 1840's, which may be related to wetter climatic conditions during this period (Schulman 1956; Swetnam and Dieterich 1985; Swetnam in press). However, none of the other fire chronologies with which we are familiar record as long a period without fire. In addition, trees in the lower canyon continued to record fires during the early 1800's, which would not be expected if a regional factor such as climate were influencing fire occurrence. After 1851, burning resumed in the upper and middle canyon, but these fires occurred in different years than fires that burned in the lower canyon. This also suggests a more localized phenomenon was influencing the fire regime.

A possible explanation for the early 1880's change in the fire regime may have to do with a change in fuel continuity in the canyon. Before 1801, when fire frequently appears to have been a canyon-wide event, fuel continuity was probably such that fire had the potential to carry throughout the drainage. But it appears something may have happened to this continuity around 1801 which restricted fire spread. Fires recorded by trees at the mouth of the canyon after 1801 are not recorded on trees higher in the drainage. Also, assuming fires were still ignited in the higher areas of the basin, none appear to have been able to burn into the canyon bottom. The single fire recorded during the long interval in the middle portion of the canyon on RHY 16 (See Figure 2) seems to have been an isolated occurrence and apparently the fire was not able to spread further into the canyon.

Two alternative causes of the observed gap in the fire record are proposed. The first possibility is that a flood event in the early 1800's introduced barriers to fire spread at several places in the canyon, and perhaps scoured the creek bottom to such an extent that fuels and litter necessary for fire propagation were removed. Flood-scarred trees have been noted in the canyon and there is a large debris flow berm (sand, gravels, boulders, etc.) at the mouth of Sarah Deming Canyon extending into Rhyolite for a least one-fourth of its width. This berm has mature vegetation and trees growing on it. It is possible that a large outwash of sand and gravel from a flood event emanating from Sarah Deming formed this berm, which was then an effective barrier to the spread of fires up or down canyon.

A second hypothesis is that lack of fire during this period was related to human activity. The reduction in fire frequency beginning in the 1880's and 90's has been noted in almost all of the fire-scar records from throughout the southwest and most researchers agree that it was the result of a combination of two processes: 1) widespread grazing of cattle and sheep caused a reduction in the fine fuels necessary for fire propagation; and 2) fire suppression efforts by government agencies. It is likely that in the late 1800's the former process was the more important of the two. It is possible the early 1800's gap in the Rhyolite chronology also reflects the effects of intensive livestock grazing during this time period.

An increase in fire frequency at the lower part of the canyon starting in the mid-1800's may also represent human influence on the fire regime. Many researchers have documented and speculated on use of fire by aboriginal populations of the southwest (Hastings and Turner 1965; Dobyns 1981; Pyne 1984; Bahre 1985). Human ignition is a difficult, if not impossible, component to separate from lightning ignition in the analysis of past fire regimes. However, it seems likely that human-caused fires were an important factor during this period in Rhyolite fire history. It is known that Apache Indians inhabited the Chiricahua Mountains in the 1800's and used fire for hunting and other purposes (Bahre 1985; Pyne 1984; Dobyns 1981). Thus, it is possible that Apache burning near the mouth of Rhyolite was responsible for the increased fire frequency observed in the late 1800's.

**The Historical Record**

The above two questions concerning the potential impact of human activity on the fire regime of Rhyolite Canyon can best be viewed in the historical context of the region. Although nothing specific is known of the cultural history of Rhyolite before the late 1800's, when several homesteads were established at or near its mouth, some insight can be gained from a review of the land-use history of southeastern Arizona and northern Sonora.

The ebb and flow of European civilization in the southwest in the late 18th and 19th centuries, first of the Spanish, then the Mexicans, and finally the Americans, was dependent to a great extent upon the whims of the Apache (Spicer 1962). After an initial good start in relations in the early 18th-century, characterized by tolerance and little more, the Apaches began to predate on Spanish mines and ranches, which were rich and easy targets. A cycle of Apache raids and Spanish retaliations began. However, by the late 1780's the Spanish had concluded that a policy of Apache extermination would not work. The Apache were too elusive, using effective guerrilla warfare in outwitting and outrunning their technologically superior foe (Wagoner 1975).

In 1786, Bernardo de Galvez was appointed Viceroy of New Spain and initiated a pragmatic plan for negotiating with the Apache. Galvez' plan involved the establishment of feeding stations, termed "establecimientos de paz", where food, liquor, and cheap firearms were given to the Apache in return for their settling down where the Spanish army could watch over them. Wagoner (1975, p.151) quotes Galvez:

> After all, the supplying of drink to the Indians will be a means of gaining their goodwill, discovering their secrets, calming them so they will think less often of conceiving and executing their hostilities, and creating for them a new necessity which will oblige them to recognize their dependence upon us more directly.

From 1790 to the early 1820's, numerous land grants were issued by the Spanish and Mexican governments for cattle ranches throughout what is now southern Arizona. Wagoner calls the decades following 1790 "the golden age" of Spanish rule in the southwest "characterized by a relative degree of peace" (1975 p.156). Ranchers not only grazed their own lands but were permitted to graze the surrounding areas known as "overplus". Cattle numbers increased greatly, running mostly feral over much of the range (Wagoner, 1975 p.159). One of the larger grants, San Bernardino, located on the south end of the Chiricahua Mountains, was said to have had 100,000 cattle, 10,000 horses, and 5,000 mules at the height of operations (Haskett 1935). Other large grants in relatively close proximity to the Chiricahuas included the San Juan de las Boquillas y Nogales and the San Rafael del Valle on the San Pedro River and the San Ignacio del Babocomari north of the Huachuca Mountains.

In 1811, the Mexican Revolution began to occupy Spain's attention to the detriment of its northern frontier. By 1833, Apache raids were again in full swing, causing the effective abandonment of southern Arizona and northern Mexico with the exception of some heavily fortified towns and presidios. Wagoner (1975 p.240) quotes Don Ignacio Zuniga, a commander of the northern presidios, as estimating that by 1835, the Apache had killed at least 5,000 people with another 3,000 to 4,000 forced to flee to the south.

The ranches and haciendas were left to ruin and the cattle left to run wild. Several early explorers of southern Arizona comment on encountering feral cattle during their travels, including the somewhat infamous "Battle of the Bulls" by the Mormon Battalion of Col. P. St. George Cooke in 1846:

> This section of the country seemed to abound with herds of wild cattle, and the males among them were much more bold and ferocious than among buffalo. Attracted by curiosity these herds gathered along the line of march, alternately scampering away and approaching: and some of the bolder ones, as if in resentment of the Battalion's invasion, attacked the column. Several mules were gored to death by them, both in the teams and in the pack animals: and Col. Cooke records how some of the wagons were thrown about by the mad charge of these furious beasts (Tyler, quoted in Haskett [1935, p.8]).

John R. Bartlett, surveying the Treaty of Guadalupe Hidalgo boundary between the U.S. and Mexico in 1851, commented when he visited the ruins of the San Bernardino hacienda:

> Vast herds of cattle were formerly raised here, but the frequent attacks of the Apaches led to the abandonment of the place. Some cattle which had strayed away were not recovered at the time, have greatly multiplied since, and now roam over the plains and in the valleys, as wild and more fierce than the buffalo (Bartlett 1854, [1965 reprint, p.255]).

Rhyolite Canyon may not have escaped the influence of this ranching and cultural history of southeastern Arizona. If grazing was heavy during the early 1800's, it may have disrupted the fuel continuity in the canyon bottom and prevented fire from spreading. The lower end of the canyon may have continued to burn due to its proximity to the larger, more contiguous desert grassland of the bajada on the edge of the mountains.

The increased fire frequency after 1851 is especially suggestive of human influence. A survey of the cultural resources of the Faraway Ranch at the mouth of Rhyolite did not find any evidence of Apache presence, with the exception of a modified rifle cartridge which may have been an Apache "tinkler" (Baumler 1984). However, Bonita Canyon, the next major canyon north of Rhyolite, was historically used as a route of travel through the mountains by the Apache. In 1885, the Army established a camp close to the mouth of Bonita and Rhyolite specifically to end Apache use of this area (Baumler 1984). It would seem, therefore, that the increased Apache presence sometime in the mid to late 1800's may correspond with the increase in fire frequency. Furthermore, a more accurate date for an increase in Apache presence in this area of the Chiricahuas might be inferred from this increase in fire frequency seen in the tree-ring fire-scar record. Similarly, the end of the fire regime in the late 1880's could be directly linked to the establishment of the Army camp, removal of the Apache and the advent of intensive grazing in the area.

It also seems possible that some of the ignitions within the canyon prior to the 1850's, and even before the 50-year gap, may have been of Apache origin. This suggests another possible "human explanation" for the gap. Perhaps the Apache occasionally burned Rhyolite Canyon in order to improve travel conditions up or down the canyon, or for some other purpose.[3]

Then for some unknown reason they ceased this practice after about 1801.

Unfortunately, if the 50-year gap was due to some human influence it may never be possible to positively identify the exact relationship. However, at this time the "human explanations" we have posed, i.e., changes in Apache burning

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[3]Dense oak thickets and accumulated woody debris in parts of the canyon pose some difficulty in traveling along the canyon bottom. Much of this live and dead vegetation is a result of 60 or more years of fire exclusion. Thus, from an Apache perspective, motivation for burning may have included improving ease of travel and other benefits such as an open forest where game were more readily seen.

patterns and/or introduction of intensive grazing, do not seem to us as plausible as a "natural explanation", such as a flood event that disrupted fuel continuity within the canyon. We do feel that further investigation has a strong probability of turning up additional clues to this puzzle, and possibly even a full explanation. Some potential investigations are briefly outlined following the next section.

## SUMMARY AND MANAGEMENT IMPLICATIONS

A number of basic facts were revealed by tree-ring dating of fire scar specimens. Perhaps most fundamental was the observation of large episodic fires at intervals of 9 to 22 years. Prior to 1801 these fires were usually canyon-wide events. Smaller fires were also observed in some locations within the canyon between the canyon-wide events, but they were generally infrequent. Relatively short-interval fires, ranging between about 6 and 10 years, were recorded during briefer periods in the early 1700's in the upper canyon and after 1851 in the lower canyon.

An unusual gap without fire was observed in the upper and middle canyon between 1801 and 1851. This 50-year gap stands out as a unique feature of the Rhyolite fire history. The gap may be due to human causes or other natural changes within the canyon.

In general, the Rhyolite fire history seems to offer a range of options to a fire management program designed to reintroduce "natural" fire processes. Small prescribed burns covering only portions of the canyon, such as the lower end below Sarah Deming, would be within the range of typical coverage of some pre-suppression fires. The evidence of canyon-wide fires during the 18th-century, however, may provide the basis for a long-term objective of allowing lightning ignited fires, or if necessary, planned ignitions, to burn along the entire length of the canyon. The fifty-year interval in the early 1800's suggests that fire exclusion due to grazing activities and the actions of the Forest Service and National Park Service during this century may not have resulted in unprecedented vegetation and fuels changes in the canyon. On the other hand, the 18th-century fire gap may have been preceded, or even caused by, a sudden reduction in fuels, therefore the current conditions might be quite anomalous. Relatively heavy live and dead fuel accumulations are now observable in portions of the canyon, and so a concerted and cautious restoration effort may be required before more ambitious canyon-wide, free burning fires are allowed.

Given the fire scar record of abundant fires before 1900 and the low rate of lightning ignitions within the canyon during the 20th century, it appears that many past fires originated outside of Rhyolite Canyon proper. Source areas would probably have included ponderosa pine stands above (east and north) of Rhyolite and from the grass and oak woodlands below the mouth of the canyon. Since practical limitations may preclude allowing fires to spread from these relatively distant areas, an active planned burning program may be necessary for returning and maintaining a fire regime within Rhyolite that more closely resembles the one that existed before 1900.

Evidence of the seasonal timing of past fires suggests that prescribed burning during any portion of the growing season of conifers, i.e., approximately late April to mid or late September, would be within the range of variability observed before the 20th-century. Most 18th and 19th-century fires, however, probably burned between late April and late July. Fires may also have started somewhat earlier (early April), although fires much later than the usual growing season (e.g., late September to October) were probably relatively rare.

Prescribed burning during the typical arid southwestern spring and foresummer will always carry an unknown level of risk due to the uncertain timing of arrival of the monsoon pattern later in the summer, and the possibility of extended dry and windy conditions in the interim. Especially in areas of unnaturally heavy fuel accumulation managers should consider planned burning only during cooler and wetter conditions. Thus, restoration of pre-settlement fuel loadings may be a prerequisite to a truly "natural" fire program. However, longer-term objectives of wilderness fire management programs should be aimed at reintroducing or simulating fire regimes that are of critical importance to plant and animal communities. The true test of the success of National Park Service fire management within Rhyolite may be the day when a lightning ignited fire is allowed to freely burn along the entire length of the Canyon during the driest and windiest week in late June.

## RESEARCH QUESTIONS AND POTENTIAL FUTURE STUDIES

The very interesting and somewhat complex results of this study raise some questions concerning the fire regime in Rhyolite Canyon. As presently formulated, these questions may be summarized as follows:

1. What role, if any, did human influence have on the pre-1900 fire regime?

2. Why is there a 50-year fire free interval in the upper and middle portions of the canyon in the 1800's, but not in the lower portion?

3. Was the 50-year fire free interval caused by a flood event and its effects on fuel continuity and thus fire spread patterns within the canyon?

4. Is this gap unique to Rhyolite drainage or is it reflected in other nearby canyons (e.g., Jesse James or Bonita)?

5. What is the cause of the increase in fire activity in the upper canyon around 1700 and in lower canyon during the 1850's and 1860's?

6. Where and what were the sources of ignition for the fires burning in the canyon bottom?

7. How has the composition and age structure of the plant community, especially the tree species, changed since the cessation of the natural fire regime? Is the 50-year fire interval of the early 1800's reflected in the age structure and composition of mature trees within the canyon?

The issues of human influence, the 50-year fire-free interval, changes in fire frequency, and possible source areas for ignitions are perhaps intertwined. Collection of additional fire-scar samples in strategic locations could provide the basis for resolving them. Target areas would be: 1) The heads of Sarah Deming, Hunt, and Rhyolite Canyons as potential ignition source areas; and 2) Bonita basin and Jesse James Canyon as reference areas, the former a probable high use area, and the latter as a control more similar to Rhyolite drainage.

The hypothesis that a flood event caused the 50-year fire-free interval might be tested by: 1) aging trees growing on outwash berms as an indication of time of deposition; 2) locating and sampling flood-scarred trees in Rhyolite and associated drainages in an attempt to date past flood events; and 3) increment boring to determine the time of tipping of overstory trees along the stream course as an indicator of flood events.

Changing stand composition and age structure could be addressed by systematic tree-ring and plot sampling of the dominant species growing in the canyon.

The existing collection would provide an excellent base on which to expand the present findings. We believe that management and interpretation of the natural resource would both benefit from the resolution of these issues.

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# APPENDIX A

# GUIDE TO INTERPRETING FIRE SCAR DATA CODING SYSTEM

Scar dates for each sample were determined and saved in a dBase III Plus file along with the following information: (1) a tree identification code; (2) tree number; (3) sample group number; (4) coded species name for sample; (5) type of vegetation the sample was collected in; (6) elevation; (7) inside date; (8) outside date; and (9) position of scar within a ring.

Sample group numbers refer to locations within Rhyolite canyon where samples were obtained. They are as follows: (1) upper canyon in area of junction with Hunt Canyon; (2) area around junction with Totem Pole Canyon; (3) area of the first small side canyon below Totem Pole Canyon on the south side of Rhyolite; (4) hillslope in area of the second small side canyon below Totem Pole Canyon; (5) canyon bottom below hillslope described above; (6) immediate east side of Sarah Deming Canyon; (7) area from the west side of Sarah Deming to just below Echo Canyon; and (8) lower canyon area just above monument headquarters. On upper canyon refers to group 1, mid-canyon to groups 2 - 6, and lower canyon to groups 7 - 8.

Species sampled and species codes are *Pinus ponderosa* (PIPO), *P. engelmanii* (PIEN) and *Cupressus arizonica* (CUAR). Codes for type of vegetation in which samples were collected are (DFMC) Douglas-fir montane conifer forest, (MPOW) Mexican pine-oak woodland.

Outermost rings were designated as: (1) at bark (B), showing year of death or date of sample collection for samples where bark or bark surface is apparent; (2) last ring present (L) on a sample when it cannot be determined if this is a bark ring; and (3) approximate (*) outside date plus or minus one or more rings (usually due to presence of rotten sapwood or reduced growth resulting in very small or missing rings). Innermost rings were designated: (1) pith date (P); (2) near pith (N); (3) only an innermost ring dated (not pith) (I); and (4) approximate innermost ring date (plus or minus one or more rings) because dating uncertain near innermost portion of ring series (*).

Questionable scars are indicated with a question mark (?) following the scar date. An asterisk (*) indicates an approximate date with plus or minus one or more years.

Scar positions within a ring are indicated using the following terminology; occurrence in latewood (L), during the dormant season (D), and in earlywood (E) with the latter position usually broken down into early in the earlywood (EE), mid earlywood (ME), and late in the earlywood (LE). If position could not be determined scars were classified as unknown (U). General criteria used in defining positions are as follows (see text for interpretation of possible months of fire occurrence):

E = Scars occurring anywhere within the earlywood of a ring. This classification was usually given when a further subdivision of scar position within earlywood (i.e., EE, ME, LE) could not be determined. Scars occurring within false rings (diffuse latewood type bands) were also defined as earlywood scars.

EE = Scars occurring within approximately the first third of the earlywood portion of the annual rings.

ME = Scars occurring within the middle third of the earlywood.

LE = Scars occurring in the last third of the earlywood (just before the appearance of latewood type cells).

L = Scars occurring within in the latewood type cells of the ring but prior to the cessation of a years growth.

D = Scars occurring at the latewood/earlywood boundary between two years of ring growth. This could mean the fire occurred in the year of latewood (previous year) but after tree growth had ceased, or in the year of the earlywood, but prior to initiation of ring growth at that site and tree. By convention dates given for dormant position scars are assigned to the year of adjacent earlywood (Dieterich and Swetnam 1984).

U or blank = Position of a scar within an annual ring was not determined though the scar was datable. This may be due to decayed wood, insect damage, tightness of the rings in the scar area, or other problems associated with crossdating the ring patterns.

D/E = Scars that occurred very near the ring boundary and had some minor, but not totally convincing evidence that they may be within the earlywood.

# APPENDIX B

## LIST OF ALL DATED FIRE SCARS AND POSITION OF SCARS WITHIN RINGS

| TREE ID | GROUP | TREE SPP. | VEG. TYPE | ELEV | INSIDE DATE | OUTSIDE DATE | SCAR SIDE | DATE | POS. |
|---|---|---|---|---|---|---|---|---|---|
| CH1 | 8 | PIEN | MPOW | 5440 | 1743 P | 1977 * | R | 1748 | D/E |
| | | | | | | | R | 1758 | U |
| | | | | | | | R | 1765 | E |
| | | | | | | | L | 1775 | U |
| | | | | | | | R | 1775 | ME |
| | | | | | | | L | 1788 | |
| | | | | | | | R | 1788 * | L |
| | | | | | | | L | 1801 | E |
| | | | | | | | R | 1801 | ME |
| | | | | | | | L | 1810 * | U |
| | | | | | | | L | 1820 * | U |
| | | | | | | | R | 1820 | E |
| | | | | | | | L | 1841 | E |
| | | | | | | | R | 1841 | D/E |
| | | | | | | | R | 1852 | D/E |
| | | | | | | | R | 1856 | ME |
| | | | | | | | L | 1867 | ME |
| | | | | | | | R | 1867 | LE |
| | | | | | | | R | 1873 | ME |
| 1 | 2 | PIPO | DFMC | 6300 | 1650 * | 1851 L | L | 1716 | |
| | | | | | | | R | 1716 | |
| | | | | | | | R | 1723 ? | |
| | | | | | | | L | 1738 | |
| | | | | | | | R1 | 738 | ME |
| | | | | | | | L | 1752 | |
| | | | | | | | R | 1752 | LE |
| | | | | | | | L | 1765 | |
| | | | | | | | R | 1765 | |
| | | | | | | | L | 1774 | |
| | | | | | | | R | 1774 | |
| | | | | | | | R | 1789 | |
| | | | | | | | L | 1801 | |
| | | | | | | | L | 1801 | |
| | | | | | | | R | 1801 | |
| 2 | 2 | PIPO | DFMC | 6300 | 1724 I | 1950 * | L | 1752 | |
| | | | | | | | R | 1752 | |
| | | | | | | | R | 1765 | |
| | | | | | | | R | 1774 | |
| | | | | | | | R | 1789 | |
| | | | | | | | L | 1851 | |
| | | | | | | | R | 1851 | LE |
| | | | | | | | L | 1863 | |
| | | | | | | | R | 1863 | |
| | | | | | | | L | 1886 | |
| | | | | | | | R | 1886 | |

| TREE ID | GROUP | TREE SPP. | VEG. TYPE | ELEV | INSIDE DATE | OUTSIDE DATE | SIDE | SCAR DATE | POS. |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 2 | PIPO | DFMC | 6300 | 1610 I | 1850 * | R | 1685 | |
| | | | | | | | R | 1707 ? | |
| | | | | | | | R | 1738 | |
| | | | | | | | R | 1752 | |
| | | | | | | | R | 1765 | |
| | | | | | | | R | 1774 | |
| | | | | | | | R | 1789 | |
| | | | | | | | R | 1801 | |
| 4 | 2 | PIPO | DFMC | 6300 | 1582 P | 1878 * | R | 1738 | E |
| | | | | | | | R | 1752 | ME |
| | | | | | | | R | 1765 | E |
| | | | | | | | R | 1774 | ME |
| | | | | | | | R | 1789 | E |
| | | | | | | | R | 1801 | E |
| 5 | 2 | PIPO | DFMC | 6300 | 1752 I | 1987 B | R | 1752 * | |
| | | | | | | | R | 1765 | ME |
| | | | | | | | R | 1774 | LE |
| | | | | | | | R | 1789 | ME |
| | | | | | | | R | 1851 | LE |
| | | | | | | | R | 1855 | EE |
| | | | | | | | R | 1863 | |
| 6 | 2 | PIPO | DFMC | 6300 | 1622 P | 1891 L | R | 1666 ? | |
| | | | | | | | L | 1707 | |
| | | | | | | | R | 1707 | |
| | | | | | | | R | 1752 | |
| | | | | | | | R | 1765 | |
| | | | | | | | R | 1789 * | |
| | | | | | | | R | 1801 | |
| | | | | | | | R | 1863 * | |
| 7 | 3 | PIPO | DFMC | 6200 | 1670 I | 1987 B | R | 1738 | ME |
| | | | | | | | R | 1765 | EE |
| | | | | | | | R | 1774 | E |
| | | | | | | | R | 1789 * | |
| | | | | | | | R | 1801 | E |
| | | | | | | | R | 1851 | LE |
| | | | | | | | R | 1863 | D/E |
| | | | | | | | R | 1886 | ME |
| | | | | | | | R | 1894 | U |
| | | | | | | | R | 1924 | EE |
| | | | | | | | R | 1980 * | L/D |

| TREE ID | GROUP | TREE SPP. | VEG. TYPE | ELEV | INSIDE DATE | OUTSIDE DATE | SIDE | SCAR DATE | POS. |
|---|---|---|---|---|---|---|---|---|---|
| 8 | 3 | PIPO | DFMC | 6200 | 1632 N | 1975 * | R | 1685 | D |
| | | | | | | | L | 1723 | ME |
| | | | | | | | R | 1723 | ME |
| | | | | | | | L | 1738 | ME |
| | | | | | | | R | 1738 | ME |
| | | | | | | | R | 1752 | ME |
| | | | | | | | L | 1765 | D/E |
| | | | | | | | R | 1765 | EE |
| | | | | | | | R | 1774 | ME |
| | | | | | | | R | 1789 | LE |
| | | | | | | | L | 1801 | ME |
| | | | | | | | R | 1801 | ME |
| | | | | | | | L | 1851 | ME |
| | | | | | | | R | 1851 | E |
| | | | | | | | L | 1863 | U |
| | | | | | | | R | 1863 | U |
| | | | | | | | L | 1924 | U |
| | | | | | | | L | 1924 | U |
| | | | | | | | R | 1924 | E |
| 9 | 3 | PIPO | DFMC | 6200 | 1604 P | 1987 B | R | 1625 ? | |
| | | | | | | | R | 1636 ? | |
| | | | | | | | R | 1655 | |
| | | | | | | | R | 1666 | LE |
| | | | | | | | R | 1685 | |
| | | | | | | | R | 1707 | U |
| | | | | | | | R | 1774 | U |
| | | | | | | | R | 1789 | ME |
| | | | | | | | R | 1801 | EE |
| | | | | | | | R | 1851 | L |
| | | | | | | | R | 1863 | EE |
| | | | | | | | L | 1886 | E |
| | | | | | | | R | 1886 | U |
| | | | | | | | R | 1924 | E |
| 10 | 3 | PIPO | DFMC | 6200 | 1640 I | 1987 B | R | 1685 | |
| | | | | | | | R | 1723 | U |
| | | | | | | | R | 1738 | U |
| | | | | | | | R | 1752 | LE |
| | | | | | | | R | 1765 | ME |
| | | | | | | | R | 1789 | E |
| | | | | | | | R | 1801 | E |
| | | | | | | | R | 1851 | LE |
| | | | | | | | R | 1863 | U |
| | | | | | | | R | 1886 * | U |
| | | | | | | | R | 1924 | D/E |

| TREE ID | GROUP | TREE SPP. | VEG. TYPE | ELEV | INSIDE DATE | OUTSIDE DATE | SIDE | SCAR DATE | POS. |
|---|---|---|---|---|---|---|---|---|---|
| 11 | 3 | PIPO | DFMC | 6200 | 1602 P | 1841 L | R | 1606 * | |
| | | | | | | | L | 1685 | U |
| | | | | | | | R | 1685 | EE |
| | | | | | | | L | 1697 | U |
| | | | | | | | R | 1697 | EE |
| | | | | | | | L | 1707 | |
| | | | | | | | R | 1707 | E |
| | | | | | | | R | 1723 | E |
| | | | | | | | L | 1738 | U |
| | | | | | | | R | 1738 | EE |
| | | | | | | | L | 1752 | D/E |
| | | | | | | | R | 1752 | EE |
| | | | | | | | L | 1765 | ME |
| | | | | | | | R | 1765 | U |
| | | | | | | | L | 1789 | E |
| | | | | | | | R | 1789 | E |
| | | | | | | | L | 1801 | U |
| | | | | | | | R | 1801 | E |
| 12 | 3 | CUAR | DFMC | 6200 | 1820 P | 1987 P | R | 1851 | LE |
| | | | | | | | R | 1863 | E |
| | | | | | | | R | 1886 | E |
| 13 | 3 | CUAR | DFMC | 6200 | 1830 P | 1987 B | R | 1863 | EE |
| | | | | | | | R | 1886 | E |
| 14 | 3 | CUAR | DFMC | 6200 | 1819 P | 1987 B | R | 1863 | E |
| | | | | | | | R | 1886 | ME |
| 15 | 4 | PIPO | MPOW | 6300 | 1659 I | 1886 L | L | 1685 | |
| | | | | | | | R | 1685 * | |
| | | | | | | | L | 1707 | |
| | | | | | | | R | 1738 * | |
| | | | | | | | R | 1752 | E |
| | | | | | | | R | 1765 | EE |
| | | | | | | | R | 1774 | E |
| | | | | | | | R | 1789 | D |
| | | | | | | | R | 1801 | E |
| | | | | | | | R | 1851 | E |
| | | | | | | | R | 1863 | E |
| | | | | | | | R | 1886 | E |

| TREE ID | GROUP | TREE SPP. | VEG. TYPE | ELEV | INSIDE DATE | OUTSIDE DATE | SIDE | SCAR DATE | POS. |
|---|---|---|---|---|---|---|---|---|---|
| 16 | 4 | PIPO | MPOW | 6300 | 1675 I | 1890 * | L | 1707 | D |
| | | | | | | | L | 1723 | D/E |
| | | | | | | | L | 1738 | |
| | | | | | | | R | 1738 | E |
| | | | | | | | L | 1752 | |
| | | | | | | | R | 1752 | D/E |
| | | | | | | | L | 1765 | EE |
| | | | | | | | R | 1765 | E |
| | | | | | | | L | 1774 | ME |
| | | | | | | | R | 1774 | ME |
| | | | | | | | L | 1789 | D/E |
| | | | | | | | R | 1789 ? | U |
| | | | | | | | L | 1801 | ME |
| | | | | | | | R | 1801 | D/E |
| | | | | | | | L | 1818 | U |
| | | | | | | | L | 1851 | U |
| | | | | | | | R | 1851 * | ME |
| | | | | | | | L | 1863 | E |
| | | | | | | | R | 1863 | E |
| | | | | | | | R | 1886 * | U |
| 17 | 4 | PIPO | MPOW | 6300 | 1658 I | 1866 L | R | 1685 | |
| | | | | | | | R | 1712 | E |
| | | | | | | | R | 1723 | |
| | | | | | | | L | 1738 | |
| | | | | | | | R | 1738 * | |
| | | | | | | | L | 1752 | |
| | | | | | | | R | 1752 | LE |
| | | | | | | | L | 1765 | E |
| | | | | | | | R | 1765 | EE |
| | | | | | | | L | 1774 | LE |
| | | | | | | | R | 1774 | ME |
| | | | | | | | L | 1789 | LE |
| | | | | | | | R | 1789 | ME |
| | | | | | | | L | 1801 | |
| | | | | | | | R | 1801 | E |
| | | | | | | | R | 1851 | L |
| | | | | | | | R | 1863 | |
| 18 | 4 | PIPO | MPOW | 6300 | 1752 I | 1987 B | R | 1752 | L |
| | | | | | | | R | 1765 | ME |
| | | | | | | | R | 1774 | E |
| | | | | | | | R | 1789 | ME |
| | | | | | | | R | 1801 | E |
| | | | | | | | R | 1851 | L |
| | | | | | | | R | 1863 | ME |
| | | | | | | | R | 1875 | D/E |
| | | | | | | | R | 1886 | LE |

| TREE ID | GROUP | TREE SPP. | VEG. TYPE | ELEV | INSIDE DATE | OUTSIDE DATE | SIDE | SCAR DATE | POS. |
|---|---|---|---|---|---|---|---|---|---|
| 19 | 8 | PIEN | MPOW | 5440 | 1625 P | 1884 * | L | 1685 | ME |
| | | | | | | | R | 1685 | ME |
| | | | | | | | L | 1707 | U |
| | | | | | | | R | 1707 | D/E |
| | | | | | | | L | 1738 | E |
| | | | | | | | R | 1738 | ME |
| | | | | | | | L | 1748 | U |
| | | | | | | | R | 1748 | D |
| | | | | | | | R | 1765 | U |
| | | | | | | | L | 1775 | |
| | | | | | | | R | 1775 | ME |
| | | | | | | | L | 1788 | |
| | | | | | | | R | 1788 | D/E |
| | | | | | | | L | 1801 | ME |
| | | | | | | | R | 1801 | ME |
| | | | | | | | L | 1810 | EE |
| | | | | | | | R | 1810 | EE |
| | | | | | | | L | 1820 | LE |
| | | | | | | | R | 1820 | ME |
| | | | | | | | L | 1826 | ME |
| | | | | | | | R | 1826 | ME |
| | | | | | | | L | 1841 | EE |
| | | | | | | | R | 1841 | E |
| | | | | | | | L | 1852 | EE |
| | | | | | | | R | 1852 | E |
| | | | | | | | L | 1856 | ME |
| | | | | | | | R | 1856 | ME |
| | | | | | | | L | 1859 | ME |
| | | | | | | | R | 1859 | ME |
| | | | | | | | L | 1867 | LE |
| | | | | | | | R | 1867 | LE |
| | | | | | | | L | 1873 * | |
| | | | | | | | R | 1873 | LE |

| TREE ID | GROUP | TREE SPP. | VEG. TYPE | ELEV | INSIDE DATE | OUTSIDE DATE | SIDE | SCAR DATE | POS. |
|---|---|---|---|---|---|---|---|---|---|
| 20 | 8 | PIEN | MPOW | 5440 | 1631 I | 1899 * | R | 1694 | D |
| | | | | | | | R | 1707 | D |
| | | | | | | | R | 1716 | D/E |
| | | | | | | | R | 1738 | ME |
| | | | | | | | R | 1748 | E |
| | | | | | | | L | 1765 | D/E |
| | | | | | | | R | 1765 | D/E |
| | | | | | | | L | 1775 * | U |
| | | | | | | | R | 1775 | ME |
| | | | | | | | R | 1788 * | |
| | | | | | | | R | 1801 | E |
| | | | | | | | R | 1820 * | U |
| | | | | | | | R | 1841 | EE |
| | | | | | | | L | 1859 * | |
| | | | | | | | R | 1859 | LE |
| | | | | | | | L | 1867 | LE |
| | | | | | | | R | 1867 | LE |
| | | | | | | | L | 1873 | ME |
| 21 | 8 | PIEN | MPOW | 5440 | 1713 P | 1987 B | R | 1756 ? | U |
| | | | | | | | R | 1775 | ME |
| | | | | | | | R | 1788 | LE |
| | | | | | | | R | 1801 | U |
| | | | | | | | R | 1882 * | U |
| | | | | | | | R | 1924 | U |
| 22 | 8 | PIEN | MPOW | 5440 | 1718 P | 1987 B | L | 1748 | U |
| | | | | | | | L | 1765 | U |
| | | | | | | | R | 1820 * | U |
| | | | | | | | R | 1841 | EE |
| | | | | | | | R | 1852 | D/E |
| | | | | | | | R | 1856 | ME |
| | | | | | | | R | 1859 | LE |
| | | | | | | | R | 1867 | LE |
| | | | | | | | R | 1873 | LE |
| | | | | | | | R | 1882 * | U |
| | | | | | | | R | 1982 | L |
| 25 | 1 | PIPO | DFMC | 6800 | 1603 N | 1841 * | R | 1625 * | |
| | | | | | | | R | 1636 | E |
| | | | | | | | R | 1655 | D |
| | | | | | | | R | 1685 | D |
| | | | | | | | R | 1697 | D |
| | | | | | | | R | 1703 * | |
| | | | | | | | R | 1709 | D |
| | | | | | | | R | 1738 | |
| | | | | | | | R | 1752 | |
| | | | | | | | R | 1765 | ME |
| | | | | | | | R | 1774 | LE |
| | | | | | | | R | 1789 | |

| TREE ID | GROUP | TREE SPP. | VEG. TYPE | ELEV | INSIDE DATE | OUTSIDE DATE | SIDE | SCAR DATE | POS. |
|---|---|---|---|---|---|---|---|---|---|
| 26 | 1 | PIPO | DFMC | 6800 | 1630 N | 1884 * | L | 1648 | |
| | | | | | | | R | 1648 | ME |
| | | | | | | | L | 1752 | |
| | | | | | | | R | 1752 | E |
| | | | | | | | R | 1765 | EE |
| | | | | | | | R | 1793 | E |
| | | | | | | | R | 1801 | E |
| | | | | | | | R | 1851 | LE |
| | | | | | | | R | 1863 | ME |
| | | | | | | | L | 1876 * | |
| | | | | | | | R | 1876 | ME |
| 27 | 1 | PIPO | MPOW | 6800 | 1609 I | 1876 L | R | 1789 | U |
| | | | | | | | R | 1801 | E |
| | | | | | | | R | 1851 | ME |
| | | | | | | | R | 1863 * | |
| | | | | | | | R | 1876 | LE |
| 28 | 1 | PIPO | DFMC | 6800 | 1599 I | 1815 * | R | 1604 | ME |
| | | | | | | | L | 1632 | |
| | | | | | | | R | 1632 | E |
| | | | | | | | R | 1643 | E |
| | | | | | | | R | 1665 | D |
| | | | | | | | R | 1685 | D/E |
| | | | | | | | R | 1697 | D |
| | | | | | | | R | 1703 | D/E |
| | | | | | | | R | 1705 | ME |
| | | | | | | | R | 1738 | EE |
| | | | | | | | R | 1752 | U |
| | | | | | | | R | 1765 | D/E |
| | | | | | | | R | 1774 | ME |
| | | | | | | | R | 1789 | EE |
| | | | | | | | R | 1801 * | |
| 29 | 2 | PIPO | DFMC | 6300 | 1622 P | 1801 L | R | 1685 | D/E |
| | | | | | | | R | 1707 | D |
| | | | | | | | R | 1723 | |
| | | | | | | | R | 1738 | E |
| | | | | | | | R | 1752 | E |
| | | | | | | | R | 1765 | U |
| | | | | | | | R | 1774 | U |
| | | | | | | | R | 1789 | L |
| | | | | | | | R | 1801 | U |

| TREE ID | GROUP | TREE SPP. | VEG. TYPE | ELEV | INSIDE DATE | OUTSIDE DATE | SIDE | SCAR DATE | POS. |
|---|---|---|---|---|---|---|---|---|---|
| 30 | 5 | PIPO | MPOW | 6080 | 1621 P | 1765 L | R | 1655 | |
| | | | | | | | R | 1666 | ME |
| | | | | | | | L | 1685 | D/E |
| | | | | | | | R | 1685 | D/E |
| | | | | | | | R | 1694 | EE |
| | | | | | | | L | 1707 | EE |
| | | | | | | | R | 1707 | E |
| | | | | | | | L | 1716 | EE |
| | | | | | | | R | 1716 | |
| | | | | | | | L | 1723 | U |
| | | | | | | | R | 1723 | U |
| | | | | | | | L | 1738 | U |
| | | | | | | | R | 1738 | ME |
| 31 | 5 | PIPO | MPOW | 6080 | 1640 I | 1848 * | L | 1707 | EE |
| | | | | | | | R | 1707 | E |
| | | | | | | | R | 1723 | ME |
| | | | | | | | L | 1738 | EE |
| | | | | | | | R | 1738 | E |
| | | | | | | | L | 1752 | EE |
| | | | | | | | R | 1752 * | |
| | | | | | | | L | 1765 | |
| | | | | | | | R | 1765 | D/E |
| | | | | | | | R | 1768 | D |
| | | | | | | | L | 1774 | U |
| | | | | | | | R | 1774 | ME |
| | | | | | | | R | 1789 | E |
| | | | | | | | R | 1801 | EE |
| 32 | 6 | PIPO | MPOW | 5920 | 1641 I | 1783 L | R | 1655 * | |
| | | | | | | | R | 1666 * | |
| | | | | | | | R | 1685 ? | |
| | | | | | | | R | 1707 | |
| | | | | | | | R | 1723 | E |
| | | | | | | | R | 1738 | ME |
| 33 | 6 | PIPO | MPOW | 5920 | 1632 I | 1892 * | R | 1666 * | |
| | | | | | | | R | 1685 | D |
| | | | | | | | R | 1694 * | |
| | | | | | | | R | 1723 | E |
| | | | | | | | R | 1738 | |
| | | | | | | | R | 1752 * | |
| | | | | | | | R | 1765 | |
| | | | | | | | R | 1768 * | |
| | | | | | | | R | 1774 * | |
| | | | | | | | R | 1789 | |
| | | | | | | | R | 1851 * | |
| | | | | | | | R | 1863 * | |
| | | | | | | | R | 1886 * | |

| TREE ID | GROUP | TREE SPP. | VEG. TYPE | ELEV | INSIDE DATE | OUTSIDE DATE | SIDE | SCAR DATE | POS. |
|---|---|---|---|---|---|---|---|---|---|
| 34 | 6 | PIPO | MPOW | 5920 | 1637 P | 1987 B | L | 1655 | E |
| | | | | | | | R | 1655 | E |
| | | | | | | | R | 1666 | |
| | | | | | | | R | 1685 | D |
| | | | | | | | L | 1707 | EE |
| | | | | | | | R | 1707 | D/E |
| | | | | | | | L | 1723 | ME |
| | | | | | | | R | 1723 | ME |
| | | | | | | | L | 1738 | |
| | | | | | | | R | 1738 | LE |
| | | | | | | | L | 1752 | |
| | | | | | | | R | 1752 | LE |
| | | | | | | | R | 1765 | |
| | | | | | | | R | 1851 | |
| | | | | | | | R | 1886 | |
| 35 | 6 | PIPO | MPOW | 5920 | 1610 I | 1900 * | R | 1666 | E |
| | | | | | | | R | 1685 | |
| | | | | | | | L | 1765 | |
| | | | | | | | R | 1765 | |
| | | | | | | | R | 1789 | |
| | | | | | | | R | 1801 | |
| | | | | | | | R | 1851 | LE |
| | | | | | | | R | 1863 | |
| | | | | | | | R | 1873 | LE |
| | | | | | | | R | 1886 | E |
| 36 | 7 | PIPO | MPOW | 5920 | 1628 P | 1865 * | R | 1655 | E |
| | | | | | | | R | 1666 | ME |
| | | | | | | | R | 1685 * | |
| | | | | | | | L | 1738 | ME |
| | | | | | | | R | 1738 * | |
| | | | | | | | L | 1765 | D/E |
| | | | | | | | L | 1774 | ME |
| | | | | | | | L | 1789 | ME |
| | | | | | | | L | 1820 ? | |
| 37 | 7 | PIPO | MPOW | 5720 | 1664 * | 1841 L | R | 1738 | |
| | | | | | | | L | 1765 | |
| | | | | | | | R | 1765 | |
| | | | | | | | R | 1789 | |
| | | | | | | | R | 1820 * | |
| | | | | | | | R | 1841 | |