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Fire History Along an Elevational Gradient in the Siskiyou Mountains, Oregon

Abstract

Fire history was investigated at two sites in the Siskiyou Mountains of southern Oregon. Kinney Creek in the eastern Siskiyous and Oregon Caves National Monument in the central Siskiyous span an elevational gradient from the Mixed Evergreen zone through the White Fir (*Abies concolor*) zone. The fire frequency of the forest around Kinney Creek, based on fire scars, was about 16 years between 1760 and 1860. Photographic evidence in 1916 of fires from 1854 to 1915 was difficult to corroborate in 1988 based on vegetation evidence. Oregon Caves fire history, reconstructed using a conservative natural fire rotation technique, was 37 years during 1650-1930 for the lower elevation Douglas-fir/oak (*Pseudotsuga menziesii/Lithocarpus-Quercus* spp.) community and 64 years for the highest elevation white fir/herb community, with substantial variation by century. The fire-free interval since 1921 is the longest in more than 300 years. These old-growth forests developed with a much more frequent disturbance history than the wetter, cooler Douglas-fir forests of the Olympic and Cascade Mountains of Washington.

Introduction

The Siskiyou Mountains are within one of the more diverse and complex forest regions of western North America (Whittaker 1960). A wide range of climatic, topographic, and edaphic conditions, and the transitional location of these mountains between diverse regional floras, make the Klamath Region the most central of the forest floras of the West (Whittaker 1960). A complex fire history adds further diversity to the forests of the Siskiyou Mountains.

This study was designed to document fire history along an elevational gradient in the central and eastern Siskiyou Mountains (Figure 1). The Kinney Creek area in the eastern Siskiyous was selected because it was the focus of an earlier study of fire effects (Peterson 1916, Hofmann 1917); it is representative of the lower Mixed Evergreen zone (Franklin and Dyrness 1973). Located at ca. 1200 m elevation, the north aspect of the Kinney Creek study site is a Douglas-fir/Oregon grape (*Pseudotsuga menziesii/Berberis nervosa*) plant association (after Atzet and Wheeler 1984), while the south aspect is a mosaic of Douglas-fir forest, chaparral, and woodland. The Kinney Creek area receives about 90 cm of annual and 13 cm of May-September precipitation (McNabb *et al.* 1982, Frochlich *et al.* 1982).

Oregon Caves National Monument, 20 km to the west in the central Siskiyou Mountains, is a higher elevation (1300-1800 m), higher precipitation site which includes the upper edge of the Mixed Evergreen zone and forest communities characteristic of the White Fir (*Abies concolor*) zone (Franklin and Dyrness 1973). Forest communities

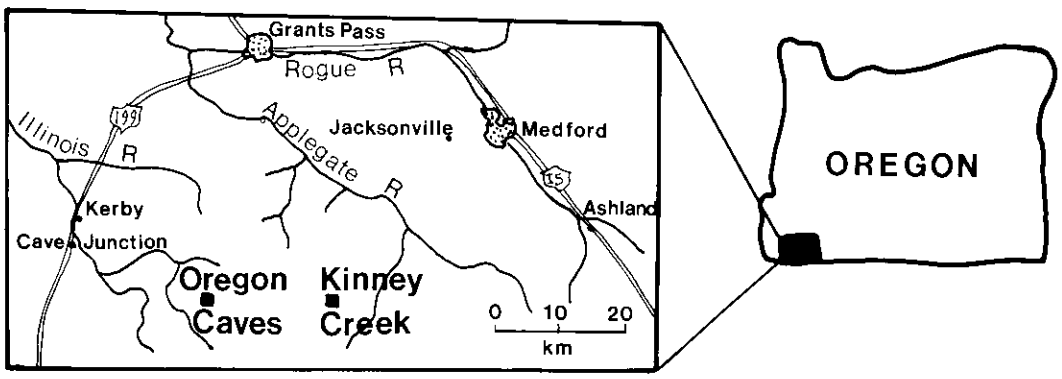

Figure 1. Location of Kinney Creek and Oregon Caves in the Siskiyou Mountains, Oregon.

identified by Agee *et al.* (1990b) include the dry, warm Douglas-fir/oak (*Lithocarpus-Quercus* spp.) community; dry and mesic white fir–Douglas-fir communities; and a white fir/herb community, the coolest and wettest at the monument. Annual precipitation at Oregon Caves is approximately 165 cm, and May-September precipitation averages 16 cm (McNabb *et al.* 1982, Froehlich *et al.* 1982).

Methods

Kinney Creek

Photographic evidence and fire scar records from stumps were used to describe fire history at Kinney Creek. Three locations near Kinney Creek, originally photographed in 1916 (Hofmann 1917), were rephotographed in 1988 from similar camera points. Tree growth since 1916 obscured retakes of some of the original vistas. Increment cores of trees were used to verify dates of fire events identified on the 1916 photographs. On the north-facing slope of Kinney Creek, fire history was reconstructed from scars on 14 stumps over a 2 ha area near the ridgetop. All stumps having fire scars that could be accurately field-counted were included in the sample. This area was logged in 1985 (Richard Marlega, District Ranger, Applegate Ranger District, Rogue River National Forest, personal communication). Annual rings were counted on stumps back to the edges of scarred tissue, and the occurrence year of a fire could then be estimated. A composite fire frequency developed from the stumps in this small area is interpreted as a point frequency.

Oregon Caves

Fire history at Oregon Caves was reconstructed using tree establishment dates as well as fire scars. Tree age data were assembled by placing 50 0.01 ha plots across the 197 ha area, or about 1 per 4 ha. Plots were subjectively chosen to provide uniform spacing and coverage of all forest communities present. On each forested plot, an average of 8 (range 3-24) trees were aged, incorporating the range of size classes on the plot. Samples were cored to the center of the tree and as close to the ground as possible. For each tree sampled, species, diameter at breast and core height, bark thickness, and tree height were recorded. Scars on standing trees were sampled using the increment core technique of Barrett and Arno (1988) whenever possible rather than wedge sampling (Arno and Sneck 1977). Most of the wedge sampling was done on stumps in surrounding Forest Service clearcuts or areas near the boundary of the monument; several wedges were removed from live trees. Samples were returned to the laboratory and sanded. Ages of core or wedge samples were dated using a dissecting microscope.

Dates of tree establishment and fire scars were recorded on topographic maps of the monument and surrounding lands. Fire events, defined either as single fires or a series of fires closely spaced in time, were reconstructed using, in priority order, (a) fire scars from wedge samples, (b) cores extracted to date a fire scar, (c) tree establishment dates, and (d) cores exhibiting aberrant ring patterns associated with dates determined from (a) or (b). Only early seral species (such as Douglas-fir in plant communities of the white fir series, or knobcone pine [*Pinus attenuata*] in plant communities of the Douglas-fir series) were used as evidence of disturbance when tree establishment dates were used to estimate the year of disturbance.

Most of the scar dates were from increment core samples, or stumps adjacent to the monument. Because ring counts on stumps were made in the field, samples were not crossdated and fire events were defined on the basis of scars closely spaced in time together with tree establishment dates from the plots. Accuracy is estimated to be plus or minus: 10 years for samples before 1700, 5 years for samples between 1700-1800, and 2 years for samples after 1800.

Fire events were constructed by first placing dates from fire scars or tree establishment data on the monument map. Fire events previous to 1650 were estimated from individual older trees and scars. Fire events after 1650 were defined under one of the following conditions: two scars evidently of the same time or similar year, 1 scar plus establishment of pioneer tree species, or consistent establishment dates of later seral species (such as white fir) at higher elevation. Single scars not substantiated by other scars or age class evidence were common but were deemed unreliable for indicating the extent of past fire events. Where closely-spaced dates occurred, circles of 250 m radius were drawn around the locations containing each date (Figure 2). The extent of the fire was reconstructed by joining the circles. Circles were not connected if the space between them was larger than a circle diameter, unless the space was more

than 2/3 encircled already. For example, in Figure 2, the area to left center not incorporated in any individual circles is assumed to have burned because that space is essentially surrounded by circles to the left and right. The boundary of the fire was then adjusted slightly in some cases to account for topographic influences on fire behavior: for example, ridgelines were often followed even if the circles slightly overlapped the ridge. Each fire event was separately mapped.

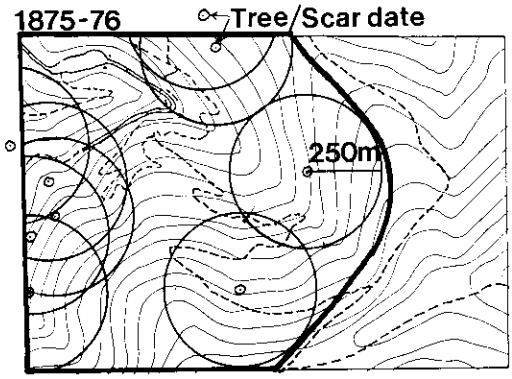

Figure 2. Historic fire extent was reconstructed by locating fire scars or contemporary early seral trees and drawing 250 m radius circles around each point. Fire boundaries were then drawn around those circles, in this case including the western two-thirds of the monument (see Figure 7, 1875-76).

Fire return intervals were calculated using the natural fire rotation (NFR) method (Heinselman 1973). A selected time interval divided by the proportion of the study area burned within that time interval yields the NFR. As applied here, the NFR method produces conservative estimates of fire frequency, because of the need to reconstruct past fire events, some of which may have been erased from the landscape by later fires, and the decision to discard single pieces of evidence. NFR's were calculated by century and by forest community type.

Results

Kinney Creek

The photographic comparison suggests succession has proceeded without perceptible disturbance in most areas since 1916, with edaphically-controlled boundaries remaining stable. The south-facing slope of Kinney Creek in 1916 is shown in Figure 3A, with its 1988 counterpart below (Figure 3B). The boundaries of shallow soil areas (left center) on the far slope are stable over the 70 year period. The texture of the far-distant slope appears similar between 1916 and 1988. There appear to be a few more large trees in 1916 on the east (right) end of the slope, and a few more mature trees to the west (left) in 1988. These are mostly Douglas-fir with some ponderosa pine (*Pinus ponderosa*). The open and brushy portion of the foreground slope is likely the result of an earlier fire. In 1988 (3B) much of this slope is obscured by trees.

Figures 4A-4B show an area slightly upstream from Figures 3A-3B. The Kinney Peak road leaves the Kinney Creek canyon bottom just off the lower right of Figure 4B. In 1916 (Figure 4A) recent fires had burned over the slopes, leaving Douglas-fir residuals along the ridgetops, in the ravines, and along the west-facing (left) slope of the spur ridge in the center of the photograph. By 1988, coniferous forest had regenerated across most of the landscape. In areas that had a mottled texture in 1916, indicating exposed soil and possible periodic slope instability, Pacific madrone (*Arbutus menziesii*) is the current dominant.

The area along Kinney Ridge looking southeast (Figure 5A-5B) has changed markedly since 1916. Prior to the 1916 photograph, this area was repeatedly burned, with numbers on Figure 5A corresponding to fire dates from Hofmann (1917): 1 = 1915; 2 = 1914; 3 = 1910; 4 = 1897; 5 = 1886; and 6 = 1854. Hofmann noted that the repeated burning and complex mosaic of burned and unburned areas made reconstruction of the events very difficult. His map of the burned area (Figure 5C, Peterson [1916]) does not indicate which areas reburned over the 1854-1915 period, although some of the older burns (such as the 1886 burn) are patches separated in 1916 by the more recent burns of 1914 and 1915. Burns closely spaced in time favored those species that can reach maturity quickly with a protected seed bank, such as knobcone pine, which has serotinous cones, or species that sprout (*Quercus* spp., some *Arctostaphylos* spp.).

Hofmann did not indicate how he reconstructed the events of the previous 70 years. The patchiness of such fires in terms of severity complicates reconstruction of fire events based on vegetation present in later decades. A survey of this area in 1988 indicated that Hofmann's chronology would now be very difficult to reconstruct. Three Douglas-firs increment cored in Hofmann's area 5 (at right,

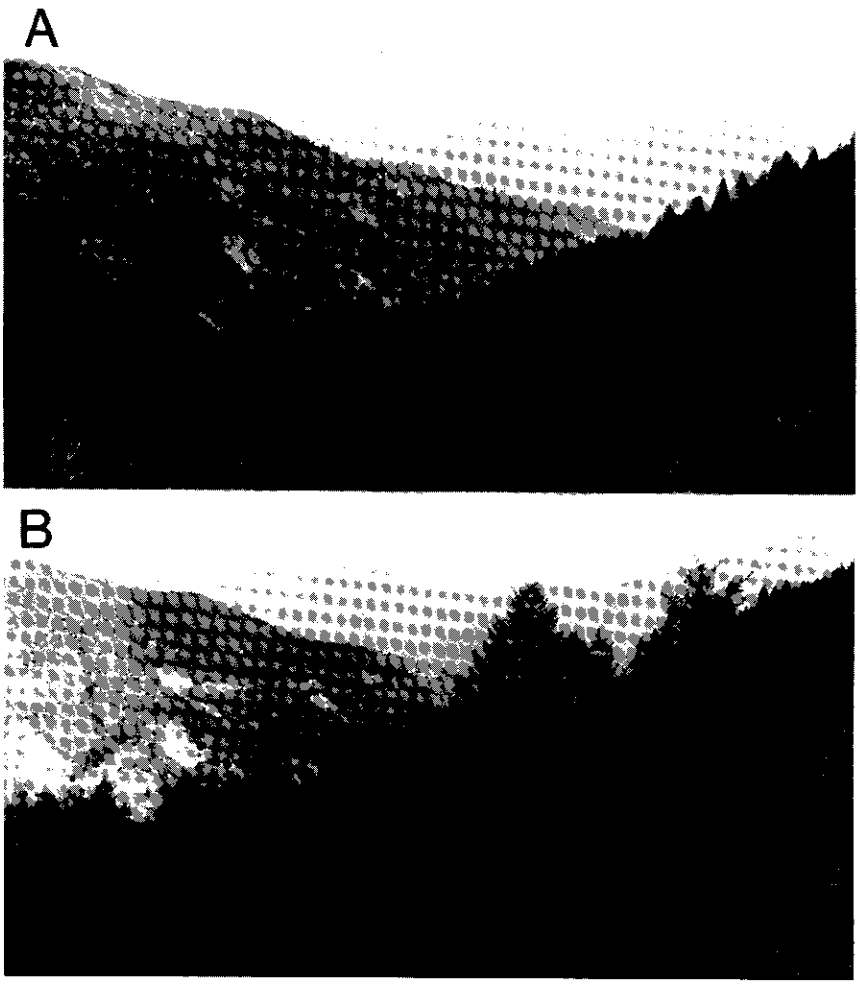

Figure 3. The lower Kinney Creek area in (A) 1916 and (B) 1988, looking northeast from the north aspect of Kinney Creek. Arrow denotes stable boundary of shallow soil area.

Figure 5A-C) yielded estimated dates for germination (which may be 1-3 years in error) of 1889, 1901, and 1905. These dates could be interpreted either as continuous reproduction after the 1886 fire, or regeneration after the 1886 and 1897 fires. A canyon live oak (*Quercus chrysolepis*) cored near the east edge of Area 4 (1897) appeared to have sprouted around 1910, the year of the fire in adjacent Area 3. In area 4 (1897–Figure 5A), two Douglas-firs cored were estimated to have germinated in 1884 and 1899. The 1884 tree must have been missed by the 1897 fire, because at age 13 it likely would have been killed if burned.

On the north aspect of the ridge, immediately out of view to the left of Figure 5A-B and identified by a black dot in Figure 5C, eight fire events since about 1750 were reconstructed based on age class and fire scar data (Table 1). The fire frequency in this 2 ha patch between 1760 and 1860 is about 15 years. Few of the fires identified by Hofmann between 1854 and 1915 burned very far into the mature, north-facing stand of trees, which he identified as "unburned" but which had experienced at least eight fires since the oldest trees had established. The 1915 fire is associated with one Douglas-fir that germinated in 1916 near the crest of the north slope, and Hofmann's 1854 fire may well be the 1856 fire identified by scars; the intermediate fires (1886, 1897, 1910, 1914)

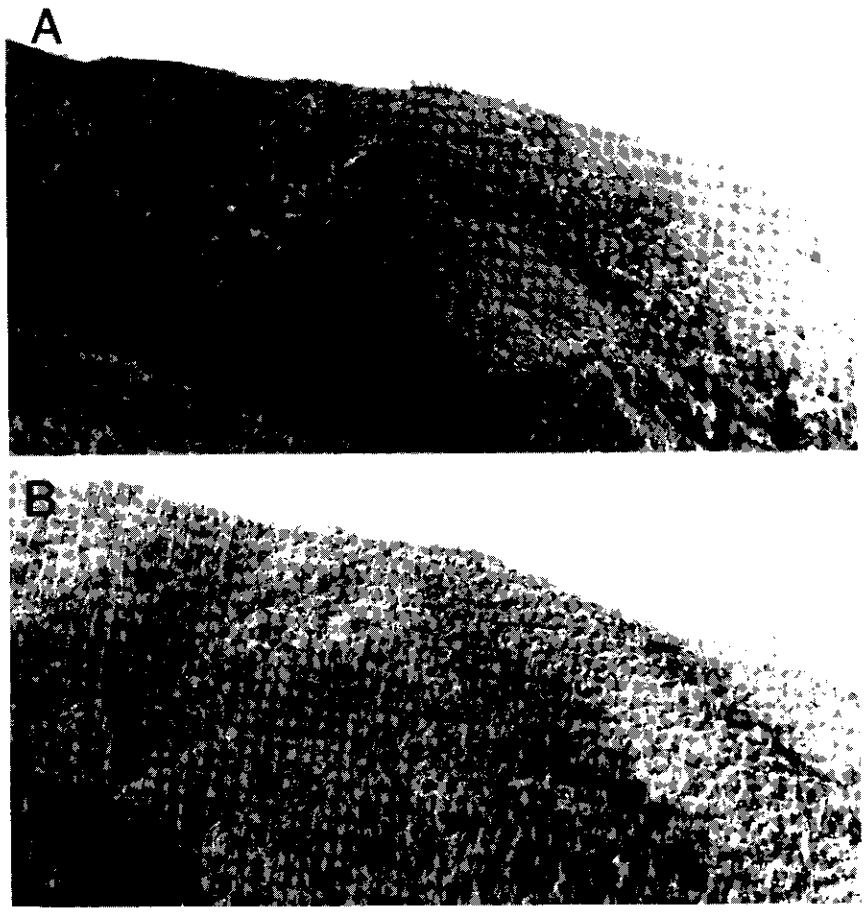

Figure 4. The middle Kinney Creek area in (A) 1916 and (B) 1988. This slope is just above where the present-day road leaves the valley bottom towards Kinney Ridge, and the view looks north.

are all missing from the north aspect set of fire scars, most of which predate the 1850's.

Oregon Caves

The plant communities of this study (Figure 6; Agee *et al.* 1990b) are distributed along a gradient of increasing elevation from northwest to southeast. Lower elevation sites burned more frequently than higher elevation sites (Figure 7).

The oldest detectable fire at Oregon Caves occurred in the 1480's; evidence for this event is very limited. A Douglas-fir stump of that age was found just southeast of the monument in a white fir/gooseberry (*Ribes* spp.) plant association, and a large Port Orford cedar (*Chamaecyparis lawsoniana*) had the oldest of its three fire scars created prior to the early 1500's; this tree probably survived the ca. 1480 fire.

No fire activity was capable of being reconstructed for the 1500's. Evidence of fires that may have occurred has been obscured by subsequent burning. The next fire reconstructed was ca. 1650. Two stump dates from Douglas-fir were found just southeast of the monument boundary. A white fir stump in a riparian area, a sapling-sized tree at the time of the event, showed a significant growth release just after that time, and a Port Orford-cedar along the eastern boundary had a fire scar of that vintage.

Fire evidence becomes more abundant by the end of the 1600's. A fairly widespread age class of Douglas-fir became established along the northern portion of the monument boundary during that

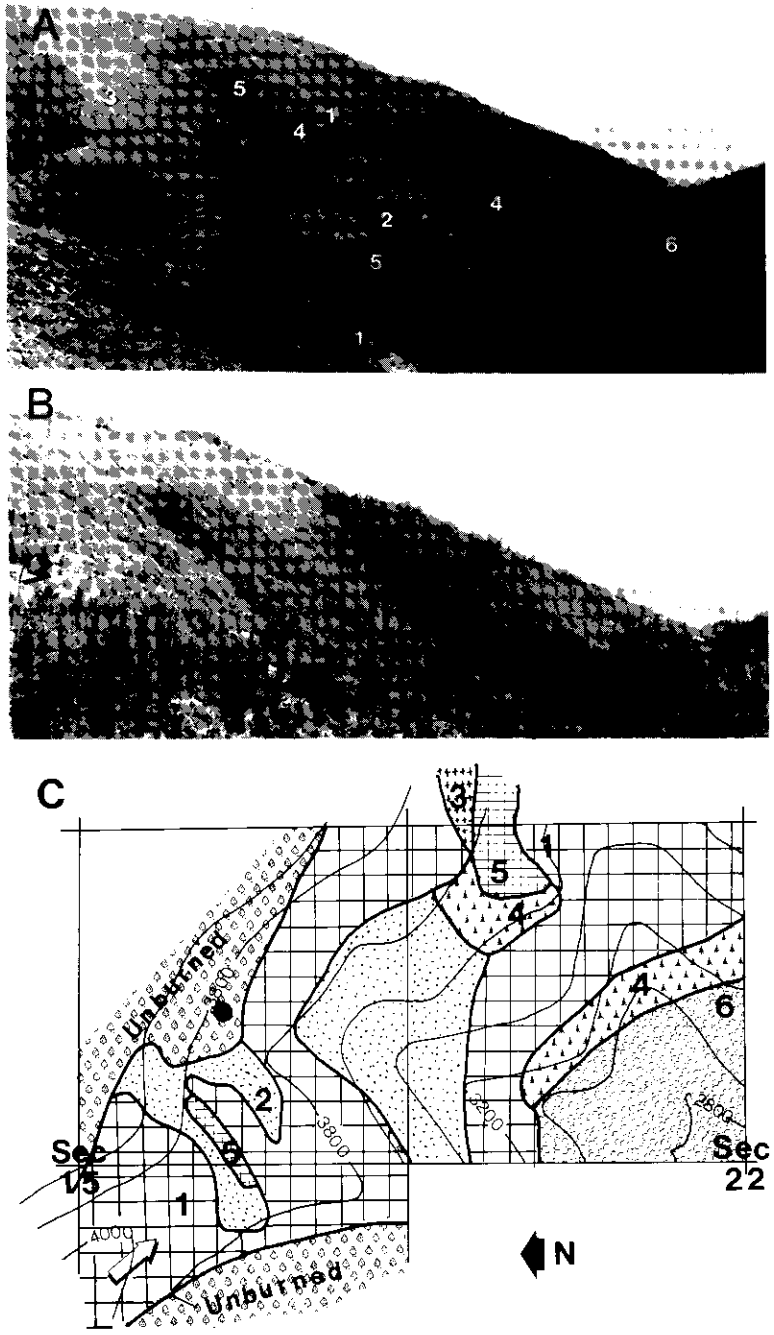

Figure 5. A. The Kinney Ridge area in 1916. The numbers refer to fires identified by Hofmann (1917): 1 = 1915; 2 = 1914; 3 = 1910; 4 = 1897; 5 = 1886; and 6 = 1854. B. The same area in 1988. The arrow at the left is the location of the clearcut stump data shown in Table 1. C. A map of the area redrawn from Hofmann survey (Peterson 1916). The SE 1/4 of Section 15 and NE 1/4 of Section 22, T40S, R4W, is shown, oriented to the line of sight of Figure 5A-B. The numbers represent the general location and same fire years as shown in (A). The black dot near the top is the location of the data in Table 1.

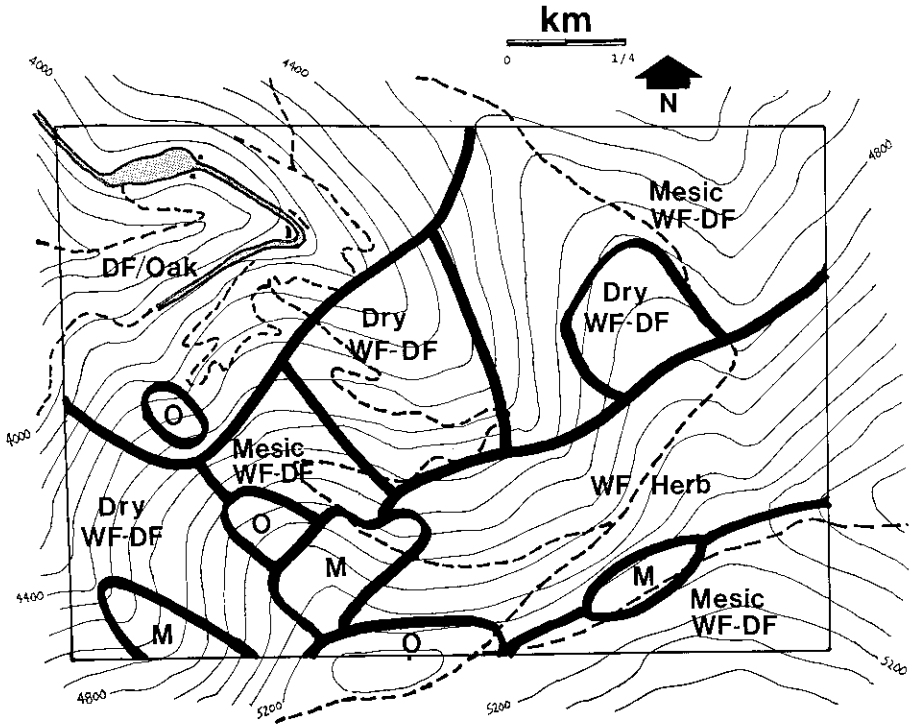

Figure 6. Major plant communities at Oregon Caves, identified with symbols: DF = Douglas-fir; WF = white fir; O = oak; and M = nonforested meadow.

TABLE 1. Estimated fire dates from Kinney Creek clearcut. All trees are Douglas-fir and cut date is assumed to be 1985. Area surveyed was approximately 2 ha.

Tree Number	Scar or Tree Establishment Date(s)								
1		1857	1841	1825	1807	1790?			1747g
2				1825			1780g		
3				1831g					
4		1856					1778		1748g
5			1839						
6						1794		1766g	
7					1807			1773g	
8						1795			
9						1798		1764g	
10			1839			1794			
11				1825					
12								1764g	
13				1825		1797		1765g	
14	1916g								
Estimated Fire Dates*	1915	1856	1839	1825	1807	1795	1778	1763	1746

? = rings not clear
g = estimated germination date
* Estimated fire dates from field counts are subject to some error within a year or two; fire dates estimated from germination dates (column on left and two columns on right) are to be interpreted as the latest date possible (e.g., 1763 might be 1760 or earlier but not 1765).

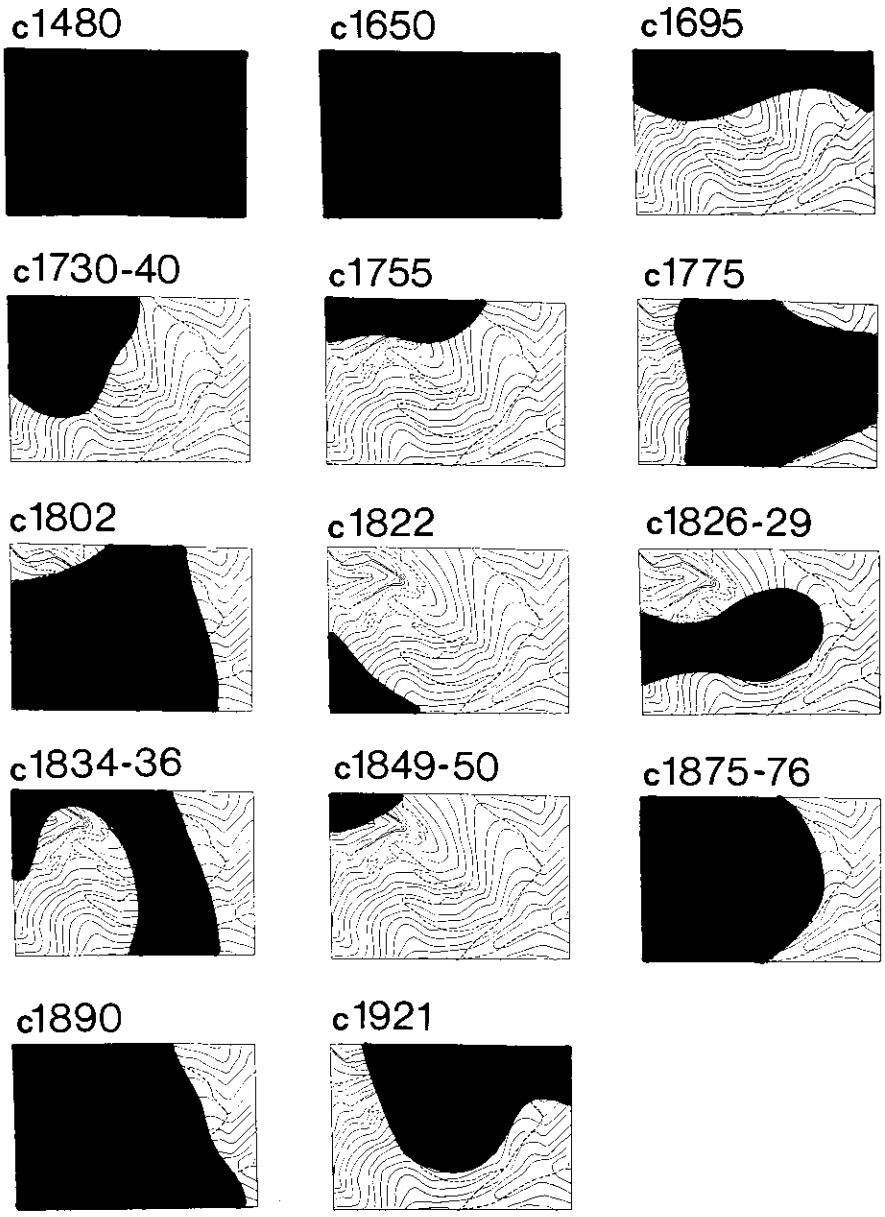

Figure 7. Reconstructed fire events at Oregon Caves since 1480, using the technique presented in Figure 2.

time, suggesting a disturbance date of ca. 1695. This age cohort of Douglas-fir (with germination dates of interspersed trees ranging from 1695 to 1730) suggests one or more moderate to high severity fires; many Douglas-fir became established. Two closely spaced fires seem unlikely due to the lack of any scars on the earliest established members of the cohort. Between 1730 and 1850, at least eight additional fires burned portions of the monument.

Major fires were reported in the vicinities of Kerby and Jacksonville (Figure 1) in the 1865-67 period (Morris 1934) but apparently they did not reach Oregon Caves. In ca. 1875-76, most of the western monument burned. The eastern boundary of this fire is similar to fires in 1802, 1826-29,

and 1834-36. Along the central western edge of the monument, this was a high severity fire. In ca. 1890, another fire burned almost the same area, but was of low severity across much of the monument, leaving occasional scars but not killing many of the young trees that regenerated after the ca. 1875-76 event.

The last significant fire event identified from scars at Oregon Caves occurred in 1921. No administrative records have been uncovered that substantiate this event, but it occurred at a time of frequent burning (Hofmann 1917) and apparently was a low severity underburn within the monument. Since 1921, no major fires have started within or entered the monument. This 70 year period has been the longest fire-free period in more than 300 years.

Fire return intervals (Tables 2, 3) show that fire has not been a spatially or temporally uniform process. The temporal record is biased in that earlier fires of low severity or spatial extent were probably missed. The 16th century is the only century of the last six that fire activity was apparently absent. The increase in fire activity in the nineteenth century may reflect the ability to more accurately identify more recent fires, although the Kinney Creek history suggests that even late nineteenth century fires may be difficult to reconstruct in the Mixed Evergreen zone.

The lower elevation boundary of the white fir/herb type at Oregon Caves appears to have acted as a barrier to fire spread for many fires. Douglas-fir is not common in this type, comprising only 3 percent of the average 72 m^2ha^{-1} basal area. The herbaceous cover may exceed 100 percent during the summer, and the high foliar moisture of the green herbage may retard the spread of surface fires until the herbs cure in late summer. The presence of an all-aged white fir forest (Figure 8), the presence of numerous windthrow mounds, and the absence of Douglas-fir suggest that small scale wind disturbances have encouraged gap-phase reproduction of white fir.

TABLE 2. Natural fire rotation for Oregon Caves by century.

Time Period	Area Burned (ha)	Proportion (p)	Natural Fire Rotation (years)
1400-1500	197	1.0	100
1500-1600	0	0	–
1600-1700	244	1.24	81
1700-1800	213	1.08	93
1800-1900	576	2.92	34
1900-1989	86	0.44	204
1480-1989	1317	6.68	76

TABLE 3. Natural fire rotation for major community types at Oregon Caves, 1650-1930.

Community Type	Area in Type (ha)	Natural Fire Rotation (years)
Douglas-fir/oak	45.1	37
Dry white fir/ Douglas-fir	42.0	43
Mesic white fir/ Douglas-fir	55.4	61
White fir/herb	35.9	64

The mesic white fir/Douglas-fir type has substantially more Douglas-fir: 45 percent of the average 61 m^2ha^{-1} basal area is Douglas-fir. This type had slightly more frequent fire than the white fir-herb type. These two mesic types have the highest numbers of older trees (Figure 8), and historical fires of the last several centuries have typically been of low to moderate severity. The dry white fir/Douglas-fir type, with Douglas-fir comprising 63 percent of the 49 m^2ha^{-1} basal area, has burned more frequently, and surviving trees from earlier fires are more sparse. Most of the trees are younger than the 1875-76 event.

Discussion

When modern forest management developed in the United States, one of the major factors stimulating legislation and policy was the threat of wildfire, particularly large events in the Pacific Northwest in 1902 and 1910 (Pyne 1982). Fire in the forest was characterized as the antithesis of forest management (Agee 1989), and southern Oregon was a center of Forest Service efforts to oppose the use of fire in the forest. Peterson (1916) claimed that local communities opposed fire prevention because of a misunderstanding of the "conservation ideas." He noted that stockmen thought range carrying capacity had declined in the few years that fire protection had been in place. Hofmann (1917) implied in his Kinney Creek study that fires were a product of modern human activity. Haefner (1917) claimed burning by Indians, miners, stockmen, and hunters in the late

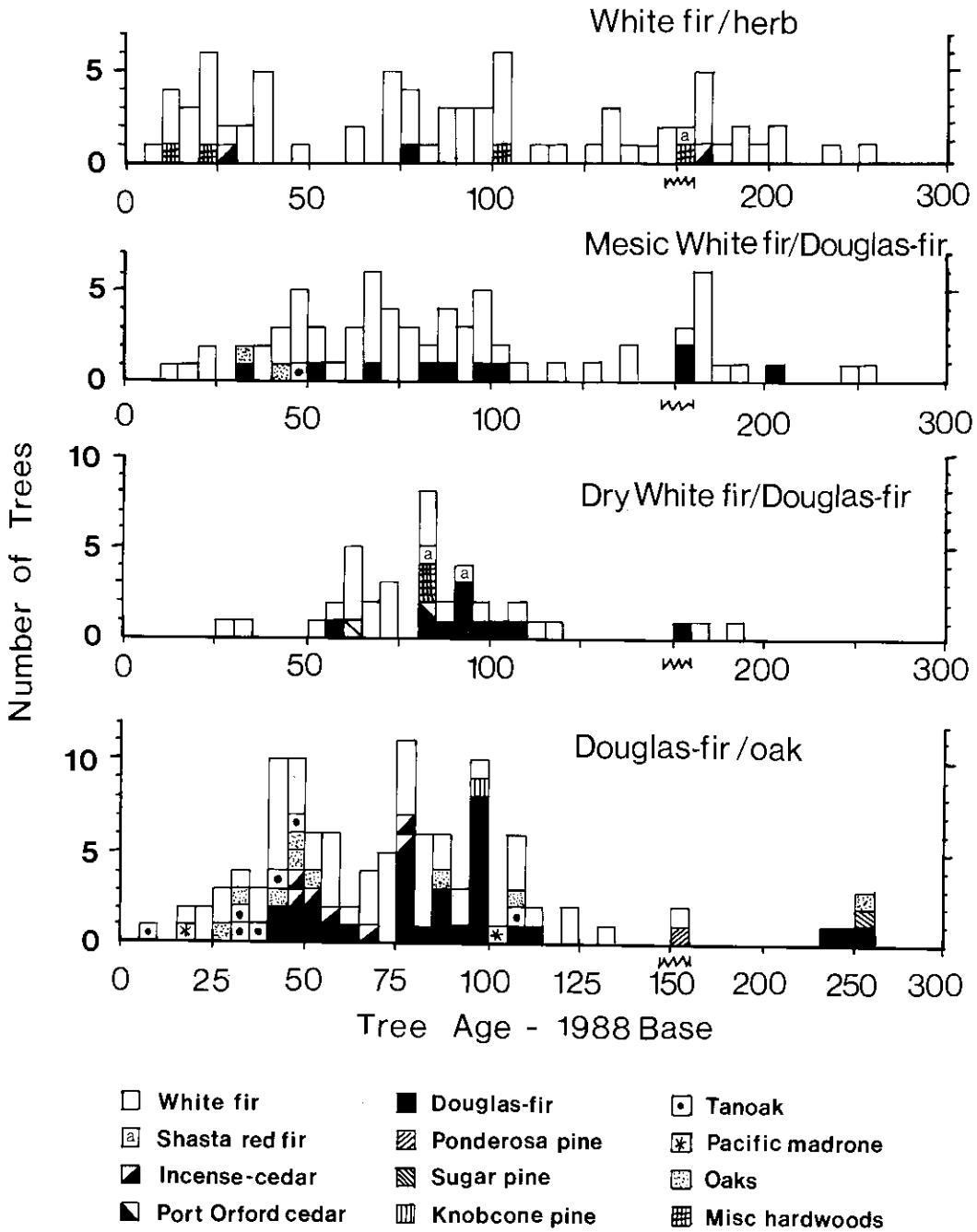

Figure 8. Age classes of forest tree species present in the major forest communities of Oregon Caves National Monument. Note that the horizontal scale changes from 5 years to 10 years at age 150 for each of the graphs. Species not previously identified in the text include: Shasta red fir (*Abies magnifica* var. *shastensis*), incense-cedar (*Calocedrus decurrens*), sugar pine (*Pinus lambertiana*), and tanoak (*Lithocarpus densiflora*).

nineteenth century had so increased fire frequency in the Siskiyou Mountains (Atzet and Wheeler 1982) that little trace was left of virgin stands in many areas. Yet the evidence for such claims, such as the area fire frequency of about 12 years between 1850 and 1920 across the extensive south-facing slope at Kinney Creek (Figure 5A), is not so different from the previous century (1760-1860) fire frequency of 16 years on the north-facing slope. This latter frequency estimate was made on a smaller area, which often increases the apparent fire return interval, and thus makes it a conservative estimate. Haefner's (1917) claims that southern Oregon did not experience forest fires prior to Euroamerican settlement are not justified.

The 1400-1989 natural fire rotation of 76 years for Oregon Caves (Table 2), although conservatively estimated, is similar to fire frequency in other dry Douglas-fir forests west of the Cascades. Natural fire rotations of 80 and 100 years have been estimated for dry Douglas-fir forests in western Washington (Agee and Dunwiddie 1984, Agee *et al.* 1990a), and for western Oregon (Morrison and Swanson 1990, Teensma 1987). If only the 1650-1930 period is considered, the overall NFR drops to 49 years, a more frequent fire history than most other Douglas-fir forests west of the Cascade Mountains (Agee, in press). The high fire frequency for Douglas-fir forest at Kinney Creek may be indicative of both a very dry, warm environment and the proximity of lower elevation types like ponderosa pine that, at least in other areas (e.g., McNeil and Zobel 1980), historically burned frequently. The close proximity of forest community types with typically different fire frequencies can result in a mixing of "typical" fire regimes (e.g., Agee *et al.* 1990a).

Old-growth Douglas-fir forests in southwest Oregon reflect the effects of multiple disturbances by fire. They will often be a mosaic of stands that contain very old trees and some younger age classes interspersed with other stands that were established after a stand replacement fire event. The landscape often has a patchy appearance created by interactions of fire frequency and severity, increasing forest structural and species diversity. Single fires separated by decades and those of low severity tend to result in Douglas-fir establishment, while ecosystems with fires closely spaced in time or severe fires have often favored knobcone pine, madrone, oak, or shrub species. Fire appears to have been a major determinant of historical landscape diversity in the Siskiyou Mountains. Future management scenarios, if they are to be successful, must recognize the inevitable flammability of this landscape, and the advantages of planning with fire as well as against it.

Acknowledgments

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