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THE FIRE HISTORY
CORAM EXPERIMENTAL FOREST

by

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ABSTRACT

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The Fire History of Coram Experimental Forest

Director: Robert W. Steele

This thesis documents the fire history and assesses the role of fire in the western larch/Douglas-fir forest of the Coram Experimental Forest in northwestern Montana. Primary attention was given to the frequency, areal spread, relative severity, and effects of fires prior to the advent of active suppression efforts in order to determine the natural occurrence and influence of fire.

Fire scars and stand age-classes were used to develop a fire chronology for the period 1602 to 1976. The mean fire-free interval during the historical fire period (1735-1910) varied according to topographic location: valley bottom >117 years, montane slopes 121 years, lower subalpine slopes 146 years, and upper subalpine slopes >146 years. A fire occurred somewhere in the 2984 ha experimental forest on an average of once every 11 years during the 374-year record period. The incidence of fire was high in the late 1800's and early 1900's.

Most fires were small (20 to 90 ha). However, fragments of charcoal in the soil indicated fire was a widespread occurrence throughout the forest.

Evidently most fires were moderately intense with occasional "runs" of high intensity flames which entered the crowns of the overstory, usually near the tops of ridges. Most fires stopped along ridgelines, ravines, and creeks. Single burns thinned the overstory resulting in mixed conifer regeneration and favoring western larch, Douglas-fir, and lodgepole pine. Multiple burns changed the composition usually promoting lodgepole pine. Fire is a major factor creating diversity of forest vegetation on similar sites and has maintained a heterogeneous tree age-class and canopy structure over the landscape.

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CHAPTER I

INTRODUCTION

Fire is a natural factor in coniferous forests of North America (Muir 1901, Show and Kotok 1924, Larsen 1929, Weaver 1968, Intermountain Fire Research Council 1970, Kilgore 1972 and 1973, Habeck and Mutch 1973, Heinselman 1973, Wright and Heinselman 1973, Swain 1973, Arno 1976). Indeed, fire is necessary for the continuation of certain biotic communities. Acknowledging fire as an integral part of the environment, Mutch (1970) hypothesized that the species in a fire-dependent community, in contrast with species in a community not fire-dependent, demonstrate flammable characteristics which promote fire. These characteristics ensure that fire remains a factor in the community.

The changing attitude about fire's role in the environment and its subsequent influence on fire management policies have raised questions about the types and patterns of fires that occurred in the past:

--how much fire was natural?

--how frequent were fires?

--how severe were the burns?

--how much land area burned?

--how widespread was fire in an area?

--what was the characteristic behavior of fires?

--what was the effect of fire on plant communities and, in turn, on animal communities?

--what has been the influence of settlement?

--what has been the effect of suppression?

The historical analysis of fire reveals the frequency, relative severity, and areal spread of past fires. Collectively, this information describes characteristic fire behavior and effects for an area, which in turn helps to determine the "role" of fire in a forest type. The role can be further used to understand the autecological effects of fire on individual species as well as fire's relationship to plant communities. Fire history studies provide the insight to fire in various ecosystems and the effects of fire exclusion. In order to make use of a natural force, i.e., fire, it is necessary to understand its function and pattern in the past.

Fire is an integral factor of natural systems, and its occurrence has direct or indirect effects on all resources: soil, water, animals, vegetation, etc. Provided with fire history information, land managers have a scientific basis on which to develop fire management prescriptions to maintain or restore resources and to evaluate the consequences of policy alternatives. Knowledge of historic fires more clearly defines the risk involved in permitting fire as well as the benefits.

Various information can be compiled to aid the reconstruction of historical fires: fire-scar analyses, stand age-class inventories, historical records, agency fire records, and aerial photos. The most complete analysis results when all are employed to describe the fire regime.

Coram Experimental Forest was selected for a fire history study for several reasons. Primarily, the study was an extension of fire history investigations into a more mesic forest area and climatic environment than encountered by Arno (1976) in the predominately ponderosa pine (*Pinus ponderosa* Laws.)--Douglas-fir (*Pseudotsuga menziesii* (Mirbel.)) and lodgepole pine (*Pinus contorta* Dougl.) forest types of the Bitterroot Valley, Montana. Coram was a good area to examine because of the 2984 ha size of the forest unit and its documented history of logging operations and fires since the 1920's. Finally, a fire history investigation would be a continuation of the research programs in the experimental forest.

Objectives of this study were as follows:

1. To determine and describe the fire history of Coram Experimental Forest through fire-scar analysis and stand age-class structure.
2. To interpret the role of fire in Coram Experimental Forest using the study results and historical fire information for surrounding forested areas.
3. To field test the fire history methodology being developed by Arno and Sneck (1977) and modify the techniques to investigate heavily logged areas and a mesic forest type.

CHAPTER II

GENERAL DESCRIPTION OF THE STUDY AREA

Location

The study area is Coram Experimental Forest located in the Hungry Horse Ranger District of the Flathead National Forest in northwestern Montana (figure 1). In this thesis, "Coram" will be used in reference to the Coram Experimental Forest and not the town of Coram, Montana. The experimental forest is about 11 km (7 mi.) south of West Glacier, Montana, and 34 km (21 mi.) northeast of Kalispell, Montana. The forest occupies 2984 ha (7460 ac.) located in T 30 N, T 31 N, R 18 W, and R 19 W, Montana Principal Meridan. The boundary lies along watershed divides on the northern and eastern sides and on legal subdivision lines (section lines) on the southern and western sides.

The Coram forest lies on the west side of Desert Mountain and is drained by Abbott Creek (figure 2). Elevation ranges from 1911 m (6370 ft.) on top of the mountain to 1006 m (3300 ft.) on Abbott Flats. Desert Mountain is the dominant topographic feature. Its main ridge, which runs about 8 km (5 mi.) southeastward from the peak forms the eastern boundary. A high spur ridge extends southwest into the area from the mountain top and forms the western slopes of Abbott Creek drainage. The southwestern portion of Coram Experimental

Figure 1. Location of Coram Experimental Forest in northwestern Montana.

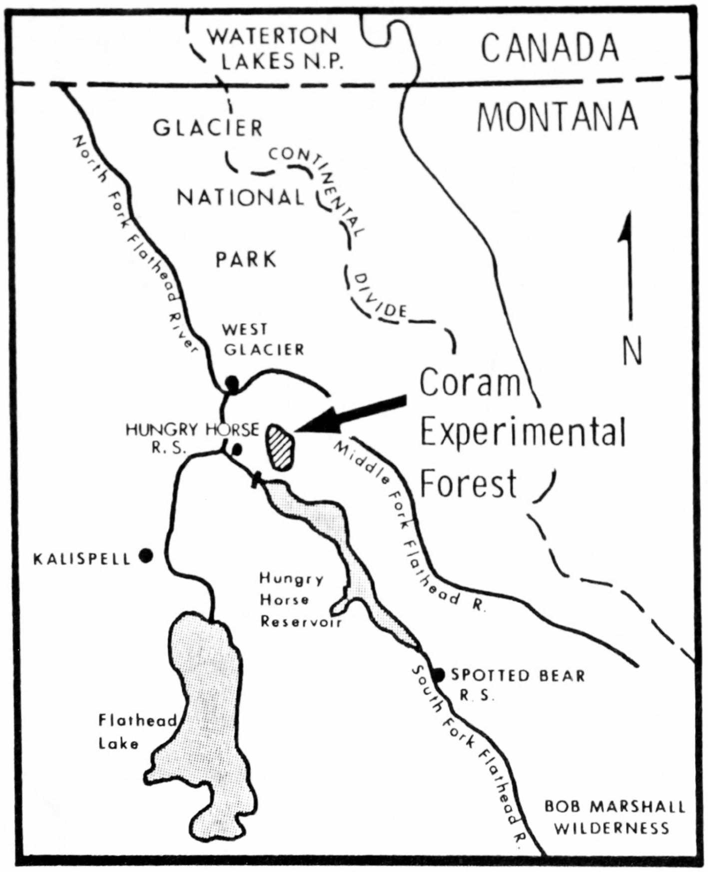
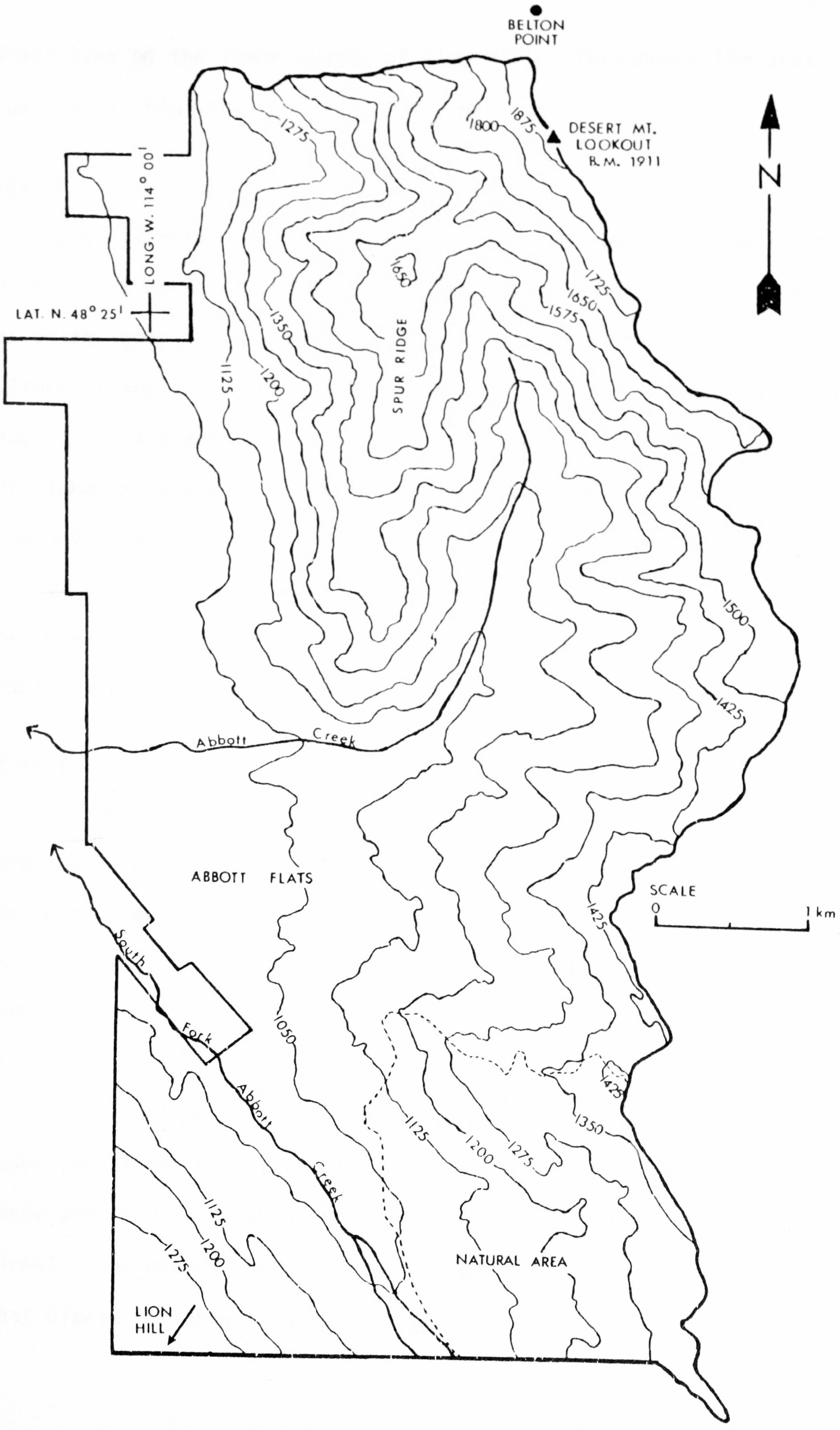


Figure 2. Coram Experimental Forest, Flathead National Forest.



Forest lies on the lower slopes of Lion Hill. Throughout the area, slopes vary from very gentle to 80% (39°).

History

Coram Experimental Forest was formally approved and established by the Chief Forester, USDA Forest Service, on June 21, 1933. It was established for the purpose of studying the ecology and silviculture of western larch (*Larix occidentalis* Nutt.) forests (Weidman 1932). In 1946 active research was initiated to develop guidelines for timber management. In recent years, research programs have examined other facets of resource management. The Intermountain Forest and Range Experiment Station, USDA Forest Service, conducts the research efforts while fire protection, road maintenance, and timber sales are the responsibility of the Flathead National Forest.

Climate

The mean annual temperature for Coram is about 6°C (45°F) computed from weather stations throughout the forest (Newman 1976). The mean temperature is approximately 16°C (61°F) for summer (June, July, August) and -7°C (19°F) for winter (December, January, February). Frost occurs as late as the end of May and as early as the beginning of September.

The annual precipitation is approximately 760 mm (30 in.) at the lower elevations (Weidman 1932, Klages *et al*. 1976, Newman 1976). There are no historical precipitation records for the experimental forest. The nearest weather stations are at Hungry Horse Dam and West Glacier. Table 1 summarizes their precipitation records and

Table 1. Average monthly precipitation in millimeters for West Glacier (WG) and Hungry Horse Reservoir Dam (HH), Montana (Climatological Data: Montana Section 1974).

	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
WG	83	62	45	47	63	86	36	37	56	65	79	80	739
HH	187	96	106	57	72	79	42	29	60	11	103	70	909

indicates what might be expected on the average at the lower elevations of Coram Experimental Forest. The data was extracted from long term records for the two stations (Climatological Data: Montana Section 1974).

Snow may begin to accumulate in early October and can last as late as May in the higher elevations. Summers tend to be short and cool. The driest months are July and August.

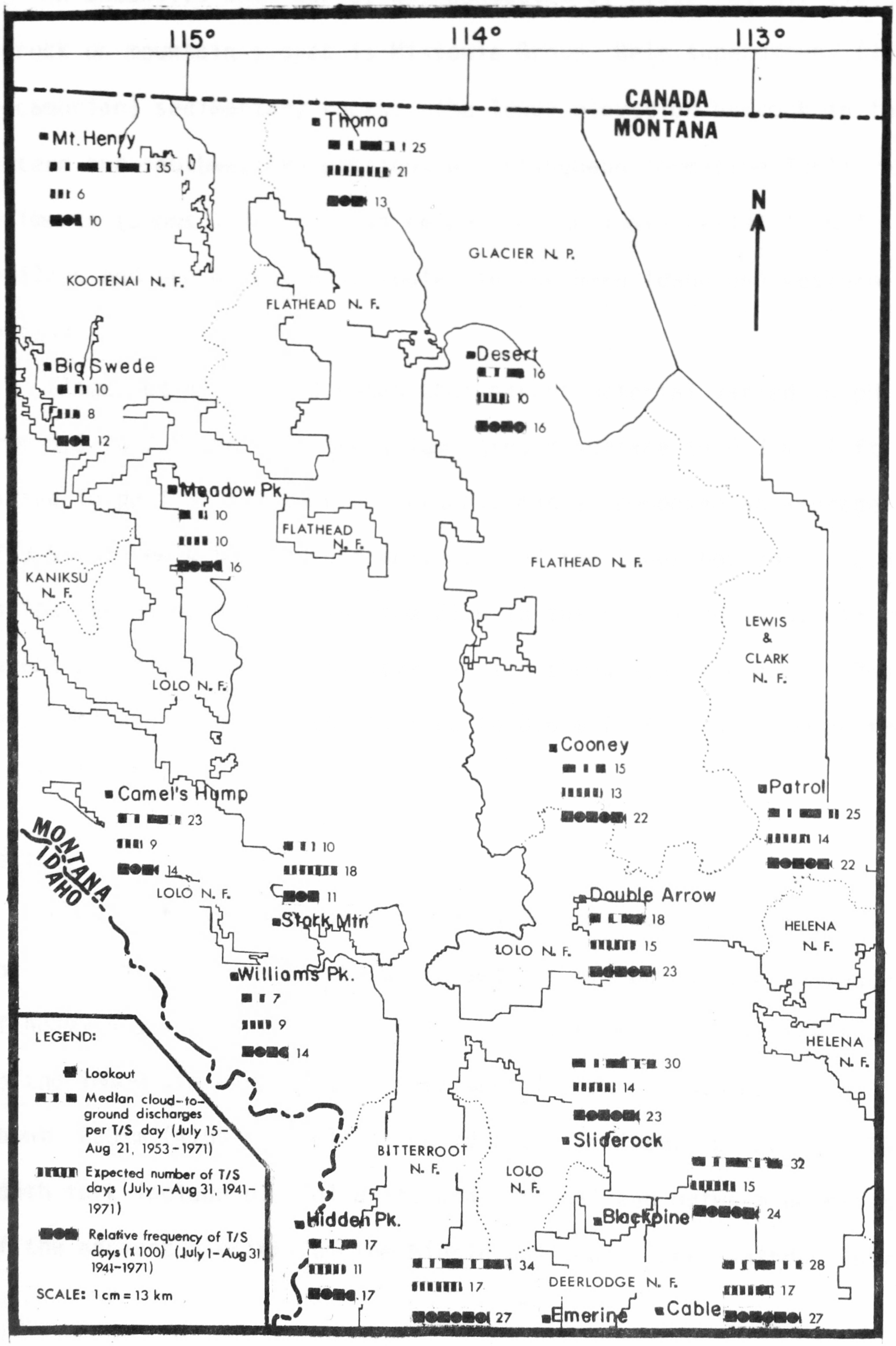
Pacific maritime polar air masses bring most of the annual precipitation and are the predominant air masses influencing the climate (Newman 1976). These masses are responsible for 90 percent of the winter moisture and 70 to 90 percent of the summer precipitation. Arctic continental polar air masses appear mainly in the winter months.

Summer thunderstorms generally approach from the southwest and are usually weakened by the time they reach the Coram Experimental Forest. Barrows (1951) reported that fewer lightning fires occurred in the forests of northern Idaho and northwestern Montana than in forests farther south.

Figure 3 shows the thunderstorm days and cloud-to-ground lightning activity data compiled for twenty to thirty years from fire lookouts in western Montana for Project Skyfire (Northern Forest Fire Laboratory, Missoula, Montana). The figures from Big Swede and Meadow Peak lookouts to the west of Desert Mountain are probably low because the full-radius views of lightning activity are blocked by mountains to the west (Finklin, 1977). The map illustrates that thunderstorms and associated lightning is greater in the south than in the north. Also, the expected number of thunderstorm days, the relative frequency of thunderstorm days, and the median cloud-to-ground lightning discharges per thunderstorm day were often lower for Desert Mountain than for nearby lookouts.

Glacier National Park lookouts were not included in Project Skyfire. However, Colony (1977) stated that summer storms generally approach the park in the late afternoon travelling in a southwest-northeast direction across Flathead Valley and usually dissipating before reaching the Continental Divide. Only major storm systems are capable of crossing the divide. The average number of lightning fires is about ten per year. The mode is about fifteen per year. Most of the fires occur on Apgar Hill, Synder Ridge, and Howe Ridge, all located in the proximity of Lake McDonald. Colony noted that the forests on the west side of the Continental Divide have a higher lightning fire incidence than those on the east side. Habeck (1970) and MacKenzie (1973) discussed the higher occurrence of lightning fires on the west side of the divide.

Figure 3. Long-term data for thunderstorm (T/S) days and cloud-to-ground lightning discharges compiled for several lookouts in western Montana (courtesy of Project Skyfire, Northern Forest Fire Laboratory, Missoula, Montana).



Soils

An extensive soil survey was conducted by Klages et al. (1976). Bedrock on mountain slopes is Missoula Group, Belt supergroup, (late Precambrian) sedimentary rocks. The lower elevation bedrock in the western and southwestern portions are Kishenehn formation Tertiary sediments (Johns 1970). Soils belong to the loamy-skeletal soil families and are widely distributed in northern Idaho and western Montana.

Klages et al. (1976) noted that parent material varied in pH from 5.2 to 7.8 and that the solum (ground surface to 0.3 m (1 ft.)) varied in pH from 5.0 to 6.9. Organic matter composed an average of 3.6% of the A horizon but only 0.3% of the lower horizons. C:N ratios decreased with depth from 21.0 in the A horizon to 8.1 in the parent material. Fertility level varied throughout the area. Roots were most abundant from the surface to 0.6 m (2 ft.) and common from 0.6 to 1.3 m (2 to 4 ft.).

Geology

Prominent U-shaped valleys, extensive morainal deposits, and pot-hole lakes in the northwestern section of Montana are evidence of heavy glaciation. Glacial till and pot-holes occur inside and to the immediate west of the experimental forest. Slopes up to about 1230 m (4100 ft.) elevation adjacent to Abbott Creek and its south fork include glacial drift and morainal and outwash deposits of the ancient glaciers of the Middle and South Fork Flathead lobes

(Klages *et al*. 1976). Steep mountain slopes at higher elevations were probably lightly glaciated.

Much of the area has a thin layer of volcanic ash not far below the surface.

Vegetation

Coram Experimental Forest is a western larch--Douglas-fir forest type (SAF 212) (Weidman 1932, Society of American Foresters 1954, Shearer 1961). The habitat types occurring in the forest according to Pfister *et al*. (1977) are: *Abies lasiocarpa/Clintonia uniflora* h.t. (subalpine fir/queen cup beadlily); *Abies lasiocarpa/Menziesia ferruginea* h.t. (subalpine fir/menziesia); *Abies lasiocarpa/Linnaea borealis* h.t. (subalpine fir/twinflower); *Abies lasiocarpa/Xerophyllum tenax* h.t. (subalpine fir/beargrass); and *Pseudotsuga menziesii/Physocarpus malvaceus* h.t. (Douglas-fir/ninebark), and small amounts of *Tsuga heterophylla/Clintonia uniflora* h.t. (western hemlock/queen cup beadlily; and *Abies lasiocarpa/Oplopanax horridum* h.t. (subalpine fir/devil's club).

The forest tends to have an open canopy at high elevations especially near the top of Desert Mountain where the climate is cold and soils are poorly developed. At lower elevations the forest cover is generally dense and continuous. The forest is typically a mixed stand, although small nearly-pure pockets of western larch, lodgepole pine, Douglas-fir, subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.), and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) do occur. Spruce (*Picea glauca* x *Picea engelmannii* (Lunan and Habeck

1973) is commonly found in mixed stands primarily with Douglas-fir and subalpine fir. Ponderosa pine and western white pine (*Pinus monticola* Dougl.) are rather scarce.

CHAPTER III

LITERATURE REVIEW

The most complete fire history information is obtained from analysis of fire scars in the annual growth rings of surviving trees. Dendrochronology, or growth ring analysis, is the science which treats of the accurate dating of past events through the ring records. Gardner (1905) and Clements (1910) used tree-ring analysis to study the occurrence and effects of forest fires in Colorado. Later investigators elaborated on the basic dendrochronological techniques and refined the procedures. Additional fire history information can be acquired by reading the following publications which present the chronology and role of fire in several areas of North America:

Alberta--Byrne 1968, MacKenzie 1973, Tande 1977
British Columbia--Howe 1915
Montana--Arno 1976, Gabriel 1976
Idaho--Marshall 1928, Burkhardt and Tisdale 1976
Washington--Weaver 1961
Oregon--Keen 1940, Weaver 1959, Soeriaatmadja 1966, McNeil 1975
Wyoming--Loupe and Gruell 1973, Houston 1973, Taylor 1974
Colorado--Clagg 1975
Nevada--Blackburn and Tueller 1970
California--Show and Kotok 1924, Kotok 1933, Biswell 1959, Wagener 1961, Kilgore 1973, McBride and Laven 1976

Arizona--Leopold 1924, Weaver 1951

New Mexico--Weaver 1961

Minnesota--Spurr 1954, Frissell 1971, Heinselman 1973

Wisconsin--Massurow 1941

New Hampshire--Henry and Swan 1974

In addition to the use in fire history, dendrochronological data have been used for dating various other types of historic events such as beaver activity (Neff 1955), porcupine activity (Spencer 1958), soil movements on permafrost (Zoltai 1975), glacial movement (Sigafoos and Hendricks 1961), prehistoric human cultures (Douglas 1941), deer damage to trees (Lutz and Chapman 1958), and insect epidemics (Evenden 1940). Dendrochronological studies can use any woody plants which bear growth rings (Roughton 1962).

Indicators of forest fires include fire-killed standing or fallen trees, burned stumps, charred trunks, and charcoal in the soil. Severe fires may kill nearly all forest trees. An even-aged stand of seral tree regeneration often results from such fires. In less severe fires, resistant trees are more likely to be scarred than killed. By dating the scars, the history of fire can be determined. In addition to its use in dating firest, the scar information can be used to confirm stand age-classes arising after the fire.

Identification of Fire Scars

A scar results when the tree is exposed to a sufficient degree of heat long enough to kill a portion of the cambium. The tree attempts to heal itself by growing new wood over the dead area from the edges of the wound. If successful, the scar becomes a hidden or buried wound. When the healing process is interrupted by another fire or when the tree is unable to cover the wound, a catface or open scar develops.

The development of a fire scar depends on fire behavior (rate of spread, residence time, and intensity), bole diameter, bark thickness, fire resistance of the species, topographic location, stand density, localized fuel accumulation, previously scarred tissue, bark flammability, season of burning, climatic factors, and fuel characteristics of the crown. Some of these factors have been discussed by Lacmund (1923), Show and Kotok (1924), Flint (1925), Fahnestock (1960), Frissell (1971), McNeil (1975), Tande (1977), and Zackrisson (1977), Gill (1974) also discussed the heat partitioning around tree boles.

Agents other than fire can cause scars on trees (Frissell 1971, Gabriel 1976, Arno and Sneck 1977, Tande 1977, Zackrisson 1977). However, fire scars possess the following characteristics which distinguish them from scars caused by other factors (Rowe _et al_. 1974):

a. Elongate or triangular in shape with the broadest part usually at the base of the trunk.

b. Black charcoal on the trunk (outer bark) and, with subsequent burns, on the exposed scar wood.

c. In the cross-section view, ring width usually increases or decreases dramatically following a fire.

d. In the cross-section view of multiple scars, a black crust marks the outer margin of the annual ring which was formed in the year in which the fire occurred.

Field Sampling

Subjective sampling for fire scarred trees and regeneration can prevent oversampling atypical vegetative and fire environments and allow selective placement of study sites when there is a scarcity of suitable forested land (Show and Kotok 1924, Heinselman 1973, Arno and Sneck 1977, Zackrisson 1977). Potential fire boundaries, i.e., ravines, ridges, lake shores, and wetland margins, are good locations to collect data (Tande 1977).

When there is a choice, it is best to sample trees with the greatest number of scars. The tree species is also important because some species, such as lodgepole pine, ponderosa pine, and Douglas-fir, characteristically have clearer growth rings and are less susceptible to rot and insect damage (Frissell 1971, McNeil 1975, Gabriel 1976, Arno and Sneck 1977, Tande 1977, Zackrisson 1977).

Trees. Methods of cutting the growth-ring sample from live trees may vary with investigator. Some remove wedge-shaped partial cross-sections from the stems (Heinselman 1973, McNeil 1975, Gabriel 1976, Tande 1977). A technique to remove flat partial cross-sections has been described by Arno and Sneck (1977) which was developed to facilitate transporting a number of cross sections from the field. Also, because these partial cross sections lie flat under the microscope (unlike wedge sections), the growth-ring counting process was enhanced.

The cutting method by McBride and Laven (1976) to obtain scarred tissue was developed to remove as little wood as possible. It would be appropriate in some forests where it is necessary to minimize the visual impact and structural damage to trees.

Stumps. Analysis of growth rings on stumps has been used previously by investigators to determine fire history (Show and Kotok 1924, Wagener 1961, Frissell 1971, Kilgore 1972, Zackrisson 1977). Stumps 30 to 40 years old are often satisfactory if they are relatively sound, i.e., not decomposed or burned (Arno and Sneck 1977). If the year of logging is unknown, the chronology from stumps can be correlated with scars on living trees (Frissell 1971, Zackrisson 1977).

Regeneration. Using increment borings to obtain stand-origin dates is an established technique (Marshall 1928, Heinselman 1973, Arno 1976, Zackrisson 1977). However, relying on increment borings of regeneration solely to determine the precise year of a fire is not advisable because most regeneration may be delayed for at least two or more years following fire because of a lack of seed parents, bad seed years, or unfavorable post-germination conditions (Arno 1976, Zackrisson 1977).

Laboratory Analysis

Growth ring phenomenon. Scars on various trees inflicted during a specific fire year often occur one or a few rings before or after the actual date because of such growth phenomenon as missing rings, false rings, or additional rings (Show and Kotok 1924, Douglass 1928, Glock 1937, Ferguson 1968, Frissell 1971, McNeil 1975, Arno and Sneck 1977). False rings are generally faint and discontinuous but may not be recognized in partial cross-sections. Additional rings may occur during a growing season when climatic changes cause growth to cease, then commence again before the winter months; however, this is generally not a problem in western conifers (Ferguson 1970, Arno and Sneck 1976). Inaccurate ring counts can also result from rot or insect damage in the sample.

Severe fire injury or defoliation may cause temporary growth cessation. Craighead (1927) examined some ponderosa pines which discontinued forming annual rings for as long as five years after extensive injury and defoliation but which remained alive and eventually resumed annual growth.

Recognizing the fire-scarred growth ring usually is not difficult because post-fire growth rings are often either narrower or wider than the pre-fire annuli (Rowe et al. 1974, Zackrisson 1977). Craighead (1927) reported narrow ring growth in pine following varying degrees of crown defoliation by fire. McNeil (1975) found that a growth rate decrease occurred the year of the fire or the year after. Increased radial growth following fire was reported by Molnar and

McMinn (1960). This phenomenon is probably due to the stand-thinning function of fire (Weaver 1947).

Increment core analysis. If the pith is omitted when obtaining an increment core, Arno and Sneck (1977) suggest estimating the curvature and thickness of the innermost rings to project the number of additional rings to the pith. A similar technique has been described by Stokes and Smiley (1968). Henry and Swan (1974) estimated the number of missing rings by dividing the radial width of the missing portion by the average width of the readable surface.

Growth factor. To obtain the total age of a tree from which was taken a cross-section or increment core, it is necessary to add the estimated number of years for seedling establishment and growth to curring or boring height. One method is to age a large number of seedlings then determine a general growth factor (Arno 1976, Arno and Sneck 1977). Another method was used by Henry and Swan (1974). Increment borings were made at 23 cm (9 in.) above the ground to obtain age- and growth-rate estimates. The growth factor was determined by boring ten trees of each species at ground level and at 23 cm to get the number of years by which the cores taken at 23 cm were short of the stem age.

Fire chronology. A fire-year chronology is based on cross-dating the fire history records from individual trees and stand age-class information (Clements 1910, Show and Kotok 1924, Spurr 1954, Frissell 1973, Heinselmann 1973, McNeil 1975, Arno and Sneck 1977, Zackrisson

1977). The individual tree chronologies should be adjusted to identify fire years. The final chronology may partition fire years by habitat types, stands, topography, or any catagorization which delineates the role of fire.

The information from the chronology is used to determine the fire frequency (or fire-free interval), usually presented as an average. Frequency often is given for an era or period of years (or decades) to assess the effect of suppression policies and settlement on the "natural" fire regime (Frissell 1971, Heinselman 1973, Burkhardt and Tisdale 1976, Arno and Sneck 1977, Tande 1977, Zackrisson 1977).

Fire spread maps. Plotting the samples on a map makes it possible to estimate the spread of individual fires and the total area burned. Aerial photographs can also delineate fire boundaries. Difficulty occurs when more recent fires eliminate the evidence of the spread of earlier fires (Frissell 1971, Heinselman 1973, Habeck 1976, Arno 1976, Gabriel 1976, Tande 1977).

Fire History in the Vicinity of Coram Experimental Forest

Ayres (1900a) described past fires in the Flathead Forest Reserve, now Glacier National Park and adjacent lands to the west in the Flathead National Forest. He remarked on the severity and extent of the fires, especially the more recent burns. These destructive fires changed the forest composition by killing much of the overstory and favoring replacement by dense stands of lodgepole pine. Mountain slopes that had been burned repeatedly often became barren of tree cover. In the higher elevations, sizeable burns were less frequent but the effects were often as destructive particularly after repeated burns. Ayres did find some areas within the reserve which had not experienced high intensity fires. In areas that had been burned by light to moderate fires, the composition of the regeneration was similar to that of the overstory, and the regeneration was better than on intensely burned sites. Some forests in the Reserve had escaped fire for numerous years.

The Stillwater Valley had a unique history of fire in relation to surrounding areas which had been severely burned. Ayres wrote:

> "Very destructive fires have been rare in this region, although there is evidence that fires have frequently run over the land. Fire-killed areas, however, are found along the mountain slopes, where some of these areas are bristling with small dead trees. The fires that have run over the greater portion of the valley have been moderated by the abundant bear grass, which, remaining green throughout the season, retards fire. Fires have scorched and slightly injured butts of large trees, and occasionally, blackened stubs are found. Here and there are areas of several acres on which small trees, up to 2 inches in diameter, have been killed by these light fires, but in the main valley no large areas were found where fire had killed many large trees, except in the upper portion of the Stillwater Valley and on the mountain slopes."

A recent fire management report for Glacier National Park agreed with Ayres' description of fire disturbance in that area (Glacier National Park 1977). Information from recent studies included in the report provided historical frequencies for various vegetation types. Fires in the high country (>2000 m or 6100 ft.) are rarely extensive and are infrequent, perhaps occurring naturally every 300 to 600 years. In a moist, sheltered valley along Avalanche Creek, a western redcedar and western hemlock community has escaped a crown fire for 500 years, but scars and char on the bark are evidence that ground fires occurred. Upstream at a slightly higher elevation, much of the forest burned in about the year 1800 and has developed into a dense, almost-pure hemlock forest with occasional redcedar, larch, and white pine. Spruce stands in the moist draws are 250 to 370 years old. The moist, shaded ground fuels usually act as fire breaks to all but high intensity fires. In the drier forest communities fire occurs every 25 to 100 years compared with perhaps every 250 years in the moderately moist communities. Grasslands and adjacent open lodgepole pine stands probably were burned by ground fires at 10- to 15-year intervals. Fire maintained communities are the rule rather than the exception in Glacier National Park.

Ayres (1900b) also described fire disturbance in the former Lewis and Clarke Forest Reserve which is now partitioned into the Flathead and the Lewis and Clark National Forests, lying respectively west and east of the Continental Divide. Fire disturbance was similar to the Flathead Forest Reserve, and individual fire years were common to both. Ayres described fires as being generally severe, stand-destroying burns. Multiple burns created shrubfields. Ayres estimated that as of the year 1900 one-third of the reserve had been burned by destructive fires and that most fires occurred within the previous 60 years. Many light and moderate burns also occurred: these left seed trees and favorable seedbeds and killed fire-sensitive species to the advantage of fire resistant (thick-barked) trees.

Ayres described the Swan Valley (southwest of Coram Experimental Forest) as having had destructive fires but in the upper valley there was evidence of moderate burns. Antos (1977) stated that on mountain slopes in the Swan Valley most fires were severe, killing the overstory and initiating a new stand, usually of lodgepole pine and/or western larch. The presence of multiple-aged larch stands in the valley bottom suggested repeated moderate-intensity fires, while even-aged stands of lodgepole pine again indicated occasional high intensity fires. Frequent fires maintained the Abies grandis habitat types in seral forest communities. Most stands were fire-initiated; however, many of those on the valley bottom are (or were before logging) greater than 300 years old.

Gabriel (1976) investigated the fire history of the Danaher Creek Basin in the Bob Marshall Wilderness and reported patterns of fire frequency, spread, and intensity. The Danaher area has less annual precipitation (500 mm/yr or 20 in/yr) than Coram Experimental Forest (760 mm/yr or 30 in/yr), consequently these forests were dominated mostly by lodgepole pine with Douglas-fir and western larch secondary. Subalpine fir dominated the high elevation forests. In the southern half of the drainage, low intensity surface fires were recorded at 20- to 40-year intervals in each stand. In contrast, large stand-destroying fires were characteristic of the northern half of the study area.

Gabriel (1976) found old mixed stands (100 to 300 years old) of the predominately shade tolerant conifers throughout the lower elevations. These stands showed no ready evidence of fire even though adjacent forests had been burned. This information plus the locations of single- and multiple-scarred trees and of fire-initiated stands indicated a sporadic pattern of stand replacement burns even when high intensity fires occurred.

In the subalpine fir zone, fires occurred in a seemingly random manner, and scars on adjacent trees were often from different fires (Gabriel 1976). This pattern was attributed to the high incidence of lightning fires and low fuel quantities which confined fires to a small area. However, there were occasions of high intensity burns entering from lower elevations and largely destroying some subalpine stands.

The fire history for the Waterton Lakes National Park presented by MacKenzie (1973) was quite similar to the reports by Ayres (1900a, 1900b), Gabriel (1976), and Antos (1977). Lodgepole pine was the dominant species and had been perpetuated by fire. MacKenzie only investigated stand-destroying fires so the history of low intensity fires was not discussed. Approximately 80 percent of the park had burned since 1830. The variable pattern of fire spread and intensity was demonstrated by the mosaic of young seral stands, old-growth forests, and fire-created shrubfields.

A consistent feature of the reports by Ayres (1900a, 1900b), Gabriel (1976), and MacKenzie (1973) was that a history of severe fires greatly changed the species composition and structure usually perpetuating lodgepole pine at the expense of western larch and

Douglas-fir. Multiple burns within a span of a few decades often turned forests into shrubfields. This effect was most pronounced in the lower subalpine zone. In addition, the severe and multiple burns obliterated much of the evidence of past fires so that it would be very difficult to trace fire history back as far as the 18th century.

CHAPTER IV

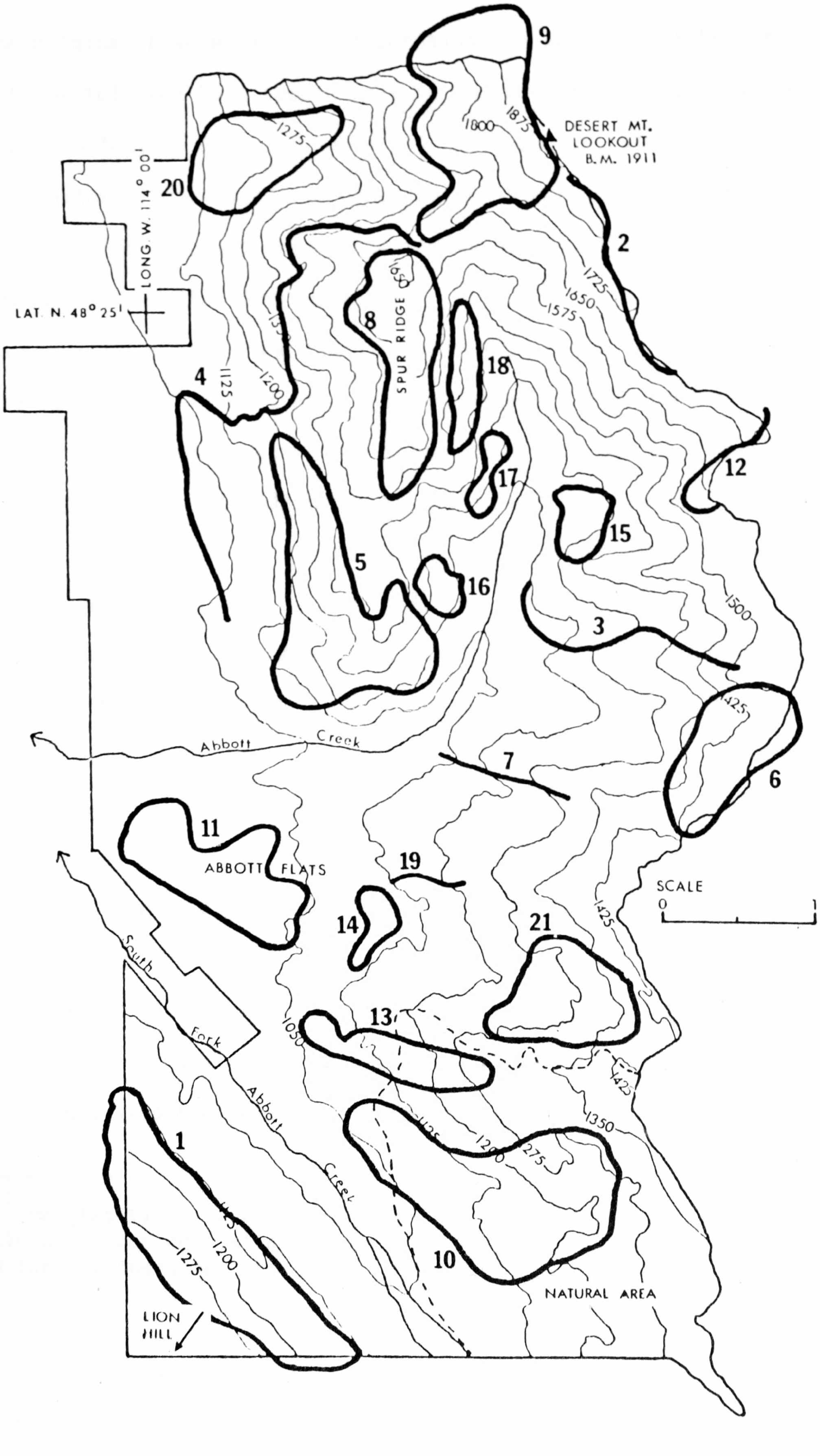
METHODS

Transect System

Fire scars on trees and stumps were intensively examined and sampled on the Coram Experimental Forest and in selected logged areas of the Flathead National Forest. The techniques used to investigate fire history generally followed those suggested by Arno and Sneck (1977). The procedures were to age and correlate dates of fire scars and to identify age classes of apparent fire-initiated regeneration in a stand.

After an initial field reconnaissance of Coram, a network of transects was laid out on a topographic map (figure 4). Transects were dispersed over the forest, mainly on the slope, and were designed to cover all elevations and aspects. Stream bottoms and ridges were not as intensively sampled since these landforms have vegetation and fire environments not representative of most of the area. The transects were subjectively placed; they often followed established trails and varied in length and design. Trees that were sampled were located near the route. However, when a transect crossed a logged unit, the area was intensively and systematically examined in a zigzag pattern for stumps of fire-scarred trees. In very extensive logging operations (>40 ha or 100 ac.) only selected portions of the cutting units were examined.

Figure 4. Network of transects used in the fire history study.



The original plan entailed a reconnaissance walk of the transect system to be followed by a second walk to collect samples as suggested in the methodology by Arno and Sneck (1977). However, since trees which had external fire scars were scarce and since most trees had only one scar the plan was changed to sample nearly all scarred trees when encountered on the first walk.

Care was taken to become familiar with fire scars to avoid mistaking a scar caused by root rot, scraping from a fallen tree or logging incident, frost cracks, and animal or insect damage. Scars caused by fire were distinguishable by having pitch or charcoal deposits, char on the bark or external scarred tissue, usually being located on the upslope side of the tree, and having dates corresponding to those found on neighboring samples. Also, certain scar formations were learned to be fire caused by examining scars from areas with known fire years.

Three types of field observations were made along the transects:

1. An account of habitat types[1] (Pfister _et_ _al_. 1977) and local vegetation was made on the field form checklist. Logged areas were habitat-typed in the cutting unit and/or in a similar, unlogged stand nearby. Habitat-type plots and ecotones were indicated on a field map. The forest had also been habitat-type mapped in 1973.

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[1] "Habitat type" is the aggregation of land units which are capable of producing similar plant communities at climax. It is named for the characteristic climax plant association.

2. Fire-scarred trees and stumps were described in field notes, sampled, and located on a topographic map. The following information was recorded for each sample in a "log of fire-scarred trees and stumps" (appendix A-1, A-2, A-3):
    a. transect number
    b. tree or stump sample number
    c. species
    d. d.b.h. or diameter at 0.3 m (1 ft.) for stumps
    e. total number of fire scars
    f. number of growth rings to fire scars and to the pith
    g. habitat type and phase
    h. elevation
    i. aspect
    j. description of sample location
    k. record of photograph if taken
3. Fire-initiated stands were described. In each, 0.04 ha (0.1 ac.) plots were subjectively chosen which appeared to have representative timber types and stand conditions. In these plots, increment borings were taken from trees at 0.3 m (1 ft.) above the ground level to determine the age class of the stand. Annual rings of a core were counted in the field for an estimate of the tree's age. A sufficient number of trees in a plot were bored to get a proper representation of the age-class, i.e., at least three cores were collected to confirm one age-class. The cores were

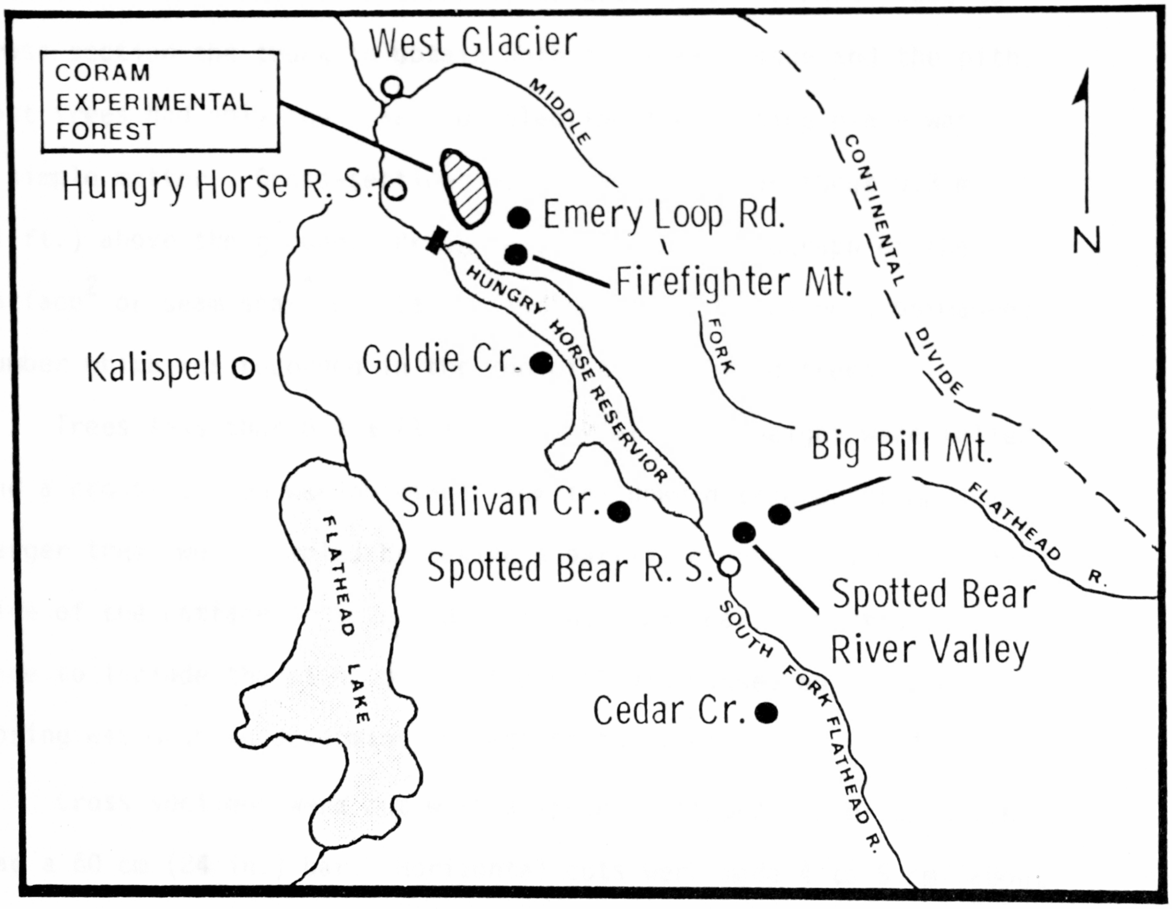
placed into sealed plastic straws and labeled by transect number, location, species, and tree d.b.h. In logged areas, age classes were determined by counting annual rings on stumps or obtaining increment borings from trees adjacent to the cutting unit.

Adjacent areas of the Hungry Horse and Spotted Bear Ranger Districts, Flathead National Forest, were also studied (figure 5). Logged areas were specifically examined because experience gained at Coram Experimental Forest had shown that more information was obtainable from stumps than trees. Also, the extensive wildfires since 1889 had been recorded and mapped by the Flathead National Forest, Kalispell, and spot checks of the age of the fire-initiated regeneration correlated with the Forest Service fire spread maps. A transect system was not used here; instead, the logged areas were canvassed for fire-scarred stumps. Habitat types were determined in the logged sites and in similar forests nearby. Fire-scarred stumps and fire-initiated regeneration were sampled and documented in the same manner as previously described for Coram.

Field Sampling Techniques

Trees. Nearly all fire-scarred trees encountered were sampled. Those that were rotten or had poor scar formation were not sampled. Also, when a fire year was represented by at least three cross sections and stand age-class dating, then it was considered unnecessary to obtain more cross sections from scarred trees in the burnt area.

Figure 5. Logging units (●) with fire history evidence in the extended study area around Hungry Horse Reservoir.



In such cases, increment borings were taken from the unsampled scarred trees to estimate the date the fire scar and ensure it was the same year as previously collected.

Scars were examined externally to determine the best place to cross-section the trunk to obtain both the scar tissue and the pith. Most trees had only one scar, so selecting the cutting place was a simple matter. Cross-sections were generally made about 0.3 m (1 ft.) above the ground. Prior to cutting, a photograph of the catface[2] or seam scar[3] was taken, and the tree was given a permanent number which was recorded in the log of fire-scarred trees.

Trees less than 0.3 m (1 ft.) thick at stump height were felled, and a cross-section was obtained from the downed tree or stump. Larger trees were sampled by taking a partial cross-section from one side of the catface or both sides of the seam scar. An effort was made to include the pith, but if the pith was missed an increment boring was made to determine the age of the tree.

Cross sections were cut with a sprocket-tipped chain saw which had a 60 cm (24 in.) bar. Horizontal cuts were made 4 to 5 cm (about 1.5 to 2 in.) apart and extended through the cambium to the pith. These cuts were made deep enough to insure that they went beyond the deepest scar so ring counting could be done in unscarred tissue.

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[2] In this study a "catface" is an open scar or scars resulting from one or more fires.

[3] A "seam scar" is a vertical, occluded fire scar possible extending 2 to 3 m (6 to 9 ft.) up the trunk.

Vertical cuts were made along the back of the parallel cuts to free the sample. The sample tree number was written on the cross section and on the tree. A field count was taken to estimate the date of the scar ring and the pith and was included in the field notes.

Stumps. Annual rings of sample stumps were counted in the field (using a 10x hand lens when necessary) enough times to obtain a good estimate of fire scar and pith dates. The top of the stump was photographed with markers to pinpoint fire scars and the pith. The stump was numbered and recorded in the field notes.

Regeneration. Stand-origin dates were mainly taken from early seral (shade-intolerant) species whose presence in large numbers in an age class could be related to forest fires. Most cores were collected from western larch and lodgepole pine, which are very aggressive seral species (Schmidt *et al*. 1976, Shearer 1976), and from Douglas-fir, which is a seral species in *Abies lasiocarpa* habitat types (Pfister *et al*. 1977). Lodgepole pine occurs throughout the forest but in several of the *Abies lasiocarpa* habitat types, it is the major pioneer species following fire (Pfister *et al*. 1977). However, there are known cases where the potential climax species have regenerated immediately after fire (Habeck and Mutch 1973). In a few cases, the climax species were used to age stands in Coram when it was apparent they represented the fire sere.

Maps and Aerial Photographs

A timber type/stand age-class map was used with aerial photographs (1:15,840) to identify stands and fire boundaries and to locate them on the ground. The map (figure 6) was originally drawn in 1934 but was updated for this fire history study.

Laboratory Analysis

Fire scar analysis.

The cross sections were dried, sanded and examined with a binocular microscope (7x to 25x). Ring counts proceeded from the cambium to the pith. Every tenth ring was marked in red pencil with a "-" and every fire-scar ring with a "+". (The same markings were used when counting rings on stumps in the field.) Counts were taken on three separate occasions to verify the dates.

Increment core analysis.

Increment cores were air-dried and glued onto core boards, which were made by cutting grooves in a 2.5 by 20 cm (1 by 8 in.) piece of lumber. The core boards prevented the cores from breaking and provided a secure mounting for counting rings under the microscope. The counting and marking procedure was the same used for analyzing cross sections. When the pith was not included, the number of additional rings to the pith was estimated by consideration of the curvature and thickness of the innermost rings. The projected pith was drawn on an index card which had been placed along the core (Arno and Sneck 1977).

The age-class information was later correlated with the fire chronology.

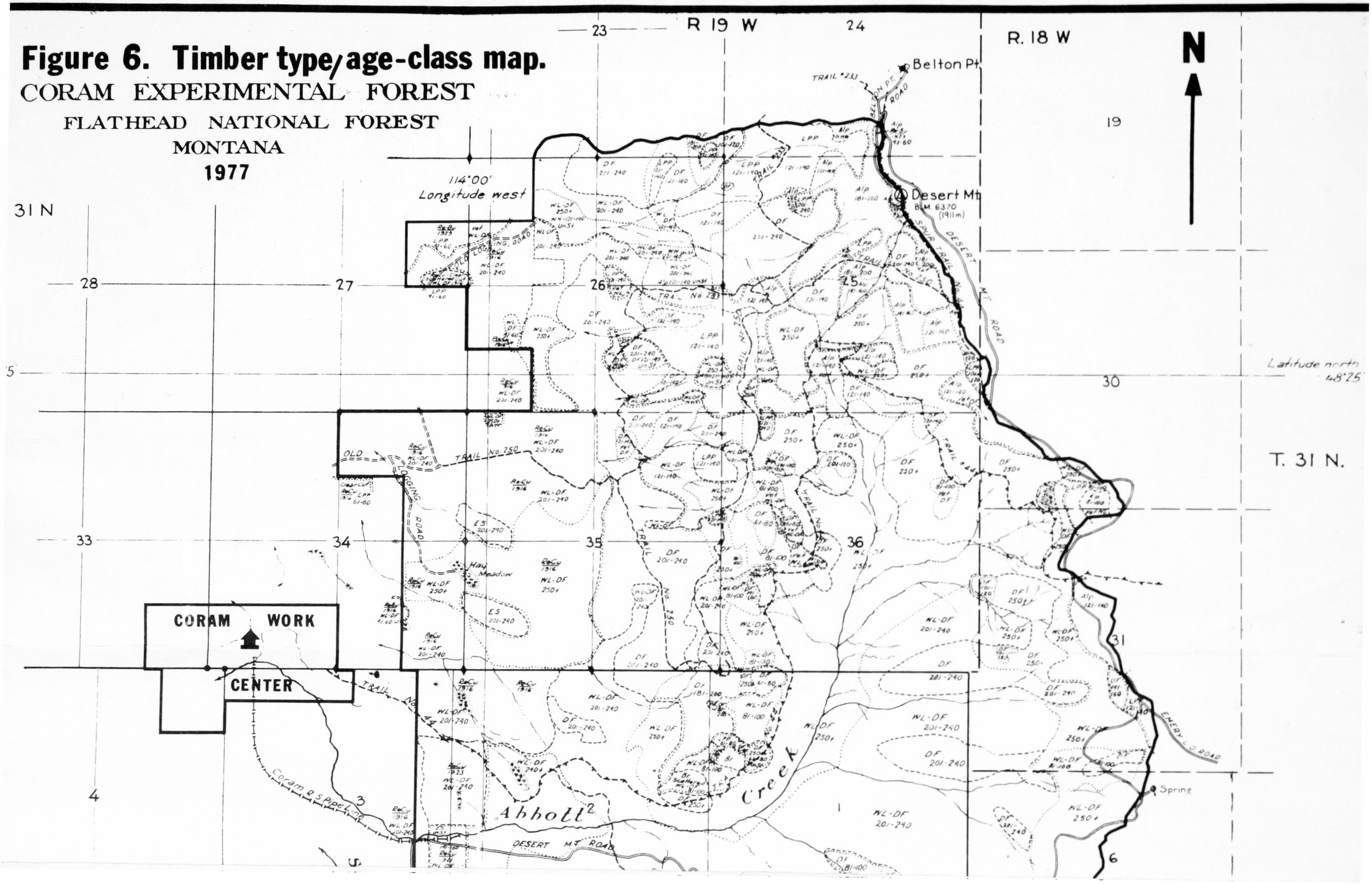
Figure 6. Timber type/age-class map.

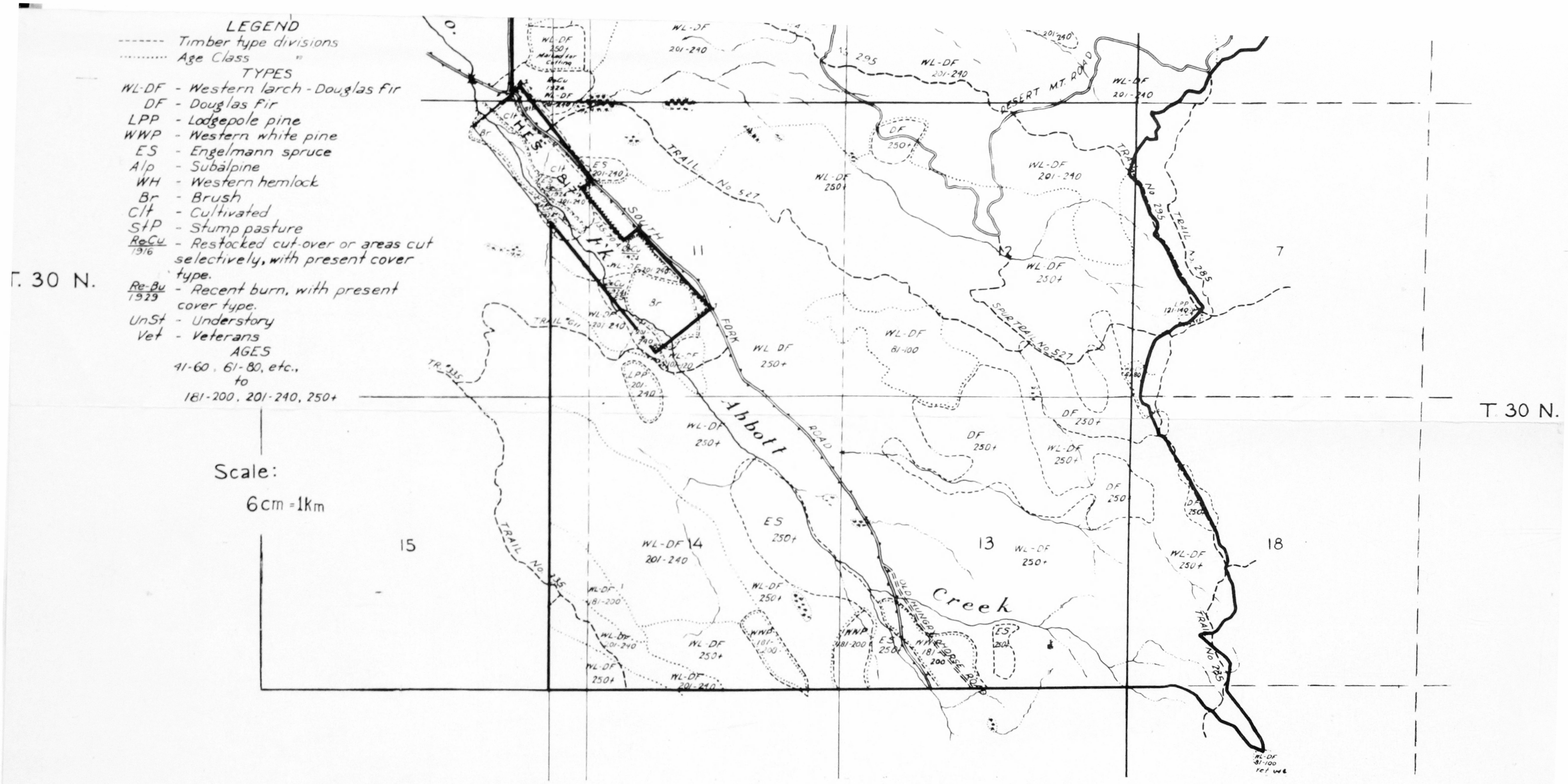
CORAM EXPERIMENTAL FOREST

FLATHEAD NATIONAL FOREST

MONTANA

1977





LEGEND

------- Timber type divisions
.... Age Class

TYPES

WL-DF - Western larch - Douglas fir
DF - Douglas fir
LPP - Lodgepole pine
WWP - Western white pine
ES - Engelmann spruce
Alp - Subalpine
WH - Western hemlock
Br - Brush
Clt - Cultivated
StP - Stump pasture
RoCu/1916 - Restocked cut-over or areas cut selectively, with present cover type.
Re-Bu/1929 - Recent burn, with present cover type.
UnSt - Understory
Vet - Veterans

AGES

41-60, 61-80, etc.,
to
181-200, 201-240, 250+

Scale:
6cm = 1km

Compiled from 1916 South Fork Flathead River timber reconnaissance; J. B. Yule, chief topographer; and additional 1934 Coram Experimental Forest survey, by George M. Fisher, chief of party.

Section lines adjusted March 1951, according to G L O Survey of 1940

PRINCIPAL MERIDIAN, MONTANA
Polyconic projection
North American datum

Traced by L. H. Carnall

Original
12-8-34

Age Classes Adjusted 15 May 1977 K.M. Sneck

Growth factor. The total ages for individual cross sections and increment core samples were determined by adding the pith count and the estimated number of years for each species to reach 0.3 m (1 ft.) which is the boring and sectioning height. Throughout the study area, several seedlings of the sampled species which were about 0.3 m tall were aged by cutting them at the stem base and counting growth rings. This resulted in a general growth factor by species for the period between germination and attaining 0.3 m in height. The factor for western larch and lodgepole pine was four years, Douglas-fir was five years, and subalpine fir, whitebark pine, and spruce was six years. Six years was determined for the latter species since they were sampled in fairly open stands and on ridges. A longer growth factor would be necessary if samples had been obtained from closed-canopy forests. The factors for each species were confirmed by Shearer (1977). Of course, these are generalized factors and actual growth rates on individual seedlings vary.

Data base. The locations of sample trees and stumps in Coram Experimental Forest were plotted on a topographic map (figure 7a). The map is partitioned into three segments to show the numbering of the samples. Segment A is the southern half of the forest, primarily Abbott Flats (figure 7b). Segment B is the northern half of the experimental forest excluding Segment C (figure 7c). Segment C is located within the western half of Segment B on the western slopes of Abbott Creek drainage (figure 7d).

Figure 7a. Location of sampled trees (x), stumps (•), and regeneration (R) in Coram Experimental Forest.

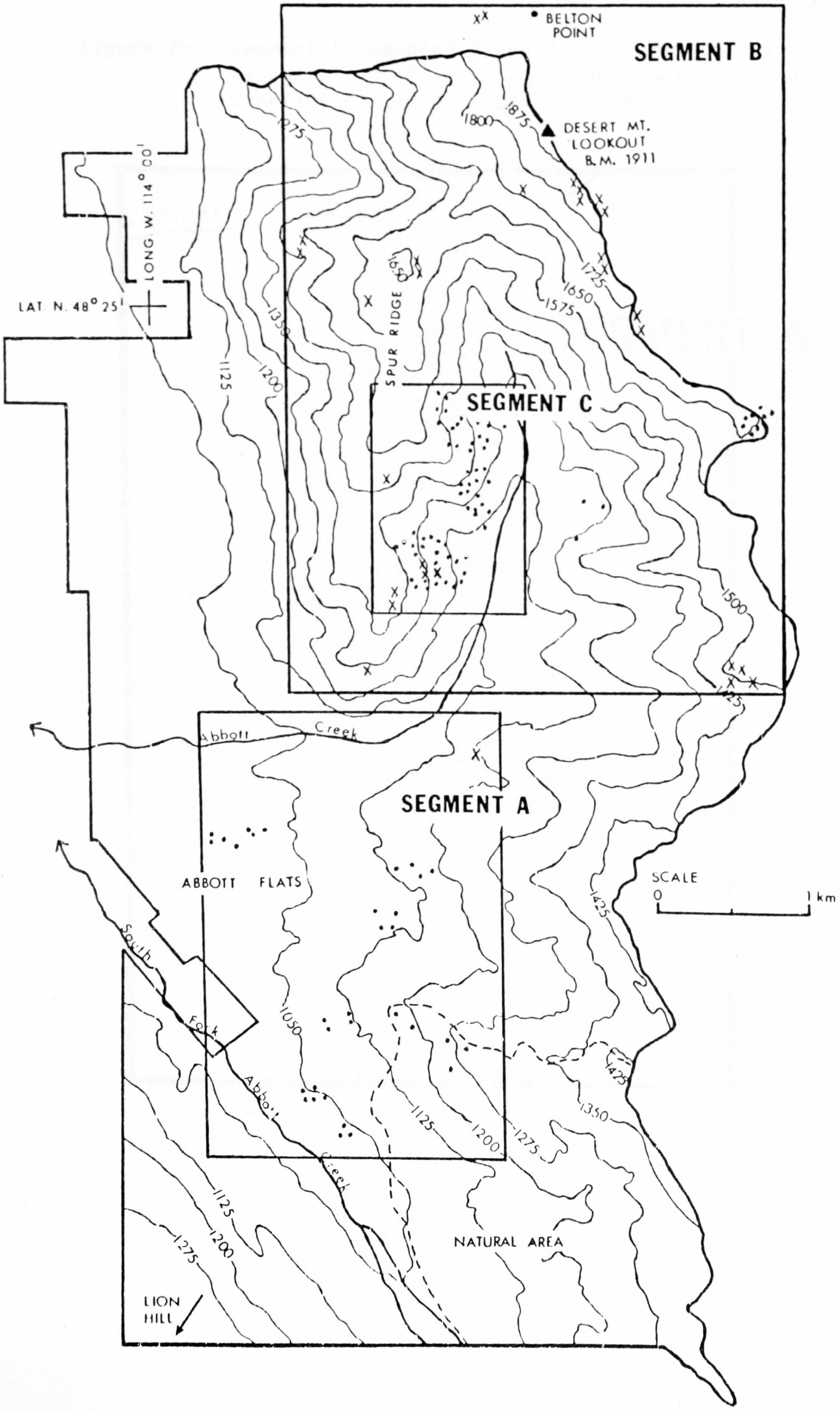


Figure 7b. Segment A: sampled trees (x), stumps (•), and regeneration (R) in the southern half of Coram Experimental Forest, primarily Abbott Flats.

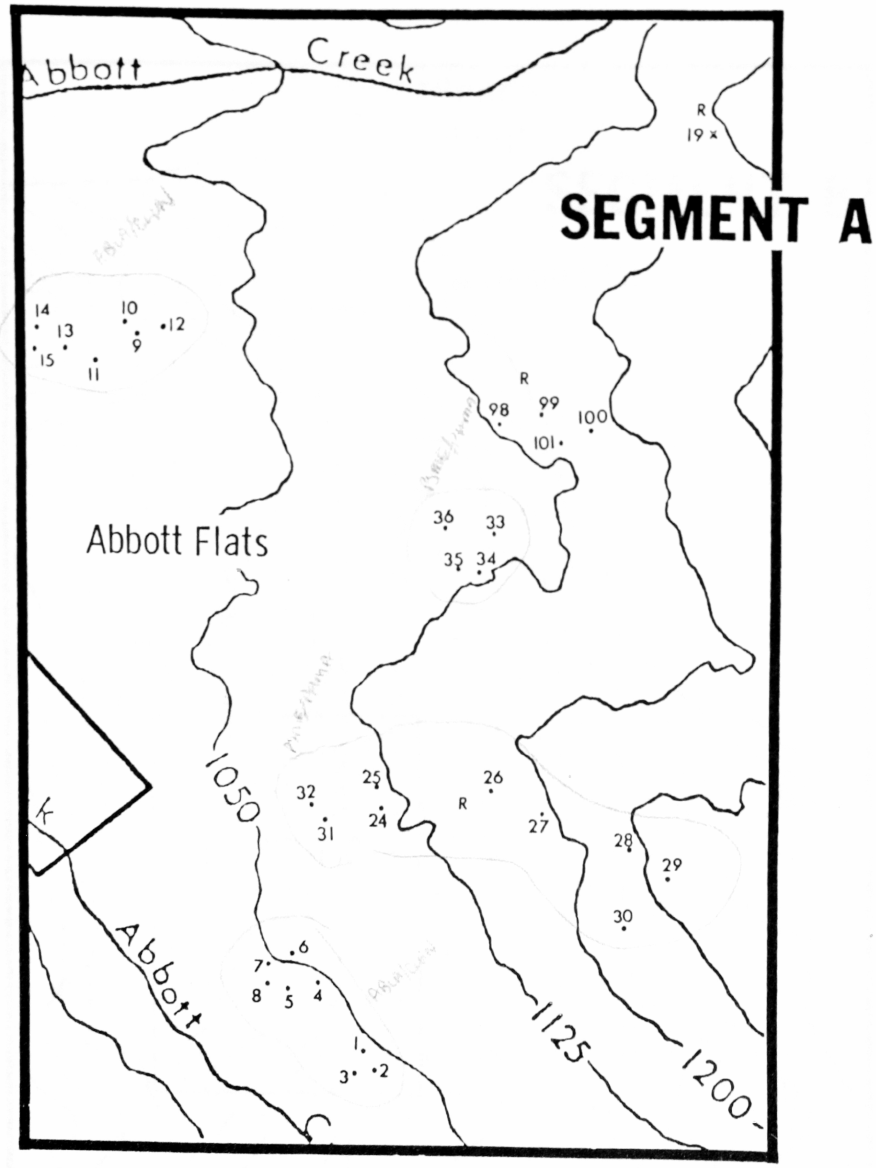


Figure 7c. Segment B: sampled trees (x), stumps (•), and regeneration (R) in the northern half of Coram Experimental Forest (excluding Segment C).

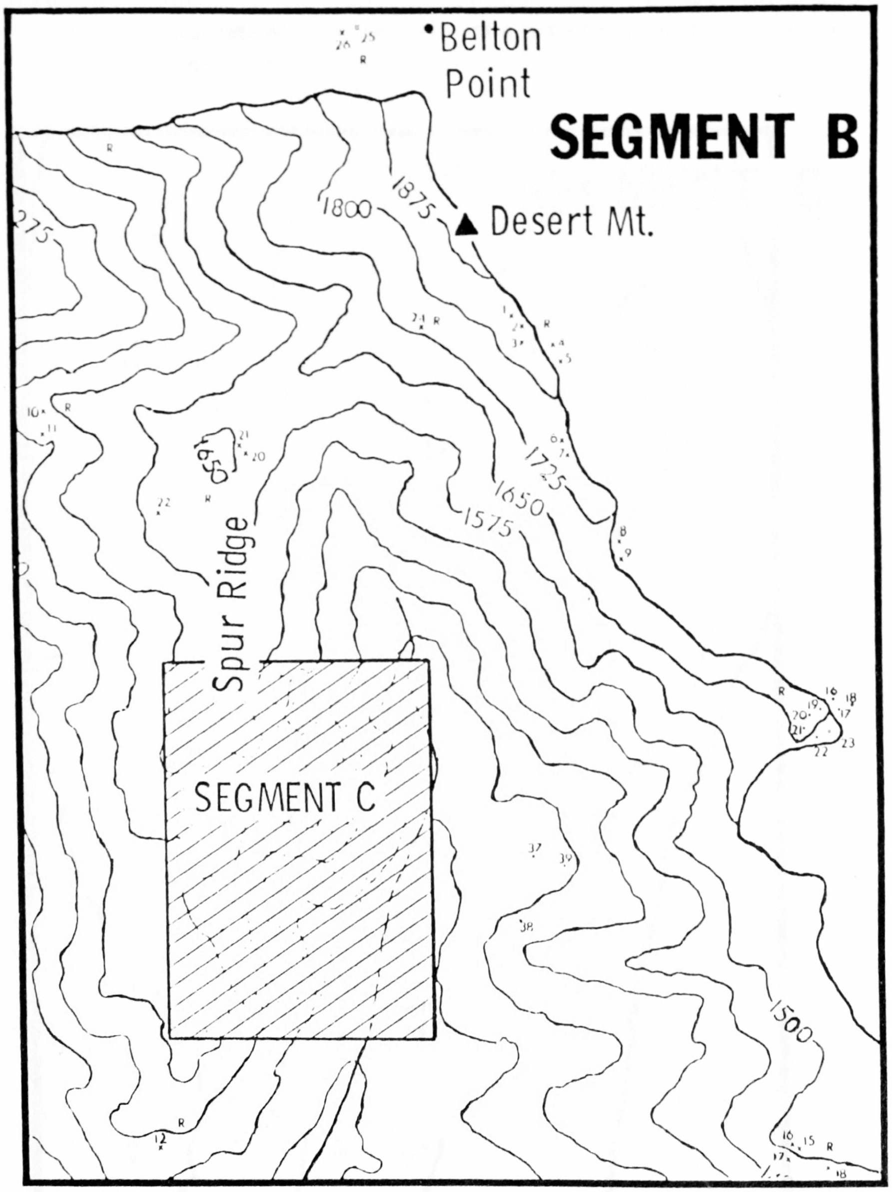
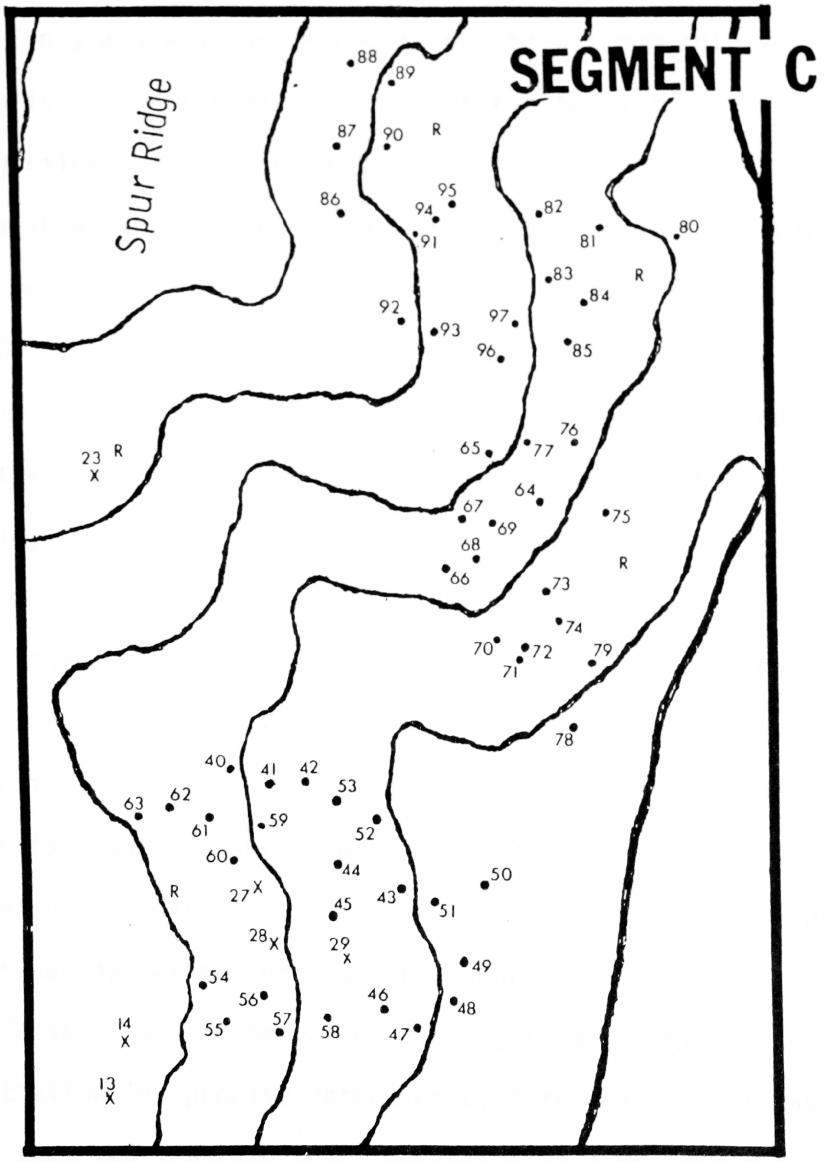


Figure 7d. Segment C: sampled trees (x), stumps (•), and regeneration (R) on the western slopes of Abbott Creek drainage.



The tree and stump data were arranged by stands--considering both habitat type and geographic location (figure 8). Appendix B shows the data base used to determine the stands, i.e., the habitat types, geographic locale, the sample species and chronologies, and the fire-initiated regeneration. The growth factors (i.e., 4 to 6 years depending on the species) have been added in calculating the pith dates. Ten years was considered to be the maximum interval for initial establishment after fire because of factors such as favorable seed years, germination success, and survival.

Table 2a shows an example of the fire chronology for the Coram Experimental Forest. The remainder of these chronologies are shown in appendix C. Table 2b (in appendix C) is the chronology for the other areas in the Flathead National Forest which were examined. In the tables, the stands are arranged in ecological-geographical order from the valley bottom to the upper subalpine slopes.

The fire history of each stand was determined by making adjustments in the individual chronologies of the stand members (Arno and Sneck 1977). Cross sections with the clearest ring formations presented the best fire chronology. Also, the largest total number of scars on a certain date strongly indicates the probable fire year. The adjustment process is illustrated in tables 2a and 2b. The dates were synchronized by moving the scattered scars ahead in time (suggesting false rings) or backward (missing rings). Minor ring errors do not allow for precise detection of fire years so it was hypothesized that two separate scarring-intensity fires did not occur

Figure 8. Location of forest stands in Coram Experimental Forest (x = trees, o = stumps, and R = regeneration).

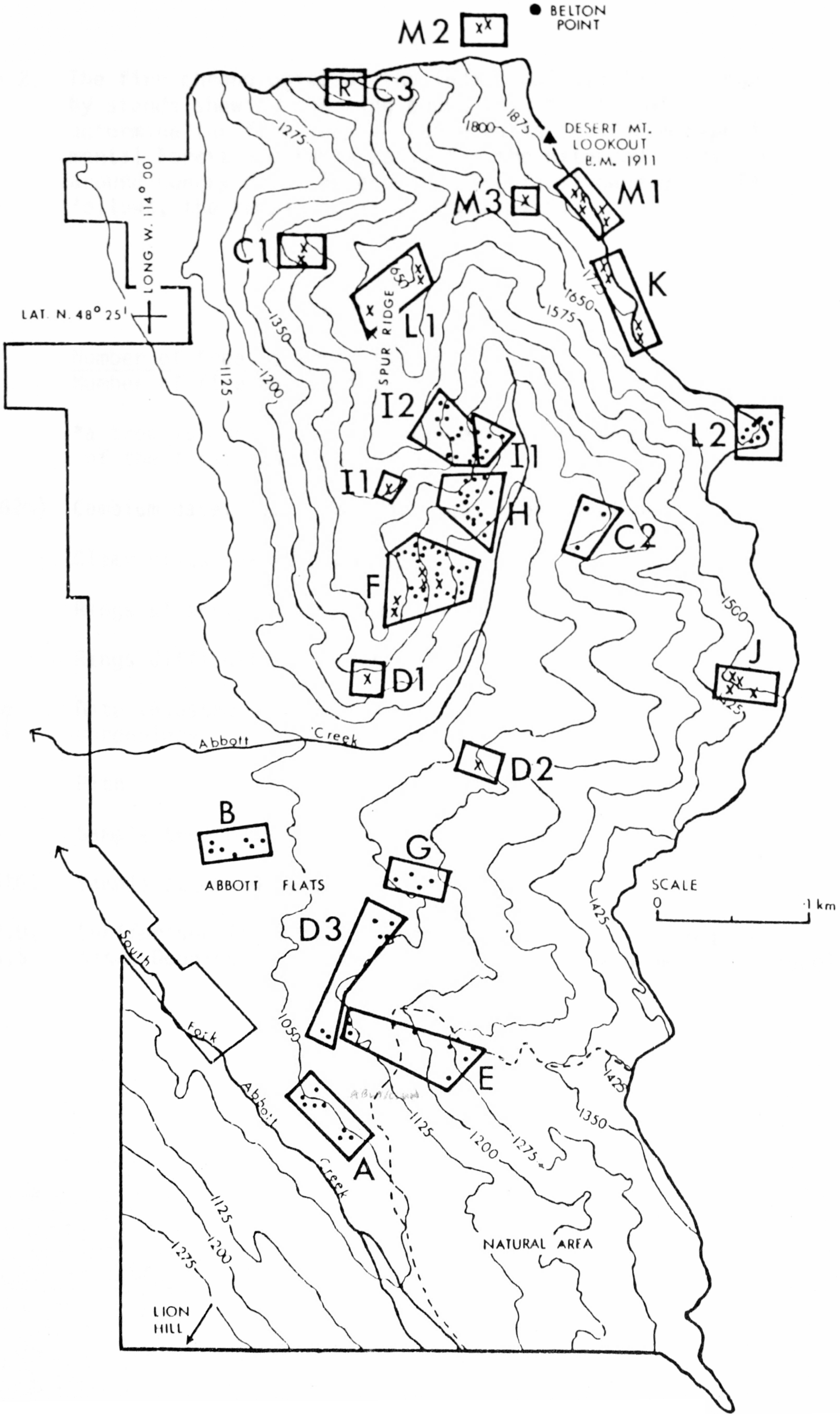
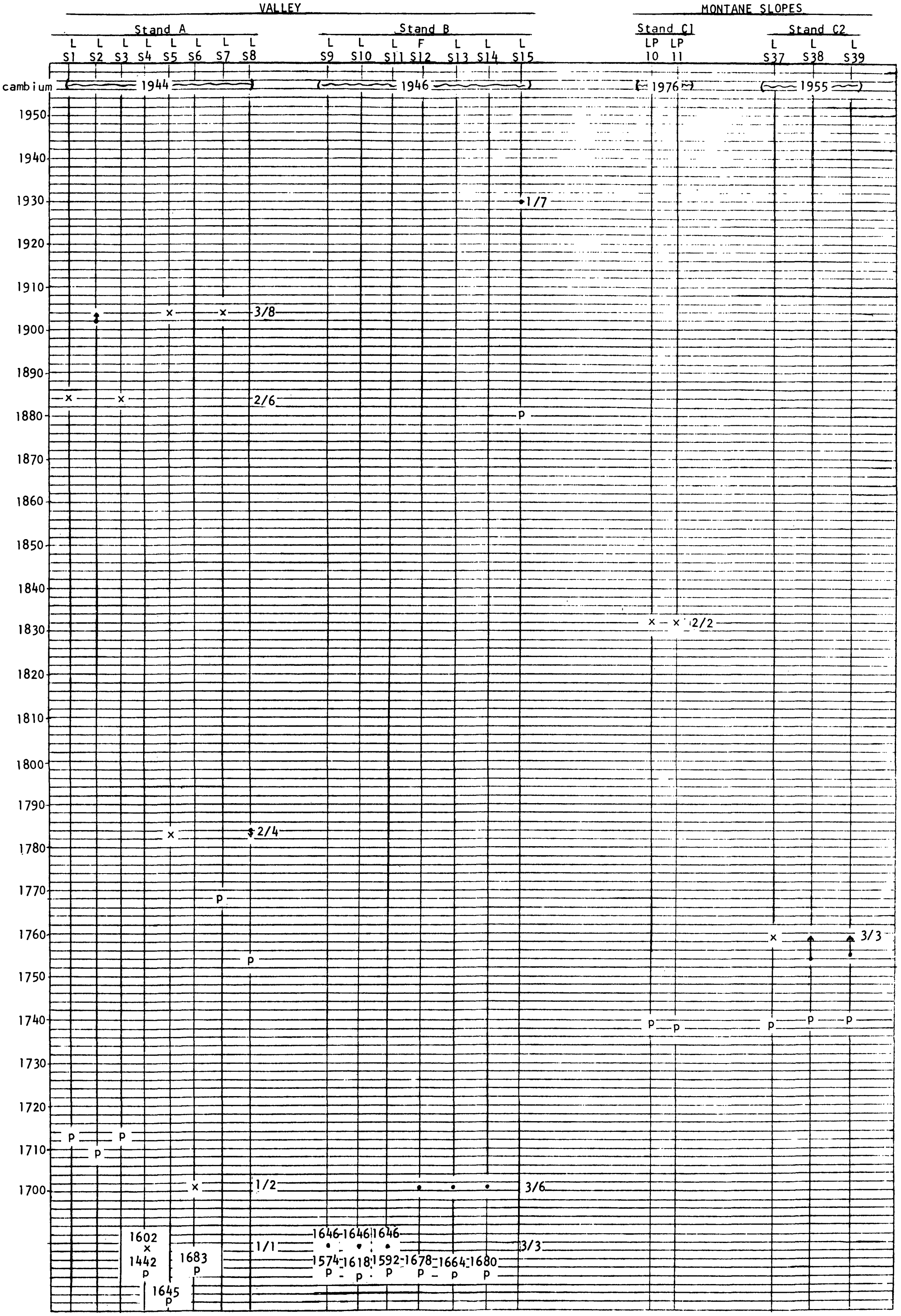


Table 2. The fire chronologies of the individual samples arranged by stands showing the ring-count adjustments made to determine the fire years. Table 2a is for Coram Experimental Forest and table 2b is for the extended study area around Hungry Horse Reservoir. The first page of table 2 follows; the remainder is in appendix C.

Legend

3/6	Number of trees scarred that year Number of fire-susceptible trees* *a tree is considered fire-susceptible on the date of the first scar and thereafter.
(∿1962∿)	Cambium date, i.e., date of logging or sampling
X	Clear rings (easy to count)
●	Rings slightly obscure (date approximated)
o	Rings difficult to interpret
X↕ ●↓ o↓	Date adjusted, in direction of arrow, to correlate chronology
P	Pith
1-29	Sample tree numbers
S1-S101	Sample stump numbers
L,LP,D, F,WB,S	Conifer species (respectively: western larch, lodgepole pine, Douglas-fir, subalpine fir, whitebark pine, and spruce)

Table 2a


VALLEY
MONTANE SLOPES
Stand A
Stand B
Stand C1
Stand C2
L L L L L L L L
S1 S2 S3 S4 S5 S6 S7 S8
L L L F L L L
S9 S10 S11 S12 S13 S14 S15
LP LP
10 11
L L L
S37 S38 S39
cambium
1944
1946
1976
1955
1950
1940
1930
1920
1910
1900
1890
1880
1870
1860
1850
1840
1830
1820
1810
1800
1790
1780
1770
1760
1750
1740
1730
1720
1710
1700
1/7
3/8
2/6
2/2
2/4
3/3
1/2
3/6
1/1
3/3
x
p
1602
1442
1683
1645
1646
1646
1646
1574
1618
1592
1678
1664
1680

within three to four years of each other in one stand. This span was selected since the scattering of scars around a data was usually within a three to four year range.

Historical Records

Additional information about the fire history of Coram Experimental Forest and the Flathead National Forest was obtained by talking to personnel and by consulting records of the Forestry Sciences Laboratory, Missoula, and the Flathead National Forest, Kalispell.

Forest Composition

Information was collected to compare forest tree composition between burned and unburned areas. The 1892 fire was chosen because it was the largest area burned within the past century. Also, the fire boundary was distinguishable. Stand composition inventories were taken along the western boundary (along the spur ridge) because the abundance of fire scarred trees, the scarcity of surviving trees, and the density of conifer regeneration indicated that the fire was most intense on that edge. Eight paired sample points were established along the fire edge. They were located at right angles to the edge and two chains into the burned and unburned forest. The points were subjectively positioned because the fire edge was intertwined with a recently-constructed logging road. At each point, the basal area was measured with a Relaskop using a B.A.F. of 40. The trees were recorded by species, age and diameter at breast height (d.b.h.). The information was used to construct a stand table and to compare the species composition, d.b.h., and density.

Modification of Existing Methodology

The methodology by Arno and Sneck (1977) provides the basic techniques for fire history analysis which would be generally applicable to coniferous forests of the western United States and Canada, excluding the coastal forests. However, it may be necessary to modify the methodology to fit an individual study area considering the evidence available to analyze fire history. Following are modifications in the general methodology by Arno and Sneck (1977) which were devised to meet the needs of the Coram study area.

a. Trees with visible, external fire scars were uncommon because so many of the scars had been healed over. Consequently additional emphasis was placed on information from stumps and fire-initiated regeneration.

b. The transects were walked only once, and nearly all the fire-scarred trees were sampled.

c. A timber type/stand age-class map (already available for Coram) was used to identify and locate stand boundaries and burned areas.

d. Stumps provided the most fire history information because all scars were visible. Therefore, logged areas were most intensively examined.

CHAPTER V

RESULTS AND DISCUSSION

A total of 136 scars were examined on 130 cross sectioned trees and stumps in Coram Experimental Forest. The only multiple scars occurred on two lodgepole pines and four western larches which each had two scars. There were 24 stumps sampled in logged units around Hungry Horse Reservoir. Only six large larch stumps had multiple scars. Three had double scars, and there was one each with three, four, and five scars. The latter were rare cases as it seemed that a large number of scars per tree is uncommon in this portion of the Flathead National Forest.

In the southern half of the Danaher Creek drainage about 129 km (80 mi.) southeast of Coram Experimental Forest. Gabriel (1976) commonly reported one or two scars on living lodgepole pine at lower elevations and three or four scars on lodgepole pine adjacent to dry grassland meadows. Douglas-fir commonly had one or two and occasionally three fire scars. Rarely, five scars would be found on lodgepole or Douglas-fir. In the northern half of the Danaher drainage, Gabriel found few trees with more than two scars. Western larch, ponderosa pine, subalpine fir, and spruce bore no multiple scars, but on rare occasions whitebark pine, alpine larch (*Larix lyalli* Parl.), and limber pine (*Pinus flexilis* James) had more than one scar. This scarcity of multiple scars was quite different from the large number of scars per tree found by investigators in drier forest types (Show and Kotok 1924, Arno 1976, McBride and Laven 1976).

Mature western larch is considered "most resistant" to fire damage primarily because of bark thickness, low resin content of the bark, high and open branching habitat, and relatively uncombustible foliage. Mature Douglas-fir, ponderosa pine, and western white pine are "very to medium resistant" largely because of their thick, insulative bark. Lodgepole pine has "intermediate resistance" and is followed by Engelmann spruce and subalpine fir, which have "low resistance" (Flint 1925, Haig _et_ _al_. 1941, Wellner 1970). Wellner (1965) discussed the relationship of these species to fire in the Inland Empire.

It was found in this study that some scar formations were characteristic of certain species. Seam scars occurred only on western larch and were quite common. Buried scars[4] were the most frequently encountered scar formation and occurred only on western larch and Douglas-fir. These species constituted the bulk of the total sample. The thin-barked lodgepole pine, subalpine fir, spruce, and whitebark pine characteristically developed catfaces after heat damage. Catfaces were occasionally seen on larch and Douglas-fir.

Western larch, lodgepole pine, and Douglas-fir were the predominant species sampled in this study. At higher elevations whitebark pine, subalpine fir, and spruce were taken. Most of the samples had

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[4] "Buried scars" are scars which have gradually closed as peripheral tissues resume growth. They are undetectable on the trunk.

clear annual ring formations which were easy to analyze; however, lodgepole pine provided the clearest records. Mature and overmature larch were the most difficult to analyze because of heart rot and very narrow growth rings (often ≥30 rings/cm of radial growth). Douglas-fir sometimes had extensive rot or carpenter ant damage.

Fire History of Coram Experimental Forest

The locations of the samples have been shown in figures 7a-d. In Segment A the sample stumps had been logged in 1944, 1945, and 1946. On the western side of Abbott Flats very few intact stumps remained to examine because of the logging history; portions had been selectively logged in 1916, 1923, 1924, 1943, and 1946. In 1960 the area was clear-cut then dozer piled and burned. It is quite probable that the destruction of the stumps in the logging operations have created a void in the fire record of the flats. This seems especially true when considering the long-term fire history obtained from stumps in the eastern half of Abbott Flats. Larch stumps were the predominant data source in this segment.

Trees on the subalpine slopes provided most of the fire record in Segment B. Two samples were located outside the experimental forest on Belton Point in order to obtain more evidence on the Half Moon Fire of 1929. Stumps which had been examined were logged in 1970. Lodgepole pine was the main sample species, but in this segment subalpine fir, spruce, and whitebark pine furnished a significant portion of the information.

Segment C primarily entailed the stumps in Blocks 11, 12, 12, and 21 of the 1974 skyline harvest project. Most of the sample species were larch and Douglas-fir.

Of the total 130 Coram samples, only 29 were trees. Stumps provided the greatest proportion of the history because buried scars were visible. The areas sampled had been logged between 1944 and 1974 so the soundness of the stumps varied. About 7 to 10 years after logging, they were too decomposed to remove a cross section. However, 20 to 30 year old stumps were generally not difficult to analyze because the summerwood was less weathered than the springwood which facilitated counting growth rings.

There were limitations for using logged areas to assess fire history. When logging slash was burned, the stumps were often badly damaged. Also, stumps on mesic, shaded slopes could not be used when larch regeneration was over a meter (3 ft.) tall because needle-fall accumulation on and around the stumps accelerated decomposition, making the growth rings indistinguishable.

<u>Master fire chronology</u>. The dates of 35 fires found to occur in Coram Experimental Forest between 1602 and 1976 are shown in the master fire chronology (table 3). The chronology was constructed by aligning the adjusted individual chronologies from each tree with its neighbors in the stand (table 2a) and incorporating data on fire-initiated regeneration. (The location of each stand has been shown in figure 8.) Many dates were based on only one or two fire scars. From 1737 to 1952 the dates are probably within a year of the actual

Table 3. The master chronology of fire scar data from Coram Experimental Forest showing the number of scars during each fire year in each stand and indicating which fires caused conifer regeneration.

	Habitat Type Group and Stand																				
	Valley		Montane													Lower subalpine			Upper subalpine			Total scars
	A	B	C1	C2	C3	D1	D2	D3	E	F	G	H	I1	I2	J	K	L1	L2	M1	M2	M3	
Fire year	(8)*	(7)	(2)	(3)	(0)	(1)	(1)	(6)	(7)	(29)	(4)	(16)	(7)	(12)	(4)	(4)	(3)	(8)	(5)	(2)	(1)	(130)
1952	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	4
1940	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1R	-	-	-	-	1
1930	-	1?	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
1929	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2R	-	2
1924	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	3
1922	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
1919	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-	8
1917	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	4	-	-	7
1915	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	2
1913	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	2
1908	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	2
1905	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
1892	-	-	-	-	-	1R	-	-	-	25R	-	10R	5R	9R	-	-	-	-	-	-	-	50
1890	-	-	-	-	-	-	-	-	7R	-	-	-	-	-	2R	-	-	-	-	-	-	9
1888	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
1884	2	-	-	-	-	-	1R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
1867	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	0
1861	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	2R	-	1R	3
1854	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
1841	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	2
1832	-	-	2R	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	2
1821	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2
1816	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
1803	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	0
1798	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	0
1793	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	2
1783	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
1765	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
1759	-	-	-	3	-	-	-	4	-	1	-	-	-	-	-	-	-	-	-	-	-	8
1737	-	-	R	R	-	-	-	R	-	-	4R	1R	-	-	-	-	-	-	-	-	-	5
1718	-	-	-	-	-	-	-	-	-	-	-	-	1R	-	-	-	-	-	-	-	-	1
1710	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	0
1701	1R	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
1646	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
1602	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Total scars	9	7	2	3	0	1	1	7	7	31	4	16	7	12	4	4	3	8	7	2	1	136

* Number of sample trees and/or stumps in stand

1R Regeneration supporting fire date based on stand age-class samples.

R Fire date determined by regeneration stand age-class.

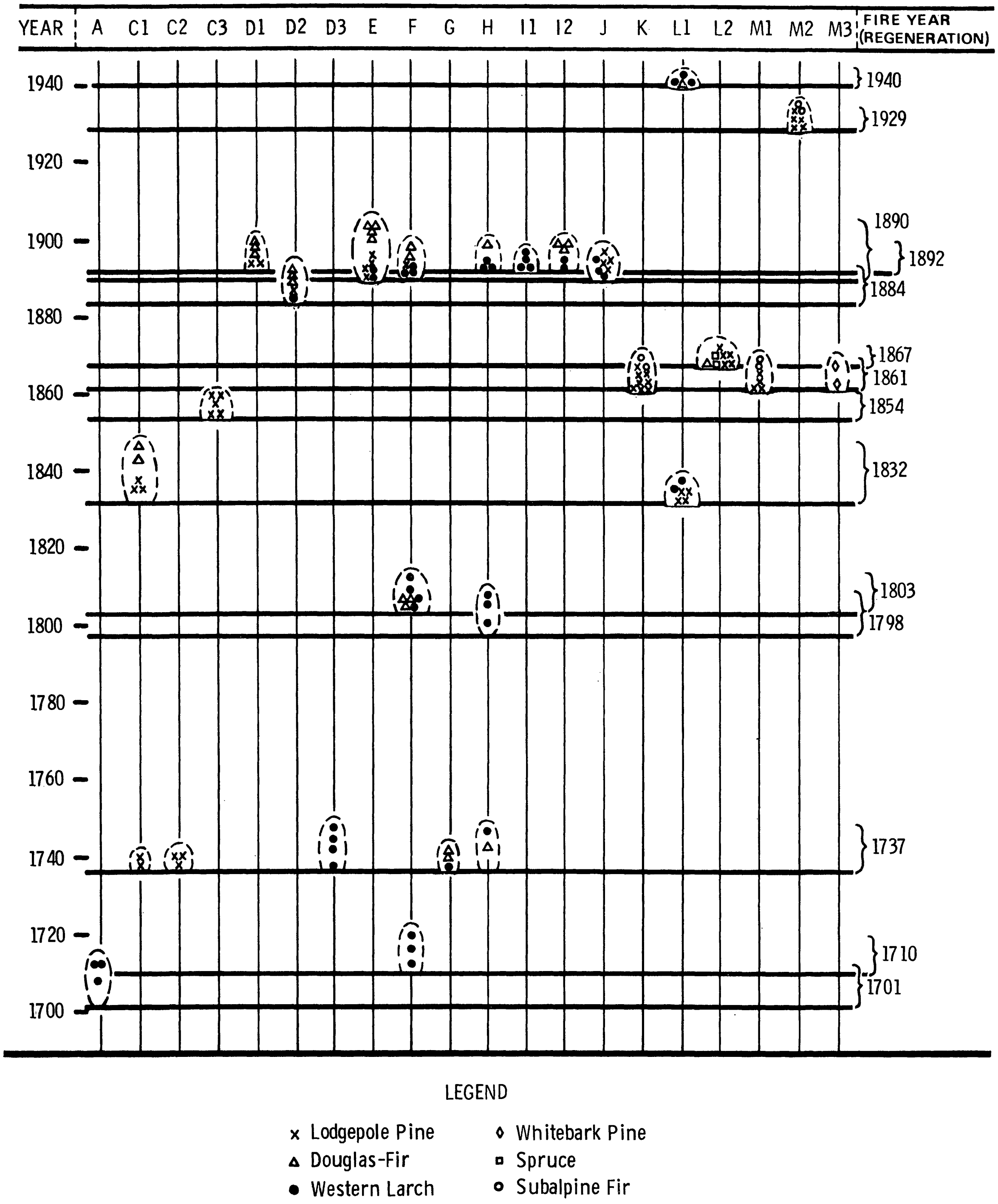
date. A fire year was more accurately determined when fire-initiated regeneration was correlated with the scar data. The fire years from 1602 to 1718 should be considered as approximate because the sample sizes were small and accuracy diminishes with time. Fire dates based solely on stand age classes are probably within three to five years of the actual date. It is difficult to pinpoint fires by age classes even when the pioneer species were sampled because there are too many factors which can delay establishment of regeneration.

Stand age-class analyses were used to determine fire years and augment the fire scar data. Figure 9 shows the fire of origin for the trees sampled in 20 stands. The position of the samples on the scale indicates the year of germination. This information was incorporated with the scar data to compose the master fire chronology where the regeneration was represented by a "R".

The master fire chronology undoubtedly does not include all the fires occurring in Coram Experimental Forest during the record period. Although the transect system was extensive, it did not cover the entire area. Consequently, some small burns were missed. Moreover, it is extremely difficult if not impossible to record low intensity fires which do not leave long-termed evidence such as scarred trees or regeneration.

Fire frequency. To calculate fire frequency, a logical time period had to be established. From 1735 to 1910 was designated as the "historical fire" period when fires were primarily caused by lightning. Prior to 1735 the chronological information became too

Figure 9. Age-class designations of fire-initiated regeneration based on total ages of trees. Total age is the age of the increment core plus a growth factor to reach boring height (0.3 m). The heavy line is the fire year The dashed line encloses regeneration which corresponds to a fire year.



sparse and fire frequency could not be satisfactorily calculated. Also, 1735 was chosen because it was the beginning of Arno's (1976) historical fire period (1735-1900) in the Bitterroot National Forest. Similar historical periods would enhance comparison of fire history between Coram Experimental Forest and the Bitterroot National Forest. About 1907 fire protection for the Flathead National Forest was officially organized (Robinson 1976). However, it was not until after the notorious fires of 1910 in northern Idaho and western Montana that extensive suppression efforts were organized. The period from 1911 to 1976 can be considered the "fire suppression" period when concerted efforts were made to contain fires.

In this study, the term fire frequency denotes the number of years between fires or the fire-free interval. For the historical fire period, the average frequency was calculated on an area basis first by computing the frequency for each stand then obtaining the average of the stands in each habitat type (table 4). (The actual intervals between the historical fires in each stand are given in appendix C with the average fire frequency for the stand and the habitat type classification.) The mean fire-free interval (fire frequency is the average of the frequencies for the habitat types in a geographical unit (column 2 of table 4). It represents the average frequency of fire on a particular site (5 to 10 ha, 12 to 25 ac.). Since a stand may be largely destroyed by fire, the reoccurrence of fire is referred to the site itself. The minimum and maximum intervals (column 7 of table 4) represent the range of actual

Table 4. Fire frequency between 1735 and 1910 by habitat type for the Coram Experimental Forest. Frequencies are based on all fire years identified within stands (habitat type units).

Habitat type* groups	Topographic description	General Elevation range (meters)	Dominant trees with continued fire exclusion (most abundant species first)	Dominant trees before 1910 (most abundant species first)	No. of stands (No. of trees)	Mean fire-free interval (min-max interval**)
ABLA/CLUN h.t., ARNU phase ABLA/CLUN h.t., ARNU phase	Valley	1020-1140	Douglas-fir western larch	western larch Douglas-fir	2 (15)	>117 years (21- 175)
PSME/PHMA h.t., CARU phase PSME/PHMA h.t., PHMA phase ABLA/CLUN h.t., ARNU phase ABLA/CLUN h.t., VACA phase ABLA/CLUN h.t., XETE phase ABLA/CLUN h.t., PHMA phase+ ABLA/CLUN h.t., CLUN phase ABLA/LIBO h.t., VACA phase	Montane slopes	1200-1650	Douglas-fir western larch	Douglas-fir western larch lodgepole pine	11 (88)	121 years (6- 173)
ABLA/CLUN h.t., XETE phase ABLA/XETE h.t.	Lower subalpine slopes	1575-1800	subalpine fir Douglas-fir	subalpine fir Douglas-fir lodgepole pine	3 (15)	146 years (47- 132)
ABLA/XETE h.t.	Upper subalpine slopes	1800-1920	subalpine fir Douglas-fir	subalpine fir lodgepole pine whitebark pine	3 (8)	>146 years (47- 175)

* Habitat types according to Pfister _et al_. 1977.

** The maximum interval was the longest fire-free interval within the period 1735 to 1910. For example, >175 means no fire between 1735 and 1910. The minimum interval was the shortest interval between fires during the period.

\+ ABLA/CLUN h.t., PHMA phase was a locally occurring variation of ABLA/CLUN h.t. only found in a small area of Coram Experimental Forest identified by Pfister _et al_. (personal communication).

intervals (in the 1735 to 1910 period) between fires in the stands of a unit.

The mean fire-free intervals may seem long considering the total number of fires which occurred in Coram, but the master fire chronology (table 3) illustrates that many of the stands had only one fire during the historical fire period. The major exceptions were stands D3, F, and H, which had up to six fires during the period. The long intervals are also substantiated by the fact that most trees had only one scar.

Even though reoccurrence of fire on a site was infrequent, 35 fires were recorded for the 374-year period. This represents a fire somewhere in Coram Experimental Forest on an average of once every 11 years between 1602 and 1976 and every 12 years from 1735 to 1910, the historical fire period. The highest frequency of fire during the historical period occurred in the latter decades. Many of the fires in the northern Rocky Mountains during the late 1800's have been attributed to white man's activities by Ayres (1900a, 1900b) and Leiberg (1900). Later investigators (Habeck 1976, Gabriel 1976, Arno 1977) have commented that Ayres and Leiberg neglected the role of lightning in fire ignition.

The mean fire-free intervals varied among the geographical units. Although the differences were not large, there was a trend of decreasing frequency with increasing elevation. The "greater than" sign denotes that some stands had no fires during the historical fire period, for example, stand B (appendix B).

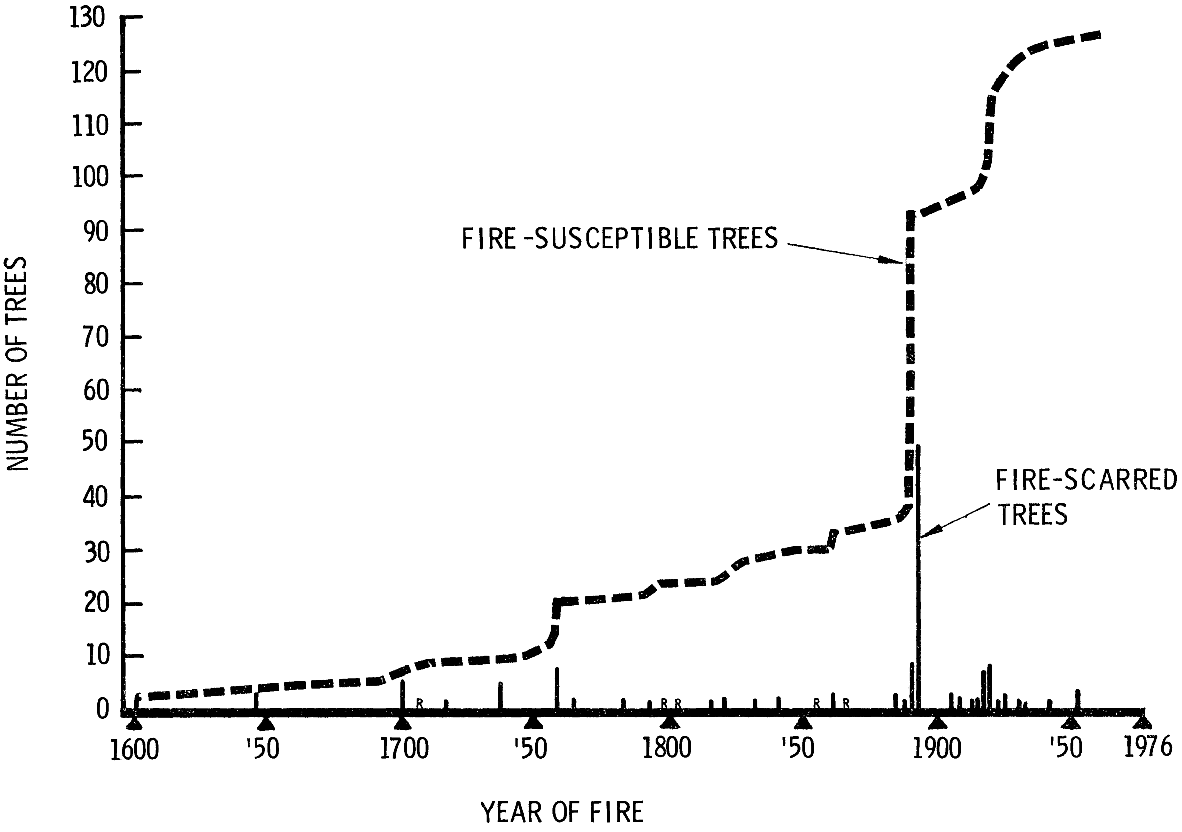
There was not enough information to correlate fire frequency with habitat type because there were only a few stands in each type. Also, the frequencies for stands varied considerably within a habitat type, e.g., PSME/PHMA h.t., PHMA phase from stands D1, D2, and D3 (appendix B). Differences would probably be greatest among dissimilar habitat types.

Ironically, fire has been most frequent during the suppression period. From 1911 to 1976, a fire has occurred on a average of every 7 years. The highest actual frequency occurred during the first three decades of the period. The heavy load of lightning fires, careless burning by the white man, the fuel~~d~~ created by the disastrous 1910 fire year, and the severe drought years between 1910 and 1940 were factors of the high fire incidence and large acreage burned (Wellner 1970, Leapheart and Stage 1971).

The fire frequency of Coram Experimental Forest is illustrated in figure 10. The graph displays the number of trees scarred in a fire year and the accumulated total of fire-susceptible trees for each fire year. "R" represents fire years based on stand age-class analysis. The illustration shows the increase of fire activity around 1900 and the diminishing sample size in the early years of the record. Fires occurred more regularly in the intervening years.

Fire spread. Using the location of scarred samples and fire-initiated regeneration, the areal spread of each fire was plotted on a series of maps (figures 11a-g). The accuracy of the maps depends on the amount of data available for each fire. The smooth-

Figure 10. Graph of the number of trees* scarred during each fire year. The accumulated total of fire-susceptible trees in each year is shown as the dashed line. Fire-susceptible trees are those which have been scarred at least once. R represents fire years determined by age-classes of fire-initiated regeneration.



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* "Trees" include sample stumps since they were live trees when scarred.

Figure 11. Areal spreads of fires occurring in Coram Experimental Forest from 1602 to 1952. (Smooth boundary delineates the known spread assessed from field evidence and maps. Zigzag boundary represents the minimum probable spread determined from available evidence.)

Figure 11a.

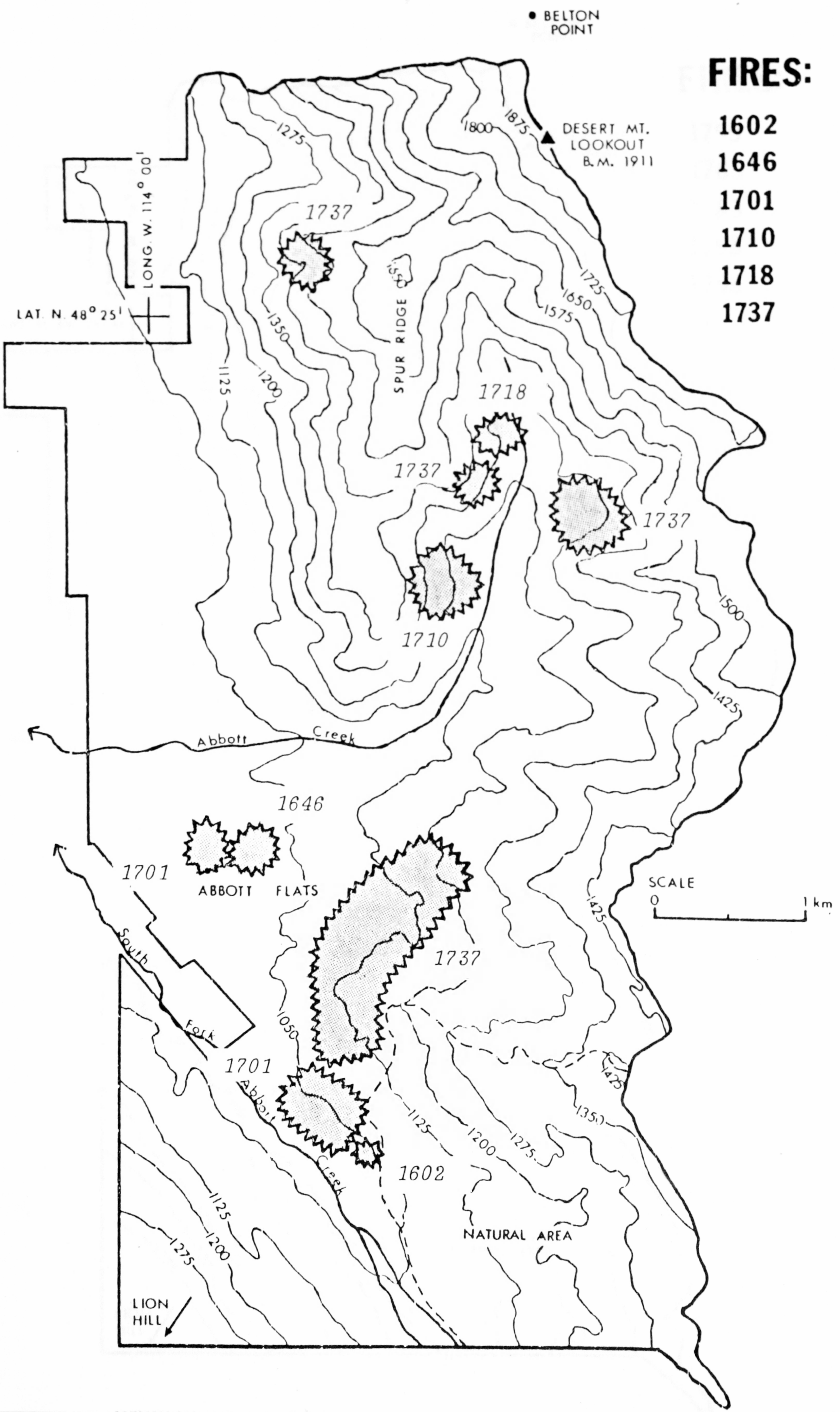

BELTON POINT
FIRES:
1602
1646
1701
1710
1718
1737
DESERT MT. LOOKOUT B.M. 1911
1800
1875
1275
1737
LONG. W. 114° 00'
LAT. N. 48° 25'
SPUR RIDGE
1550
1350
1125
1200
1725
1650
1575
1718
1737
1737
1500
1710
1425
Abbott Creek
1646
1701
ABBOTT FLATS
SCALE
0
1 km
1425
1737
South Fork
1050
1701
Abbott Creek
1125
1200
1275
1350
1425
1602
NATURAL AREA
1125
1200
1275
LION HILL

Figure 11b.

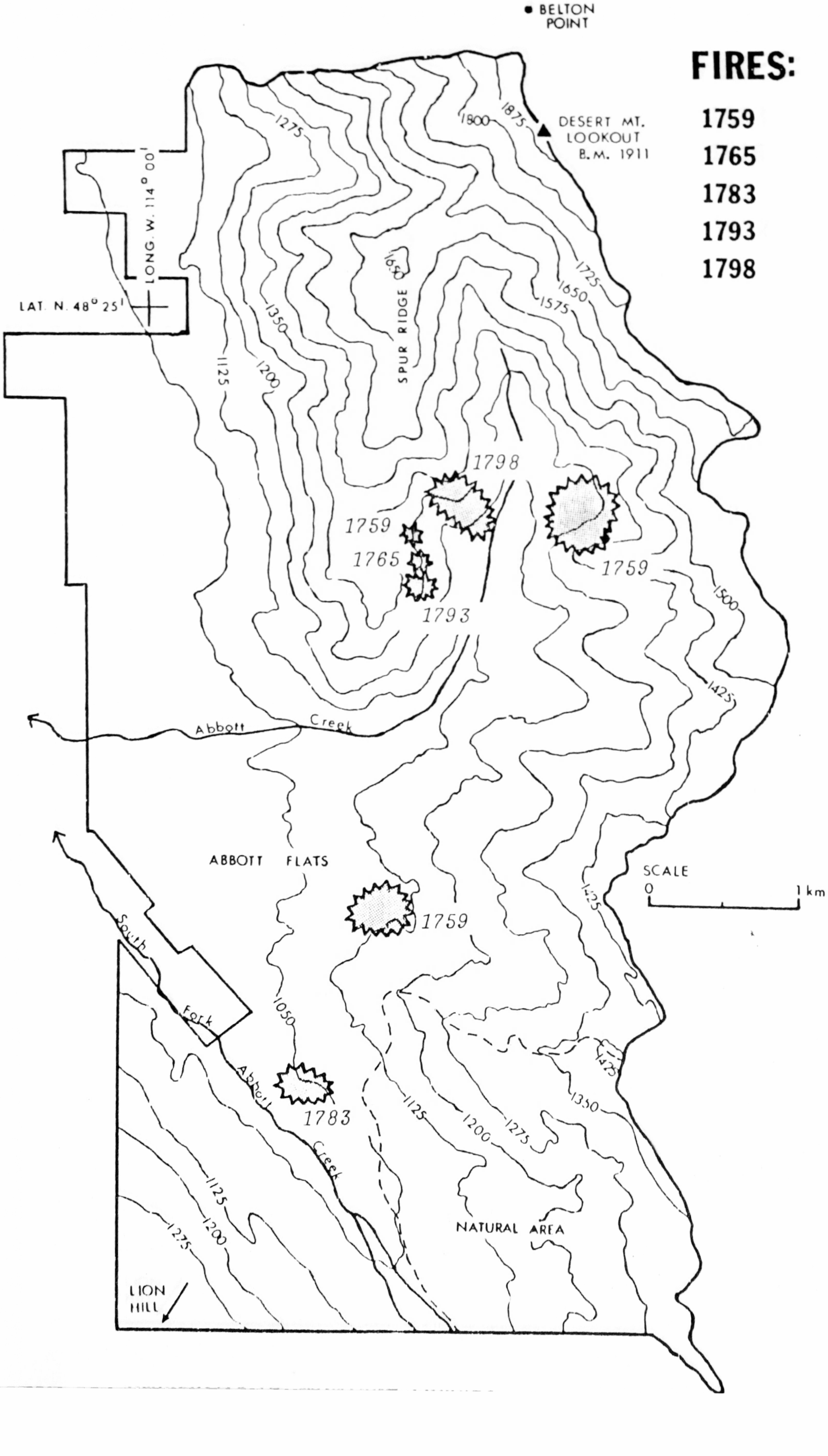

BELTON POINT
FIRES:
1759
1765
1783
1793
1798
DESERT MT. LOOKOUT B.M. 1911
1875
1800
1275
LONG. W. 114° 00'
LAT. N. 48° 25'
1650
SPUR RIDGE
1725
1650
1575
1350
1125
1200
1798
1759
1765
1793
1759
1500
1425
Abbott Creek
ABBOTT FLATS
SCALE
0
1 km
1425
1759
South Fork
1050
Abbott Creek
1783
1425
1350
1125
1200
1275
NATURAL AREA
1125
1200
1275
LION HILL

Figure 11c.

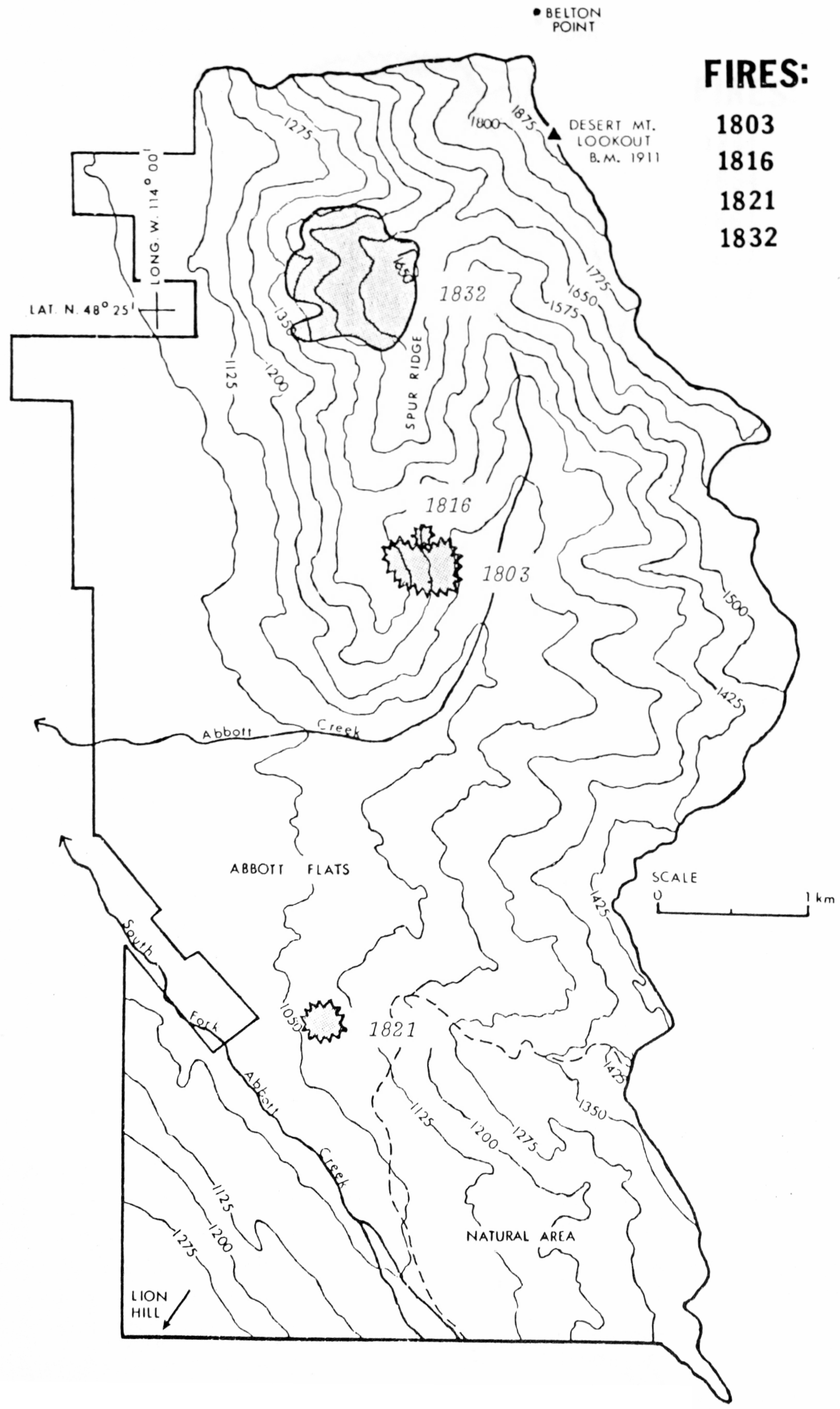

BELTON POINT
FIRES:
1803
1816
1821
1832
DESERT MT. LOOKOUT B.M. 1911
1800
1875
1275
1725
1650
1575
LONG. W. 114° 00'
LAT. N. 48° 25'
1350
1650
1832
SPUR RIDGE
1125
1200
1816
1803
1500
1425
Abbott Creek
ABBOTT FLATS
SCALE
0
1 km
1425
South Fork
Abbott Creek
1050
1821
1425
1350
1125
1200
1275
NATURAL AREA
1125
1200
1275
LION HILL

Figure 11d.

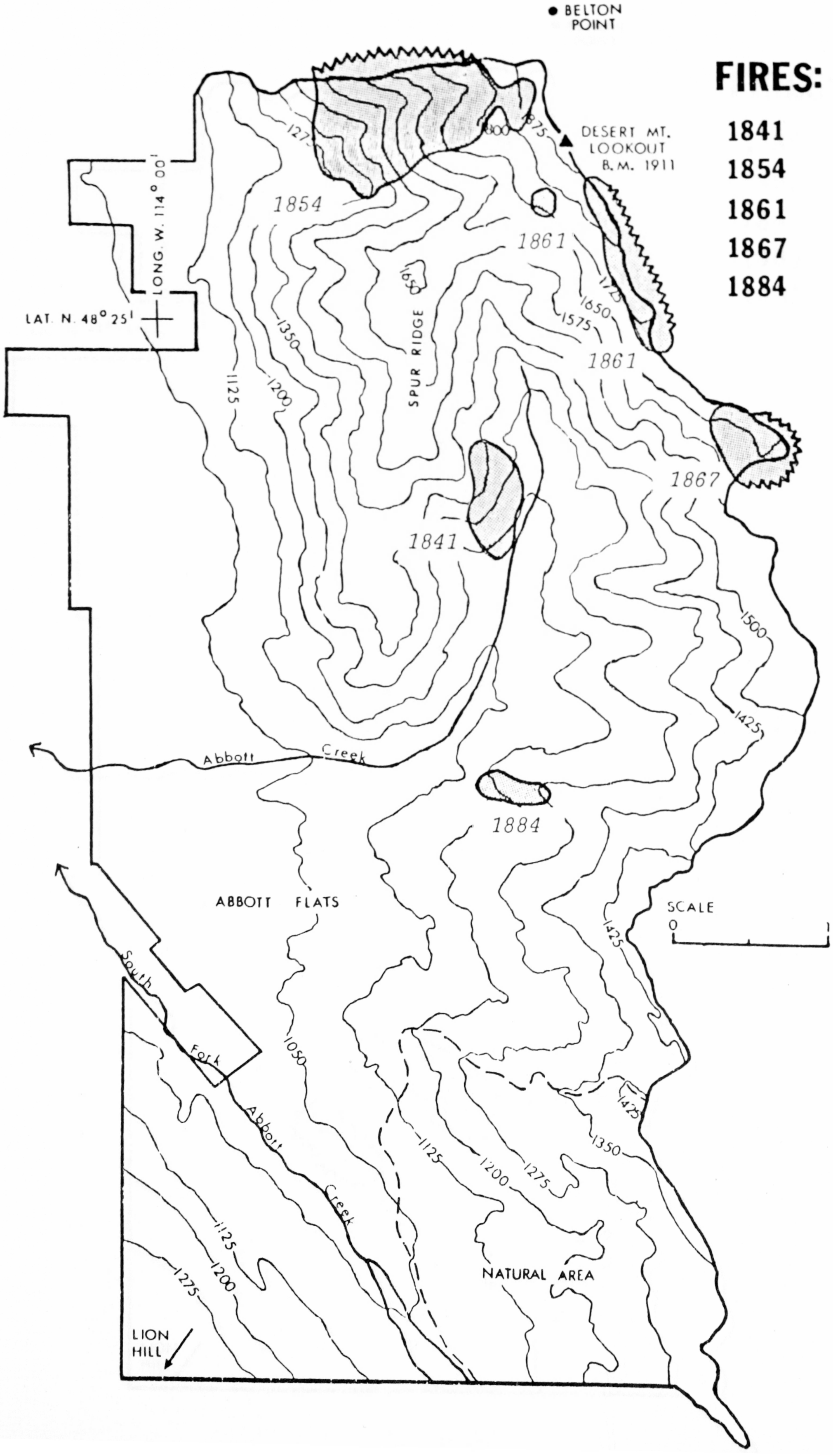

BELTON POINT
FIRES:
1841
1854
1861
1867
1884
DESERT MT. LOOKOUT B.M. 1911
LONG. W. 114° 00'
LAT. N. 48° 25'
1275
1800
1875
1854
1861
1725
1650
1575
SPUR RIDGE
1350
1200
1125
1861
1867
1841
1500
1425
Abbott Creek
1884
ABBOTT FLATS
SCALE
0
1 km
1425
South Fork Abbott Creek
1050
1425
1350
1125
1200
1275
1125
1200
1275
NATURAL AREA
LION HILL

Figure 11e.

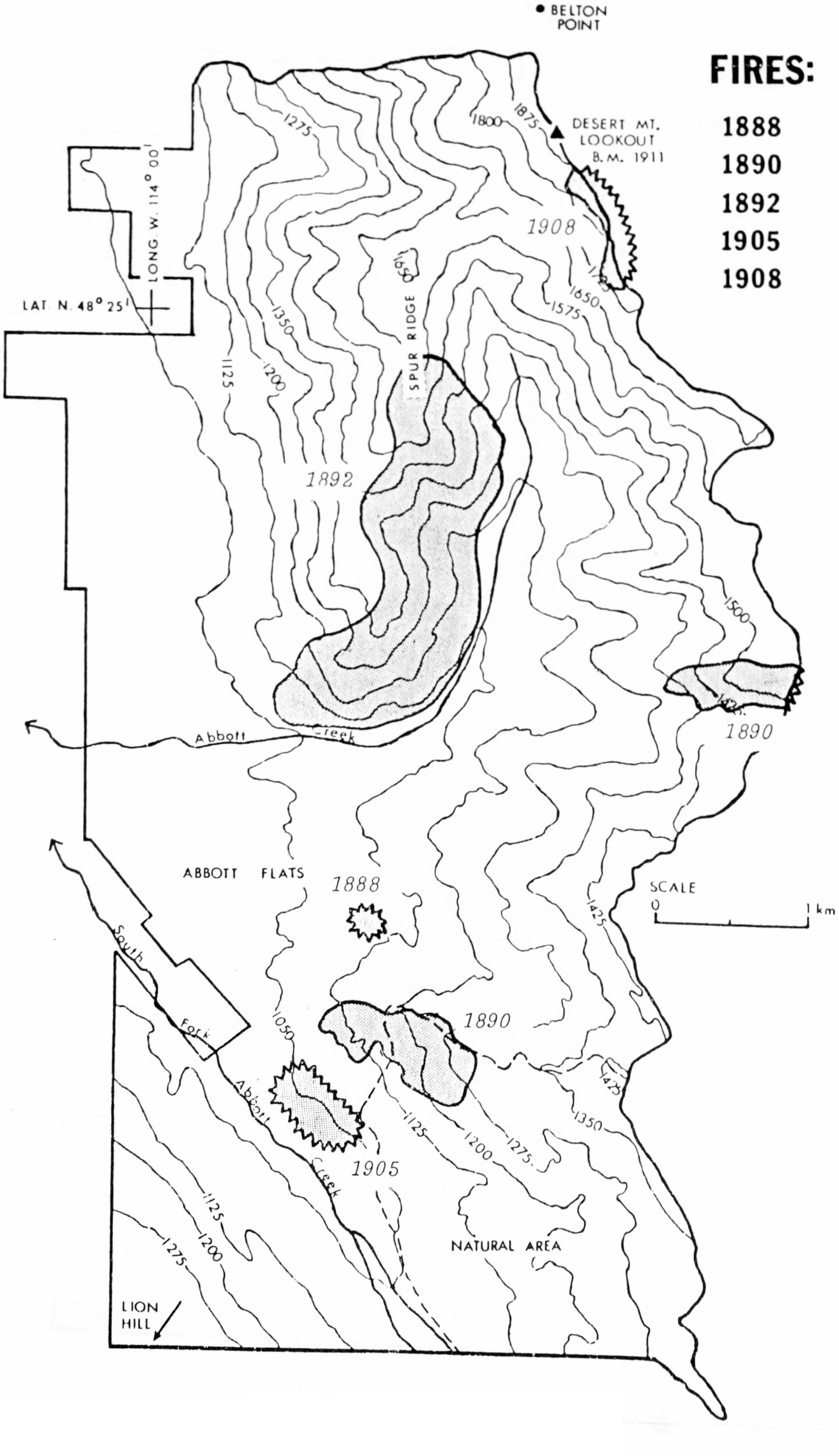
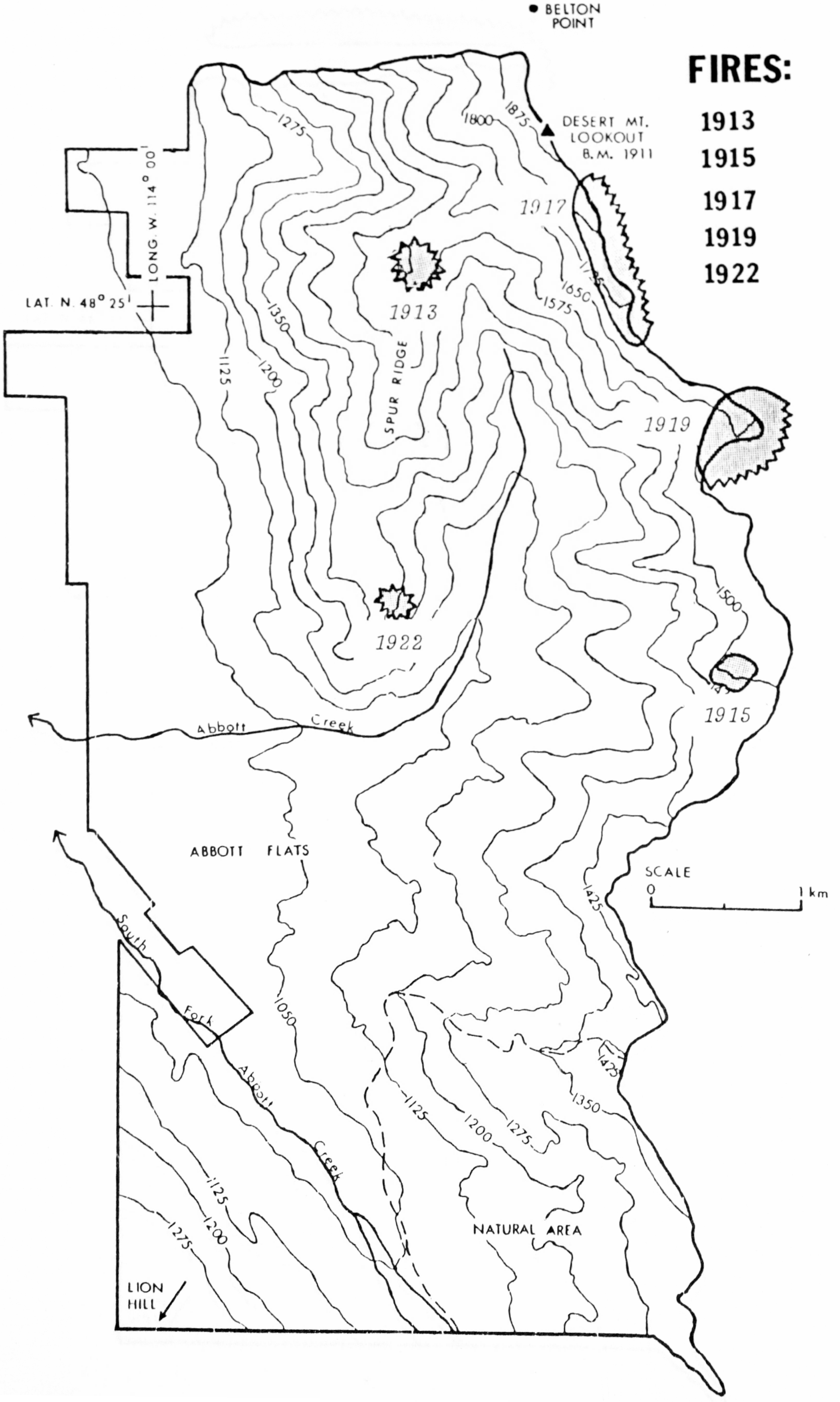
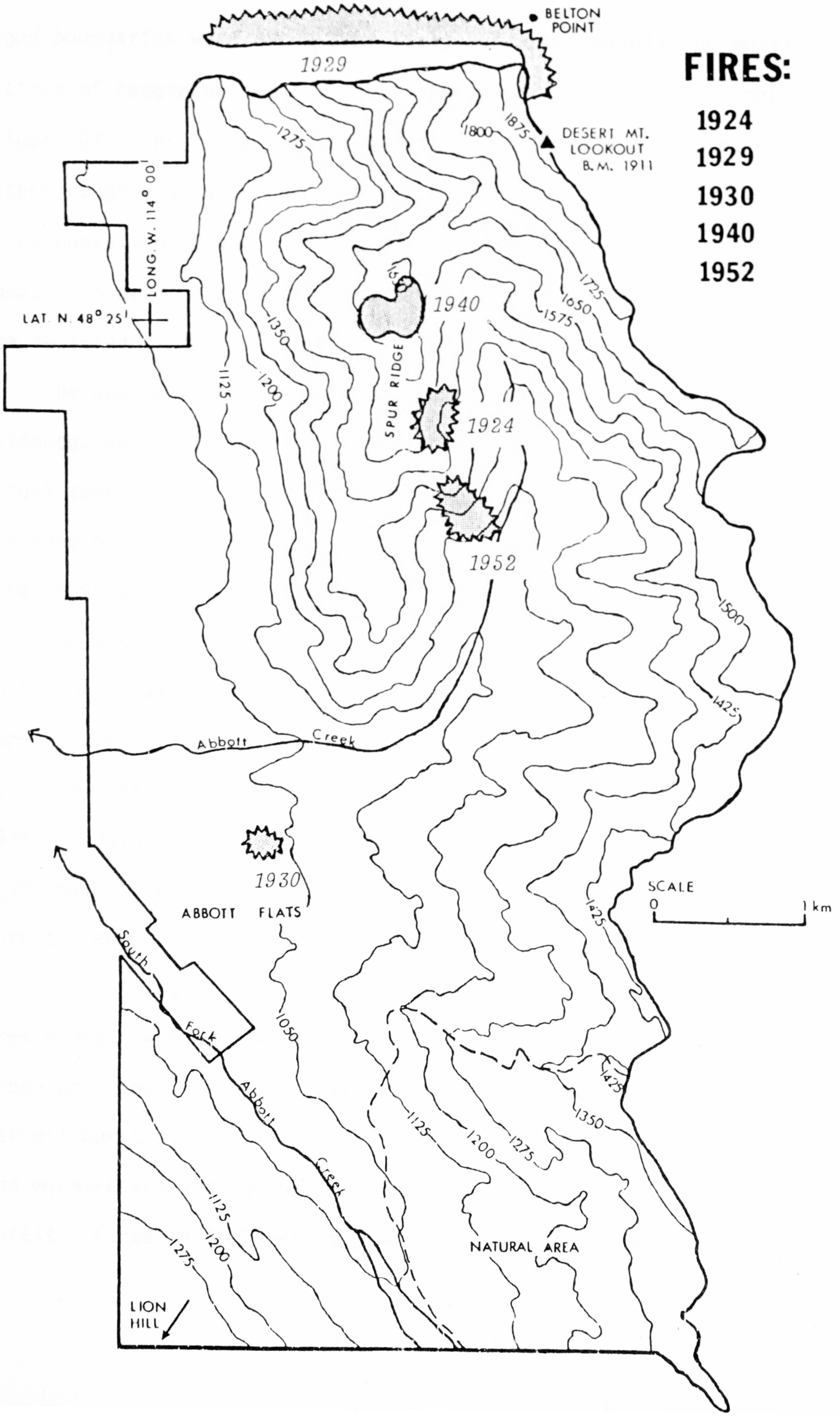

BELTON POINT
FIRES:
1888
1890
1892
1905
1908
DESERT MT. LOOKOUT B.M. 1911
1875
1800
1275
1908
1725
1650
1575
1350
1125
1200
SPUR RIDGE
LONG. W. 114° 00'
LAT. N. 48° 25'
1892
1500
1890
Abbott Creek
ABBOTT FLATS
1888
SCALE
0
1 km
1425
South Fork
1050
1890
1425
1350
1275
1200
1125
1905
Abbott Creek
1125
1200
1275
NATURAL AREA
LION HILL

Figure 11f.



BELTON POINT
FIRES:
1913
1915
1917
1919
1922
DESERT MT. LOOKOUT B.M. 1911
1875
1800
1275
1725
1650
1575
1917
1913
1919
1922
1915
LONG. W. 114° 00'
LAT. N. 48° 25'
1350
1200
1125
SPUR RIDGE
1500
Abbott Creek
ABBOTT FLATS
SCALE
0
1 km
1425
South Fork
Abbott Creek
1050
1125
1200
1275
1350
1475
NATURAL AREA
1125
1200
1275
LION HILL

Figure 11g.


BELTON POINT
1929
FIRES:
1924
1929
1930
1940
1952
DESERT MT. LOOKOUT B.M. 1911
1875
1800
1275
LONG. W. 114° 00'
LAT. N. 48° 25'
1725
1650
1575
1940
1350
1200
1125
SPUR RIDGE
1924
1952
1500
1425
Abbott Creek
1930
ABBOTT FLATS
SCALE
0
1 km
1425
South Fork Abbott Creek
1050
1425
1350
1125
1200
1275
1125
1200
1275
NATURAL AREA
LION HILL

edged boundaries were drawn from field evidence, mainly the mosaic pattern of regeneration, and the timber type/stand age-class map (figure 6). The spread of several fires could only be portrayed rather roughly because only a few cross-sections or a small sample of regeneration served as basic data. These fires were usually located in areas that have since been logged, and their boundaries are depicted in a zigzag manner.

The approximate areal spreads were drawn closely around the evidence, and therefore, represented the minimum probable spread. Actual spreads were probably slightly greater than indicated by this evidence because of the lack of physical barriers to fire spread other than small creeks and marshes.

The most significant finding of the study, which is illustrated in the maps, was that fires were usually small. The sizes of known spreads are not large generally ranging from 6 to 190 ha (15 to 475 ac.). No extensive fires occurred in the forest between 1602 and 1976. Judging from the 374-year historical record, large fires (≥100 ha, 250 ac.) are not characteristic of Coram Experimental Forest. However, they did occasionally occur.

Fairly large fires occurred in 1832, 1854, and 1892. The largest area burned (475 ac.) was in 1892 on the western slopes of Abbott Creek drainage. Coincidentally, 1892 was the year of one of the largest burns cited by Arno (1976) in the Bitterroot National Forest and more recently found by the same investigator in the Lolo National Forest. Fires in 1737 were mapped in four places. While the entire spreads are not known, there was no evidence to suggest these fires constituted one burn. Possibly the 1701 fire in Abbott Flats was a single burn since spot fires could have carried the flames across marshes (see figure 6).

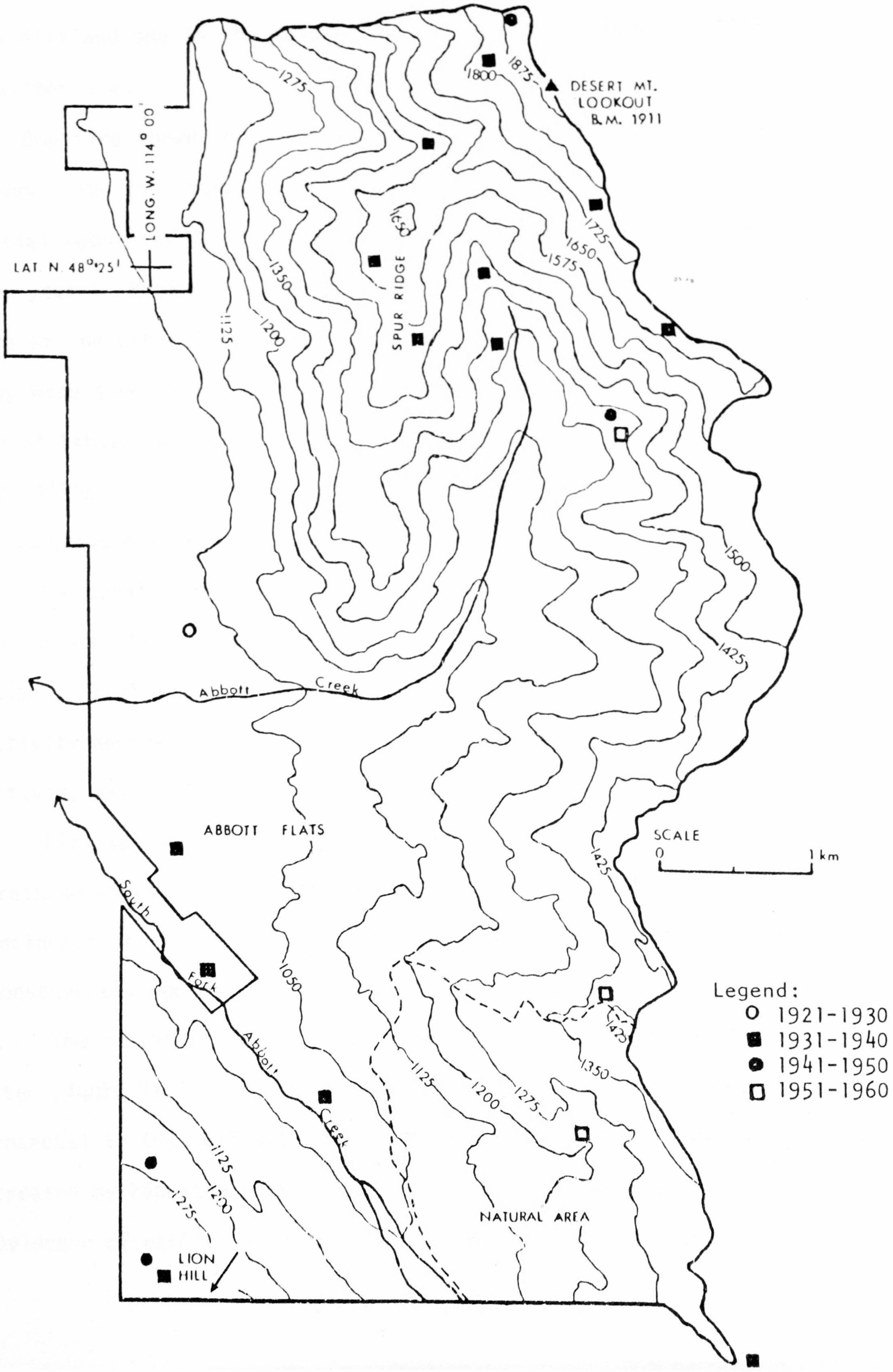
The Half Moon fire in 1929 burned an extensive area from Columbia Falls to West Glacier. The headfire missed Coram Experimental Forest although the forests on Lion Hill and around the present site of Hungry Horse Dam were intensely burned. However, two days after the headfire had passed, the southern flank became active and turning south developed into a holocaustic blaze which threatened the experimental forest. Gisborne (1931), who was at Desert Mountain Lookout, described the explosive fire which devastated the forests on the north slopes of Belton Point and Desert Mountain and in the valley below. While he did not mention why the fire stopped on the ridges, Gisborne did discuss a cold, heavy wind from the southwest which was drawn into the fire by the rising hot air mass from the raging flames at the base of the slopes. He stated that the wind was so strong that it "bounced me up against the lookout house." He continued that when the oxygen in the fresh air reached the superheated fuels, everything on the upper slopes burst into flames. Approximately three square kilometers (2 square mi.) of standing forest were devastated in just a few minutes.

Judging from the fire spread (shown in figure 11a) the southwestern wind must have continued long enough and with enough force to subside the flames. The fire boundary lies along the divides to the south and west of Belton Point. Surely, if the winds stopped or favored the fire, more of the Coram forest would have burned.

Daubenmire and Daubenmire (1968) stated that charcoal fragments are universally present in forest soils of the Northern Rockies and testify to the extent of historical fires. Charcoal found in the soils throughout Coram Experimental Forest proved that fire has been a widespread occurrence (Harvey 1977). Fragments were commonly found at the base of the duff layer to a depth of 15 cm (6 in.), either scattered throughout the soil profile or forming distinct layers. Three sites have been intensively examined: a Douglas-fir stand, a subalpine fir stand, and a western hemlock stand. The dry-site Douglas-fir stand had the most charcoal which was scattered throughout the soil. The wetter western hemlock site had the least charcoal which appeared in layers. Despite the differences between the two sites, this indicated the Douglas-fir site had more frequent, less intense fires than the western hemlock site.

Fire occurrence. Three areas of the forest appeared to have the highest incidence of fire. These were Abbott Flats, the western slopes of Abbott Creek drainage, and Desert Mountain. This pattern is partially supported by a map which shows the location of lightning-caused fires from 1921 to 1960 that were suppressed by the Hungry Horse Ranger District (figure 12). (There were no fires recorded after 1956.) Although no lightning fires were shown on the western slopes of Abbott Creek drainage for the 30-year period, five lightning-struck trees were found along the transect routes on these slopes.

Figure 12. Location of lightning-caused fires suppressed by the Hungry Horse Ranger District between 1921 and 1960.



The District lightning-fire map showed two fires on the slopes of Lion Hill and one in the Natural Area. This study found no fires in either area.

One fire shown in figure 12 was located in the fire history survey. The 1940 burn on the spur ridge which apparently was a partial reburn of forest burned in 1832 and 1913. 1940 was a noted fire year in Region One (Barrows 1951, Glacier National Park 1977). None of the other fires shown in figure 12 were located even when they were specifically sought out; this suggests they were small and of little consequence. Hardy (1977) stated that in the 1920's and 1930's it was common practice for one man from the fire lookout to suppress a fire as soon as it was located.

The areal spread maps (figure 11) indicated periods of activity for Abbott Flats. In the 1700's fire was recorded four times. Those in 1701 and 1737 appeared to have burned the largest areas. Activity decreased after 1759 and remained low until 1888. Fire activity has been negligible since 1905.

Fire was more frequent on the western slopes of Abbott Creek drainage where 14 burns occurred between 1710 and 1952. The high incidence of fire could maintain low to moderate ground fuel levels, consequently would contribute to the small area spread.

The southernmost portion of the 1892 burn is a shrubfield (see figure 11e). Lightning-struck trees, old burned stumps, and charcoal in the soil within the shrubfield suggested it was possibly created by repeated burns over time, but there was insufficient evidence of earlier fires to confirm this belief for this study.

Desert Mountain peak and the immediate ridge lines showed a high fire occurrence in figures 11 and 12. In this study, fires were recorded from 1854 to 1929 with the greatest activity around 1900 (figure 11). Only a few fires spread into the upper subalpine slopes from the lower slopes of the experimental forest. The fires of 1854, 1861, 1867, 1890, 1908, 1917, 1919, and 1929 burned both the Coram forest and some adjacent forested land. The larger areal spread, more complete overstory kill, and denser regeneration on the adjacent burned forest indicated that some of these fires (e.g., 1890, 1917, 1919, and 1929) burned up to the adjacent slopes and crossed the mountain ridges into Coram. Along the ridge, some of the burns in the predominately _Xerophyllum_ _tenax_ undergrowth were evidently light judging from the fact that thin-barked species (lodgepole pine and subalpine fir) were scarred but not killed (e.g., 1908, 1917, and 1919). Others were intense and initiated new stands (e.g., the larger 1861 burn, 1867, and 1929).

Repeated burns on the ridge area of Desert Mountain gave rise to nearly pure stands of lodgepole pine (e.g., 1890 and 1915; 1861, 1908, and 1917). Small lightning fires that naturally burned out were often not detected in this field investigation because of the limited evidence they leave. The small burn in 1861 was the only one found.

Fire behavior and effects. Fires burned with varied behavior. Given favorable burning conditions, the fuel characteristics (moisture content, quantity, size, continuity) would be a major factor of fire behavior and effects. Heavy down matter occurred locally but litter (leaves, twigs, and branches) and lower vegetation constituted the bulk of the surface and ground fuels.

A 1961 inventory rated fuels as predominately medium-medium types throughout Coram Experimental Forest (Shearer 1961). Medium-medium fuel types are a general description of the fire behavior and control potential during bad burning conditions in specific overstory classifications (USDA Forest Service 1964). This fire danger rating system represents a medium rate of spread (6 chains/hour) and medium control potential (.6 chain/man hour of fire line construction). The Burning Index for medium-medium fuel types is 70 on a 100 scale.

Thirteen-year fire weather records were obtained from Desert Mountain, West Glacier, and Hungry Horse weather stations using AFFIRMS (Administrative and Forest Fire Information Retrieval and Management System) (Furman and Brink 1975). The records were used to describe the worst average fire danger or the upper limit of the behavior of fires that might occur during the hottest part of the day from June 1 to September 15 according to National Fire Danger Rating System (NFDRS) (Deeming _et_ _al_. 1978). Coram Experimental Forest represents a fuel model H where fires are typically slow-spreading and are dangerous only in scattered areas where the downed woody material is concentrated. Table 5 shows the NFDRS ratings which occur 90% of the time. For example, 90% of the time the ingition component probability for Desert Mountain is ≤ 40.7. This means 40.7% or less of the fires required suppression action. The ratings describe a general moderate-intensity fire behavior that is within the prescribed burning range. The highest ratings (not shown) for the three stations represented a situation where fire behavior approaches the limit of control for manual attack methods. The greatest fire danger occurs in mid-August for all stations.

Fires that occurred in the experimental forest were generally low to moderate in intensity with occasional runs of higher intensity flames which killed most of the overstory except mature western larch and Douglas-fir. Within one burn it was common to find indications of various intensities. For example, only mature fire-resistant trees (larch and Douglas-fir) would survive in one portion while not far away small-stemmed trees of all species were scarred but not killed.

Grasses and grass-like vegetation predominated in the open canopy forests of the exposed slopes of the upper elevations. Grassy undergrowth fuels contribute most to fire intensity and spread when cured because they are readily burnable. In the subalpine zone where *Xerophyllum tenax* constituted a continuous fuel and where topography was uniform, fire behavior would not be widely variable.

It is difficult to assess historic fires in the valley because of the logging. However, fire spread evidence suggested that fires usually covered small areas (20 to 90 ha; 50 to 225 ac.), most of them being moderately intense but a few severe enough to cause stand replacement.

Table 5. Fire danger ratings which occur 90% of the time. Ratings are based on 13-year fire weather records which were processed in the National Fire Danger Rating System (Deeming *et al*. 1978)

Weather Station	Ignition component	Spread component (m/min.)	Energy release component (BTU/.09 sq m)	Burning index	Timelag fuel moisture			
					1 hour	10 hour	100 hour	1000 hour
Desert Mountain	≤40.7	≤ .98	≤30.1	≤24.4	15.6	21.3	17.6	21.9
West Glacier	≤49.0	≤1.16	≤26.0	≤23.5	13.6	17.4	18.2	22.1
Hungry Horse	≤51.9	≤1.01	≤31.9	≤25.5	11.9	17.5	16.8	20.1

On the exposed montane slopes where western larch and Douglas-fir predominate, ground cover is composed of shrubs and grasses which may be readily ignitable but do not sustain high intensities. On less exposed slopes, more shrub cover and down woody matter result in higher intensities. The areas burned in the 1884 and 1892 fires exemplify this latter situation.

Vegetation on cool exposures and in ravines and creeks is commonly a dense growth of conifers (commonly larch, Douglas-fir, spruce, and subalpine fir) and tall shrubs. When the overstory has formed a closed canopy the undergrowth is low, shade-tolerant herbacous plants. The fuels vary on these sites. Some of the large ravines in the northwestern portion of the forest have extensive areas of heavy, waist-deep downfall. Generally these moist, shaded areas have long fire-free intervals and often do not burn unless extreme fire danger conditions exist. When they do burn, the fire is usually a stand destroying crown fire. In these close-canopied forests, ground fires would be retarded by the lack of combustible ground fuels and the moist, shaded conditions.

In the western-most portion of Coram Experimental Forest there are areas on relatively dry, west facing slopes which have burned intensely in the past and have propagated a similar situation for the future. The burns of 1832 and 1854 are examples. Stand replacing fires killed much of the overstory and led to regeneration of even-aged stands of lodgepole pine and Douglas-fir. Douglas-fir is regenerating on the burned sites and replacing the decadent members of the lodgepole pine overstory. Douglas-fir saplings are creating a fuel ladder to the crowns of the overstory, a condition which increases the potential destructiveness of fires (Lunan and Habeck 1973). Heavy fuels occur as standing and fallen snags of the original overstory and downfall of the current stand. Fuel conditions are developing which would support stand-replacing fires.

There was no evidence of extensive, stand-destroying fire within the Coram forest. The Half Moon fire of 1929 which burned on the northern boundary of the experimental forest was the most severe fire during the record period (1602 to 1976). While portions of some individual burns were intense, the fires covered relatively small areas on the average (20 to 90 ha; 50 to 225 ac.). Many appeared to stop on ridges and in ravines (or creeks). Probably this was due to changes in the availability of fuels and in the weather.

The general tendency was for infrequent fires to thin the overstory, reduce ground fuels, and prepare a mineral seedbed. On montane slopes, the result was fairly even-aged regeneration of larch, lodgepole pine, and Douglas-fir growing beneath the opened overstory. The regeneration was composed of a mixture of these conifers or nearly pure pockets of one of the species, largely depending on the composition of the original stand and the available seed. Where fire destroyed the overstory the effect was more dramatic. The western boundary of the 1892 fire was intense leaving about 2 to 3 trees/hectare. Some of the few surviving mature larch and Douglas-fir have catface scars, and the regeneration has returned as dense thickets.

Multiple burns, too, caused modification of the conifer component. This was particularly noticeable in a stand of larch and lodgepole along Coram's eastern boundary which burned in 1890 and 1915 (figure 11e-f). Western larch was represented by about 8 trees/hectare, and most of the trees were killed in the second burn. The result was that fire-initiated regeneration is predominately lodgepole pine. Lodgepole pine's cone serotiny and early seed production would favor the pine over associated species (Brown 1975, Lotan 1976).

In the grand fir climax forests of the Swan Valley, Antos (1977) found that intense and repeated fires have kept much of the forest in seral communities composed mainly of western larch, lodgepole pine, Douglas-fir, and western white pine. Most mountain slopes were covered by stands originating from high intensity replacement burns. Extensive, severe fires have resulted in large areas of lodgepole pine. The abundance of lodgepole pine in the upper Swan Valley indicated a high frequency of stand replacement burns.

Multiple burns also create shrubfields in the northern Rocky Mountains (Ayres 1900a, 1900b, Wellner 1970). Forested areas which repeatedly burned in a short period of time (i.e., at least two fires within 25 years) did not have sufficient time for conifers to regenerate and reproduce seed crops. Shrub and grass cover increase in the absence of an overstory. Multiple-burn sites usually remain without tree cover for long periods especially on south-facing slopes (Larsen 1925). Evidence suggests the shrubfield on the southern portion of the 1892 fire (figure 11e) was created by repeated burns.

Fires on the lower subalpine slopes thinned the overstory and temporarily removed much of the duff, humus, and undergrowth thus allowed lodgepole pine, subalpine fir, and whitebark pine to regenerate. Hotter fires killed more of the overstory and burned larger areas.

Lodgepole pine was the most prolific, especially on sites which experienced a high intensity fire like the 1929 burn. Age-class examination of the regeneration following the Half Moon fire showed that both lodgepole pine and subalpine fir regenerated within a few years after 1929. This indicated that each is well adapted to revegetate burned areas and that subalpine fir does not require modified site conditions of later successional stages.

Whitebark pine also appeared to take on the role of a pioneer species and benefit from immediate post-fire conditions. The small fire of 1861 was determined from a catface scarred whitebark pine. The regeneration dating to that fire was whitebark pines which germinated 1 to 2 years after the fire. Other investigators have found whitebark pine to regenerate promptly after fires (Habeck and Mutch 1973, Loope and Gruell 1973, MacKenzie 1973).

Forest Composition

The results of the paired point sample survey of forest tree composition are shown for the forest burned in 1892 (table 6a) and for the adjacent unburned forest (table 6b). Both areas are ABLA/CLUN h.t.s. In the burned area fire intensity was evidently great since much of the original overstory was killed, about 2 to 3 trees/hectare

Table 6a. Stand table for burnt area, 1892 fire, Coram Experimental Forest (trees/ha)

10"-24"

Species/DBH (cm)	0- 9.9	10.0- 19.9	20.0- 29.9	30.0- 39.9	40.0- 49.9	50.0- 59.9
Douglas-fir	694	776	235	12	-	-
Lodgepole pine	-	959	119	32	-	-
Western larch	148	376	-	12	7*	-

average density: 509 trees/ha

*these were survivors from the pre-1892 fire stand.

Table 6b. Stand table for unburnt area adjacent to 1892 fire, Coram Experimental Forest (trees/ha)

Species/DBH (cm)	0- 9.9	10.0- 19.9	20.0- 29.9	30.0- 39.9	40.0- 49.9	50.0- 59.9
Douglas-fir	-	54	106	69	35	10
Lodgepole pine	-	49	20	44	15	5
Western larch	-	-	42	25	17	25

average density: 109 trees/ha

survived. Conifer seedlings thrived in the mineral seedbed left by the fire. Table 6a indicates that all three species (Douglas-fir, western larch, and lodgepole pine) regenerated in the aftermath of the fire. It appeared from the stand density of the fire-initiated regeneration in the 10 to 19.9 cm (4 to 8 in.) class that lodgepole pine and western larch occurred primarily in the immediate post-fire sere and did not continue to regenerate as the density of conifer and understory regeneration increased. The more shade tolerant Douglas-fir continued to regenerate successfully despite the increased canopy closure. Some of the larger stems in table 6a were from the original stand. The bulk of the regeneration was Douglas-fir but table 6b shows that this species was dominant in the unburned forest.

The 1892 fire intensity over the entire burn area was variable so not all trees were killed. Many of the Douglas-fir and western larch stumps examined in Block 11, 12, 13 and 21 (skyline harvest project) had small diameters at the time of the fire. Their retained evidence of the 1892 fire in the form of buried scars. In most cases the annual rings showed a marked growth increase, probably resulting from the thinning function of the burn. A prime example was a Douglas-fir (stump no. 44) which was 87 years old in 1892 and had a diameter of 7 cm at .3 m (3 in. at 1 ft.) above the ground. When it was logged in 1974 its diameter was 61 cm (24 in.).

A pattern of fire effects appears typical of the predominately western larch, lodgepole pine, and Douglas-fir covered montane slopes throughout Coram. Fires open up the stand, expose the soil, and prepare the seedbed. The fires range in intensity so the amount of site preparation is variable. Western larch and lodgepole pine regenerate actively within one to ten years after the fire, but seedling establishment decreases as succession progresses. Especially on protected slopes, Douglas-fir can regenerate promptly, and it is also able to regenerate in the later stages of succession that are unsuitable for larch and lodgepole. Fire maintains seral communities throughout much of the experimental forest.

Weather Records

An examination of the climatological records was undertaken for Columbia Falls, West Glacier, and Hungry Horse Reservoir to assess any relationship between fire years and summer weather for Coram Experimental Forest. Information was available only after 1900. Between 1910 and 1940 there were occasions when fire years correlated with low precipitation and high temperatures. There were also hot, dry summers in years without fire incidence, but the lack of fire would suggest no ignition rather than the lack of available fuels. The limited information indicated that fire occurrence was related to hot, dry weather which made fuels burnable. Wellner (1970) mentioned that the northern Rocky Mountains experienced a severe unprecedented drought between 1916 and 1940, which would be partial explanation for the forest area burned in Coram during those years.

Fire History in the Extended Study Area

The extension of the study to areas around Hungry Horse Reservoir produced a history quite different from that of Coram Experimental

Forest. Several logged units were examined but only a few had scar evidence of past fires. These units were located at Big Bill Mountain (stand N), Spotted Bear River Valley (O), Goldie Creek (P), Sullivan Creek (Q), Cedar Creek (R), Emery Loop Road (S), and Firefighter Mountain (T) (figure 5). Table 7 is the master fire chronology of these stands determined from the 24 stump cross sections and from age-class data obtained from conifer regeneration and stumps. Cross section information and the location of the units are given in appendix A-3. Since most of the logged units had been burned by the major fires in the Flathead National Forest, the USDA Forest Service spread maps of these fires were used in conjunction with the field information to verify fire years. Major fires occurred in 1885, 1889, 1890, 1893, 1903, 1910, 1914, 1919, 1921, 1926, and 1929. Although the areal spread maps were not always entirely accurate, they helped to confirm fire years and clarify history of multiple burns. Many of the earlier fires are based on only one or two cross sections so may not be the precise fire year.

It was not possible to accurately describe the early fires (prior to 1885) because of the scarcity of information and because of the effects of later fires. The latest major fires were widespread severe, stand-destroying burns which obscured evidence of earlier fires. Dense stands of lodgepole pine and western larch regeneration and fire-killed overstory identified high intensity burns. The fact that western larches had catface scars also indicated intense burns. On some of the slopes, fires were so hot that all mature larch crowned

Table 7. Master fire chronology of fire scar and stand age-class data from the extended study area showing the number of scars in each fire year in each stand and indicating conifer regeneration

Fire Year	Stand and Habitat Type							Total Scars
	Valley		Montane					
	N ABLA/ CLUN-ARNU (6)*	O ABLA/ CLUN-VACA (2)	P ABLA/CLUN (2)	Q ABLA/ CLUN-ARNU (3)	R ABLA/ CLUN-VACA (5)	S ABLA/ CLUN-XETE (2)	T ABLA/LIBO (4)	
1936	-	-	-	-	-	-	1	1
1929	-	R	-	-	-	-	-	0
1926	-	-	-	-	-	-	R	0
1910	-	-	-	-	2R	-	R	2
1903	3	-	1	-	-	-	-	4
1889	-	-	-	3	3R	-	-	6
1880	2	-	-	-	-	-	-	2
1868	-	-	-	-	-	-	1	1
1859	-	-	1	-	-	-	-	1
1821	-	1	-	-	-	-	-	1
1820	-	-	-	-	-	2	-	2
1809	-	-	-	-	R	-	-	0
1790	-	1	-	-	-	-	2	3
1774	-	1	-	-	-	-	-	1
1739	-	2	-	-	-	-	-	2
1726	4	-	-	3	-	-	-	7
1628	1R	-	-	-	-	-	-	1
1471	-	1	-	-	-	-	-	1
Total Scars	10	6	2	6	5	2	4	35
Mean fire free interval during historical fire period (1735-1910) in years:								
	88	44	88	88	175	88	175	

* Number of sample stumps in stand.

R Fire data determined by regeneration stand age-class.

1R Regeneration supporting fire date based on stand age-class samples.

out. Solitary, branchless snags (33 to 48 m or 100 to 150 ft. tall) are a common sight around the southern half of the reservoir. Trees were killed by one fire and reburned in another.

A brief aerial reconnaissance was taken during the study. It became evident that historic fires had been widespread and extensive throughout the eastern-most portion of the Flathead National Forest. Documentation of past fires has been presented by Ayres (1900b), Gisborne (1931), Gabriel (1976), and Antos (1977).

Forested areas which were repeatedly burned by severe fires in the last century often were conferted to a shrubfield. A typical example of the effect of reoccurring fires within a short time span was found on a mountain slope near the Spotted Bear Ranger Station. Two vegetative communities resulted from multiple burns. First, the forested community on the slope burned twice in 27 years in 1903 and 1929. Second, the adjacent community which once was forested burned three times in 27 years (1903, 1910, and 1929) and was converted into a shrubfield.

The scarcity of surviving trees in the original overstory, standing snags, and dense even-aged regeneration indicated that both burns in the forest community were intense. Much of the mature overstory was killed by the 1903 fire and later reburned in 1929. Many trees surviving the 1903 fire were killed in 1929. The undergrowth developing after the 1903 burn provided a continuous ground fuel for the later fire. Moreover, the conifer regeneration acted as a fuel ladder to carry fire into the crowns of the overstory. There was a continuous strata of fuel to carry an intense fire. Consequently, the original overstory was largely destroyed. Evidently the two fires did not deplete the seed source because dense regeneration, composed primarily of lodgepole and larch, followed the 1929 fire.

The shrubfield was probably created by the intensity and short interval between the three fires. The dead matter from the 1903 fire and the continuous ground cover of young trees, shrubs, and grasses provided fuel for the 1910 burn. Apparently these successive burns drastically reduced the overstory and the conifer seed supply. The intense 1929 fire consumed snags and heavy fuels created from previous burns. There are now very few snags and fallen trees from the original overstory remaining. Small, isolated groups of conifers growing in the ravines and depressions have regenerated after the 1903, 1910, or 1929 fires. Conifer regeneration is slowly invading the shrubfield from the isolated groups and adjacent forests.

CHAPTER VI

MANAGEMENT IMPLICATIONS

Methodology

One purpose of this study was to field test the fire history methodology being developed by Arno and Sneck (1977) in a forest that was more heavily logged and had less frequent fires than the Bitterroot National Forest, where the initial procedures were developed by Arno (1976). Findings in the Coram study have been incorporated into the Arno and Sneck (1977) method to make it more applicable to the wide array of forest types in the inland coniferous forests of western North America.

Changes in the initial methodology (discussed on page 47) were necessary because logged units provided more information than live trees in uncut stands. Therefore, emphasis was placed on examining stumps. The successful use of this methodology to determine the fire history of the experimental forest demonstrates its flexibility in different forest types and indicates it can be widely used in coniferous forests.

The general applicability of the methodology permits direct comparison of fire history between different areas and forest types (e.g., Coram Experimental Forest and the Bitterroot National Forest). In addition, the fire history information (frequency, severity, and areal spread) from one study area can be used to interpret the fire regime of an area which has similar vegetation features and habitat types.

Fire History

When the fire chronology is partitioned into historical periods, it is possible to determine the effects of settlement and fire suppression on the natural (historical) fire frequency. Since the early 1900's, efforts have been made to contain fire spread. This policy was created partly because of the severe, stand-destroying fires around the turn of the century and because of the lack of understanding of fire as an integral, natural factor. A recent study of fire history has shown some undesireable side effects of a half-century of fire suppression. In the Bitterroot National Forest, Arno (1976) found that the years since the last burn on most of the forested land now exceeds the longest fire-free intervals in the historical fire period (1735-1900). In some forest types, this has allowed fuels to accumulate and understories to become established--conditions which lead to high fire intensities.

In the Coram Experimental Forest, the suppression period has had less effect because fires are much less frequent. However, fire exclusion could eventually lead to severe, stand-replacing fires.

Another consequence of fire suppression is that less forest land has been burned during the past 50 to 70 years. This may foster gradual replacement of seral stands by climax communities. Heinselman (1970) stated that the vegetation that might develop with fire exclusion is unnatural and is largely unknown to science since fire has been an integral factor of some ecosystems.

Wilderness and national parks. Management plans which allow fire to play a more natural role are in effect in several areas, mainly in Wilderness and national parks (Mutch and Habeck 1975).

In presenting the planning guidelines and inventory procedures for wilderness fire management, Aldrich (1973) stated the importance of using fire history studies to define the natural role of fire. In the White Cap study area in the Selway-Bitterroot Wilderness, fire's role was determined from historical records, agency fire records, aerial photographs, and field investigations (Habeck 1976). While a range of fires exists, there is a characteristic kind of fire to consider for management planning. The historical information acquaints wilderness managers with the type of fire to expect and its effect on the vegetation communities.

Expansion of innovative fire policies had been limited and has largely depended on the success and results of such plans in Wilderness and parks. In 1974 a plan called DESCON, based on management needs, was initiated in the Francis Marion National Forest, South Carolina, which allowed all fires to burn that fit into the predetermined prescription (Devet 1975). More attention is currently being given to permit fire to perform naturally in national forests (Mutch 1977).

Wildlife. The abundance and variety of wildlife depends on the quality and distribution of habitat requirements, i.e., food, water, cover, and special features. Habitat requirements are dynamic and vary throughout the life of the animal. Some animals find most of their needs in recently burned areas, others in intermediate successional stages, and still others in climax stages. But, more frequently animals need a combination of vegetation communities to fulfill habitat requirements daily, seasonally, or during the life span. Fire is rarely uniform in intensity so it often produces a mosaic of plant forms which favor many forms of wildlife (Hayes 1970). The "edge effect" resulting from fires is a noted benefit (Dasmann 1964). Diverse vegetation, i.e., the mosaic of community types, stand composition, age, structure, life forms, species, and cover, sustains healthier and often larger populations.

Subsequent plant growth is relatively higher in protein and other essential nutrients and can support a denser population of grazers and browsers, especially in areas of plent~~y~~iful rainfall (Dasmann 1964).

The population of herbivores in western Montana and northern Idaho markedly increased after the fires between 1910 and 1930 (Lyon 1966, Orme and Leege 1976). Populations have been declining in the past four decades largely because of efficient fire suppression which has permitted the uninterrupted development to mature forest on thousands of acres. A knowledge of the periodicity, severity, and extent of past fires can be used by managers to implement a fire management plan which will maintain and create habitats for wildlife, i.e., shrubfields, early seral forests, forage species, etc.

Insects and diseases. In northern temperate regions, fire sanitizes forests by thinning stands or by eliminating old stands before insects or diseases can overtake them, thereby controlling the possibility of epidemics (Heinselman 1970). With continued fire exclusion old trees become increasingly less resistant to attack (Hare 1961). Epidemics create tremendous fuel loadings by killing trees over extensive areas (Wellner 1970). However, damaging insects and diseases are vital components of the dynamic ecosystem and by their activities increase fuel quantities and the probability of fire (Lyon and Pengelly 1970).

Past outbreaks could be examined in view of the fire history of the area. Stand-destroying fires like those around 1900 created snag-fields which may be breeding grounds for some insects to develop epidemic-sized populations. In addition, intense repeated fires tend to yield even-aged, single-species. In such cases, fire, by tending to create monocultures, has predisposed the stands to more-severe infestation by diseases and insects (Fellin 1977). However, when fire creates and maintains a variety of age-class structures and species composition and of forest floor conditions, it provides the most effective control against widespread epidemics.

Silviculture. Fire is an agent which destroys and renews stands. In silvicultural management, it is important to know fire history information in order to understand the types of fires which created forest stands and the potential risk to timber interests. In areas where intense, stand-destroying fires are typical or where fire suppression has created increased fuel accumulations, the silviculturist may want to prescribe practices that will alleviate those problems. If a stand is older than the average fire frequency and if there is a high risk to losing it to an intense fire, then the cutting rotation age may be set in accordance with fire frequency. Or, special suppression efforts (fuel breaks, vegetation mosaics, additional fire crews and aerial detection during high fire danger periods) can be employed to prevent an ignition from spreading.

The fire history study of Coram Experimental Forest has indicated areas within the forest which experienced stand-replacing fires. These areas may warrant extra attention when the fire danger is highest in late August. In addition, the study has shown that fires generally burn out along natural firebreaks (ravines and ridgetops). This information would aid fire suppression on the experimental forest.

After logging, fire has often been used to reduce the debris and prepare a mineral seedbed in the Coram forest. The seral trees, which are the most important timber species in this forest type, require an early successional stage and usually fail to become established without major disturbance. Studies in northwestern Montana have shown clearcutting coupled with broadcast burning results in better stocking than cutting without seedbed preparation (Shearer 1976, 1976), especially for larch. Surface fires reduce slash and prepare seedbeds following most logging practices.

Experimental burning in a western larch--Douglas-fir forest in west central Montana by Norum (1976, 1977) demonstrated the technique and effectiveness of prescribed burning for hazard reduction in an old growth forest. An associated experiment showed that proper fire application can release nutrients with no accelerated loss below the root zone (Stark 1977). In addition, overland flow and surface erosion were negligible.

Many studies have proven fire is an integral factor of plant and animal community development. Moreover, fire is a natural force that has to be reckoned with. Because of human interests, fire can no longer be allowed to select its own course. The result is a demand for specific fire management plans that delineate the acceptable uses, purposes, and prescriptions for fire. Fire history studies provide a scientific basis to develop fire management policies in accordance with total resource management.

CHAPTER VII

SUMMARY

Vast areas of seral forest communities, fire-scarred trees, and charcoal evidence verify the prevalence and ecological importance of fire in forests of the northern Rocky Mountains. Coram Experimental Forest is no exception. Historical investigations showed that fire has been a regular and widely occurring feature of the forest at least as far back as the year 1600.

The basic fire history methodology described by Arno and Sneck (1977) was used in the Coram forest. It was modified to intensively sample logged units and to age nearly all external fire scars encountered on trees. The successful application of this methodology in a mesic forest area indicates the techniques are generally applicable to inland coniferous forests of North America.

The fire chronology was based on aging of fire scars and identifying age-classes of shade-tolerant trees whose origin is attributed to fire. Only about one-fifth of the fire scar data was obtained from live trees; the remainder was from stumps of logged trees. External open scars were uncommon and were generally found on thin-barked lodgepole pine, subalpine fir, spruce, and whitebark pine. Fire-resistant, thick-barked western larch and Douglas-fir usually had healed over or buried scars. These were undetectable on the trunk of trees but could be readily identified on cut stumps.

Thirty-five fire years were documented for the record period (1602-1976). Additionally, it is probable that many small-area or low intensity burns were not detected. Between 1602 and 1976, fire occurred somewhere in Coram Experimental Forest (2984 ha) on an average of every 11 years and every 12 years during the historical fire period (1735-1910). In the suppression years (1910-1976), fires averaged every 7 years but most burns occurred between 1910 and 1930.

During the historical fire period (1735-1910), the mean fire-free intervals for stands of 5 to 10 ha (12 to 25 ac.) were >117 years in the valley bottom, 121 years on montane slopes, 146 years on the lower subalpine slopes, and >146 years on the upper subalpine slopes.

Medium fuel loadings prevail (in 1976) throughout the forest. Understory vegetation, litter, and medium-sized debris constitutes the bulk of the ground fuels. Heavy accumulations occur as downfall on some protected sites and where Douglas-fir bark beetles had been active in the past.

Areal spreads of historic fires were usually small (ranging from 6 to 190 ha; 15 to 475 ac.). There was no evidence of extensive, stand-destroying fires burning between 1602 nad 1976 which indicated that such fires are not typical of Coram. Fires usually stopped along ridges, ravines, and creeks suggesting that fuel availability and weather influences controlled spread. Fires in the valley bottom were usually small, but spot fires could have carried some fires across the marshes in Abbott Flats. Fragments of charcoal in the soil also show that fire had occurred extensively throughout the forest in the past.

Typically, fires were moderately intense on the montane slopes and increased intensity near the ridgetops. They functioned primarily as agents to break-up stands, reduce fuels, and prepare seedbeds. Nearly all coniferous species were promoted by fire, but western larch, Douglas-fir, and lodgepole pine benefitted most. Without continued disturbance, only the tolerant species regenerated.

Single, infrequent burns were most prevalent and resulted in an even-aged stand of regeneration composed of mixed conifers or small pockets of a single species. Severe burning created a more definite even-aged structure. Intense, multiple burns within a short time (<30 years) reduced the original stand members and modified the species composition, generally favoring lodgepole pine or shrubfield in extreme cases.

Literature and vegetation evidence testify to the occurrence of extensive high-intensity fires in the Flathead National Forest and surrounding areas. These types of fires are dramatic and their effects are obvious for decades. In contrast, the historical occurrence of low to moderate fires is probably understated because their effects are less dramatic or even noticeable.

The fire history of Coram Experimental Forest is evidently <u>not representative</u> of the bulk of the surrounding forested lands. The predominately medium fuels, mesic climate, and small amounts of lightning activity are not conducive to extensive crown fires. Instead, fire varies in intensity and has diverse effects on the vegetation. The literature relates that there are other valleys in the Flathead National Forest and surrounding areas that also experience a characteristically moderate intensity fire regime.

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Appendix A

Log of fire-scarred trees and stumps in Coram Experimental Forest and in the extended study area around Hungry Horse Reservoir

Appendix A-1: Log of fire-scarred trees sampled in Coram Experimental Forest.

Transect Number	Tree number	Species	d.b.h.	Number of fire scars	Number of rings to:		Habitat type and phase	Elevation	Aspect	Location
					scars	pith				
			cm					m		
2	1p*	LP	38	2	67 112	rot	ABLA/XETE h.t., XETE phase	1845	S 37° W	Desert Mountain spur trail.
	2p	LP	41	1	60	129	ABLA/XETE h.t., XETE phase	1845	S 40° W	
	3p	LP	43	2	59 114	167	ABLA/XETE h.t., XETE phase	1830	S 23° W	
	4p	LP	30	1	59	148	ABLA/XETE h.t., XETE phase	1815	S 70° E	
	5p	LP	38	1	59	rot	ABLA/XETE h.t., XETE phase	1815	S 76° E	
	6p	L	36	1	59	≅283	ABLA/XETE h.t., XETE phase	1770	S 26° W	
	7p	LP	20	1	68	113	ABLA/XETE h.t., XETE phase	1770	S 26° W	
	8p	LP	23	1	58	111	ABLA/XETE h.t., XETE phase	1710	S 51° E	
	9p	LP	28	1	61	112	ABLA/XETE h.t., XETE phase	1695	S 87° E	
4	10p	LP	33	1	144	237	ABLA/CLUN h.t., ARNU phase	1470	S 83° W	Trail 233 south from saddle to flats to the west.
	11p	LP	36	1	144	238	ABLA/CLUN h.t., ARNU phase	1425	S 62° W	
5	12p	L	66	1	84	≅231	PSME/PHMA h.t., PHMA phase	1245	S 23° E	Forest by loop road above Block 11.
	13p	F	28	1	54	rot	ABLA/CLUN h.t., ARNU phase	1365	S 49° E	
	14p	L	36	1	84	rot	ABLA/CLUN h.t., ARNU phase	1380	S 43° E	
6	15p	LP	28	1	61	80	ABLA/LIBO h.t., VASC phase	1500	S 38° W	Desert Mountain road by cutoff to the spring.
	16p	LP	23	1	61	82	ABLA/LIBO h.t., VASC phase	1500	S 42° W	
	17p	L	58	1	86	281	ABLA/LIBO h.t., VASC phase	1485	S 40° W	
	18	L	53	1	86	≅274	ABLA/LIBO h.t., VASC phase	1500	S 2° W	

* p indicates that a photograph was taken of the sample tree.

Appendix A-1 (cont.)

Transect number	Tree number	Species	d.b.h.	Number of fire scars	Number of rings to: scars	pith	Habitat type and phase	Elevation	Aspect	Location
			cm					m		
7	19p	L	46	1	92	248	PSME/PHMA h.t., PHMA phase	1230	S 31° W	Slopes across from clearcut.
8	20p	LP	23	1	63	112	ABLA/CLUN h.t., XETE phase	1635	S 39° E	West ridge above Blocks 21 and 23.
	21p	LP	15	1	63	123	ABLA/CLUN h.t., XETE phase	1635	S 41° E	
	22p	L	76	1	35	≅297	ABLA/CLUN h.t., XETE phase	1560	S 88° W	
	23p	L	76	1	84	293	ABLA/CLUN h.t., XETE phase	1455	S 21° W	
9	24p	WB	38	1	115	rot	ABLA/XETE h.t.	1755	S 11° W	Telegraph Trail from saddle, Belton Point, and Trail 233.
	25p	WB	25	1	47	142	ABLA/XETE h.t.	1905	N 57° W	
	26p	LP	8	1	47	171	ABLA/XETE h.t.	1905	N 61° W	
16	27p	D	61	1	82	169	ABLA/CLUN h.t., ARNU phase	1275	N 90° E	Blocks 11 and 12.
	28	L	58	2	82 211	rot	ABLA/CLUN h.t., ARNU phase	1260	S 88° E	
17	29	L	46	1	84	rot	ABLA/CLUN ht., ARNU phase	1275	S 87° E	Block 11.

Appendix A-2: Log of fire-scarred stumps examined in Coram Experimental Forest.

Transect number	Stump number	Species	Stump diameter at 0.3 m	Number of fire scars	Number of rings to: scars	pith	Habitat type and phase	Elevation	Aspect	Location
			cm					m		
10	1p*	L	41	1	60	231	ABLA/CLUN h.t., ARNU phase	1050	S 43° W	Natural area
	2p	L	43	1	41	235	ABLA/CLUN h.t., ARNU phase	1050	S 43° W	flats clearcut
	3p	L	56	1	≅60	≅230	ABLA/CLUN h.t., ARNU phase	1050	S 44° W	T. 30 N., R. 19 W.,
	4p	L	89	1	≅342	≅502	ABLA/CLUN h.t., ARNU phase	1050	S 39° W	Sec. 13 and 14.
	5p	L	53	2	39 161	299	ABLA/CLUN h.t., ARNU phase	1050	S 39° W	Logged 1944.
	6p	L	102	1	≅243	≅261	ABLA/CLUN h.t., ARNU phase	1050	S 36° W	
	7p	L	53	1	39	176	ABLA/CLUN h.t., ARNU phase	1050	S 38° W	
	8	L	51	1	≅162	≅190	ABLA/CLUN h.t., ARNU phase	1050	S 40° W	
11	9p	L	94	1	≅300	≅372	ABLA/CLUN h.t., VACA phase	1035	N 80° W	Abbott Flats
	10p	L	61	1	≅300	≅328	ABLA/CLUN h.t., VACA phase	1035	N 86° W	clearcut,
	11p	L	99	1	≅300	≅353	ABLA/CLUN h.t., VACA phase	1035	N 86° W	T. 30 N., R. 19 W.,
	12	F	46	1?**	16	64	ABLA/CLUN h.t., VACA phase	1020	N 84° W	Sec. 2.
	13p	L	76	1	≅245	≅268	ABLA/CLUN h.t., VACA phase	1020	N 89° W	Logged 1946.
	14p	L	41	1	≅245	≅282	ABLA/CLUN h.t., VACA phase	1020	N 87° W	
	15p	L	66	1	≅245	≅266	ABLA/CLUN h.t., VACA phase	1020	N 89° W	
12	16	F	43	1	51	109	ABLA/CLUN h.t., XETE phase	1650	N 43° E	East ridge
	17p	S	53	1	49	82	ABLA/CLUN h.t., XETE phase	1650	N 52° E	saddle
	18	D	71	1	50	102	ABLA/CLUN h.t., XETE phase	1650	N 50° E	clearcut,
	19	F	51	1	52	89	ABLA/CLUN h.t., XETE phase	1650	N 46° E	T. 30 N., R. 18 W.,
	20p	S	48	1	51	101	ABLA/CLUN h.t., XETE phase	1650	N 54° E	Sec. 30 and 31.
	21p	S	41	1	51	102	ABLA/CLUN h.t., XETE phase	1650	N 50° W	Logged 1970.
	22	D	58	1	53	93	ABLA/CLUN h.t., XETE phase	1650	N 41° W	
	23p	F	46	1	51	97	ABLA/CLUN h.t., XETE phase	1650	S 38° W	

* p indicates that a photograph was taken of the sample stump.

** ? indicates possibly not fire scar

Appendix A-2 (cont.)

Transect number	Stump number	Species	Stump diameter at 0.3 m	Number of fire scars	Number of rings to:		Habitat type and phase	Elevation	Aspect	Location
					scars	pith				
			cm					m		
13	24	D	74	1	54	rot	PSME/PHMA h.t., CARU phase	1110	S 23° W	Natural area slopes selective cutting, T. 30 N., R. 19 W., Sec. 12. Logged 1944
	25	D	81	1	54	93	PSME/PHMA h.t., CARU phase	1125	S 23° W	
	26	LP	48	1	52	103	PSME/PHMA h.t., CARU phase	1170	S 33° W	
	27p	D	76	1	51	98	PSME/PHMA h.t., CARU phase	1200	S 46° W	
	28	L	71	1	54	105	PSME/PHMA h.t., CARU phase	1260	S 43° W	
	29	D	69	1	54	102	PSME/PHMA h.t., CARU phase	1305	S 13° W	
	30	L	58	1	50	97	PSME/PHMA h.t., CARU phase	1245	S 37° W	
	31	L	97	1	123	206	PSME/PHMA h.t., PHMA phase	1065	S 43° W	Upper Abbott Flats clearcut, T. 30 N., R. 19 W., Sec. 11 Logged 1944.
	32	L	79	1	≅120	265	PSME/PHMA h.t., PHMA phase	1065	S 40° W	
14	33	L	71	1	185	204	PSME/PHMA h.t., PHMA phase	1095	N 23° W	Upper Abbott Flats clearcut, T. 30 N., R. 19 W., Sec. 11 and 12. Logged 1945
	34p	L	69	1	≅179	253	PSME/PHMA h.t., PHMA phase	1110	N 14° W	
	35p	L	64	1	186	206	PSME/PHMA h.t., PHMA phase	1095	N 43° W	
	36p	L	51	2	58 186	207	PSME/PHMA h.t., PHMA phase	1080	N 39° W	
15	37	L	69	1	197	231	ABLA/CLUN h.t., ARNU phase	1260	N 18° W	Upper Abbott Creek drainage clearcut, T. 31 N., R. 19 W., Sec. 36. Logged 1955
	38	L	76	1	≅195	≅230	ABLA/CLUN h.t., ARNU phase	1275	N 37° W	
	39	L	61	1	≅196	≅230	ABLA/CLUN h.t., ARNU phase	1275	N 20° W	

Appendix A-2 (cont.)

Transect number	Stump number	Species	Stump diameter at 0.3 m	Number of fire scars	Number of rings to: scars	Number of rings to: pith	Habitat type and phase	Elevation	Aspect	Location
			cm					m		
16	40p	L	53	2	82 215	302	ABLA/CLUN h.t., CLUN phase	1290	N 87° E	Block 11,
	41p	L	56	1	158	243	ABLA/CLUN h.t., CLUN phase	1290	N 90° E	T. 31 N., R. 19 W.,
	42	L	43	1	81	161	ABLA/CLUN h.t., CLUN phase	1290	N 89° E	Sec. 36.
	43	L	64	1	80	261	ABLA/CLUN h.t., CLUN phase	1290	N 89° E	Logged 1974.
	44p	D	61	1	82	169	ABLA/CLUN h.t., CLUN phase	1275	N 90° E	
	45	D	43	1	82	167	ABLA/CLUN h.t., CLUN phase	1275	N 88° E	
	46	D	69	1	80	281	ABLA/CLUN h.t., CLUN phase	1245	N 85° E	
	47p	D	76	1	82	rot	ABLA/CLUN h.t., CLUN phase	1245	N 84° E	
	48	L	66	1	82	167	ABLA/CLUN h.t., CLUN phase	1230	N 83° E	
	49	L	58	1	82	257	ABLA/CLUN h.t., CLUN phase	1215	N 90° E	
	50	D	41	1	82	129	ABLA/CLUN h.t., CLUN phase	1230	N 89° E	
	51p	D	79	1	82	rot	ABLA/CLUN h.t., CLUN phase	1230	N 88° E	
	52	L	81	1	81	169	ABLA/CLUN h.t., CLUN phase	1260	N 90° E	
	53p	D	36	1	82	109	ABLA/CLUN h.t., CLUN phase	1275	N 87° E	
	54	D	61	1	79	113	ABLA/CLUN h.t., CLUN phase	1335	N 90° E	
	55	L	36	1	80	139	ABLA/CLUN h.t., CLUN phase	1335	N 90° E	
	56p	L	66	1	181	254	ABLA/CLUN h.t., CLUN phase	1320	N 89° E	
	57p	D	69	1	180	234	ABLA/CLUN h.t., CLUN phase	1305	N 87° E	
	58	L	61	1	82	rot	ABLA/CLUN h.t., CLUN phase	1260	N 85° E	
	59	L	66	1	82	rot	ABLA/CLUN h.t., CLUN phase	1290	N 86° E	
	60	L	48	1	79	119	ABLA/CLUN h.t., CLUN phase	1320	N 80° E	
	61	L	89	1	82	220	ABLA/CLUN h.t., CLUN phase	1335	N 81° E	
	62	L	66	1	82	269	ABLA/CLUN h.t., CLUN phase	1350	N 82° E	
	63	L	38	1	81	165	ABLA/CLUN h.t., CLUN phase	1350	N 81° E	

Appendix A-2 (cont.)

Transect number	Stump number	Species	Stump diameter at 0.3 m	Number of fire scars	Number of rings to: scars	pith	Habitat type and phase	Elevation	Aspect	Location
			cm					m		
17	64	L	61	1	237	254	ABLA/CLUN h.t., PHMA phase	1320	S 47° E	Block 12
	65	L	66	1	82	264	ABLA/CLUN h.t., PHMA phase	1335	S 51° E	T. 31 N., R. 19 W.,
	66p	D	56	1	22	165	ABLA/CLUN h.t., PHMA phase	1320	S 52° E	Sec. 36.
	67	L	53	1	22	rot	ABLA/CLUN h.t., PHMA phase	1320	S 48° E	Logged 1974.
	68p	D	61	1	21	205	ABLA/CLUN h.t., PHMA phase	1320	S 45° E	
	69p	D	58	1	82	rot	ABLA/CLUN h.t., PHMA phase	1320	S 60° E	
	70p	L	43	1	82	167	ABLA/CLUN h.t., PHMA phase	1275	S 54° E	
	71	L	61	1	81	burnt	ABLA/CLUN h.t., PHMA phase	1275	S 56° E	
	72	L	56	1	82	275	ABLA/CLUN h.t., PHMA phase	1275	S 47° E	
	73	L	51	1	81	267	ABLA/CLUN h.t., PHMA phase	1290	S 49° E	
	74	L	64	1	82	260	ABLA/CLUN h.t., PHMA phase	1290	S 52° E	
	75	L	69	1	79	213	ABLA/CLUN h.t., PHMA phase	1290	S 48° E	
	76	L	58	1	80	228	ABLA/CLUN h.t., PHMA phase	1320	S 50° E	
	77	D	61	1	82	230	ABLA/CLUN h.t., PHMA phase	1335	S 50° E	
	78	L	71	1	131	173	ABLA/CLUN h.t., PHMA phase	1215	S 47° E	
	79	D	28	1	22	147	ABLA/CLUN h.t., PHMA phase	1215	S 49° E	
	80p	L	79	1	256	277	ABLA/CLUN h.t., XETE phase	1245	N 72° E	Block 13,
	81	L	58	1	81	248	ABLA/CLUN h.t., XETE phase	1260	N 71° E	T. 31 N., R. 19 W.,
	82p	L	48	1	82	152	ABLA/CLUN h.t., XETE phase	1320	N 72° E	Sec. 36.
	83p	L	43	1	82	215	ABLA/CLUN h.t., XETE phase	1320	N 73° E	Logged 1974.
	84p	L	46	1	82	138	ABLA/CLUN h.t., XETE phase	1320	N 73° E	
	85	L	61	1	133	176	ABLA/CLUN h.t., XETE phase	1320	N 73° E	

Appendix A-2 (cont.)

Transect number	Stump number	Species	Stump diameter at 0.3 m	Number of fire scars	Number of rings to: scars	Number of rings to: pith	Habitat type and phase	Elevation	Aspect	Location
			cm					m		
18	86p	F	30	1	50	86	ABLA/CLUN h.t., XETE phase	1485	N 83° E	Block 21,
	87p	F	23	1	52	63	ABLA/CLUN h.t., XETE phase	1485	S 1° E	T. 31 N., R. 19 W.,
	88p	F	25	1	47	rot	ABLA/CLUN h.t., XETE phase	1485	S 11° E	Sec. 36.
	89	D	43	1	82	129	ABLA/CLUN h.t., XETE phase	1485	S 13° E	Logged 1974.
	90p	D	36	1	82	111	ABLA/CLUN h.t., XETE phase	1470	S 1° E	
	91p	D	38	1	81	143	ABLA/CLUN h.t., XETE phase	1455	N 68° E	
	92p	D	53	1	82	233	ABLA/CLUN h.t., XETE phase	1440	N 89° E	
	93	L	53	1	82	rot	ABLA/CLUN h.t., XETE phase	1440	N 89° E	
	94	L	46	1	81	120	ABLA/CLUN h.t., XETE phase	1410	N 73° E	
	95	L	43	1	82	169	ABLA/CLUN h.t., XETE phase	1410	N 77° E	
	96	L	53	1	82	199	ABLA/CLUN h.t., XETE phase	1365	S 8° E	
	97	D	48	1	82	102	ABLA/CLUN h.t., XETE phase	1365	S 6° E	
19	98p	L	41	1	208	261	ABLA/CLUN h.t., VACA phase	1170	S 46° W	Lower Abbott
	99p	D	33	1	207	rot	ABLA/CLUN h.t., VACA phase	1185	S 45° W	Creek drainage.
	100p	D	46	1	207	rot	ABLA/CLUN h.t., VACA phase	1170	S 47° W	T. 30 N., R. 19 W.,
	101p	L	74	1	205	311	ABLA/CLUN h.t., VACA phase	1185	S 47° W	Sec. 12. Logged 1945

Appendix A-3: Log of fire-scarred stumps examined in the Flathead National Forest around Hungry Horse Reservoir.

Transect number	Stump number	Species	Stump diameter at 0.3 m	Number of fire scars	Number of rings to: scars	Number of rings to: pith	Habitat type and phase	Elevation	Aspect	Location
			cm					m		
n.a.	102	L	117	1	≅160	348	ABLA/LIBO h.t.	1185	N 87° E	Firefighter
	103	LP	48	1	162	rot	ABLA/LIBO h.t.	1185	N 74° E	Mountain.
	104	L	97	1	17	324	ABLA/LIBO h.t.	1185	N 81° E	Logged 1952.
	105	L	74	1	84	293	ABLA/LIBO h.t.	1185	N 87° E	
n.a.	106	L	51	1	75	149	ABLA/CLUN h.t., VACA phase	1140	S 45° E	Spotted Bear
	107	L	64	1	74	197	ABLA/CLUN h.t., VACA phase	1140	S 47° E	Ranger District,
	108	L	46	1	55	137	ABLA/CLUN h.t., VACA phase	1140	S 48° E	Cedar Creek
	109	L	53	1	54	151	ABLA/CLUN h.t., VACA phase	1140	S 2° E	clearcut,
	110	L	43	1	76	114	ABLA/CLUN h.t., VACA phase	1140	S 5° E	T. 24 N., R. 14 W.,
										Sec. 7.
										Logged 1965.
n.a.	111p*	L	135	1	227	539	ABLA/CLUN h.t., VACA phase	1110	0°	Spotted Bear
	112p	L	130	5	147	623	ABLA/CLUN h.t., VACA phase	1110	0°	River Valley
					175					clearcut,
					194					S.B.R.D.,
					229					T. 25 N., R. 15 W.,
					497					Sec. 10.
										Logged 1968.

* p indicates that a photograph was taken of the sample stump.

Appendix A-3 (cont.)

Transect number	Stump number	Species	Stump diameter at 0.3 m	Number of fire scars	Number of rings to: scars	pith	Habitat type and phase	Elevation	Aspect	Location
			cm					m		
n.a.	113p	L	94	3	59	388	ABLA/CLUN h.t., ARNU phase	1125	S 80° E	Big Bill
					82					Mountain
					334					clearcut,
	114p	L	79	1	234	315	ABLA/CLUN h.t., ARNU phase	1125	S 79° E	S.B.R.D.,
	115p	L	81	1	236	373	ABLA/CLUN h.t., ARNU phase	1125	S 82° E	T. 25 N., R. 14 W.,
	116p	L	79	1	237	419	ABLA/CLUN h.t., ARNU phase	1125	S 49° E	Sec. 14.
	117p	L	91	1	59	324	ABLA/CLUN h.t., ARNU phase	1125	S 63° E	Logged 1962.
	118p	L	76	4	58	382	ABLA/CLUN h.t., ARNU phase	1125	S 80° E	
					84					
					235					
					334					
n.a.	119p	L	53	2	76	257	ABLA/CLUN h.t., ARNU phase	1185	N 40° W	Sullivan Creek
					243					clearcut,
	120p	L	74	2	79	276	ABLA/CLUN h.t., ARNU phase	1185	N 42° W	S.B.R.D.,
					248					T. 26 N., R. 17 W.,
	121p	L	81	2	80	252	ABLA/CLUN h.t., ARNU phase	1185	N 42° W	Sec. 12.
					244					Logged 1968.
n.a.	122p	L	46	1	≅62	235	ABLA/CLun h.t.	1140	N 74° E	Goldie Creek
	123	L	66	1	106	348	ABLA/CLUN h.t.	1155	N 4° E	selection cut,
										Hungry Horse
										Ranger District,
										T. 29 N., R. 18 W.,
										Sec. 36.
										Logged 1965.
n.a.	124	L	91	1	≅140	224	ABLA/CLUN h.t., XETE phase	1260	S 11° E	Emery Loop
	125	L	102	1	≅140	252	ABLA/CLUN h.t., XETE phase	1260	S 11° E	Road, H.H.R.D.,
										Logged 1960.

Appendix B : Fire history for each stand based on sample trees and stumps and on age classes of regeneration. Fire frequency is determined for the historical fire period, 1735 to 1910.

LEGEND

Species: L (western larch), D (Douglas-fir), LP (lodgepole pine), F (subalpine fir), S (spruce), WB (whitebark pine).

Sample Number: 1-29 sample trees, S1-S101 sample stumps.

R: Conifer regeneration dating from a specific fire year.

1735-1910: Historical fire period.

F1905: Apparent fire year determined from scarred samples.

R1737: Apparent fire year determined from age-class regeneration.

X: Fire scarred trees or stumps.

P: Pith date, the total age of regeneration following a specific fire year. Total age is the age of an increment bore at 0.3 m plus the growth factor to boring height.

Appendix B (cont.)

Valley

Stand A ABLA/CLUN h.t., ARNU phase

Sample number:	S1	S2	S3	S4	S5	S6	S7	S8
Species:	L	L	L	L	L	L	L	L
Year								
* 1910								
5) F1905	-	X	-	-	X	-	X	-
21) F1884	X	-	X	-	-	-	-	-
101) F1783	-	-	-	-	X	-	-	X
48) 1735								
1713	P	-	P	-	-	-	-	-
1709	-	P	-	-	-	-	-	-
F1701	-	-	-	-	-	X	-	-
F1602	-	-	-	X	-	-	-	-

Frequency⁺ = 58 years

Stand B ABLA/CLUN h.t., VACA phase

Sample number:	S9	S10	S11	S12	S13	S14	S15
Species:	L	L	L	F	L	L	L
Year							
F1930	-	-	-	X?	-	-	-
2. 1910							
175) 1735							
55 F1701	-	-	-	-	X	X	X
F1646	X	X	X	-	-	-	-

Frequency > 175 years

* Indicates the intervening years between fires within the period, 1735 to 1910, or between a fire and the end of the period.

$^+$ Frequency = $\dfrac{\text{historical fire period}}{\text{number of fires in period}}$

Appendix B (cont.)

Montane slopes

Stand C1 ABLA/CLUN h.t., ARNU phase

	Sample number:	10	11	R	R	R	R	R
	Species:	LP	LP	D	D	LP	LP	LP
	Year							
	1910							
78)	1846	-	-	P	-	-	-	-
	1844	-	-	-	P	-	-	-
	1837	-	-	-	-	-	P	-
	1835	-	-	-	-	P	-	P
	F1832	X	X	-	-	-	-	-
95)	1739	P	-	-	-	-	-	-
	1738	-	P	-	-	-	-	-
	R1737	-	-	-	-	-	-	-
2)	1735							

Frequency = 88 years

Stand C2 ABLA/CLUN h.t., ARNU phase

	Sample number:	S37	S38	S39
	Species:	L	L	L
	Year			
	1910			
151)	F1759	X	X	X
22)	1740	-	P	P
	1739	P	-	-
	R1737	-	-	-
2)	1735			

Frequency = 88 years

Stand C3 ABLA/CLUN h.t., ARNU phase

	Sample number:	R	R	R	R	R
	Species:	LP	LP	LP	LP	LP
	Year					
	1910					
56)	1857	P	-	-	P	-
	1856	-	P	-	-	-
	1855	-	-	P	-	P
	R1854	-	-	-	-	-
119)	1735					

Frequency = 175 years

Stand D1 PSME/PHMA h.t., PHMA phase

	Sample number:	12	R	R	R	R	R
	Species:	L	D	D	LP	LP	D
	Year						
	1910						
18)	1897	-	P	-	-	-	-
	1896	-	-	-	-	-	P
	1895	-	-	P	-	-	-
	1894	-	-	-	P	P	-
	F1892	X	-	-	-	-	-
157)	1735						

Frequency = 175 years

Appendix B (cont.)

Montane slopes (cont.)

Stand D2 PSME/PHMA h.t., PHMA phase

	Sample number:	19	R	R	R	R	R
	Species:	L	D	D	D	LP	L
	Year						
	1910						
26	1892	-	P	-	-	-	-
	1891	-	-	-	P	-	-
	1889	-	-	P	-	-	-
	1886	-	-	-	-	P	-
	1885	-	-	-	-	-	P
149	F1884	X	-	-	-	-	-
	1735						

Frequency = 175 years

Stand D3 PSME/PHMA h.t., PHMA phase

	Sample number:	S31	S32	S33	S34	S35	S36
	Species:	L	L	L	L	L	L
	Year						
	1910						
22	F1888	-	-	-	-	-	X
67	F1821	X	X	-	-	-	-
62	F1759	-	-	X	X	X	X
22	1747	-	-	P	-	-	-
	1745	-	-	-	-	P	-
	1744	-	-	-	-	-	P
	1738	P	-	-	-	-	-
	R1737	-	-	-	-	-	-
2	1735						

Frequency = 44 years

Stand E PSME/PHMA h.t., CARU phase

	Sample number:	S24	S25	S26	S27	S28	S29	S30	R	R	R	R	R	R	R	R	R	R
	Species:	D	D	LP	D	L	D	L	D	D	D	D	LP	LP	L	L	LP	LP
	Year																	
	1910																	
20	1909	-	-	-	-	-	-	-	-	P	-	P	-	-	-	-	-	-
	1903	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-	-	-
	1901	-	-	-	-	-	-	-	P	-	-	-	-	-	-	-	-	-
	1895	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-
	1894	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P
	1893	-	-	-	-	-	-	-	-	-	-	-	P	-	-	P	-	-
	1892	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	P	-
155	F1890	X	X	X	X	X	X	X	-	-	-	-	-	-	-	-	-	-
	1735																	

Frequency = 175 years

Appendix B (cont.)

Montane slopes (cont.)

Stand F ABLA/CLUN h.t., CLUN phase

Sample number:	13	14	27	28	29	S40	S41	S42	S43	S44	S45	S46	S47	S48	S49	S50	S51	S52	S53	S54	S55	S56	S57	S58	S59	S60	S61	S62	S63	R	R	R	R	R	R
Species:	F	L	D	L	L	L	L	L	L	D	D	D	D	L	L	D	D	L	D	D	L	L	D	L	L	L	L	L	L	L	L	D	D	LP	L
Year																																			
F1922	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1910																																			
18) 1897	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-
1896	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-
1894	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	P
1893	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	P	-	-	-	-
74) F1892	-	X	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	X	X	X	X	X	X	-	-	-	-	-	-
F1816	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13) 1813	-	-	-	-	-	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1809	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-	-
1807	-	-	P	-	-	-	-	-	-	-	P	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1805	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10) R1803	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28) F1793	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6) F1765	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F1759	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24) 1735																																			
1720	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1717	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1713	-	-	-	-	-	-	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
R1710	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Frequency = 29 years

Appendix B (cont.)

Montane slopes (cont.)

Stand G ABLA/CLUN h.t., VACA phase

	Sample number:	S98	S99	S100	S101	R	R	R
	Species:	L	D	D	L	D	D	L
	Year							
	1910							
173)	1741	-	-	-	-	-	P	-
	1740	-	-	-	-	P	-	-
	1739	-	-	-	-	-	-	P
2)	F1737	X	X	X	X	-	-	-
	1735							

Frequency = 175 years

Stand H ABLA/CLUN h.t., PHMA phase**

	Sample number:	S64	S65	S66	S67	S68	S69	S70	S71	S72	S73	S74	S75	S76	S77	S78	S79	R	R	R	R
	Species:	L	L	D	L	D	D	L	L	L	L	L	L	L	D	L	D	L	L	D	L
	Year																				
	F1952	-	-	X	X	X	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-
	1910																				
18)	1898	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-
	1894	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-
	1893	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	P
51)	F1892	-	X	-	-	-	X	X	X	X	X	X	X	X	X	-	-	-	-	-	-
43)	F1841	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-
	1809	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1807	-	-	-	-	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-	-
	1801	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-
61)	R1798	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1746	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-	-	-
	1744	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-	-
2)	F1737	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1735																				

Frequency = 44 years

** Habitat type and phase occurring only in a small area of Coram Experimental Forest.

Appendix B (cont.)

Montane slopes (cont.)

Stand 11 ABLA/CLUN h.t., XETE phase

Sample number:	23	S80	S81	S82	S83	S84	S85	R	R	R	R
Species:	L	L	L	L	L	L	L	L	L	L	L
Year											
1910											
18) 1895	-	-	-	-	-	-	-	P	-	-	-
1894	-	-	-	-	-	-	-	-	-	-	P
1893	-	-	-	-	-	-	-	-	P	P	-
51) F1892	X	-	X	X	X	X	-	-	-	-	-
106) F1841	-	-	-	-	-	-	X	-	-	-	-
1735											
F1718	-	X	-	-	-	-	-	-	-	-	-

Frequency = 88 years

Stand 12 ABLA/CLUN h.t., XETE phase

Sample number:	S86	S87	S88	S89	S90	S91	S92	S93	S94	S95	S96	S97	R	R	R	R	R
Species:	F	F	F	D	D	D	D	L	L	L	L	D	D	D	L	L	L
Year																	
F1924	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1910																	
18) 1899	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	P
1897	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-
1895	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-
1894	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-
157) F1892	-	-	-	X	X	X	X	X	X	X	X	X	-	-	-	-	-
1735																	

Frequency = 175 years

Stand J ABLA/LIBO h.t., VASC phase

Sample number:	15	16	17	18	R	R	R	R	R
Species:	LP	LP	L	L	L	L	LP	LP	L
Year									
F1915	X	X	-	-	-	-	-	-	-
1910									
20) 1896	P	-	-	-	-	-	-	-	-
1894	-	P	-	-	-	P	-	-	-
1893	-	-	-	-	-	-	-	P	-
1892	-	-	-	-	P	-	P	-	-
1891	-	-	-	-	-	-	-	-	P
155) F1890	-	-	X	X	-	-	-	-	-
1735									

Frequency = 175 years

Appendix B (cont.)

Lower subalpine slopes

Stand K ABLA/XETE h.t.

Sample number:	6	7	8	9	R	R	R	R	R	R	R
Species:	L	LP	LP	LP	LP	LP	LP	LP	LP	F	F
Year											
F1917	X	-	X	X	-	-	-	-	-	-	-
1910											
2) F1908	-	X	-	-	-	-	-	-	-	-	-
47) 1868	-	-	-	-	-	-	-	-	-	P	-
1867	-	-	-	-	-	-	-	-	P	-	P
1865	-	-	P	-	-	-	-	P	-	-	-
1864	-	-	-	P	-	P	-	-	-	-	-
1863	-	P	-	-	P	-	P	-	-	-	-
R1861	-	-	-	-	-	-	-	-	-	-	-
126) 1735											

Frequency = 88 years

Stand L1 ABLA/CLUN h.t., XETE phase

Sample number:	20	21	22	R	R	R	R	R	R	R	R	R	R
Species:	LP	LP	L	L	L	D	L	L	L	LP	LP	LP	LP
Year													
1943	-	-	-	P	-	-	-	-	-	-	-	-	-
1942	-	-	-	-	P	P	P	-	-	-	-	-	-
F1940	-	-	X	-	-	-	-	-	-	-	-	-	-
F1913	X	X	-	-	-	-	-	-	-	-	-	-	-
1910													
78) 1836	-	-	-	-	-	-	-	P	-	-	-	-	-
1835	-	-	-	-	-	-	-	-	P	-	-	P	P
1834	-	-	-	-	-	-	-	-	-	P	P	-	-
R1832	-	-	-	-	-	-	-	-	-	-	-	-	-
97) 1735													

Frequency = 175 years

Stand L2 ABLA/CLUN h.t., XETE phase

Sample number:	S16	S17	S18	S19	S20	S21	S22	S23	R	R	R	R	R
Species:	F	S	D	F	S	S	D	F	LP	LP	LP	LP	LP
Year													
F1919	X	X	X	X	X	X	X	X	-	-	-	-	-
1910													
43) 1870	-	-	-	-	-	-	-	-	-	P	-	-	-
1869	-	-	-	-	P	-	-	-	-	-	P	-	P
1868	-	-	P	-	-	P	-	-	P	-	-	P	-
R1867	-	-	-	-	-	-	-	-	-	-	-	-	-
132) 1735													

Frequency = 175 years

Appendix B (cont.)

Upper subalpine slopes

Stand M1 ABLA/XETE h.t.

Sample number:	1	2	3	4	5	R	R	R	R	R	R
Species:	LP	LP	LP	LP	LP	LP	LP	LP	LP	F	F
Year											
F1917	-	X	X	X	X	-	-	-	-	-	-
1910											
2⟩ F1908	X	-	-	-	-	-	-	-	-	-	-
47⟩ 1867	-	-	-	-	-	-	-	-	-	P	-
1866	-	-	-	-	-	-	-	-	-	-	P
1865	-	-	-	-	-	-	-	P	-	-	-
1864	-	-	-	-	-	-	-	-	P	-	-
1863	-	-	-	-	-	P	P	-	-	-	-
126⟩ F1861	X	-	X	-	-	-	-	-	-	-	-
1735											

Frequency = 88 years

Stand M2 ABLA/XETE h.t.

Sample number:	25	26	R	R	R	R	R	R	R
Species:	WB	LP	LP	LP	LP	LP	LP	F	F
Year									
1934	-	-	-	-	-	-	-	-	P
1932	-	-	-	-	-	P	-	P	-
1931	-	-	-	-	P	-	P	-	-
1930	-	-	P	P	-	-	-	-	-
F1929	X	X	-	-	-	-	-	-	-
1910									
175⟩ 1735									

Frequency ⟩175 years

Stand M3 ABLA/XETE h.t.

Sample number:	24	R	R
Species:	WB	WB	WB
Year			
1910			
49⟩ 1867	-	P	-
1863	-	-	P
126⟩ F1861	X	-	-
1735			

Frequency = 175 years

Appendix C

Table 2. The fire chronologies of the individual samples arranged by stands showing the ring-count adjustments made to determine the fire years. Table 2a is for Coram Experimental Forest and table 2b is for the extended study area around Hungry Horse Reservoir.

Legend

3/6	$\frac{\text{Number of trees scarred that year}}{\text{Number of fire-susceptible trees*}}$ *a tree is considered fire-susceptible on the date of the first scar and thereafter.
(∿1962∿)	Cambium date, i.e., date of logging or sampling
X	Clear rings (easy to count)
●	Rings slightly obscure (date approximated)
o	Rings difficult to interpret
X↕ ●↓ o↓	Date adjusted, in direction of arrow, to correlate chronology
P	Pith
1-29	Sample tree numbers
S1-S101	Sample stump numbers
L,LP,D, F,WB,S	Conifer species (respectively: western larch, lodgepole pine, Douglas-fir, subalpine fir, whitebark pine, and spruce)

Table 2a

MONTANE SLOPES

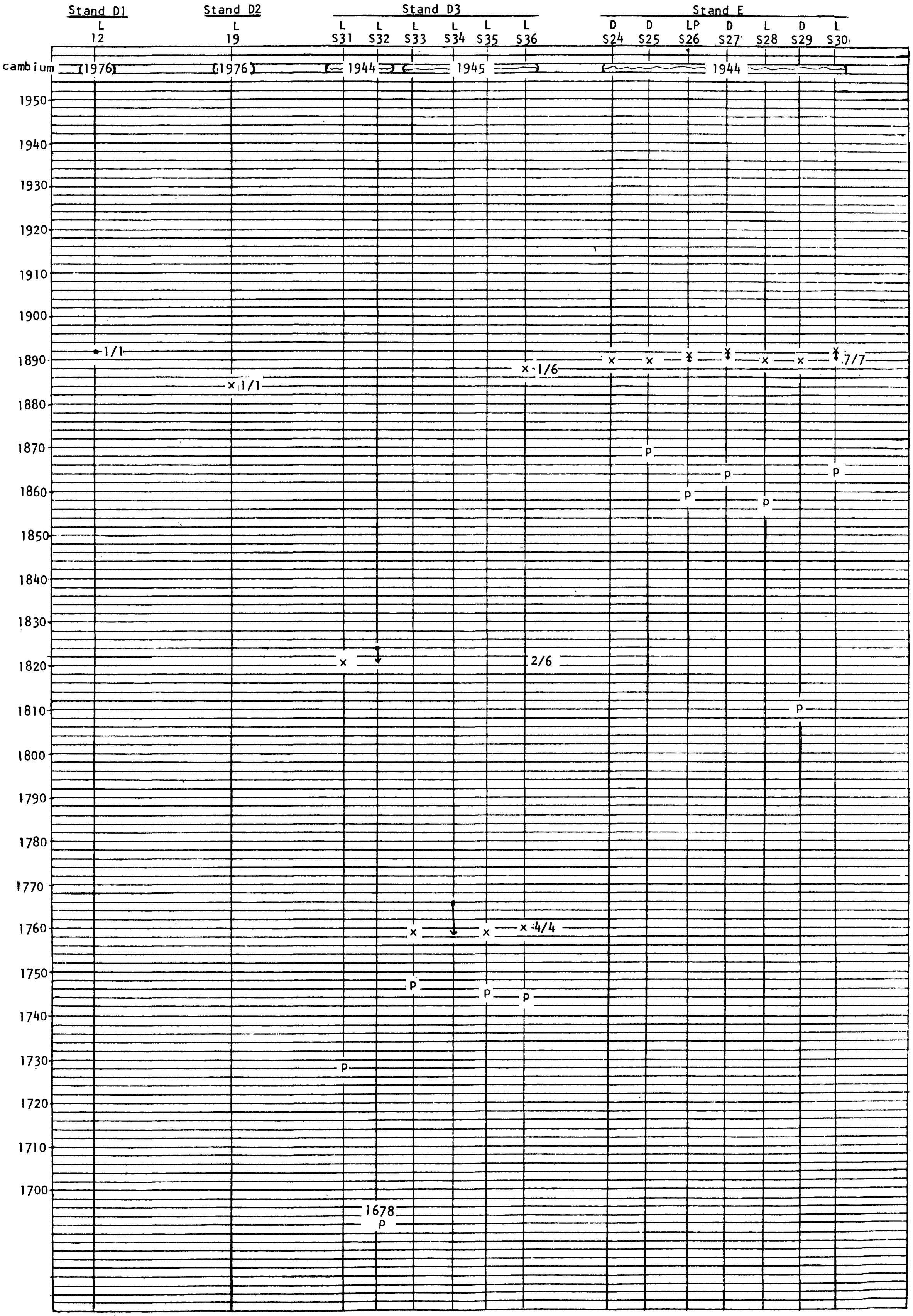


Table 2a

MONTANE SLOPES

Stand F

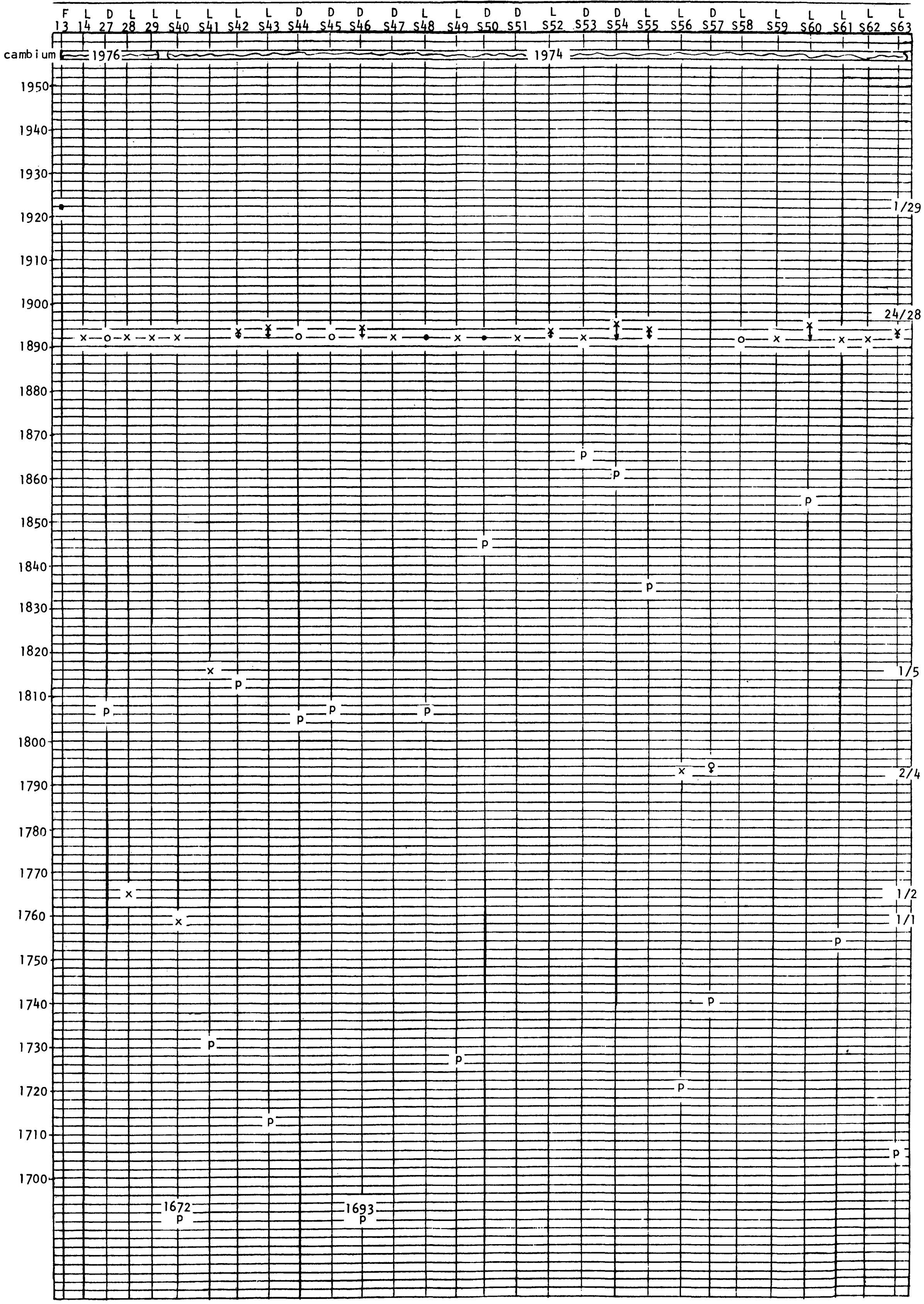


Table 2a

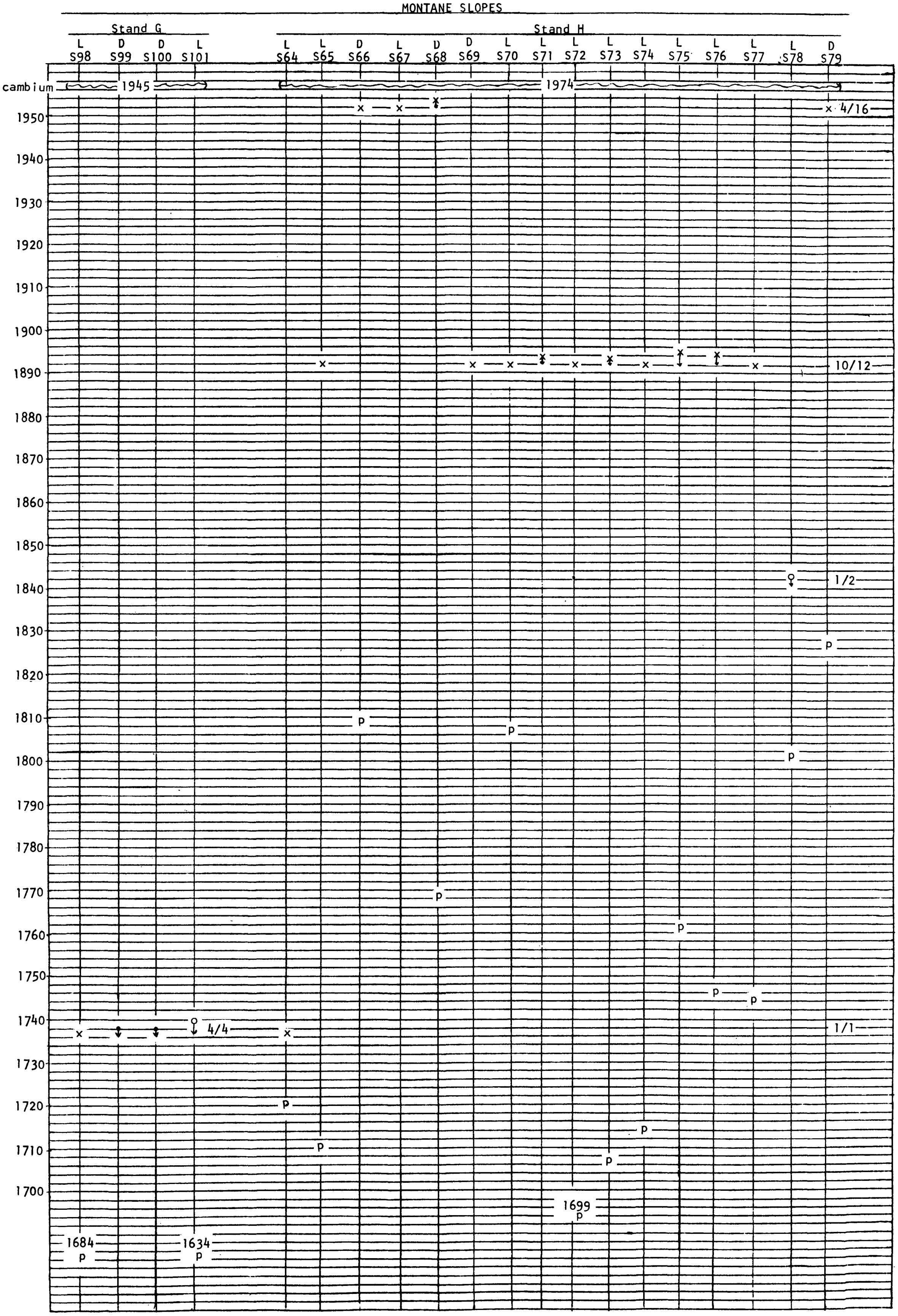

MONTANE SLOPES
Stand G
Stand H
L D D L
S98 S99 S100 S101
L L D L D D L L L L L L L L L D
S64 S65 S66 S67 S68 S69 S70 S71 S72 S73 S74 S75 S76 S77 S78 S79
cambium
1945
1974
1950
1940
1930
1920
1910
1900
1890
1880
1870
1860
1850
1840
1830
1820
1810
1800
1790
1780
1770
1760
1750
1740
1730
1720
1710
1700
4/16
10/12
1/2
1/1
4/4
p
1699
1684
1634

Table 2a

MONTANE SLOPES

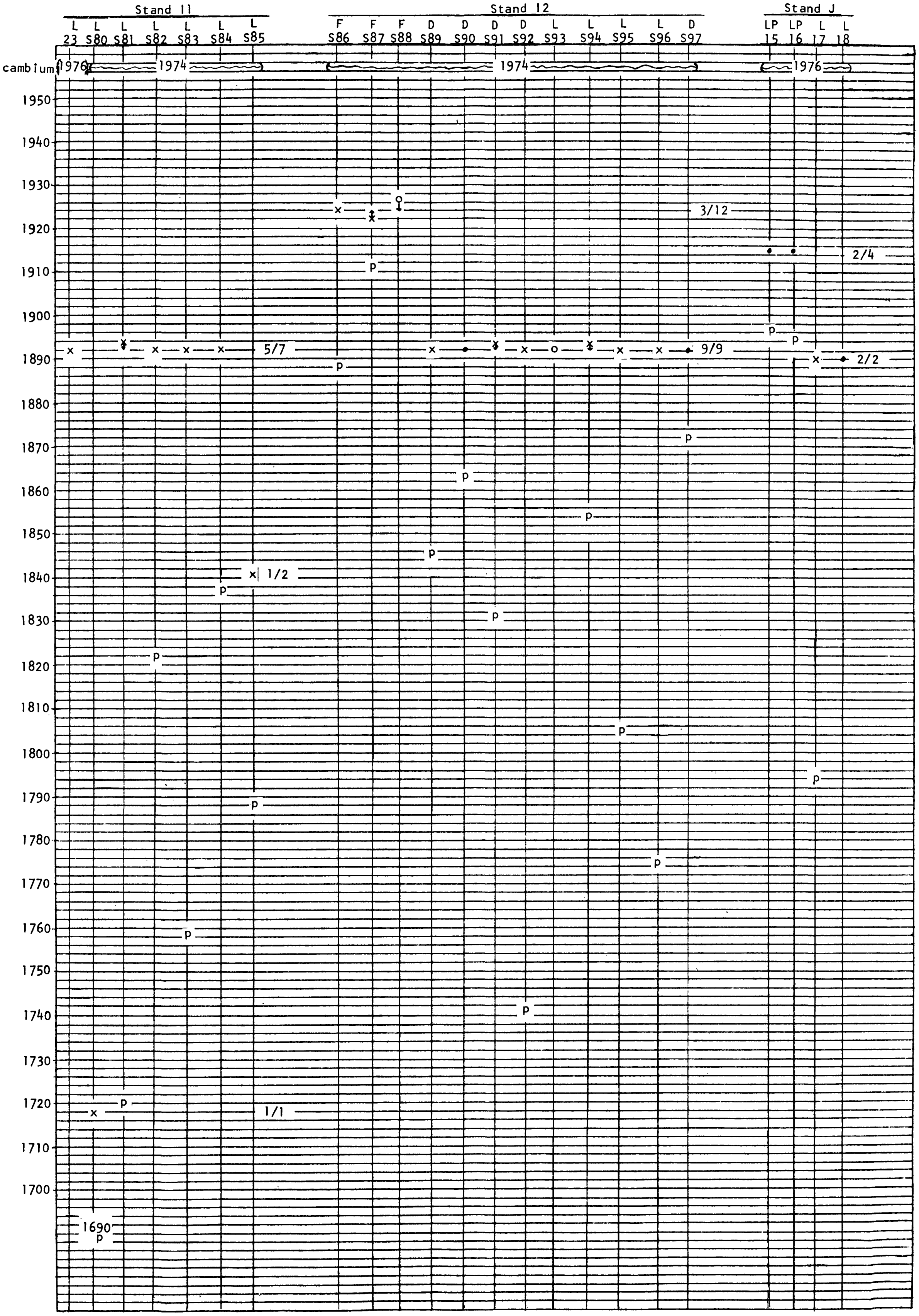
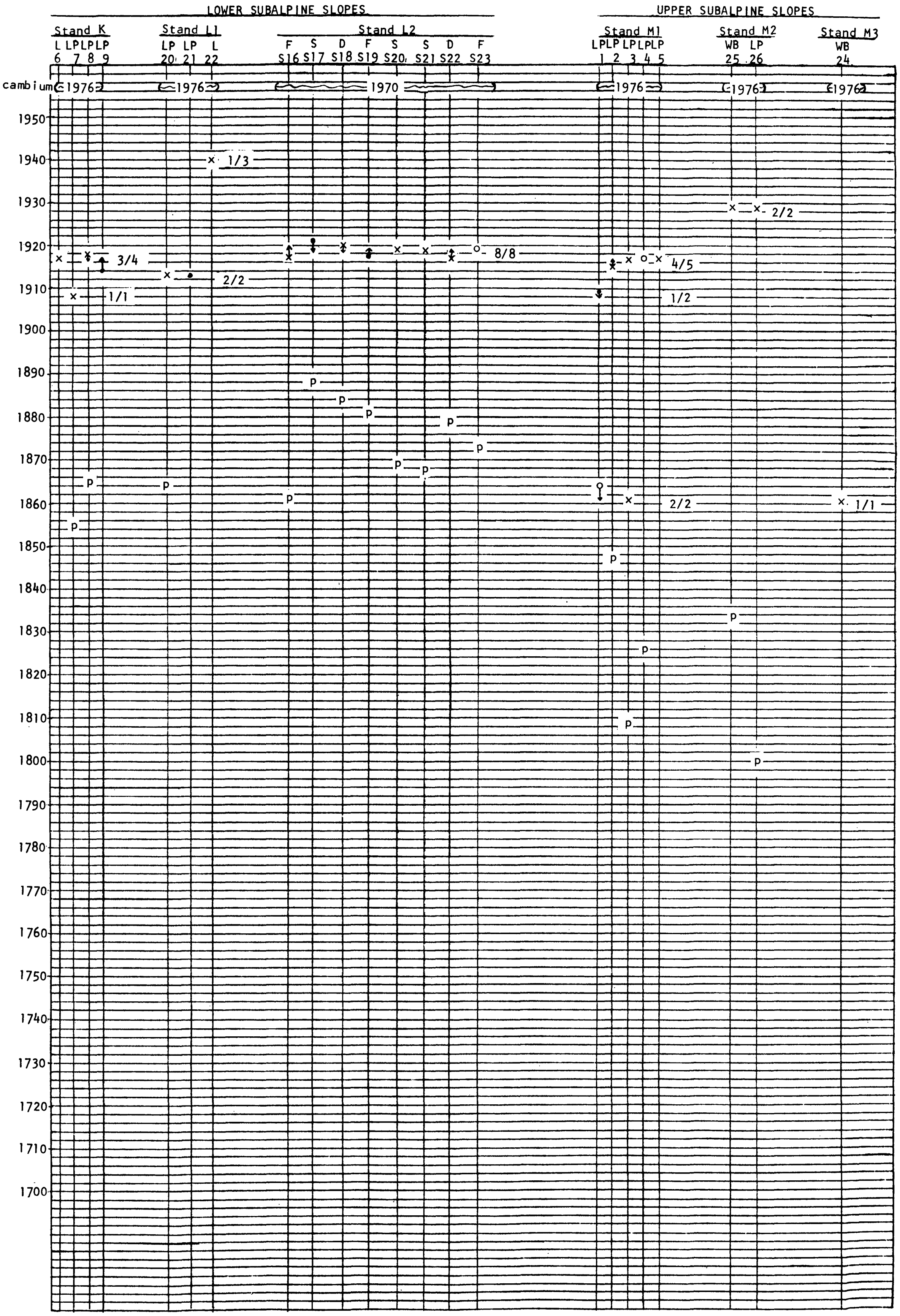
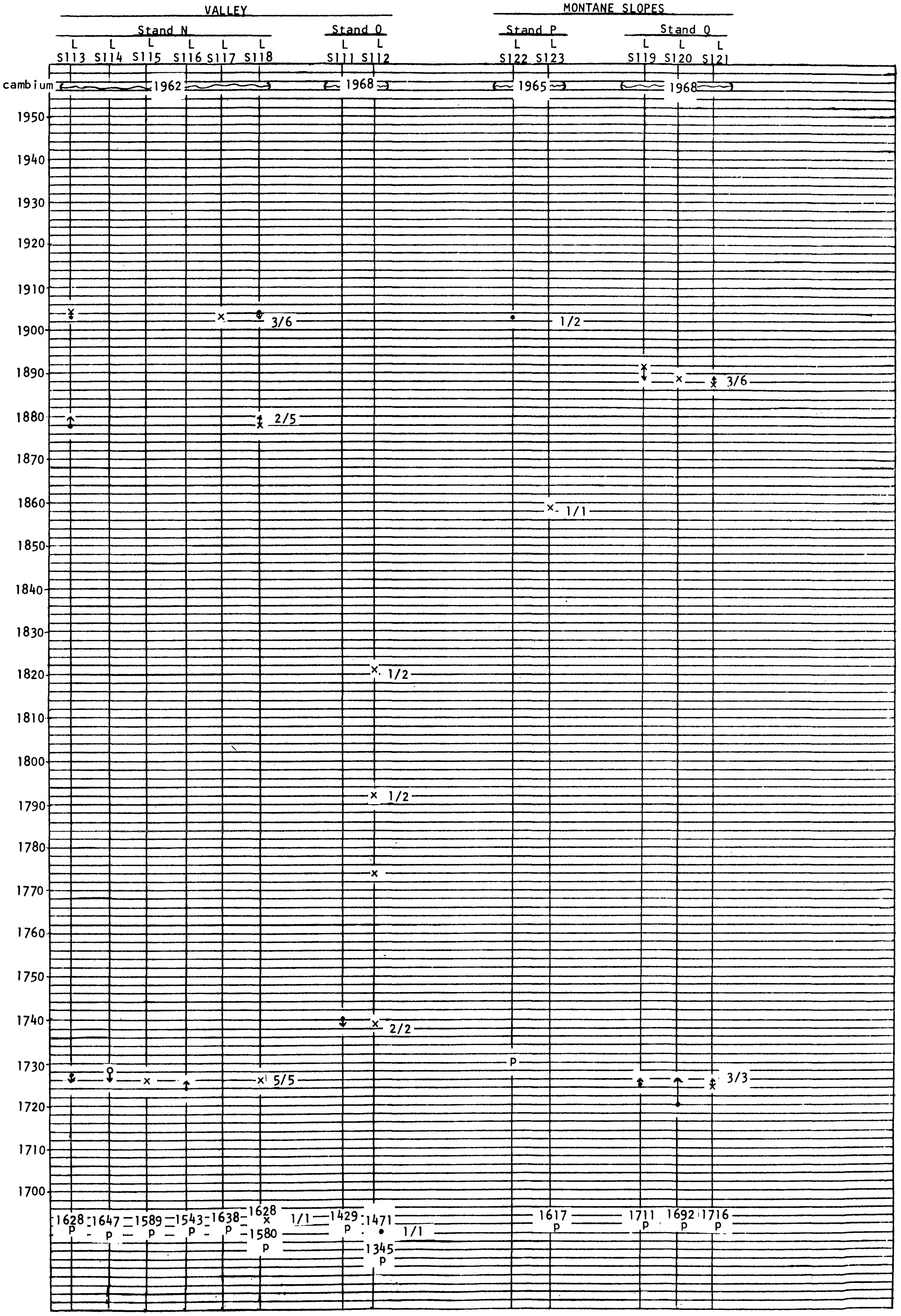


Table 2a


LOWER SUBALPINE SLOPES
UPPER SUBALPINE SLOPES
Stand K
L LPLPLP
6 7 8 9
Stand L1
LP LP L
20 21 22
Stand L2
F S D F S S D F
S16 S17 S18 S19 S20 S21 S22 S23
Stand M1
LPLP LPLPLP
1 2 3 4 5
Stand M2
WB LP
25 26
Stand M3
WB
24
cambium
1976
1976
1970
1976
1976
1976
1950
1940
1930
1920
1910
1900
1890
1880
1870
1860
1850
1840
1830
1820
1810
1800
1790
1780
1770
1760
1750
1740
1730
1720
1710
1700
1/3
2/2
3/4
8/8
4/5
2/2
1/1
1/2
2/2
1/1
p

Appendix C (cont.)

Table 2b



Appendix C (cont.)

Table 2b