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Hayle Buchanan, Weber State College

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FIRE HISTORY OF THE FORESTS

OF

BRYCE CANYON NATIONAL PARK, UTAH

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THE PRE-HISTORIC FIRE REGIME OF THE FORESTS OF BRYCE CANYON NATIONAL PARK, UTAH

Hayle Buchanan and Joseph Mark Tolman

The National Park Service was created by Congress in 1916 and charged with the task of conserving the natural biotic communities within a system of national parks in such a manner that they would be left unimpaired for the recreational use of future generations. The national parks were intended to represent remnants of primitive North America, areas where activities of modern civilization are minimized or absent.

National Park Service policies regarding land management objectives have changed considerably during the past 67 years. As each national park was created by a separate act of Congress the area was simply left alone with some degree of protection from hunting, logging and grazing by domestic livestock. (The biota of many of the forested areas included in national parks had been disturbed and degraded by exploitative activities prior to their inclusion in the national park system.) The viewpoint that such modified forests would revert to natural or pristine forests by simply being left alone is unrealistic and ecologically unsound.

Although the National Park Service proclaimed that forested areas should not be "managed", a policy of rigid fire protection was adopted, which indeed did involve considerable disturbance to forest ecosystems. Fire had negative connotations prior to the 1960's and nearly everyone was convinced that fire should be excluded from national parks as well as from national forests. After many decades of such protection from fire certain changes became evident in the forests of many national parks. In 1963, Dr. Starker Leopold and others on an

advisory committee to Stewart Udall, Secretary of the Interior, suggested that natural fires and even prescribed burning might be the most natural way to restore primitive-like conditions in our national parks. The National Park Service adopted the Leopold Report of 1963 as policy in 1968, as quoted:

"As a primary goal, we would recommend that the biotic associations within each park be maintained, or where necessary, recreated as nearly as possible in the condition that prevailed when the area was first visited by the white man. A national park should represent a vignette of primitive America." (Leopold et. al. 1963, p. 3)

The report called for the reversal of the old policy of rigid fire protection:

"The presence or absence of natural fire within a given habitat is recognized as one of the ecological factors contributing to the perpetuation of plants and animals native to that habitat. 'Natural fires'....are recognized as natural phenomena and may be allowed to run their course when burning can be contained within pre-determined fire management units and when such burning will contribute to the accomplishment of approved vegetation and/or wildlife management activities. Prescribed burning to achieve approved vegetation and/or wildlife management objectives may be employed as a substitute for natural fire." (in Kilgore 1976, p. 46)

Bryce Canyon National Park was created by an act of Congress in 1928. The forest communities of the park had been grazed by domestic livestock for over 50 years. Logging, hunting, predator control, water diversion and introduction of exotic plants and animals had also occurred in these forests. Visitors to Bryce Canyon National Park during the period from 1928 - 1968 were generally convinced, along with officials of the National Park Service, that general protection from grazing, logging, fires, and insect epidemics was beneficial to the forest communities. Forests of the national park were considered "natural", especially when compared to areas that were being managed under multiple use policies.

Unlike most national parks, however, Bryce Canyon National Park was carefully inventoried for forest cover in 1957 - 1959, approximately 30 years after the area became a National Park (Buchanan, 1960). That study provided a qualitative and quantitative report on the nature, extent and condition of the plant communities of the Park, together with an appraisal of the environmental factors that affected them. The sample plots used to secure the data were permanently marked so that they could be reinventoried at a later time to quantify changes in plant cover. The plots were re-inventoried in 1978 - 80, 21 years after the first inventory. Very striking changes occurred in the forests during this period, and it is assumed that these changes followed trends that began first with over-grazing during the period 1873 - 1928 and fire protection during the period from 1916 to the present time. (During the 21 year period all forest types extended their boundaries into adjacent unforested areas,) but more impressive is the increase in density and volume of tree growth. Over-all density of trees had increased 84%. Many of the saplings (young trees 10 cm dbh) of 1957 - 59 had reached tree-size but they had been replaced by so many recruitments from the ranks of seedlings (young trees 30.5 cm ht.) that the number of saplings had increased by 322%. Meanwhile, the number of seedlings had decreased by 79%, due to diminishment of ecological space and increase of forest density. During the 21 years tree volume increased by 82%. Thickening of the tree stand triggered changes on the forest floor. Absolute cover of non-tree vascular species declined from 27 to 19% in the 21 year period, a reduction of 30% in relative terms. Shrub cover declined 38%, grasses and grass-like herbs declined 25% and forbs declined 14%. The numbers of understory vascular species of all three groups declined by 14%. (Buchanan and Harper. 1981)

In order to apply a policy of natural fire management to replace total fire suppression, the development of a fire management plan is necessary. The purpose

of the fire history study of 1983, is to give insight to the National Park Service as a fire management plan is developed. The record of fires in pre-historic times in the forests of Bryce Canyon National Park will help in the development of an ongoing education program of park visitors. They must be convinced that a natural fire or a prescribed burn can become acceptable and beneficial to the forests.

Objectives of the fire history study of the forests of Bryce Canyon National Park are as follows:

1. To determine the types of fires that occurred prior to 1873.
2. To appraise the effects of European settlers from 1873 to 1928 and their grazing animals on the original fire regime.
3. To appraise the changes in the primeval forest as a result of the rigid fire suppression policy of the U.S. Forest Service from 1916 to 1928 and of the National Park Service from 1928 to the present.
4. To determine the changes in forest composition which may significantly alter fire behavior and effect when fire is allowed to burn again.

STUDY AREA

The Paunsaugunt Plateau is one of several high elevation tablelands of the Colorado Plateau physiographic province of southern Utah (Hunt, 1956). The Paunsaugunt occupies a position midway between 37 and 38 degrees north latitude and lies 16 km (10 miles) west of the 112th meridian. It is a block of sedimentary rock elevated by two fault systems and tilted in both the northerly and the westerly directions. Bryce Canyon National Park includes a narrow strip of "breaks" and tableland comprising 14,267 hectares (56.06 square miles) along the southeastern edge of the Paunsaugunt Plateau (Fig. 1). Elevations within the park on top of the plateau vary from 2383 to 2776 m (7,850 to 9,105 ft). The park boundaries below the scenic rock outcrops extend downward to 2,027 m (6,650 ft.) elevation. The forest communities in this study occupy the top of the plateau, except for two drainages below the canyon rim at Swamp Canyon and Sheep Creek. ^{Ridge Spgs → Swamp Bryce Pt →} The highest ^{Swamp Canyon} elevation of the Park is attained at the southeastern extremity of the north-south axis of the plateau. The gradual dip of more than 381 m (1,250 ft.) toward the north in the 32 km (20 mile) strip of forest land upon the plateau within the Park combines with a slope to the west to insure that runoff water from the plateau moves northwest and into the East Fork of the Sevier River. The eastern edge of the Paunsaugunt Plateau forms the drainage divide between the Great Basin to the west and the Colorado River to the east. ^{N. end of park?}

A distinctive feature of Bryce Canyon National Park is the system of short canyons along the rim of the Paunsaugunt Plateau which expose the Pink Cliffs of the Wasatch or Claron Formation of the Eocene strata. These rim canyons are outstanding examples of local erosion by rain and melting snow. Such erosional processes are enhanced by changing temperatures and the rather soft limestone substrate.

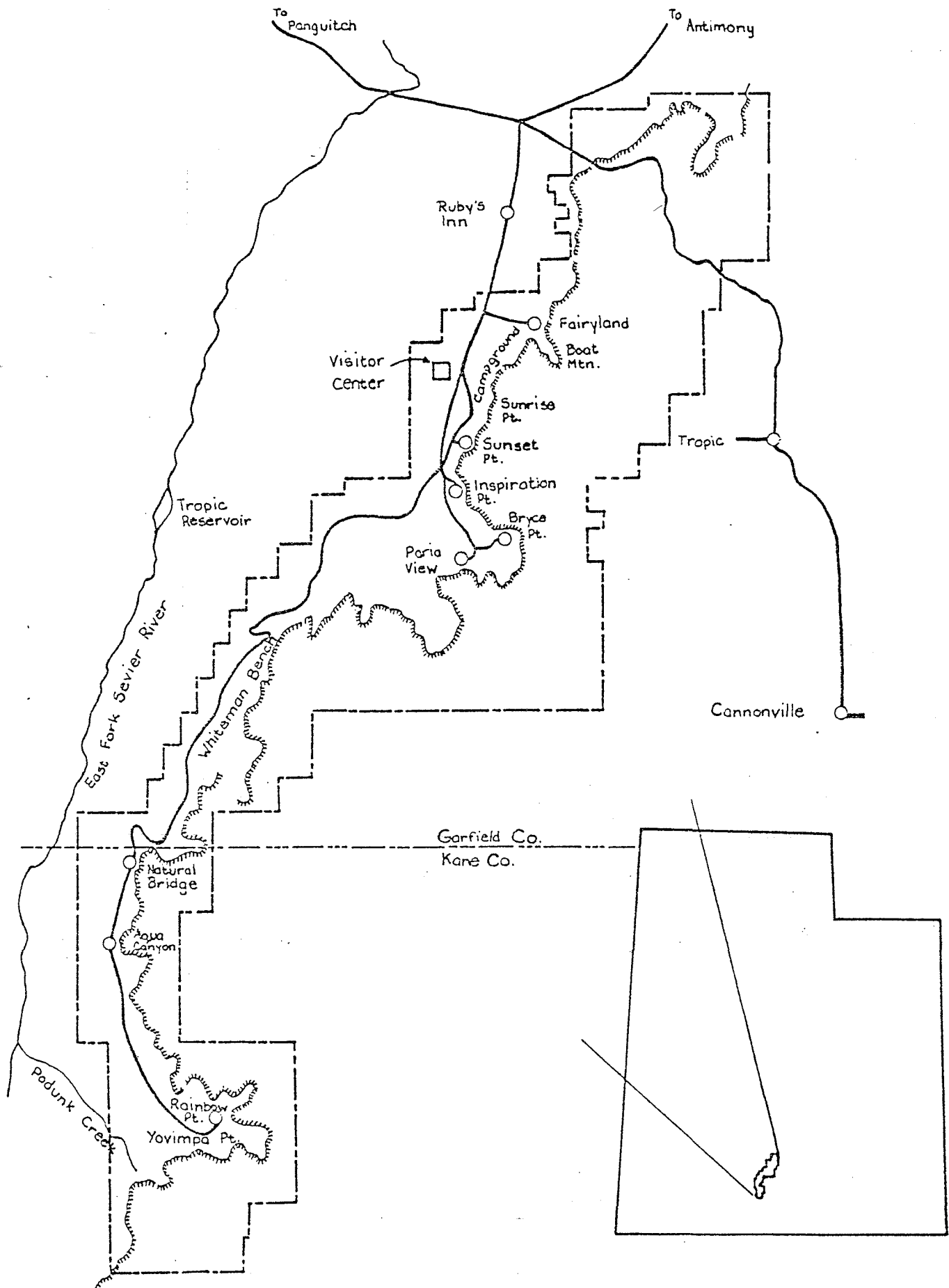


Fig. 1 Location of the study area, Bryce Canyon National Park, Utah

SOIL

Soils on the high relatively flat top of the Paunsaugunt Plateau are residual. Thinness of topsoils and rapid erosion rates are characteristic of the forests that occupy this part of the Park. In the valleys the soil is built up by alluvial deposits.

The ponderosa pine forest in the northern 1/3 of the Park has soils of the Brycan-Paunsaugunt series on 1-15 percent slopes which are upland stony to gravelly loam; Rachert-Paunsaugunt Series, which are well-drained soils from limestone bedrock on mountain slopes and ridges that have a high erosion hazard; Pahreah gravelly loam soils that are moderately deep and excessively drained on mountain slopes and ridges; and very gravelly loam soils of the Losee series that are excessively drained on ridges and mountain slopes.

Ponderosa pine forests are also prevalent in the Swamp Canyon and Sheep Creek areas below the canyon rim on cobbly-alluvial soils and on Pahreah Gravelly Loam soils. Deposition of materials is so rapid that trunks of living Ponderosa pine trees have been buried up to 1.5 meters (5 ft.) within the 300 + years of the lifetime of the trees.

The Whiteman Bench and higher elevation forests on the Paunsaugunt Plateau are mixed conifers, occurring on soils of the Whiteman Series, Opert Series, Swapp Series, Hatch Series, Losee Series, and Pahreah Series. The Whitemen Series soils are excessively drained on mesa tops and are very cobbly clay loam soils underlain by bedrock at depths of 25-50 cm (10-20 in.). The remaining soil series listed are generally well-to excessively-drained, thin to moderately deep cobbly to heavy clay loam soils with moderate to high erosion hazards on mountain slopes and ridges.

Soil series names are from a soil survey of Bryce Canyon National Park by Stott et. al. (1968) of the Soil Conservation Service. ★

VEGETATION

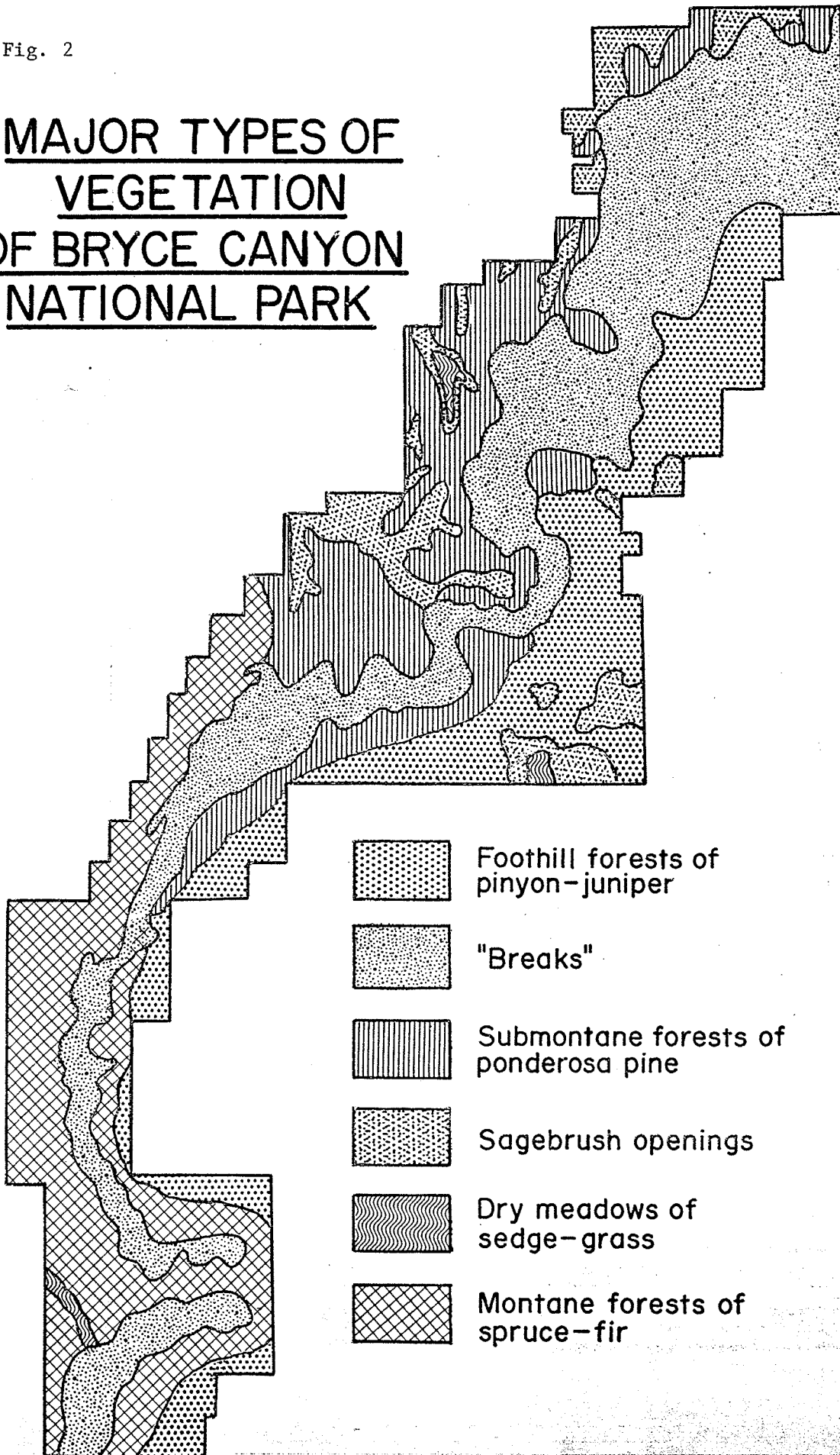
The forests of Bryce Canyon National Park on top of the Paunsaugunt Plateau are thoroughly described by Buchanan (1960). Fig. 2 is a vegetational map of the major types of vegetation of Bryce Canyon National Park. The foothill forests of pinyon-juniper are not involved in the fire history study and neither are the sagebrush openings and dry meadows of sedge grass. The scenic pink cliffs or "breaks" are sparsely vegetated and form a sharp division between the forests on top of the Plateau and those in the Colorado River drainage at low elevations. Buchanan and Harper (1981) recognized six forest types on the Plateau on the basis of tree composition: (1) ponderosa pine-Rocky Mountain juniper; (2) ponderosa pine-Douglas fir; (3) mixed conifer with limber pine; (4) ponderosa pine-white fir dominant mixed-conifer forest; (5) Douglas fir-white fir dominant mixed-conifer forest; and (6) white fir dominant forest. Generally the forest types are arranged along an elevational gradient from 2,377 to 2,743 m. Lower elevations are dominated by ponderosa pine forests, while Douglas fir becomes the second most common tree on other low elevation sites. Ponderosa pine also dominated south-facing slopes at higher elevations. Limber pine, Douglas fir and especially white fir perform best above 2,600 m.

CLIMATE

Climatic observations have been recorded since 1916 in the ponderosa pine zone at the northern end of Bryce Canyon National Park. The weather station is currently located near Park headquarters at an elevation of 2,412 m (7,915 ft.). Average annual precipitation for the period 1916-75 was 40 cm (15.9 in.). Mean annual temperature was 5.0° C (41.0° F) with an average of -5.0° C (21.° F) for January and 17.0° C (62.9° F) for July for the same time period. Consecutive frost-free days averaged 60 at Park headquarters. Precipitation was fairly equally distributed throughout the year with 25% in the January-March period, 22% in the

Fig. 2

MAJOR TYPES OF
VEGETATION
OF BRYCE CANYON
NATIONAL PARK



April-June interval, 33% in the July-September season and 20% in the October-December period (Eubank and Brough 1979).

Three snow courses have been maintained in the Park since about 1970. The courses are located near Park headquarters, Farview Point and at Rainbow Point. The results show that April 1st snowpacks hold an equivalent of about 11.0 cm. (4.3 in.) of water at Park headquarters and about 22 cm. (8.7 in.) at the other two locations, as reported by Whaley and Lytton (1979). Since moisture recharge of the soil body is primarily dependent on melting snowpacks in our area, the higher elevation portions of the Park can be expected to support considerably more mesic vegetation than do lower elevation sites.

Assuming that the relationship between elevation and precipitation is similar to that observed elsewhere in the state, annual precipitation at Rainbow Point probably averages somewhere between 49.5 and 55.4 cm (19.5 - 21.8 in.). This estimate is based on studies by Lull and Ellison (1950) and Harper, et. al. (1981) in Ephraim Canyon and in the Uinta Mountains respectively.

HISTORY

The scenic geological formations that are presently included in Bryce Canyon National Park were discovered in 1866 by Mormon pioneers. Government surveys by scientists described the formations and the luxuriant vegetation adjacent to the scenic cliffs, beginning with Powell in 1870, Thompson in 1871, Gilbert in 1872, and Bailey in 1876 as reviewed by Gregory (1951). The first use of the resources of the land within what is now Bryce Canyon National Park was by the Kanarra Cattle Company beginning in 1873. Cattle owned by this company were brought onto the East Fork of the Sevier River for summer grazing. Sheep were brought onto the plateau in 1877 to graze on the abundant forage produced there. During the winter months, sheep were grazed on Sheep Flat, which is east of the plateau, but within

the boundaries of present Bryce Canyon National Park.

The first settler near the present Park was Ebenezer Bryce, who established a cattle and sheep ranch near the present location of the town of Tropic in the fall of 1875. When the Park was created over a half century later, it was named in his honor. Ebenezer Bryce was soon followed by other settlers who established several small communities in the upper Paria valley. Their herds of sheep and cattle were grazed in Bryce Canyon and over the whole Paunsaugunt Plateau. The grazing pressure on these areas probably increased in intensity from 1875 to 1905 when the U.S. Forest Service was created and the area became part of the Sevier National Forest. Regulation of grazing by the U.S. Forest Service in the first part of the 20th century probably did not check the deterioration of the range forage resource or soil erosion that had begun during the 30 years prior to the inception of Park Service control.

Lumbering in the area now occupied by the Park dates back to the time of the first homesteaders in 1875. Sawmills in Water Canyon, Dave's Hollow and near Ruby's Inn utilized the larger ponderosa pine trees for lumber during the period 1890-1907. The lumber was used for buildings in nearby settlements and for shipment to Salt Lake City.

Recreational visitors to Bryce Canyon were few prior to 1915 owing to the inaccessibility of the area and to the lack of publicity concerning the superlative scenery. By 1918, an annual excursion of visitors to Bryce Canyon had begun in response to written accounts and photographs that appeared throughout the state and nation in newspapers and magazines. Recommendations that began in 1919 for creation of a national park resulted in creation of a small National Monument in 1923, and finally culminated in the establishment of Bryce Canyon National Park in 1928. The present Park boundaries were established in 1930.

It was several years after Bryce Canyon National Park was created before

Park Service policies regarding grazing resulted in any significant reduction of grazing pressure within the new National Park. The policy of the Park Service was to hold grazing of domestic livestock to a minimum and to eventually eliminate it from the national parks. A fencing project was begun in 1934 to eliminate grazing from the headquarters area of the Park: the fence was completed in 1937. The fence was not extended southward to enclose the whole Paunsaugunt forest until the 1960's. Even after completion of that fence, grazing trespass in summer through fences broken by heavy winter snow packs was of frequent occurrence.

REVIEW OF LITERATURE

A thorough review of the literature concerning the role of fire in ecosystems was made by West and Madany (1981). Some of that literature is pertinent to the pre-historic fire regime of the forests of Bryce Canyon National Park. Following is a summary of reports:

Wildfires, both lightning and man-ignited, have a pervasive influence on nearly all of the world's ecosystems which have enough fuel to carry the flames. It is estimated that 50,000 wildland fires are caused each year. (Taylor, 1974) Different wildfires have had very different effects, depending on the intensity, frequency, and seasonality of the conflagration. Each geographic region has its own peculiar fire regime. Species in communities within a region have evolved adaptations to survive these cyclic burnings. The intricate interplay between recurring fires and different successional stages helps produce a mosaic of communities along with edaphic factors and microclimatic factors. Mutch (1970) suggested that certain dominant species such as ponderosa pine evolve in a manner that makes the communities they control intrinsically more flammable.

Heinselman (1978) has postulated six basic fire regimes for North American ecosystems:

1. Infrequent (25+ year intervals) light surface fires.
2. Frequent (1-25 year intervals) light surface fires.
3. Infrequent (25+ year intervals) severe surface fires.
4. Short return interval (25-100 years) crown fires.
5. Long return interval (100-300 years) crown fires.
6. Very long return interval (300+ years) crown fires.

Crown fires destroy the forest stand and initiate succession with a new generation of trees, whereas surface fires alter only the lower strata of vegetation, leaving canopy and some of the groundlayer of forest species alive. The overall community composition undergoes less drastic changes from surface fires than following crown fires. Ecosystems are characterized by a particular fire regime, as they are also related to a certain set of climatic circumstances.

Fire may increase the availability of nutrients. Seedlings may get established in recently burned areas better than in the litter and debris in pre-burn situations. As different plants respond differently to surface fires some may be favored in competition for space, nutrients, and water. Fires may destroy fungi and other pathogens of plant hosts or may kill weakened hosts.

Thick-barked trees such as ponderosa pine can easily withstand surface fires. Trees that develop thick bark later, such as white fir and juniper are more likely to be killed by surface fires. Many shrubs produce seeds that lie dormant in the soil until it is heated by a fire or sprout readily from a root system if the fire burns the aerial part of the plant. Most perennial grasses and other herbaceous perennials have perennating buds below the soil surface and can sprout during the season following a surface fire. Soil is an excellent insulator against the high temperatures.

When fire is excluded from an ecosystem that developed along with recurring fire the effects can be drastic: species composition may change, density of a

forest may increase, nutrient cycling may be interrupted, or the physiognomy may change. (Franklin 1978)

A fire history of a forest can be obtained by a careful study of living trees that are fire-scarred. The frequency and extent of such fires can be determined by collecting samples of such trees and counting growth rings from the cambium back to the ring where fire interrupted the cambium. How many trees that were damaged by a certain fire and the age structure of both fire-tolerant and fire-sensitive tree species give clues as to the intensities of past fires.

In most fire history studies of western North America the last two centuries are sufficiently documented that comparisons of pre- and post-settlement conditions are valid. Recording trees steadily diminish so that conclusions as to fire frequency and extent become more and more tentative the further back the record is examined.

Arno and Sneek (1977) report that rings may be missing, or false rings present which may cause inaccuracies in dating fires by several years. If scar dates on adjacent trees are checked an average date of the fire may be chosen which is more accurate than that obtained from counting the growth rings of a single tree. Researchers agree that an individual tree fails to record all fires it survives in its lifetime with separate scars. A composite account from clusters of adjacent trees provides the most accurate record of pre-historic fire history, according to Kilgore and Taylor (1979).

Kilgore and Taylor (1979) have proposed terminology to be used in describing the occurrence of fire in an area. "Fire frequency" refers the intervals between fires in a very small area, such as a cluster of trees or a single tree. "Fire incidence" was the interval between fires which burned some part of a drainage-system or forest of a certain size, but not necessarily involving the same point. Incidence is size-related, whereas frequency reflects fuel, climate, and ignition

factors of the forest type.

Cooper (1961) has described the ponderosa pine forests of northern Arizona as they have changed in response to post-settlement grazing and alterations of fire regimes. He describes the groves of even-aged ponderosa pine trees which average .08 ha (.2 acre) in size. Seedlings become established in openings between the groves on unusually moist spring seasons. Frequent surface fires thin out the seedlings and combine with climatic factors to produce an overall uneven age structure of the forest (Cooper 1961). Dense sod of perennial grasses may restrict successful ponderosa pine establishment through competition for water and nutrients. The grasses may also produce chemicals to inhibit pine regeneration (Rietveld, 1975). The grasses furnished the fuel for flash fires to carry the surface fire over the forest floor of open ponderosa pine stands. The pristine condition of such forests was altered in the 1870's by the introduction of livestock and decrease in fires. The forest community was greatly changed by these two events. When wet weather conditions later allowed the massive establishment of seedlings a dense thicket of ponderosa pine was created (Arnold 1950). The lack of thinning fires along with decline in grass brought about by overgrazing made these changes possible. Fifty years later the growth of dense pine understory resulted in the death and disintegration of some of the even-aged groves of veteran ponderosa pine. Cooper (1960) surmised that competition for water by the vigorous dense understory had resulted in death of the older trees. Ironically, these trees had survived numerous surface fires and seemed to have succumbed to the lack of burning.

Fuel conditions became hazardous with fuel ladders created by the dense understory trees and saplings. Crown fires became possible in a forest that had probably never had them. No researchers have found evidence of stand-destroying wildfires in ponderosa pine forests prior to the 20th century. Pearson et. al. (1972) and others have described the disastrous effects of recent wildfires on the ponderosa pine forests of northern Arizona.

Ponderosa pine research in other areas show similar effects of overgrazing by livestock and cessation of burning. Stagnation of second-growth trees results from uninhibited regeneration as reviewed by Biswell (1973), Weaver (1974), and Wright (1978).

METHODS

(A basic vegetational survey of the Bryce Canyon forests was made in the 1950's by Buchanan (1960) and repeated 21 years later as reported by Buchanan and Harper (1981).) The present pre-historic fire study complements these earlier forest vegetation studies, either to verify or modify the conclusions contained therein. The primary objective of the present project was the determination of the fire chronology for the study area. A limited number of plots were set out and data collected to supplement the earlier more comprehensive vegetational surveys.

Because the field study was limited to one growing season, 1983, most of the time was devoted to the collection of sections of fire-scarred trees for developing a fire chronology. The trees chosen for sampling were located along or near 11 transects, which were plotted on a map prior to field study to represent either the several forest types on top of the Paunsaugunt Plateau or forests just below the "breaks" at two locations, Swamp Canyon and Sheep Creek. The field reconnaissance methods of Arno and Sneek (1977) were applied. Transects generally traversed broad slopes on several aspects from low to high elevations. Placing transects along narrow ridgetops or parallel to intermittent stream bottoms for great distances was avoided because these have vegetative and fire environments that may not be typical for the area.

Field reconnaissance involved two people who located and recorded all fire-scarred trees in a swath of forest along the transect route. One person sighted the compass direction of the transect and the other person walked parallel about

Bryce Canyon National Park

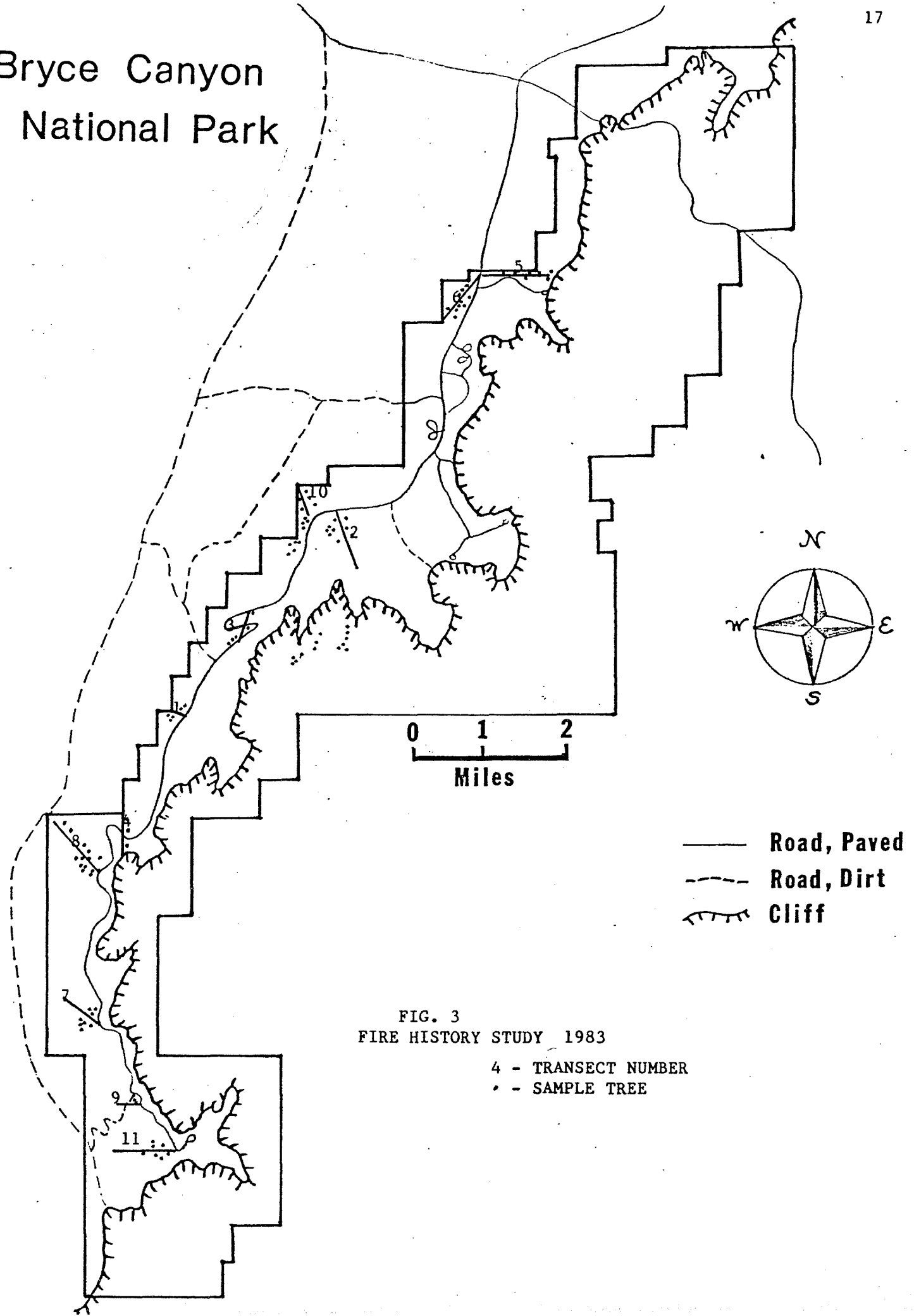


FIG. 3
FIRE HISTORY STUDY 1983

4 - TRANSECT NUMBER
• - SAMPLE TREE

45m (50 yards) to his left. The swath covered about 91m (100 yards) wide. Each person kept constant watch for the oldest "catfaced" trees. (Catface is a term for an open scar resulting from one or more fires.) Fire-scarred trees were given temporary numbers along the transect and marked with colored plastic tape so that they could be relocated.

A catface originated on a tree where a surface fire burned through the forest and local buildups of fuel caused a hot enough flame to scorch through the cambium and into the wood near the base of the tree. During subsequent years a healing callus formed generally triangular with the base at ground level. Given enough time the calluses from the two edges of the catface can grow over the catface surface and meet, resulting in a buried scar, which can still be recognized by a trained observer. A tree is more sensitive to future scarring following creation of the initial catface. Each individual fire scar has a separate fold or band of healing tissue, often appearing on both sides of the catface. Sometimes the folds or bands of healing tissue were burned away by later fires and are not evident externally, but may be located on a partial cross-section of the tree trunk through at least half of the catface. In the forests of Bryce Canyon National Park the majority of fire-scarred trees were ponderosa pine. White fir, Douglas fir, blue spruce, limberpine, bristlecone pine, and Rocky Mountain juniper occasionally had catfaces.

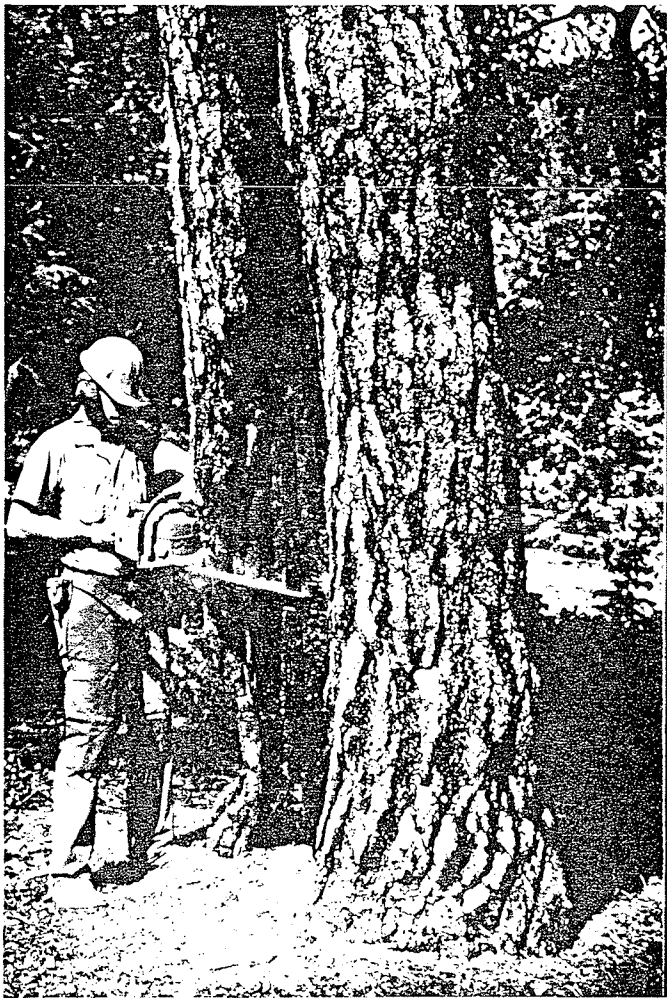
The following information was recorded for each tree on the "Log of Fire-Scarred Trees": transect number, habitat type, species, d.b.h., maximum height of catface, number of externally visible scars, elevation, aspect, remarks (such as descriptive location and recommendation for sampling).

Clusters of trees were chosen along the transect for collection of partial cross-sections. Two or three trees in close proximity were needed to correlate fire-scar chronologies. Trees with the greatest number of externally visible, individual fire scars had the highest priority for sampling.

If, on the way to sample the previously chosen sample fire-scarred trees, better scarred trees were found near the transect that had been previously overlooked, such trees were also used for partial cross-sectioning. The catface was photographed so that a tree number would be clearly visible in the photograph. The tree was assigned a permanent number, which was recorded on a "Log of Sampled Trees" along with the number of cross-sectional scars and photograph number.

A good partial cross-section includes the pith, fire-scars and cambium on one side of the catface. In most cases only 15-25% of the basal area of the tree was removed. A 24-inch bar chain saw was used to make parallel horizontal cuts 4 to 5 cm (1 1/2 to 2 inches) apart, extending from the pith to the cambium across the clearest portion of the scar sequence on the catface surface. The cut was made just deep enough to go behind the deepest penetration of each scar so that the ring count could be made in unscarred tissue. The tip of the saw was used to make a vertical cut towards the pith. The final tip cut was along the back of the parallel cuts from cambium to pith. At certain times the parts of the partial cross section separated, then perpendicular arrows were drawn across the broken parts to aid reassembly later in the laboratory. The sample tree number was written in pencil on all pieces of the sample and also within the tree where the partial cross-section was removed. Fig. 4 shows the method of obtaining a partial cross-section sample.

In many cases a cluster of two or three trees was included within the boundaries of a study plot 16 m x 16 m (50 x 50 ft.). The study plot method was a modification of the method used by West and Madany (1981). The plot was laid out so as to contain a homogenous portion of the forest in terms of slope, exposure, and vegetation type. The north-east corner of the plot was marked with steel rebar to which red plastic flagging was attached. The four sides of the plot were delineated with blue nylon cord. Physical features measured at the plot were; aspect and slope (both with



A



B



C

Fig. 4 Obtaining a partial cross-section of a fire-scarred tree.

- A Two parallel horizontal cuts are made from pith to cambium across the catface surface.
- B A vertical cut is made towards the pith of the tree.
- C The final vertical cut is made along the back of the parallel cuts from cambium to pith.

a Brunton compass); topographic position (whether the plot was on the lower 1/3 of the slope, the mid 1/3 of the slope, or the upper 1/3 of the slope); and the elevation. Soil depth was determined by taking ten measurements with a steel rod plunged into the soil at one meter intervals along the eastern boundary of each plot. Fire evidence at each plot was recorded by counting the number of charred logs or charred snags in each plot in addition to the fire-scarred trees. The number of fire-scarred trees visible from the plot was recorded. Fuel load was estimated for each plot using a scale of one (no fuel accumulation) to ten (maximum fuel accumulation). All trees within the plot were recorded by species and size class. Increment cores were taken from representative trees within the various size classes present in the plot. Understory cover was estimated for the whole plot in the following categories: saplings which were 10.5 cm ht. to 5 cm diameter at 1.5 m height (1 ft. ht. to 2" dbh), seedlings which were 10.5 cm ht. (less than 1 ft. ht.), shrubs, and herbaceous plants.

The partial cross-sections of fire-scarred trees were dried in a warm building. Sharp knives were used to trim a portion of the cross-section from the cambium to the pith to provide a smooth surface for dating with a variable power, long-arm dissecting microscope.

The date of each fire was determined by counting the annual growth rings, starting at the cambium and proceeding back in time to the inner ring in each healing curl. The number of years back to the most recent fire and between each previous fire was recorded. The pith year (or oldest ring in cases where the pith was not reached) was recorded. The rings were carefully counted by one person and then verified by another person to insure accuracy. The data for each partial cross-section was recorded on a separate data sheet, then compiled onto data sheets for the various transects.

The fire-scarred sample trees were located along transects drawn on a master

map of Bryce Canyon National Park. On this map and on a main fire chronology table for the park the date of each fire was compared with the location of the fire. Raw dates on the main fire chronology table were not assumed to be accurate due to the possibility of locally missing or false growth rings. In order to compensate for inherently inaccurate dates, correlations between dates of trees in the same general vicinity were attempted. In a few cases a consensus date could be chosen from two samples bearing dates a year apart and a realignment of one of the dates was done. In most cases no realignment of dates of fires was done.

Results

Catfaces were found on larger ponderosa pine trees in every part of the forests at higher elevation of Bryce Canyon National Park and in the forests immediately below the scenic cliffs in Swamp Canyon and in Sheep Creek. Fire scars were also found on Rocky Mountain juniper, Douglas fir, limber pine, blue spruce, and bristle-cone pine, but the fire records of ponderosa pine were most complete. Stumps of many other fire-scarred trees were found that were logged prior to the creation of the National Park, or that had been cut down since 1928 after being seriously damaged or killed by bark beetles. Numerous charred logs on the forest floor and standing burnt snags were left to attest to the occurrence of pre-historic fires in every part of the ponderosa and mixed conifer forests of Bryce Canyon National Park.

TABLE 1 is a fire chronology for Bryce Canyon National Park based on 93 fire scarred trees. The mixed-conifer forest included 43 of the sample trees; the above-rim ponderosa forest included 41 of the sample trees, and 9 of the samples were from under-rim ponderosa pine forests. West and Madany (1981) discuss the problems of locally missing and false growth rings, which may account for inaccuracies of dating of pre-historic fires. Sample trees in clusters or pairs in close

TABLE 1. Fire chronology for Bryce Canyon National Park, showing number of sample trees scarred during each fire year in 5 geographic units from 1565 to 1983.

Year	<u>Mixed Conifer Forest</u>		<u>Ponderosa Pine Forest</u>			TOTAL
	Nat. Bridge- Rainbow pt.	Whiteman Bench	East Creek	Fairyland V.P.	Under-rim Forest	
1565			1			1
1583			1			1
1608			1			1
1616	1					1
1618	1					1
1622					1	1
1622					1	1
1660					1	1
1662			1			1
1669					1	1
1673			1			1
1688					1	1
1690				1		1
1691		1				1
1692	1					1
1693	1					1
1696				1		1
1697					1	1
1709	1					1
1710					1	1
1712			1			1
1713	1					1
1716	1					1
1719				1		1
1720		1				1
1723	1					1
1725	1					1
1726	1			1		2
1728	1					1
1732	1			1		2
1735			1			1
1737	3					3
1738	1					1
1743			1			1
1746			1			1
1748	1					1
1749					1	1
1751			1			1
1752	1				1	2
1755		1				1
1756				1		1
1761					1	1
1765	1					1
1766	1					1
1767	1					1

Year	<u>Mixed Conifer Forest</u>		<u>Ponderosa Pine Forest</u>			TOTAL
	Nat. Bridge- Rainbow pt.	Whiteman Bench	East Creek	Fairyland V.P.	Under-rim Forest	
1771		1	1			2
1773			1			1
1775	1					1
1778			1			1
1781	1	1				2
1783				1		1
1784					1	1
1785	1	1				2
1787	1				1	2
1791			1			1
1793	1					1
1796	1	1				2
1798	1	1				2
1799					1	1
1800			1			1
1801		1				1
1802	1		1		1	3
1804		1				1
1805	2					2
1808	2	1				3
1809		1				1
1810					1	1
1812		1				1
1813	2					2
1814				1		1
1816	3					3
1818	1					1
1819			1			1
1820					1	1
1821					2	2
1823	2		1	1		4
1824				1		1
1827		1		1		2
1828				1	1	2
1829	1					1
1830				1		1
1832	1					1
1834				1		1
1835			1			1
1836	1			1		2
1838	1					1
1839			2			2
1840	1		1		1	3
1841				1		1
1843				1		1
1845	1		1	1		3
1846				1	1	2
1847	1					1
1848			1	1		2

Year	<u>Mixed Conifer Forest</u>		<u>Ponderosa Pine Forest</u>			TOTAL
	Nat. Bridge- Rainbow pt.	Whiteman Bench	East Creek	Fairyland V.P.	Under-rim Forest	
1849		1			1	2
1850	1				1	2
1852	2	1	1	1		5
1853				1		1
1854				1		1
1858				1		1
1860	1	1				2
1861			1			1
1862		1				1
1864	3			1		4
1865		1			1	2
1868	3					3
1869	1				1	2
1870	1					1
1872				1		1
1873			2	2		4
1874		2		1		3
1876	1				1	2
1877				2		2
1879	1					1
1881				1		1
1882					1	1
1883				1		1
1884				1	1	2
1887		1			1	2
1894	1				1	2
1895	1					1
1898			1			1
1903			1			1
1905			1			1
1906		1				1
1912	1					1
1919		1				1
1926	1					1
1928	1		1			2
1943					2	2
1959	1					1

~~343 yrs / 92 fires = 3.7~~

~~378 yrs / 98 fires = 3.8~~

proximity were examined to check on the accuracy of counting of tree rings. Few clues could be found that false growth rings or missing growth rings have caused inaccurate dating of fires. Consequently the fire chronology of TABLE 1 has had very little reallignment or consolidation into fewer fires or lower fire frequency.

Of the 93 fire-scarred sample trees, 78 were ponderosa pine. Of these ponderosa pine tree samples, 44 included the pith, so that the age of the tree when first scarred could be determined. Fig. 5 shows the age at first scarring of 44 ponderosa pine trees. Once initial scarring takes place, the tree acts as a sensitive recorder of later fires. Fifty of the 93 sample trees recorded two or more fires. West and Madany (1981) found that the period when a ponderosa pine is most susceptible to scarring is between the ages of 10 and 80 years. The data from Bryce Canyon forests did not agree with that conclusion, in that only 14 of the 44 ponderosa pine tree samples which included pith were 80 years or younger when first scarred. Four trees were over 250 years when first scarred. The majority of sample trees were scarred between ages of 50 and 170 years.

Two of the fire-scarred sample trees were located near the park boundary on Whiteman Bench within the confines of a small burn that occurred in 1981. Most of the surrounding younger Douglas fir and white fir trees had been killed by the fire, as well as saplings and seedlings of all species. The older pine trees which had catfaces survived the 1981 fire, as shown in Fig. 6. Also in Fig. 6 are views of very tall fire scars at other locations in the Park.

Conclusions

The study of fire scars of living trees in 1983 showed that fires were very common in all of the mixed-conifer and ponderosa pine forests of Bryce Canyon National Park. ^{for both types} The frequency of fires was every 4 to 7 years. Each portion of the ponderosa pine and mixed-conifer forests had a fire at least once every decade and probably more often. Fire in these primeval forests was a very important ecological factor, equal in importance to climate and soils, as influences of forest development.

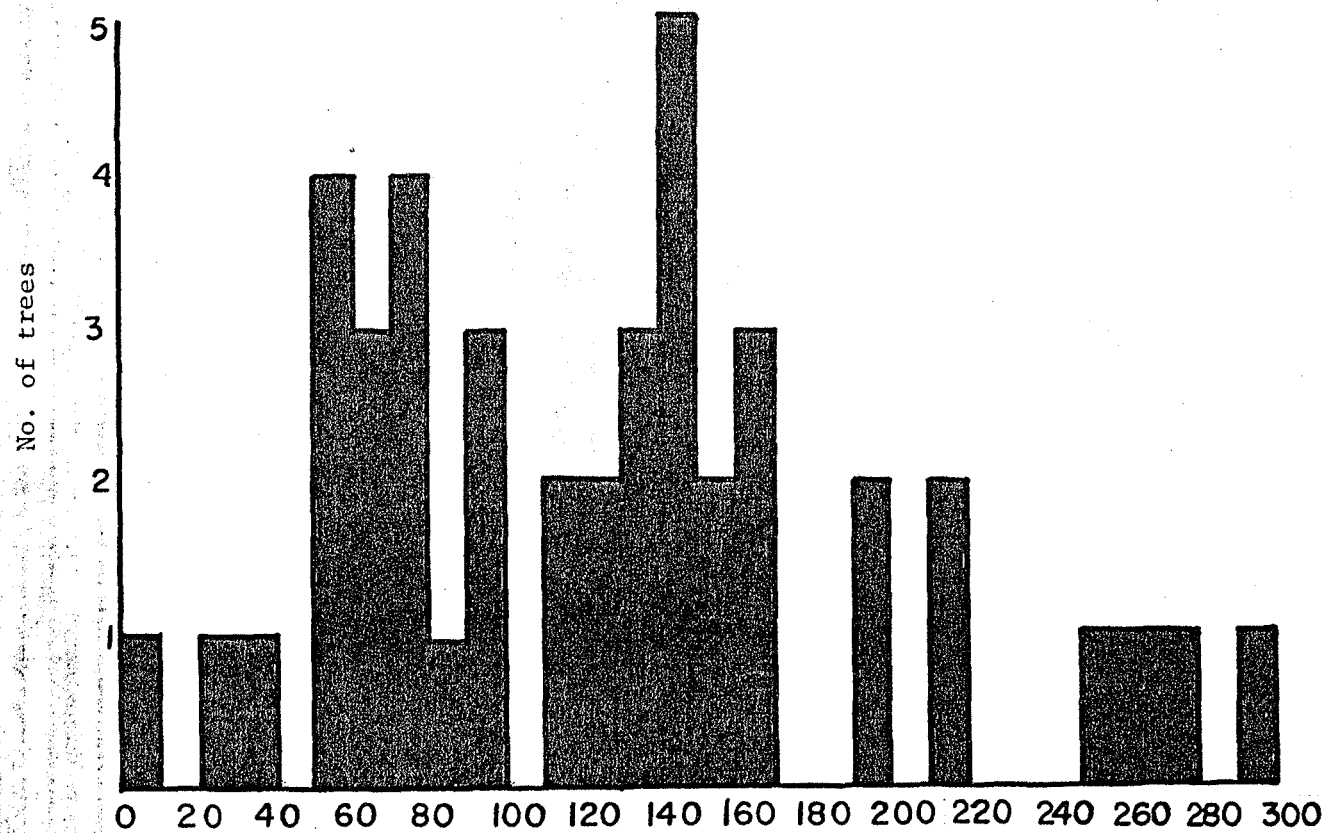


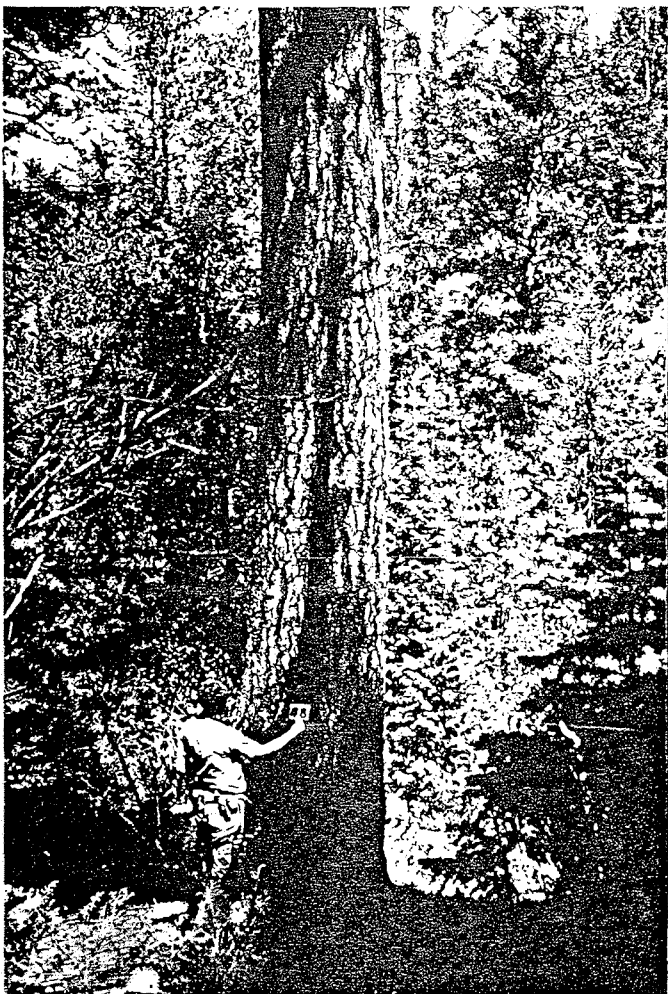
Fig. 5 The age of first scarring of 44 ponderosa pine trees.



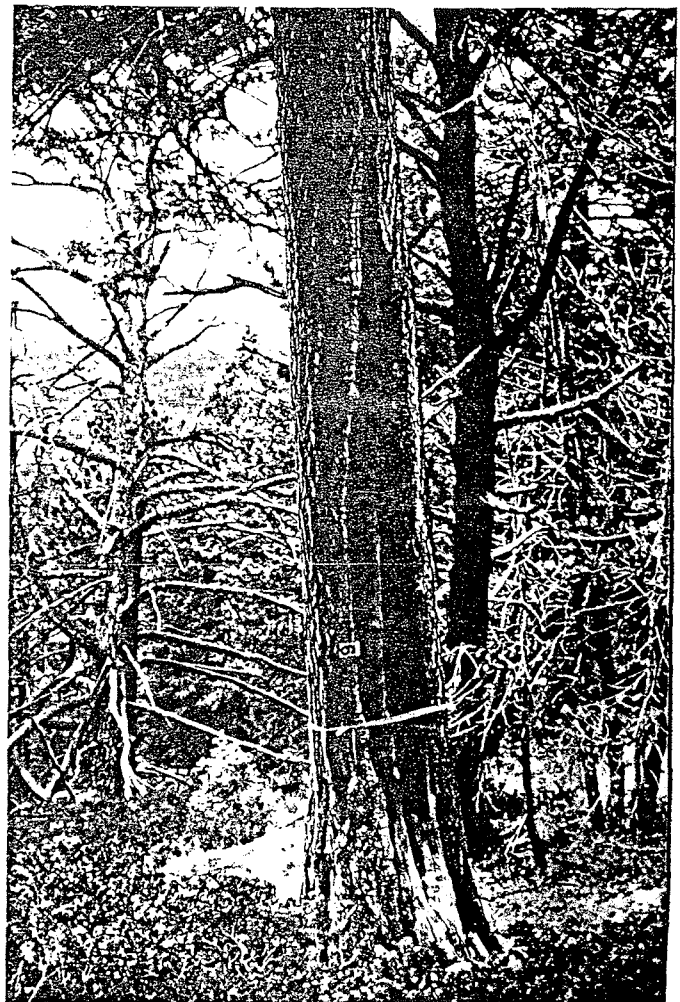
A

Fig. 6 (a) Two previously fire-scarred ponderosa pine trees within a 1981 burn area.

- (b) Very tall fire scars
(c)



B



C

One could speculate regarding ignition causes of these early forest fires. Man-ignited fires have been a feature of many human societies, according to various studies. There is no evidence at present that the Paiute Indians were responsible for any of the fires that occurred in the forests of Bryce Canyon National Park. It is assumed that the main cause of the fires in these forests was lightning, which is of common occurrence during the months of July and August. It is during these late summer months that dry grasses and dry needles under the trees would be available fuel for a forest fire to begin and to spread.

The fire regime for the forests of Bryce Canyon would be Heinselman's (1978) *For all?* number 2: frequent (1-25 year intervals) light surface fires. Few of the fire-scarred trees in the same immediate vicinity burned during the same year. If the sample size had been larger, more evidence would be available for estimating the size of the fires that burned. No one tree records all of the fires that burned around it, even if it had been previously scarred. A fire record is kept by a tree only under conditions of fuel accumulation at the base of the tree near the catface.

The frequent light surface fires maintained a mosiac of groves of trees interspersed with grassy areas. Tree regeneration was prevented or retarded in these areas between groves of trees by the dense growth of grasses and other herbaceous plants. The light surface fires were carried through the groves by the accumulation of needles, cones, and twigs from the trees and between the groves by the drying herbaceous plants, especially grasses. Any young tree seedlings and saplings that became established were thinned by the frequent light surface fires. Only occasionally would an older tree or dead snag burn. Most of the larger trees survived the fires because of their thick fire-resistant bark and a canopy that was out of reach of the flames of the fire. The surface fires usually altered only the

lower strata of vegetation. Crown fires in these forests were unknown. The surface fires not only thinned young forest trees, thus reducing competition for mineral nutrients, but also quickly cycled mineral nutrients to the soil which supported faster growth of the remaining trees. Following fires, typically growth rings were larger for several years.

The introduction of numerous grazing animals into these forest ecosystems which had been under the influence of frequent light fires for centuries caused gradual changes in species composition. As palatable perennial grasses decreased over the first few decades of grazing use, the flash fuel for the light surface fires was removed. On a given early summer when weather conditions were favorable massive establishment of ponderosa pine seedlings took place to create "doghair" thickets of young trees. The lack of thinning fires and the decline of grasses brought about through overgrazing by livestock caused the drastic change of forest understory. After three quarters of a century of growth by the dense young pine understory the ecological ramifications are numerous. Evidence of these forest community changes were provided by the age-class studies of younger trees as shown in Fig. 6. The peak establishment period of second-growth ponderosa pine corresponds to the period of most intense grazing pressure. An unusually wet spring and early summer, resulted in the establishment of many seedlings in seedbeds that had been created by overgrazing.

During the early grazing period from 1873 to 1905 there were probably no efforts to control naturally-caused fires. Nevertheless the frequency of fires and the area burned both decreased due to the decrease of flash fuel of perennial grasses. With the coming of management of the area by the Forest Service early in the 20th century fire suppression began, which further reduced fire occurrence and extent. The National Parks Service has continued a rigid fire suppression policy since 1928.

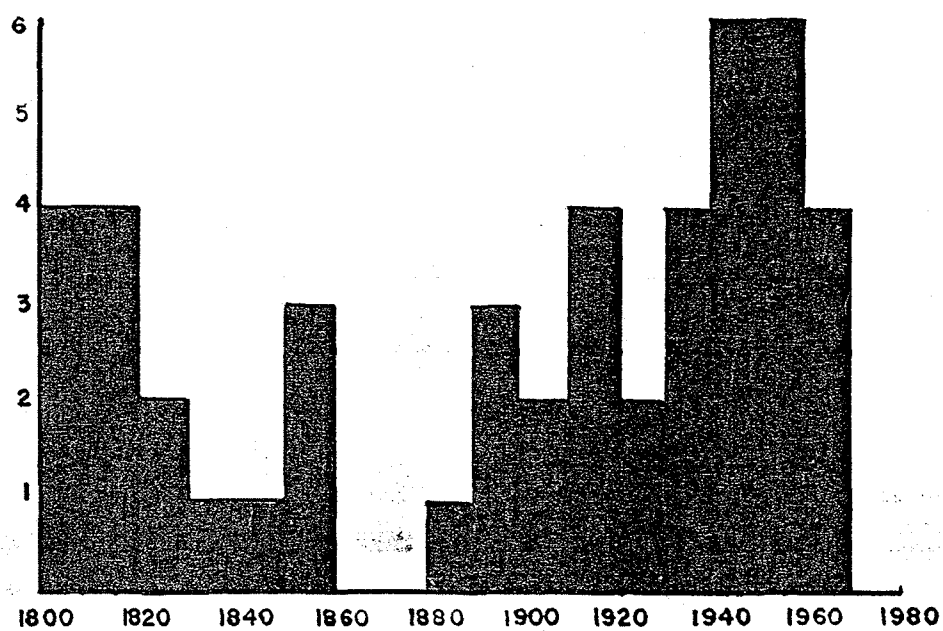


Fig. 7 Establishment dates of unscarred ponderosa pine trees

Fuel conditions in these forests have become very hazardous, with dense understory of brush, young trees and older second-growth trees providing a highly flammable fuel ladder, connecting the debris and litter on the forest floor to the canopy of even the mature forest trees. Crown fires, which have not occurred in the forests of Bryce Canyon National Park for many centuries have become possible. Crown fires have occurred in recent years in similar forests in Arizona (Pearson, et al., 1972) and in New Mexico at Bandelier National Monument (Foxy and Potter, 1980), through which many large ponderosa pine trees were killed. In the LaMesa burn in ponderosa pine forests of Bandelier National Monument all trees were killed in areas that had not had a forest fire for more than 40 years. Total destruction would probably be the outcome of a crown fire at Bryce Canyon National Park.

The mixed conifer forests at higher elevations in Bryce Canyon National Park have probably been modified even more than have the ponderosa pine forests. In pre-grazing times frequent fire prevented dense stands of trees, such as those which occur at present. Ponderosa pine was probably the dominant species in this forest and occurred in groves which were separated by grass-covered openings. The frequent surface fires not only prevented profuse regeneration of ponderosa pine, but also seedlings of white fir and Douglas fir. As the surface fire thinned young ponderosa pine saplings, even older saplings and trees of white fir and Douglas fir were killed. Isolated large trees of these two species did occur along with mature ponderosa pine in groves, where their thicker bark finally enabled them to survive recurrent fires. In more mesic sites quaking aspen was of frequent occurrence in ~~dense clones.~~ These aspen groves were islands of low flammability in the highly flammable open forests interspersed with perennial grasses. At certain times an entire aspen grove or part of a grove may have burned, but the aspen trees and associated ground vegetation easily regenerated from buried root systems that were

not damaged by the fire. The mixed-conifer forests were typified by openness and great diversity.

The sharp decline of burning following heavy grazing brought drastic changes to the mixed-conifer forests. As the palatable grasses decreased the flash fuels to carry fires were gone. Shrubs, such as greenleaf manzanita (Arctostaphylos patula) became more abundant in the forest understory. After three-quarters of a century these dense stands of shrubs are now senescent with many dead branches, which greatly increases the fuel to carry fire through the forest. There is a proliferation of white fir seedlings, saplings, and trees, covering what were once grassy openings in the forest as well as the understory in groves of old pine and other tree species. (The great numbers of white fir trees throughout these forests form a fuel ladder that will easily carry fires into the forest canopy to become catastrophic crown fires. The aspen groves are decreasing in size, number and vigor as the fire-controlled succession has favored white fir and other conifers. Fuel accumulation, especially of dead branches, tree trunks, litter, and duff is excessive and extremely flammable. The stage is truly set for catastrophe in case a wild fire occurs.)

The radical changes in the ground layer and understory of the forests of Bryce Canyon National Park has created great challenges for their management as "natural" ecosystems. The original fire regime of frequent light surface fires has been changed to one of long return interval crown fires. If fire suppression is continued the crown fire which eventually burns will be a holocaust of unparalleled intensity for these forests. The fire would probably destroy the humus of the soil due to its great intensity, and leave no trees to provide seed-sources for forest regeneration. The aspen trees are so far depleted that even their root systems may not provide for clonal regeneration. A totally different succession leading

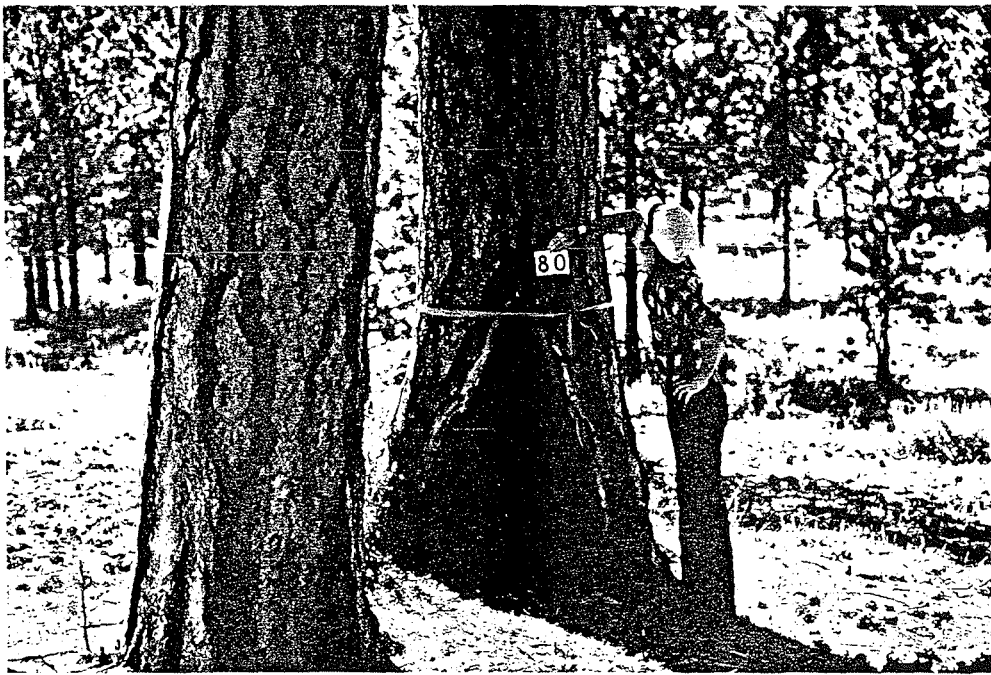
to further departure from the pristine-like biotic communities (the goal of management by the National Park Service) would take place.

The long-term goals of the National Park Service in management of the forests of Bryce Canyon National Park should include the gradual return of fire, along with a program of fuel reduction, both manually and by prescribed burning. In some cases lightning-caused fires should be allowed to burn, even though limited portions of the forest would be modified or destroyed. Within these burned areas succession would occur to provide diversity in an otherwise uniform, monotonous dense conifer forest.

The outcome of appropriate vegetation modification by restoration of fire to Bryce Canyon National Park would be an attractive and healthy mosaic of forest communities in varied stages of succession and with openings between groves of conifer trees. Animal diversity and flowering plant cover would be high in such forests. ✓

The management options recommended for the forests of Bryce Canyon National Park are in conformity with the policies of the National Park Service (1970), which specify that active management of the natural environment is a requirement, inasmuch as passive protection is not sufficient. Native environmental complexes are to be restored, protected and maintained at levels determined through historical and ecological research. Further support for the management recommendation is provided by the management policies of the National Park Service (1975) which states: "Manipulation of terrain and vegetative cover may be carried out to encourage, stimulate, or restore natural conditions on lands altered by human activity through: restoration to a natural appearance of areas disturbed by fire control activities.... (and) restoration of landscapes, altered by human activities prior to park establishment, to a natural appearing state."

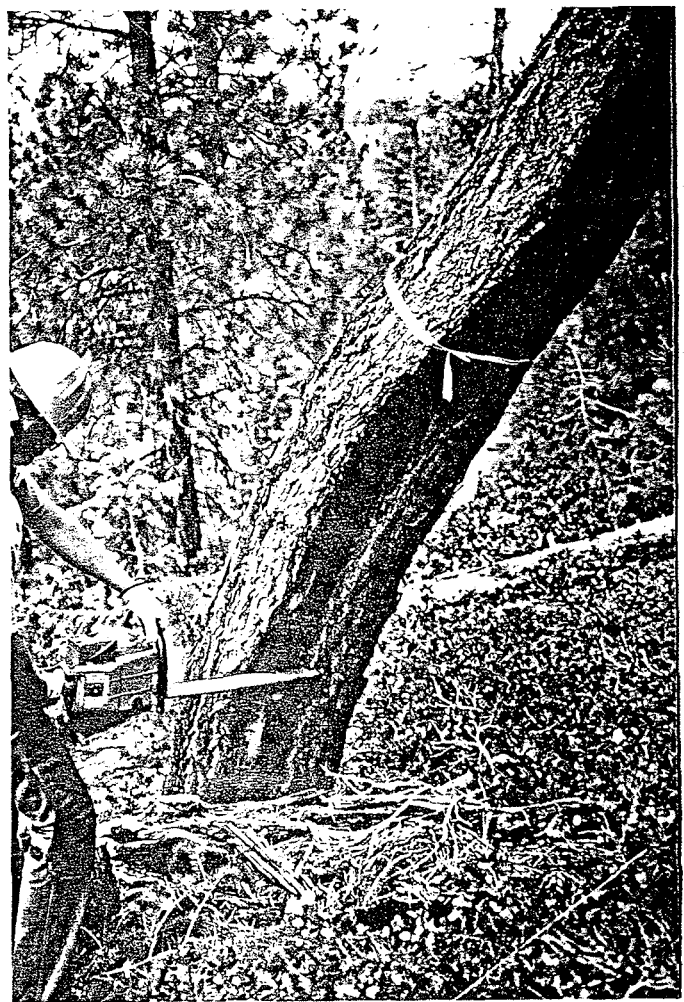
In a National Park Service Occasional Paper (5) recommendations similar to those of this paper are made concerning the forests of Yosemite National Park. In Yosemite Valley "...large accumulation of woody debris and the continuous vertical canopy created by trees of many heights produce an excessive wildfire hazard. These fuel conditions could cause extensive conflagrations during dry windy weather. Understory fuels should be reduced by removing dead limbs from large trees, eliminating small overtopped trees, and prescribed burning of the accumulated debris during safe weather conditions. Burning was a natural process in the pristine Yosemite Valley. The ultimate objective should be restoration of open forest conditions by reducing large bodies of fuel in nearly all the forests.... Vistas cut through forests should be wide and irregular to give the appearance of natural openings."



A



B



C

Fig. 8

- A. Large catface on older ponderosa pine.
- B. Cluster of three fire-scarred ponderosa pine trees in mixed-conifer forest.
- C. Fire scar on a leaning ponderosa pine tree. Removing a partial cross-section will seriously weaken the trees supporting structure.



A



B

Fig. 9

- A. Douglas fir tree with a buried firescar.
- B. Site of very hot prehistoric fire which scarred living tree to a height of about 9 feet. Still-standing burned snag was probably a living tree which was killed by the fire. In the foreground is the partial stump of another tree that was destroyed by fire.



A



B



C

Fig. 10

- A. A very tall firescar on a ponderosa pine. All of the surrounding trees are younger than the date of the last fire.
- B. A fire scarred ponderosa pine in Sheep Creek below the colored cliffs. Erosion is so rapid that the tree trunk has been buried several feet by deposition.
- C. A fire-scarred Rocky Mountain juniper tree.

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