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Black Butte presents a unique natural laboratory for ecological study. It is a volcanic cone of uniform configuration located in the rain shadow on the east flank of the Oregon Cascades. Soils are of very recent origin with no obvious development of horizons. Physical and chemical analysis revealed little dissimilarity within the study area. However, fire has played an important ecological role. Dendrochronological analysis of cross sections of mature Pinus ponderosa revealed repeated widespread burning at an average interval of 12.3 years for the years 1830 to 1903. The Forest Service has practiced fire exclusion since that time.

The vegetation of the lower slopes is dominated by mature Pinus ponderosa. Libocedrus decurrens, Pseudotsuga menziesii, Abies grandis, Pinus albicaulis, and Abies lasiocarpa become successively more abundant at progressively higher elevations. Tree, shrub and herb data were gathered via the point centered

quarter method at 1000 foot elevation intervals along eight transects radiating from the summit. In subsequent analysis, designed along the lines of a continuum analysis, it was possible to demonstrate via relative importance values that some species gradually give way to other species along environmental gradients. However, considerations of the age class patterns of mixed stands revealed that they are not stable and therefore with freedom from disturbance by fire or other catastrophe will come to be less heterogeneous in overstory composition.

In most instances, this will be at the expense of Pinus ponderosa which, due to its superior resistance to fire, has been able to occupy and thrive in habitats considerably more mesic than its true habitat type. After 60 years of fire exclusion, species of greater shade tolerance and with generally higher moisture requirements are now responding with relatively greater reproduction than Pinus ponderosa on these mesic sites.

These patterns of reproduction allow one to project to six climax associations which will come to occupy six different habitat types. Due to the uniformity of soil and topography within climatic climax zones, these may be interpreted theoretically as encompassing single habitat types with variation in seres being due to rate of succession following fire.

These distributional patterns are very similar to those

described by other workers for the east slope of the Cascades. However, due to the relatively xeric conditions of Black Butte, equivalent types occur at approximately 500 feet higher elevation.

Spatial and Developmental Patterns of the Vegetation of Black Butte, Oregon

by

Robert James Sherman

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SPATIAL AND DEVELOPMENTAL PATTERNS OF THE VEGETATION OF BLACK BUTTE, OREGON

INTRODUCTION

It has become a widely accepted ecologic principle that, at the edge of its climatic range, a species becomes more and more dependent upon the edaphic or topographic feature which will compensate for the climatic adversity. Thus, through studies of species distribution over environmental gradients, insights into limiting factors may be developed.

The study of altitudinal zonation has long been recognized as a means of improving the understanding of the complex interactions of environmental factors with individual species and plant communities. The classic zonation study dates from 1890 when C. Hart Merriam published his observations of the San Francisco Peaks region of Arizona (Merriam, 1890). In this study, and in several subsequent studies, Merriam (1891, 1898) attempted to define life zones almost entirely on the basis of differences in temperature.

The work of Piper (1906) and Standley (1921) serves to illustrate some of the difficulties encountered in the application of this single factor approach. In attempting to correlate vegetation and temperature values, both workers arrived at the same general conclusion, that life zones are rather indistinct.

More recent work by Weaver and Clements (1938), Spilsbury and

Tisdale (1944) and Daubenmire (1942, 1946) has emphasized a different approach than that of Merriam and his followers. These more recent workers have attempted to delimit the distribution of the biota without first attempting to delineate the areas where it occurs climatologically. A second tendency, the recognition of definite groupings of organisms within zones, is reflected in the nomenclature of Weaver and Clements and of Daubenmire. For example, among the life zones recognized by Daubenmire (1946) are the spruce-fir and the fescue-wheatgrass life zones.

Daubenmire has also pursued an autecological approach to this problem. In greenhouse studies of Rocky Mountain species he tentatively concluded that the species most commonly successful at lower altitudinal ranges are those better able to endure soil drought (Daubenmire, 1943a). In a subsequent study (Daubenmire, 1956) this general conclusion was verified, and in addition it was indicated that at least for higher elevations vegetation may be limited, not by moisture, but by critical heat deficiencies. This temperature relationship was indicated rather indirectly by Merriam and later by Pearson (1924) who more accurately stressed the significance of low maxima rather than low minima. Daubenmire (1956) supports this point of view.

As Billings (1964) emphasized, somewhere between the limiting points of these two environmental factors an optimum zone of

maximum primary productivity must exist, but as yet there is very little information as to where this may be.

The most enlightening work on this problem is that of Whittaker (1966). In a study, primarily of the vegetation of the Great Smoky Mountains, he calculated average above ground net annual production of 1000 to 1200 g/m^2 per year for mesic communities. These values decreased at higher elevations and on more xeric sites. Whittaker also determined that above 1400 m evergreen spruce-fir forests are more productive than deciduous forests at the same elevation, and at these higher elevations production was higher on south slopes than on north slopes. It was also suggested that, as many foresters have maintained, production is greater in unstable forests than in climax forests.

Unfortunately, little information of this nature is available for western forest communities. As changes due to logging, exclusion of natural patterns of fire, and recreational use become prevalent it is becoming more difficult to accurately obtain this information.

Moreover, such information as now exists is often of limited value because of the lack of adequate identification of the communities from which it is obtained. It is the intent of this study, through synecological classification of the vegetation of Black Butte, to provide this basis which hopefully will allow more meaningful data collection and effective communication in subsequent studies.

DESCRIPTION OF STUDY AREA

Physical Features

Location

The Cascade Mountain region of central Oregon is dotted with many cinder cones or buttes of relatively recent volcanic origin. These often project upward from nearly level terrain and in some cases are of sufficient elevation to demonstrate marked differences in the native vegetation. Black Butte typifies this situation. It is located at 121° 35' W longitude, 44° 23' N latitude on the east flank of the Cascades, about nine miles northwest of Sisters, Oregon (Figure 1).

Black Butte (Figure 2) is approximately four miles across at the base, and thus occupies an area of about 16 square miles which is entirely within the Metolius District of the Deschutes National Forest.

Geology and Soils

As may be noted in Figure 3, the only large departure from the uniform conical form of the butte is a massive fault which completely bisects the butte along a northeast-southwest line. The elevation of the summit is 6436 feet, about 3150 feet above average surrounding

Figure 1. Map of portion of Bend Quadrangle, Oregon (U. S. Geological Survey Map. 1955).

Figure 2. Aerial photograph of Black Butte, September, 1953.

terrain. Although there are no springs on its slopes, many originate at or near its base, probably through passages formed by faulting which is common in the region.

Geology land form maps which include Black Butte indicate its composition to be light gray pyroxene andesite and olivine-bearing andesite in composite cones as pyroclastic rock of the upper Pleistocene or a more recent period (D. L. Peck, 1961). Baldwin (1959) also indicates that Black Butte is among the younger volcanic cones in this region. He notes that the lack of disturbance of the conical shape indicates a post glacial formation. This is considerably more recent than most of the peaks of the high Cascades which are thought to be of lower Pliocene origin (Williams, 1953).

The soils of the region, derived from the basic igneous rocks, are regosols with sandy loam to loam texture (West, 1964). Pumice, common in soils to the south (Dyrness, 1960), is not abundant in soils of Black Butte. The soil is typically very nearly structureless. It is soft when dry and friable when moist. Little surface organic matter is present at low elevations, but on more mesic upper north slopes, one to two inches of duff may form an A_{oo} horizon which decomposes to produce a shallow A_o horizon.

Climate

The climate of this area may be generally described as semi-continental rain shadow (Wells, 1951). This is due to the interception of the eastward movement of moist marine air by the Cascades. As storms are forced over these mountains, adiabiatic cooling results in heavy precipitation on the west slopes, exceeding 100 inches annually in some sections. Accordingly, precipitation on the east slope is greatly diminished. Extrapolation from data gathered at the Sisters Ranger Station (Table 1) indicated average annual precipitation in the vicinity of the base of Black Butte to be approximately 18 inches. Upper slopes undoubtedly receive greater amounts of precipitation but no precise measurements have been made. Estimates based on altitudinal variation in precipitation observed in Europe (Geiger, 1965) indicate that the summit of Black Butte may be expected to receive roughly 100% more precipitation than the base. Much of this precipitation occurs as snow in the months of November through March. DeMoy (1966) has indicated that drifts in excess of three to four foot depths may accumulate on the lee side immediately below the summit. Occasional thunderstorms may contribute small amounts of rain during the summer.

The temperatures in the area during the summer often include highs of 90° to 100° F, but night-time frost is a possibility during

Table 1. Climatological data for Sisters, Oregon.

13 Year Record--1921-1934 (Wells, 1941)

	Average precipitation in inches											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.
	2.64	1.94	1.16	.85	1.09	.68	.68	.32	.86	1.05	3.24	2.14	16.65

Recent Records (Climatological data, 1958-1965)

	Average precipitation in inches												
Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.
1958	----	----	----	----	----	----	----	----	.28	.36	2.99	1.07	----
1959	2.57	1.84	.75	.12	.46	.34	.05	.11	.53	.81	.45	.59	8.62
1960	1.55	2.22	3.31	1.02	.54	.02	.05	.17	.19	.66	4.55	1.80	16.08
1961	.84	3.78	1.43	.66	.84	.68	.04	.06	.55	1.44	4.64	3.20	18.16
1962	1.87	1.50	1.63	.65	1.09	.04	.01	.48	.35	2.30	2.03	1.90	13.85
1963	2.21	1.92	1.07	1.01	.78	.39	.36	.20	.67	.26	2.66	1.41	12.94
1964	3.48	.02	.71	.26	.07	.62	.09	.16	.02	.23	2.30	12.24	20.20
1965	3.05	.38	.10	.98	.20	.84	1.37	1.59	.07	.35	2.15	.72	11.80
1966	3.35	.46	.63	.05	.17	.22	.78	.00	.31	1.00	1.73	2.87	11.57
1967	4.06	.16	1.50	1.25	.22	1.09	.00	.00	.12	1.59	.66	1.94	12.59

	Average temperature (F.)													Extremes	
Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.	High	Low
1958	----	----	----	----	----	----	----	----	54.4	47.8	38.9	38.0	----		
1959	33.7	32.8	38.7	43.7	45.8	56.7	63.8	58.8	53.0	47.5	38.4	31.4	45.4	100 7/22	-11 1/ 4
1960	26.0	31.3	38.8	43.3	46.9	57.3	66.0	59.1	56.0	47.5	35.4	31.1	44.9	99 7/18	-12 2/27
1961	34.5	39.4	38.3	43.4	48.2	60.9	63.3	66.1	50.6	45.5	34.3	31.5	46.3	98 7/12	- 8 12/11
1962	29.7	33.4	36.7	46.4	46.2	55.1	60.7	59.4	55.6	46.1	40.1	35.3	45.4	95 7/23	-28 1/22
1963	27.3	41.4	36.8	40.3	50.2	54.5	58.0	61.6	60.9	47.7	39.0	32.4	45.8	99 9/27	-16 1/12
1964	33.2	36.3	36.8	40.5	46.8	54.4	61.4	58.5	51.5	46.6	34.0	29.9	44.2	99 7/27	-16 12/17
1965	32.9	37.6	36.5	43.6	46.1	55.1	62.7	61.3	50.3	50.4	39.6	30.3	45.5	92 7/16	- 2 12/17
1966	33.4	33.8	38.8	43.8	51.0	54.4	60.1	60.9	57.3	48.0	39.3	34.1	46.2	95 8/ 2	6 2/10
1967	36.2	37.9	36.4	37.8	49.6	57.6	64.0	67.2	60.5	48.5	38.6	29.9	47.0	100 8/19+	- 6 12/15

any of the summer months. Winter temperatures frequently drop into the 0 to -10° F range but daytime readings above freezing are also frequent.

History

Fire

An outstanding feature of the ponderosa pine (Pinus ponderosa)[1] forest, prior to present management by lumber interests, was its repeated burning as a result of lightning and possibly Indian game drives. Occurring at average intervals of 16 years (Weaver, 1959), these fires typically removed litter, brush, and dead snags and thus produced a forest which Weaver (1961) described as having a park-like appearance.

Apparently these fires were very mild and rarely resulted in a crown fire. However, local accumulation of litter, particularly on upslope sides of tree bases, sometimes provided fuel for a fire of sufficient intensity to consume the bark and kill the cambium on one side of the tree. Once this fire scar or "cat face" was formed, susceptibility to damage by subsequent fires was increased markedly (Soeriaatmadja, 1965). Thus a repeating pattern of scars and

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[1] Scientific and common botanical names follow M. E. Peck (1961) except as noted.

cambial regrowth is present in the cross section of many ponderosa pine. This pattern serves as an excellent chronological record of fire in this forest prior to Forest Service records (Roughton, 1962).

The Forest Service began an active fire prevention program in early 1900. Two landmarks in the area, the lookout atop Black Butte and the historic Allingham Guard station five miles north of the Butte, are the result of this program. They have been remarkably successful in this area. Only one fire, due to a lightning strike in 1946, has burned any significant portion of Black Butte (DeMoy, 1966). This consumed about two acres of mixed subalpine fir and white-bark pine on the north slope just below the summit.

Grazing

Accurate records of grazing use for this region are not available. However, it is well known that a great deal of livestock passed through the area from about 1880 to 1908 (Brogan, 1964). Occasionally cattle were driven to market west of the Cascades along the Santiam Toll Road which passes several miles to the south of Black Butte. Apparently the movement of herds of sheep was more common in this area. They were usually driven to mountain meadows in the late spring and returned back through the area in the fall.

These seasonal drives slowly diminished in magnitude until 1940 when they were completely abandoned (Benson, 1965). At the

present time, no livestock grazing is allowed on the Forest Service land in the vicinity of Black Butte. However, this author frequently found grazing by game animals, principally mule deer, to be heavy.

Logging and Thinning

Black Butte was free from commercial logging disturbance until 1958 when cutting occurred on the lower south east slope. This was accompanied by a felling of most incense cedar over 8 inches DBH. Aerial photos taken in 1958 verify this to be the situation. However, in 1962, 1963, and 1965, essentially all areas of commercial value were logged on a selective cutting basis.

On the steeper upper slopes, disturbance has been extensive. This is particularly true in the vicinity of the main access road which traverses the north and east slope at about 4800 to 5000 feet. In the open south slope ponderosa pine forest this does not appear to be severe, but it is in this area that thinning operations have been more extensive. This has been done in an effort to "release" saplings which, in pine forests, characteristically tend to grow in dense, even-age thickets.

Other Studies in the Area

Several studies conducted in the vicinity of Black Butte are relevant to the current study. Johnson (1958) compiled a list and key

to the vascular flora of the Butte. No attempt was made to obtain quantitative information. However, he suggested a tentative classification of the present vegetation into associations based only on subjective observations.

Swedburg (1961) described a "coniferous ecotone" from hemlock-alpine fir stands at the crest of the Cascades to the much drier juniper regions 16 miles to the east. His major emphasis was on the tree species which he discussed on the basis of their environmental position. Swedburg felt quantitative data in the form of DFD indices demonstrated a continuum in spite of the successional trends he observed on the study sites. Franklin and Mitchell (1967) have also investigated successional trends on sites very similar to those at the west end of Swedburg's transect.

West (1964) did extensive work at the base of Black Butte as a part of a transect from Sisters to Suttle Lake. His primary objective was a comparison of methodology of the habitat type and continuum approaches to vegetation classification. However, much information relating to the ponderosa pine communities is presented therein. Other work, more autecological in nature, is that concerned with bitterbrush (Stanton, 1959 and Sherman, 1966) and the relationship of understory plant distribution to shade patterns (Robinson, 1967).

METHODS

Site Selection and Location

The major intent of this study was the determination of altitudinal and aspectual distribution patterns of vegetation. Therefore, sample sites were located at 1000 foot altitudinal intervals of 3500, 4500 and 5500 feet along eight transects radiating from the summit. Additional sample sites were located at 6000 feet on the north, south, east and west transects. One site was centered on the summit and, as conditions permitted, one site was located at 5000 feet on the southeast transect (Figure 3). Actual field location of sites was facilitated by use of an altimeter, compass, and topographic map. Some latitude in exact placement of the sites was allowed to negate the influence of local variations from the general sloping topography of the butte. This made possible the location of all sites on slightly convex slopes. Only one significant departure from the desired azimuth was necessary, that being on the southwest transect which would have fallen on concave (draw) topography. Hereafter, all references to sample sites will be on the basis of the aximuth from the summit to the site and the elevation of the site. For example, the site on the north azimuth at 6000 feet is designated N60.

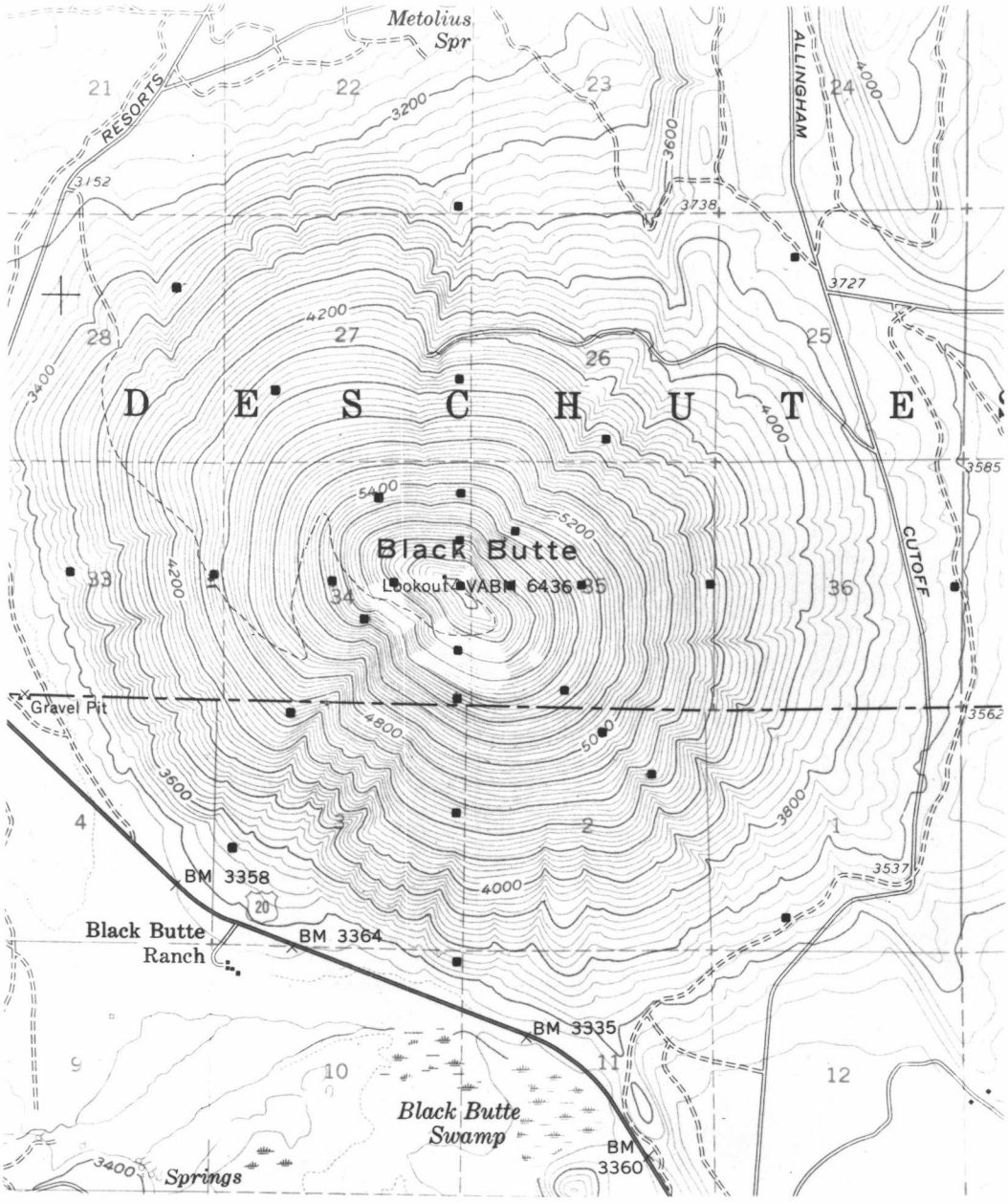

Figure 3. Topographic map of the study area showing location of sampling sites (U. S. Geological Survey Map, Sisters Quadrangle, Oregon. 1959).

Sampling Method

Some of the major sampling problems in the ponderosa pine forests are associated with the heterogeneous mixture of two components, the relatively young even-age thickets and mature, open stands. To avoid characterization of communities based on samples drawn from only one of these categories, two major considerations were made in design of the data collection plan. Sample sites were of a size sufficient to include several representatives of each component and data collection points were located randomly within sample sites to avoid the possibility of falling into "phase" with the repeating pattern of thickets and open stands. These considerations have the disadvantage of masking differences within a stand but more important, from the standpoint of this study, facilitate comparisons between stands.

At each site the south and west sides of a 90 yard square were marked with chalk lines conspicuously marked at 10 yard intervals. Thus, the site was divided into 100 points indicated by the combination of the two coordinate numbers (Figure 4). Twenty five of these points, previously selected from a table of random numbers from 00 to 99, were then located and marked. Data were gathered at these points following the point centered quarter method (Cottam and Curtis, 1956).

Quarters were delimited by the cardinal points of the compass

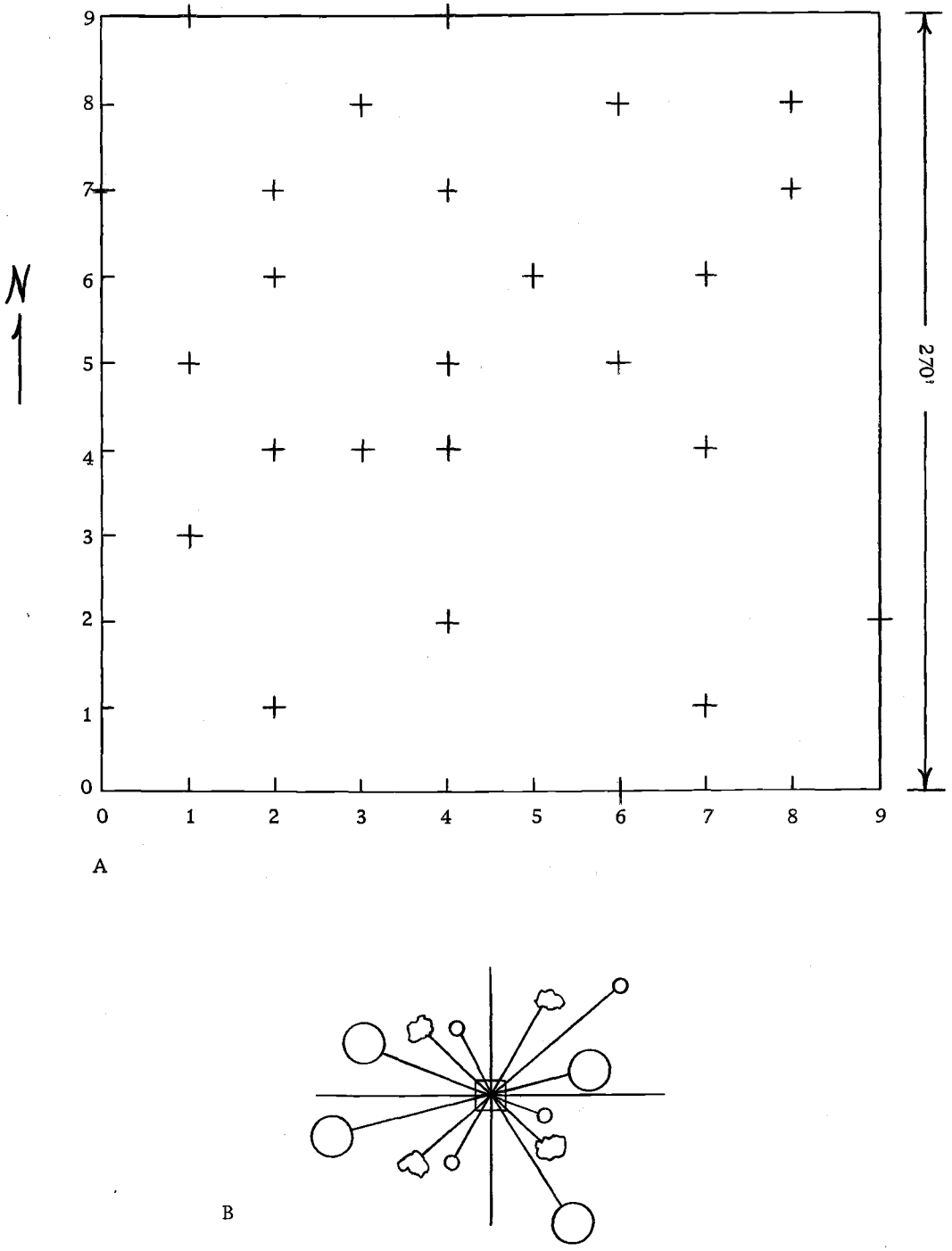

Figure 4. A. Layout of sample site with 25 randomly located sampling points.
B. Detail of sampling point (See text for additional details).

(Figure 4). Within each quarter, the distances from the center point and the species of the nearest tree equal to or greater than four inches DBH, (diameter breast height), nearest tree less than four inches DBH, and nearest shrub were determined. Thus three classes, trees equal to or greater than four inches, trees less than four inches, and shrubs, with 100 individuals in each class, were sampled at each site. An Edscorp range finder was used for all linear measurements from each point. DBH was determined using a diameter tape and was recorded for each tree sampled. Crown cover, on the basis of an average of a measurement of maximum crown diameter and diameter at a right angle to the maximum, was determined for shrubs. The presence by species of herbs and tree seedlings in a one meter square centered on each point was also recorded. A notation was also made of the percent slope, aspect, and depth of litter at each of the 25 points.

In some cases, logging or thinning disturbance made rigid adherence to the procedure described above unrealistic. At points affected by these factors, the stumps of cut trees were recorded just as if the trees had been standing. However, because the natural herbaceous vegetation was sometimes completely destroyed by skid trails, it was not uncommon to offset the location of the meter square to the nearest undisturbed area of sufficient size.

In open areas such as the sparsely forested meadow area (S60)

no trees or shrubs were encountered within 100 feet from the point in a given quarter. In other instances, a tree or shrub that had been previously sampled from another point was encountered. This was recorded just as if it had not been previously sampled except that it was indicated as a duplicate in the field notes. The methods of handling of these data are discussed below.

Methods of Analysis

All distances from the 25 points for all species in a given class were totaled and the mean (d) computed. True density (D) in terms of number of individuals per acre (A) was then calculated for both classes of trees and for shrubs via the formula:

$$\frac{43560}{d^2} = \frac{n}{A} = D$$

Basal area (BA) for trees equal to or greater than four inches DBH was calculated in square feet by first converting DBH to BA for each individual sampled and summing these to get the total BA for the stand. This was divided by the number of individuals sampled to obtain mean BA which was then multiplied by true density to determine BA per acre.

Shrub cover was determined in square feet from crown diameter measurements. Average crown diameter was determined from the raw data in the same manner as the DBH for trees. This figure was

multiplied by true density to obtain square feet of shrub cover per acre.

Values of relative density, relative frequency, and relative dominance (in terms of BA) were then calculated for trees (equal to or greater than four inches DBH), saplings (less than four inches DBH) and shrubs following the method of Cottam and Curtis (1956). These values in percentages were then added to give an importance value (IV) for all the species in a given class (i.e. trees equal to or greater than four inches, etc.) for each stand. This IV totaled 300 for all species within a class for each stand. However, various authors have used different numbers of values in computing IV's. To facilitate comparisons, it is now customary to divide the IV by the number of values involved in its computation, in this study, three. Therefore, the total IV for all species in a given category in a single stand must total 100, and is hereafter designated as Relative Importance Value (RIV) (Bliss, 1963).

The two previously mentioned difficulties, lack of trees or shrubs and the sampling of duplicates were handled as follows. A category of "species lacking" was established and its importance value was determined much as for individual species. Its relative density and frequency were determined directly as percentages. Dominance for this item was arbitrarily set equal to the average of all other species and thus an RIV could be calculated. In cases where

the only problem was that of duplicates, these were simply dropped from the sample and the relative values calculated as usual.

For estimates of true density rather than relative density, distance values for duplicates were multiplied by 1.5 and for "species lacking" d was multiplied by two times the number of occurrences. A new sum of distances, a new value for d, and a new value for D, were then calculated. These values (1.5 and 2) were selected following a trial and error experiment in which the density (D) of trees over four inches DBH on plot S60, a grassy bald with trees near the margins, was determined to be less than one.

Tree and shrub components of stands were compared by means of the dissimilarity index as described by Bray and Curtis (1957). The objective of the calculation of a dissimilarity coefficient is the ordination of that which is to be compared, in this case, stands. The dissimilarity coefficient was determined according to the formula:

$$C = 0.85 - \frac{2w}{a + b}$$

where w was the RIV for species common to both the stands under consideration, and a and b were equal to the total of the RIV's on each of the two stands being compared (i.e. 200). In this manner, dissimilarity values were computed for every possible pair of stands and the coefficients arranged in a matrix.

The stand with the highest total dissimilarity to all other stands

was designated a and assigned a value of 0 on the x-axis. The stand with the greatest dissimilarity to stand a was designated b and was placed at the opposite end of the x-axis. The distance of each stand from stand a along the x-axis was determined according to the formula:

$$x = \frac{L^2 + Da^2 - Db^2}{2L}$$

where L is equal to the dissimilarity value between stand a and b; Da the dissimilarity value between stand a and the stand in question; and Db the dissimilarity value between stand b and the stand in question.

In the calculation of the y-axis coordinates, the stand with the poorest fit on the x-axis was determined according to the formula:

$$e = \sqrt{Da^2 - Db^2}$$

The stand with the highest poorness of fit value was located at 0 on the y-axis and designated a'. The stand with the greatest dissimilarity to a' and within 1/10 L of a' on the x-axis was designated b' and located at the opposite end of the y-axis. Stands were then located on the y-axis in the same manner in which they were located on the x-axis.

Determination of Fire History

Although logging activities interfered with collection of data in many respects, they were advantageous from the standpoint of fire history determinations. It is not uncommon for workers to attempt analysis of fire histories with increment cores from fire scarred trees. As Glock, German and Agerter (1963) have indicated, the accuracy of these methods is often very limited. However, in this instance, due to the felling of many scarred trees, complete stem cross sections were available for analysis. In addition to providing more desirable material it was also possible to transfer the ring counting procedures to the laboratory where preparation of the specimens with an electric sander and observation with better optical equipment undoubtably improved the accuracy of the analysis.

Due to the frequently encountered problems of omitted rings and multiple rings for a given year, it has become common practice to compare patterns of relative ring widths. In this fashion, errors based on a dendrochronology of any one tree may be detected and eliminated. This procedure was used with great difficulty in this study. The extremely small outer growth increments common to the mature trees in this area exhibited little discernable variation among the annual rings. However, intervals between fires were compared and adjustments made accordingly.

Soil Sampling

Due to the limited access to laboratory facilities, soil samples for this study were collected on a restricted basis. In each of twelve areas, soil observations were made in two locations about 100 feet apart. Samples for laboratory analysis were collected at both points and combined. These samples included material from a depth of 6 inches to the C horizon. A description of the profile characteristics at each site was also recorded.

Physical Analysis

Physical analyses were based on the methods outlined by Dawson (1965). Rocks and stones were first removed by passing the samples through a 2 mm sieve. Soil texture was determined following mechanical analysis via the hydrometer method. "Available moisture" was determined on the basis of differentials between percent water by weight at field capacity (moisture equivalent centrifuge method) and at the hygroscopic coefficient (equilibration at 98% relative humidity) which is nearly equivalent to PWP for sandy soils. Parent material was inspected visually using 15 - 45x magnification after separation of material in four size class, greater than .02, .02-.01, .01-.004, and less than .004 inches.

Chemical Analysis

Chemical analyses of samples were conducted by the author in the Oregon State University Soil Testing Laboratory. The following tests were made: soil reaction using a glass electrode pH meter and a 1:1 soil paste; available P using the sodium bicarbonate method; exchangeable K, Ca, and Mg using flame photometry; C. E. C. using the ammonium acetate method; and organic matter using the Walkley-Black method (Alban and Kellogg, 1959).

Calculation of Relative Insolation

Relative insolation values were determined by interpolation from the data of Frank and Lee (1966) using the percent slope and aspect of the site as determined from field observations. Geiger (1965) indicates that for clear sky conditions incoming radiation increases by one percent for every 100 meter increase in elevation. Therefore, the data derived from Frank and Lee were multiplied by the appropriate values.

RESULTS

Soils

The soil profiles on all sites are essentially the same. In all cases, the soil is single grained throughout. There is no distinct horizon development of the solum in most areas except for an occasional partially decomposed A_o layer on the surface. This is most frequent on the upper north slope where it ranges from one to two inches in depth. In the areas sampled (Table 2) it was possible to dig to a depth of 12-27 inches before encountering extensive rocks (Figures 5 and 6). However, on many ridges, rock outcrops are common.

The moist color of all samples was judged to be within the range 10 YR 3/2 to 10 YR 4/2. Two samples contained large amounts of iron concretions. These contributed a reddish cast (2.5 YR 5/8) that partially obscured, but could be separated from,the dark brown color.

In all cases, the soils were classified on the basis of mechanical analysis as loamy sand. The presence of large iron concretions and basaltic fragments account for the coarse nature of the soil (Table 3). The percent H_2O at field capacity and the low CEC level are not unusual for a soil of loamy sand texture (Buchman and Brady, 1960).

Table 2. Physical properties of soil of Black Butte.

Site	Depth of Solum	Color	% Sand	% Silt	% Clay	Textural Class	% Moist. at F. C.	% Moist. at Hygroscopic Coefficient	Approximate % Avail. Moist.
Smt.	13	10 YR 3/2	84	11	5	loamy sand	15.7	1.9	13.8
N64	16	"	84	11	5	"	14.7	2.5	12.2
S64	18	"	83	12	5	"	15.3	1.8	13.5
S60	12	"*	83	12	5	"	13.6	1.8	11.8
N48	18	10 YR 3/2*	79	16	5	"	14.8	2.9	11.9
E49	27	10 YR 3/3	80	15	5	"	15.7	2.0	13.7
S49	12	10 YR 4/2	74	21	5	"	17.3	3.2	14.1
W47	24	10 YR 3/4	79	16	5	"	14.5	2.0	12.5
NW35	18	10 YR 3/2	85	11	4	"	13.9	1.9	11.0
NE37	21	"	81	14	5	"	14.6	2.4	12.2
SE35	20	"	80	15	5	"	15.5	3.4	12.1
SW35	18	"	80	15	5	"	14.8	2.5	12.3

*Also contained iron concretions 2.5 YR 5/8.

Figure 5. Photograph of soil profile, north slope.

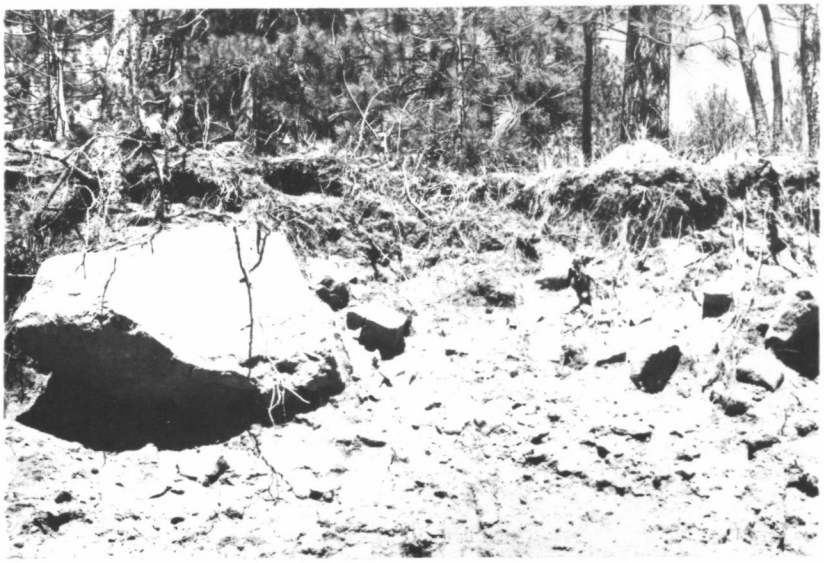

Figure 6. Photograph of soil profile, south slope.

However, it was not possible to leave the soil in the 98% relative humidity environment for more than 5 days. This may in part account for the somewhat low values of the hygroscopic coefficient and correspondingly high percent available moisture. The results of chemical analyses of soil samples appear in Table 4.

Table 3. Analysis of relative representation of parent materials in soil of Black Butte.

Sample #	Type of Material	Size of Separates .02 in.	.02-.01 in.	.01-.004 in.	.004 in.
Smt.	Fe concretions	40%	40%	40%	30%
	basalt	48	45	50	60
	feldspar	10	10	5	5
	other	2	5	5	5
N48	Fe concretions	30	40	20	25
	basalt	43	45	65	65
	feldspar	22	10	10	5
	hornblend	2	2	2	1
	other	3	3	3	4
S49	Fe concretions	58	45	40	40
	basalt	35	45	55	55
	feldspar	5	5	4	4
	other	2	5	1	1
NE37	Fe concretions	55	45	45	40
	basalt	40	45	50	55
	feldspar	3	3	4	3
	other	2	2	1	2

Table 4. Chemical properties of soil of Black Butte.

Sample	pH	Available P (ppm)	Exchangeable K (meq/100 g)	Exchangeable Ca (meq/100 g)	Exchangeable Mg (meq/100 g)	Total Bases (me/100 g)	Cation Exchange capacity (meq/100 g)	Percent Base Sat.	Organic Matter (%)
Smt	6.2	2.	0.13	1.90	0.42	2.45	9.7	25.2	3.16
N64	6.3	3.	0.26	1.75	0.58	2.59	10.3	25.2	1.86
S64	6.1	3.	0.51	2.90	0.58	3.99	10.0	39.9	3.05
S60	6.8	3.	1.36	5.76	1.50	8.62	10.0	86.2	2.15
N48	6.4	93.	0.28	2.75	0.83	3.86	7.1	54.4	0.57
S49	6.8	257.	0.74	9.75	1.50	11.99	14.5	82.8	3.73
NE37	6.7	78.	0.38	2.75	1.25	4.38	8.6	21.0	1.47
SE35	6.7	221.	0.98	4.50	1.50	6.98	15.5	45.0	1.70

Fire History Analysis

The results of the fire scar analysis may be seen in Figure 7. On the basis of absolute ring counts, indicated by dots in Figure 7, a rather uncertain history evolved. Much of this difficulty stemmed from lack of clarity in some growth increments formed following the last fire of sufficient intensity to form a scar. However, many of the better specimens commonly bore a scar for the year 1902 or 1903. Therefore, the last scar on each cross section was designated as having been formed in 1903. The intervals between that scar and all other scars on the same cross section were maintained. The resulting pattern is indicated by the x's in Figure 7.

It is readily apparent, especially for the years from 1840 to 1905, that essentially all of the butte below approximately 5000 feet has burned with regularity. These data also suggest that some fires may have individually burned over large portions of the butte. This conclusion seems to be most plausible for the fires indicated in approximately the years 1829, 1841, 1856, 1871, 1882, 1892, and 1903. Thus for this period the average interval between fires equals 12.3 years, not greatly different from the 16 year interval cited by Weaver (1959). However, the problem of accurately determining exact years of fire occurrence clouds the picture considerably, especially as one considers more recent fires where it is not possible

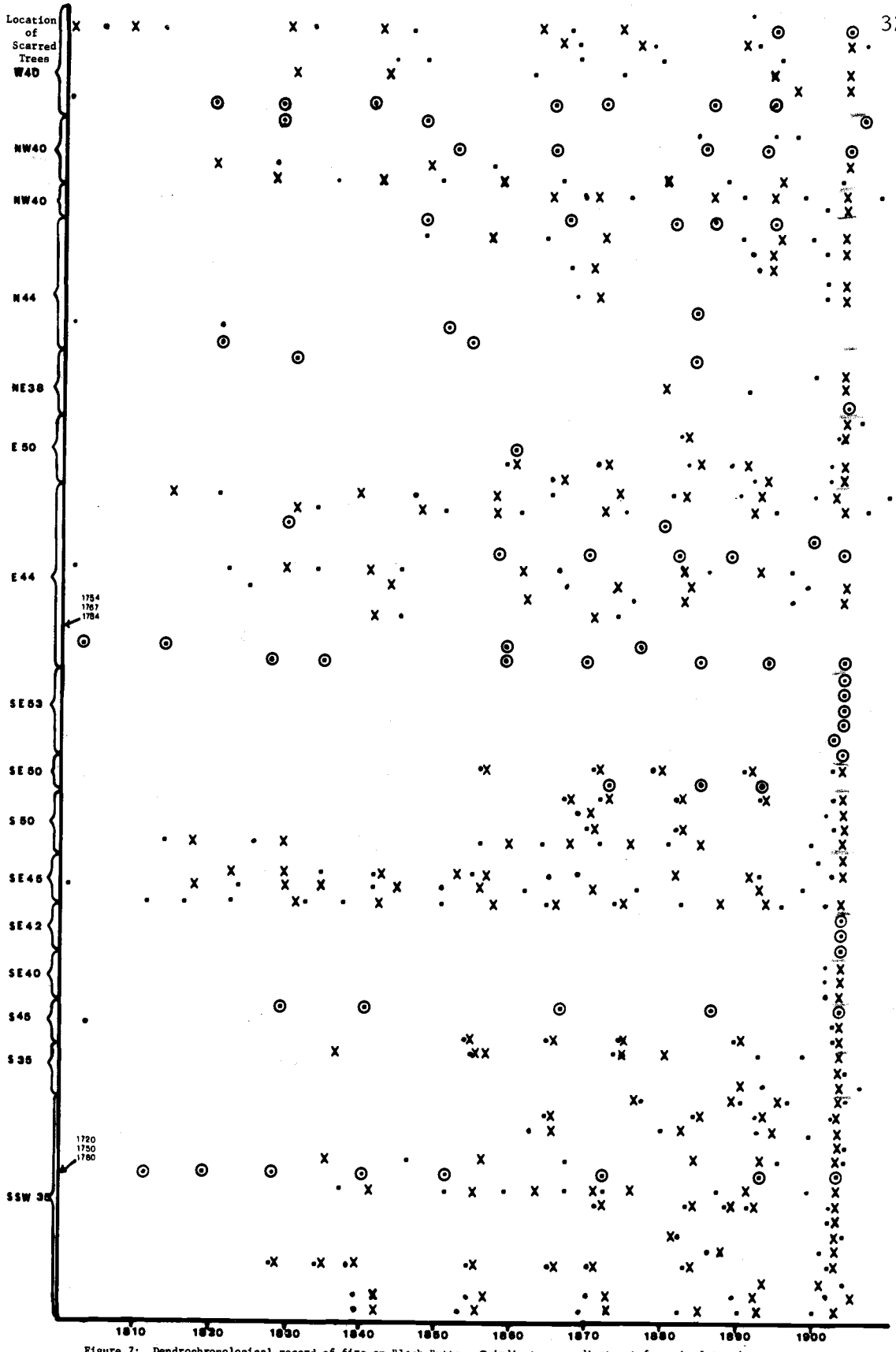

Figure 7: Dendrochronological record of fire on Black Butte. ⊙ indicates no adjustment from absolute ring count. See text for additional explanation.

to definitely state whether there have been many fires of relatively restricted extent or a few fires of general distribution. Possibly, combinations of general and restricted fires have prevailed with occasional favorable combinations of fuel and weather conditions resulting in extensive, severe fires interspersed with restricted, mild fires.

Vegetation

Three essentially separate methods of stand ordination were used. Table 5 and Figure 8 (derived from Table 6) represent a one-dimensional and a two-dimensional ordination respectively. The approach to the two dimensional ordination has been previously discussed. It should be reemphasized that subjective judgments do not play a role in this ordination.

The one dimensional ordination, however, is based on ecological judgments. It also differs from ordinations of the classic southern European school of thought in separation of the vegetation into categories (i.e. trees, grasses, etc.). The basic approach in arrangement of this table was to place the most mesic and usually most shade tolerant species in the upper left of each category. This was accomplished by sorting species vertically and stands horizontally. Additional data relating to density, cover, and site characteristics are presented in this table.

Table 5. Summarized data for plant species and site characteristics on Black Butte.

Site location[a]	Smt.	N 60	NE 55	E 60	N 55	E 55	NW 55	N 45	NE 45	NW 45	NW 35	SE 55	E 45	SE 50	N 35	NE 37	SW 55	W 55	W 60	S 60	S 55	W 35	SE 45	S 35	E 35	SE 35	W 45	S 45	SW 35	SW 45
Environment																														
Aspect	--	N	NNE	ENE	N	ENE	NNW	N	NE	NW	NW	ESE	E	ESE	NW	NE	S	WSW	W	SSW	SSW	W	ESE	S	E	SSE	W	S	SSW	SSW
% slope	0	47	43	45	47	37	44	45	42	27	19	32	47	42	18	2	49	49	41	45	44	25	42	25	2	10	32	39	22	45
Relative insolation	55	33	35	46	33	48	35	33	39	43	45	56	51	58	44	45	67	59	54	66	65	51	57	59	51	52	51	64	58	64
Trees ≥ 4" DBH																														
# trees ≥ 4"/A	46	420	379	454	414	256	380	195	138	188	46	90	102	61	243	72	21	74	221	< 1	95	27	36	71	46	60	61	66	21	54
BA (ft.^{2})/A	20	149	213	201	204	218	240	220	186	246	108	150	185	132	338	106	74	116	77	< 1	217	62	108	75	108	64	107	112	53	156
Species[b]																														
Abies lasiocarpa	44[c]	48	54	59	19	12																								
Pinus monticola		44	3		21	1	3																							
Pinus contorta		3																												
Tsuga mertensiana		1	1																											
Abies grandis		4	32	23	47	79	87	49	39	27	14	48	18	25	9	5		1	15											
Larix occidentalis			6						3	1			2		2															
Pseudotsuga menziesii			2	2	7			28	14	21	15		22	5	46	35														
Pinus albicaulis	53			16													2	27	77	28										
Libocedrus decurrens													2			6						5	15	22	20	49	2	2		
Pinus ponderosa	3		2		6	8	10	23	44	51	71	52	56	70	43	54	98	72	8	35	100	95	85	78	80	51	96	98	100	100
Trees lacking																				37										
Trees < 4" DBH																														
# trees < 4"/A	48	1186	1684	529	741	730	689	878	646	556	424	352	1414	323	408	1507	21	109	208	7	23	627	121	460	1084	1433	214	48	80	32
Species																														
Abies lasiocarpa	46	95	77	84	36	11													4											
Sorbus sitchensis	2																													
Pinus monticola					23																									
Abies grandis		5	23	10	34	89	100	85	73	15	5	75	13	45	20				15		4							2		
Larix occidentalis									3																					
Pseudotsuga menziesii					7			15	10	17	2		9		51	12														
Salix scouleriana									3																					
Pinus albicaulis	52			6										2			21	54	76	25										
Prunus emarginata									2								10													
Populus tremuloides																		3	3											
Libocedrus decurrens										2	2		4		3	37						13	38	25	78	60		30		
Pinus ponderosa									9	66	91	25	74	53	15	51	69	42	2	12	82	87	62	73	22	40	98	70	98	100
Juniperus occidentalis																				3				2						
Reproduction lacking															1			1		60	14						2			
Shrubs																														
# shrubs/A	554	0	26	39	14	30	30	83	364	42	259	27	360	158	65	492	467	735	811	150	89	802	238	1245	2810	438	330	186	970	243
Cover (ft.^{2} x 100)/A	77	0	12	7	2	15	5	25	145	3	55	2	24	30	6	146	52	71	63	39	7	238	60	249	162	358	45	36	206	40
Species																														
Arctostaphylos nevadensis	11																													
Haplopappas bloomeri	13																													
Symphoricarpos vaccinoides	18			2													39	17	31	40	37									
Ribes cereum	19			2													11	4	8	2										
Amelanchier florida	2				1		1										11	10	26	50	15	2								
Castanopsis chrysophylla			38	8	24	64	20	96	94	19	21	1	8	20	12	5	12	22			3	3					1			
Arctostaphylos patula	37		5	14	2						2	65	24	20		10	19	20	27		24	35	15	54	15	29	12	42	36	17
Ceanothus velutinus									6	8	72		62	54	10	80	8	14			21	58	64	29	4	21	87	56	54	83
Purshia tridentata																5		13	6	8		2	21	17	81	50		1		
Shrubs lacking		100	57	74	73	37	78	4		72	5	34	8	5	78				2											
Herbs																														
Species																														

Table 6. Matrix of coefficients of dissimilarity

Stands	N 60	NE 55	E 60	N 55	E 55	NW 55	N 45	NE 45	NW 45	NW 35	SE 55	E 45	SE 50	N 35	NE 35	SW 55	W 55	W 60	S 60	S 55	W 35	SE 45	S 35	E 35	SE 35	W 45	S 45	SW 35	SW 45
N60	.00	.58	.59	.63	.77	.83	.83	.83	.83	.83	.83	.83	.83	.83	.83	.85	.84	.83	.85	.85	.85	.85	.85	.85	.85	.84	.85	.85	.85
NE55		.00	.38	.44	.43	.40	.48	.47	.60	.64	.60	.67	.58	.73	.76	.75	.70	.73	.83	.80	.82	.82	.82	.82	.82	.80	.82	.82	.82
E60			.00	.58	.63	.67	.69	.69	.69	.72	.66	.65	.69	.76	.74	.71	.63	.60	.75	.76	.77	.78	.78	.78	.78	.78	.78	.78	.78
N55				.00	.41	.47	.43	.43	.56	.60	.56	.64	.57	.70	.73	.75	.69	.73	.81	.79	.79	.81	.81	.81	.81	.80	.81	.81	.81
E55					.00	.27	.15	.30	.58	.63	.56	.69	.58	.72	.76	.75	.69	.73	.80	.80	.80	.81	.81	.81	.81	.80	.81	.81	.81
NW55						.00	.45	.50	.56	.63	.55	.67	.57	.71	.74	.73	.67	.71	.78	.78	.78	.80	.80	.80	.80	.79	.80	.80	.80
N45							.00	.03	.40	.48	.49	.50	.45	.51	.55	.68	.62	.73	.74	.72	.72	.74	.74	.74	.74	.72	.74	.74	.74
NE45								.00	.31	.35	.43	.40	.35	.45	.49	.54	.49	.73	.63	.59	.59	.60	.60	.61	.60	.59	.60	.60	.60
NW45									.00	.31	.45	.32	.31	.39	.40	.51	.45	.73	.60	.54	.54	.55	.55	.58	.55	.54	.55	.54	.55
NW35										.00	.50	.06	.02	.39	.09	.36	.31	.73	.57	.36	.18	.16	.34	.46	.48	.11	.20	.21	.13
SE55											.00	.38	.35	.59	.51	.50	.48	.60	.59	.47	.41	.52	.32	.52	.47	.52	.38	.36	.51
E45												.00	.00	.36	.05	.41	.36	.61	.57	.33	.14	.17	.31	.47	.36	.18	.16	.18	.14
SE50													.00	.45	.18	.33	.23	.63	.57	.28	.16	.15	.25	.41	.39	.16	.13	.13	.15
N35														.00	.34	.55	.51	.77	.64	.55	.55	.56	.56	.62	.56	.55	.56	.56	.56
NE35															.00	.47	.41	.71	.55	.41	.19	.15	.33	.45	.39	.10	.23	.25	.13
SW55																.00	.16	.48	.33	.00	.23	.30	.34	.35	.47	.26	.24	.24	.24
W55																	.00	.50	.26	.19	.30	.28	.27	.33	.37	.35	.32	.33	.34
W60																		.00	.27	.46	.66	.65	.65	.71	.65	.36	.67	.68	.73
S60																			.00	.31	.55	.53	.53	.53	.56	.57	.56	.57	.57
S55																				.00	.03	.24	.23	.35	.37	.23	.13	.12	.16
W35																					.00	.00	.10	.32	.31	.01	.00	.00	.00
SE45																						.00	.13	.23	.24	.04	.05	.13	.03
S35																							.00	.18	.15	.24	.08	.08	.23
E35																								.00	.15	.36	.34	.35	.35
SE35																									.00	.43	.33	.35	.41
W45																										.00	.02	.04	.00
S45																											.00	.00	.00
SW35																												.00	.00
SW45																													.00

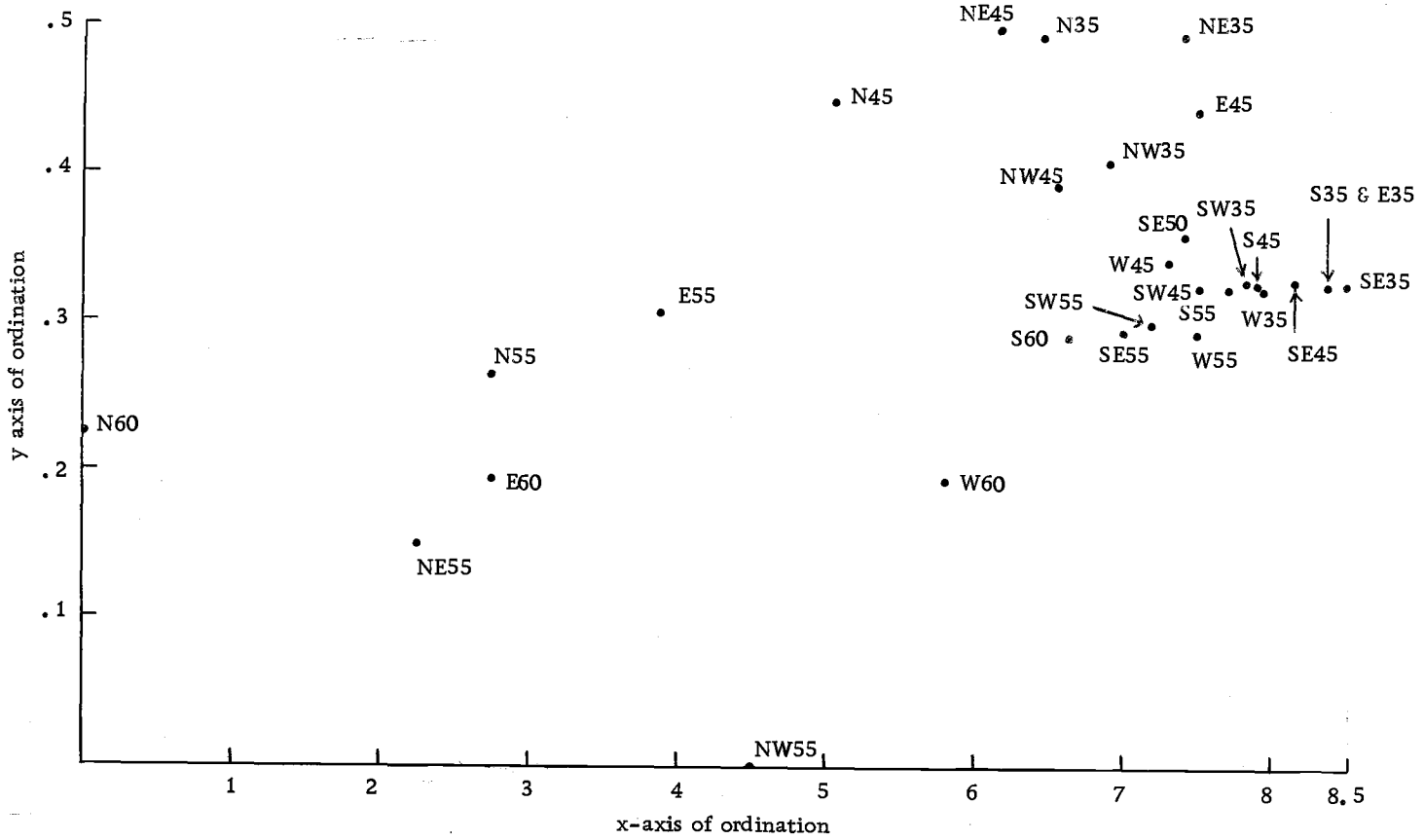

Figure 8. Ordination of stands on the basis of species (trees ≥ 4"DBH and shrubs) dissimilarity.

A third grouping of stands was based on size (age) class distribution of tree species. These results are presented in Table 9 of the Appendix.

It is apparent by visual inspection of Figure 7 and Table 5 that some communities are quite sharply defined while others appear to intergrade almost imperceptably.

These numerical data strongly suggest a continuum interpretation. For example, it may be seen in Table 5 that the RIV for Abies lasiocarpa gradually decreases from left to right while RIV's for Abies grandis and Pseudotsuga menziesii gradually increase. These species are in turn replaced by Libocedrus decurrens and Pinus ponderosa.

Similar patterns occur in the shrub understory. Castanopsis gives way first to Ceanothus, and then to a complex of Ceanothus and Arctostaphylos. It may also be noted from Table 5 that some changes of tree synusia are not accompanied by corresponding changes of the understory synusia thereby supporting the continuum interpretation. On the other hand, a consideration of age class patterns (Table 9, Appendix) may lead one to a community interpretation.

One of the most distinctive communities, the Abies lasiocarpa/Pachistima/Arnica, is composed of stands where Abies lasiocarpa is dominant. It occupies the most mesic sites of Black Butte, those from 5500 feet to the summit on primarily north facing slopes

(Figures 9-11).

A number of other tree species of very limited distribution on Black Butte are found in this community. These include Tsuga mertensiana, Pinus monticola, Pinus contorta, and Larix occidentalis. Pseudotsuga menziesii and especially Abies grandis, both widely distributed on the butte, are more frequent.

At the summit, this community intergrades with the Pinus albicaulis community which is restricted to the high elevations on the south slopes (Figure 12). The data from the summit (Table 5) thus represent a complex of north slope and south slope components which may be seen to separate within most categories in the association table.

The understory of the Abies lasiocarpa community is generally strongly limited, with the absence of shrubs and herbs a common characteristic. However, occasional open areas may support a relatively rich understory. These areas are apparently formed by death of individual trees and maintained by accumulations of snow which tend to injure young seedlings and also contribute to shorter growing seasons.

Castanopsis chrysophylla was the most frequent shrub in these open areas with Arctostaphylos patula essentially the only other shrubby species. Dead Arctostaphylos patula was often found both in the open areas and under the dense overstory (Figure 13).

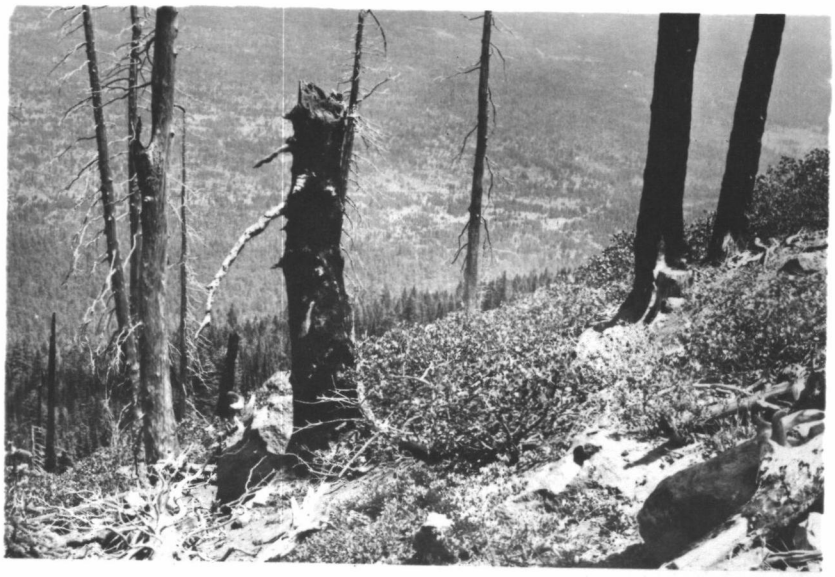

Figure 9. Photograph of Abies lasiocarpa stand burned in 1946.

Figure 10. Photograph of Abies lasiocarpa community.

Figure 11. Photograph of Arnica latifolia in burned-over Abies lasiocarpa-Pinus albicaulis stand near summit.

Figure 12. Photographic view of Abies-Pinus ecotone at the summit.

Figure 11. Photograph of Arnica latifolia in burned-over Abies lasiocarpa-Pinus albicaulis stand near summit.

Figure 12. Photographic view of Abies-Pinus ecotone at the summit.

Figure 13. Photograph of Abies lasiocarpa community with dead Arctostaphylos understory.

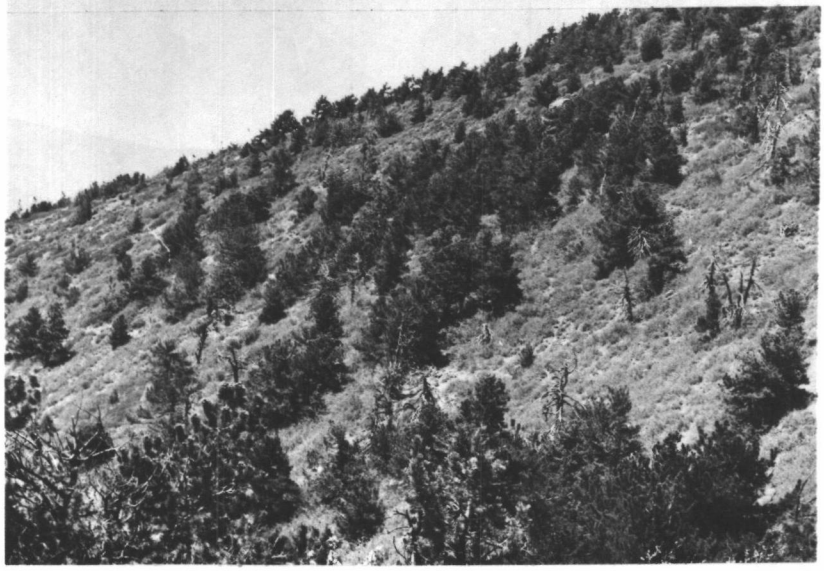

Figure 14. Photograph of Pinus albicaulus/ Symphoricarpos-Ribes-Amelanchier/ Collomia community.

Many of the herbaceous species in this community may be considered strongly selective sensu Daubenmire (1968). One such species, Pachystima myrsinites, ordinarily considered as a shrub, was included as an herbaceous species in this study because of its extremely low stature. Other selective species included Arnica latifola, Penstemon nemorosus, Goodyera oblongifolia, Pyrola secunda, and Pyrola picta. In addition to being a strongly selective species, Arnica latifola is also of interest because of its apparent role as a tolerant subordinate, capable of occupying the habitat even though the overstory may have been removed or only partially developed (Figure 11).

The Pinus albicaulis/Symphoricarpos-Ribes-Amelanchier/Collomia community (Figure 14) which occupies the upper southwest slope, while extremely distinctive, is very difficult to place on the association table. At the summit it merges with the Abies lasiocarpa community, and at its lower extreme it merges with Pinus ponderosa. On the southeastern edge it merges with and is invading a Festuca bald (Figure 15) while on the west it is subject to invasion by Abies grandis.

The relatively sparse overstory is locally absent, with a corresponding increase in cover by shrubs in much of this area. Three species, Symphoricarpos vaccinoides, Ribes cereum and Amelanchier florida were nearly exclusive to these sites.

Figure 15. Photograph of Festuca-Balsamorahiza community.

Figure 16. Photograph of mixed stand of Abies grandis, Pseudotsuga menziesii and Pinus ponderosa in the Pinus ponderosa-Pseudotsuga community.

Many herbaceous species are also exclusive to this community. Cirsium americanum, Collomia grandiflora, and Aquilegia formosa serve as examples. The grassy bald, Festuca-Balsamorahiza, community occupies the relatively small area on the south slope from 7500 to 6350 feet. Three species of fescue, Festuca idahoensis, Festuca viridula and Festuca occidentalis, combine to dominate the physiognomy of this stand. However, a great deal of Carex is also present. Balsamorahiza deltoidea and Lathyrus lanszwertii are all dominant herbs.

Essentially below the Abies lasiocarpa community but intergrading with much of it are stands dominated by Abies grandis. Castanopsis is the dominant shrub in this community, although it is often sparse and, as in the Abies lasiocarpa community, the absence of shrubs is rather common. Many of the common herbs such as Smilacina, Fragaria, Rosa gymnocarpa, and Pteridium are at their most mesic limits in this community. These stands are designated as members of the Abies grandis/Castanopsis/Chimaphila community.

Abies grandis is also abundant in the mixed community immediately below the Abies grandis community proper, but on the middle southeast and west slopes, grades directly into pure Pinus ponderosa and in effect a zone is omitted.

In addition to Abies grandis, Pseudotsuga menziesii and Pinus

ponderosa are the best represented trees in the mixed community which occupies a large portion of the lower north slope and middle elevations (Figure 16). Larix occidentalis is usually present although rarely abundant throughout these stands. Only two shrubs, Castanopsis (Figure 17) and Ceanothus, are abundant in this community. However, Castanopsis is largely replaced by Ceanothus on the less mesic sites. A host of herbaceous plants such as Pteridium, Fragaria, Cynoglossum, and Hieracium, are abundant in this community but few seem to be good character species. The community is designated as the Pinus ponderosa - Pseudotsuga/Ceanothus/ Cynoglossum community.

Pinus ponderosa stands occupy the middle and lower south, southwest, and west slopes. At upper elevations the shrub understory of these stands is similar to that characteristic of the Pinus albicaulis community but, on most lower sites, it is composed exclusively of Ceanothus and Arctostaphylos patula (Figure 18). Herbaceous species, Pteridium and Lathyrus are present in these shrubby areas but also occur in grassy areas (Figure 19) accompanied by Carex, Bromus orcuttianus and small amounts of Sitanion hystrix. Thus this community consists of a mosaic in physiognomy with mixed shrubby and grassy areas all under a Pinus ponderosa overstory. It is designated Pinus ponderosa/Arctostaphylos-Ceanothus/ Pteridium community.

Figure 17. Photograph of Pinus ponderosa-Pseudotsuga community with Castanopsis understory.

Figure 18. Photograph of the shrub component of the Pinus ponderosa community.

Figure 19. Photograph of a graminoid component of the Pinus ponderosa community.

Figure 20. Photograph of Pinus ponderosa-Libocedrus/Purshia community.

On slightly lower slopes, two additional species, Libocedrus decurrens and Purshia tridentata assume progressively greater importance until they eventually achieve the status of co-dominant and dominant in their respective layers (Figure 20). Where this is the case the stands are very depauperate from the standpoint of abundance and number of herbaceous species. These stands are designated as members of the Pinus ponderosa-Libocedrus/Purshia community.

The communities described above are delineated in Figure 21.

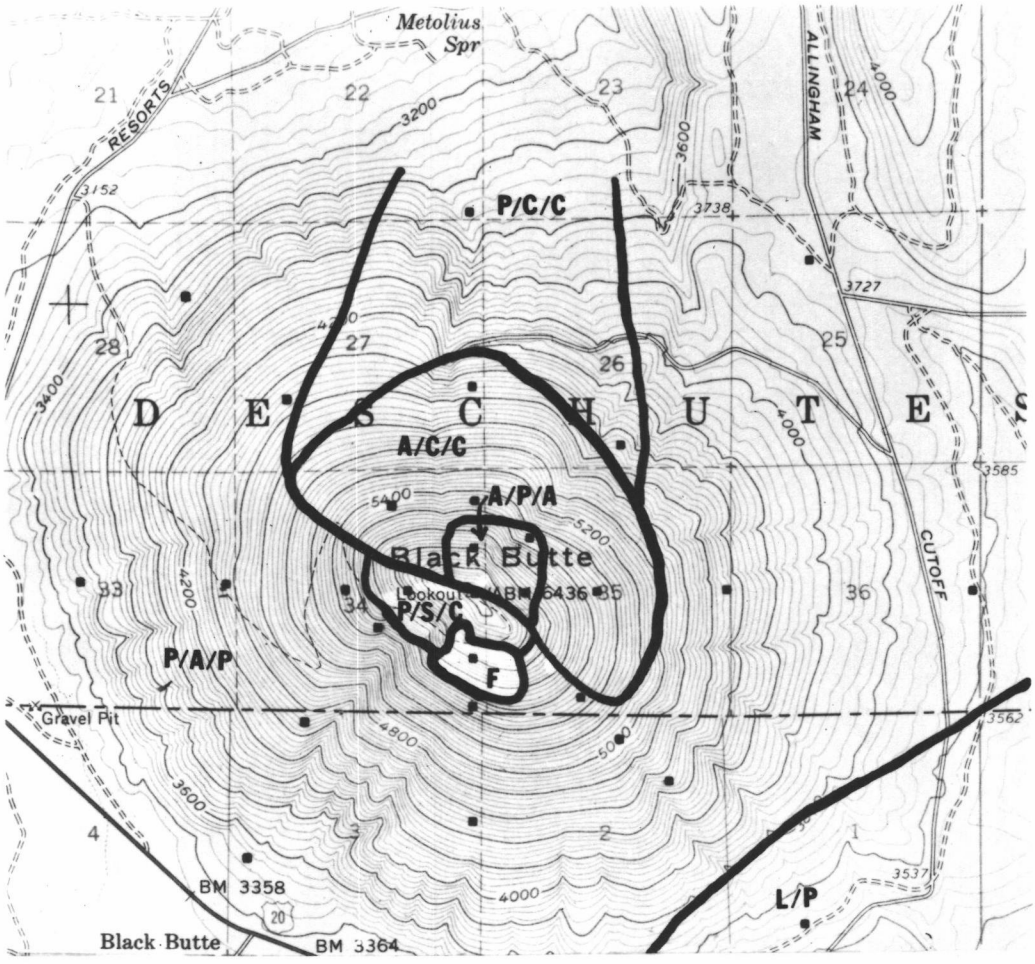

Figure 21. Delineation of existing communities on Black Butte.
A/P/A indicates Abies lasiocarpa/Pachistima/Arnica community.
A/C/C indicates Abies grandis/Castanopsis/Chimaphila community.
P/S/C indicates Pinus albicaulis/Symphoricarpos-Ribes-Amelanchier/Collomia community.
F indicates Festuca community.
P/C/C indicates Pinus ponderosa-Pseudotsuga/Ceanothus/Cynoglossum community.
P/A/P indicates Pinus ponderosa/Arctostaphylos-Ceanothus/Pteridium community.
L/P indicates Pinus ponderosa-Libocedrus/Purshia community.

DISCUSSION

Any consideration of distributional patterns of plant communities must include two basic elements, the chance patterns of dissemination of species and the variation in the environmental factors which influence these species. On Black Butte it appears that some of these environmental factors are of greater significance than others. Physical features of the soil have already been described as rather uniform, moreso than chemical features which demonstrate variations which tend to accompany variations of other environmental features.

One of the greatest variables with altitude is moisture. Thus, the upper soils (Smt., N64, and S64) which tend to receive the most precipitation are subjected to the greatest leaching. This was reflected in the lower percent base saturation and relatively low pH. The fact that the pH was not lower at these levels of base saturation was probably due to the presence of iron oxides which have a high titration curve, and also conceivably contribute additional ion exchange sites (Dawson, 1967).

Samples from Smt., N64 and S64, also tended to be parallel in other characteristics such as P, K, Ca, and Mg levels. In all three samples, these minerals were present in small amounts. These three samples did show considerable variation in organic matter. The soil from the north slope was much lower in organic matter than

the other two. This trend carried through in the other samples. Samples N48 and NE37 were both low in organic matter, while samples S64, S60, S49, and SE35 were relatively high in organic matter. This may be due to more extensive growth of grasses on the south slopes and the resulting accumulations of organic matter from the fibrous root systems, but in the case of the sample S49 (a very shallow soil) higher percent OM appeared to be due to inclusion of unusual amounts of partially decomposed duff.

The presence of grasses and resulting organic matter is probably also responsible for the higher CEC of the south slope soils and the higher levels of K, in particular in sample S60, a grassy "bald."

P levels did show a definite pattern. All upper slope soils were very low in phosphate, but P levels in lower slope soils, especially those on south slopes, were extremely high. Youngberg (1968) could not recall any forest soils with P levels of this magnitude. However, he suggested that in areas of relatively high manzanita litter, P levels would tend to be somewhat higher than usual. In these soils, phosphate is primarily organic in origin and consequently more closely reflects than governs the distribution of various plant species.

Other than these variations, the soils were quite uniform, certainly with less variation than that reported within associations by Daubenmire (1952) and definitely not approaching the variation demonstrated by the vegetation on Black Butte.

The variation of severity both between different fires and within a single fire has probably greatly influenced the fire scar record. It is obvious from the presence of trees with charred but unbroken bark that some ground fires have passed through areas without resulting in permanently scarred woody tissue. The other extreme, very severe fires, could result in complete destruction of the trees. An indication of the severity of these fires may be gained by a comparison of Figure 10, an Abies lasiocarpa stand at the summit, with Figure 9, the area burned in 1946.

Fire of this magnitude is strongly suggested for nearly all upper slopes, even on much of the more mesic northeast slope, by the general absence of fire scarred trees and the abundance of charred wood on the surface of the ground. Many of these areas also have evidence of fire in their species composition. Upper south slopes are in general grassy or shrubby with poor overstory representation. Arctostaphylos patula, Pinus contorta and Larix occidentalis, commonly regarded as fire perpetuated species (Daubenmire, 1952), were found scattered on much of the upper north slope. However, reproduction of these species on these sites is now essentially nonexistent (Table 9, Appendix). In fact, the presence of dead Arctostaphylos patula is a common characteristic of the rapidly closing openings in the north slope fir forest.

It also appears that very few trees of great age are present on

upper slopes. Spot checks of Pinus albicaulis and Abies lasiocarpa (Table 8, Appendix) revealed only occasional specimens with more than 130 annual growth rings when sampled at breast height.

This is in contrast to the many trees well over 300 to 400 years of age in the pure Pinus ponderosa stands (Sherman, 1966) where fire has been of a more moderate intensity, but sufficient to cause many scars.

Variation of meterological factors was not measured directly. Relative insolation as calculated on the basis of percent slope, aspect and elevation gives one a general impression of the great differences between north and south slopes.

This latter consideration in particular serves to make upper elevation south slopes a very harsh environment. These sites are subjected to both the greatest radiation load during the day and most rapid cooling via reradiation during the night.

On Black Butte, the upper south and west slopes are also subjected to the full force of the winds which are usually most severe in winter and spring. These winds tend to promote physiologic drought in two ways. In the winter, they carry much of the snow to the lee slopes of the butte and when dry they contribute to greater evapotranspiration stress on the exposed sites. They also cause mechanical damage which may be observed from 5000 feet to the summit.

Temperature stratification is also of significance on Black Butte,

especially during the growing season. Daubenmire (1947) indicates a decrease of approximately 3° F for each 1000 feet increase in elevation. This would amount to about a 10° difference from the base of the butte to the summit, assuming inversions did not occur. These, of course, may be fairly common in areas where nighttime cold air drainages are favored by steeply sloping topography and result in thermal belts at mid-slope approximately 1000 feet above the base of the slope (Hays, 1941). However suitable traps for cold air accumulation are lacking at the base of Black Butte and therefore strong local inversions are unlikely.

With all of these environmental considerations compounded by the physiologic variation between and among species and chance distributions of species both in time and space, it is not surprising that a unidimensional or even a two dimensional stand ordination proves unsatisfactory. This is essentially the same conclusion reached by Buell et al. (1966) in the description of the upland forest continuum in northern New Jersey. It was their conclusion that the results of unidimensional approaches were most likely expressions of successional status rather than rankings of stands along a gradient. It is this author's impression that the unidimensional continuum on the east slope of the Cascades described by Swedberg is in part a product of these same processes.

The communities described herein are quite similar in overstory

composition and elevational sequence to those described by Swedberg. They are also similar in understory composition.

Swedburg found Tsuga mertensiana, Abies lasiocarpa and Pinus albicaulis from 6000 feet down to 5400 feet. At the upper limits, Abies amabilis was present, while Pinus contorta was found at the fringes of the zone. Shrubs characteristic of this area included Arctostaphylos patula, Arctostaphylos nevadensis, Ceanothus velutinus, and Vaccinium scopulinum. Pyrola secunda and Penstemon nemorosus were characteristic of the sparse herb layer.

Thus, it is apparent that the composition of this community closely matches the upper segments of that designated as the Abies lasiocarpa community (at about 6400 feet) in the current study. However, Swedburg's stands had a greater Tsuga mertensiana component.

Daubenmire (1952), on the basis of studies in the Rocky Mountains, indicated Abies lasiocarpa as the apparent climax. However, Franklin and Mitchell (1967) point out, contrary to Baker (1950), that Abies amabilis and Tsuga mertensiana, which are generally absent in the Rocky Mountain area but present in the Cascade Mountains, are more shade tolerant. They have thus reached the conclusion that Abies lasiocarpa is seral on most sites in the Cascades. This conclusion is well documented with data such as that for their Big Lake stand (12 miles southwest from Black Butte), which showed similar although somewhat simpler species and age class patterns to

plot N60 (Table 9, Appendix). Pinus contorta was found to be giving way, especially in the under 4-inch class to Abies lasiocarpa. Moreover, Tsuga mertensiana was just beginning to invade the site.

Franklin and Mitchell refer to their Santiam Pass site approximately 10 miles west from Black Butte as representing a near climax forest of Abies amabilis and Tsuga mertensiana with age class patterns indicating Abies amabilis will eventually replace Tsuga mertensiana. This stand was also similar to N60 in that Pinus monticola and Pinus contorta were represented in the older age groups but were either dead or, if living, not successfully reproducing.

Both of these sites are situated at about 5000 feet on the Cascade crest and receive about 60 inches annual precipitation. Franklin and Mitchell's Wenatchee province, which is free of Abies amabilis and Tsuga mertensiana but includes Pinus contorta, Pinus monticola, Abies grandis, and Pseudotsuga menziesii, is relatively dry despite its elevation and, probably because of this, Picea engelmanii is often absent. This also resembles the situation on Black Butte.

Swedburg also found that Pinus contorta, especially in larger size classes, was abundant from 5400 to 4800 feet. Abies lasiocarpa and Tsuga mertensiana were present primarily in younger age classes at the lower fringe of this zone which marked their approximate lower limits. This elevation also represented the upper limit of Pinus monticola which was apparently represented primarily by mature

individuals and Abies grandis which was present only in the small size classes. Occasional large Pinus ponderosa were also found there. Understory species included Arctostaphylos nevadensis, Pyrola secunda, Chimaphila umbellata and Chimaphila menziesii. In addition, considerable dead Arctostaphylos patula was present. This bears very strong resemblence to N55 on Black Butte with the exception that N55 has very heavy representation in the < 4 inch DBH class and has apparently experienced more recent disturbance.

As on stands E55, NW55, and N45 on Black Butte, Swedburg found Abies grandis to be dominant in all size classes but at 4800 to 4000 foot elevations the occurrence of relict Pinus ponderosa and over-mature Pinus contorta was relatively common. Swedburg found essentially the same understory species as this author found in the Abies grandis community on Black Butte. Below 4000 feet down to about 3300 feet, Swedburg observed that the dominant, Abies grandis, gave way to increasing numbers of Pseudotsuga menziesii, Libocedrus decurrens and Pinus ponderosa. However, Abies grandis was reproducing heavily under the Pseudotsuga menziesii overstory. As at higher elevations, Pinus ponderosa was present only in the large size classes.

Castanopsis was the common shrub, especially in openings. At slightly lower elevations, a Pinus ponderosa community characteristic of much of the lower slope was observed. This was open with many

shrubby species such as Arctostaphylos patula, Ceanothus velutinus, and Purshia tridentata. Tree reproduction was observed to include, in addition to Pinus ponderosa, many seedlings of Pseudotsuga menziesii and especially Libocedrus decurrens.

This pattern of zonation repeats almost precisely the pattern of zonation observed on Black Butte. However, the equivalent zones on Black Butte, especially the more mesic ones are approximately 500 feet higher in elevation. Especially striking is the repeated close correlation of overstory dominants and associated shrubs and herbs. It is also apparent in comparisons of the size (age) class patterns for trees on Black Butte (Table 9, Appendix) with those described above, that the same successional trends are occurring. Thus, Swedburg's own data support both the concept of repeatable communities in space and the lack of validity of application of the continuum concept in seral vegetation.

This being the case, it seems potentially more profitable to attempt to define boundaries of various combinations of species in terms of the habitat types represented.

Certainly it is recognized that the communities which may come to occupy various habitat types described below will intergrade with adjacent communities, and will therefore form ecotones rather than absolute boundaries. However, the width of these ecotones would not be expected to approach that of the communities they separate.

Habitat type has been defined (Daubenmire, 1952) as "the collective area which one association occupies or will come to occupy as succession advances." That succession prior to 1905 was continually turned back or interrupted by the numerous fires is a certainty.

On the basis of current trends, it appears that, barring catastrophic disturbances such as fire and logging, the vegetation of Black Butte may be represented as belong to six distinct associations (Figure 22).

North slopes from the summit to about 5000 feet will come to be occupied by the tolerant Abies lasiocarpa. Species such as Pinus contorta and Pinus monticola which are presently found on these sites are not represented in the younger age classes and will be replaced. Given extremely long periods of time, Tsuga mertensiana would probably achieve at least co-dominance with Abies lasiocarpa. However, two features of Black Butte do not favor this situation. The number of individuals of Tsuga available as a seed source is exceedingly low and the sites available to it are very marginal from the standpoint of adequate moisture. Therefore, this type is somewhat intermediate to that described by Daubenmire (1952) and that described by Franklin and Mitchell (1967).

The Pinus albicaulis type occupies approximately the same elevational limits as the Abies lasiocarpa type but is restricted to the

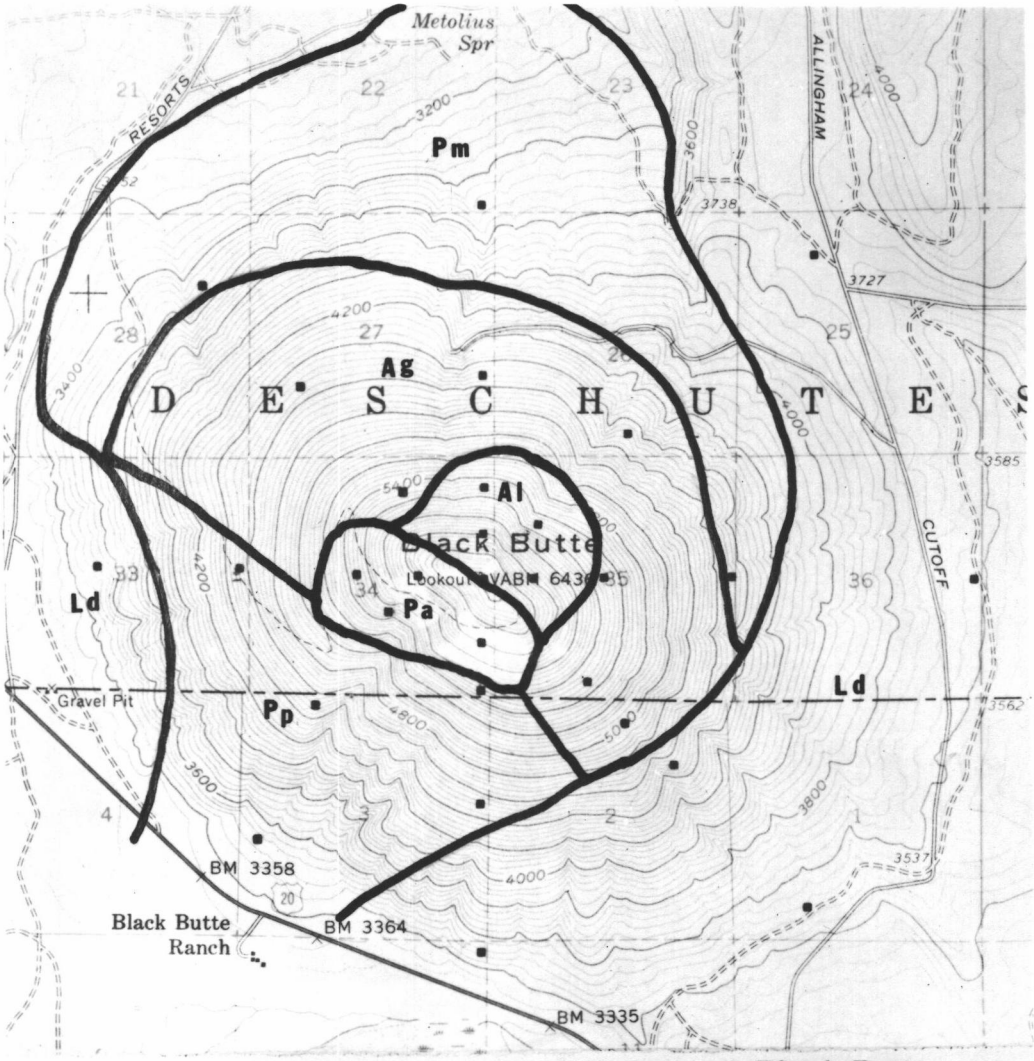

Figure 22. Delineation of habitat types on Black Butte.
Al indicates Abies lasiocarpa type.
Ag indicates Abies grandis type.
Pa indicates Pinus albicaulis type.
Pm indicates Pseudotsuga menziesii type.
Pp indicates Pinus ponderosa type.
Ld indicates Libocedrus decurrens type.

south-southwest exposures which are relatively xeric due to high levels of insolation and their direct exposure to the prevailing winds. Because of the severe nature of this type, its occupancy by the major tree species will proceed at a much slower rate than that observed on north slopes. Thus, the grassy and shrubby areas which presently occupy the south-southwest slopes at about 6000 feet will persist for some time to come. However, as isolated individuals do become established, the moderating influences of these individuals will promote a more rapid development of the climax.

The extent of advance of this association from its present lower limits at approximately 5500 feet is uncertain. It appears from age profiles on adjacent lower west slopes that relict Pinus ponderosa will be purged from these sites by Abies grandis and Pseudotsuga menziesii as well as Pinus albicaulis. Thus the Pinus albicaulis type is indicated in Figure 22 as bordering the Abies grandis and Pseudotsuga menziesii type on the west rather than the Pinus ponderosa to which it is now adjacent. On the south, the present boundary of Pinus albicaulis and Pinus ponderosa will probably prevail, but perhaps at a slightly lower elevation.

The Abies grandis type occupies the majority of the middle and lower north slope of Black Butte. The dominant species on most of these lower slopes is at the present Pinus ponderosa. Larix occidentalis is also presently occupying this type although it rarely

equals the density of Pinus ponderosa. Throughout its lower elevation, this type is also occupied by large quantities of Pseudotsuga menziesii which is considered the dominant of the next lower type. This boundary is very indistinct but, on the basis of the work by Pharis (1966), it is likely that it will probably be defined at the point where Abies grandis is limited due to moisture stress. On the more mesic sites, now supporting young Pseudotsuga menziesii, Abies grandis will probably prevail as a result of its greater shade tolerance.

The Pseudotsuga menziesii type is very limited, restricted to the lower north slope sites and slightly higher elevations on the west and east exposures due to the presence of the more mesic Abies grandis and the more xeric Libocedrus decurrens, both of which are rated as more shade tolerant. Thus, Libocedrus decurrens is capable of surpassing Pseudotsuga where Abies does not.

The Libocedrus decurrens type is at present difficult to define. It is slightly more xeric than the Pseudotsuga menziesii type, but due to present distributional patterns in which Libocedrus is essentially restricted to the east slope, it is difficult to project its zone of occupancy on the lower west slope. This restriction is apparently the result of repeated burning to which Libocedrus seedlings are highly susceptible. However, mature Libocedrus, because of their thick bark, are very resistant to ground fire and thus relicts, present in some areas, are a seed source.

Pinus ponderosa, the most xeric and intolerant of the tree species present in quantity on the butte, is presently greatly extended beyond the limits of its habitat type. This is very clear in the size class profiles of many north slope and upper elevation sites which are predominantly Pinus ponderosa overstory with other more tolerant species relatively more abundant in the sapling and seedling class. On lower slopes in areas of moderate insolation, Libocedrus is coming to occupy a large portion of this Pinus ponderosa range. Thus, it appears that the habitat type of Pinus ponderosa is restricted to the areas of high insolation on the middle and lower south and southwest slopes. Possibly Purshia tridentata will eventually form the subordinate union on these sites, but is presently excluded from the upper areas of the type due to lack of a seed source.

SUMMARY AND CONCLUSIONS

Black Butte presents a unique natural laboratory for ecological study. Its uniform configuration and soils make it possible to attribute many differences in vegetational distribution to the influences of altitude and aspect. However, historical factors, especially the repeated burning in the years prior to 1905 and present exclusion of fire have strongly influenced the vegetation.

In an analysis of the vegetation of Black Butte designed along the lines of a continuum analysis, it is possible to demonstrate via relative importance values that some species gradually give way to other species along environmental gradients. However, this conclusion is not considered as validating the continuum concept. Consideration of the vegetation in the context of succession reveals that definite communities may be described for the present vegetation. Moreover, the age class profiles of mixed stands indicate that they are not stable and therefore with freedom from the disturbance by fire or other catastrophe will come to be less hetergenious in overstory species composition. In most instances, this will be at the expense of Pinus ponderosa which, due to its superior resistance to fire, has been able to occupy and thrive in habitats considerably more mesic than its true habitat type. After 60 years of fire exclusion, species of greater shade tolerance and with higher moisture

requirements are now responding with relatively greater reproduction than Pinus ponderosa on these mesic sites.

These patterns of reproduction allow one to project to the climaxes which will come to occupy various portions of this butte. Six different habitat types are identified. These include areas which will come to be dominated by Abies lasiocarpa, Pinus albicaulis, Abies grandis, Pseudotsuga menziesii, Libocedrus decurrens, and Pinus ponderosa. These types are presently represented in varying degrees by combinations of the components of existing communities.

These distributional patterns are very similar to those described by other workers for the east slope of the Cascades. However, due to the relatively xeric conditions of Black Butte, equivalent types occur at approximately 500 feet higher elevation.

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Table 7. Species encountered on sample site. (Nomenclature based on M. E. Peck (1961) except as noted.)

Abies grandis Lindl. *
Abies lasiocarpa (Hook.) Nutt.
Achillea millefolium L. var. lanulosa (Nutt.) Piper**
Agoseris glauca (Pursh) Raf. var. monticola (Greene) Q. Jones ex Cronq. **
Agropyron spicatum (Pursh) Scribn. and Sm.
Amelanchier florida Lindl.
Apocynum pumilum (Gray) Greene.
Aquilegia formosa Fischer.
Arctostaphylos nevadensis Gray.
Arctostaphylos patula Greene.
Arnica latifolia Bong.
Balsamorahiza deltoidea Nutt.
Bromus orcuttianus Vasey
Bromus tectorum L.
Calamagrostis rubescens Buckl.
Carex spp.
Castanopsis chrysophylla (Dougl.) A. DC.
Ceanothus velutinus Dougl.
Chamaesachara nana Gray.
Chimaphila menziesii (R. Br.) Spreng.
Chimaphila umbellata (L.) Nutt. var. occidentalis (Rydb.) Blake
Cirsium americanum Robins.
Cirsium vulgare (Savi) Airy-Shaw.
Clarkia rhomboidea Dougl.
Collomia grandiflora Dougl.
Comandra pallida A. DC. **
Crepis acuminata Nutt.
Cynoglossum occidentale Gray.
Epilobium angustifolium L.
Erigonum proliferum Torr. and Gray.
Erigonum umbellatum Torr.
Festuca idahoensis Elm.
Festuca occidentalis Hook.
Festuca ovina L.
Festuca viridula Vasey.
Fragaria virginiana Druch. ssp. platypetala (Rydb.) Staudt. **
Fritillaria autopurpurea Nutt.
Gayophytum diffusum Torr. and Gray.
Gillia aggregata (Pursh) Spreng.
Goodyera oblongifolia Raf.
Hackelia californica (Gray) Johnst.

Table 7. (Continued)

Haplopappus bloomeri (Hook.) Gray
Hieracium albiflorum Hook.
Hieracium scouleri Hook.
Hydrophyllum capitatum Dougl.
Juniperus occidentalis Hook.
Kelloggia galioides Torr.
Larix occidentalis Nutt.
Lathyrus lanszwertii Kill. ssp. aridus (Piper) Bradshaw.
Libocedrus decurrens Torr.
Lillium washingtonianum Kell.
Lithospermum ruderale Dougl.
Lomatium lallii (Wats.) C. and R.
Lomatium martindalei C. and R.
Lupinus caudatus Kell.
Melica aristata Thurb.
Montia perfoliata (Donn) Howell var. depressa (Gray) Jenson
Osmorhiza chilensis (Hook.) Arn.
Pachystima myrsinites (Pursh) Raf.
Penstemon euglaucus English.
Penstemon nemorosus (Dougl.) Trautv.
Phacelia heterophylla Pursh.
Pinus albicaulis Engelm.
Pinus contorta Loud.
Pinus monticola Dougl. ex D. Don
Pinus ponderosa Dougl.
Poa alpina L.
Poa ampla Merr.
Poa compressa L.
Populus tremuloides Michx.
Prunus emarginata (Dougl.) Walp.
Pseudotsuga menziesii (Mirb.) Franco.
Pteridium aquilinum (L.) Kuh. var. pubsecens Underw.
Pterospora andromedea Nutt.
Purshia tridentata (Pursh) DC.
Pyrola picta J. E. Sm.
Pyrola secunda L.
Ribes cereum Dougl.
Rosa gymnocarpa Nutt.
Salix scouleriana Barr.
Silene douglasii Hook.
Sitanion hystrix J. G. Sm.
Smilacina racemosa Desf.
Sorbus sitchensis Roem.

Table 7. (Continued)

Staphanomeria lactucina Gray.
Stipa spp.
Symphoricarpos vaccinoides Rydb. **
Tsuga mertensiana (Bong.) Sarg.
Vaccinium caespitosum Michx.
Vicia americana Muhl. var. oregana (Nutt.) Nels.
Viola purpurea Kell.

*This taxon represents both Abies grandis and A. concolor Lind. and Gord. which apparently hybridize freely on Black Butte (Johnson, 1961).

**Consult Johnson (1961).

Table 8. Tree DBH and age data.

Elevation	Aspect	Species	DBH	Age BH
6430 feet	N	Pinus albicalus	8.2	84
"	E	"	8.5	80
"	N	"	9.1	90
"	N	"	9.6	85
"	N	"	10.9	87
"	N	"	12.9	85
"	E	"	13.5	105
"	N	Abies lasiocarpa	6.7	97
"	N	"	7.0	95
"	N	"	7.8	130
"	N	"	8.8	160
"	E	"	9.0	65
"	E	"	9.0	65
"	E	"	10.0	80
"	N	"	10.4	127
"	N	"	10.5	129
"	N	"	11.7	110
"	N	"	12.4	125
"	N	Tsuga mertensiana	12.5	125
3500 feet	NW	Abies grandis	12.0	50
"	"	"	12.0	50
"	"	Pseudotsuga menziesii	9.5	30
"	"	"	12.0	35
"	"	"	17.0	35
"	"	"	17.5	45
"	"	"	27.0	85
"	"	Pinus ponderosa	.7*	41
"	"	"	.8*	31
"	"	"	1.0*	30
"	"	"	1.0*	45
"	"	"	2.0*	47
"	"	"	2.0*	50
"	"	"	3.5*	55
"	WNW	Pinus ponderosa thicket #1	.8*	56
"	"	"	1.0*	40
"	"	"	1.2*	50
"	"	"	1.25*	53
"	"	"	1.5*	47
"	"	"	2.0*	52

Table 8. (Continued)

Elevation	Aspect	Species	DBH	Age BH
3500 feet	WNW	Pinus ponderosa thicket #1	2.5*	52
"	"	Pseudtosuga menziesii	12.0	55
"	"	"	12.0	56
"	"	Pinus ponderosa thicket #2	.8*	35
"	"	"	1.1*	36
"	"	"	1.1*	41
"	"	"	1.2*	41
"	"	"	1.2*	45
"	"	"	1.4*	40
"	"	"	1.8*	43
"	"	"	2.0*	35
"	"	"	3.3*	49
3700 feet	E	Pinus ponderosa thicket #1	1.1	34
"	"	"	1.1	38
"	"	"	1.3	43
"	"	"	1.5	39
"	"	"	1.6	40
"	"	"	2.1	45
"	"	"	2.5	50
"	"	"	2.5	48
"	"	Pinus ponderosa thicket #2	1.1*	45
"	"	"	1.5*	35
"	"	"	2.5*	52
"	"	"	2.7*	52
"	"	"	3.0*	47
"	"	"	3.0*	51
"	"	"	3.5*	52
"	"	"	4.5*	53
4200 feet	SE	Pinus ponderosa thicket #3	2.2*	53
"	"	"	2.6	55
"	"	"	3.8	55
"	"	"	3.9	57
"	"	"	3.7	60

Table 8. (Continued)

Elevation	Aspect	Species	DBH	Age BH
4200 feet	SE	Pinus ponderosa thicket #3	4.5	55
"	"	"	4.5	56
"	"	"	4.5	60
"	"	"	4.5	60
"	"	Libocedrus decurrens	3.7	50
3750 feet	S	Pinus ponderosa	2.5	30
"	"	"	2.8	34
"	"	"	3.0	33
"	"	"	3.2	32
"	"	Libocedrus decurrens	2.5*	47
"	"	"	3.2*	56
5400 feet	E	Pinus ponderosa	3.8*	356
"	"	Abies grandis	4.0*	117

*Diameter and ring count of stump near ground level.

Table 9. Number of trees per acre calculated by size classes (DBH) in stands indicated.

Plot and species	Size classes (diameter in inches)					
	< 4	4-11.9	12-19.9	20-27.9	28-35.9	36+
N60						
Abies lasiocarpa	1832	210	13			
Pinus monticola		16	13			
Pinus contorta		8				
Tsuga mertensiana		4				
Abies grandis	57	13				
NE55						
Abies lasiocarpa	1380	197	38	4		
Pinus monticola		4				
Tsuga mertensiana		4				
Abies grandis	303	72	15		4	4
Larix occidentalis		19				
Pseudotsuga menz.			4			
Pinus albicaulis		8				
Pinus ponderosa			4			
E60						
Abies lasiocarpa	485	243	60			
Abies grandis	26	64	19			
Pseudotsuga menz.			5			
Pinus albicaulis	16	41	23			
N55						
Abies lasiocarpa	281	95				
Pinus monticola	155	107	4			
Abies grandis	259	103	66			
Pseudotsuga menz.	44	17	4			
Pinus ponderosa		8		4		
E55						
Abies lasiocarpa	36	16	8			
Abies grandis	693	152	49	18	5	
Pinus albicaulis		3				
Pinus ponderosa					3	3
W60						
Abies lasiocarpa	6					
Abies grandis	28	33	2			
Pinus albicaulis	173	156	16			
Pinus ponderosa	3	14				
W55						
Abies grandis		1				
Pinus albicaulis	68	25	1			
Pinus ponderosa	39	24	9	1	7	6

Table 9. (Continued)

Plot and species	Size classes (diameter in inches)					
	< 4	4-11.9	12-19.9	20-27.9	28-35.9	36+
SW55						
Pinus albicaulis	3	4				
Pinus ponderosa	17	5	3	2	7	2
S60						
Pinus albicaulis	2	1	T*			
Pinus ponderosa	T	T	T			
Juniperus occidentalis	T					
NW55						
Albies grandis	690	293	34	23	8	
Pinus albicaulis		8				
Pinus ponderosa		4	4	8		
N45						
Abies grandis	798	89	20	8		
Pseudotsuga menz.	79	37	12	4		2
Pinus ponderosa		4		8	8	
NE45						
Abies grandis	549	74	6	1		
Larix occidentalis	13	4				
Pseudotsuga Menz.	45	19		1		
Pinus ponderosa	39	3	3	6	13	7
SE55						
Abies grandis	281	46	4	6	1	
Pinus ponderosa	70	9	6	5	8	4
SE50						
Abies grandis	142	17	T	T	T	
Pseudotsuga menz.		3				
Pinus albicaulis	3					
Pinus ponderosa	177	8	8	12	7	3
NW45						
Abies grandis	61	52			6	2
Larix occidentalis		2				
Pseudotsuga menz.	72	45				
Pinus ponderosa	412	21	21	23	8	12
Libocedrus decurrens		11				
NW35						
Abies grandis	13	8				
Pseudotsuga menz.	4	8				
Pinus ponderosa	403	4	3	14	9	T

Table 9. (Continued)

Plot and species	Size classes (diameter in inches)					
	< 4	4-11.9	12-19.9	20-27.9	28-35.9	36+
N35						
Abies grandis	73	243				
Pseudotsuga menz.	233	146				3
Pinus ponderosa	57	5	10	12	27	5
Libocedrus decurrens	40					
E45						
Abies grandis	127	19				1
Larix occidentalis		2				
Pseudotsuga menz.	71	19	1			2
Pinus ponderosa	1189	19	10	16	8	2
Libocedrus decurrens	28	2				
NE37						
Abies grandis		3	T			
Pseudotsuga menz.	136	34	3			
Pinus ponderosa	829	12	4	3	7	4
Libocedrus decurrens	543	2				
S55						
Abies grandis	T					
Pinus ponderosa	21	30	25	24	12	3
SW35						
Abies grandis	1					
Pinus ponderosa	79	11		2	8	T
W45						
Abies grandis		1				
Pinus ponderosa	214	23	9	13	9	6
Libocedrus decurrens		1				
SW45						
Pinus ponderosa	1339	9	14	21	8	3
S45						
Pinus ponderosa	37	13	32	16	5	
Libocedrus decurrens	11		1			
W35						
Pinus ponderosa	570	10	5	5	4	1
Libocedrus decurrens	56	1				
SE45						
Pinus ponderosa	78	5	6	11	8	2
Libocedrus decurrens	42	3			1	1

Table 9. (Continued)

Plot and species	Size classes (diameter in inches)					
	< 4	4-11.9	12-19.9	20-27.9	28-35.9	36+
S35						
Pinus ponderosa	363	39	12	5		
Libocedrus decurrens	91	10		1		1
Juniperus occidentalis	5					
E35						
Pinus ponderosa	173	10	8	10	8	1
Libocedrus decurrens	910	6	2	T		1
SE35						
Pinus ponderosa	516	8	9	9		
Libocedrus decurrens	918	31	1	2	1	1

*Trace