THE CONIFEROUS ECOTONE OF THE EAST SLOPE OF THE NORTHERN OREGON CASCADES

by

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

Page

LIST OF FIGURES

LIST OF FIGURES (Continued)

THE CONIFEROUS ECOTONE OF THE EAST SLOPE OF THE NORTHERN OREGON CASCADES

INTRODUCTION

Much of the remaining timber resource of the United States is located in the mountainous west. Weaver and Clements (64, p. 481) designate six forest climaxes for North America, with the *Thuja-Tsuga* formation of the coast forest, the *Picea-Abies* formation of the subalpine forest, and the *Pinus-Pseudotsuga* formation of the montane forest all occurring here. Notable in all these formations is the abundance of coniferous species.

The *Thuja-Tsuga* formation lies along the Pacific coast from central California through southern Alaska. It is bounded on the east by the Sierra Nevada and Cascade Mountains in the United States, and the Rocky Mountains north of the Canadian border. This area has or will develop a climax forest of western red cedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*) under the prevailing climatic conditions (64, p. 500-504). Arboreal pioneers in sandy areas along the Pacific coast are lodgepole pine (*Pinus contorta*) and Sitka spruce (*Picea sitchensis*), with dune stabilization ultimately allowing replacement by western hemlock and western red cedar. Port Orford cedar (*Chamaecyparis lawsoniana*) in southern Oregon, and coast redwood (Sequoia sempervirens) in northern California accompany and eventually replace the lodgepole pine and Sitka spruce along these frequently rocky coasts.

Northward in the vicinity of Washington's Olympic peninsula the coastal zone of Sitka spruce, western hemlock, and western red cedar broadens to some 25 miles in one of the world's most productive forest stands. Mountain hemlock (Tsuga mertensiana) and Alaska yellow cedar (Chamaecyparis nootkatensis) are mixed in with these climax and subclimax species into western British Columbia and southern Alaska. Other northern modifications of this cedar-hemlock climax include grand fir (Abies grandis), silver fir (A. amabilis), and western yew (Taxus brevifolia) in scattered mixed and pure stands as far north as northern British Columbia. Limited to Washington and Oregon is noble fir (Abies procera) (48, p. 35-119).

Inland where conditions are generally more xeric are other exceptions to the hemlock-cedar climax (25, p. 54-57; 38, p. 619-620; 42, p. 457-458). The relatively xerophytic trees such as Douglas fir (Pseudotsuga menziesii) and the more shade tolerant grand fir serve locally as climax species in such areas as the east slope of the Coast Range and the Willamette Valley in Oregon (54, p. 96). The fire resistant Douglas fir, also an aggressive invader of burned areas, exists as a fire maintained subclimax in many areas (54, p. 465).

The west slopes of the Cascades which bound this formation on the east are heavily forested with western white pine (Pinus monticola), western hemlock, silver fir, noble fir, grand fir, Douglas fir, Engelmann spruce (Picea engelmanni), western yew, and western red cedar. These western slopes in northern California and southern Oregon have a forest of sugar pine (Pinus lambertiana), western white pine, ponderosa pine (P. ponderosa), knobcone pine (P. attenuata), Douglas fir, white fir (Abies concolor), California red fir (A. magnifica), and incense cedar (Libocedrus decurrens) (48, p. 7-119).

The subalpine formation has a discontinuous range because of its high altitude or high latitude requirement, and includes areas near the tree line from southern Alaska to Mexico (64, p. 492-496). Engelmann spruce and alpine fir (Abies lasiocarpa) are the chief dominants, with other species of considerable abundance being lodgepole pine, mountain hemlock, dwarf juniper (Juniperus communis var. saxatilis), and alpine larch (Larix lyallii). Of more limited range are California red fir in California and southern Oregon, whitebark pine (Pinus albicaulis) in the western part of the formation, and limber pine (P. flexilis) in the eastern part.

The montane formation is the most extensive of the western forest climaxes, extending from the Black Hills of South Dakota to the mountains of west Texas, southern California, and central British Columbia (64, p. 504). It bears a close relationship to the coast forest, with a number of species being common to both. Ponderosa pine is the most characteristic species of the formation, while Douglas fir and white fir are common in the western part of the region. Lodgepole pine, western larch (*Larix occidentalis*), limber pine, and whitebark pine are also prevalent (64, p. 505). Central Oregon and Washington have extensive stands of western juniper (*Juniperus occidentalis*) occurring in pure stands or in association with ponderosa pine in somewhat more mesic sites.

The Sierran montane forest of California and southern Oregon includes as major dominants sugar pine, ponderosa pine, Jeffrey pine (*Pinus jeffreyi*), Douglas fir, white fir, and incense cedar. The pioneer species in this association is knobcone pine (48, p. 9-95).

Study Location

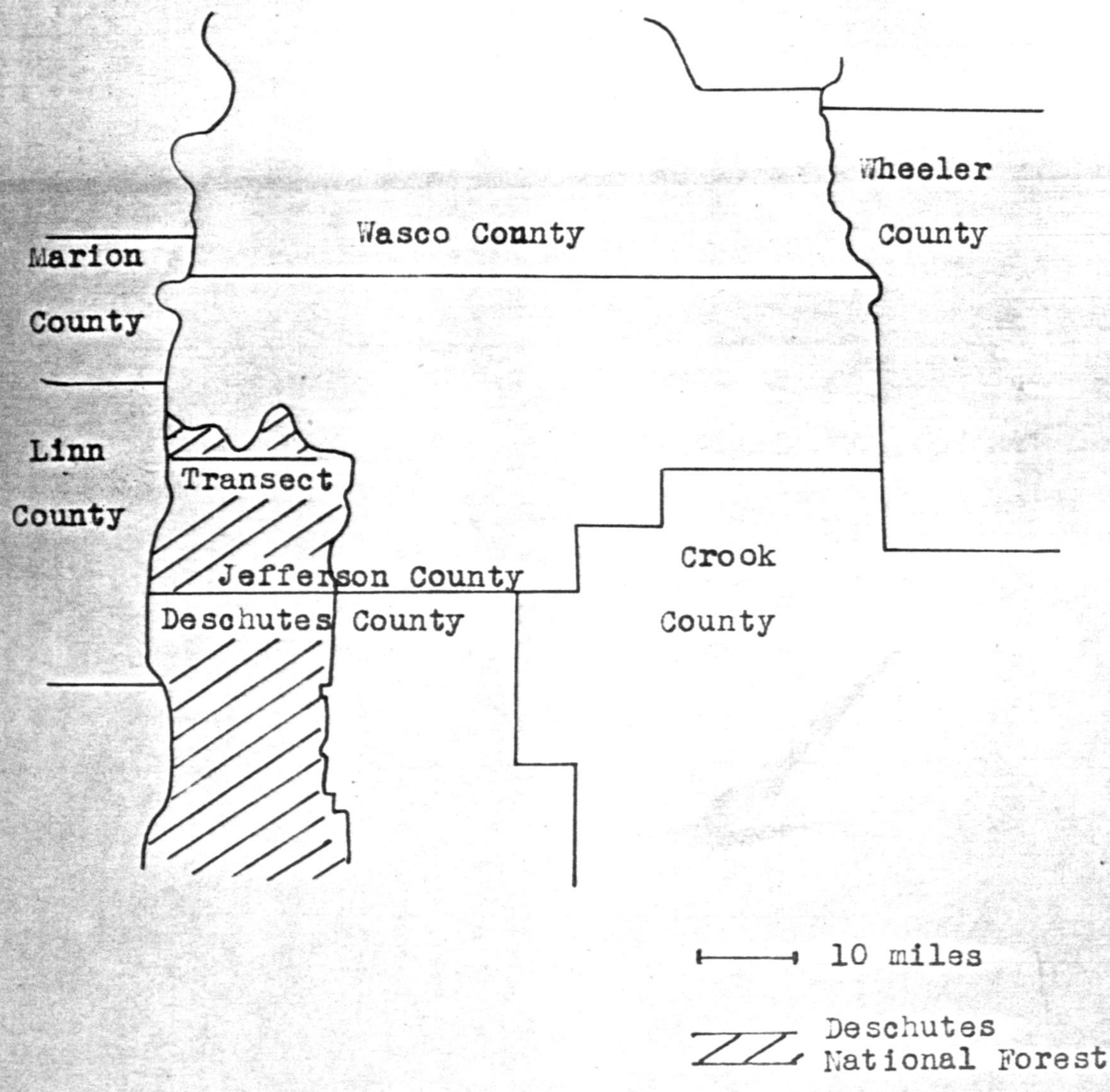
The longitudinally narrow Coast Formation owes its existence to high winter precipitation resulting from consistently on-shore winds from the Pacific Ocean. The eastern boundary of this heavily watered zone is imposed by the orographic effects on rainfall of high, north-south oriented mountain ranges. Within the state of Oregon, this functional barrier is formed by the Cascade Mountains.

The leeward slope of the Cascade Range in Oregon has a rapidly decreasing precipitation gradient from west to east, with this diminution being dramatically exhibited by the ecotonal forest that has developed. Overlapping ranges of species from the above-mentioned climax formations give this slope a profusion of coniferous species.

This study involves the measurement, description, and analysis of a segment of this transition zone between the high elevation fir-hemlock stands to the west, and the juniper woodlands of the northern part of the Great Basin to the east. It is in this sense, including all of the intermediate stands between two vastly different vegetational formations, that the term "ecotone" is here used.

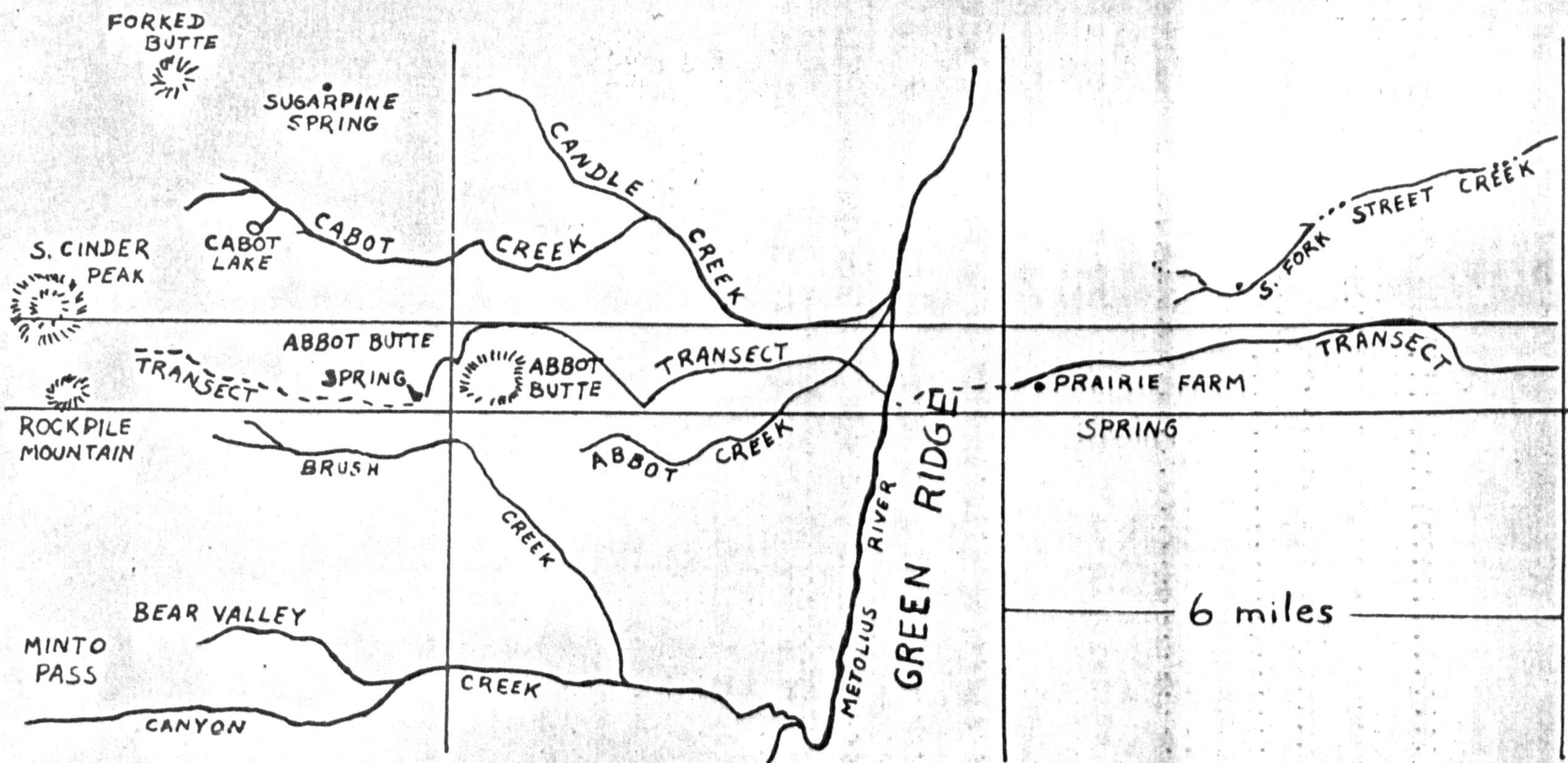
The area selected for the study lies within the northern part of the Deschutes National Forest in western Jefferson County, Oregon, as shown in Figure 1. A transect was established within T. 12 S. of the Mt. Jefferson and Madras Quadrangles, and extends through Sections 3-6 of R.8 E., Sections 1-6 in R. 9E., Sections 1-6 in R. 10E., and Sections 1-2 in R. 11E., as shown in Figure 2. Latitude ranges from approximately 44° 33' N. to 44° 34' N., with the longitude being 121° 47' W. at the western extremity of the transect and 121° 30' W. on the east.

FIGURE 1



Location of Transect

FIGURE 2



MAP OF STUDY AREA

The combination of accessibility and absence of logging disturbance was more favorable here than in any other region viewed during a two weeks' reconnaissance in June, 1959. Sections 3 and 4 of R. 8E. are included within the Mt. Jefferson Primitive Area, thus are free of disturbance; while only salvage operations to remove dead or dying trees have affected the region west of Section 6, R. 10E. East of this point more or less drastic alteration by logging has occurred.

The study was made financially possible by the assistance of a Cooperative Fellowship from the National Science Foundation, which enabled the purchase of necessary equipment and the hiring of appropriate vehicular transportation for traveling the irregularly maintained roads and logging trails in the area.

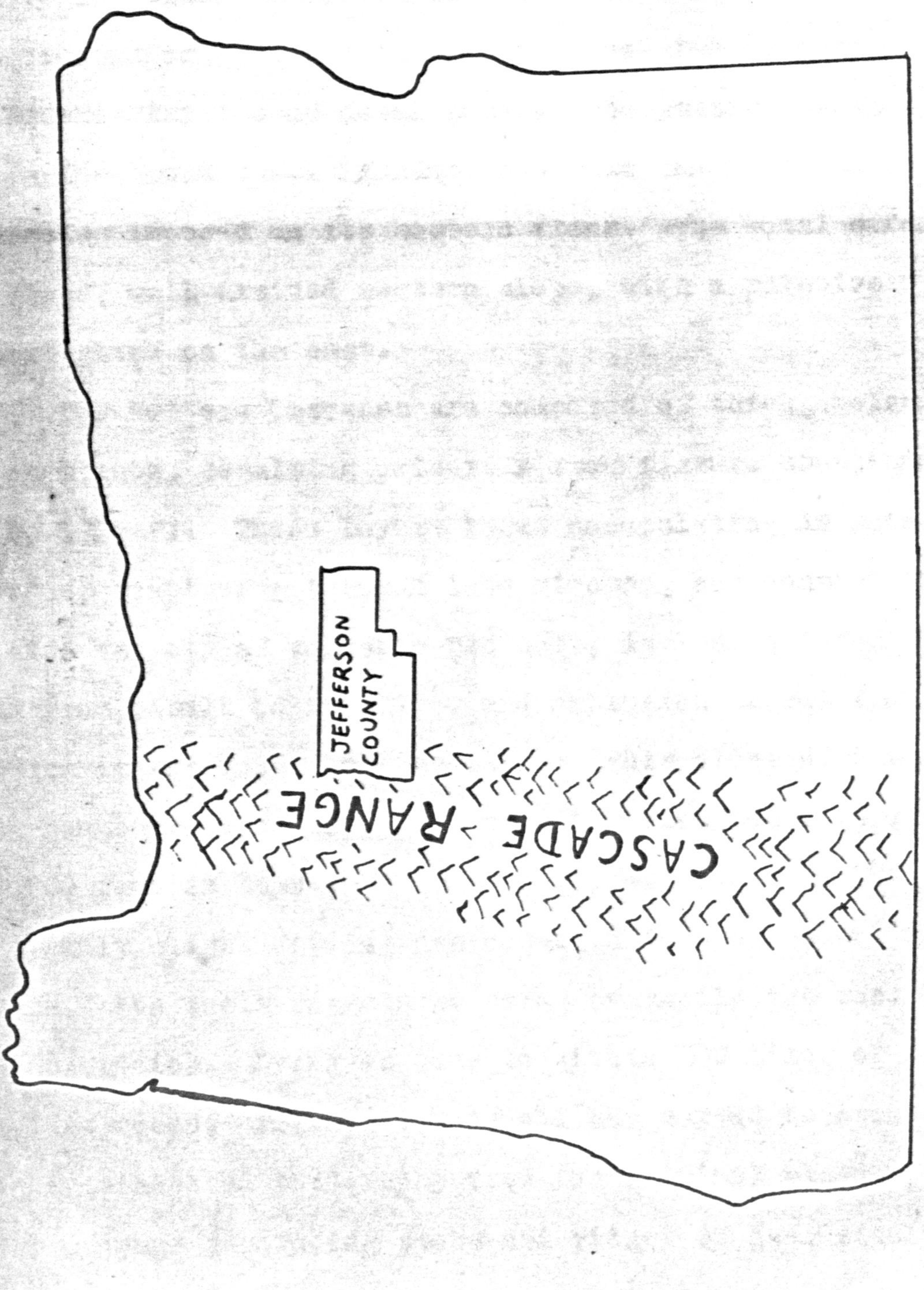
GEOLOGY AND PHYSIOGRAPHY

The Cascade Mountains are the most conspicuous and one of the more important features in the relief of Oregon. This mountain range, with the location of the Oregonian segment shown in Figure 3, is part of the physiographic unit designated Sierra-Cascade Province (17, p. 419). The Cascades are structurally a continuation of the Sierra Nevada fault block mountain to the east of the central Great Valley of California, extending from extreme northern California through western Oregon and Washington to merge with the Rocky Mountains in southern British Columbia.

The orogeny of the Sierra-Cascades Province began in upper Jurassic with the Nevadian disturbance (55, p. 332-333), but that part of the range located within Oregon owes its present height and configuration almost exclusively to deposits in and since the lower Tertiary.

Various parts of the province have quite different developmental histories. The Sierra Nevadas are the result of erosion of a massive fault block, while the Northern Cascades are composed of strongly folded, metamorphosed, granite-intruded sedimentary rocks. The younger Middle and Southern Cascades are considerably more simple in composition, consisting almost exclusively of volcanic rocks. This study is located within the Middle Cascades sub-province.

FIGURE 3



POSITION OF THE CASCADE RANGE IN OREGON

In Oregon, the Cascades in cross-section can be placed into two fairly distinct physiographic divisions (4, p. 51). The older component is the Western Cascades of Eocene to Miocene origin, and the younger the High Cascades of Pliocene-Pleistocene development. The Western Cascades form the broad basal foundation of the range, with the High Cascades imposed on its eastern flank. The total effect is a broad, well drained western slope, with a relatively short slope on the east.

The Western Cascades are composed of thick, volcanic rock strata, resulting primarily from fissure eruptions (68, 1 leaf). These layers began accumulating in late Eocene, continuing through late Miocene, and consist of a wide variety of volcanic products, including lavas ranging from basalt to rhyolite, and explosion debris from coarse agglomerates to fine tuffs. This older division of the range averages 50 miles in width, with deposits up to 13,000 feet in depth.

Only slight folding has occurred in the Western Cascades, with their ruggedness being primarily the result of water erosion. Lying as they do within 100 miles of the Pacific Ocean, orographic rainfall has served to create a highly dissected topography from the original plateau, with deep canyons separating peaks and ridges of near equal height.

Williams believes that the volcanoes of the High Cascades began to erupt in the lower Pliocene. The early outpourings came mostly from broad shield volcanoes with little explosive activity. These quiet flows consisted of gray olivine basalt and olivine-bearing basaltic andesites, with the High Cascades exhibiting less variety of composition than the Western Cascades. Later eruptions in many of the presently existing high peaks were explosive, capping the mountains with fragmental ejecta. Many parasitic cones were formed at the bases of the larger peaks during this time also, with an excellent example on the southwest flank of South Cinder Peak near the west end of the study area (Figure 2).

Pleistocene glaciation has altered the High Cascades to some extent, obliterating many of the parasitic cones, and cutting wide valleys separated by steep, narrow ridges in the major peaks. Glaciers still exist on a number of these High Cascades peaks, including the Three Sisters, Three-Fingered Jack and Mount Jefferson near the area of this study.

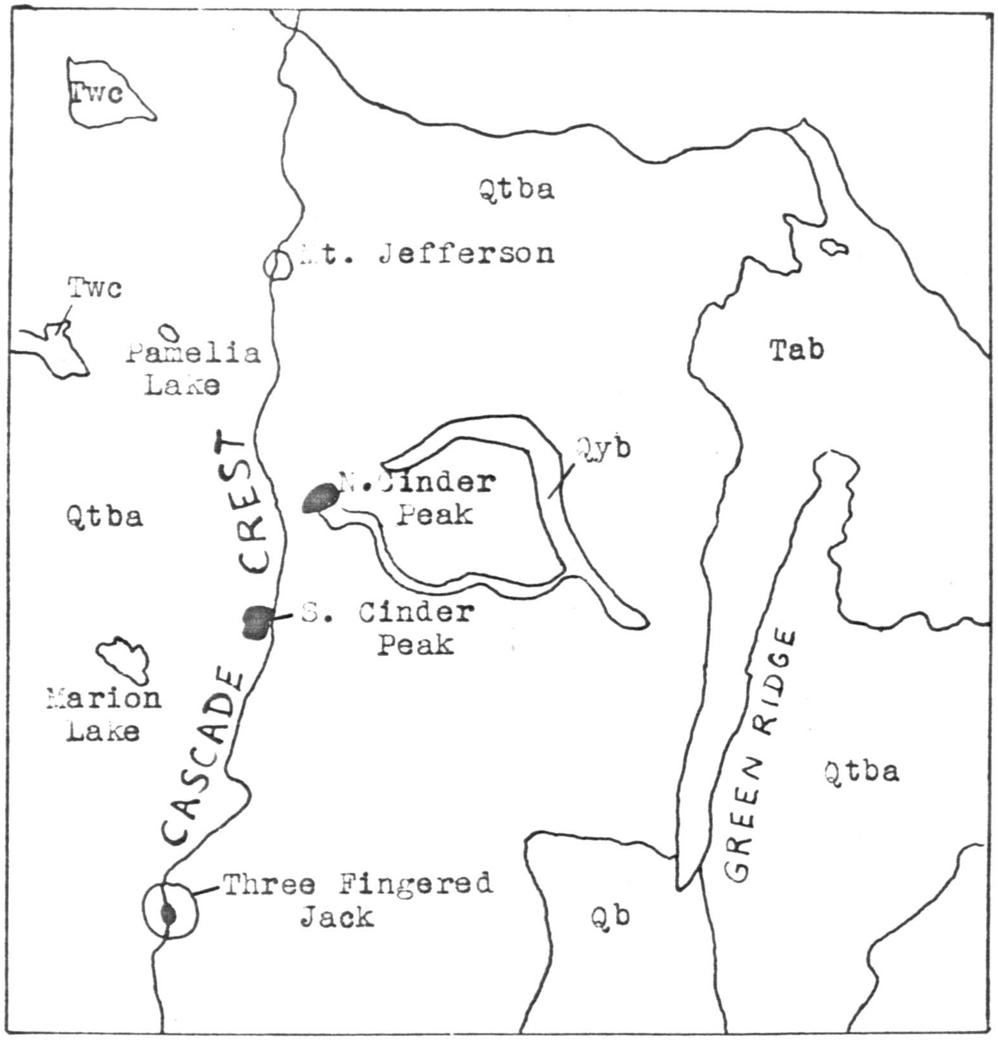
A number of cinder cones, including North and South Cinder Peaks near the western end of the study area, appear unaffected by glaciation, so must have developed after the general recession of the Pleistocene glaciers.

Because of the recent orogeny of the High Cascades and the less abundant rainfall on the leeward slope, the east side of the range is not nearly as dissected as the western slope. Pleistocene glaciation has augmented development of the canyons begun and now continued by stream erosion, but it has left some broad ridges between the canyons that are relatively uncomplicated by north or south facing slopes. Thus it was possible to find gently eastwardly inclined tableland from one to one and one-half miles wide, between the deep canyons of Brush Creek to the south and Cabot Creek to the north (Figure 2).

The drop in elevation from the western end of the transect to the Metolius River a little more than eight miles away, is about 3,000 feet, as shown in Figure 5. The topography here involves a predominantly east facing slope with no north or south facing exposures of consequence. The surface is quite uniform with the exception of Abbot Butte, which was circumvented to the north, and a few ill-defined drainage channels inclined southeastward between one and two miles east of Abbot Butte (Figure 5).

Immediately east of the Metolius River the west facing fault scarp of Green Ridge rises about 1,700 feet within a map distance of one and a quarter miles. The rock strata composing Green Ridge here are gently tilted toward the east, so that the slope in that direction is much more gradual.

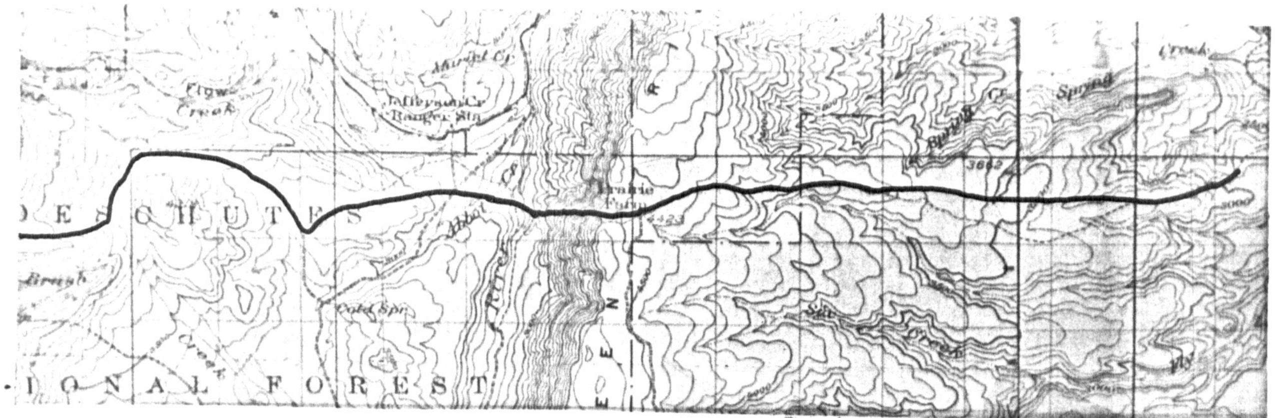
FIGURE 4



Qb - Basalt, basaltic andesite lavas and cinder cones
Qtba - Olivine basalt and basaltic andesite
Tab - Pre-Newberry basalt and andesite
Twc - Volcanoes
Qyb - Youngest basaltic lavas

Adapted from Williams (68,1 leaf)

FIGURE 5



Topographic View of Study Area with Transect Marked by Black Line

The specific area involved in this study is geologically simple. Williams designates only two formations present in the region covered by the transect. The exposed scarp on the west side of Green Ridge consists of well bedded basaltic tuffs, with some pre-Pleistocene basalt and andesite as well (Figure 4). The age of this geomorphically unstable exposure is uncertain, but Williams suggests that the rocks have equivalents in the Western Cascades.

All of the remainder of the area is classified as lavas of olivine basalt and basaltic andesite, much of it being reworked by activity of glaciers and their attendant melt waters. Generally thin layers of soil have developed on the surface of these deposits.

Just north of the transect are the Recent narrow lava flows of olivine basalt in the Jefferson Creek and Cabot Creek canyons. These are similar in appearance to the flows along the Santiam and McKenzie Highways, some of which are postulated to be less than 600 years old (49 p. 32-34).

SOILS

The soils of this area of the Cascades eastern slope are derived from basic igneous rocks of fairly recent, though indeterminate age. All soils checked are listed as loam or sandy loam[1] in texture containing stones of all sizes to ten inches in diameter. The stones are of andesite and basalt, and appear to be larger and more prevalent toward the west. Parent material, containing also some cinders but very little pumice, has been transported, probably as glacial outwash. The sorting of particles indicated by the increased proportion of larger stones to the west would tend to support the idea of an outwash origin.

The soils are classified as regosols, and are moderately well drained to well drained. The loam is soft when dry and very friable when moist. The pH is within the slightly acid range. The upper 18-25 inches are very porous and nearly structureless. Organic material on the surface varies from a trace to approximately one and one-half inches and is little decomposed, particularly at elevations below 4,000 feet. Above this level moisture content of the soil is higher and there is evidence of a fermented layer between the litter and the mineral soil. A three to four

1. Terminology follows that of the U. S. D. A. Soil Survey Manual.

inch dark surface layer is typical, being very dark brown to dark brown in color. Below the surface layer is a dark brown to dark reddish brown layer extending to 18-25 inches below the surface of the mineral soil. This material rests on a soil layer of different origin, slightly finer in texture and somewhat more consolidated.

With the exception of the Green Ridge escarpments where gravitational movement of variously sized rock particles has prevented any substantial soil deposition or development, the soils along the transect appear to be quite uniform. The only differences that might be consistent, although not definitely established, are the larger proportion of stones to the west, and a tendency for the better watered soils of the west to be redder in comparison with a characteristic brown for dryer soils to the east. The soils do not at this stage of their development exhibit gradients approaching the magnitude of those shown by the vegetation.

CLIMATE

Oregon is separated into two substantially different climatic zones by the Cascade Mountains. In general the west side of the range is characterized by a maritime climate with heavy rainfall and a relatively narrow range of temperature. The east side has essentially a continental climate with greater extremes of temperature, although the means are similar to the western temperatures as shown by Figure 6. The pattern of light summer rainfall and heavy winter precipitation is shared by both sides, with the extremes being much more apparent in the west.

Since the state lies in the belt of prevailing westerlies, air moves generally from the Pacific Ocean inland. The warm southwest winds and cooler land of the winter result in heavy precipitation; while relatively cooler northwest winds and warm land surface in summer result in drought during this season. Data compiled by Wells (66, p. 1086) show that the proportion of precipitation falling per season is:

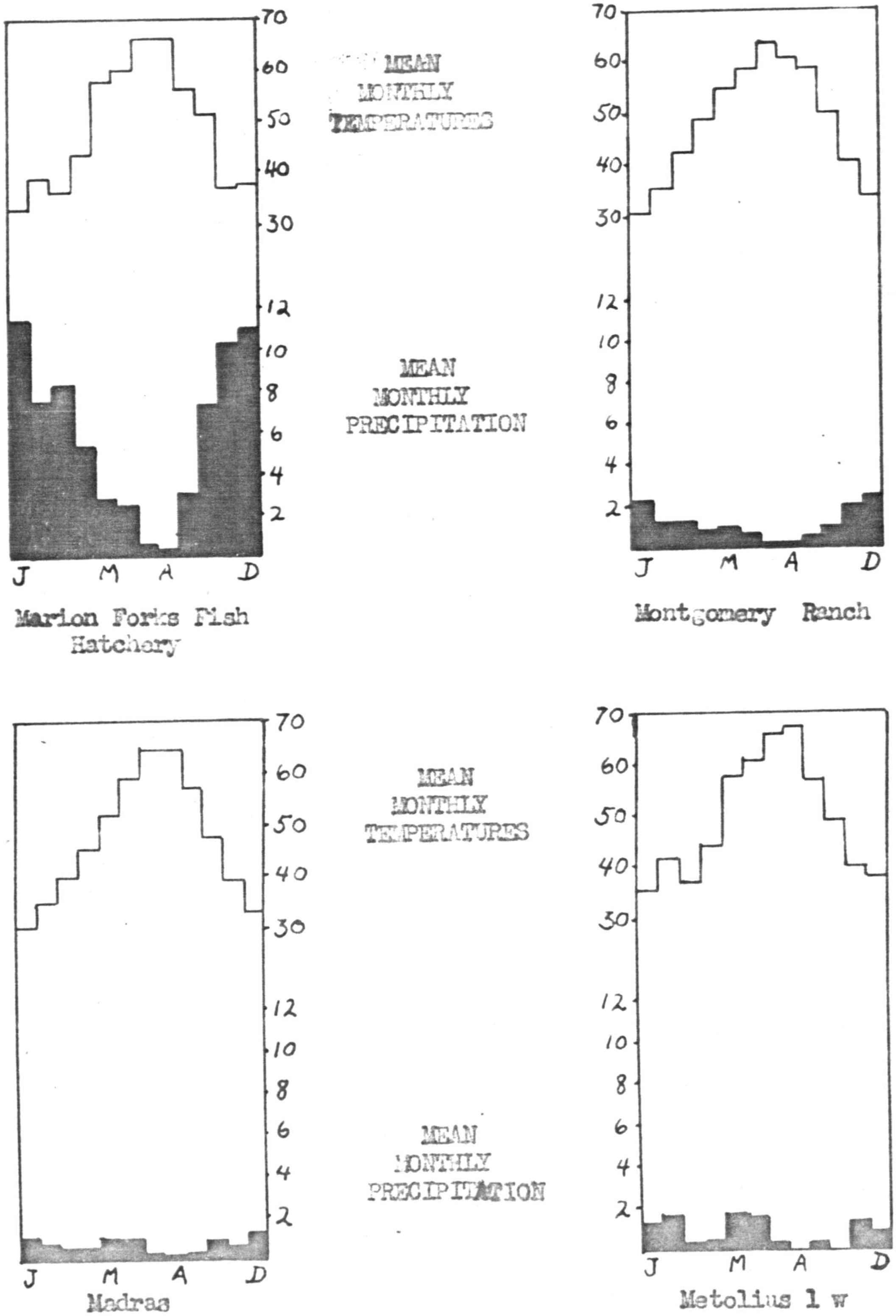
West of the Cascades	East of the Cascades
Winter - 44%	Winter - 37%
Spring - 24%	Spring - 27%
Summer - 5%	Summer - 12%
Fall - 27%	Fall - 24%

The necessity for rising over the Cascade crest, here between 5,500 and 6,000 feet, results in adiabatic cooling and resultant loss of moisture by the air mass as it is forced upward. Conversely, the air warms as it flows down the leeward slope, and precipitation decreases sharply.

The absence of nearby weather data collection points makes specific statements about the weather impossible. Baker (2, p. 238) did not describe the leeward slope climate of central Oregon because of the absence of stations. Thus, the four stations whose locations are shown in Figure 7 are sufficient only for generalizations about the climate. Records were not kept concurrently at all of these stations, thus direct comparison between Montgomery Ranch (with records from 1938-1947) and the other three stations must be made advisedly. Average temperatures and precipitation for these four stations are shown in Figure 6. The Marion Forks Fish Hatchery is on the west side of the Cascade crest, while the other three are east of the transect. Figure 8 is a generalized extrapolated weather map for the state of Oregon (66, p. 1085), showing that the 60 inch, 40 inch and 20 inch isolines all pass through the study area.

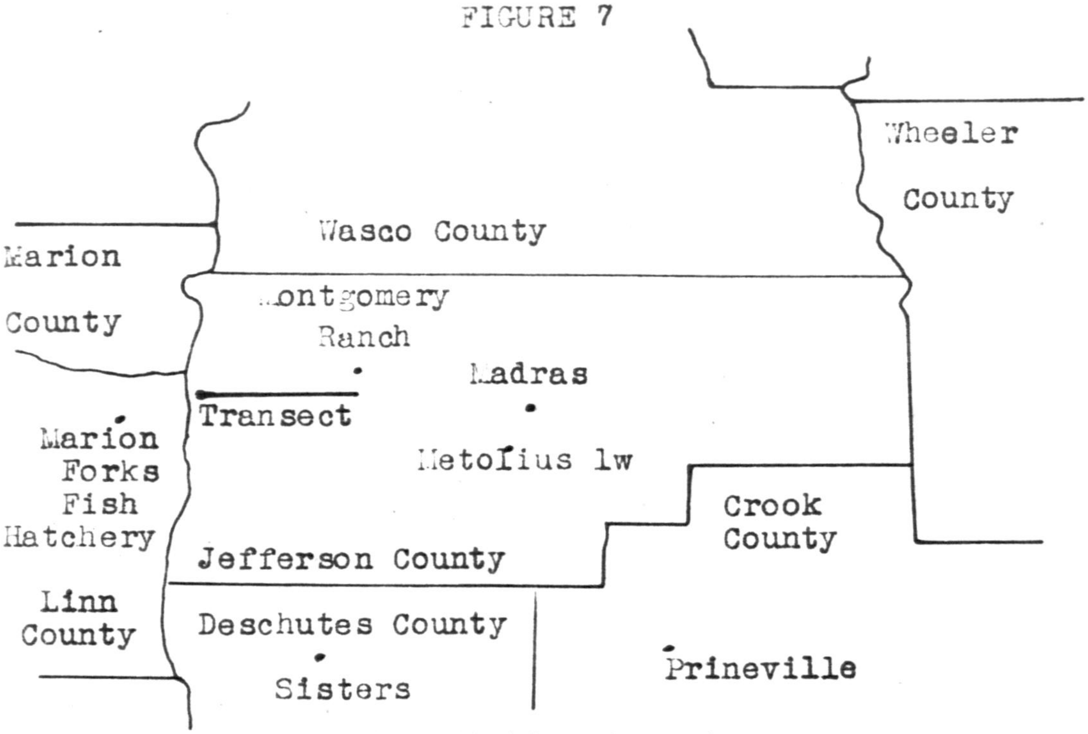
The temperature extremes of the region are more closely affiliated with those of eastern Oregon, with lows of 0° F. and highs of 95° F. not uncommon. Much of the precipitation in the area falls as snow, particularly at

FIGURE 6



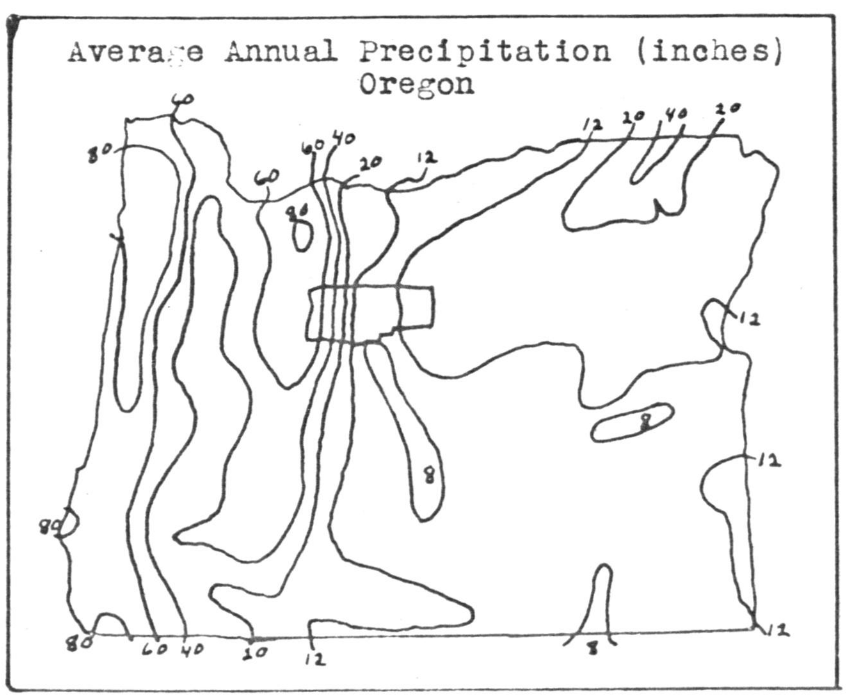
Temperature and Precipitation Graphs

FIGURE 7



Weather Station Location

FIGURE 8



high elevations, with roads above 4,000 feet normally blocked for several of the winter months. Snow patches were still present on June 1st at 4,000 feet, and at 5,700 feet on July 12, 1960.

METHODS

Transect Establishment

A variety of methods for describing, classifying, and analysing vegetation has evolved in both Europe and North America, with characteristics dependent in part on the level of classification sought, facet or facets of emphasis, point of geographical origin, and trends of general and/or scientific thought during their formative periods. Based in part on language barriers and diversity of the world's vegetation, enthusiastic practitioners of a number of schools of thought have been independently active, and no general agreement on the systematics of vegetation exists (5, p. 413-475; 26, p. 66).

The absence of agreement in methods for classifying homogeneous vegetation makes the problems connected with ecotones seem particularly imposing. It has been suggested that ecotones might better be left to study until the patterns for vegetation systematics have evolved from the study of homogeneous vegetation, and then the ecotones be treated within this system (47, p. 235; 26, p. 102). Where the primary objective is the classification of the community, this might be necessary, but information to be gained from a quantitative study of the ecotone supercedes this ideal when the undisturbed vegetation, even in the

Pacific northwest, becomes scarcer every year. It was thus determined to treat this particular ecotone in the manner that seemed most fitting after becoming familiar with it in the field.

Cain and Castro (8, p. 2-3) have pointed out that the ecologist or any other scientist must adopt or adapt a system most appropriate for his problem. Since the study undertaken here concerns the description and interpretation of a band of vegetation deliberately selected as intermediate between the fir-hemlock of the High Cascades crest and the pine-juniper of the northwestern periphery of the Great Basin, and since the observed ranges of the tree species overlap extensively, emphasis is in terms of species or populations, rather than real or abstract communities (65, p. 362-370). The ecotonal status of this forest and the relatively limited area observed in detail would require a prohibitive degree of arbitrariness in definition of communities in terms of species composition. Thus, the term "stand" will be employed to designate any unit of vegetation under discussion, with no intention of its having any phytosociologic significance.

Of the major schools of vegetational classification, it appears that the continuum (14, p. 480-495) best fits the distributional complex found here, and methods to facilitate analysis at this level have been employed.

It was determined to utilize a transect established at right angles to the plant zonation in order to obtain the most meaningful quantitative data. Accordingly a functional transect was established at 5,800 feet elevation from the east rim of Brush Creek Canyon to the west rim of Fly Creek Canyon at 3,000 feet elevation and some 18 miles to the east.

It was impracticable to establish a compass-line transect throughout this distance because of difficulty in traversing parts of the area. Examination of United States Forest Service maps indicated that Sections 1 and 2 of R. 8E., T. 12S., 1-6 of R. 9E. and R. 10E., T. 12S., and Sections 3-6 of R. 11E., T. 12S. have either roads or forest trails for most of the distance from east to west. Road and trail builders seek regularity of topography, and since these thoroughfares in this area receive quite light useage it became evident that the basic transect could most advantageously be established on these roads and trails. Figure 2 shows the position of the transect in relation to the sections crossed.

Sampling Methods and Data Collection

Analysis of the variation within a specific area is best accomplished by a method of uniform sampling, so it was determined to use systematic, rather than random sampling (21, p. 20-22). There is no statistical method for determining sampling error that does not depend on random sampling, but the primary value of the sampling error estimate would be for comparison with possible future studies involving problems similar in species composition and pattern. In the light of this uncertainty, it seems that the insurance of uniform coverage provided by systematic sampling outweighs the value of the opportunity of estimating sample error, and so the adequacy of sample size was determined empirically as described below.

A pair of 32x32 feet plots were placed along the transect at intervals of 50 feet of elevation, beginning at the east rim of Brush Creek Canyon and extending eastward to the Metolius River. The elevational interval was widened to 200 feet on the western face of Green Ridge because of the simplicity of the stand and the exertion of climbing and working on this uncomfortably steep, unstable slope. East of the top of this ridge the elevational interval of sampling was set at 75 feet, since recent logging operations are extensive enough to make direct comparison with the non-logged areas to the west of somewhat curtailed value. It was felt that the data were worth the effort of collection in spite of this disturbance, since the east slope of Green Ridge is topographically a replication of comparable elevations to the west between Brush Creek

Canyon and the Metolius River.

Uniform sampling points along the transect were determined by use of a Taylor Altimeter along the forest trails and by the vehicle odometer where such travel was possible. When the odometer was used, readings in miles between section line markers were obtained by traveling the roads, and these were compared with the isobars on the topography map. Points approximating 50 feet drops in elevation were estimated on the basis of this comparison and marked with red cloth strips, with allowances made for departures from the generally uniform degree of decline to the east, where necessary.

It is felt that the odometer-topography map combination was superior to the altimeter where applicable, because of the latter's considerable temperature sensitivity.

Systematic sampling consisted of the placing of a quadrat 50 paces to the south and another 50 paces to the north of the point designated by the altimeter or odometer. This distance was lengthened to 100 paces below 3,500 feet of elevation, where the stand began to be somewhat more open. These distances were sufficient to diminish bias, since the quadrat location could not be seen from the transect. When topographic conditions were atypical at the basic distance, or when logging disturbance or substantial rock outcrops affected the site, additional increments of 50 paces in the same direction were added until the condition was remedied. This adjustment was necessary for 57 of the 186 quadrats established.

The quadrats were subdivided into eight subplots with dimensions of 8x16 feet, with the long axes of these subplots laid in east-west alignment. Cotton rope with wooden stakes driven into the ground at the corners served to delimit the quadrat. Conspicuous knots in the rope at 16 foot intervals on the north and south sides and at eight foot intervals on the east and west sides with imaginary lines extended at right angles into the quadrat provided the boundaries for the subplots. These subplots were lettered A to H, commencing in the northwest corner and continuing counter-clockwise to the northeast corner.

Within each subplot all trees over one foot in height were identified, counted and recorded. All trees more than 10 feet in height were measured at breast height with a diameter tape and recorded individually as to diameter and species. No quantitative data were taken for trees less than one foot in height, with this height being set arbitrarily as the size necessary to prove establishment. Presence of seedlings less than one foot in height was to be noted if species different from those of the larger size classes occurred, but this situation was not present within any of the plots.

Shrubs and herbs within and near the quadrats were listed and given subjective abundance ratings of 1-5 where (6, p. 30):

1 - very rare

2 - rare

3 - infrequent

4 - abundant

5 - very abundant

Vascular plants were collected from along the entire transect. This collection does not contain all of the plants of the transect area, but most of those with an abundance rating of three or more are included.

Increment cores were taken with a Swedish Increment Borer from trees within or near each quadrat. Because of the diversity of forest types along the transect and because of the different histories of various stands, no consistent set of criteria could be applied in selection of the trees to be bored, but the most useful cores came from trees selected for the probability of containing fire history information. Individuals of ponderosa pine and Douglas fir were frequently too large to make boring practical, while others, such as the true firs and incense cedar, consistently contained a heart rot that made extraction of a core more than a few inches in length impossible.

A number of nearby areas were reconnoitered to supplement observations from the more intensively studied area. These include the Cascade crest between Rockpile Mountain and South Cinder Peak to the west; the Minto Pass and Brush Creek burned areas, Canyon Creek, and Bear Valley to the south; the south wall of Cabot Creek Canyon and the lower reaches of the Candle Creek area to the north; the valley of the Metolius River both north and south of the transect for several miles; and the head of the canyon occupied by the South Fork of Street Creek northeast of Prairie Farm (Figure 2).

Data Treatment

Quantitative field data were prepared for presentation in phytographs after the manner of Lutz (36, p. 8-10), with certain modifications. These alterations were deemed necessary because of the attempt made here to analyse the total forest in terms of populations of gymnosperm species that vary substantially in size and morphology.

Modifications from the statistics of Lutz are these.

1. Determination of percentage frequency was based on the number of subplots containing one or more individuals of the species at least one foot high instead of the 10 inch d.b.h. minimal size used by Lutz. This was the most effective way of portraying the numerous thickets of young trees, or the mature individuals of species of small

dimensions, such as lodgepole pine.

2. In determination of percentage frequency, presence or absence of the species within the 8x16 feet subplots was used as the basis for computation. Grieg-Smith (21, p. 30) has pointed out that the major objective in determination of quadrat size and number when sampling is random is the symmetry of the distribution curve. While these systematically collected data are not subject to statistical procedures, this criterion is still reasonable. Computing percentage frequency with any of the possible larger combinations of subplots led to an excessive number of high frequencies, thus masking real differences in amounts and distributions of the species involved. Data from six quadrats are included in each line of phytographs in Figures 9 through 13.

While it is realized that contiguous plots will be affected by contagious distribution, or pattern, it is felt that the benefit to be gained from symmetry of the frequency distribution curve outweighs this disadvantage. In addition, the combining of quadrats in adjacent sets of six, each with eight subplots, serves to diminish the possible effects of a clumped pattern. This combination of six quadrats was effected to simplify presentation and to more closely approach the ideal sample size. Combination of more than six quadrats would group data from too wide a variety of elevations to be of maximum usefulness.

3. Relative density is based on all trees over 10 feet in height. This limit was selected because it is felt that trees this large or larger will have a substantial effect on the total impression of density. Trees smaller than 10 feet in height will not produce much shading effect individually, while trees over 10 feet will typically cast enough shadow to affect the light received by the herbaceous plant layer. The demarcation line must obviously be arbitrary, since the difference is admittedly quantitative rather than qualitative.

Again the numerous thickets of young trees are responsible for this modification from the 10 inch d.b.h. minimum of Lutz. This statistic under these circumstances portrays a more inclusive density, leaving the influence of larger trees to be manifested by the length of the basal area axis.

4. Basal area was computed using all trees over 10 feet in height, since as explained above, all such trees were measured for diameter. Relative dominance will thus be high for the thickets mentioned above only if no large trees occur in the plots, since basal area for 10 trees of four inches d.b.h. is less than that of one tree 13 inches in diameter. Basal areas were obtained from Bruce and Schumacher (7, p. 406).

5. Only four sizes of classes are used here, since only trees one foot or more in height have been counted. This is opposed to five in the phytographs of Lutz. The largest class includes trees over twelve inches in diameter at breast height, which was selected as a compromise with trees such as lodgepole pine infrequently reaching this stature, while ponderosa pine and Douglas fir at this size are relatively small when compared to their potential.

The axes, beginning with the vertical and proceeding clockwise are:

a) Percentage frequency, the proportion of the subplots containing one or more individuals of the species under consideration.

b) Relative density within the quadrats, the proportion of trees over 10 feet in height that belong to the species under consideration.

c) Relative dominance within the six quadrats, the proportion of the total basal area contributed by the species under consideration.

d) Number of size classes present for the species under consideration, in which:

Class 1 - one to 10 feet in height

Class 2 - over 10 feet high, less than 3.6 inches d.b.h.

Class 3 - 3.6 to 12 inches d.b.h.

Class 4 - 12.1 inches or more d.b.h. (Figures 9-13)

When computing these statistics, frequency, density, and dominance were plotted for selected species by using successively larger fractions of the data. Sufficient sample size was then determined by examining these sample plottings for plateaus in the curves. Results indicated more than adequate sampling for the most abundant species, and less than adequate sampling for the rare species.

Since these calculations were made after the data had been collected, and since sampling appeared adequate or excessive for the abundant species, it was determined to use all the data available for all species, recognizing that it is not a completely accurate portrayal of the less abundant trees.

The DFD indices were computed by adding together relative density, percentage frequency, and relative dominance as measured by the percent of total basal area contributed by the species under consideration (13, p. 5-6). These values were then plotted as shown in Figures 14 and 15. The separation of species into three graphs per figure was done for clarity of presentation only, and has no other significance. Values obtained may vary from 0 to 300 on the ordinate, with elevations shown on the abscissa.

In Table 1 are arranged 11 species common to the stands between 3,000 and 4,500 feet on the Cascades eastern slope and the east slope of Green Ridge. Abundance ratings of three or more are recorded for 150 feet increments of elevation for each of these two stands.

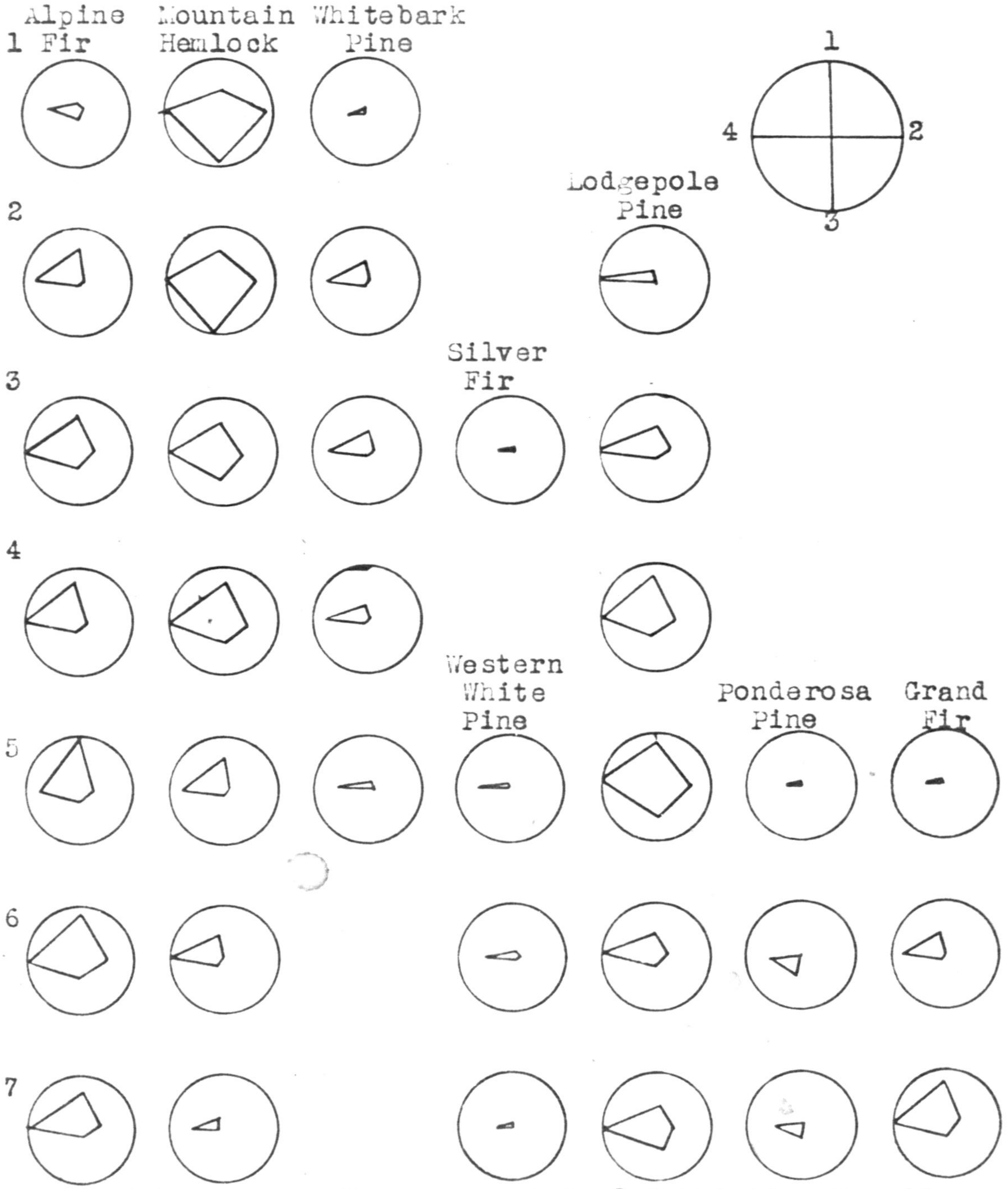
Increment cores were mounted in the depressions of corrugated cardboard and fastened in position with Elmer's Glue-All. The exposed surface was sanded smooth with sandpaper and the rings counted with the aid of a binocular dissection scope (20, p. 5-6).

Increment cores were used to indicate relative ages of trees within areas suspected of having had a fairly recent fire. Ring counts for trees showing fire damage and for the various smaller sized trees in the vicinity made possible estimates of the time elapsed since the fire, since a burn severe enough to damage the tree's trunk normally results in a few years of restricted abnormal rings, although exact dating requires examination of some cross-sections of tree trunks (28, p. 175-180). Observations of the 15 year old burn along Brush Creek substantiated conclusions drawn about older fires.

Vascular plants collected were identified and placed on file in the Oregon State College Herbarium (1, 4 volumes; 46, p. 1-866).

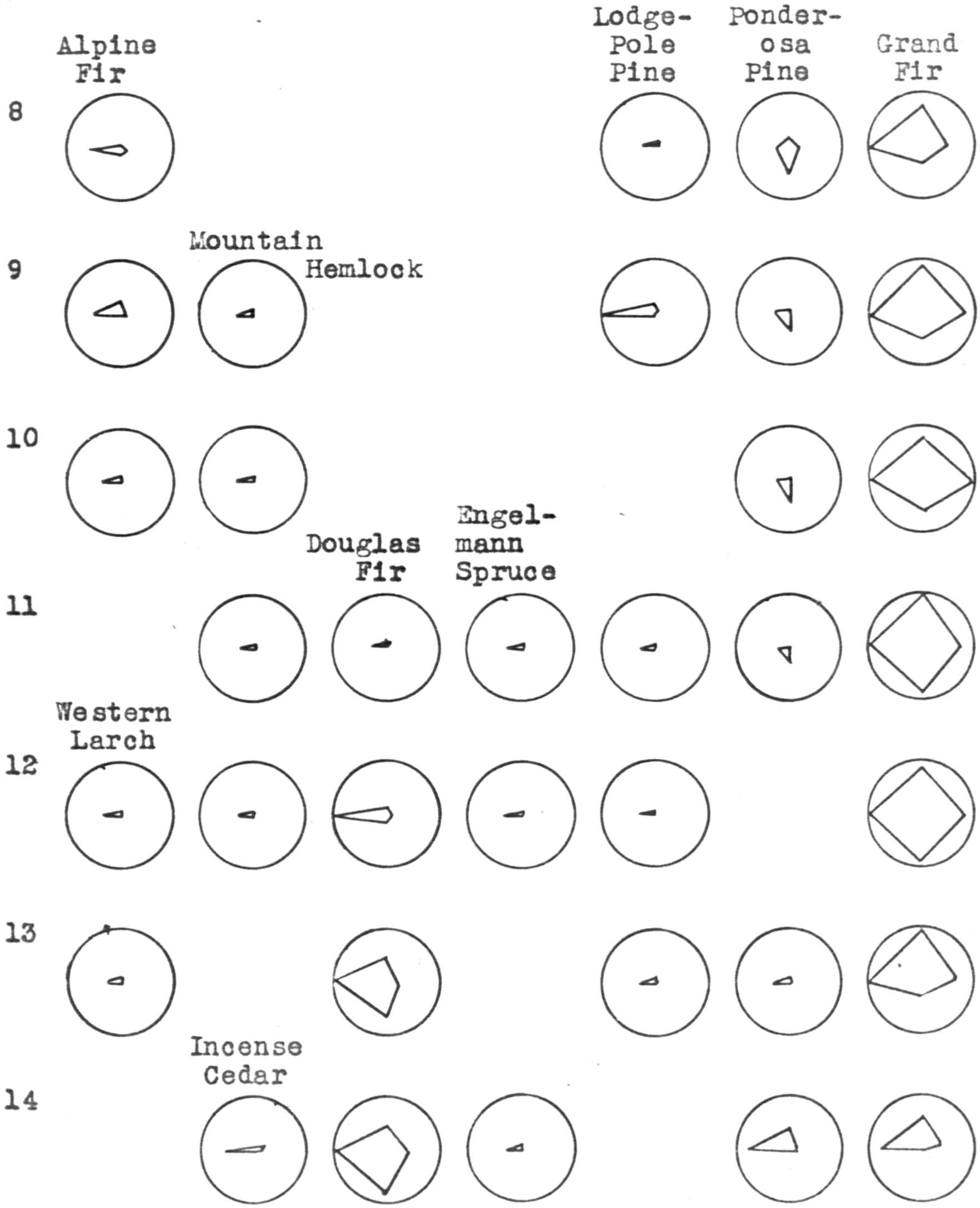
A listing of the species collected is included in the appendix. Species are listed here according to the elevation at which they were collected.

FIGURE 9



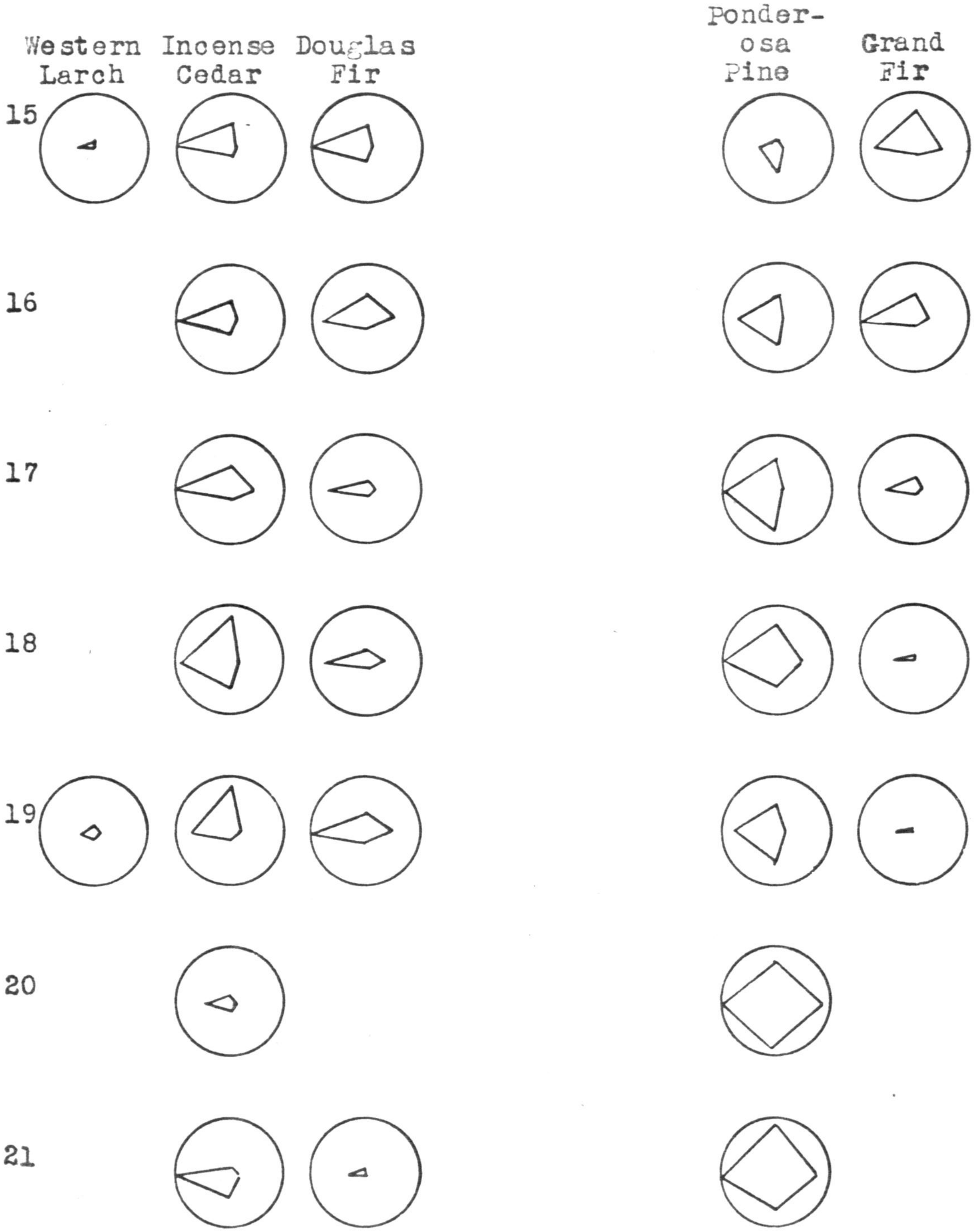
Axis 1 = Percentage Frequency Axis 2 = Relative Density
Axis 3 = Relative Dominance Axis 4 = Size Classes Present
Average elevation for Row 1 = 5750 ft., Row 2 = 5600 ft., Row 3 = 5451 ft., Row 4 = 5300 ft., Row 5 = 5150 ft., Row 6 = 5000 ft. and Row 7 = 4850 ft.

FIGURE 10



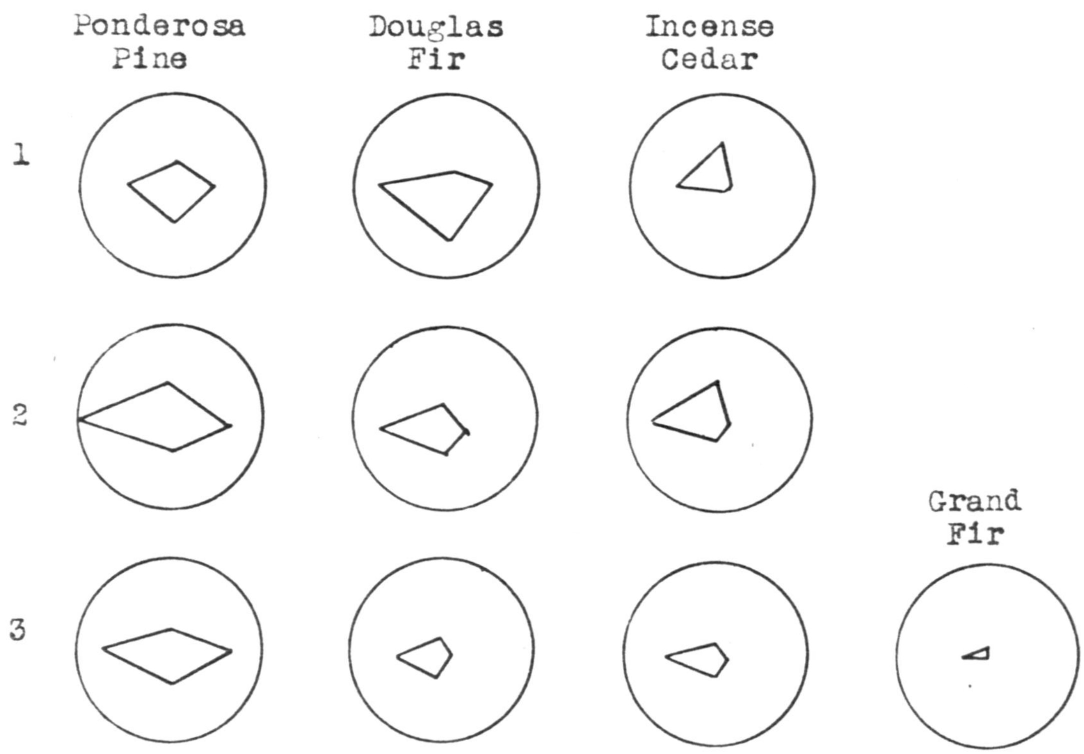
Average elevation for Row 8 = 4700 ft.; Row 9 = 4550 ft.; Row 10 = 4400 ft.; Row 11 = 4250 ft.; Row 12 = 4100 ft.; Row 13 = 3950 ft.; Row 14 = 3800 ft.

FIGURE 11



Average elevation for Row 15 = 3650 ft.; Row 16 = 3500 ft.
Row 17 = 3350 ft.; Row 18 = 3200 ft.; Row 19 = 3050 ft.;
Row 20 = 2900 ft.; Row 21 = 2800 ft.

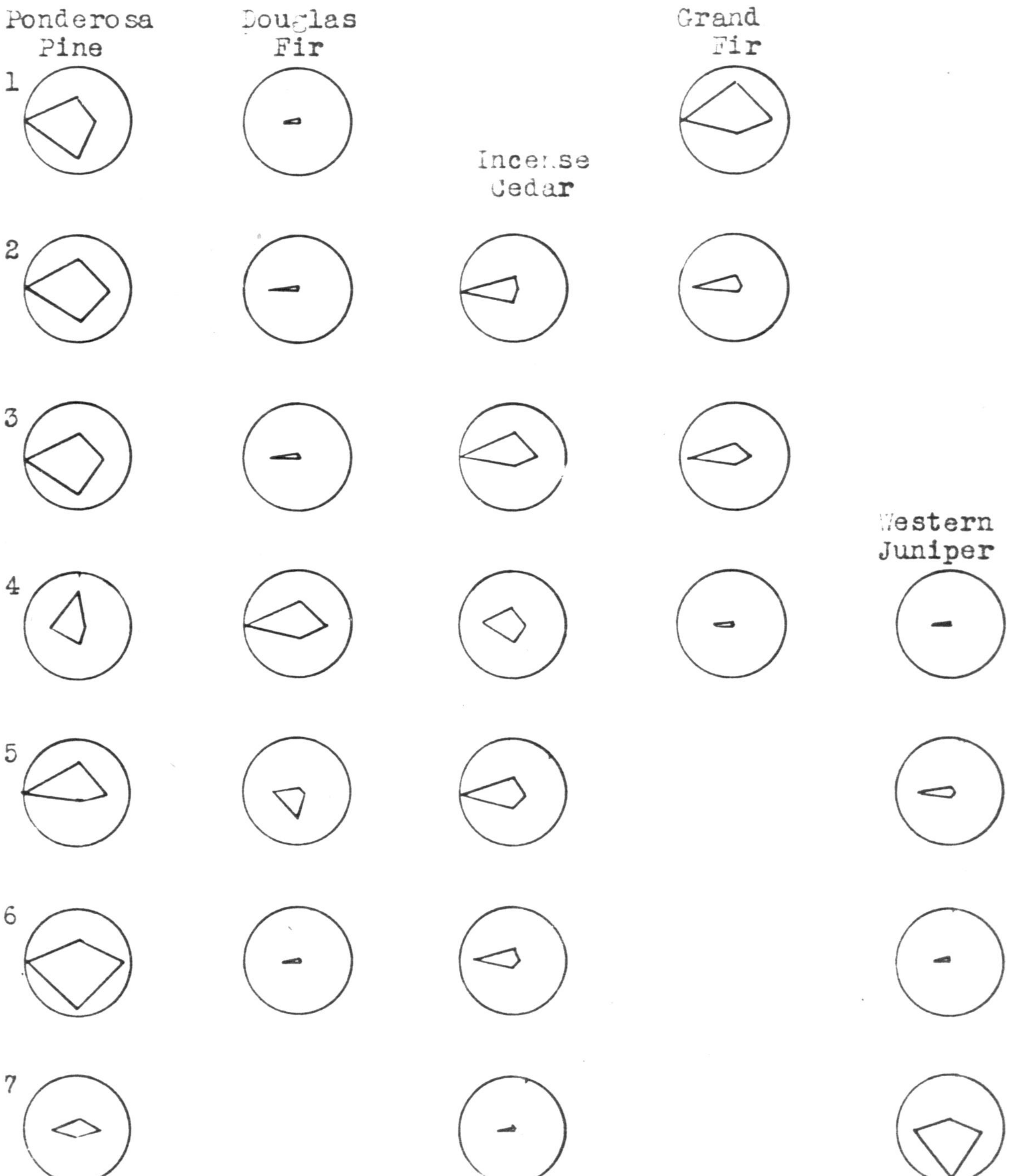
FIGURE 12



Average elevation for Row 1 = 3100 ft.; Row 2 = 3700 ft.; Row 3 = 4300 ft.

West Slope of Green Ridge

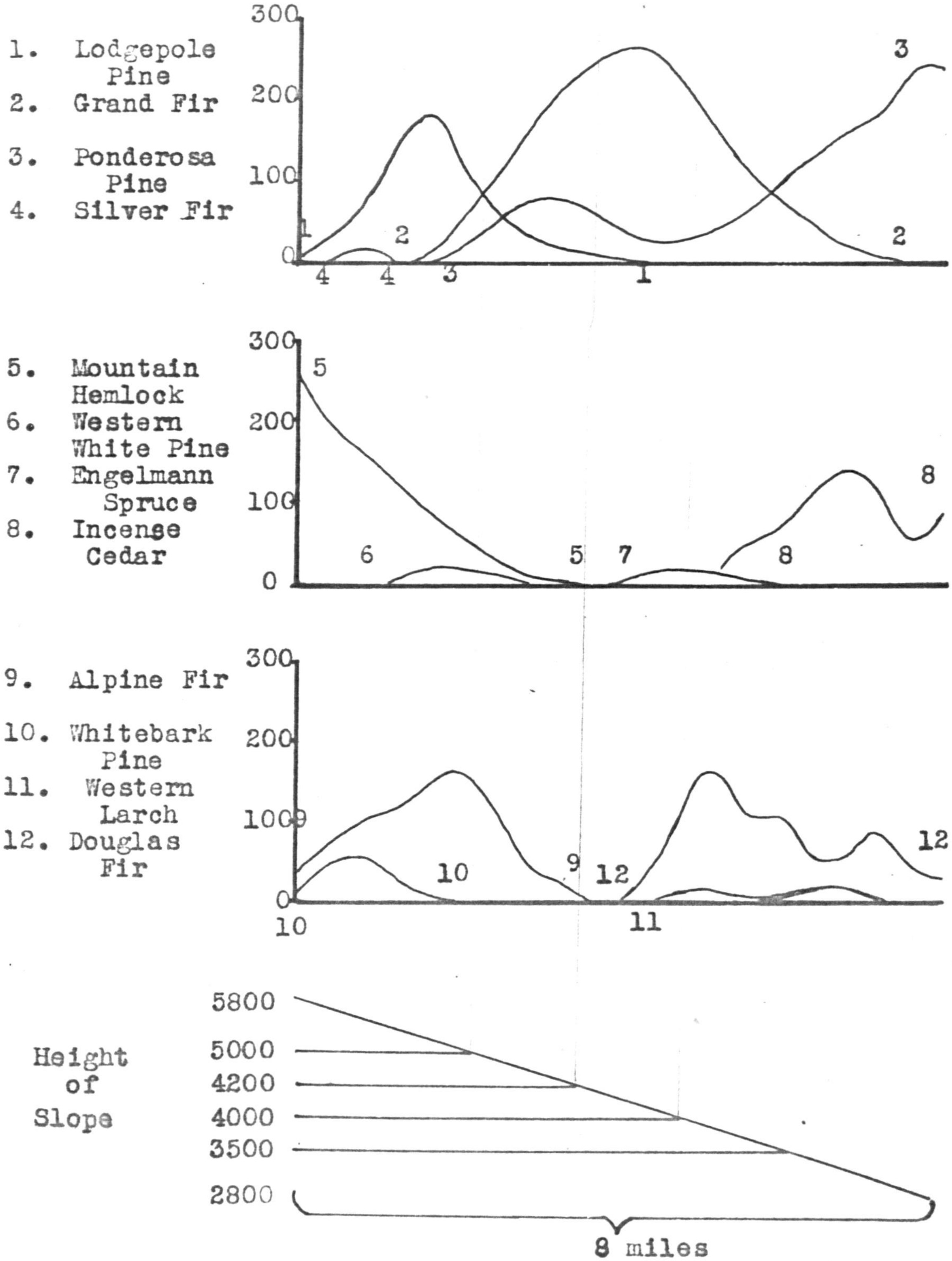
FIGURE 13



Average elevation for Row 1 = 4400 ft.; Row 2 = 4200 ft.; Row 3 = 4000 ft.; Row 4 = 3800 ft.; Row 5 = 3600 ft.; Row 6 = 3400 ft.; Row 7 = 3200 ft.

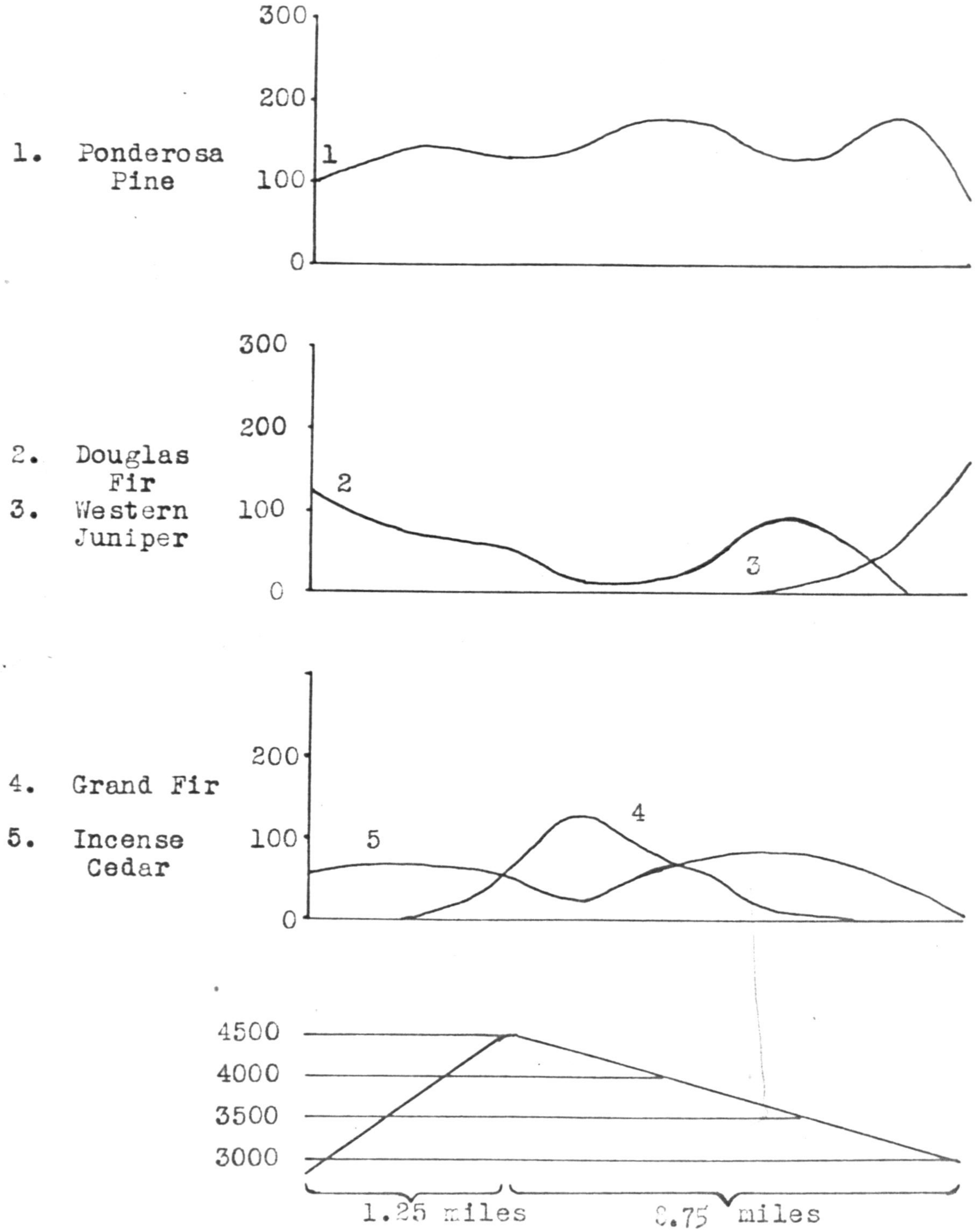
East Slope of Green Ridge

FIGURE 14



D.F.D. Index Graphs: From Metolius River Westward

FIGURE 15



D.F.D. Index Graphs: From Metolius River Eastward

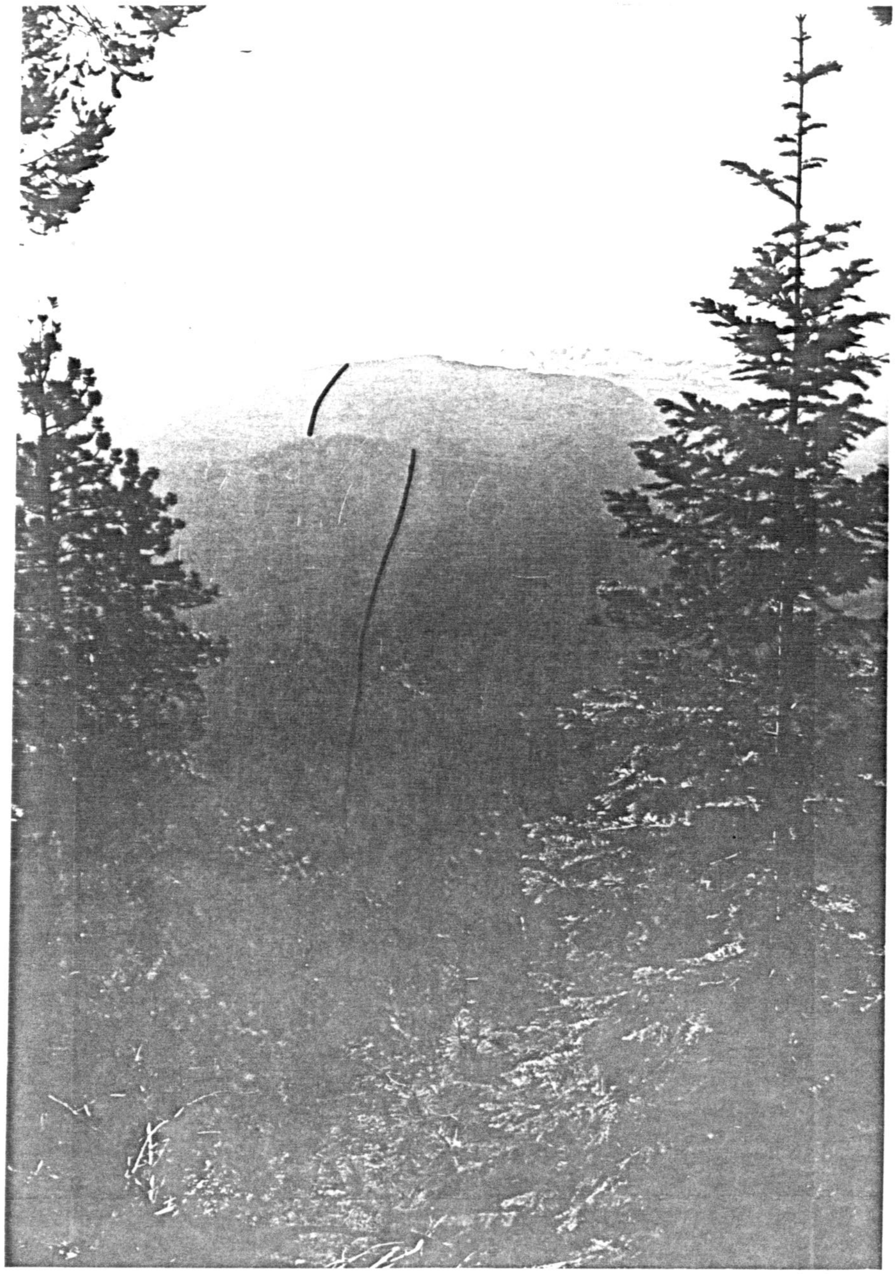
DESCRIPTION OF THE VEGETATION

General

The transition forest of the leeward slope of the Cascade Range is a complex mosaic of species distributions, even in this area selected for its edaphic and physiographic simplicity (Figure 16). The general trend is, however, for individuals of a species to occur in greatest concentration in zones that can be delimited by contour lines. The downward extension of these zones on shaded slopes and intrusions upward on sunny slopes indicate that altitude per se is not the major controlling factor; but as pointed out in the section on climate, precise correlations between climate and vegetation are impossible because of the local absence of weather data.

Perhaps the simplest method of showing graphically the importance of the various tree species at points along the transect is represented in the DFD indices in Figures 14 and 15 (13, p. 5-6). This technique results in statistics that estimate the total importance of the various species found at a given point or series of points within the areas sampled. Direct comparison of sets of points at different loci along the abscissa can be misleading in illustrating forest physiognomy, however, since two of its three components, relative density and relative dominance, will always

FIGURE 16



View of Study Area West From Crest of Green Ridge
Black Line Follows Transect

total 100% for the total species at a locus no matter how many stems are present, thus masking the effect of high or low frequency. Comparative frequencies are elucidated in the phytographs of Figures 9 through 13.

Generally speaking, the high altitude forest is a comparatively open stand, becoming increasingly dense as one descends from the crest. Whitebark pine, mountain hemlock and alpine fir are the prevalent tree species in these forests, with the latter two increasing in importance as the canopy cover increases with lower elevations. Lodgepole pine is also of considerable importance in the makeup of the denser stands away from the top of the ridge, primarily in the larger size classes.

Ponderosa pine appears in limited numbers at about 5,000 feet but, with few exceptions, only as mature trees. Grand fir, primarily as young specimens, and western white pine also reach the upper limit of their distribution here.

Within the region traversed by this transect, the forest canopy is essentially closed from 5,000 feet down to about 3,500 feet. Lodgepole pine, mountain hemlock and alpine fir extend downward to about 4,400 feet, while Douglas fir, western larch and Engelmann spruce appear at roughly this same level. Grand fir is by far the most important tree within these elevational limits, with all others except Douglas fir playing a very minor role. Incense cedar with its greatest concentrations somewhat lower, achieves some slight occupancy up to about 3,800 feet.

Toward the lower third of the 3,500-5,000 foot zone the total frequency of all trees begins to diminish, and ponderosa pine and incense cedar become increasingly important. Grand fir and Douglas fir are present primarily as saplings and small trees in these open stands.

The more typical open stands of ponderosa pine occupy the area between 2,800 and 3,300 feet. Dense stands of young incense cedar and ponderosa pine are present in much of this region, marring the park-like quality characteristic of many ponderosa pine forests.

The transect crosses the Metolius River at about 2,750 feet and extends up over Green Ridge at 4,500 feet. The river bottom flora is considerably richer in both quality and quantity, while the steep west slope of Green Ridge is characterized by low frequency and density of ponderosa pine, incense cedar and Douglas fir.

The gentle east slope of Green Ridge is in many respects a duplication of comparable elevations in the transect to the west, differing in characteristics that will be elaborated below. Western juniper becomes an important component of the community east of Green Ridge at about 3,500 feet, increasing in number and size to 3,000 feet, where the study was terminated at the west rim of Fly Creek

Canyon.

Detailed

The quantitative data as presented here indicate that the tree species form a continuous series of independently overlapping species distributions; in other words a continuum. As summarized by Whittaker (67, p. 6), "Species are distributed, not in terms of associations, but each according to its own physiology and genetic pattern, and hence no two are alike....". Thus the creation of distinct associations in terms of species distribution can be accomplished only by considering very limited numbers of species. Since there is virtually no overlap of whitebark pine, Douglas fir, and western juniper, associations could be defined in terms of these species. The addition to consideration of ponderosa pine, incense cedar and grand fir complicates matters seriously, while the inclusion of all coniferous species encountered in the transect makes such classification virtually hopeless. Certainly the same generalization could be made for the understory vegetation.

Any attempt to describe the vegetation in toto, however, indicates that the existence of a continuum provides little help in itself. Study of this ecotone suggested that the current characteristics and reactions within the vegetation might provide helpful analytical tools. Since the arboreal vegetation along this transect differs at various elevations in its history, in the conditions currently controlling or affecting the plant growth, and even the roles played by a single species, another basis for classification presents itself. In order to discuss this complex in a meaningful fashion, the description of the vegetation has been segmented into units based primarily on the history and secondarily on current environmental controls at different elevations. This concession to more traditional classifications of vegetation points up the difficulty in dealing simultaneously and directly with several populations of species whose ranges overlap to varying degrees. Thus in spite of the belief that the trees being considered here do truly form a continuum, the goals of this study are better served by treating parts of this continuum separately. These fragments of the continuum then, are treated as "zones" principally on the basis of the unifying events in their histories, usually the length of time since the last destructive fire.

5,400-6,000 Feet

The principle tree species present at these elevations are mountain hemlock, alpine fir, and white bark pine, as illustrated by Figures 9 and 14. The physiognomic pattern between 5,800 and 6,000 feet tends toward openings varying in size from one half to four or five acres in extent, separated by a reticulation of woodland between 50 feet and 200-300 yards in width. Stands differ considerably in density, with mountain hemlock forming the most tightly closed canopy. These trees are typically clumped in pattern with three to eight stems per group. A compact, dark felt layer of hemlock litter and mycelial filaments an inch or two in thickness covers the ground under these mature mountain hemlock stands. The fungal mass grows actively only as long as this litter is moist, and when the snow melts in early or mid-July and the litter dries out, the mat cracks into plates from two to twelve inches in diameter. This ground cover is quite sterile, supporting only scattered mountain hemlock and alpine fir seedlings and saplings, and a sparse herbaceous flora.

The alpine fir and whitebark pine components increase in importance toward the edges of the dense mountain hemlock stands. Lodgepole pine and silver fir are also present in lesser numbers in these stands, with lodgepole pine being locally near its upper elevational limits, and silver fir occurring only as widely scattered individuals below 5,600 feet.

Within the openings in the forest may be found seedlings and saplings of all of the above-mentioned species, with mountain hemlock apparently the most successful colonizer here. Snow accumulation in these clearings causes a great deal of bending and breaking of these young trees.

The transect terminated at 5,800 feet on the east rim of Brush Creek Canyon, a sharp, rocky, exposed ridge. Whitebark pine, lodgepole pine, alpine fir and dwarf juniper form the bulk of the stand on this site, with lesser amounts of mountain hemlock, and a very little silver fir. Where the dense canopy extended all the way to the ridge top, mountain hemlock was the most abundant species. A single healthy Douglas fir of ten feet in height was found growing in a sunny, sheltered spot on the ridge at 5,800 feet, some 1,300 feet higher than any others of its species seen along the transect.

This ridge is well below timberline, which is over 6,000 feet on Mount Hood some 60 miles to the north and at 6,500 feet in the Three Sisters 30 miles to the south (61, p. 27), and so trees are not seriously crippled, but consistently westerly winds have created banner shaped crowns.

North along this ridge adjoining Brush Creek Canyon, and west across the same canyon, the forest is essentially similar, including, however, a larger proportion of silver fir of all size classes. The largest concentration of this species was seen three miles northward, at 6,000 feet between Forked Butte and Sugarpine Spring on the ridge north of Cabot Creek (See Figure 2). Here it occurs in a mature stand mixed with mountain hemlock and alpine fir, with somewhat lesser amounts of lodgepole pine and whitebark pine. At the higher elevations, up to 6,200 feet, the stand is more discontinuous, with trees growing on rocky ridges (61, p. 41) or in isolated timber atolls (22, p. 554) separated by barren cinder flats.

Shrub species present between 5,400 and 6,000 feet include *Arctostaphylos patula*, *A. nevadensis*, *Ceanothus velutinus*, *Holodiscus glabrescens*, and *Vaccinium scoparium*. All except the last mentioned grow most vigorously on the severely exposed sites, such as the rim of Brush Creek Canyon. *Vaccinium scoparium* appears to do somewhat better where soil moisture level is higher. Treeless basins where the snow drifts remain well into the summer frequently are surrounded by *V. scoparium*, *Phyllodoce empetriformis*, and *Luetkea pectinata*. The bottoms of these shallow depressions support a characteristically alpine meadow flora, including *Castilleja spp.*, *Lupinus spp.*, *Ranunculus spp.*, and *Juncus mertensianus*.

Mesic areas, protected from deep snow accumulation and direct insolation have a scanty herbaceous cover of *Pyrola secunda*, *Hypopitys latisquama*, *Penstemon nemorosus*, *Polemonium californicum* and *Sitanion hystrix*.

Sites subjected to deep snow cover, followed by intense isolation after snow melt, support Eriogonum marifolium, E. pyrolaefolium, Polygonum newberryi, Aster alpigenus, and Lupinus spp. on a cindery, mineral soil. Sedum spathulifolium is common in crevices of the larger rocks, particularly on the severe exposures afforded by the narrow ridge between Brush Creek and Cabot Creek Canyons.

4,800-5,400 Feet

Lodgepole pine reaches its greatest abundance along this transect between 5,000 and 5,200 feet (See Figures 9 and 14). This stand is characterised by high frequency, density, and dominance for lodgepole pine, with the majority of the individuals in the two larger size classes. Alpine fir, as shown by its high frequency and lower densities and basal area, is evenly dispersed throughout this stand, principally in the smaller size classes. Mountain hemlock is of less importance at these lower elevations, but is present in fairly large numbers in the lesser size classes.

Ponderosa pine is rare at this elevation, but does occur in the largest size class. This species grows as high as 5,600 feet along the Brush Creek Canyon rim south of the transect. The upper limits for grand fir and for western white pine are also in this vicinity with only a very few seen higher than 5,200 feet. There are a few cone bearing western white pine at these elevations, but grand fir is without exception small. The most extensive western white pine stand seen was on the south, shaded side of Cabot Creek Canyon above 4,600 feet. Whitebark pine, at the lower extremity of its range here, is present in small numbers. As in the Sierra Nevadas, the range common to both these white pines is slight (30, p. 5-16).

The understory layer is considerably richer in these lodgepole pine dominated stands than at higher elevations, with *Arctostaphylos nevadensis*, *Xerophyllum tenax*, *Calochortus lobbii*, *Corallorhiza maculata*, *Pyrola secunda*, *Chimaphila unbellata*, *C. menziesii*, *Lupinus spp.* all present in large numbers. There is considerable dead and bleached *Arctostaphylos patula* present, with a little still living, or with one or two branches alive.

4,000-4,800 Feet

This heterogeneous segment of the transect has as its only unifying characteristic the high density, frequency, and dominance of grand fir. As shown by Figures 10 and 14, grand fir is by far the most important species within these altitudinal limits. Throughout this entire area, there are grand fir of all size classes, with their homogeneity disrupted only by a few openings resulting from blow-down, or a few slight ridges with larger than the usual number of ponderosa pine. Toward the upper limits of these elevations, alpine fir occurs at the lower extremity of its range. Mountain hemlock has a similar status, but apparently encroaches a little lower than alpine fir, with one sapling seen at about 3,900 feet. Quite a number of veteran ponderosa pines are scattered throughout this grand fir dominated area, with the crowns of many either dead or dying. Lodgepole pine likewise is present, but only as very mature specimens that are currently dying and falling.

The canopy is essentially closed, particularly under the very large grand fir, which measured up to 38½ inches in d.b.h. within the quadrats. Size of the grand fir was particularly large in a slight depression extending to the west and up the slope from Abbot Butte Spring.

The small ravine at 4,100 feet, occupied and probably formed by Abbot Butte Spring, was of particular interest in regard to diversity of species. This ravine extends for about 300 yards in an east-west direction, with the spring currently occupying the lower 75 yards where the walls are steepest with a 40% slope. The shallow upper end serves to drain off snow melt water in the spring, being non-functional the rest of the year because of summer drought and winter snow cover. The lower end broadens into a two to three acre outwash flat that has served as a campsite periodically in the past. The combination of high soil moisture and locally unique topography have served to create a microclimate sufficiently different from adjacent undissected terrain to support an unusual variety of plants.

The middle section of this ravine bears one of the only two stands including western hemlock along the transect, the other being 600 feet lower on Abbot Creek. Sizes range from seedlings to trees with 12 inch d.b.h., with the larger trees producing cones. This area is shared with a few pole-sized western larch in a slightly better lighted site, some alpine fir saplings whose range is discontinuous below the general distribution of the population, a few cone bearing western white pine, and considerable Engelmann spruce.

The largest trees present in the immediate area are Douglas fir and ponderosa pine, with the latter species being usually 100 feet or more from the ravine bottom. Grand fir of all age classes are also present. The flat just below the present spring course is covered by very large specimens of grand fir, Douglas fir, ponderosa pine, western larch and some 10-18 inch d.b.h. Engelmann spruce. Young trees in the vicinity are preponderantly grand fir, with lesser numbers of Douglas fir, and a few Engelmann spruce.

As would be expected, there is a great variety of shrubby and herbaceous species prevalent within these 800 feet of elevation, particularly toward the 4,000 foot level. Included in the upper half of this zone are Rubus lasiococcus, Arenaria macrophylla, Chimaphila umbellata, C. menziesii, Berberis nervosa, Calamagrostis rubescens, Xerophyllum tenax, Circium americanum, Goodyera decipiens and Vaccinium ovalifolium. The lower 400 feet of elevation include Smilacina sessiligolia, S. stellata, Pyrola secunda, Anemone lyallii, Campanula scouleri, Aquilegia formosa, Lilium washingtonianum, Anaphalis margaretacea, Rubus parviflorus, Listera convallarioides, Ribes lacustre, Asarum caudatum, Pyrola picta, Rubus vitifolius, Pyrola aphylla, Castanopsis chrysophila, Clintonia uniflora, Rosa gymnocarpa, Pachistina myrsinites, Fragaria bracteata, Trillium ovatum, Linnaea borealis, Tiarella unifoliata, Adenocaulon bicolor, Viola glabella, Osmorhiza chilensis, Piperia unalaschensis, Hieracium albiflorum; as well as most of those species found between 4,400 and 4,800 feet.

3,800-4,000 Feet

Grand fir reaches its greatest importance at slightly higher levels, as shown by the phytographs of Figures 10 and 11, with Douglas fir, incense cedar and ponderosa pine increasing in numbers within these elevational limits. The frequency and density remain high for grand fir through Row 15, thus down to 3,600 feet, but the dominance drops off rather sharply in Row 13 at 4,000 feet. This mirrors a heavy growth of young grand fir, with Douglas fir the predominant large tree. The largest individual recorded within the quadrats here was a 63½ inch d.b.h. Douglas fir. This species also has some trees in size classes 2 and 3, but they are situated primarily in the slightly better lighted sites.

Ponderosa pine is a little less important than Douglas fir and grand fir within these elevations, consisting almost exclusively of the largest size class, with one tree measured at 44 inches d.b.h. Some fully mature incense cedars appear in the area, although only the smaller size classes occurred within the plots. A few Engelmann spruce are also present, but size is limited to about six or eight inches d.b.h., as soil moisture conditions are probably marginal for the species(34, p. 651).

There are also a few large western larch along the transect, with a fairly extensive stand appearing just north of Abbot Butte, some 300-400 yards south of the transect. The density of the surrounding young grand fir and Douglas fir prevented a closer examination of this site.

The stand begins to appear somewhat less closed toward the lower extremity of this zone, with incense cedar and ponderosa pine becoming proportionately more important. The openest areas are occupied by <u>Castanopsis chrysophylla</u>, Amelanchier florida, Ceanothus velutinus, Acer circinatum, and Arctostaphylos patula. Under heavier canopies are found Ribes viscosissimum, Berberis nervosa, Rosa gymnocarpa, and Pachistima myrsinites. Herbaceous species farily abundant here include Pteridium aquilinum, Trillium ovatum, Clintonia uniflora, Goodyera decipiens, Corallorhiza maculata, Pyrola picta, Trientalis latifolia, Tiarella unifoliata, Galium spp., Campanula scouleri, Adenocaulon bicolor, and Achillea millifolium.

2,800-3,300 Feet

The common characteristic of these elevations is the dominant role played by ponderosa pine. This would thus probably be the upper limit of Merriam's Transition Zone (39, p. 79), since ponderosa pine is one of the chief indicators for this zone. Such species, however, as Hypericum anagalloides and Pinus monticola, used as indicators for the Canadian zone by Wynd (69, p. 333-336) make any very exact boundary doubtful.

Ponderosa pine as a shade intolerant species (3, p. 180) encounters here a soil moisture level limiting the overstory to only partial closure. Where light levels of undiminished or only slightly diminished sunlight reach the ground, there is adequate or superfluous regeneration of the species, with this being indicated by the frequency, size classes present and density axes of the phytographs of Figure 11.

Other species of considerable importance in this zone are Douglas fir and incense cedar. Both are present in all size classes, with Douglas fir reaching its greatest abundance a little farther to the west and at somewhat higher elevations than incense cedar. Both are regenerating very effectively, even disproportionately, under the pine overstory, as shown by Figure 11. Grand fir is much less important here, growing principally in better watered sites afforded by three shallow, currently dry drainage channels, which, no doubt, possess more favorable soil moisture relationships. There are a few small western juniper at about 2,800 feet, with this apparently being the westernmost frontier of the species range here.

Needle litter is heavy throughout most of this elevational zone, and shrubs and herbs, including grasses, are present in quantity. Brush species common within these elevations include *Ceanothus velutinus*, *Arctostaphylos patula*, *Symphoricarpus albus*, *Purshia tridentata*, *Haplopappus bloomeri* and *Holodiscus discolor*, with the last preferring moister sites. Herbaceous species present in considerable numbers are: *Festuca idahoensis*, *Bromus tectorum*, *Poa pratensis*, *P. compressa*, *Elymus glaucus*, *Sitanion hystrix*, *Collinsia parviflora*, *Lotus douglasii*, *Collomia* grandiflora, Tragopogon dubius, Potentilla gracilis, Piperia elegans, Trientalis latifolia, Horkelia fusca, Montia perfoliata, Draba verna, Clarkia rhomboidea, Lathyrus bijugatus var. sandbergii, Achillea millifolium, Lupinus leucophyllus, Antennaria luzuloides, Phacelia mutabilis, Madia gracilis, Balsamorhiza sagittata, Pteridium aquilinum, and Chimaphila menziesii.

2,800-4,500 Feet - West Slope of Green Ridge

This fault scarp is steep (Figure 5) and relatively barren, with rock outcroppings and slides involving all sized particles limiting the amount of available tree habitat. Its western exposure also subjects it to severe dessiccation by the summer sun. As shown by the phytographs of Figure 12, ponderosa pine is the major component of the slope, being present in all size classes, although not attaining the large sizes of trees on the stable surfaces across the Metolius River. The only other species of importance on this slope are Douglas fir and incense cedar. As indicated by the high frequency and low density (which is based on trees over 10 feet in height) incense cedar appears to be increasing, with very effective regeneration. Douglas fir has been less successful in seedling establishment than either of the other two species, as shown by its low frequency in spite of its substantial percentage of the total basal area.

The only other trees seen on this slope were grand fir, toward the top and the bottom of the slope primarily, and a few scattered western juniper in the smaller size classes.

Near the top of Green Ridge the density and frequency of trees increases. Soil depths appear to be a little more substantial, and the slope angle is much less. Incense cedar is rare here, while grand fir appears particularly in the three smaller size classes. Some old growth Douglas fir and ponderosa pine dominate the forest physiognomy, but are not reproducing effectively.

Shrubby species prevalent for the full height of the slope are Purshia tridenta, Amelanchier florida and Arctostaphylos patula. Concentrated in the upper elevations reached here are Castanopsis chrysophylla, Prunus emarginata, Ceanothus velutinus, Acer glabrum and Holodiscus discolor.

Among the herbaceous plants Bromus tectorum, Festuca idahoensis, Trientalis latifolia, Lupinus spp., Delphinium spp., Castilleja spp., Smilacina sessilifolia, Hydrophyllum capitatum, Phacelia mutabilis, Collinsia parviflora and Epilobium angustifolium are all present in some abundance.

<u>3,000-4,500 Feet - East of Green Ridge</u>

As shown by Figures 13 and 15 this zone of some eight miles in width where crossed by the transect is a rather heterogeneous one. It has been all included in the same unit because of the overriding effect of its history of logging. As the phytographs of Figure 13 indicate, ponderosa pine, Douglas fir, and incense cedar are the prevailing species throughout most of these elevational limits. This is true, in general, of similar elevations measured to the west, but the role played by ponderosa pine is stronger here. This, coupled with the occurrence of western juniper throughout this zone is indicative of a generally dryer climate.

A stand of primarily grand fir extends from the top of Green Ridge eastward for one-half to one mile. As shown by the short basal area axis for this species in Row 1, Figure 13, the bulk of these trees are young. Ponderosa pine makes up most of the largest size class, with a few old decadent or dead western larch and Douglas fir also present, but not falling within the quadrats. This forest is perhaps most comparable to stands at about 3,800 feet farther west.

Some of the grand fir in this area have morphological characteristics of white fir (<u>Abies concolor</u>), including needles twisted toward the upper side of the twig, stomatal bloom on the upper surface of the needle, and rounded cone bracts. Since ranges of these two species overlap in the vicinity (48, p. 78-81), hybridization is a possibility. Scheplitz (50, p. 73-74) found that hybrids between grand and white fir had some morphological characteristics of each. The F-1 generation showed Mendelian ratios in several characters in a number of combinations indicating heterozygosity in the parent stock.

A general observation here indicated that some trees that were morphologically grand fir on the shaded side exhibited characteristics of white fir on the side of the tree exposed to direct sunlight. Whether hybridization does actually occur is beyond the scope of this study with all the trees herein treated as Abies grandis, since most of the genes in the population appear to belong to that species.

This closed canopy stand has a heavy ground litter, with some dead Arctostaphylos patula still rooted in the ground in places. Shrub species present include: Castanopsis chrysophylla, Amelanchier florida and Ceanothus velutinus, mostly in relatively better lighted habitats. The herbaceous layer includes Chimaphila umbellata, C. menziesii, Hieracium spp., Lupinus spp., Trientalis latifolia and Smilacina sessilifolia.

Just to the east of this stand there occurs a clearing, Prairie Farm, where a sawmill was formerly established. This clearing was bypassed to the north for the purposes of tree data collection. The mill has not been operative for several decades, with a few crumbled remains of buildings and a dry log pond, created by an earthen dike, being evidence for its past existence. The clearing does not now appear to have been forested, but there are some stumps of exceedingly large pines on the low ridges that intrude into the 40 acre opening. An intermittent stream with short tributaries crosses this nearly treeless opening, flowing into the early summer and then drying up. Competition by grass species (45, p. 316-320) now seems sufficient to exclude tree invasion of these well drained, sun baked, porous soils, since only a few ponderosa pine, showing poor vitality, are growing on the edge of the intermittent stream. An earthen dam has been built across the lower end, impounding water for a large flock of sheep that graze there in June. Surrounding this pond is a stand of trembling aspen (Populus tremuloides) and lodgepole pine. Ribes cereum occurs on the south side of this clearing in considerable abundance, along with some Amelanchier florida and Purshia tridentata. Herbaceous species prevalent here include Montia perfoliata, Hydrophyllum capitatum, Collinsia parviflora, Lithophragma bulbiferum, Veratrum spp. and Hesperochiron pumilis.

Moving eastward, Douglas fir and incense cedar become of increasing importance although the removal by logging of large ponderosa pine probably makes this condition more apparent than real. Douglas fir seems to favor slight north exposures and somewhat more mesic sites than are required by either ponderosa pine or incense cedar, but differences, if real, are subtle. Grand fir is absent or rare below 3,800 feet, about the same elevation where western juniper first appears in the data. The western juniper does occur as scattered individuals as high as 4,400 feet, however.

In small areas affected by slash burning, between 3,700 and 4,000 feet, heavy stands of Arctostaphylos patula and Ceanothus velutinus have developed. Purshia tridentata appears to increase in density to the eastward, and continues to be the most important shrub species to the terminus of the transect. The decumbent Ceanothus prostratus occupies a range between 3,800 feet and 3,300 feet.

Herbaceous species occurring within these open stands include: Castilleja spp., Lupinus spp., Trientalis latifolia, Balsamorhiza sagittata, Hieracium spp., Epilobium angustifolium, Senecio integerrimus, Lathyrus bijugatus var. Sandbergii, Draba verna, Collinsia parviflora, Pteridium aquilinum, Bromus tectorum and Festuca idahoensis.

Western juniper becomes more important below 3,500 feet, but does not become the dominant tree within the length of this transect. Incense cedar continues to be present, with size and vitality appearing to suffer somewhat more than that of ponderosa pine as more xeric conditions are reached to the east. The level, rocky ledge at the edge of Fly Creek Canyon, which essentially simulates more xeric conditions east of the transect, has a widely spaced stand of western juniper, ponderosa pine and incense cedar. Western juniper predominates, with ponderosa pine and incense cedar showing poor growth form. On the north facing slope, however, Douglas fir is still present, indicating that at moisture levels found here[1] exposure is all important.

Ponderosa pine between five and 20 feet in height at the lower elevations is rather severely infected with dwarf mistletoe, and has also been extensively damaged by porcupines.

Arctostaphylos patula occurs as low as 3,300 feet, with its vitality being very low at this level. _Ceanothus velutinus_ was found at 3,750 feet, but not lower. _Purshia tridentata_ and _Chrysothamnus nauseosus_ are the most important brush species at the lowest elevations studied. Characteristic herbs at these lower elevations include: _Erigeron linearis_, _Blepharipappus scaber_, _Madia exigua_,

1. Montgomery Ranch two miles north averaged 14.47 inches precipitation from 1938 to 1947.

Zygandenus gramineus, Linanthus bolanderi, Sitanion hystrix, Microsteris gracilis and Leucocrinum montanum.

2,700-2,800 Feet - The Metolius River

The Metolius River, flowing northward, crosses the transect at right angles, as shown in Figure 2. Because of its departure from the climatic and topographic gradients involved in this study, no quantitative data were taken. The additional available soil moisture along the stream has made possible the development of a forest different from the xeric stands on either side. At the point where the transect crosses the river, ponderosa pine and incense cedar are the most apparent trees, achieving the largest sizes. Some Douglas fir and grand fir of lesser dimensions are also fairly abundant. From three to five miles south of the transect are the most extensive stands of western larch to be found within this general region (16, p. 56), with all size classes present but frequently grouped into even-aged patches of varying dimensions.

The forest to the north has a different character, with a drop in elevation and a somewhat more pronounced valley. The stand consists of more and larger Douglas fir, grand fir and Engelmann spruce as the conditions become increasingly mesic. There are also a few scattered western white pine, and even fewer sugar pine, with two of these being seen about four miles north of the transect.

The transition from ponderosa pine forest to river bottom forest is very abrupt where the transect crosses, with such species as Purshia tridentata apparently encroaching scarcely at all into the bottomland forest. Such shrubs as Alnus sinuata, Acer circinatum, Holodiscus discolor, Physocarpus capitatus and Amelanchier florida are common. Herbaceous species include: Sisyrinchium idahoense, Hypericum anagalloides, Thalictrum occidentale, Limnorchis leucostachys and Lysichitum americanum.

Canyon Creek 3,800-4,000 Feet

The banks of this stream about four miles south of the transect (See Figure 2) are particularly rich in species composition. Here, at the 3,800 foot level, was one of the only two locations where western red cedar was found. Also present here are grand fir, Douglas fir, western hemlock, western larch, western yew, ponderosa pine, mountain ash (Sorbus sitchensis), and black cottonwood (Populus trichocarpa).

Cabot Lake 4,500 Feet

One-half mile east of Cabot Lake (Figure 2) were found the only noble fir seen in this area. They occur in the bottom of an intermittent stream bed, and bore cones in

1959. Although not measured, diameters would have placed them in size class 4. Around Cabot Lake are some very large silver fir and Engelmann spruce. Alpine fir, mountain hemlock and western white pine are also plentiful at this elevation.

Candle Creek 3,000 Feet

The banks of Candle Creek at 3,000 feet have a mixed old growth stand including Engelmann spruce, western hemlock, western red cedar, western white pine, Douglas fir, and grand fir. The recent lava flow just north of the creek has a sparce stand of old Douglas fir and ponderosa pine. At about 3,500 feet and south of the creek, considerable western yew and western hemlock were seen.

Abbot Creek 3,200 Feet

Along this stream at about 3,000-3,300 feet are quite a number of old growth Engelmann spruce, some western yew, and at least one western hemlock. Douglas fir and grand fir are also prevalent here, with lesser numbers of ponderosa pine and western larch.

Prairie Farm Spring 4,300 Feet

This spring emits a substantial volume of water in the early part of the year, but was barely flowing on July 11,

1960. Around its drainage basin are some Engelmann spruce and western yew, with the more characteristic species for the area being Douglas fir, grand fir, ponderosa pine, and western larch.

South Fork of Street Creek

Toward the head of the south fork of Street Creek Canyon is a mixed stand of sugar pine, ponderosa pine, and Douglas fir (Figure 2). The largest sugar pine measured was a little over five feet in diameter at breast height.

DISCUSSION

5,400-6,000 Feet

The forest present between 5,400 and 6,000 feet corresponds approximately to the Hudsonian Zone of Merriam (39, p. 19-20), although limited reconnaissance to the north and south of the transect made apparent the difficulty in drawing demarcation lines on the basis of these observations alone (9, p. 50-55). Tree species in descending order of importance are mountain hemlock, alpine fir, whitebark pine, lodgepole pine and silver fir.

In an attempt to explain the composition and physiognomy of this sub-alpine forest, examination of the autecology of these species is revealing. Baker's (3, p. 180) revised tolerance table includes alpine fir in the category of "very shade tolerant", mountain hemlock and silver fir as "tolerant", lodgepole pine as "intolerant", and whitebark pine as "very intolerant". Moisture requirements based on a list including lodgepole pine and alpine fir for northern Idaho(33, p. 69) indicate that more moisture is necessary for the shade tolerant species. Longevity is listed as 100-175 years for lodgepole pine, 250 for alpine fir, and 400-500 years for mountain hemlock, with a mountain hemlock 15½ inches in diameter measured at over 280 years in this study. Fire resistance is rated as moderate

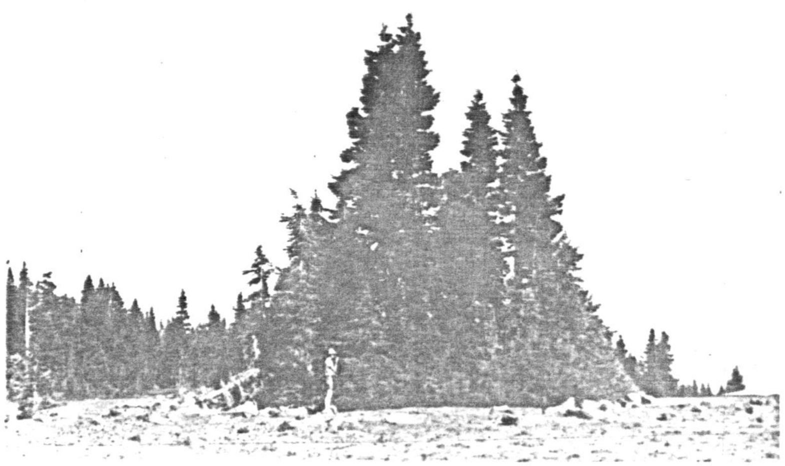
(54, p. 465) for mountain hemlock, and low for lodgepole pine, with the presence of some serotinous cones in the latter being partially responsible for its well known ability to germinate and establish after a fire (11, p. 72). Mountain hemlock (56, p. 19), alpine fir (59, p. 57) and lodgepole pine (57, p. 5) all produce seeds at 20 years of age or less.

As pointed out by Hansen (24, p. 27) the shade tolerance, moisture requirements, age at which the species first produces seeds, amount and consistency of seed production, resistance to and ability to recover from fire are the chief characteristics operative in determining the role a species plays in forest succession. In this sub-alpine forest, the presence of dense stands of the shade tolerant mountain hemlock and alpine fir, including trees of all size classes, indicates a stand long undisturbed by storm or fire (Figure 17). Lodgepole pine and whitebark pine occur in these dense stands only as large mature or decadent trees, with the smaller size classes of these two intolerant pines only at the periphery of the closed canopy forest, or on the exposed crest of Brush Creek Canyon. Silver fir, as yet unimportant below 5,900-6,000 feet, may yet become more prevalent at somewhat lower elevations, since Schmidt (51, p. 19) found in British Columbia that silver fir requires 700-800 years after a fire before

FIGURE 17

A Typical Nearly Pure Stand of Mountain Hemlock at 5500 Feet

FIGURE 18



Timber Atoll of Principally Alpine Fir and Mountain Hemlock becoming reestablished, with this long delay due to the short range of seed dispersal. The mixed mountain hemlock-silver fir stand to the east of Forked Butte thus is probably a very old stand.

The species present and the importance of each would then indicate an absence of damaging fire for 300 years or more. In spite of the lightning storms, frequently unaccompanied by rain, that occur every, or nearly every, summer, this is not unlikely for at least two reasons. First, all except the lower part of this stand includes many openings of fairly substantial size which could serve as natural fire breaks and secondly, the ground at this elevation is snow covered much of the year. Snow had fallen before October 1st, 1959, and there were still extensive snow patches remaining in more sheltered spots on July 12th, 1960. In addition, the weight of the snow tends to flatten and pack the litter to such an extent that very hot fires developing in it are less likely.

The openings that occur in the stands at 5,500-5,600 feet and above appear to be the result of a number of contributing factors. As mentioned above, snow does remain within these gaps later into the summer season. Some of them are small basins that held a foot or two of water in July, 1960, as a result of the melting snow. These basins bear a typical alpine perennial flora later in the summer, and appear to be resisting even the invasion of lodgepole pine with its shallow root system (18, p. 98). Others, particularly toward the upper limit of this zone, have a cindery mineral soil that dries out very rapidly at the surface. On July 3rd, 1960, on a clearing where the snow had recently melted, was a very heavy natural planting of fir and mountain hemlock seeds, the result of an excellent seed year for these trees in 1959. The soil was still moist to the surface but germination was absent, or very scanty, on this date. On July 12th, the soil had dried to a depth of one or two inches over most of the area and most of the seeds had blown away. Some germination had occurred on one shaded side of the opening, with the seedlings unidentified as to species because of the difficulty in identifying conifer seedlings bearing only cotylendonary leaves. As pointed out by Larsen (34, p. 648-654) survival of an individual depends not on germination but on ability to establish after germination, and the conditions present here make the chance of survival slim indeed.

Yet another factor apparently important in these barren areas is the severe frost heave that keeps the soil surface porous and uncompacted; and between the 1959 and 1960 growing seasons pulled large numbers of tap rooted perennials an inch or more out of the ground, exposing the root and apparently killing the plant. Snow creep is important on the steeper slopes with saplings present at the periphery of some of these clearings listing downslope 45^{o} under the weight of two remaining feet of residual snow on July 3rd, 1960. Mountain hemlock saplings appear to recover from snow creep least damaged, with this species upright when the snow had melted and the area was revisited on July 12th. Small whitebark pine, lodgepole pine, alpine fir and silver fir all show considerable breakage by snow, with varying degrees of subsequent recovery.

The forested areas surrounding the openings also show some interesting relationships. In the upper part of this zone, the clumped nature of alpine fir and particularly mountain hemlock is quite striking. This appears to be a reaction to the short period of time when the ground is free of snow. The "black body" effect of trees at high elevations is a well known phenomenon (Figures 19 and 20). The dark surface of the tree trunk absorbs much of the radiation falling on it, and reemits this light and heat energy at a longer wave length (19, p. 46-47), resulting in more rapid melting of the snow near the tree trunk. This frees the soil adjacent to the tree from snow some days or weeks earlier than the area further away, providing an available seed bed early enough for a seedling to establish during the short growing season.

Another factor possibly contributing to such spacing

FIGURE 19

The Melted Snow Around the Base of These Mountain Hemlocks is Typical of Black Body Radiation in Areas of Deep Snow

FIGURE 20

This Clumped Character of the Mountain Hemlock Shown Here is Common at Elevations Over 5600 Feet, Probably Resulting From Black Body Radiation relationships is the ability of alpine fir and mountain hemlock (59, p. 363) to layer, although this was definitely established in this area only for alpine fir. Because of the heavier snowfall, it seems likely that the lower branches of the trees at high elevations are most apt to be trained or covered by enough debris to keep them in contact with the soil long enough to develop adventitious roots.

Some clumps of trees on the Cascades crest between extensive cindery flats appear to qualify as timber atolls (22, p. 554) such as the one shown in Figure 18. This particular atoll occurs at about 6,100 feet, and is composed of alpine fir, whitebark pine, mountain hemlock, and a little dwarf juniper. The explanation for their formation involves the establishment of a single tree or small group of trees, with centrifugal spreading accomplished by layering or by the protection afforded young trees by the original colonizers. The analogy to the coral atoll is completed when the pioneers die and fall, leaving a vacant center or "lagoon". In this atoll the central trees are not yet dead, but the density is considerably higher at the periphery.

At these same high elevations are a number of stony ridges nearly submerged by coarse cinders that have developed stands of whitebark pine, mountain hemlock, alpine fir, dwarf juniper and a little silver fir. The rocks afford some protection during the period of seedling establishment, and thus are capable of developing a forest while the cinder flats are not (61, p. 41).

5,000-5,400 Feet

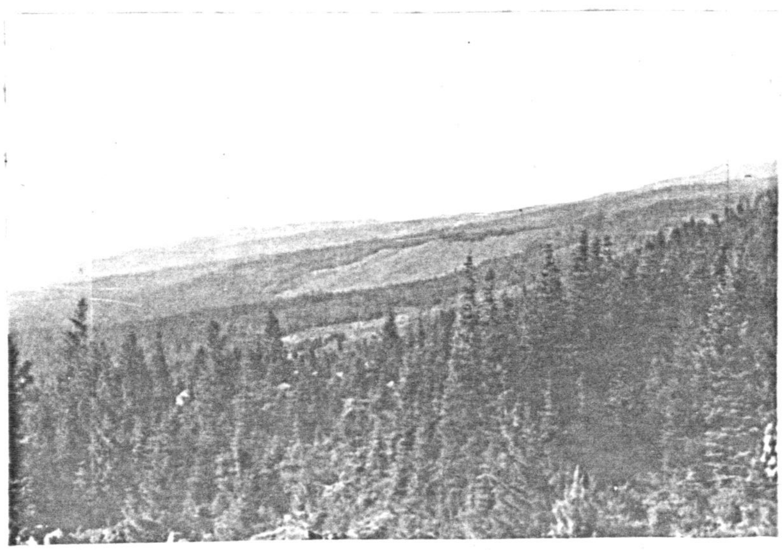
The stand passed through by the transect at these elevations is probably primarily within Merriam's Canadian Zone, with some Hudsonian affiliated plants at the upper limit. The most conspicuous feature is the large number of lodgepole pine present here, with only alpine fir rivaling it in importance (Figure 21). The majority of these lodgepole pines are fully mature, as shown by its relatively high dominance rating. Lodgepole pine does not appear to be wind firm (57, p. 15; 18, p. 98) with quite a number of downed trees opening the canopy at irregular intervals. Only in these openings in the stand are there lodgepole pine seedlings or saplings in any quantity. Ponderosa pine, with only a few decadent trees present, is also in a stage of senescence at these elevations.

In the smaller size classes are large numbers of alpine fir and mountain hemlock, as shown by the small contributions made to dominance, and the high density and frequency of these species (Figure 9). Scattered grand fir and western white pine are also to be found in this stand.

FIGURE 21

Mature Lodgepole Pine With Understory of Alpine Fir and Mountain Hemlock

FIGURE 22



Minto Pass Burn (most distant light colored area) and Brush Creek Burn (nearer light area) South of Stand in Figure 21

The presence of a lodgepole pine population that does not appear to be regenerating indicates conditions that are currently different from those at the time the stand became established. Increment cores taken from a number of trees indicate that the lodgepole pines are primarily about 85 years old. Many of the cores showed restricted rings during the last 30 years or more, indicating this short-lived species will soon be replaced (23, p. 16).

A stand similar in intolerant tree composition is to be found a mile south at comparable elevations on the 15 year old Brush Creek burn (Figure 22). Here, just now appearing over the tops of the shrub species (principally <u>Arctostaphylos patula</u>, <u>Ceanothus velutinus</u> and <u>Holodiscus discolor</u>) are saplings of lodgepole pine and a few ponderosa pine. Many of these trees appear to be 8-10 years old, based on node counts. The burn includes a number of skipped areas, with these islands including some mountain hemlock, alpine fir, western white pine, ponderosa pine and lodgepole pine, with considerably more grand fir than occurs at this elevation along the transect. The prevalence of grand fir may be partially explained by the fact that much of this area is a south facing slope, thus somewhat more xeric than this level along the transect.

It is thus indicated that the lodgepole pine present at 5,000-5,400 feet was the pioneer here after a drastic fire. Increment cores from the large ponderosa pine in the area should give some idea of how long ago the burn occurred, since some of them do show fire scars. One core was taken from a ponderosa pine, but the heartwood was decayed, and wood representing only about 100 years was extracted. There appeared to be no restricted rings in this core such as a fire can cause, thus indicating that the burn must have occurred more than 100 years ago.

There is still remaining some dead and near dead Arctostaphylos patula within parts of this lodgepole pine stand, as noted in the description of the vegetation, with the wood of this shade intolerant species resisting breakage and decay for considerable lengths of time.

An age for this burn of more than 150 years seems exceedingly unlikely, with 125 years probably sufficient to include it. More exact dating of the burn would require trunk cross-sections, which were not obtained from this area (28, p. 175-180). The Brush Creek Canyon burn generally stopped at the crest of its canyon, but there are two or three fairly extensive intrusions over the top of the canyon. It is proposed that this lodgepole pine stand developed on such an intrusion which left unburned, or only partially burned, forests both above and below.

Succession, barring future fire, will inevitably result in the replacement of the pines, with the climax probably involving alpine fir, grand fir and mountain hemlock. Grand fir as the tree with the slightly lower moisture requirements will become more important if the precipitation should become less. There is also some indication that heavy winter snow pack is an important limiting factor in the upper limit of grand fir (23, p. 19).

4,000-4,800 Feet

This grand fir dominated stand, unlike the lodgepole pine zone just above, is characterized by trees of all age groups. The implication is, then, that there has been no catastrophic fire of the magnitude required to make possible colonization by an even aged stand of pioneers. Several of the old trees of this zone do show fire scars, but recovery from them has been nearly complete. Since, as mentioned above, increment core extraction from large trees, particularly the firs, is impractical or impossible, the length of time since the last burn is difficult to determine. The largest trees occur between the elevations of 4,100 and 4,500 feet, although there are some large grand fir throughout the zone. The conclusion must be that while a fire may have burned parts of the zone lightly, the most serious conflagration could not have been more damaging to this area than were the recent Minto Pass and Brush Creek burns to the tree islands left in their midst.

Healthy unscarred grand firs up to 100 years in age were cored, while an alpine fir at 4,650 feet was 110 years old and 13½ inches in diameter. Grand fir, relatively fire resistant as a mature tree (54, p. 465), has a low, dense crown in its youth and would be fairly fire susceptible in dense stands. This would seem to indicate escape from burning by a sizeable number of seed trees for over 100 years.

As in the plant successions in the Willamette Valley on the other side of the Cascades (52, p. 96), grand fir appears to be here the climax tree. Its size and growth rate are such that it can outgrow alpine fir and mountain hemlock at the upper part of this zone, with the available soil moisture probably also being near minimum for the latter two species (33, p. 69). The canopy closure is too complete for lodgepole pine, western larch and ponderosa pine regeneration, as evidenced by their absence of smaller size classes. Western white pine, as pointed out by Huberman (27, p. 148-149) for northern Idaho, is a seral species. Although its moisture requirements are listed as being slightly less than that for grand fir (33, p. 69), its distribution in the transect area is somehow limited, since it is prevalent only on the north facing slope of Cabot Creek Canyon. Baker (3, p. 180) lists grand fir as being considerably more shade tolerant than western white pine, with this certainly true in this region.

Only around Abbot Butte Spring do Engelmann spruce and western hemlock find enough soil moisture to take advantage of their superior shade tolerance. Douglas fir becomes increasingly important at the expense of grand fir toward the lower and presumably dryer part of the zone, very likely because of its lesser moisture requirements (33, p. 69; 35, p. 44). Douglas fir, unable to regenerate when canopy closure is complete (43, p. 664), is reproducing here in the better lighted sites occurring in openings in the stand.

This zone will, under the present set of environmental conditions, continue to appear much as it does today, with a stand of grand fir occupying most of the area except for especially wet or dry habitats. Because of its considerable shade tolerance and ability to recover from an aged, stunted status when released by a break in the dense canopy, it should maintain or improve upon its present importance until or unless destroyed by fire.

<u>3,300-4,000 Feet</u>

This zone differs from the one just above in having a number of large old Douglas fir in the overstory. As in most of the rest of the forest crossed by the transect, there is evidence of past burning in fire scarred boles and blackened bark. Some of these old trees, particularly those close to the 3,300 foot boundary, have living branches low on the stem. This is an indication that the tree was open grown, since the species is shade intolerant (40, p. 21).

Other large trees, with diameters at breast height in the vicinity of three feet, are ponderosa pine and incense cedar. Ponderosa pine is notable for its fire resistance (54, p. 465) and the older incense cedars with their thick bark (32, p. 815-817) are also capable of withstanding moderate burning.

As in the zones above and below, the striking thing about this stand is its abundance of trees in size classes 1, 2, and 3. Increment cores taken from grand fir, Douglas fir, and incense cedar indicate that many of these trees are about 75 years old or less, and exhibit quite a rapid growth rate as measured by annual increment of wood. A few Douglas fir and ponderosa pine of a hundred or more years in age show restricted rings between 70 and 80 years ago, which might indicate a severe fire then, although no exact chronological pattern emerged from the few trees bored in this study.

The suspected fire history of this area is not particularly different from the adjoining areas, with the major difference lying in the trend of the succession, and thus evidently in the controlling environment. The numbers of incense cedar and particularly Douglas fir found within these elevational limits are a drastic departure from the zones above and below. The stand has a more irregular canopy than any encountered within the 1,000 feet of elevation above its upper limit, with soil moisture levels apparently low enough to allow Douglas fir an increasing competitive advantage over grand fir. It is near the lower part of this zone that the boundary between a grand fir climax and a Douglas fir climax will ultimately develop, barring fire, with the lower limit of xeric tolerance by grand fir being the deciding factor.

The role of incense cedar in this stand is difficult to interpret. As pointed out by Mitchell (40, p. 19), the seedlings and saplings of this species are nearly impossible to kill by shading, but require more light as they approach maturity. Stands of seedlings and saplings are abundant toward the lower elevations of this zone but growth does not appear to be very rapid (63, p. 18). A tentative observation suggests that they do not stand browsing well, which might contribute to their slow growth rate since they do appear to be lightly browsed by deer and/or sheep. With optimum moisture conditions similar to those of Douglas fir, but with considerably greater tolerance of xeric conditions than this species, incense cedar appears to have considerable potential in the area. The rapid growth rate of Douglas fir and grand fir seems to indicate that incense cedar will more effectively compete on a short term basis with ponderosa pine than with either of the firs. Significant increases in the proportion of incense cedar in stands of the firs would probably have to occur over a period of two or more generations of grand fir or Douglas fir.

Since incense cedar is here near the northern extremity of its range, low temperature or some unidentified factor or factors could conceivably halt its current increase in status.

2,800-3,300 Feet

Within this zone ponderosa pine is clearly now the dominant species, but changes are impending, particularly toward its upper limit. Cooper (10, p. 151) found in northern Arizona that, characteristically, ponderosa pine occurs in even aged groups of several trees each, with the individual groups within the stand being of various ages. This condition seems to be generally true for the ponderosa pine within this study area also. Cooper found, furthermore, that pure pine stands from which fire has been excluded have regenerated superfluously, with the resulting density of the young stand causing a stagnation of growth.

Conversely, a forest in which fire was not excluded, and which burned on the average of once every eight years appears to be successfully maintaining the pattern of even aged groups in an uneven aged stand. Cooper believes this is accomplished by the action of fire. Litter accumulates in greatest density under the mature stand as a result of the natural pruning and needle drop of these trees. On the other hand, the seedling establishment is best effected under gaps in the stand which occur as a result of tree death and wind fall (62, p. 8). Thus, a fire going through such an area will burn the fuel under the mature stand, essentially circumventing the gaps where fuel is scarcer. This serves to kill any seedlings that have established under the mature stand, as well as to keep the litter, and thus the hazard of a damaging fire, at a minimum.

As the clumps of saplings grow, litter accumulates until enough fuel to carry a fire through this young stand has developed. Cooper's (10, p. 154) study showed that 18% of the very small trees survived a light fire, while 84% of those in the four to six inch d.b.h. class survived. Fire thinning has been reported to effectively release trees from competition so that growth on burned plots had exceeded that on unburned plots within six years (41, p. 207). This ineffective fire resistance of the young trees serves to thin the stand sufficiently to maintain the most nearly ideal tree spacing, in a truly remarkable adaptation to existence under what appear superficially to be adverse conditions.

As pointed out by Weaver (63, p. 15) this situation is even more compounded in the ponderosa pine of this part of Oregon by the aggression of the less commercially valuable grand fir, incense cedar, and Douglas fir (Figures 23 and 27). Low branches on large Douglas firs at 3,300 feet in the study area indicate an open grown condition during their youth that is now disappearing in much of this zone.

Increment cores taken from three trees in a single, dense clump in this area serve as an indication of what is happening. A ponderosa pine about 30 feet high and six inches in diameter was 58 years old at breast height. A Douglas fir growing within 10 feet was 30 years old at breast height, eight inches in diameter and 35 feet high. A grand fir over 35 feet high and eight inches in diameter was 34 years old. Since these trees appear to all be receiving essentially the same treatment by the environment, it suggests that grand fir and/or Douglas fir have a competitive advantage over the pine. A pine growing 50 feet away in an opening in the stand was over 35 feet high, nine inches in diameter and 49 years old at breast height.

FIGURE 23

Mixed Douglas Fir and Ponderosa Pine Stand, With Douglas Fir Sapling Understory

FIGURE 24

Ponderosa Pine Stand With Incense Cedar and Ponderosa Pine Sapling Understory. Bush in Foreground is Arctostaphylos patula. Accumulating litter makes forest increasingly flammable.

While this evidence is insufficient by itself, it does support the findings and opinions of Cooper and Weaver.

In a study of fire damage to incense cedar and ponderosa pine, Lachmund (32, p. 815-817) found in California that 87% of the incense cedar and 69% of the pine were fire scarred by a moderate fire. However, only 12% of the pine was seriously damaged, while 33% of the incense cedar received serious injury. Furthermore, the pine showed greater capacity for healing these wounds, and was more resistant to further damage by insects infecting the scars. While no comparisons were found between ponderosa pine, grand fir and Douglas fir, the fire control of the original pine forest physiognomy suggests that this species is better adapted to frequent burning than are either grand fir or Douglas fir.

Cooper (10, p. 51-54) and Weaver (62, p. 8-9) point out that the typical park-like ponderosa pine stands are dependent on frequent fires, and that once considerable unburned litter has accumulated an uncontrolled fire will probably burn and kill mature trees (Figure 24).

The elevations near 2,800 feet within this zone do contain a near pure stand of ponderosa pine (Figure 11, Row 20-21) that appears quite healthy, although somewhat overstocked with young trees. As pointed out by Krauch (31, p. 463-464), intolerant trees can perpetuate themselves only in dry areas where the physiological requirements of possible competitors exclude them. In this immediate area the increasing shade provided by an unthinned ponderosa pine stand is providing suitable habitat over most of its range for species formerly excluded by fire.

An animal agent in ponderosa pine seed planting seems to be indicated in these dry soils by the fairly frequent groups of closely associated seedlings and saplings that were observed. Stanton (53, p. 38) found rodents were responsible for considerable planting of _Purshia tridentata_ seeds, with germinating caches of these seeds also occurring in the study area. Since a number of rodents do eat the seeds of ponderosa pine (12, p. 8) it seems not unlikely that they inadvertantly plant some as well.

2,800-4,500 Feet: West Slope of Green Ridge

As within most of the stands crossed by the transect, trees on this slope show signs of fire damage in scars at the bases of the trunks. Douglas fir, ponderosa pine, and incense cedar, the three species found here, are all fire resistant (54, p. 465; 32, p. 815-817). The wide spacing of trees present, however, will have prevented the devastation of a serious fire, as is shown in the wide range of tree sizes occurring within the quadrats.

In effect, the spacing of trees imposed by the rocky, unstable ground surface makes this forest more analogous to the stands of 100 or more years ago than any other studied. Minor slides of rock would serve to uproot or cover seedlings and saplings, thus functioning as a thinning agent much as fires have done in the past (10, p. 151-154; 62, p. 8,9), while bare rock outcroppings will obviously not support tree growth. The wide spacing of habitats suitably protected for tree establishment have prevented development of a canopy dense enough to shade out high light requiring species.

This segment of the ridge then will probably not undergo changes of any consequence within the future, at least within times meaningful in the life spans of men. Green Ridge is about 15 miles long, and parts of it do appear relatively stable and heavily forested. These more stable areas would be subject to a climax stand of more shade tolerant species, with composition depending on the available moisture. Grand fir on sites mesic enough to support it, Douglas fir in areas too xeric for grand fir, and incense cedar possibly becoming increasingly important at the expense of Douglas fir would be the probable pattern of the replacement of the fire maintained ponderosa pine.

3,000-4,500 Feet: East Slope of Green Ridge

This zone differs from the others in that most of it has been subjected to a 20-30% cut within the last ten years. The logging process is comparable to a fire in the sense that it does create openings in the canopy, but an important difference is the absence of sapling thinning necessary to prevent excessively dense stands from stagnating.

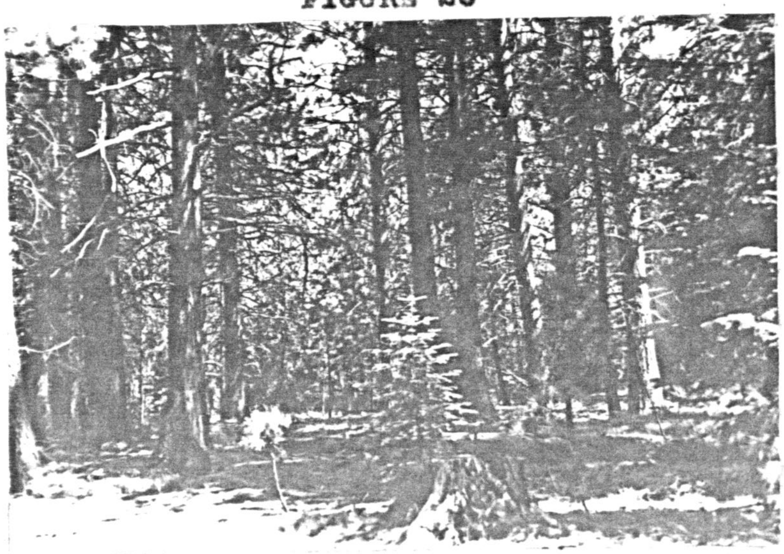
Numbers of saplings present are generally adequate to restock the cutover areas, with ponderosa pine, Douglas fir, and incense cedar most important in the area as a whole. There is considerable grand fir above 4,000 feet (Figures 25 and 26) and western juniper below 3,500 feet (Figure 28). The numbers of species other than ponderosa pine in this size class may be somewhat disproportionate, although, as mentioned above, selective cutting of the pine makes interpretation on the basis of present stand appearance subject to error. The ability of young ponderosa pine to withstand fire (37, p. 3-7; 10, p. 54) would probably alter this proportion should fire go through the area; with grand fir, Douglas fir, and incense cedar benefiting as a result of developing canopy density and exclusion of fire.

The limited observations made on western juniper indicate that its shade intolerance (3, p. 180) will be no serious handicap to the species in its present range, since moisture is apparently limiting to the establishment of

FIGURE 25

Grand Fir Stand on Top of Green Ridge
Large tree at left is a dead western larch, downed log is grand fir.

FIGURE 26



Dense Ponderosa Pine Stand With Grand Fir and Douglas Fir Sapling Understory
Sapling in center is grand fir.

FIGURE 27

Ponderosa Pine With Understory of Incense Cedar (extreme right) and Ponderosa Pine Saplings and *Purshia tridentata*

FIGURE 28

Western Juniper Stand at Eastern Terminus of Transect other species within this area.

As stated in the description of the vegetation, this slope of Green Ridge essentially replicates the same elevations further west, since relief is quite similar. The only major difference indicated would be less precipitation in this area as compared to the similar elevations across the Metolius River. Evidence to support this belief comes from the lower occurrence of grand fir on the Cascades slope and the greater abundance of western juniper east of Green Ridge.

In an attempt to learn whether the understory vegetation supports the belief that there is less precipitation on the east slope of Green Ridge than at comparable elevations on the Cascades eastern slope, Table 1 was prepared. From this table it can be seen that without exception the ranges of the species common to both these slopes extend to lower elevations in the more westerly stand. Although these understory plants are at least partially dependent on the environment contributed by the overstory, as noted for Arctostaphylos patula and Purshia tridentata (53, p. 14) the consistent pattern shown by these comparative ranges is quite striking in its support of the conclusion reached on the basis of tree distribution. Trientalis latifolia, for one, seems to tolerate wide ranges of light quantity, appearing in full sunlight and in dense shade. Moisture

TABLE I

		Average Elevation									
		4400	4250	4100	3950	3800	3650	3500	3350	3200	3050
Chimaphila umbellata	a.	x									
	b.	x	x	x	x	x					
C. menziesii	a.	x	x								
	b.	x	x	x	x		x	x	x		
Symphoricarpus albus	a.	x	x								
	b.		x	x	x		x		x		
Lathyrus bijugatus	a.		x	x							
	b.								x		
Castanopsis chrysophyla	a.	x			x						
	b.	x		x			x				
Holodiscus discolor	a.	x	x	x	x						
	b.								x		
Trientalis latifolia	a.	x				x					
	b.			x	x	x	x	x	x	x	x
Ceanothus velutinus	a.	x	x	x	x	x					
	b.					x	x		x	x	
Arctostaphylos patula	a.	x	x	x	x	x	x	x	x	x	
	b.								x	x	x
Purshia tridentata	a.		x		x	x	x	x	x	x	x
	b.								x	x	x
Balsamorhiza sagittata	a.					x	x	x		x	x
	b.								x	x	x

Comparative Ranges of Understory Species at 4500-3000 Feet On:
a: East slope of Green Ridge
b: East slope of the Cascades

availability then seems most likely to be the controlling environmental factor. No serious effort to separate cause and effect has been attempted in this study, however.

This table also serves to illustrate a continuum in overlapping species ranges in the subordinate vegetation.

The fire history of an area as extensive as this, with the transect here crossing eight sections, may well vary from place to place. As would be expected in a frequently burned ponderosa pine forest, trees of all ages are found. One tree, 24 inches in d.b.h., contained 479 annual rings in a core just nine and five-eights inches in length. As pointed out by Keen (29, p. 597-598), the oldest trees within this species are invariably found growing on somewhat unfavorable habitats. Restricted rings as recent as 18 years ago were found in cores from this zone, with the 479 year old tree containing several sets of these thin rings. Discretion must be exercised in naming any specific set due to fire, however, since damage by porcupines, insects, or fungi might conceivably cause similar retardation.

Just east of Prairie Farm, a group of ponderosa pine varying in diameter from 6.0-22.8 inches was sampled with the increment borer. Ages ranged from 70 to 105 years with no correlation between size and age appearing. This points up the danger in assuming small trees are necessarily younger than their large neighbors, when considerable discrepancies can be caused by different light and water relationships for adjacent trees.

SUMMARY AND CONCLUSIONS

An eighteen mile transect was established in western Jefferson County on the leeward slope of the Cascades. This geologically young, uniform slope is covered by a forest including at least 19 coniferous species. An abrupt diminution in the amount of precipitation begins at the Cascade crest, decreasing from approximately 60 inches to less than 20 inches within this 18 mile distance.

Uniform sampling along the transect included data collection for determination of tree density, frequency, basal area and size classes present. These statistics are presented in phytographs (Figures 9-13) and DFD indices (Figures 14-15) arranged according to elevation.

These graphs describe a continuum of species ranges with dense stands of mountain hemlock, alpine fir, and silver fir at highest elevations separated by alpine meadows and cinder flats with lodgepole pine, whitebark pine and dwarf juniper on their margins. The generally closed canopy forest below 5,000 feet includes lodgepole pine, grand fir, Douglas fir, western white pine, western larch, mountain hemlock and alpine fir.

Ponderosa pine and incense cedar become increasingly abundant below 3,800 feet, and the tree spacing becomes wider. Green Ridge is essentially a dryer replication of comparable elevations to the west, with the only additional species of importance being western juniper.

This study area, selected on the basis of its absence of human disturbance, contains evidence of being in a seral stage. One of the basic reasons for the failure of this ecotonal forest to have become stabilized involves the abrupt change in the environmental component of fire. The effects of wildfire until approximately a century ago and its subsequent exclusion appear to be the basis for the successional trends present today.

Throughout the areas studied those stands with a recent fire history are changing. The most apparent alteration is the increasing density and frequency of individuals within the stand, but species composition is also being modified. Alpine fir and mountain hemlock at 5,000 feet have high percentage frequencies and small basal area totals, indicating a highly successful, youthful stand (Figure 9), while the even aged stand of lodgepole pine is decadent. Douglas fir at 3,600-4,000 feet has high dominance but low frequency and density, indicating ultimate replacement by the shade tolerant grand fir (Figure 10). Just below these elevations ponderosa pine assumes the senescent role, while Douglas fir and incense cedar rate high in frequency and density.

The essentially xeric conditions created by frequent burning in the past are no longer enforced, and invasion or re-invasion by formerly excluded species is occurring. Whether the resulting plant succession is unidirectional will depend on whether limiting agents such as insects or disease are or will be controlled (62, p. 13) and whether prevention of catastrophic fire can be continued in an increasingly flammable forest.

Assuming conditions do remain essentially as they are today, a general eastward shift of species ranges within the area where fire formerly was effective can be expected. The species ranges will probably not become static since the close association between trees not usually associated indicates environmental conditions near the tolerance limits for many of them. Slight environmental modifications, in climate for instance, would thus be reflected in the increase of those species favored by the change, and the decline in importance of those not favored. Thus, only general trends can be defined.

It now appears that the high altitude forests will remain much as they are today, with whitebark pine, lodgepole pine, and dwarf juniper at the margins of mixed mountain hemlock, alpine fir, and silver fir stands. Enough factors contribute to maintaining the openings in the stand so that it is unlikely they will disappear.

Below 5,000 feet the most important pioneer species are lodgepole pine and ponderosa pine, with the ranges of both of these extending downward and eastward nearly as far as the transect continues. The ratios change within these limits from nearly all lodgepole pine at 5,000 feet to nearly all ponderosa pine at 2,700 feet. Lodgepole pine at its lower limits may be found in areas with high water tables, while ponderosa pine grows on well drained, sunny habitats at its upper limits, reflecting particularly the depth of their root systems (15, p. 367).

These pioneers are being replaced at the upper limits by alpine fir, mountain hemlock, and grand fir, with the latter becoming more abundant at the expense of the other two at decreasing elevations. Douglas fir assumes an intermediate role between ponderosa pine and grand fir at about 4,000 feet, being more shade tolerant and requiring higher soil moisture levels than ponderosa pine, and less shade tolerant and less moisture requiring than grand fir. Douglas fir thus can successfully compete with ponderosa pine in areas too xeric for grand fir. Incense cedar in turn appears able to compete on a long term basis with Douglas fir and ponderosa pine.

The species of minor importance in the area appear to be limited to specialized habitats so that their roles are not likely to change with slight environmental shifts. Western red cedar, western yew, western hemlock, noble fir, and Engelmann spruce will be confined to ravines, stream banks and north slopes as they are today (44, p. 455-456). Western white pine is a seral species apparently unable to maintain itself in competition with grand fir. Western larch is a pioneer species in moist habitats, frequently in association with lodgepole pine in young stands, but with its longer life span and greater growth potential enabling it to outgrow lodgepole pine within a century. Sugar pine, currently limited to mesic sites within generally xeric areas, gives little evidence of substantial increase. Western juniper, as mentioned above, has a low moisture tolerance that has enabled it to avoid serious competition with other species.

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APPENDIX

Vascular Plants Collected in the Area

Elevation	Plant	Abundance (6, p. 30)
6000		
	Luetkea pectinata (Pursh) Hook	4
	Tsuga mertensiana (Bong.) Sarg.	?
	Haplopappus bloomeri Gray	3
	Juncus mertensianus Bong.	2
	Aster alpigenus Gray	2
	Penstemon nemorosus (Dougl.) Trautv.	2
	Pedicularis racemosa Dougl.	2
	Sedum spathulifolium Hook.	2
	Holodiscus glabrescens (Greene) Hel.	1
5800		
	Eriogonum marifolium T. and G.	3
	Pinus albicaulis Engelm.	3
	Polemonium californicum Eastw.	2
	Eriogonum pyrolaefolium Hook.	2
	Sitanion hystrix (Nutt.) J.G. Smith	2
	Pseudotsuga mensiesii (Mirb.) Franco	1
	Hackelia californica (Piper) Johnsf.	1
5600		
	Viola orbiculata Geyer.	4
	Dodecatheon jeffreyi Van Houtte	2
5400		
	Polygonum newberryi Small.	4
	Ranunculus alismaefolius Geyer var. alismellus Grey	3
	Caltha biflora DC.	3
	Anemone lyallii Britt.	3
	Phlox diffusa Benth var. longistylus (Wher.)	3
	Potentilla flabellifolia Hook	1
5000		
	Abies lasiocarpa (Hook.) Nutt.	4
	Pinus monticola Dougl.	3
	Mitella pentandra Hook	2
	Calochortus lobbii Baker	1
	Gilia aggregata (Pursh.) Spreng.	1
4800		
	Xerophyllum tenax (Pursh.) Nutt.	5
	Tsuga heterophylla (Raf.) Sarg.	3
	Taxus brevifolia Nutt.	3

Ele-vation	Plant	Abundance (6, p. 30)
4800		
	Fragaria cuneifolia Nutt.	3
	Goodyera decipiens (Hook.) St. John & Const.	1
4600		
	Crataegus douglasii Lindl.	5
	Abies procera Rehd.	3
	Arenaria macrophylla (Hook.)	3
	Hydrophyllum capitatum Dougl.	3
	Calamagrostis rubescens Buckl.	2
	Frittilaria pudica (Pursh.) Spreng	1
	Circium americanum (Grey) Robins	1
4200		
	Ceanothus velutinus Dougl.	5
	Linnaea borealis L.	5
	Ribes viscosissimum Pursh.	5
	Stachys ciliata Dougl.	4
	Rubus macropetalus Dougl.	3
	Fragaria bracteata Hel.	3
	Rubus parviflorus Nutt.	3
	Ribes lacustre (Pers.) Poir.	3
	Tiarella unifoliata Hook.	3
	Adenocaulon bicolor Hook.	3
	Campanula scouleri Hook.	3
	Symphoricarpus albus (L.) Blake	3
	Trillium ovatum Pursh.	3
	Smilacina sessilifolia (Baker) Nutt.	3
	Senecio triangularis Hook.	3
	Amelanchier florida Lindl.	3
	Aconitum howellii Nels.	3
	Berberis repens Lindl.	3
	Bromus marginatus Nees.	
	Rubus vitifolius C. and S.	2
	Hieracium albiflorum Hook.	2
	Acer glabrum Torr.	2
	Castanopsis chrysophylla (Dregl.) A.DC.	2
	Kelloggia galioides Torr.	2
	Galium triflorum Michx	2
	Asarum caudatum Lindl.	2
	Smilacina racemosa (L.) Desf.	1
	Anaphalis margaritacea (L.) B. and H.	1
	Mimulus moschatus Dougl.	1

Elevation	Plants	Abundance (6, p. 30)
4200		
	Corallorhiza maculata Raf.	1
	Listera convallarioides (Sw.) Torr.	1
	Hypericum anagalloides C. and S.	1
	Viola glabella Nutt.	1
4000		
	Clintonia uniflora (Schult.) Kunth.	3
	Populus tremuloides Mich h.	3
	Rosa gymnocarpa Nutt.	3
	Holodiscus discolor (Pursh.) Maxim.	1
	Disporum oreganum (Wats.) B. and H.	1
3800		
	Anemone lyallii Britt.	4
	Arctostaphylos patula Greene	4
3600		
	Abies grandis Lindl.	?
	Pachistima myrsinites (Pursh.) Raf.	4
	Alnus sinuata (Regel) Rydb.	3
	Pinus lambertiana Dougl.	2
	Aquilegia formosa Fisch.	2
	Prunus emarginata (Dougl.) Walp.	1
	Sorbus sitchensis Roem.	1
	Piperia elegans	1
3200		
	Montia perfoliata (Donn.) How.	5
	Antennaria dimorpha (Nutt.) T. and G.	3
	Poa secunda Presl.	2
	Collinsia parviflora Dougl.	2
	Microsteris gracilis (Dougl.) Greene	2
	Hydrophyllum capitatum Dougl.	2
	Lithophragma parviflorum (Hook.) Nutt.	2
3000		
	Acer circinatum Pursh.	3
	Lotus douglasii Greene	3
	Collomia grandiflora Dougl.	2
	Rhamnus purshiana DC.	1

Elevation	Plant	Abundance (6, p. 30)
2800		
	Hesperochirom pumilus (Dougl.) Porter	1
	Horkelia fusca Lindl.	1
	Cerastium arvense L.	1
	Cornus stolonifera Mich X	1
	Juniperus occidentalis Nutt.	1
	Lysichitum americanum Hulten and St. J.	1