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# VEGETATION AND SOILS IN THE SUBALPINE FORESTS OF THE SOUTHERN WASHINGTON CASCADE RANGE

By

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To the Resident Instructional Staff:

The members of the Committee appointed to examine the thesis of JERRY FOREST FRANKLIN find it satisfactory and recommend that it be accepted.

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# INTRODUCTION

Dense coniferous forests characterized by species of Abies and Tsuga are found along the upper slopes and crest of the Cascade Range in Oregon and Washington. These forests occupy the Tsuga mertensiana and Abies amabilis Zones which together are the least known of the major phytogeographic units in the Pacific Northwest.

Forest composition and environments vary markedly within the Abies-Tsuga Zones. Fourteen tree species play the role of major components: Pacific silver fir (Abies amabilis), western hemlock (Tsuga heterophylla), mountain hemlock (Tsuga mertensiana), noble fir (Abies procera), subalpine fir (Abies lasiocarpa), Douglas-fir (Pseudotsuga menziesii), western redcedar (Thuja plicata), Alaska-cedar (Chamaecyparis nootkatensis), Shasta red fir (Abies magnifica var. shastensis), Engelmann spruce (Picea engelmannii), grand fir (Abies grandis), western white pine (Pinus monticola), lodgepole pine (Pinus contorta), and western larch (Larix occidentalis). The diversity in environmental conditions of these zones can easily be imagined for they extend through 7 degrees of latitude, cross the width of the Cascade Range, and range through as much as 5,000 feet of elevation.

The wealth of tree species, a history of past disturbances, and a complex and diverse environmental mosaic have produced an apparently chaotic assemblage of forest types within the Abies-Tsuga Zones. It was apparent that these forests needed to be stratified into areas of essentially equivalent environment, i.e., habitat types, before meaningful autecological and

silvicultural research could be carried out. Accordingly, a three-part study was planned. The first phase entailed development of a habitat type classification based on systematic study of plant communities, soils, and landforms. The second would investigate major environmental differences between habitat types to determine factors correlated with and responsible for boundaries between habitats. The third phase would evaluate the significance of the classification in resource management, e.g., differences in productivity between habitats. Autecological and silvicultural studies could then proceed on a sound basis.

This thesis provides a description and classification of forest communities and soils in the Abies amabilis and Tsuga mertensiana Zones of the southern Washington Cascade Range, presents data on vegetation composition and seral relationships among tree species within these zones, and correlates vegetation with selected aspects of environment.

## DEFINITIONS

Few of the specialized terms essential for presentation of ecological studies have a universally-accepted definition. Consequently, their use in this paper needs to be specified.

A community or stand is any aggregation of plants relatively uniform in physiognomy and composition, and growing in relatively uniform environmental conditions, regardless of its successional status. A community or species is seral if populations are undergoing a directional change (as opposed to the minor fluctuations of a basically stable population). Climax is used where there is no evidence that the community or species is being replaced by another. A climax tree species can reproduce under canopy conditions typical of the association (defined below); it typically exhibits a j-shaped distribution curve when number of trees is plotted against size class. The seral tree lacks representation in reproductive and intermediate size classes or either.

The association is abstract in that it includes all climax communities and only climax communities) more closely related to each other than any others as determined by composition, relative importance (coverage and frequency) of the plant species, and their environmental relationships. The association is defined by the entire range of characteristics of the individual climax stands belonging to it.

Types of climax may be distinguished as follows:

> The type of climax vegetation which is characteristic of undulating topography and loamy soils that are moderately drained zonal habitats, is called the climatic climax. . . . Within a small region those climaxes which differ from the climatic climax because of some stable but peculiar

> and ecologically important soil condition are called edaphic climaxes. On still other habitats where mature vegetation differs from the climatic climax because rough topography results in excessive exposure to, or protection from, direct solar radiation, or where wind manifestly modifies vegetation, such vegetation is considered topographic climaxes. Frequently soil peculiarities accompnay strong topographic influence, and in such cases the term topoedaphic climax seems appropriate.

Daubenmire (1952) goes on to point out that associations may play different climax roles in different parts of an area, e.g., a climatic climax in one location may be a topographic climax in another.

Vegetation zones are those portions of the landscape having the same community as the climatic climax. In forests of the Pacific Northwest, vegetation zones are generally distinguishable as belts occupied or potentially occupied by different climax tree species on zonal habitats.

A habitat type is those parts of a landscape which one association occupies or would occupy through natural succession. While the association and habitat type are designated by the same plant names, the association refers to a particular climax community and the habitat type to area regardless of present vegetative cover. The association simply defines the habitat type by showing those areas which have the same biologic potential--those which will develop the same climax community (association).

Frequency and coverage are characteristics of individual species in a stand. Frequency refers to the percent of plots in which a particular species occurs. Coverage refers to the percent of ground covered by the canopy of a particular species, i.e., to "canopy coverage" as defined by Daubenmire (1959). Constancy is the percentage of stands of a particular association in which a species occurs. A species which occurs in all stands of an association has 100 per cent constancy for that association.

# THE STUDY AREA

## Geographical Limits

The study area comprised the southern Washington Cascade Range, bounded roughly by Mount Rainier, Mount St. Helens, Mount Adams, and the Columbia River. A few plots were located north of Mount Rainier and as far south as Mount Hood to obtain additional data on some plant associations (Fig. 1).

Most of the forests studied occurred between elevations of 2,500 and 5,000 feet, with extremes of 1,500 and 6,500 feet. Lower elevational limits of the study area were determined by occurrence of Abies amabilis. Timberline delineated the upper elevational limits.

The study area included two major geographic units which differ in geology, physiography, soils, climate, and vegetation:the Mount Rainier and Mount Adams Provinces (Franklin, 1965b). Major environmental differences between the provinces are outlined in the following discussion; vegetative differences are considered in the results.

## Climate

The climate within the study area is distinctly maritime, cool and moist with muted extremes. Annual precipitation is heavy, ranging from about 50 inches at the lowest elevations studied to over 100 inches at higher elevations of the Tsuga mertensiana Zone (Table 1). Precipitation normally increases rapidly with elevation on western slopes, but a marked rain shadow occurs even at higher elevations east of the Cascade Divide. Usually less than 10 per cent of the annual precipitation falls between late June and September. Much of the

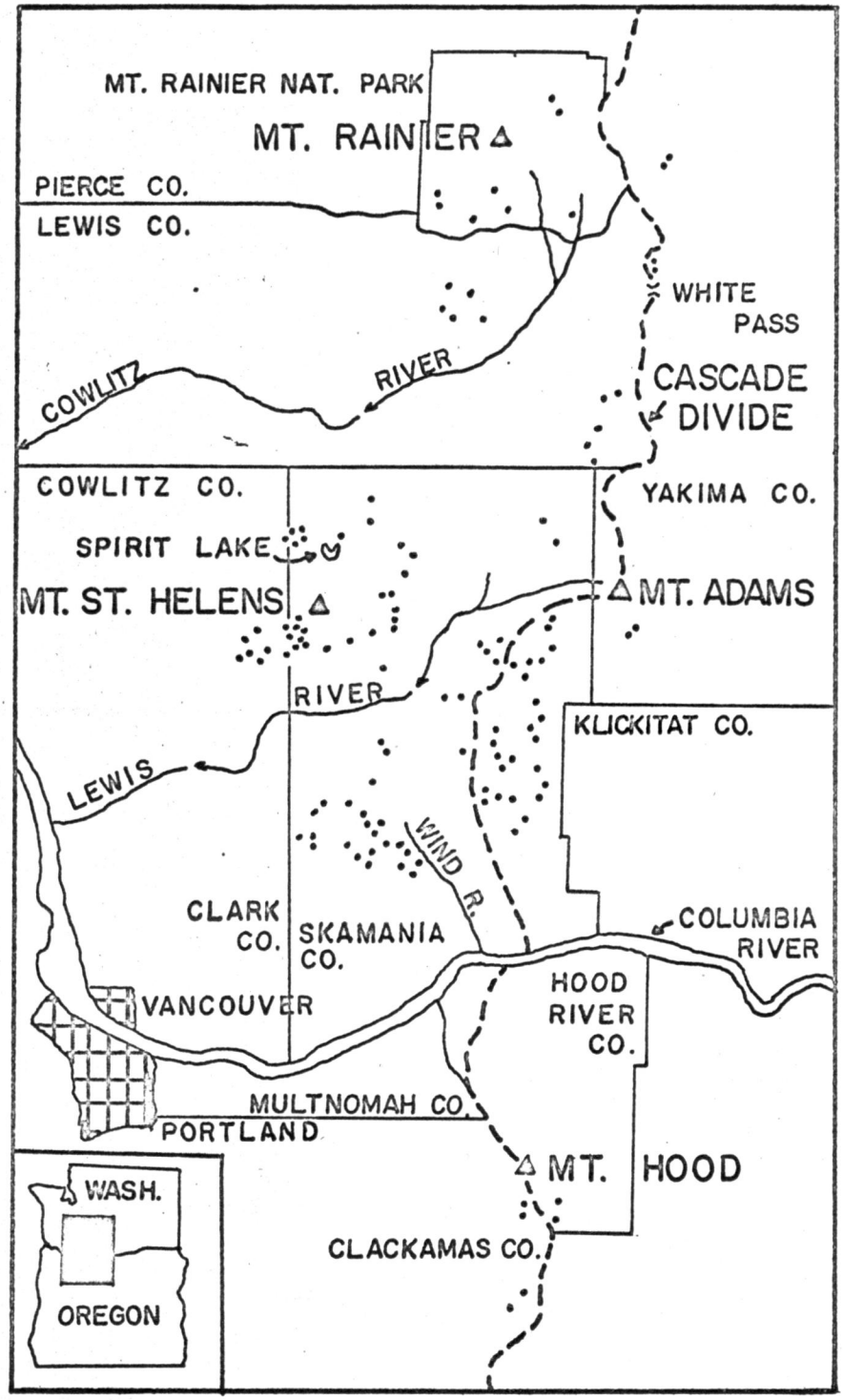



Fig. 1.--Location of the study area and of plots used in the analytic phase of the study.

Table 1.--Climatic data from representative stations in the southern Washington Cascade Range[a]

| Ecological Province and Weather Station | Zone | Elev. in Feet | Precipitation in Inches | | | Temperature in Degrees F | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total Annual | June, July, & Aug. | Annual Snow-fall | Av. Annual | Mean Monthly | | Av. Jan. Min. | Av. July Max. |
| | | | | | | | Jan. | July | | |
| Mount Rainier | | | | | | | | | | |
| Wind River | Tsuga heterophylla | 1150 | 96.55 | 4.55 | 85.8 | 48.1 | 31.8 | 63.4 | 24.9 | 80.1 |
| Parkway | Abies amabilis | 2640 | 54.93 | 4.35 | 135.9 | 44.8 | 30.3 | 59.8 | 25.1 | 73.7 |
| Longmire | Abies amabilis | 2762 | 79.44 | 6.37 | 179.4 | 45.2 | 30.0 | 61.1 | 23.6 | 74.9 |
| Spirit Lake | Abies amabilis | 3240 | 88.69 | 5.52 | 282.6 | 42.0 | 28.4 | 58.8 | 24.1 | 72.2 |
| Stampede Pass | Tsuga mertensiana | 3958 | 93.60 | 7.34 | 473.4 | 39.9 | 23.7 | 56.9 | 19.8 | 67.2 |
| Paradise | Tsuga mertensiana | 5550 | 101.49 | 9.08 | 536.4 | 38.5 | 26.3 | 53.1 | 20.1 | 62.8 |
| Mount Adams | | | | | | | | | | |
| Mt. Adams R.S. | Abies grandis | 1960 | 48.21 | 1.91 | 118.5 | 46.7 | 28.1 | 65.3 | 20.8 | 83.3 |

[a]For 1931 through 1952 (U. S. Weather Bureau, 1956).

winter precipitation is snow, with depth of the snowpack increasing markedly with elevation.

Winters are relatively warm (mean January temperatures 24 to 30 F) and summars are cool (mean July temperatures 53 to 60 F) and often cloudy (Table 1).

In general, the Mount Adams Province has warmer summers, cooler winters, and less annual and growing season precipitation than the Mount Rainier Province to the west. This is due to (1) its position east of a series of mountains 30 to 40 miles wide (the Western Cascades), and (2) its position closer to the continental air masses which push into eastern Washington from the north.

## Geology

The Cascade Range is a relatively youthful mountain system. Extending from British Columbia to the vicinity of Lassen Peak it has several major segments which differ in genesis and, consequently, in present-day physiography and rock types. The study area includes parts of the High Cascades and Western Cascades.[1]

### Geologic History

Relevant geologic history of the southern Washington Cascade Range begins with deposition of thick beds of lavas and other epiclastic and pyroclastic rocks in the Eocene, Oligocene, and early Miocene. The Ohanapecosh Formation from the Mount Rainier area (Fiske, Hopkins, and Waters, 1963) exemplifies this material. It is composed of basaltic andesite lava flows, rhyolite, breccias, and other volcanic materials. The Ohanapecosh Formation attains thicknesses of more than 10,000 feet, to which can be added at least 5,000 additional feet of other known Tertiary formations (Fiske et al., 1963).

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[1]The terms Western Cascades and High Cascades have been used for Oregon where these two parts of the range adjoin in shart contrast. The terms are here extended to geologically comparable areas in southern Washington.

During the late Miocene and Pliocene, volcanic activities continued but plutonic masses occasionally intruded, a phenomenon rare in the southern part of the study area but increasingly common near Mount Rainier and Snoqualmie Pass. Probably about the same time warping of the earth's crust began which resulted in folding and upwarping of volcanic beds layed down earlier and gave the Cascade Range much of its elevation.

In the late Pliocene and Pleistocene, volcanism continued to build the Cascade Range. In Oregon activity was mainly along the eastern edge of the range. In southern Washington the activity was mostly localized around today's major peaks--Mount Rainier, Mount Adams, and Mount St. Helens. In Oregon and the Mount Adams area a "plateau of andesite and basalt capped by overlapping shield volcanoes, strato-volcanoes, cinder cones, and other volcanic forms . . . " developed (Peak, Griggs, and Schlinker, 1964). Thus, Mount Adams and Mount Hood are built on the High Cascades plateau. The composite cones of Mount Rainier and Mount St. Helens, on the other hand, are isolated segments of Pleistocene-Recent materials covering a base of the older (Tertiary) volcanics.

Simultaneous with much of this Pleistocene volcanic activity, climatic changes brought on the ice age. Alpine glaciers carved much of the present landscape, particularly around major peaks and along the crest of the Cascade Range. Volcanic activity continued very nearly to the present, however, resulting both in widespread post-glacial deposits of volcanic debris and in Mount St. Helens, a volcanic cone which may be less than 1,000 years old (Mullineaux and Crandall, 1961).

## Physiography

The major ecological influences of southern Washington's geologic history are seen today in the landforms and soil parent materials on which the true fir-hemlock communities exist.

Uplifted and eroded deposits of the Tertiary form the major part of the study area, where erosion has dissected original volcanic landscapes into a mature ridge and valley topography. The rugged topography is comparable to that described in the homologous Western Cascades of Oregon: "Narrow stream valleys at altitudes of 500 to 2,000 feet are separated by long acute ridges, the crests of which are at altitudes of 3,000 to 5,000 feet. Slopes of $10^{o}$ to $20^{o}$ are common." (Peck et al., 1964). Mount Rainier and Mount St. Helens constitute islands of High Cascades geology and topography surrounded by a Western Cascades landscape.

The precipitous erosional landforms of the Western Cascades produce sharp changes in elevation, slope, and aspect. High elevation tracts, especially those of sufficient elevation for development of the Tsuga mertensiana Zone, are insular and generally small.

Around Mount Adams extensive Pliocene, Pleistocene, and Recent deposits have produced a typical segment of High Cascades physiography, where younger landforms have been less modified by erosion. The area is generally a rolling or sloping plateau with poorly defined drainage patterns and little precipitous topography. Pumice, volcanic ash, and other pyroclastic materials cover most of the landscape and many deposits have been reworked little if any since deposition. The crest line of the High Cascades ranges from 4,000 to 6,000 feet in elevation.

The relatively gentle topography of the High Cascades provides rather gradual changes in environment and greater uniformity over a greater area. Abies-Tsuga zones are extensive and contiguous because of the generally higher elevation than in the Mount Rainier Province.

## Soils

This study has involved the first extensive description of soils and

soil-forming materials in Abies-Tsuga zones of the southern Washington Cascade Range. Detailed soil descriptions will be provided later, but the scanty information in the literature combined with general observations of my studies are necessary as background.

Soil surveys have extended into only the periphery of the Cascade Range, so a review of soil types described in southern Washington is not directly relevant. The few series from Abies-Tsuga zones which have been described are characterized in only the most general way, e.g. the St. Helens pumicy sandy loam of the Skamania County survey.

## Parent Materials

Parent rocks are almost exclusively igneous extrusives. Andesites, andesitic breccias, and basalt are by far the most common. Unconsolidated deposits of pyroclastic materials such as volcanic ash, pumice, cinders, and lapilli are also common and often profoundly influence morphology of soil profiles. The uncommon, scattered outcrops of granitic rock are concentrated north and east of Spirit Lake and around Mount Rainier.

Transported parent materials are the rule within the study area. Weathered parent rock moves extensively down the steep slopes of the Mount Rainier Province, and, consequently, soils there are often developed on colluvium. Alluvium is deposited in low-lying areas and valley bottoms in both provinces. Furthermore, lahars[2], some of which might be considered alluvial deposits, often occupy extensive areas around major peaks (Fig. 2). Deposits of volcanic debris, believed or known to be lahars, have been identified in the Kalama River valley and at Spirit Lake near Mount St. Helens (Mullineaux and Crandall,

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[2]"The term, lahar, includes all of the broad textural range of debris flows and mudflows of volcanic origin. . . any unsorted or poorly sorted deposit of volcanic debris that moved and was deposited as a mass and owed its mobility to water." (Mullineaux and Crandell, 1962).

1962), and at Mount Rainier (Ballard, 1963). Lahars are often noteworthy for their distinctive soils and plant communities.

Glaciers have been common in the study area, although most were small alpine types. Tills, usually poorly-sorted mixtures of boulders, rocks, and sand, are generally confined to higher elevations, the occasional U-shaped valleys, or around major peaks. Much of the till has been subjected to washing or sliding since deposition.

Aeolian deposits of unconsolidated volcanic ejecta are among the more outstanding features of parent materials. Ash, cinders, lapilli, and scoria (following the definitions of Wentworth and Williams, 1932) are deposited within the study area, volcanic ash, of both accessory and essential origin, and pumiceous lapilli being the most common. Many older deposits of ejecta also have been incorporated into conglomerates, tuffs, and breccias or mixed with other parent materials by water, gravity, or glaciers. Volcanic ejecta blanket almost the entire Mount Adams Province as well as broad areas from Mount St. Helens to the east and north to beyond Mount Rainier. Elsewhere in the Mount Rainier Province ejecta are invariably present in soil profiles but may be mixed with other parent materials.

There are undoubtedly many sources of ejecta. Mount St. Helens has been particularly productive of pumiceous lapilli. Mullineaux (1964) has described three distinctive ash falls from this mountain, 160, 500, and 3,000 years of age. Though thickest on the slopes and shoulders of Mount St. Helens, deposits are thick enough to form conspicuous layers many miles to the north and east (Crandell et al., 1962). Mount Rainier has ejected similar materials. These deposits of essential ejecta are mineralogically distinctive, permitting positive identification of their source (Wilcox, 1965). In addition to the major peaks, many other cinder cones and craters in both Mount Rainier and Mount

Adams Provinces have produced a varied geographical complex of volcanic ejecta. Mount Mazama has undoubtedly contributed some volcanic ash to the parent materials of this region, also (Wilcox, 1965).

## Soil-Forming Processes

The complex of soil-forming processes on zonal habitats in the Abies-Tsuga Zones lead toward the development of podzolic soil types. The most characteristic of these processes are:(1) accumulation of strongly acid mor- or moder-type organic layers several inches in depth (O1 and O2); (2) eluviation of humus and sesquioxides from a surface horizon (A2) and their deposition in an underlying horizon (B2irh or B2hir); and (3) development of acid soil horizons of low base saturation and fertility.

The degree to which these processes have proceeded varies greatly with elevation, ecologic province, vegetation, and age and type of parent material. In general, A2 and B2ir horizons are best developed at middle elevations, 3,000 to 4,500 feet, under the dense coniferous forests of the upper Abies amabilis Zone, and in the wetter climate of the Mount Rainier Province. At lower elevations in the Abies amabilis Zone of the Mount Adams Province soils tend toward Brown Podzolic types rather than Podzols. Within these generalities local differences in habitat have affected the functioning of the above mentioned processes to various degrees.

Variations in intensity and type of soil-forming processes at lower elevations in the Abies amabilis Zone may result in development of Reddish Brown Lateritics or Sols Bruns Acides with distinctive strongly to moderately acid surface horizons rich in organic matter, but of relatively low base saturation and with high C/N ratios. On wetter sites, continually or seasonally wet subsoils provide the reducing conditions necessary for development of gleyed horizons and Gley Podzols result.

Azonal soil types--alluvial, regosolic, and lithosolic--are, of course, represented in the study area. Lithosols are well represented although not so common as one might expect in steep mountainous topography. This is certainly due, in part, to the extensive aeolian and colluvial deposits. Regosols are more or less common, depending on where one draws the line between a Regosol and a Brown Podzolic profile; certainly many soils are developing in relatively youthful deposits of unconsolidated materials of gravelly sand to sandy loam texture.

The reader should note that I am using the soil classification scheme developed by the Soil Conservation Service between 1938 and 1949, specifically the orders and great soil groups outlined in "Soils of the Western United States" (Agricultural Experiment Stations, 1964). It was not possible, because of a lack of certain types of laboratory data, to place most of the profiles in the new soil classification scheme (Soil Conservation Service, 1960). Some equivalences between the older great soil groups utilized in this paper and the orders of the 1960 classification can be suggested: (1) Podzols, some Brown Podzolics, and Gley Podzols would probably be classed as Spodosols; (2) Sols Bruns Acides and some Brown Podzolics as Inceptisols; and (3) Lithosols, Regosols, Alluvial, and some Brown Podzolics as Entisols. Much additional laboratory work would be required to place many of the soils positively in an order, and any of the soils in suborders, great groups, and subgroups of the 1960 classification.

Layering of parent materials is a soil-forming process worthy of special note in the study area. None of the soils examined during the study is believed to have developed from a single parent material; soils with three or four parent materials exposed in a six-foot pit are common, and as many as 18 different materials have been described in a single profile.

Layering has produced some of the more distinctive soil features. Textural differences between layers often profoundly influence the operation of other, currently operative, genetic processes. In some youthful profiles layers are the most morphologically distinct horizons and may be mistaken for genetic horizons. Although the most outstanding examples of layering are usually due to consecutive aeolian deposits of volcanic ejecta, layered deposits of colluvium or glacial till are also common.

Layering can be conspicuous, particularly in the Mount Adams Province or in the main area of Mount St. Helens deposits, e.g., the South Prairie and Badger Peak profiles described later in this report. Elsewhere layering may be much more subtle, particularly if layers of ejecta have been incorporated into colluvium or glacial till, e.g., the Siouxon and Stabler soils described later in this report.

## Vegetation

Heusser (1960), Scott (1962), and Franklin (1965a, 1965b) have written generalized accounts of vegetation in which the study area is located. The few detailed vegetative studies which are relevant will be discussed later in this paper.

# METHODS

## Reconnaissance

A general reconnaissance of the study area preceded quantitative sampling of stands. During reconnaissance about 200 stands accessible by car were visited, including a full range of elevations, aspects, and landforms. In each stand abundance of each tree species (both mature specimens and reproduction), coverage of understory species, and site quality were estimated. The soil at each site was briefly described.

The reconnaissance provided information on the flora, general nature and range in characteristics of the Abies-Tsuga communities and soils, and sampling problems which might be encountered. Communities were not grouped into tentative associations on the basis of reconnaissance data. Quantitative sampling of communities did not, therefore, proceed from a previously determined base.

## Analytic Phase

### Selection of Stands

The stands selected for detailed analysis were the oldest available that had sufficient size to provide a uniform area for plot location, and which were free of recent disturbance such as salvage logging, fire, or grazing. Such stands were selected to represent adequately the major environmental variable encountered during reconnaissance--geography, elevation, soils, etc.

Following quantitative sampling of 75 stands, the data were analyzed and stands grouped into associations. Approximately 45 additional stands were

then sampled. These stands met the earlier criteria of maturity and uniformity but half were selected as representative of a particular association.

Collection of Data

Plots were placed in each stand subjectively, to maximize homogeneity in vegetation, soil, and relief. Suspected ecotones or gradients between different intensities of environmental factors or adjacent forest types were avoided. Insofar as could be determined, plots were located on areas uniform in soil type and depth, aspect, and slope.

The macroplot, 15 X 25 meters, was outlined on the ground with cloth tapes and divided into three 5 X 25 meter segments with two more tapes. Frequency and canopy coverage of all herbs, shrubs, and bryophytes were determined on fifty 20 X 50 cm. plots systematically placed at one-meter intervals along the inside boundaries of the center 5 X 25 meter segment. Daubenmire's (1959) procedures for estimating and calculating canopy coverage were used. The remaining macroplot was examined for additional species.

All trees over 3 inches tall were tallied on each macroplot by species and size class. Seedlings (under 3 inches tall) were tallied by species on two 1 X 25 meter strips within the macroplot. The immediately adjacent stand was examined for species or size classes not on the plot itself.

A soil pit, typically about 60 inches deep, was dug at each sampling site. In each case an attempt was made to explore the entire profile, or at least the rooting zone, but this was sometimes impossible because of rocks. The profile was described according to procedures outlined by the Soil Conservation Service (1951, 1962). Distribution of roots in the profile and rooting habits of any windthrown trees present were recorded. Samples of each soil horizon and the underlying parent rock were collected from each pit for later analysis.

Acidity was determined using a Beckman glass-electrode pH meter. Textural analysis of selected samples was carried out utilizing the modified pipette method described by Dyrness (1960). Total nitrogen, organic matter percent, cation exchange capacity, exchangeable bases, and available phorphorus were also determined for selected samples by the Oregon State University Soil Testing Laboratory using procedures outlined by Alban and Kellogg(1959).

Other environmental data recorded for each plot were elevation, slope, aspect, and other topographic features. Slope and aspect were determined with clinometer and compass, and elevation from U. S. Geological Survey topographic maps. Five topographic features were recorded: landform, shape of contour, shape of profile, wind exposure, and microtopography.

## Analysis of Data

The purpose of analysis was to group stands into associations based on similarities, primarily in vegetational characteristics and secondarily in soil and topographic features.

Data sheets were first grouped by climax tree species, i.e., those reproducing well under the tree canopy on the sample plot. Size class distribution data were essential to this first grouping, which usually delimited rather broad categories of plant communities.

Stand tables listing coverage and frequency of each plot species, soil features, elevation, slope, aspect, and landform were then prepared. The composition of each stand was compared with every other stand with those most similar in vegetational characteristics placed together. Similarities were judged not only by presence and absence of plant species, but also by their relative frequency and coverage, occurrence of groups of species together, and vegetational physiognomy. Categories of plant communities (associations) similar in structure, composition and environmental relationships thus evolved.

Plant associations were given a binomial indicating a climax tree species and a characteristic understory component. Occasionally, a soil feature associated with a particular association was so outstanding it was also added as part of the association name.

Following analysis of the first 75 stands a key to the plant associations based on vegetational, edaphic, and topographic features was prepared. The classification was tested by examing many additional stands in the field systematically, and by categorizing reconnaissance stands not revisited in the analytic phase of the study.

# RESULTS

Two adjoining forested zones were included in this study, the lower Abies amabilis Zone and the upper Tsuga mertensiana Zone. The former is mostly bounded at lower elevations by a Tsuga heterophylla Zone. In some parts of the Mount Adams Province this zone may be missing; the Abies amabilis Zone then abuts on an Abies grandis Zone. The upper limit of the Tsuga mertensiana Zone is marked approximately by timberline and a transition to true alpine vegetation.

Each of these two zones contains but one climatic climax throughout its elevational span. That is, the association which develops on zonal habitats, as defined earlier, is the same everywhere in the zone. These zones are also sharply marked by the presence of western hemlock as the major associate of Pacific silver fir in the lower zone, and mountain hemlock in the upper.

Results are presented in four sections: (1) A. amabilis Zone of the Mount Rainier Province; (2) A. amabilis Zone of the Mount Adams Province; (3) T. mertensiana Zone; and (4) communities of unique habitats. It seems best to treat the plant associations in the A. amabilis Zones of the two provinces separately since they differ markedly in many environmental and vegetational characteristics. Two associations which overlap both provinces, the A. amabilis/Oplopanax horridum and A. amabilis-T. heterophylla/Vaccinium membranaceum Associations, are treated in the Mount Rainier and Mount Adams sections, respectively. The T. mertensiana Zone is essentially the same in both provinces.

Successional status of tree species found in various associations is shown in Tables 2 and 3. Major vegetational and environmental characteristics and the geographical distribution of associations are discussed in the text.

Table 2.--Successional role and distribution of tree species by habitat type in the Abies amabilis Zone[a]

| Province and Habitat Type | Species | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Abies amabilis | Abies grandis | Abies lasiocarpa | Abies procera | Chamaecyparis nootkatensis | Larix occidentalis | Picea engelmannii | Pinus contorta | Pinus monticola | Pseudotsuga menziesii | Thuja plicata | Tsuga heterophylla | Tsuga mertensiana |
| Mount Rainier Province | | | | | | | | | | | | | |
| A. amabilis/Gaultheria | C | | | s | | | | | s | S | s | C | |
| A. amabilis/Vacc. alaskaense | C | | | s | | | | | s | S | S | Sc | |
| A. amabilis/Berberis | C | | | | | | | | s | S | S | C | |
| A. amabilis/Xerophyllum/Lithosol | C | | | | | | | | s | S | s | Sc | s |
| A. amabilis-T. heterophylla/Vacc. membranaceum | C | | s | s | s | | | | s | s | | S | s |
| A. amabilis/Streptopus | C | | | S | | | | | | s | s | S | |
| A. amabilis/Oxalis | C | | | | | | | | | S | S | C | |
| A. amabilis/Oplopanax | C | S | | s | s | | s | | | S | C | Sc | |
| A. amabilis/Menziesia | C | | | s | s | | | | s | S | | S | S |
| Mount Adams Province | | | | | | | | | | | | | |
| A. amabilis-T. heterophylla/Vacc. membranaceum | C | S | s | s | | S | s | S | S | S | s | S | s |
| A. amabilis/Achlys | C | S | s | S | | s | s | s | S | S | s | S | s |
| A. amabilis/Tiarella | C | s | | s | | | S | | s | S | | S | |
| A. amabilis/Oplopanax | C | S | | | | | S | | | s | C | s | |
| A. amabilis/Vacc. ovalifolium | C | | | | | | | | s | S | s | Sc | s |
| A. amabilis/Menziesia | C | | s | | s | | s | | s | S | | S | S |

[a]Based on reconnaissance and analytic data. C = major climax species, c = minor climax species, S = major seral species, and s = minor seral species.

Table 3.--Successional role and distribution of tree species by habitat type in the *Tsuga mertensiana* Zone[a]

| Habitat Type | Species | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Abies amabilis | Abies lasiocarpa | Abies procera | Chamaecyparis nootkatensis | Larix occidentalis | Picea engelmannii | Pinus albicaulis | Pinus contorta | Pinus monticola | Pseudotsuga menziesii | Tsuga heterophylla | Tsuga mertensiana |
| A. amabilis-T. mertensiana/Vacc. membranaceum | C | S | s | s | s | s | s | S | S | S | | S |
| A. amabilis/Veratrum | C | S | | s | | s | | S | s | s | | |
| A. amabilis/Menziesia | C | s | | s | | s | | | s | S | s | S |
| C. nootkatensis/Rhododendron/Gley Podzol | C | | | C | | s | | | s | | | S |

[a]Based on reconnaissance and analytic data. C = major climax species, c = minor climax species, S = major seral species, s = minor seral species.

## Abies amabilis Zone, Mount Rainier Province

The A. amabilis Zone is the most extensive studied. Climax forests are characterized by Pacific silver fir, together with a much smaller component of western hemlock and, on some habitats, western redcedar. Although the stands studied are old-growth forest, most are not in climax condition. Long-lived seral species such as Douglas-fir, noble fir, and western white pine are common in these old-growth stands. Many contain much western hemlock, but size-class distributions indicate that it will be largely replaced by Pacific silver fir.

Usually size-class distributions of Pacific silver fir exhibit a well-developed j-shaped curve, typical of a shade-tolerant climax species, whereas western hemlock reproduction is rather sparse with gaps often present in intermediate size classes. The western hemlock regeneration which does occur is almost invariably on rotten logs and not on the forest floor. Pacific silver fir, in contrast, seems capable of surviving equally well on either microsite.

A generalized successional sequence following disturbance of the forest associations in this zone is: (1) establishment of forests dominated by Douglas-fir, noble fir, and western white pine; (2) invasion of these stands and replacement of seral species by western hemlock; and (3) invasion by Pacific silver fir and gradual replacement of western hemlock. Size-class distributions in many of the stands studied show these three stages clearly.

Wildfire has been the major disturbing factor in the past. Fires 100 to 500 years ago gave rise to the extensive forests of one or a few age classes which dominate the study area today.

At present, logging is the most important disturbing agent; old-growth forests of the zone are rapidly being clearcut. Logging affects a site much the same as wildfire except that if logging slash is not burned, abundant advance regeneration of Pacific silver fir and western hemlock remains which

results in immediate development of forests dominated by these species.

Though young forests on burned sites are normally dominated by seral species, this is not necessarily true. If a seed source is present, western hemlock and Pacific silver fir will invade immediately. Many pure, even-aged stands of either species grow within the study area, the apparent consequence of such situations. The absence of these species from many younger stands and their later entry into the successional sequence result from their greater sensitivity to fire; also, in the case of Pacific silver fir, a heavy seed which is not suited to long-distance dispersal.

The A. amabilis Zone typically occurs between elevations of 2,500 and 4,500 feet in the Mount Rainier Province. In some valleys it may extend down to 2,000 feet. The zone is even better developed in the Mount Baker Province, to the north (Franklin, 1965b). It is distinctive throughout the Willamette, Mount Hood, and Three Sisters Provinces in Oregon, although it becomes progressively more restricted to the south.

In the broader phytogeographic view the A. amabilis Zone described in this paper can be considered simply a higher elevation phase of the widespread Tsuga heterophylla Zone, distinguished by a series of associations in which Pacific silver fir is the major climax tree species. However, in western Washington and most of western Oregon the A. amabilis Zone is such a distinctive vegetative unit that I have elected to take a more provincial view and recognize it as a separate zone.

Abies amabilis/Vaccinium alaskaense Association

This association is the climatic climax for the zone, occupying environmentally median sites. Pacific silver fir is the major climax tree species; western hemlock, though well represented, is apparently only a minor component of the climax (Table 4). Douglas-fir is the most ubiquitous seral species,

Table 4.--Stand structure and constancy of tree species in phases of the Abies amabilis/Vaccinium alaskaense Association[a]

| Phase and Species | All sizes Cn. % | Size Class (Number of Trees per Acre) | | | | |
|---|---|---|---|---|---|---|
| | | <3' tall | 3' tall to 4" d.b.h. | 4 to 12" d.b.h. | 12 to 30" d.b.h. | >30" d.b.h. |
| Typical Phase | | | | | | |
| Abies amabilis | 100 | 8,370 | 407 | 79 | 42 | 5 |
| Tsuga heterophylla | 100 | 4,100 | 73 | 9 | 9 | 12 |
| Pseudotsuga menziesii | 86 | 80 | | | 3 | 12 |
| Thuja plicata | 43 | 193 | 14 | 1 | 3 | 6 |
| Abies procera | 14 | | | | + | |
| Berberis Phase | | | | | | |
| Abies amabilis | 100 | 4,770 | 155 | 88 | 36 | 3 |
| Tsuga heterophylla | 100 | 615 | 89 | 17 | 17 | 2 |
| Pseudotsuga menziesii | 100 | 23 | | | | 21 |
| Thuja plicata | 100 | 80 | 17 | 3 | 11 | 8 |
| Pinus monticola | 43 | | | | + | 4 |
| Abies procera | 14 | | | | | 2 |
| Berberis-Xerophyllum Phase | | | | | | |
| Abies amabilis | 100 | 7,282 | 398 | 89 | 36 | |
| Tsuga heterophylla | 100 | 1,828 | 81 | 70 | 19 | + |
| Pseudotsuga menziesii | 100 | 254 | | | 11 | 15 |
| Thuja plicata | 40 | 16 | 2 | | 6 | + |
| Abies procera | 40 | | | | + | 8 |
| Xerophyllum Phase | | | | | | |
| Abies amabilis | 100 | 23,214 | 965 | 52 | 70 | 6 |
| Tsuga heterophylla | 100 | 2,067 | 95 | 4 | 6 | 4 |
| Pseudotsuga menziesii | 86 | 106 | | | 3 | 14 |
| Thuja plicata | 29 | 40 | 17 | 3 | 3 | |
| Abies procera | 43 | | | | 2 | + |
| Pinus monticola | 14 | | | | 2 | |

[a]On this and Tables 6, 8, 10 and 12 note that (1) these are average values and not representative of any given stand and (2) a + indicates a size class averaged less than 0.5 trees per acre.

followed by western redcedar. Western white pine and noble fir are occasional components.

The A. amabilis/V. alaskaense Association has been divided into four phases based on floristic and environmental differences: (1) typical phase; (2) Berberis nervosa phase; (3) B. nervosa-Xerophyllum tenax phase; and (4) X. tenax phase. Future studies of environment and productivity will determine whether recognition of all four phases is justified. Meanwhile they will be considered separately.

The understory vegetation is typified by a later of predominantly ericaceous shrubs 1/2 to 1-1/2 meters in height, a layer of low herbs, and a conspicuous ground cover of mosses (Fig. 3 and 4). Species with high constancy include: (1) V. alaskaense and V. ovalifolium in the shrub layer; (2) Cornus canadensis, Clintonia uniflora, Trillium ovatum, Chimaphila umbellata, and Linnaea borealis in the herb layer; and (3) Rhytidiopsis robusta, Dicranum fuscescens, and Hypnum circinale in the moss layer. The phases are differentiated primarily by the occurrence and relative abundance of Berberis and Xerophyllum (Table 5). The typical phase has neither species. B. nervosa is a constant and conspicuous element of the Berberis phase whereas Xerophyllum and Vaccinium membranaceum are not. All three of these species are present in significant numbers in the Berberis-Xerophyllum phase. In the Xerophyllum phase, Berberis is absent or present only in trace amounts.

Stands of the A. amabilis/V. alaskaense Association were sampled on widely varying landforms between elevations of 1,850 and 3,700 feet. The typical phase usually occurs on gentle slopes (3 to 7 percent) such as old mudflows or till surfaces or on steeper (up to 50 percent) lower slopes, at 2,500 to 3,100 feet. The Berberis phase typically occupies steeper tracts in mid- or upper-slope positions, usually of southerly aspect, and at lower

Table 5.--Constancy, frequency, and coverage values for selected understory species in the four phases of the Abies amabilis/Vaccinium alaskaense Association[a]

| Layer and Species | Phase | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | All (26) | Typical (7) | | | Berberis (7) | | | Berberis-Xerophyllum (5) | | | Xerophyllum (7) | | |
| | Cn. % | Cn. % | Fr. % | Cv. % | Cn. % | Fr. % | Cv. % | Cn. % | Fr. % | Cv. % | Cn. % | Fr. % | Cv. % |
| Shrubs and small trees: | | | | | | | | | | | | | |
| Vaccinium alaskaense | 100 | 100) | 79 | 48 | 100) | 39 | 20 | 100) | 49 | 22 | 100) | 65 | 41 |
| Vaccinium ovalifolium | 100 | 100) | | | 100) | | | 100) | | | 100) | | |
| Vaccinium membranaceum | 73 | 72 | 2 | T | 29 | 3 | 1 | 100 | 20 | 4 | 100 | 26 | 9 |
| Vaccinium parvifolium | 65 | 72 | 3 | 1 | 100 | 8 | 4 | 80 | 2 | 1 | 14 | 2 | 1 |
| Acer circinatum | 65 | 57 | 2 | 1 | 72 | 20 | 15 | 80 | 12 | 7 | 57 | 1 | 1 |
| Menziesia ferruginea | 62 | 72 | 1 | T | 29 | + | T | 60 | + | T | 86 | 3 | 1 |
| Berberis nervosa | 54 | | | | 100 | 17 | 6 | 100 | 25 | 5 | 29 | + | T |
| Gaultheria shallon | 38 | 14 | + | T | 57 | 5 | 2 | 60 | 4 | T | 29 | 1 | T |
| Sorbus sitchensis | 35 | 14 | + | T | | | | 60 | 1 | T | 72 | 3 | 1 |
| Total shrubs and small trees | | | | 52 | | | 49 | | | 42 | | | 50 |
| Herbs: | | | | | | | | | | | | | |
| Cornus canadensis | 88 | 86 | 27 | 4 | 86 | 33 | 5 | 100 | 63 | 9 | 86 | 38 | 5 |
| Linnaea borealis | 81 | 72 | 27 | 4 | 100 | 33 | 5 | 100 | 27 | 3 | 57 | 13 | 1 |
| Trillium ovatum | 77 | 86 | 2 | T | 100 | 3 | T | 80 | 2 | T | 43 | 1 | T |
| Chimaphila umbellata | 77 | 72 | 11 | 1 | 100 | 31 | 5 | 80 | 17 | 1 | 57 | 9 | 1 |
| Clintonia uniflora | 73 | 72 | 9 | 1 | 57 | 3 | T | 60 | 28 | 3 | 100 | 24 | 2 |
| Rubus lasiococcus | 73 | 86 | 3 | T | 43 | 5 | T | 80 | 8 | 1 | 86 | 16 | 1 |
| Achlys triphylla | 62 | 72 | 4 | T | 86 | 9 | 2 | 40 | 4 | T | 43 | 7 | 1 |
| Xerophyllum tenax | 65 | | | | 57 | 1 | T | 100 | 30 | 17 | 100 | 7 | 4 |
| Goodyera oblongifolia | 54 | 72 | 3 | T | 72 | 2 | T | 60 | 2 | T | 14 | 1 | 1 |
| Tiarella unifoliata | 50 | 72 | 1 | T | 100 | 8 | T | 20 | 1 | T | | | |
| Chimaphila menziesii | 54 | 43 | 3 | T | 72 | 4 | T | 20 | 3 | T | 72 | 1 | T |
| Pyrola secunda | 50 | 43 | 1 | T | 43 | 2 | T | 40 | 1 | T | 72 | 2 | T |
| Viola sempervirens | 46 | 43 | 1 | T | 86 | 15 | 1 | 60 | 4 | T | | | |
| Corallorhiza mertensiana | 46 | 29 | + | T | 29 | + | T | 60 | 1 | T | 72 | + | T |
| Rubus ursinus | 46 | 14 | + | T | 72 | 8 | 1 | 80 | 2 | T | 29 | + | T |
| Rubus pedatus | 42 | 86 | 12 | 1 | 29 | 2 | T | | | | 43 | 9 | 1 |
| Coptis laciniata | 27 | 57 | 11 | 2 | 29 | 17 | 2 | | | | 14 | 1 | T |
| Lycopodium clavatum | 27 | 29 | 3 | 1 | 29 | 2 | T | | | | 43 | + | T |
| Pyrola asarifolia | 23 | 43 | 1 | T | 29 | 3 | T | 20 | 1 | T | | | |
| Smilacina sessilifolia | 23 | 29 | 2 | T | 43 | 1 | T | | | | 14 | + | T |
| Polystichum munitum | 23 | 29 | + | T | 57 | + | T | | | | | | |
| Gaultheria ovatifolia | 23 | 29 | 1 | T | 14 | + | T | 20 | 8 | 1 | 14 | + | T |
| Hypopitys monotropa | 19 | | | | | | | | | | 72 | + | T |
| Pedicularis racemosa | 19 | 29 | 6 | 1 | | | | 20 | 1 | T | 29 | + | T |
| Rubus nivalis | 4 | | | | 14 | 9 | 1 | | | | | | |
| Total herbs | | | | 15 | | | 25 | | | 37 | | | 17 |
| Mosses, lichens, and liverworts: | | | | | | | | | | | | | |
| Rhytidiopsis robusta | 100 | 100 | 87 | 20 | 100 | 62 | 8 | 100 | 71 | 13 | 100 | 69 | 16 |
| Dicranum fuscescens | 88 | 100 | 14 | 1 | 86 | 5 | T | 60 | 6 | T | 100 | 20 | 2 |
| Hypnum circinale | 88 | 86 | 9 | T | 100 | 7 | T | 80 | 6 | T | 86 | 4 | T |
| Eurhynchium oreganum | 50 | 57 | 4 | 1 | 72 | 32 | 4 | 20 | 2 | T | | | |
| Pseudoisothecium stoloniferum | 38 | 43 | 2 | T | 86 | 8 | T | 20 | + | T | | | |
| Scapania nemorosa | 38 | 86 | 6 | T | 57 | 5 | T | | | | 14 | 1 | T |
| Cladonia spp. | 38 | 57 | 1 | T | 29 | 1 | T | 40 | 1 | T | 29 | 1 | T |
| Homalothecium megaptilum | 35 | 29 | 3 | T | 57 | 1 | T | 60 | 3 | T | | | |
| Brachythecium velutinum | 35 | 43 | 1 | T | 29 | 4 | T | 40 | 2 | T | 29 | 1 | T |
| Rhytidiadelphus loreus | 19 | 29 | 1 | T | 43 | 5 | T | | | | | | |
| Total mosses, lichens, and liverworts | | | | 22 | | | 14 | | | 13 | | | 18 |

[a]On this and Tables 7, 9, 11, and 13: (1) species with 50 percent constancy, 5 percent average frequency, or 1 percent average coverage are included; (2) number of stands of each phase or association is shown in parenthesis; (3) a + indicates average frequency is less than 0.5 percent; and (4) a T (trace) indicates average coverage is less than 0.5 percent.

elevations in the zone (between 2,000 and 2,700 feet). The Berberis-Xerophyllum phase is generally found on steep slopes (28 to 62 percent) at mid-elevations (2,900 to 3,600 feet) in the zone, but one stand occurred on a flat at 1,850 feet elevation. Finally, the Xerophyllum phase is generally found in the middle and upper parts of the zone on areas of variable steepness, generally on mid- or upper-slopes of northerly aspect.

Soils on all but one plot are Podzols of high acidity and low base saturation; the single exception was a Sols Bruns Acides on Plot GP-2, at 1,850 feet elevation. Most soils are developing in coarse-textured (sands to sandy loams) surface deposits of volcanic ejecta which overlie colluvium, alluvium, or till developed from older volcanic rocks and often containing considerable quantities of older ejecta as well. Naturally, degree of profile development varies with the nature and age of the surface deposits of ejecta. A2 horizons are usually well defined, although they may be partly artifacts of parent-material layering. Horizons of illuviation, particularly B2ir horizons, are not usually so well defined. The Siouxon soil from a site occupied by the Xerophyllum phase of this association (Plot GP-9) provides a typical example of a well developed podzolic profile:

| Horizon | Description |
|---|---|
| 01 | 4 to 3 inches, mainly loosely matted, undecomposed forest litter and moss; extremely acid (pH 4.3); 1/2 to 1 1/2 inches thick. |
| 02 | 3 to 0 inches, decomposing and humified forest litter matted in sheets; some portions gray due to fungal mycelia; extremely acid (pH 3.8); 2 to 3 1/2 inches thick. |
| A21 | 0 to 1 1/4 inches, gray (10 YR 5/1, moist) fine loamy sand; single grain; nonsticky, nonplastic; 15 percent gravel by volume, consisting of white pumice; extremely acid (pH 4.2); 3/4 to 2 inches thick; abrupt wavy boundary. |
| A22 | 1 1/4 to 1 1/2 inches, gray brown (10 YR 5/1.5, moist) sand; intermittent; single grain; nonsticky, nonplastic; 15 percent gravel by volume consisting of white pumice; very strongly acid (pH 4.7); 0 to 1 inch thick; abrupt wavy boundary. |

B21ir 1 1/2 to 3 inches, dark red brown (5 YR 3/3, moist) fine sandy loam; medium subangular blocky, moderately to weakly cemented; nonsticky, nonplastic; 20 percent gravel by volume consisting of hard rock and weathered pumice; strongly acid (pH 5.1); 1 to 1 1/2 inches thick; gradual wavy boundary.

B22 3 to 13 inches, yellowish brown (10 YR 5/4, moist) gravelly loamy sand; medium to coarse subangular blocky; nonsticky, nonplastic; 35 percent gravel by volume consisting of hard rocks and weathered pumice; common distinct coarse pockets of B21, especially in lower 8 inches of horizon; strongly acid (pH 5.3); clear irregular boundary.

IIB3 13 to 23 inches, yellowish brown (10 YR 5/6, moist) gravelly sand; massive breaking to medium subangular blocky; nonsticky, nonplastic; 50 percent gravel and rock by volume consisting of subangular hard rock and weathered pumice; medium acid (pH 5.7); clear smooth boundary.

IIC 23 to 40+ inches, yellowish brown (10 YR 5/6, moist) rocky gravelly sand; massive breaking to medium to coarse subangular blocky; nonsticky, nonplastic; 80 percent gravel and rock by volume consisting of subangular andesite and weathered pumice; medium acid (pH 5.8).

The A. amabilis/V. alaskaense Association is widespread within the Mount Rainier Province. I have encountered it during reconnaissance trips in the northern Oregon Cascade Range, where it also appears to be a climatic climax. I have not noted it north of the study area in the Mount Baker Province.

Abies amabilis/Gaultheria shallon Association

This association is an edaphic climax at low elevations in the A. amabilis Zone and in the adjacent T. heterophylla Zone. Three of the five stands analyzed were within the lower elevational zone. On the relatively poor sites characterized by the Gaultheria association, Pacific silver fir reaches its lowest elevational limit within the study area. Both Pacific silver fir and western hemlock are major climax species (Table 6). The most common seral species are Douglas-fir, western redcedar, and western white pine.

The understory is closely related to that of the T. heterophylla Zone

Table 6.--Stand structure and constancy of tree species in the Abies amabilis/Gaultheria,/Berberis, and /Xerophyllum/Lithosol, and in A. amabilis-Tsuga heterophylla/Vaccinium Associations found in the Mount Rainier Province

| Association and Species | All sizes Cn. % | Size Class (Number of Trees per Acre) | | | | |
|---|---|---|---|---|---|---|
| | | <3' tall | 3' tall to 4" d.b.h. | 4 to 12" d.b.h. | 12 to 30" d.b.h. | >30" d.b.h. |
| A. amabilis/Gaultheria | | | | | | |
| Abies amabilis | 100 | 5,088 | 229 | 87 | 28 | + |
| Tsuga heterophylla | 100 | 2,099 | 176 | 64 | 19 | 4 |
| Pseudotsuga menziesii | 100 | 111 | 11 | 2 | 11 | 6 |
| Thuja plicata | 80 | 159 | 32 | 4 | 15 | |
| Pinus monticola | 60 | + | | | + | + |
| Abies procera | 20 | 16 | 15 | 2 | 6 | |
| A. amabilis/Berberis | | | | | | |
| Abies amabilis | 100 | 9,746 | 237 | 93 | 38 | |
| Tsuga heterophylla | 100 | 5,247 | 44 | 19 | 28 | 11 |
| Pseudotsuga menziesii | 100 | 1,272 | | | 6 | 15 |
| Thuja plicata | 80 | 127 | 34 | 8 | 21 | |
| Pinus monticola | 60 | | | | | 4 |
| A. amabilis/Xerophyllum/Lithosol | | | | | | |
| Abies amabilis | 100 | 1,561 | 99 | 7 | 7 | |
| Tsuga heterophylla | 100 | 132 | 14 | 35 | 53 | 7 |
| Pseudotsuga menziesii | 100 | 106 | | | 11 | 14 |
| Pinus monticola | 67 | | 3 | | 7 | |
| Abies procera | 33 | | + | | + | |
| A. amabilis-T. heterophylla/Vaccinium | | | | | | |
| Abies amabilis | 100 | 20,060 | 625 | 131 | 60 | 14 |
| Tsuga heterophylla | 100 | 53 | 21 | | 7 | 3 |
| Pseudotsuga menziesii | 67 | | | | | + |
| Pinus monticola | 33 | + | | | | |
| Tsuga mertensiana | 33 | | | | + | |
| Chamaecyparis nootkatensis | 33 | | 7 | | | 3 |

(Table 7). Excluding the tree canopy, there are four distinct layers. The highest consists of small trees--Acer circinatum, Taxus brevifolia, and Cornus nuttallii--that form a canopy 3 to 10 meters above the ground. The shrub layer is the most conspicuous, dominated by Gaultheria shallon (average coverage 40 percent), Berberis nervosa, and Vaccinium parvifolium. The herbaceous layer includes various species, but average total coverage of herbs is only 8 percent. Constant species are Linnaea borealis, Xerophyllum tenax, Rubus ursinus, Chimaphila umbellata, and Trillium ovatum. The moss layer is better developed than the herbaceous layer, averaging 25 percent coverage. It is distinctive by inclusion of typically low-elevation species--Eurhynchium oreganum, Homalothecium megaptilum, Hylocomium splendens, Callerigonella schreberi, and Rhytidiadelphus loreus--in addition to the ubiquitous Rhytidiopsis robusta, Dicranum fuscescens, and Hypnum circinale.

Four of the study sites for this association were on extensive gentle slopes or valley bottoms at elevations of 1,100 to 2,600 feet. The fifth, actually representing a transition between the Gaultheria and A. amabilis/Berberis Associations occupied the upper third of a west-facing slope at 3,000 feet. Although two sites were in a river terrace position, examination of the soil profiles indicated the landforms were partially created by laharic deposits in one case and by glacial deposits in the other.

Soils on sites representative of the A. amabilis/Gaultheria habitat type are quite variable. On three study sites they are well-developed Podzols developed in deposits of volcanic ejecta and alluvium or colluvium over till, mudflows, or residuum. The Adams Fork soil (Plot GP-87) is representative of these podzolic profiles:

| Horizon | Description |
|---|---|
| 01 | 3 to 2 inches, loosely matted, undecomposed layer of leaves, needles, twigs; very strongly acid (pH 4.6); 1 to 2 inches thick. |

Table 7.--Constancy, frequency, and coverage values for selected understory species for the Abies amabilis/Gaultheria/Berberis, and /Xerophyllum/Lithosol, and A. amabilis-T. heterophylla/Vaccinium membranaceum Associations found in the Mount Rainier Province

| Layer and Species | Association | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A. amabilis /Gaultheria (5) | | | A. amabilis /Berberis (5) | | | A. amabilis /Xerophyllum /Lithosol (3) | | | A. amabilis-T. hetero. /Vaccinium-membranaceum (3) | | |
| | Cn. % | Fr. % | Cv. % | Cn. % | Fr. % | Cv. % | Cn. % | Fr. % | Cv. % | Cn. % | Fr. % | Cv. % |
| Shrubs: | | | | | | | | | | | | |
| Gaultheria shallon | 100 | 73 | 40 | 100 | 33 | 8 | 100 | 46 | 9 | | | |
| Berberis nervosa | 100 | 41 | 13 | 100 | 48 | 12 | 100 | 40 | 8 | | | |
| Vaccinium parvifolium | 100 | 14 | 2 | 100 | 10 | 3 | 100 | 16 | 7 | | | |
| Acer circinatum | 80 | 16 | 13 | 60 | 5 | 4 | 100 | 21 | 13 | | | |
| Vaccinium ovalifolium | 60 | 6 | 1 | 20 | 1 | T | 33 | 1 | T | 33 | 1 | T |
| Vaccinium membranaceum | 60 | 4 | T | 80 | 12 | 1 | 100 | 28 | 4 | 100 | 51 | 19 |
| Rosa gymnocarpa | 60 | 1 | T | 20 | + | T | 100 | 1 | T | | | |
| Taxus brevifolia | 60 | + | T | 60 | 8 | 6 | 100 | 3 | 3 | | | |
| Cornus nuttallii | 40 | 2 | 1 | | | | | | | | | |
| Pachistima myrsinites | 40 | + | T | 80 | 1 | T | 100 | 1 | 1 | 33 | + | T |
| Rhododendron macrophyllum | 20 | 6 | 3 | | | | | | | | | |
| Vaccinium alaskaense | 20 | 5 | 1 | 100 | 23 | 9 | 67 | 5 | 2 | 67 | 9 | 3 |
| Menziesia ferruginea | 20 | + | T | | | | | | | 67 | 1 | T |
| Amelanchier alnifolia | | | | | | | 67 | 4 | T | | | |
| Sorbus sitchensis | | | | | | | 33 | + | T | 67 | 2 | T |
| Total shrubs | | | 76 | | | 43 | | | 47 | | | 22 |
| Herbs: | | | | | | | | | | | | |
| Linnaea borealis | 100 | 22 | 2 | 60 | 22 | 3 | 100 | 33 | 3 | | | |
| Xerophyllum tenax | 100 | 4 | 1 | 80 | 15 | 9 | 100 | 76 | 50 | 100 | 56 | 40 |
| Chimaphila umbellata | 80 | 8 | T | 100 | 17 | 2 | 67 | 19 | 1 | 33 | + | T |
| Rubus ursinus | 80 | 4 | T | 20 | + | T | | | | | | |
| Trillium ovatum | 80 | 3 | T | | | | | | | | | |
| Clintonia uniflora | 60 | 9 | 1 | 20 | + | T | 33 | 1 | T | | | |
| Gaultheria ovatifolia | 60 | 8 | 1 | 60 | 7 | 1 | 67 | 9 | 1 | | | |
| Achlys triphylla | 60 | 6 | 1 | | | | 67 | 5 | T | | | |
| Chimaphila menziesii | 60 | + | T | 80 | 3 | T | | | | | | |
| Pyrola asarifolia | 40 | 4 | T | 20 | + | T | 67 | 2 | T | | | |
| Viola sempervirens | 40 | 3 | T | 20 | 1 | T | 33 | 3 | T | | | |
| Cornus canadensis | 40 | 2 | T | 40 | 2 | T | 67 | 8 | 1 | | | |
| Goodyera oblongifolia | 40 | + | T | 40 | + | T | 67 | 1 | T | 33 | 1 | T |
| Corallorhiza mertensiana | | | | 40 | + | T | 100 | 1 | T | 33 | 1 | T |
| Pyrola secunda | | | | 20 | 2 | T | 67 | 3 | T | 67 | 1 | T |
| Lilium columbianum | | | | 20 | + | T | 100 | 1 | T | | | |
| Pedicularis racemosa | 20 | + | T | | | | 33 | 4 | 1 | | | |
| Rubus lasiococcus | | | | | | | | | | 67 | 15 | 1 |
| Total herbs | | | 8 | | | 16 | | | 58 | | | 41 |
| Mosses, lichens, and liverworts: | | | | | | | | | | | | |
| Eurhynchium oreganum | 100 | 52 | 11 | 20 | 5 | T | 67 | 5 | 1 | | | |
| Rhytidiopsis robusta | 100 | 43 | 7 | 100 | 88 | 21 | 100 | 76 | 12 | 100 | 34 | 2 |
| Homalothecium megaptilum | 100 | 24 | 2 | 40 | 2 | T | 33 | 3 | T | | | |
| Dicranum fuscescens | 100 | 21 | 1 | 100 | 15 | 1 | 100 | 13 | 1 | 100 | 22 | 1 |
| Hypnum circinale | 100 | 9 | T | 100 | 4 | T | 100 | 11 | 1 | 33 | 1 | T |
| Hylocomium splendens | 60 | 21 | 4 | 40 | 2 | T | 33 | 23 | 3 | | | |
| Rhytidiadelphus loreus | 60 | 5 | 1 | 20 | + | T | 33 | 9 | 1 | | | |
| Callerigonella schreberi | 40 | 5 | T | | | | 33 | + | 3 | | | |
| Rhytidiadelphus triquetrus | 40 | 3 | T | | | | 33 | 4 | T | | | |
| Cladonia spp. | 20 | 3 | T | 40 | 2 | T | 100 | 8 | T | 33 | 1 | T |
| Scopania nemorosa | 20 | 1 | T | 80 | 4 | T | 33 | 3 | T | | | |
| Ptilidium californicum | 20 | + | T | 60 | 2 | T | 33 | 1 | T | 33 | 1 | T |
| Plagiothecium denticulatum | 20 | + | T | | | | 100 | 2 | T | | | |
| Brachythecium velutinum | 20 | + | T | | | | 33 | 1 | T | 67 | 1 | T |
| Cladonia foliacea | | | | 60 | 2 | T | | | | | | |
| Total mosses, lichens, and liverworts | | | 26 | | | 23 | | | 19 | | | 3 |

| | |
|---|---|
| 02 | 2 to 0 inches, matted decomposing forest litter, roots; very strongly acid (pH 4.5); 1 1/2 to 3 inches thick. |
| A21 | 0 to 1 inch, gray (10 YR 4.5/1, dry) fine sand; single grain; 1/2 to 1 1/2 inches thick; very strongly acid (pH 4.7); abrupt wavy boundary. |
| A22 | 1 to 1 1/2 inches, light gray (10 YR 6/1, dry) coarse sand; single grain; 0 to 1 inch thick; strongly acid (pH 5.2); abrupt wavy boundary. |
| B2 | 1 1/2 to 9 inches, yellowish brown (10 YR 5/4, dry) fine sand; single grain; common fine to medium distinct mottles of gray (10 YR 5.5/1, dry) and charcoal; strongly acid (pH 5.3); gradual wavy boundary. |
| IIB3 | 9 to 25 inches, dark yellowish brown (10 YR 4/4, moist) rocky gravelly loamy sand; very weak fine subangular blocky; 75 percent rocks and gravel by volume, rocks rounded and up to 1 foot in diameter (alluvium); occasional coarse patch of charcoal; medium acid (pH 5.6); gradual wavy boundary. |
| IIIC | 25 to 42+ inches, dark grayish brown (10 YR 4/2, moist) rocky gravelly sand; massive; 75 percent rocks and gravel by volume, rocks subangular rounded up to 6 inches in diameter (glacial till); common fine distinct mottles of yellowish red (5 YR 4/6,moist), surfaces of rocks also yellowish red; fine roots present in only upper few inches; medium acid (pH 5.6). |

On two sites (Plots GP-1 and GP-8) the soil is lateritic and appears similar in morphology to the Stabler shotty loam described in the Skamania County soil survey (Anderson et al., 1956). Soil surveyors have categorized the Stabler soil as a Brown Podzolic-"Brown Lateritic" intergrade; I feel it fits best into the Sols Bruns Acides group (Agricultural Experiment Stations, 1964). The profile described in this study is as follows (note layering of parent materials which was not recognized in the Soil Survey description):

| Horizon | Description |
|---|---|
| 01 | 1 1/2 to 1 inches, loosely matted undecomposed layer of leaves, needles, and twigs; very strongly acid (pH 4.7); 1/2 to 1 1/2 inches thick. |
| 02 | 1 to 0 inch, mainly decomposing but recognizable forest litter; extremely acid (pH 4.3); 1 to 2 inches thick. |
| A1 | 0 to 10 inches, dark brown (7.5 YR 3/2, moist) shotty sandy loam; granular; concretions and roots abundant; strongly acid (pH 5.3); gradual smooth boundary. |

A3 10 to 20 inches, brown (7.5 YR 4/4, moist) shotty sandy loam; weak medium subangular blocky breaking to granular; concretions and roots abundant; strongly acid (pH 5.4); clear wavy boundary.

B21 20 to 29 inches, dark yellowish brown to yellowish brown (10 YR 4/4 to 5/7, moist) sandy loam; moderate medium to coarse subangular blocky; 5 to 12 inches thick; roots common; slightly acid (pH 6.3); abrupt wavy boundary.

IIB22 29 to 32 inches, strong brown to yellowish brown (7.5 YR 5/6 to 10 YR 5/4 to 5/6, moist) sandy loam; massive, hard; 0 to 6 inches thick; common distinct very fine mottles of white and green and common gravel-sized particles of weathered white pumice (12.5 percent by weight); medium acid (pH 6.0); abrupt irregular boundary.

IIIB23 32 to 52 inches, dark yellowish brown (10 YR 4/4,moist) loam; strong coarse subangular blocky, vesicular; 18 to 36 inches thick; 16 percent severely-weathered gravel-sized pumice by weight; roots rare to occasional; medium acid (pH 5.9); gradual smooth boundary.

IIIB24 52 to 67 inches, yellowish red to reddish yellow (5 YR 4/8 to 7.5 YR 6/6, moist) loamy sand; weak medium subangular blocky; 6 percent severly-weathered gravel-sized pumice by weight; increasingly vesicular with depth; slightly acid (pH 6.1); abrupt smooth boundary.

IIIB3 67 to 75+ inches, dark grayish brown (10 YR 4/2.5, moist) loamy sand; massive; 14 percent severely-weathered gravel-sized pumice by weight; abundant distinct fine to coarse mottles and channels of reddish brown; medium acid (pH 6.0).

The A. amabilis/Gaultheria Association is uncommon within the study area. It did occur in all the major drainages studied in the Mount Rainier Province, however. Because Pacific silver fir generally reaches its lower elevational limits on this habitat, it is particularly interesting. Moreover, it comprises a transition between two vegetation zones.

Abies amabilis/Berberis nervosa Association

The A. amabilis/Berberis Association constitutes a topographic climax on steep (35 to 54 percent), south-or west-facing slopes at mid-elevations (2,575 to 3,000 feet) within the A. amabilis Zone. In all cases stands studied occupy the upper third of a ridgeslope.

Pacific silver fir is a major climax species; western hemlock is at

least a minor climax species (Table 6). Douglas-fir is the most important seral species followed by western redcedar. Western white pine is often present, but only in small numbers.

The shrub layer dominates the understory of this association (Table 7). Berberis nervosa, Gaultheria shallon, Vaccinium alaskaense, V. parvifolium, Acer circinatum, and Taxus brevifolia are the most important shrubs and low trees, although Acer and Taxus have constancies of only 60 percent. The only conspicuous herbs are Xerophyllum tenax, which provides over half the herbaceous cover (average 9 percent), Chimaphila umbellata, and Linnaea borealis. The moss layer is a little better developed with three constant species--Dicranum fuscescens, Hypnum circinale, and Rhytidiopsis robusta--the latter contributing most of the coverage (average 21 percent).

This association is obviously closely related to the A. amabilis/Gaultheria, /V. alaskaense, and /Xerophyllum/Lithosol Associations. The relatively low coverage of Gaultheria (15 percent or less) and topographic position distinguish it from the first. Lack of certain species of herbs, including Cornus canadensis in most cases, distinguishes it from the second. Finally, the absence of a lithosolic soil and much lower coverage of Xerophyllum distinguish it from the third.

Soils are Podzols of medium depth, developing mainly in one or more coarse-textured deposits of pumiceous ejecta. Parent materials derived from local rock types are encountered at three- to twelve-foot depths but may consist only of little-weathered rock fragments.

The A. amabilis/Berberis Association occurred throughout the areas studied within the Mount Rainier Province. Reconnaissance suggests this association will be found to the south in the northern Oregon Cascade Range but that it becomes increasingly rare to the north.

Abies amabilis/Xerophyllum tenax/Lithosol Association

The A. amabilis/Xerophyllum/Lithosol Association is a topoedaphic climax occupying steep hillsides and ridgetops having only a skim of soil. The stands analyzed are all on upper ridgeslopes of 53 to 95 percent with southeasterly exposures. Elevations of the study sites are from 2,700 to 3,300 feet, but reconnaissance has shown this association to have a greater elevational span.

Pacific silver fir and western hemlock are climax species, the fir being more important (Table 6). Douglas-fir is the major seral species. Various other trees, including noble fir and western white pine, may occur as seral components.

The understory is dominated by Xerophyllum tenax, which averages 50 percent coverage (Table 7). Shrubs also form a conspicuous part of the community. Species with 100 percent constancy are Acer circinatum, Gaultheria shallon, Berberis nervosa, Vaccinium parvifolium, V. membranaceum, Taxus brevifolia, and Pachistima myrsinites, in decreasing order of abundance. The only noteworthy herbs, other than Xerophyllum, are Linnaea borealis, Chimaphila umbellata, and Lilium columbianum. The scattered moss cover is dominated by Rhytidiopsis robusta, although Dicranum fuscescens, Hypnum circinale, Plagiothecium denticulatum, and Cladonia sp. also have 100 percent constancy.

This association is more variable in floristic characteristics than the data reported here indicate. The only consistent identifying characteristic is the dominance of Xerophyllum in combination with the lithosolic substrate since Xerophyllum will often take a dominant position on other habitat types following disturbance, especially repeated burning. Identification of the A. amabilis/Xerophyllum/Lithosol habitat type in disturbed condition then rests entirely on its topographic position and lithosolic soil. The associates in a

particular stand are partially a function of the elevation at which it occurs.

The Lithosols are shallow deposits of volcanic ejecta or colluvium underlain by a rocky B3 or C horizon at depths of 18 inches or less. The Silver Creek soil (Plot GP-100) is typical:

| Horizon | Description |
|---|---|
| 01 | 1 1/2 to 1 inches, freshly fallen needles, twigs, and leaves; extremely acid (pH 4.5). |
| 02 | 1 to 0 inch, matted layer of decomposing but recognizable organic matter; extremely acid (pH 4.2). |
| A2 | 0 to 1 inch, gray (10 YR 6/1, dry) sand; single grain; very strongly acid (pH 4.7); clear wavy boundary. |
| B2 | 1 to 2 inches, very dark grayish brown to brown (10 YR 3/2 to 4/2, dry) sand; single grain; 0 to 4 inches thick; very strongly acid (pH 4.9); clear wavy boundary. |
| C1 | 2 to 11 inches, gray (10 YR 5/1, dry) sand; single grain; common distinct fine to coarse mottles of light gray and brown; charcoal common; strongly acid (pH 5.3); abrupt smooth boundary. |
| IIB3 | 11 to 32+ inches, pale brown (10 YR 6/3, dry) rocky loamy sand; structureless; from 50 (at top) to 90 (at 32 inches) percent rocks and gravel by volume consisting mostly of angular pieces of andesite; occasional indistinct mottles of gray and common indistinct fine to coarse mottles of yellowish brown; charcoal and fine roots abundant at top to rare at 32 inches; strongly acid (pH 5.4). |

The A. amabilis/Xerophyllum/Lithosol Association occurs throughout the Mount Rainier Province, although it is limited areally. It has also been noted in the Snoqualmie Pass area to the north and as far south as the central Oregon Cascade Range. Carpenter (1961) referred to this association as the "Canadian Edaphic Type" in his study of Pacific silver fir-hemlock forests in the Mount Rainier area.

Abies amabilis/Streptopus curvipes Association

The A. amabilis/Streptopus Association is another topoedaphic climax within the A. amabilis Zone of the Mount Rainier Province, occupying lower ridgeslopes or old lahar surfaces of any exposure and up to 64 percent slope.

Elevations at study sites range from 2,900 to 3,750 feet.

Pacific silver fir is the only climax species (Table 8). Noble fir and western hemlock are important seral species, with Douglas-fir and western redcedar minor seral species. Noble fir, in particular, attains excellent development on the habitat characterized by this association (Fig. 5); the finest stand of noble fir known to exist (Franklin, 1964) occurs on this habitat type.

A rich herbaceous layer which, on the average, covers nearly 100 percent of the ground surface is the conspicuous feature of the understory (Fig. 6). The major highly constant species are Tiarella unifoliata, Achlys triphylla, Streptopus curvipes, and Vancouveria hexandra, but the complete list of herbaceous species is long (Table 9). The shrub layer is poorly developed, dominated mainly by Vaccinium ovalifolium, V. alaskaense, and V. membranaceum. The moss layer is even less developed, with 2 to 5 percent total coverage. Only three species--Rhytidiopsis robusta, Brachythecium velutinuum, and Dicranum fuscescens--show high constancy. The reduced stature of the moss layer here and in other herb-rich associations probably results from the dense herbaceous cover.

A. amabilis/Streptopus stands mostly occur on Podzols, although neither A2 nor B2ir horizons are strongly developed. Soils are usually deep, even on steeper sites, as a result of colluvial accumulation. The Blue Lake soil (Plot GP-92) is typical of a Podzol profile developing on a lower slope A. amabilis/Streptopus site:

| Horizon | Description |
|---|---|
| 01 | 1 to 1/2 inch, thin layer of needles, twigs, and leaves, mostly partially decomposed; 1/2 to 1 inch thick; extremely acid (pH 4.3). |
| 02 | 1/2 to 0 inch, humified organic matter with abundant roots; 1 to 2 inches thick; extremely acid (pH 3.9). |
| A2 | 0 to 1 inch, brown (7.5 YR 4/2, moist) gravelly sand; single grain; |

Table 8.--Stand structure and constancy of tree species in herb-rich associations occurring in the Abies amabilis Zone of the Mount Rainier Province

| Association and Species | All sizes Cn. % | Size Class (Number of Trees per Acre) | | | | |
|---|---|---|---|---|---|---|
| | | < 3' tall | 3' tall to 4" d.b.h. | 4 to 12" d.b.h. | 12 to 30" d.b.h. | > 30" d.b.h. |
| A. amabilis/ Streptopus, Typical Phase | | | | | | |
| A. amabilis | 100 | 5,604 | 145 | 65 | 35 | 5 |
| T. heterophylla | 83 | 1,418 | 19 | 5 | 2 | 2 |
| Abies procera | 83 | | | | 5 | 23 |
| Pseudotsuga menziesii | 33 | | | | + | 9 |
| Thuja plicata | 17 | | | | | 2 |
| A. amabilis/ Streptopus, Erythronium Phase | | | | | | |
| Abies amabilis | 100 | 15,677 | 382 | 30 | 61 | 19 |
| Tsuga heterophylla | 80 | 1,352 | 66 | | | 2 |
| Abies procera | 20 | | | | | 2 |
| A. amabilis/Oxalis | | | | | | |
| Abies amabilis | 100 | 1,510 | 193 | 44 | 47 | 17 |
| Tsuga heterophylla | 100 | 2,655 | 121 | 28 | 6 | 6 |
| Pseudotsuga menziesii | 80 | 6 | | | 2 | 13 |
| Thuja plicata | 80 | 270 | | | | 4 |
| Pinus monticola | 20 | | | | | + |
| A. amabilis/Oplopanax | | | | | | |
| Abies amabilis | 100 | 1,908 | 199 | 44 | 30 | 4 |
| Tsuga heterophylla | 100 | 3,068 | 40 | 19 | 15 | 8 |
| Thuja plicata | 100 | 6,487 | 23 | 6 | 30 | 23 |
| Pseudotsuga menziesii | 100 | + | | | | 6 |
| Abies procera | 50 | | | | | 2 |
| Abies grandis | 33 | | | 2 | 2 | 4 |
| Picea engelmannii | 33 | | | 6 | 19 | |
| Chamaecyparis nootkatensis | 17 | + | + | | | |

Table 9.--Constancy, frequency, and coverage values for selected understory species in the Abies amabilis/Streptopus (both phases), /Oxalis, and /Oplopanax

| Layer and Species | Association | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A. amabilis/Streptopus | | | | | | A. amabilis/ Oxalis (5) | | | A. amabilis/ Oplopanax (6) | | |
| | Typical Phase (6) | | | Erythron Phase (6) | | | | | | | | |
| | Cn. % | Fr. % | Cv. % | Cn. % | Fr. % | Cv. % | Cn. % | Fr. % | Cv. % | Cn. % | Fr. % | Cv. % |
| Shrubs: | | | | | | | | | | | | |
| Vaccinium membranaceum | 100 | 7 | 2 | 100 | 39 | 20 | 20 | 4 | T | 17 | + | T |
| Vaccinium ovalifolium | 83 | 12 | 7 | 100 | 35 | 24 | 60 | + | 1 | 83 | 2 | 1 |
| Acer circinatum | 50 | 3 | 2 | | | | 60 | 19 | 13 | 83 | 9 | 4 |
| Menziesia ferruginea | 50 | 1 | T | 100 | 3 | 2 | 20 | + | T | 17 | 1 | T |
| Oplopanax horridum | 50 | + | T | | | | | | | 100 | 47 | 31 |
| Vaccinium alaskaense | 33 | 7 | 3 | 100 | 30 | 20 | 100 | 44 | 21 | 67 | 3 | 1 |
| Rubus spectabilis | 17 | 4 | 2 | 40 | + | T | 40 | + | T | 67 | 4 | 1 |
| Ribes lacustre | 17 | + | T | | | | | | | 83 | 1 | T |
| Sorbus sitchensis | 17 | + | T | 80 | 6 | 1 | | | | | | |
| Vaccinium parvifolium | | | | | | | 80 | 4 | 2 | 33 | 2 | 1 |
| Rosa gymnocarpa | | | | | | | 40 | 2 | 1 | 17 | 1 | T |
| Berberis nervosa | | | | | | | 20 | 3 | 1 | | | |
| Total shrubs | | | 16 | | | 67 | | | 38 | | | 41 |
| Herbs: | | | | | | | | | | | | |
| Tiarella unifoliata | 100 | 79 | 18 | 100 | 70 | 22 | 100 | 58 | 14 | 100 | 66 | 12 |
| Achlys triphylla | 100 | 53 | 14 | 20 | 6 | 1 | 100 | 25 | 8 | 100 | 61 | 18 |
| Streptopus curvipes | 100 | 45 | 7 | 100 | 50 | 18 | 40 | 2 | T | 83 | 25 | 5 |
| Clintonia uniflora | 100 | 47 | 6 | 100 | 52 | 10 | 100 | 21 | 3 | 83 | 29 | 5 |
| Trillium ovatum | 100 | 7 | 1 | 60 | + | T | 80 | 3 | T | 100 | 12 | 1 |
| Rubus lasiococcus | 83 | 28 | 3 | 100 | 39 | 6 | 20 | 2 | T | 83 | 3 | T |
| Smilacina sessilifolia | 83 | 20 | 2 | 40 | 12 | 4 | 20 | 6 | 1 | 67 | 17 | 3 |
| Tiarella trifoliata | 83 | 11 | 1 | 20 | 2 | T | 80 | 13 | 2 | 33 | 16 | 3 |
| Viola sempervirens | 83 | 11 | 1 | 20 | + | T | 60 | 6 | 1 | 33 | 2 | T |
| Listera spp. | 83 | 4 | T | | | | | | | 33 | 1 | T |
| Vancouveria hexandra | 67 | 38 | 13 | 40 | 8 | 3 | 100 | 20 | 4 | 17 | 4 | 2 |
| Cornus canadensis | 67 | 8 | 1 | 80 | 22 | 3 | 80 | 18 | 2 | | | |
| Disporum smithii + oreganum | 67 | 1 | 1 | | | | 40 | 2 | 1 | 67 | 10 | 2 |
| Athyrium filix-femina | 67 | 1 | T | 40 | + | T | 80 | 6 | 2 | 100 | 29 | 19 |
| Veratrum viride | 67 | + | T | 40 | 1 | T | | | | 17 | + | T |
| Maianthemum bifolium | 50 | 9 | 1 | 40 | 2 | T | 80 | 2 | T | 17 | + | T |
| Osmorhiza chilensis | 50 | 8 | 1 | | | | | | | 50 | 2 | T |
| Rubus pedatus | 50 | 6 | 1 | 100 | 79 | 23 | 40 | 2 | T | 67 | 8 | 2 |
| Pyrola secunda | 50 | 3 | T | 60 | 3 | T | | | | | | |
| Goodyera oblongifolia | 50 | 1 | T | | | | 20 | + | T | 33 | 2 | T |
| Corallorhiza mertensiana | 50 | + | T | | | | 20 | + | T | 17 | + | T |

Table 9.--Continued

| Layer and Species | Association | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A. amabilis/Streptopus | | | | | | A. amabilis/ Oxalis (5) | | | A. amabilis/ Oplopanax (6) | | |
| | Typical Phase (6) | | | Erythron Phase (6) | | | | | | | | |
| | Cn. % | Fr. % | Cv. % | Cn. % | Fr. % | Cv. % | Cn. % | Fr. % | Cv. % | Cn. % | Fr. % | Cv. % |
| Herbs, Continued: | | | | | | | | | | | | |
| Dryopteris linnaeana | 33 | 18 | 8 | 40 | + | T | 60 | 12 | 6 | 100 | 76 | 42 |
| Arnica latifolia | 33 | 13 | 3 | | | | | | | 17 | + | T |
| Trautvettaria carolinensis | 33 | 5 | 1 | | | | | | | 50 | 7 | 2 |
| Valeriana sitchensis | 33 | 4 | 1 | 40 | 3 | 1 | | | | 17 | 1 | T |
| Anemone deltoidea | 33 | 2 | T | | | | 60 | 8 | 1 | 83 | 28 | 3 |
| Erythronium montanum | 33 | 2 | T | 100 | 17 | 2 | | | | | | |
| Luzula comosa | 33 | 1 | T | 80 | 1 | T | 20 | + | T | 17 | + | T |
| Pedicularis racemosa | 33 | 1 | T | 80 | + | T | | | | | | |
| Smilacina amplexicaulis | 33 | + | T | | | | | | | 67 | 6 | 2 |
| Streptopus amplexifolius | 17 | 4 | 1 | | | | | | | 17 | 2 | T |
| Galium oreganum | 17 | 3 | 1 | | | | | | | 17 | + | T |
| Viola glabella | 17 | 2 | T | | | | | | | 83 | 9 | 1 |
| Actaea arguta | 17 | + | T | | | | | | | 67 | 3 | 1 |
| Dryopteris spinulosa dilatata | 17 | + | T | | | | 60 | 2 | T | 50 | 2 | 1 |
| Polystichum munitum | 17 | + | T | | | | 100 | 8 | 4 | 50 | 2 | 1 |
| Struthiopteris spicant | 17 | + | T | | | | 80 | 19 | 8 | 17 | + | T |
| Xerophyllum tenax | | | | 20 | 2 | 1 | | | | | | |
| Coptis laciniata | | | | | | | 100 | 55 | 10 | | | |
| Oxalis oregana | | | | | | | 80 | 78 | 38 | | | |
| Linnaea borealis | | | | | | | 80 | 6 | T | 17 | 1 | T |
| Corydalis scouleri | | | | | | | | | | 17 | 5 | 4 |
| Mitella pentandra | | | | | | | | | | 33 | 5 | 1 |
| Asarum caudatum | | | | | | | | | | 33 | 3 | 1 |
| Total herbs | | | 88 | | | 95 | | | 111 | | | 128 |
| Mosses, litchens, and liverworts: | | | | | | | | | | | | |
| Rhytidiopsis robusta | 100 | 20 | 1 | 100 | 26 | 1 | 80 | 44 | 4 | 83 | 20 | 2 |
| Brachythecium velutinum | 83 | 8 | T | 80 | 6 | T | 20 | 1 | T | 100 | 9 | 1 |
| Dicranum fuscuscens | 83 | 5 | T | 100 | 14 | T | 40 | 1 | T | 67 | 3 | T |
| Cephalozia media | 67 | 2 | T | | | | 20 | 2 | T | 17 | + | T |
| Ptilidium californicum | 50 | 2 | T | 60 | 2 | T | 20 | + | T | | | |
| Cladonia spp. | 50 | 1 | T | | | | 20 | + | T | 33 | 1 | T |
| Bryum sandbergii | 33 | 3 | 1 | | | | | | | 67 | 2 | 1 |
| Plagiothecium denticulatum | 33 | 2 | T | 40 | 2 | T | 60 | 2 | T | 50 | 10 | 1 |
| Brachythecium starkei | 33 | 1 | T | 40 | 2 | T | | | | 50 | 6 | 1 |
| Hypnum circinale | 33 | 1 | T | 60 | 2 | T | 40 | 8 | T | 67 | 2 | T |
| Eurhynchium oreganum | 17 | 1 | T | 20 | 1 | T | 100 | 53 | 9 | 50 | 4 | 1 |
| Scapania nemorosa | 17 | 1 | T | | | | 60 | 3 | T | | | |
| Plagiothecium undulatum | 17 | + | T | | | | 60 | 10 | T | | | |
| Mnium insigne | | | | 20 | 1 | T | | | | 50 | 20 | 3 |
| Homalothecium stoloniferum | | | | | | | 80 | 9 | 1 | 17 | 2 | T |
| Rhytidiadelphus loreus | | | | | | | 80 | 9 | 1 | 33 | 2 | T |
| Mnium glabrescens | | | | | | | 40 | 6 | 1 | 50 | 2 | T |
| Total mosses, lichens, and liverworts | | | 2 | | | 1 | | | 16 | | | 10 |

0 to 1 inch thick; 21 percent gravel by weight consisting of angular andesite; abundant fine roots; extremely acid (pH 4.2); abrupt smooth boundary.

B21 1 to 4 inches, dark yellowish brown (10 YR 3/4, moist) loamy sand; moderate medium subangular block; 1 to 4 inches thick; 10 percent gravel by weight consisting of angular andesite; abundant fine to medium roots; very strongly acid (pH 4.8); clear wavy boundary.

B22 4 to 10 inches, brown (10 YR 4/3, moist) loamy sand; weak medium subangular blocky; 5 to 12 inches thick; 9 percent gravel by weight consisting of angular andesite; abundant fine to medium roots; very strongly acid (pH 5.0); gradual wavy boundary.

B3 10 to 28 inches, dark grayish brown (10 YR 3.5/1.5, moist) sand; single grain; 12 to 20 inches thick; 8 percent gravel by weight consisting of angular andesite; roots common; strongly acid (pH 5.2); clear wavy boundary.

C 28 to 42 inches, dark gray (N 4/0, moist) gravelly sandy loam; single grain; 11 to 19 inches thick; 30 percent gravel by weight consisting of angular andesite; roots common; very strongly acid (pH 5.0); abrupt wavy boundary.

II02b 42 to 43 inches, black (N 2/0, moist) band of charcoal; 0 to 2 inches thick; abrupt wavy boundary.

IIA1b 43 to 50 inches, very dark brown to dark brown (10 YR 2/2 to 3/3, moist) sandy loam; very weak fine subangular blocky; 4 to 11 inches thick; 9 percent gravel by weight consisting mostly of weathered pumice; abundant roots and charcoal; strongly acid (pH 5.2); clear wavy boundary.

IIB3b 50 to 63 inches, light olive (2.5 Y 5/4,moist) loamy sand; massive breaking to weak fine to medium subangular blocky; 6 to 15 inches thick; 5 percent gravel by weight consisting mostly of weathered pumice; common fine mottles of brown and gray; fine roots common; strongly acid (pH 5.5); clear wavy boundary.

IIC 63 to 90+ inches, grayish brown (2.5 Y 5/2, moist) loamy sand; massive breaking to weak medium subangular blocky; 11 percent gravel by weight consisting of weathered pumice; occasional krotovinas of gray sand; iron stains and roots occasional; medium acid (pH 5.8).

The geographic extent of this association is not well known. It is fairly common within the study area, although individual areas are often small. Reconnaissance in the Mount Baker area suggests this association, or a closely related one, will be found well north of the study area and may be even more common there.

Erythronium montanum phase.--This is a distinctive phase of the A. amabilis/Streptopus Association found in a limited area. The Erythronium phase occupies a distinctive topography position--upper ridgeslopes, benches on the upper third of ridgeslopes, or broad ridgetops. Stands studied are at elevations of 3,600 to 3,950 feet and mainly on northerly slopes.

All stands of the Erythronium montanum phase which were studied are pure, or nearly pure, stands of Pacific silver fir. Western hemlock and noble fir are minor seral species.

The understory of this phase has a well-developed shrubby layer as well as herbaceous layer. Vaccinium ovalifolium, V. alaskaense, V. membranaceum, and Menziesia ferruginea all have perfect constancies. V. membranaceum usually has a much higher coverage than in the typical phase of the association. Many herbs of the typical phase of the association are abundant, including Tiarella unifoliata, Streptopus curvipes, Rubus lasiococcus, and Clintonia uniflora. The complete list of herbs is much shorter, however, and Erythronium montanum and Rubus pedatus, rare in the typical association, attain 100 percent constancies and relatively high frequencies, or coverages, or both.

The Podzols of habitats characterized by the Erythronium phase are generally more strongly developed than those of the typical phase, but are shallower and rockier, because of their position on higher slopes and ridgetops.

The Erythronium phase was found in the southwestern portion of the study area, in the Lewis and Wind River drainages. It has not been found north of Mount St. Helens. It may occur in the Mount Hood area and northern Willamette Province, where topography and soils occur which are similar to those on areas where it has been identified.

Abies amabilis/Oxalis oregana Association

The A. amabilis/Oxalis Association is a relatively rare topoedaphic climax on well-watered lower slopes and benches in the study area. The sites sampled are on benches or lower ridgeslopes well supplied with ground water. Elevations range from 2,100 to 2,900 feet.

Both Pacific silver fir and western hemlock are major climax species (Table 8). Douglas-fir and western redcedar are the major seral species. A single western white pine was found at one of the five sites studied. Although this is a highly productive site, the tree canopy in several of the stands is relatively open due to severe mortality in recent years (Fig. 7). The decadence of these stands may be partially related to substantial damage by balsam woolly aphid on Pacific silver fir of this habitat (Johnson, Mitchell, and Wright, 1963).

The understory vegetation is dominated by a rich assemblage of herbs and ferns--Oxalis oregana, Struthiopteris spicant, Tiarella unifoliata, Tiarella trifoliata, Achlys triphylla, Vancouveria hexandra, Maianthemum bifolium, Polystichum munitum, etc.(Table 9, Fig. 8). Shrub layers dominated by Vaccinium alaskaense and V. ovalifolium and moss layers typified by Pseudoisothecium stoloniferum, Rhytidiadelphus loreus, Eurhynchium oreganum, and Rhytidiopsis robusta are also present, the former fairly well developed, the latter poorly developed. High coverage of Oxalis and relatively high frequency of Struthiopteris spicant differentiate this association from other herb-rich associations. The minor and inconspicuous nature of Athyrium filix-femina and Oplopanax horridum differentiate it from the A. amabilis/Oplopanax Association. Oxalis was absent from one and Struthiopteris from another of the plots studied; other characteristics of the association left no doubt as to their position in the classification, however. The relatively high coverage of Acer circinatum

on two of the study plots reflects an open tree canopy.

Soils show relatively little evidence of podzolization. Even though clean mineral grains are found at the soil surface in some profiles, occurrence of a weakly developed A1 horizon is more common. High water tables are common in the spring, although gleization of B horizons is not readily apparent. The following is a typical profile (Plot GP-45) found on an A. amabilis/Oxalis habitat:

| Horizon | Description |
|---|---|
| 01 | 2 to 1 1/2 inches, loose layer of moss and dead leaves; 1/2 to 1 inch thick; strongly acid (pH 5.5). |
| 02 | 1 1/2 to 0 inches, fibrous layer of well decomposed organic matter, fine roots, rotten wood, and charcoal; 1 to 8 inches thick; strongly acid (pH 5.4). |
| A1 | 0 to 1 1/2 inches, very dark brown (10 YR 2/2, moist) loam; moderate fine to medium granular, very friable; 1 to 3 inches thick; abundand fine roots give a fibrous aspect; strongly acid (pH 5.4); abrupt smooth boundary. |
| IIA2 | 1 1/2 to 5 inches, dark gray (10 YR 3.5/1, moist) fine sandy loam; weak coarse platy to massive; weakly cemented in spots; 2 to 5 inches thick; common fine to coarse mottles of dark brown, roots common; medium acid (pH 5.6); clear wavy boundary. |
| IIIB21 | 5 to 10 inches, very dark grayish brown (10 YR 3/2, moist) sandy loam; moderate fine subangular blocky; 4 to 11 inches thick; 23 percent gravel-sized, weathered pumice by weight; few distinct mottles of gray and reddish brown, few krotovinas of IIA2, roots common; medium acid (pH 5.6); clear wavy boundary. |
| IIIB22g | 10 to 13 inches, gray and brown (10 YR 5/1 and 4/3, moist) sandy loam; very weak medium subangular blocky; 2 to 5 inches thick; 26 percent gravel-sized weathered pumice by weight; roots common; top of horizon 8 to 16 inches below soil surface; medium acid (pH 5.6); abrupt wavy boundary. |
| IVB23 | 13 to 30 inches, brown (10 YR 4/3, moist) gravelly loam; weak medium to coarse subangular blocky; 8 to 21 inches thick; 35 percent gravel by weight consisting of weathered pumice and subangular andesite, 10 percent by volume angular andesitic rocks up to 1 foot in largest dimension; abundant fine to medium mottles of gray and grayish brown, roots common; medium acid (pH 5.7); clear wavy boundary. |
| VB3 | 30 to 50+ inches, dark yellowish brown (10 YR 4/4, moist) loamy sand; |

moderate medium subangular blocky; 16 percent gravel-sized weathered pumice by weight; abundant fine to medium mottles of gray, reddish brown, and yellowish brown; roots few; top of horizon 24 to 40 inches below soil surface; medium acid (pH 5.7).

This is a relatively rare association found only along the western margin of the study area. Discussions with other foresters and ecologists suggest it may be more common in coastal areas of Pacific silver fir occurrence such as the Willapa Hills of southwestern Washington.

Abies amabilis/Oplopanax horridum Association

The A. amabilis/Oplopanax Association constitutes an edaphic climax on the wettest forested sites studied within the A. amabilis Zones of both the Mount Rainier and Mount Adams Provinces. This association is found on river terraces and bottoms and on well-watered sites at the base or ridgeslopes. In the Mount Adams Province it is also found on poorly-drained, gently sloping areas near streams and meadows. Temporary and permanent streams, springs, and seeps are common. Streams may disappear underground and reappear below within the stand. Elevation of the study areas ranges from 2,200 to 3,950 feet.

Pacific silver fir, western redcedar, and western hemlock are ubiquitous in old-growth forests on A. amabilis/Oplopanax habitat. However, the successional position of these tree species is difficult to determine, because seedlings, saplings, and poles are sparse in the stands studied. Pacific silver fir is certainly a major climax species. Western redcedar is tentatively designated a major climax species on the basis of data from 4 of the 6 stands studied. Western hemlock is a major seral and minor climax component (based on data from 3 of the 6 stands) of the association (Table 8). In the Mount Rainier Province, Douglas-fir and noble fir are major seral species and Engelmann spruce and grand fir are minor seral species. In the Mount Adams Province only Engelmann spruce and grand fir are important seral species. In the A.

amabilis Zone of the Mount Rainier Province grand fir is found only on habitats characterized by this association.

The understory is characterized by a rich assemblage of herbs and ferns and by Oplopanax horridum. Total coverage in the herbaceous layer average 128 percent. Athyrium filix-femina, Dryopteris linnaeana, Tiarella unifoliata, and Achlys triphylla provide the bulk of the coverage and have 100 percent constancy (Table 9). The complete list of herbs is the longest for all of the associations studied. The shrubby layer is dominated by Oplopanax. Other shrubs, such as Acer circinatum, may provide significant coverage in some stands, but are low in constancy. The relatively consistent occurrence of Ribes lacustre and Rubus spectabilis is noteworthy, however, despite their low coverages. The moss layer is not well developed, and only 5 of 26 species have constancies of over 50 percent. Nonetheless, the moist habitats occupied by this association give the cryptogammic flora a distinctive composition.

Two special features should be mentioned in addition to the sparsity of tree regeneration. First, stands of the A. amabilis/Oplopanax Association often occur in close proximity to stands of the A. amabilis/Streptopus Association (A. amabilis/Tiarella unifoliata Association in the Mount Adams Province), the two forming an intricate mosaic. The former occupies the lower wetter portions of the landscapes, margins of streams, etc., and the latter occupies adjacent, better-drained ground. Such a mixture would have to be mapped as a habitat complex.

Second, the understory in at least some A. amabilis/Oplopanax stands is periodically purged by fresh alluvial deposits. An adjacent stream had recently deposited nearly two feet of coarse volcanic ejecta on one of the stands studied. Consequently, several herbaceous components and many cryptogams were reduced in coverage, and some species may have been completely,

though temporarily, eliminated.

Soils associated with the A. amabilis/Oplopanax Association vary, In the two lowest-elevation stands they are deep Reddish Brown Lateritic soils developed in colluvium and glacial till with no evidence of gleization. In other stands the soils are Azonal, layered alluvial deposits which could not be related to a zonal great soil group. The Upper Cispus soil (Plot GP-88) characterizes the lateritic profiles:

| Horizon | Description |
|---|---|
| 01 | 1 1/2 to 1/2 inches, undecomposed leaves,needles, and twigs; strongly acid (pH 5.3). |
| 02 | 1/2 to 0 inch, partially decomposed forest litter containing some mineral soil; strongly acid (pH 5.1). |
| A1 | 0 to 5 inches, dark brown (7.5 YR 3/2, moist) loam; weak subangular blocky (or very weak medium platy) breaking to fine granular; strongly acid (pH 5.3); gradual smooth boundary. |
| A3 | 5 to 14 inches, dark brown (7.5 YR 3/2, moist) loam; weak fine to medium subangular blocky breaking to weak fine granular; strongly acid (pH 5.5); abrupt wavy boundary. |
| IIB3 | 14 to 15 inches, discontinuous layer of brown (7.5 YR 4/4, moist) to very dark gray or dark gray brown (10 YR 3/1 or 4/2, moist) fine loamy sand; single grain; 0 to 1 inch thick; medium acid (pH 5.9); abrupt smooth boundary. |
| IIC | 15 to 16 inches, discontinuous layer of gray (10 YR 5/1, moist) sand; coarse at top and fine at bottom; single grain; 0 to 1/2 inch thick; medium acid (pH 5.9); abrupt wavy boundary. |
| IIIB2 | 16 to 51 inches, dark yellowish brown (10 YR 3/4, moist) sandy loam; weak medium subangular blocky; charcoal common, krotovinas of IIC and pockets of weathered pumice occasional, and occasional iron staining present especially around pumice pockets; medium acid (pH 5.9); diffuse smooth boundary. |
| IIIB3 | 51 to 74+ inches, dark yellowish brown (10 YR 3/4, moist) gravelly sandy loam; moderate medium subangular blocky; 20 percent gravel by volume consisting of rounded hard rock; charcoal common; medium acid (pH 6.0). |

The A. amabilis/Oplopanax habitat type is not extensive in either province. It is more common in the Mount Rainier Province, particularly around

Mount Rainier. It occasionally occupies a significant area on terraces and gentle slopes of glaciated valleys. In the Mount Adams Province only one stand large enough for sampling could be found. Most of the habitat in this province consists of narrow strips between drier habitats and streams or meadows. It is nonetheless distinctive. It becomes more common north of the study area and rarer to the south. It has been seen repeatedly as far north as Mount Baker. Only scattered fragments have been noted in northern Oregon, and, indeed, in the southern portion of the study area.

The A. amabilis/Oplopanax Association is closely related to the Thuja plicata/Oplopanax communities found on lowlands throughout the Tsuga heterophylla Zone of western Washington.[3] In fact, the association is probably a somewhat pauperized phase of a lower-elevation association, more restricted areally and floristically. Likewise, the A. amabilis/Oplopanax Association, particularly as it occurs in the Mount Adams Province, is closely related to the Thuja plicata-Tsuga/Oplopanax horridum Association found in northern Idaho (Daubenmire, 1952) and on the eastern slopes of the Washington Cascade Range.

An association with an herb-Oplopanax understory has been reported in the Subalpine Mountain Hemlock Zone of British Columbia (Brooke, 1965) but was not noted within the T. mertensiana Zone of southern Washington.

### Abies amabilis Zone, Mount Adams Province

The A. amabilis Zone of the Mount Adams Province is characterized by climax forests of Pacific silver fir. Western hemlock is important and ubiquitous but is not considered a climax species on most sites. The A. amabilis Zone in the Mount Adams Province typically occurs between 3,000 and 4,000 feet

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[3] An actual association of this type has not been described as yet. However, stands were often noted while traveling through the Tsuga Zone which have rich herbaceous understories, Oplopanax, and arborescent overstories of western redcedar, bigleaf maple, grand fir, Douglas-fir, black cottonwood, etc.

elevation. This zone combines many features of the wetter A. amabilis Zone to the west with some distinctly continental elements, which are most noticeable in seral communities, since western larch, grand fir, Engelmann spruce, western white pine, and lodgepole pine join Douglas-fir, noble fir, and western hemlock as common seral species. In fact, except for Pacific silver fir this zone resembles the Tsuga-Thuja Zone of northern Idaho (Daubenmire, 1952).

Wildfire has been even more important in the A. amabilis Zone of the Mount Adams Province than in the Mount Rainier Province. Unburned old-growth stands are harder to find, particularly at low elevations, doubtless a reflection of the drier climatic conditions of the province. Logging is also creating many 40- to 60-acre clearcut and burned blocks throughout the zone. Immediate reinvasion of distrubed areas by Pacific silver fir and western hemlock is much less common in this province than in the Mount Rainier Province, which may again reflect its drier climate.

Abies amabilis-Tsuga heterophylla/Vaccinium membranaceum Association

The A. amabilis-T. heterophylla/V. membranaceum Association occurs in both the Mount Adams and Mount Rainier Provinces. In the Mount Adams Province it is very widespread as the climatic climax of the A. amabilis Zone. It is found on gentle slopes (up to 30 percent) and occasionally on flats from 2,980 to 4,050 feet elevation. In the Mount Rainier Province this association is a very restricted topographic climax on ridgeslopes and benches at high elevations in the A. amabilis Zone.

Pacific silver fir is the sole climax species in this association[4] (Tables 6 and 10). Western hemlock, an important component of sub-climax old-growth forests is invariably missing from one or more of the smaller size

[4]Western hemlock is included in the association name, even though not climax, in order to distinguish it from the A. amabilis-T. mertensiana/Vaccinium membranaceum Association commonly encountered at higher elevations.

Table 10.--Stand structure and constancy of tree species in the associations found in the Abies amabilis Zone of the Mount Adams Province

| Association and Species | All sizes Cn. % | Size Class (Number of Trees per Acre) | | | | |
|---|---|---|---|---|---|---|
| | | <3' tall | 3' tall to 4" d.b.h. | 4 to 12" d.b.h. | 12 to 30" d.b.h. | >30" d.b.h. |
| A. amabilis-T. heterophylla/Vaccinium | | | | | | |
| Abies amabilis | 100 | 11,528 | 294 | 63 | 36 | 1 |
| Tsuga heterophylla | 100 | 260 | 49 | 10 | 30 | 11 |
| Pseudotsuga menziesii | 100 | 14 | | 5 | 20 | 11 |
| Tsuga mertensiana | 55 | 7 | 2 | 1 | 7 | 1 |
| Pinus monticola | 46 | | 1 | 9 | 6 | 1 |
| Thuja plicata | 27 | | 6 | 1 | 3 | |
| Abies grandis | 18 | 21 | 11 | 3 | 1 | |
| Larix occidentalis | 9 | | | | 1 | |
| Abies procera | 9 | | | | | 1 |
| A. amabilis/Achlys | | | | | | |
| Abies amabilis | 100 | 1,643 | 295 | 44 | 12 | + |
| Pseudotsuga menziesii | 100 | 64 | | 2 | 39 | 3 |
| Tsuga heterophylla | 83 | 318 | 11 | 5 | 5 | 3 |
| Abies procera | 83 | 339 | 3 | | 37 | 12 |
| Pinus monticola | 67 | 38 | | 2 | 2 | + |
| Abies grandis | 50 | 53 | | 3 | + | |
| Thuja plicata | 33 | 80 | 5 | + | + | |
| Abies lasiocarpa | 17 | 26 | 5 | | 2 | |
| Larix occidentalis | 17 | | | | 7 | |
| Picea engelmannii | 17 | | | | 2 | |
| Tsuga mertensiana | 17 | | 2 | | | |
| A. amabilis/Tiarella | | | | | | |
| Abies amabilis | 100 | 2,782 | 257 | 50 | 37 | 11 |
| Picea engelmannii | 100 | 20 | 5 | + | 3 | |
| Tsuga heterophylla | 75 | 1,212 | 26 | 16 | 16 | 5 |
| Pseudotsuga menziesii | 75 | | | | | 13 |
| Pinus monticola | 50 | | | | | + |
| Abies procera | 25 | 139 | | | | 13 |
| Abies grandis | 25 | | | | 5 | |
| Tsuga mertensiana | 25 | | 3 | | | |
| A. amabilis/Vacc. ovalifolium | | | | | | |
| Abies amabilis | 100 | 8,904 | 543 | 61 | 38 | 3 |
| Tsuga heterophylla | 100 | 3,100 | 37 | 13 | 24 | 8 |
| Pseudotsuga menziesii | 75 | 60 | | | | 11 |
| Tsuga mertensiana | 50 | | | | 8 | |
| Pinus monticola | 50 | | 3 | | + | |
| Thuja plicata | 25 | | 3 | | | |

classes; seedlings (trees less than 3 feet tall) are relatively uncommon and confined to rotten-log seedbeds. Douglas-fir and western white pine are other ubiquitous seral species. In the Mount Adams Province western larch and grand fir are locally important seral species, the latter most common on lower elevation sites. Lodgepole pine, Engelmann spruce, noble fir, western redcedar, and mountain hemlock are less common seral species. Isolated specimens of ponderosa pine occasionally are found at the lowest elevation sites representative of this habitat type.

This association is characterized by a depauperate understory dominated by V. membranaceum and Xerophyllum tenax (Tables 7 and 11). Other species with high constancy are Pyrola secunda, Rubus lasiococcus, Linnaea borealis, Clintonia uniflora, and Chimaphila umbellata. Rhytidiopsis robusta and Dicranum fuscescens dominate a poorly developed moss layer. Coverage of herbaceous species, especially Achlys triphylla, is highest in relatively young or recently disturbed stands. In dense old-growth stands the understory consists almost exclusively of ericaceous species and Xerophyllum tenax.

The Mount Rainier phase of the association differs in (1) the usual presence of either Vaccinium alaskaense or V. ovalifolium, Menziesia ferruginea, and Sorbus sitchensis, and (2)the usual lack of Linnaea, Clintonia, and Chimaphila in the herbaceous layer. Also, in the Spirit Lake area, Xerophyllum is apparently excluded by coarse pumice deposits. There V. membranaceum is sometimes the only notable understory species in stands of this association.

The A. amabilis-T. heterophylla/Vaccinium Association occurs on many soil types and depths. All are podzolic and share a coarse texture and good to excessive drainage. In the Mount Rainier Province soils have distinctive A2 and B2ir horizons, except where the very recent coarse deposits of Mount St. Helens ejecta occur. The Siouxon soil described earlier is representative of

Table 11.--Constancy, frequency, and coverage values for selected understory species in the Abies amabilis-Tsuga heterophylla/Vaccinium membranaceum and A. amabilis/Achlys, /Tiarella, and /Vaccinium ovalifolium Associations

| Layer and Species | Association | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A. amabilis-T. hetero./ Vaccinium membranaceum (11) | | | A. amabilis/ Achlys (6) | | | A. amabilis/ Tiarella (4) | | | A. amabilis/ Vaccinium ovalifolium (4) | | |
| | Cn. % | Fr. % | Cv. % | Cn. % | Fr. % | Cv. % | Cn. % | Fr. % | Cv. % | Cn. % | Fr. % | Cv. % |
| Shrubs: | | | | | | | | | | | | |
| Vaccinium membranaceum | 100 | 56 | 24 | 100 | 50 | 22 | 100 | 18 | 6 | 100 | 57 | 28 |
| Pachistima myrsinites | 73 | 6 | 2 | 83 | 14 | 2 | | | | 25 | + | T |
| Rosa gymnocarpa | 64 | 4 | 1 | 67 | 5 | 1 | 75 | 5 | 1 | | | |
| Berberis nervosa | 46 | 5 | 1 | 50 | 5 | 2 | | | | 50 | 12 | 2 |
| Vaccinium ovalifolium | 36 | 1 | T | 33 | 1 | T | 75 | 10 | 6 | 100 | 36 | 18 |
| Sorbus sitchensis | 36 | + | T | 17 | + | T | 25 | + | T | 100 | 6 | 1 |
| Symphoricarpos mollis | 27 | 2 | T | 50 | 1 | T | 25 | + | T | | | |
| Acer circinatum | 27 | + | T | 100 | 17 | 9 | 25 | + | T | 25 | 5 | 4 |
| Ribes lacustre | | | | 17 | + | T | 75 | + | T | | | |
| Rubus spectabilis | | | | | | | 50 | + | T | | | |
| Menziesia ferruginea | | | | | | | 25 | + | T | 100 | 18 | 10 |
| Total shrubs | | | 30 | | | 37 | | | 13 | | | 65 |
| Herbs: | | | | | | | | | | | | |
| Xerophyllum tenax | 100 | 28 | 16 | 50 | 1 | 1 | 25 | + | T | 100 | 54 | 36 |
| Rubus lasiococcus | 100 | 13 | 1 | 100 | 42 | 5 | 100 | 27 | 3 | 75 | 11 | 1 |
| Pyrola secunda | 91 | 5 | 1 | 100 | 20 | 2 | 75 | 10 | T | 75 | 6 | T |
| Linnaea borealis | 82 | 26 | 3 | 50 | 25 | 9 | 25 | 14 | 2 | 75 | 26 | 2 |
| Clintonia uniflora | 82 | 18 | 3 | 100 | 46 | 7 | 100 | 45 | 11 | 75 | 21 | 3 |
| Chimaphila umbellata | 82 | 6 | T | 100 | 29 | 4 | 25 | + | T | 50 | 9 | T |
| Achlys triphylla | 73 | 15 | 2 | 100 | 51 | 17 | 100 | 74 | 19 | 25 | + | T |
| Trillium ovatum | 64 | 3 | T | 100 | 5 | T | 100 | 3 | T | | | |
| Cornus canadensis | 55 | 5 | 1 | 50 | 12 | 2 | 50 | 26 | 5 | 100 | 45 | 6 |
| Pyrola asarifolia | 36 | 1 | T | 67 | 11 | 1 | | | | 75 | + | T |
| Gaultheria ovatifolia | 36 | 1 | T | | | | | | | 50 | + | T |
| Hypopitys monotropa | 36 | + | T | | | | | | | 50 | + | T |
| Viola sempervirens | 27 | 1 | T | 100 | 13 | 1 | 75 | 13 | 1 | | | |
| Goodyera oblongifolia | 27 | 1 | T | 83 | 6 | T | | | | | | |
| Disporum oreganum | 27 | 1 | T | 50 | 4 | 1 | 75 | 6 | 1 | | | |
| Anemone deltoidea | 18 | 10 | 1 | 100 | 22 | 2 | 100 | 52 | 6 | | | |
| Chimaphila menziesii | 18 | + | T | 50 | 1 | T | 50 | 4 | T | 25 | + | T |
| Pyrola picta | 18 | + | T | 50 | 1 | T | 25 | + | T | | | |
| Listera caurina | 18 | + | T | 83 | 3 | T | 50 | 2 | T | | | |
| Streptopus curvipes | 18 | + | T | 33 | 1 | T | 75 | 27 | 6 | 25 | 1 | T |
| Smilacina sessilifolia | 9 | 1 | T | 50 | 6 | 1 | 25 | 17 | 4 | | | |
| Penstemon nemorosus | 9 | + | T | 100 | 4 | 1 | | | | | | |
| Pteridium aquilinum | 9 | + | T | 67 | 4 | 2 | 25 | 4 | 2 | | | |
| Tiarella unifoliata | 9 | + | T | 50 | 7 | 1 | 100 | 80 | 22 | 25 | + | T |
| Vancouveria hexandra | 9 | + | T | 50 | 3 | T | 50 | 16 | 6 | | | |
| Smilacina amplexicaulis | 9 | + | T | 50 | + | T | 25 | 1 | T | | | |
| Anemone oregana | 9 | + | T | 33 | 1 | T | 50 | 2 | T | | | |
| Bromus suksdorfii | | | | 67 | 5 | 1 | 25 | 1 | T | | | |
| Osmorhiza chilensis | 33 | 1 | T | 50 | 2 | T | | | | | | |

Table 11.--Continued

| Layer and Species | Association | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A. amabilis-T. hetero./ Vaccinium membranaceum (11) | | | A. amabilis/ Achlys (6) | | | A. amabilis/ Tiarella (4) | | | A. amabilis/ Vaccinium ovalifolium (4) | | |
| | Cn. % | Fr. % | Cv. % | Cn. % | Fr. % | Cv. % | Cn. % | Fr. % | Cv. % | Cn. % | Fr. % | Cv. % |
| Herbs, Continued: | | | | | | | | | | | | |
| Tiarella trifoliata | | | | 33 | 1 | T | 50 | 2 | T | | | |
| Arnica latifolia | | | | 17 | 4 | T | 50 | 15 | 4 | | | |
| Valeriana sitchensis | | | | | | | 75 | 8 | 2 | | | |
| Viola glabella | | | | | | | 75 | 4 | 1 | | | |
| Athyrium filix-femina | | | | | | | 75 | + | T | | | |
| Mitella brewerii | | | | | | | 50 | 8 | 1 | | | |
| Galium oreganum | | | | | | | 50 | 6 | 1 | | | |
| Trautvettaria carolinensis | | | | | | | 50 | 4 | 1 | | | |
| Senecio triangularis | | | | | | | 50 | 2 | T | | | |
| Veratrum viride | | | | | | | 50 | 1 | T | | | |
| Rubus pedatus | | | | | | | 25 | 13 | 3 | 25 | 5 | T |
| Vicia americana | | | | | | | 25 | 4 | 1 | | | |
| Dryopteris linnaeana | | | | | | | 25 | 2 | 1 | | | |
| Corallorhiza mertensiana | | | | | | | | | | 50 | + | T |
| Total herbs | | | 29 | | | 53 | | | 103 | | | 49 |
| Mosses, lichens, and liverworts: | | | | | | | | | | | | |
| Rhytidiopsis robusta | 100 | 32 | 3 | 67 | 14 | 1 | 75 | 15 | 2 | 100 | 86 | 11 |
| Dicranum fuscescens | 91 | 23 | 3 | 83 | 6 | 1 | 100 | 4 | T | 100 | 33 | 2 |
| Ptilidium californicum | 73 | 4 | T | 33 | 1 | T | 25 | 2 | T | | | |
| Plagiothecium denticulatum | 46 | 1 | T | 33 | 2 | T | 50 | 2 | T | | | |
| Brachythecium velutinum | 27 | 1 | T | 67 | 8 | T | 75 | 5 | T | 25 | 2 | T |
| Brachythecium starkei | 9 | 1 | T | 50 | 5 | T | 75 | 2 | T | 25 | 2 | T |
| Brachythecium hylotapetum | 9 | 1 | T | 17 | 1 | T | 75 | 11 | 1 | 50 | 6 | 2 |
| Cladonia foliacea | 9 | 1 | T | | | | | | | 75 | 4 | T |
| Bryum sandbergii | 9 | + | T | 50 | 1 | T | 100 | 7 | T | | | |
| Total mosses, lichens, and liverworts | | | 6 | | | 2 | | | 3 | | | 15 |

many profiles present on Mount Rainier A. amabilis-T. heterophylla/Vaccinium habitat type.

In the Mount Adams Province most soils are developing in unreworked deposits of volcanic ejecta overlying weathered andesite, basalt, or till. The South Prairie soil (Plot GP-37) exemplifies those in which the roots are confined entirely to surficial deposits of ejecta by a coarse layer of scoria and cinders:

| Horizon | Description |
|---|---|
| 01 | 2 to 1 1/2 inches, matted layer of freshly fallen and partially decomposed forest litter; 1/2 to 1 inch thick; very strongly acid (pH 4.8). |
| 02 | 1 1/2 to 0 inches, densely matted fibrous layer of partially decomposed and humified organic matter; fungal myceleal felts common; 1 to 2 inches thick; very strongly acid (pH 4.6). |
| A2 | 0 to 1/2 inch, gray (10 YR 5/1, moist) sandy loam; single grain; 1/4 to 2 inches thick; 5 percent gravel by volume consisting of weathered pumice and scoria; roots common; very strongly acid (pH 4.7); abrupt wavy boundary. |
| B21ir | 1/2 to 1 1/2 inches, brown (7.5 YR 4/4, dry) fine loamy sand; weak fine subangular blocky, very porous; 1 to 2 inches thick; 5 percent gravel by volume consisting of weathered pumice and scoria; roots common; strongly acid (pH 5.1); clear smooth boundary. |
| B22 | 1 1/2 to 11 inches, yellowish brown (10 YR 5/5, dry) loamy sand; very weak medium subangular blocky or single grain; 15 percent gravel by volume consisting mainly of weathered scoria; roots abundant; medium acid (pH 6.0); abrupt smooth boundary. |
| B31 | 11 to 21 inches, yellowish brown (10 YR 5/6, dry) sand; weak fine to medium subangular blocky; 15 percent gravel by volume consisting mostly of weathered scoria; occasional roots and charcoal; slightly acid (pH 6.3); gradual smooth boundary. |
| B32 | 21 to 40 inches, yellowish brown (10 YR 5/7, dry) gravelly sand; massive; 20 percent gravel by volume consisting of scoria; occasional roots; neutral (pH 6.7); clear smooth boundary. |
| IIC | 40 to 60+ inches, varied colored gravelly sand (scoria) including particles of dark reddish brown (2.5 YR 3/4, 5 YR 3/4, dry), black (N 2/0, dry), strong brown ( 7.5 YR 5/8, dry), and dark brown (7.5 YR 3/2, dry); single grain; 40 percent gravel by volume; roots rare at top to absent at 50 inches; slightly acid (pH 6.5). |

The Dry Creek soil (Plot GP-30) is, perhaps, more typical, with root-favoring layers of ejecta directly overlying weathered andesitic breccia. Four of 11 plots were on this soil type:

| Horizon | Description |
|---|---|
| 01 | 3 to 2 inches, matted layer of freshly fallen and partially decomposed forest litter; 1/2 to 2 inches thick; extremely acid (pH 4.3). |
| 02 | 2 to 0 inches, fibrous layer of decomposing and humified organic matter; 2 to 4 inches thick; extremely acid (pH 3.8). |
| A2 | 0 to 1 1/2 inches, gray (N 6/0, dry) sand; single grain; 1 to 2 inches thick; 5 percent gravel by volume consisting of pumice; extremely acid (pH 4.4); abrupt wavy boundary. |
| B2 | 1 1/2 to 21 inches, brown (7.5 YR 3/4, moist) loamy sand; weak fine to medium subangular blocky; 25 percent gravel by volume consisting of pumice; abundant roots; medium acid (pH 5.9); clear wavy boundary. |
| B3 | 21 to 44 inches, dark yellowish brown (10 YR 3/4, moist) gravelly loamy sand; massive breaking to medium coarse subangular blocky; 40 percent gravel and rocks by volume consisting of both hard rock and pumice; roots occasional; medium acid (pH 5.9); abrupt wavy boundary. |
| IIC | 44 to 52+ inches, very dark gray (10 YR 3/1, moist) rocky loamy sand; structureless; 80 percent rocks and gravel by volume consisting of weathered breccia; many flecks and channels of yellow; no roots; slightly acid (pH 6.4) |

The habitat characterized by this association is the most widespread in the A. amabilis Zone of the Mount Adams Province. In the Mount Rainier Province it is confined to the highest ridges of the Western Cascades, slopes of Mount Rainier, and Cascade Crest in the vicinity of Goat Rocks. The stands in both provinces are, in fact, local representatives of a widespread association that extends at least as far south as the central Oregon Cascades and as far north as the Snoqualmie Pass area. It is interesting to note that Daubenmire (1952) did not find an association with a similar type of understory in the Thuja-Tsuga Zone of northern Idaho. The Vaccinium membranaceum-Xerophyllum tenax type of understory was found only in the Picea-Abies Zone. Probably the

extensiveness of the A. amabilis-T. heterophylla/Vaccinium membranaceum Association in the Mount Adams Province and the High Cascades in general is related to the preponderance of coarse-textured soils.

Abies amabilis/Achlys triphylla Association

The A. amabilis/Achlys Association is a relatively restricted topographic or topoedaphic climax in the Mount Adams Province. It is usually on gentle to moderate (50 percent), middle to upper slopes of any exposure. One stand studied occupies a gentle toe-slope adjacent to a saddle. Sampled stands ranged from 3,290 to 4,400 feet.

Pacific silver fir is the only climax species (Table 10). Western hemlock, noble fir, Douglas-fir, and grand fir are major seral species, while western larch, western white pine, Engelmann spruce, western redcedar, and subalpine fir are minor seral species. Within the Mount Adams Province noble fir-dominated stands are usually found only in the A. amabilis/Achlys habitat type.

A relatively rich assemblage of herbaceous species such as Achlys triphylla, Anemone deltoidea, Anemone oregana, Trillium ovatum, Viola sempervirens, Clintonia uniflora, and Bromus suksdorfii, most rarely or never occurring in climax stands on zonal habitats, characterizes the association's understory (Table 11). Vaccinium membranaceum and Acer circinatum are constant members of the shrubby layer, the latter often providing considerable coverage. Mosses have little coverage and only Dicranum fuscescens is highly constant. Xerophyllum tenax is usually absent, or when present, inconspicuous. The absence or low coverage of Tiarella unifoliata differentiates this association from the A. amabilis/Tiarella Association. Several other species often present in the A. amabilis/Tiarella Association never occur in the A. amabilis/Achlys Association (Table 11).

Soils are weakly developed Podzols of moderate depth, developing in

coarse (loamy sand to gravelly sand) layers of ejecta overlying till on four of the six plots sampled. The Nine Foot soil (Plot GP-42) characterizes these profiles:

| Horizon | Description |
|---|---|
| 01 | 1 1/4 to 1 inch, mainly undecomposed layer of needles, twigs, and leaves; strongly acid (pH 5.3). |
| 02 | 1 to 0 inch, mainly decomposing but recognizable forest litter; 1/4 to 1 inch thick; strongly acid (pH 5.1). |
| A2 | 0 to 1 inch, gray (10 YR 6/1, dry) sand; single grain; strongly acid (pH 5.2); abrupt wavy boundary. |
| B21 | 1 to 5 inches, very dark grayish brown (10 YR 3/2, moist) loamy sand; very weak fine subangular blocky; 2 to 7 inches thick; 14 percent gravel by weight consisting of white to pale brown pumice; roots and charcoal abundant; strongly acid (pH 5.3); abrupt irregular boundary. |
| B22 | 5 to 17 inches, brown (10 YR 5/3, moist) loamy sand; weak fine subangular blocky; 12 to 16 inches thick; 20 percent gravel by weight consisting of fine pale brown pumice; common indistinct fine to coarse mottles of brown (10 YR 4/3) and dark grayish brown (10 YR 4/2); roots common; strongly acid (pH 5.4); clear wavy boundary. |
| B23 | 17 to 21 inches, dark yellowish brown (10 YR 4/4, moist) gravelly sand; single grain; 2 to 6 inches thick; 27 percent gravel by weight consisting of white to pale brown pumice; roots common; medium acid (pH 5.8); abrupt wavy boundary. |
| IIB24 | 21 to 37 inches, brown (10 YR 4/3, moist) gravelly sandy loam; moderate medium fine subangular blocky; 38 percent gravel by weight consisting of subangular to angular andesitic rock and weathered pumice; krotovinas of B23 common; roots common; strongly acid (pH 5.5); clear smooth boundary. |
| IIC | 37 to 68+ inches, yellowish brown (10 YR 5/4, moist) loam; weak medium subangular blocky; 19 percent gravel by weight consisting mostly of subangular to angular andesitic rock, little weathered pumice; roots occasional at top to rare at 68 inches; strongly acid (pH 5.3). |

The habitat characterized by this association occurs in the Mount Hood as well as the Mount Adams Province. Though uncommon, it may cover considerable acreages on some extensive gently-sloping ridges and hills. A comparable association was not encountered in the Mount Rainier Province; however, a

closely related association, at least floristically, occurs along the Western Cascades (Willamette Province) in central Oregon.

Abies amabilis/Tiarella unifoliata Association

The A. amabilis/Tiarella Association is a topoedaphic climax in the A. amabilis Zone of the Mount Adams Province. The stands analyzed occupy flat areas or lower slopes that receive ground water from adjacent higher ground. Elevations ranged from 3,010 to 4,100 feet.

Pacific silver fir is the only definite climax species although size class distributions in one stand, near the lower part of the zone, suggest western hemlock may play a limited climax role (Table 10). Engelmann spruce is the only ubiquitous seral species, but Douglas-fir, grand fir, noble fir, and western white pine may be locally important seral components.

The herbaceous layer comprises the major understory feature (Table 11). Herbs of high constancy are Tiarella unifoliata, Achlys triphylla, Anemone deltoidea, Clintonia uniflora, Streptopus curvipes, Rubus lasiococcus, Valeriana sitchensis, and Trillium ovatum. Athyrium filix-femina is usually present, but only in trace amounts. A scattered layer of shrubs is typical, dominated by Vaccinium membranaceum, V. ovalifolium, and Rosa gymnocarpa. Ribes lacustre has a high constancy but low coverage. The moss layer is scattered, but occurrence of Brachythecium hylotapetum, B. starkei, B. velutinum, and Bryum sandbergii in most stands makes the layer distinctive.

Soils are Podzols on all study sites, but these are generally deeper and more fertile than those of adjacent zonal habitats. The Lost Creek soil (Plot GP-73) exemplifies these profiles:

| Horizon | Description |
|---|---|
| 01 | 2 to 1 1/2 inches, thin layer of freshly fallen needles, leaves, and twigs; strongly acid (pH 5.4). |

02 1 1/2 to 0 inches, partially decomposed and humified organic matter, the latter well mixed with mineral soil; strongly acid (pH 5.1).

A2 0 to 1/4 inch, dark grayish brown (10 YR 4/2, moist) loamy sand; single grain; 0 to 1/2 inch thick; roots common; strongly acid (pH 5.2); clear smooth boundary.

B21ir 1/4 to 7 inches, dark reddish brown (5 YR 3/4, moist) sandy loam; weak fine to strong medium subangular blocky; 4 to 9 inches thick; 6 percent pumice gravel by weight; occasional distinct mottles of dark grayish brown and very dark brown (10 YR 3/2 to 2/2); charcoal common, roots abundant; strongly acid (pH 5.4); clear wavy boundary.

B22 7 to 21 inches, dark yellowish brown (10 YR 4/4 to 3/4, moist) sandy loam; weak medium subangular blocky; 12 to 16 inches thick; 8 percent pumice gravel by weight; roots common; medium acid (pH 5.8); abrupt wavy boundary.

B31 21 to 35 inches, dark gray brown (10 YR 4/2.5, moist) fine sandy loam; weak to moderate, fine to medium subangular blocky; 11 to 16 inches thick; 1 percent weathered pumice gravel by weight; roots occasional; slightly acid (pH 6.1); abrupt smooth boundary.

B32 35 to 57 inches, dark yellowish brown (10 YR 3/4, moist) sandy loam; weak medium to coarse subangular blocky; 6 percent pumice gravel by weight; roots occasional; two bands of higher pumice content and weaker structure in lower third of horizon; slightly acid (pH 6.1); abrupt smooth boundary.

IIB2b 57 to 67 inches, very dark gray brown (10 YR 3/2, moist) loam; moderate fine subangular blocky; 1 percent gravel by weight consisting of weathered pumice and andesitic rock; vesicular, iron stains along root channels; roots rare; slightly acid (pH 6.1); clear wavy boundary.

IIIO2b 67 to 67 1/4 inches, discontinuous layer of charcoal.

IIIB2b 67 1/4 to 77+ inches, dark brown to dark yellowish brown (10 YR 3/3 to 3/4, moist) loam; massive breaking to weak medium subangular blocky; 12 percent gravel by weight consisting of concretions and very weathered pumice; occasional iron stains around root channels and textural breaks; roots rare; medium acid (pH 6.0).

The habitat typified by the A. amabilis/Tiarella Association is restricted. Only four stands representing the association could be located and one of these is in the Mount Hood Province. Often it occurs only as a narrow band between A. amabilis/Oplopanax and drier upland areas. The A. amabilis/Tiarella Association is related to the A. amabilis/Streptopus Association found

in the Mount Rainier Province. However, I consider composition and environmental relationships are sufficiently distinct to warrant separation.

Abies amabilis/Vaccinium ovalifolium Association

The A. amabilis/V. ovalifolium Association is a topographic or topo-edaphic climax occupying cooler and moister sites in the A. amabilis Zone. Representative stands, occupying ridgeslopes, benches, and extensive, gently sloping tracts, are usually found on north aspects but the association may occur on southerly aspects in lower ridgeslope position. Elevation of study sites ranges from 3,300 to 3,700 feet.

Pacific silver fir is the major climax tree species (Table 10). Western hemlock, a major component of many seral stands, is a minor climax species. Douglas-fir, western white pine, and mountain hemlock are the most common seral species.

Vaccinium ovalifolium, V. membranaceum, and Menziesia ferruginea dominate the shrubby understory (Table 11). Xerophyllum tenax is the most important species in the herbaceous layer although Cornus canadensis, Clintonia uniflora, Rubus lasiococcus, Linnaea borealis, Pyrola secunda, and Pyrola asarifolia also have high constancies. Rhytidiopsis robusta, Dicranum fuscescens, and Cladonia foliacea are the most important members of the moss layer.

This association is a lower-elevation relative of the A. amabilis/Menziesia Association and might be considered a phase of the latter. However, the high constancies for Xerophyllum, Cornus, and Linnaea, and the absence or inconspicuous nature of mountain hemlock provide substantial differentiation. The A. amabilis/V. ovalifolium Association also appears similar to the A. amabilis/V. alaskaense Association of the Mount Rainier Province. It is, perhaps, a Mount Adams representation of this latter association minus the V. alaskaense.

Soils developing on sites representative of the A. amabilis/V.

ovalifolium habitat type are typical Podzols with no particularly outstanding features. Mottling or gleying, sometimes found in A. amabilis/Menziesia habitats, was not noted.

This association was found in only a limited area--the western edge of the Mount Adams Province. Only four stands could be located. I have not seen it elsewhere in the Cascade Range.

## Tsuga mertensiana Zone

The Tsuga mertensiana Zone is the highest forested zone throughout much of the Cascade Range, including the study area. Truly climax forests are characterized by Pacific silver fir and possibly a very scattered occurrence of mountain hemlock. Most of the old-growth stands studied did, in fact, contain a major component of mountain hemlock. However, size-class distribution in these stands indicates mountain hemlock is essentially seral to Pacific silver fir. The full range of Pacific silver fir size classes is usually present, whereas reproduction of mountain hemlock in the dense old-growth stands is often completely absent. Alaska-cedar is codominant in the climax forests of one habitat.

This zone can be divided into two segments comparable to those described for the "Subalpine Mountain Hemlock Zone" in coastal British Columbia (Peterson, 1965). The lower subzone is an area of essentially continuous forest cover. The upper subzone is parkland, a mosaic of forest and meadow communities. The upper limit of the T. mertensiana Zone is considered to be the point at which alpine meadow and heather communities replace forest on the mesic portions of the landscape. That is, the point at which forest becomes a topographic climax occupying warmer and drier sites which are closely corrleated with a shorter duration of winter snowpack.

The T. mertensiana Zone is best developed in the high rolling country

of the Mount Adams Province where it covers extensive areas and in and around Mount Rainier and the Cascade Crest (Goat Rocks and north) in the Mount Rainier Province. Elsewhere in the Mount Rainier Province the zone is encountered sporadically on the highest peaks and ridges.

The T. mertensiana Zone generally occurs at elevations of 4,000 to 6,500 feet in the Mount Adams Province and 4,500 to 6,500 feet in the Mount Rainier Province.

During the 19th and early 20th centuries fires denuded large areas of the T. mertensiana Zone, particularly in the Mount Adams Province. As a result, seral stands of lodgepole pine, subalpine fir, and whitebark pine dominate extensive burns such as those around Surprise Lakes, Council Lake, and Potato Hill. Mountain hemlock is only now beginning to regain its place in many of these stands, and Pacific silver fir is absent from many areas. Some old burns are still poorly stocked with trees and the extensive stands of Vaccinium membranaceum which occupy them are prime areas for huckleberry picking. Burns similar in age, size, and vegetative composition are very common in this zone in the High Cascades of Oregon. Occasional large burned tracts are found in the Mount Rainier Province, e.g., in the Stampede Pass and Corral Pass areas.

The zone is widely distributed in the Cascade Range. It is found throughout the range in Oregon and Washington although Pacific silver fir drops out farther south, around Crater Lake.

Abies amabilis-Tsuga mertensiana/Vaccinium membranaceum Association

The A. amabilis-T. mertensiana/Vaccinium Association represents the climatic climax within the zone. The stands studied occur on moderate slopes, extensive flat to gently sloping areas, and benches of southerly exposure between elevations of 4,000 and 5,500 feet.

Pacific silver fir is the only climax species although all of the stands

examined still contained a major or dominant component of mountain hemlock (Table 12). Subalpine fir, lodgepole pine, and western white pine are the common seral species. Whitebark pine (especially at highest elevations), Douglas-fir, western larch, Alaska-cedar, Engelmann spruce, and noble fir are less common seral species. Two typical successional sequences following burning involve initial invasion of lodgepole pine and subalpine fir, gradual replacement by mountain hemlock, and a much slower encroachment of Pacific silver fir into the mature mountain hemlock stand. The second involves the direct reinvasion of mountain hemlock on burned-over sites and a slow replacement of the resulting even-aged mountain hemlock stands by Pacific silver fir.

The A. amabilis-T. mertensiana/Vaccinium Association is characterized by a very depauperate understory in which only V. membranaceum, Xerophyllum tenax, and Rubus lasiococcus are constant and conspicuous components (Table 13). Dense old-growth mountain hemlock stands growing on this habitat often have a nearly bare forest floor with very scattered shrubs and herbs of low vigor. At higher elevations, in stands interspersed with meadow, representatives of the meadow communities may occur under the trees. The moss cover is neither well-developed nor constant in composition in this association consisting mostly of limited colonies of species attaining much better development elsewhere.

Soils in habitats representative of this association are podzolic, coarse textured, and of shallow to moderate depth. All soils examined had developed in layers of pyroclastic ejecta overlying till, residuum, or much older volcanic deposits. The Miners Ridge soil (Plot SNO-1) is typical of a profile developed in ejecta overlying residuum weathered from granitic parent rock:

| Horizon | Description |
|---|---|
| 01 | 1 3/4 to 1 inches, matted undecomposed layers of needles, twigs, etc.; extremely acid (pH 4.3). |

**Table 12.--Stand structure and constancy of tree species in associations occurring in the Tsuga mertensiana Zone**

| Association and Species | All sizes Cn. % | Size Class (Number of Trees per Acre) <3' tall | 3' tall to 4" d.b.h. | 4 to 12" d.b.h. | 12 to 30" d.b.h. | >30" d.b.h. |
|---|---|---|---|---|---|---|
| A. amabilis-T. mertensiana/Vaccinium | | | | | | |
| Abies amabilis | 100 | 12,495 | 215 | 25 | 58 | 2 |
| Tsuga mertensiana | 100 | 185 | 99 | 42 | 55 | 7 |
| Pinus monticola | 60 | | | 2 | 2 | + |
| Abies lasiocarpa | 40 | 66 | 30 | 9 | 11 | |
| Pseudotsuga menziesii | 40 | | | 2 | 2 | |
| Chamaecyparis nootkatensis | 40 | 40 | 7 | 7 | | |
| Picea engelmannii | 20 | | | | 2 | |
| Pinus albicaulis | 20 | | | | 2 | |
| Larix occidentalis | 20 | | | | | + |
| A. amabilis/Veratrum | | | | | | |
| Abies amabilis | 100 | 5,088 | 98 | 21 | 23 | 2 |
| Abies lasiocarpa | 80 | 32 | 6 | 27 | 102 | |
| Tsuga mertensiana | 60 | 32 | 17 | 6 | 11 | |
| Pinus monticola | 20 | | | | | + |
| Pinus contorta | 20 | | | | 8 | |
| Abies grandis | 20 | 32 | | | | + |
| Chamaecyparis nootkatensis | 20 | 80 | | | 2 | |
| A. amabilis/Menziesia | | | | | | |
| Abies amabilis | 100 | 30,931 | 541 | 56 | 63 | 4 |
| Tsuga mertensiana | 90 | 294 | 3 | 6 | 31 | 8 |
| Tsuga heterophylla | 60 | 461 | 3 | + | 11 | 2 |
| Pseudotsuga menziesii | 40 | 32 | | | + | 1 |
| Pinus monticola | 30 | 8 | | | + | 1 |
| Abies procera | 10 | | | | | 1 |
| Picea engelmannii | 10 | | | | + | |
| C. nootkatensis/ Rhododendron | | | | | | |
| Abies amabilis | 100 | 22,769 | 623 | 51 | 53 | 2 |
| Chamaecyparis nootkatensis | 100 | 2,624 | 146 | 32 | 44 | 6 |
| Tsuga mertensiana | 100 | 302 | 34 | 2 | 17 | 11 |
| Picea engelmannii | 20 | | | | + | |
| Pinus monticola | 20 | | | | | 2 |
| Pseudotsuga menziesii | 20 | | | | + | |

Table 13.--Constancy, frequency, and coverage values for selected understory species for associations found in the Tsuga mertensiana Zone

| Layer and Species | Association | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A. amabilis-T. merten./ Vaccinium membranaceum (5) | | | A. amabilis/ Veratrum (5) | | | A. amabilis/ Menziesia (10) | | | C. nootkatensis/ Rhododendron (5) | | |
| | Cn. % | Fr. % | Cv. % | Cn. % | Fr. % | Cv. % | Cn. % | Fr. % | Cv. % | Cn. % | Fr. % | Cv. % |
| Shrubs: | | | | | | | | | | | | |
| Vaccinium membranaceum | 100 | 54 | 30 | 80 | 25 | 14 | 100 | 66 | 28 | 100 | 72 | 32 |
| Vaccinium scoparium | 60 | 3 | 1 | 20 | + | T | 10 | + | T | | | |
| Sorbus sitchensis + scopulina | 60 | 2 | T | 80 | + | T | 70 | 7 | 1 | 80 | 4 | 1 |
| Menziesia ferruginea | | | | | | | 90 | 34 | 20 | 80 | 35 | 24 |
| Vaccinium ovalifolium | | | | | | | 90 | 28 | 16 | 100 | 38 | 19 |
| Rhododendron albiflorum | | | | | | | 40 | 10 | 7 | 100 | 58 | 38 |
| Vaccinium alaskaense | | | | | | | 30 | 4 | 2 | 20 | 2 | 1 |
| Total shrubs | | | 31 | | | 14 | | | 75 | | | 114 |
| Herbs: | | | | | | | | | | | | |
| Xerophyllum tenax | 100 | 47 | 34 | 60 | 6 | 3 | 30 | 4 | 2 | 20 | 4 | 2 |
| Rubus lasiococcus | 80 | 18 | 3 | 60 | 47 | 15 | 80 | 40 | 4 | 100 | 46 | 4 |
| Luzula parviflora | 40 | 2 | 1 | 80 | 30 | 11 | 10 | + | T | | | |
| Valeriana sitchensis | 40 | 2 | T | 60 | 22 | 7 | 50 | 3 | 1 | 80 | 14 | 4 |
| Pyrola secunda | 40 | 2 | T | 40 | 2 | T | 50 | 3 | T | 80 | 6 | T |
| Viola sempervirens | 20 | 4 | T | 80 | 23 | 3 | 50 | 4 | T | 100 | 13 | T |
| Ligusticum grayii | 20 | 2 | T | 60 | + | T | | | | | | |
| Arnica latifolia | 20 | + | T | 80 | 14 | 4 | 10 | + | T | 20 | + | T |
| Mitella brewerii | 20 | + | T | 80 | 25 | 4 | | | | 40 | 1 | T |
| Listera caurina | 20 | + | T | 60 | 2 | T | 10 | + | T | 100 | 7 | T |
| Hypopitys monotropa | 20 | + | T | | | | 60 | + | T | | | |
| Osmorhiza purpurea | | | | 80 | 11 | 1 | | | | 20 | + | T |
| Bromus vulgaris | | | | 80 | 4 | 2 | | | | | | |
| Trillium ovatum | | | | 80 | 1 | T | 30 | + | T | 20 | + | T |
| Pedicularis racemosa | | | | 60 | 1 | T | | | | 60 | 1 | T |
| Carex preslii | | | | 60 | + | T | | | | | | |
| Anemone delfoidea | | | | 40 | 28 | 6 | | | | | | |
| Erythronium montanum | | | | 40 | 10 | 1 | 40 | 23 | 6 | 40 | 32 | 5 |
| Vicia americana | | | | 40 | 4 | 1 | | | | | | |
| Rubus pedatus | | | | 20 | 20 | 9 | 80 | 29 | 5 | 100 | 45 | 5 |
| Smilacina sessilifolia | | | | 20 | 11 | 4 | | | | | | |
| Carex inops | | | | 20 | 6 | 4 | | | | | | |
| Arenaria macrophyllum | | | | 20 | 6 | 1 | | | | | | |
| Polemonium pulcherrimum | | | | 20 | 4 | 1 | | | | | | |
| Festuca viridula | | | | 20 | 2 | 1 | | | | | | |
| Clintonia uniflora | | | | 20 | 1 | T | 50 | 26 | 4 | 40 | 2 | T |
| Streptopus curvipes | | | | | | | 70 | 14 | 2 | 60 | 6 | T |
| Achlys triphylla | | | | | | | 60 | 3 | T | | | |
| Tiarella unifoliata | | | | | | | 40 | 2 | T | 60 | 11 | 1 |
| Cornus canadensis | | | | | | | 30 | 6 | 2 | | | |
| Dryopteris linnaeana | | | | | | | | | | 20 | 8 | 2 |
| Total herbs | | | 39 | | | 79 | | | 27 | | | 28 |
| Mosses, lichens, and liverworts: | | | | | | | | | | | | |
| Dicranum fuscescens | 80 | 17 | 1 | 20 | + | T | 90 | 39 | 6 | 80 | 36 | 4 |
| Pohlia nutans | 60 | 1 | T | 20 | + | T | 10 | + | T | 20 | + | T |
| Brachythecium velutinum | 40 | 2 | T | 40 | 2 | 1 | 20 | + | T | 60 | 8 | 1 |
| Rhytidiopsis robusta | 40 | 1 | T | | | | 90 | 31 | 4 | 100 | 28 | 3 |
| Brachythecium starkei | 20 | 6 | 1 | 40 | 2 | 1 | 80 | 11 | 1 | 100 | 22 | 2 |
| Plagiothecium denticulatum | 20 | + | T | 20 | 1 | T | 60 | 8 | T | 80 | 10 | 1 |
| Bryum sandbergii | | | | 20 | 1 | T | 10 | + | T | 40 | 9 | 1 |
| Ptilidium californicum | | | | | | | 60 | 3 | T | 80 | 10 | T |
| Brachythecium hylotapetum | | | | | | | 40 | 8 | 1 | | | |
| Cladonia spp. | | | | | | | 20 | 1 | T | 80 | 6 | T |
| Mnium punctatum | | | | | | | 10 | + | T | 40 | 6 | 1 |
| Lophozia quinquedentata | | | | | | | | | | 20 | 4 | 1 |
| Total mosses, lichens and liverworts | | | 2 | | | 1 | | | 13 | | | 16 |

02 1 to 0 inch, densely matted partially decomposed and humified organic matter; very fibrous; extremely acid (pH 4.0).

A21 0 to 1 1/2 inches, gray (10 YR 5/1, dry) fine sand; single grain; 1 to 2 inches thick; extremely acid (pH 4.3); abrupt wavy boundary.

A22 1 1/2 to 2 inches, light gray (10 YR 6/1, dry) coarse sand; single grain; 1/2 to 1 inch thick; very strongly acid (pH 4.6); abrupt wavy boundary.

B21 2 to 9 inches, brown (10 YR 5/3, dry) gravelly loamy sand; very weak medium subangular blocky; 20 percent gravel by volume consisting of both volcanic ejecta and granite; very strongly acid (pH 4.9); abrupt smooth boundary.

IIB22 9 to 23 inches, light yellowish brown (10 YR 6/4, dry) gravelly loamy sand; moderate medium subangular blocky; 75 percent rocks and gravel by volume, rocks granitic and angular; strongly acid (pH 5.3); clear smooth boundary.

IIB3 23 to 37 inches, very pale brown (10 YR 7/3, dry) rocky loamy sand; weak fine to medium subangular blocky; 65 percent rocks and gravel by volume, rocks granitic and angular; strongly acid (pH 5.1); abrupt irregular boundary.

IIIC 37 to 42+ inches, very pale brown (10 YR 7/3, dry) gravelly sand; massive; 40 percent rocks and gravel by volume consisting of subangular granite; strongly acid (pH 5.1).

Geographically, the habitat typified by this association is the most extensive found in the T. mertensiana Zone of the study area, Furthermore, it has been observed as far north as the Snoqualmie Pass area and is common in the Oregon Cascade Range to at least central Oregon. Associations with closely similar undergrowth occur in the subalpine zone of northern Idaho (Daubenmire, 1952).

Abies amabilis/Menziesia ferruginea Association

The A. amabilis/Menziesia Association is a topographic or topoedaphic climax throughout the T. mertensiana Zone and at higher elevations in the A. amabilis Zone of both provinces. Stands representative of this association were found on two types of landforms--northerly exposed ridgeslopes of up to 55 percent and extensive gently-sloping areas or benches of any aspect which

are subject to cold air drainage and poor soil drainage. Most of the stands sampled are at 4,000 to 4,100 feet elevation, but the association does occur throughout the elevational span of the T. mertensiana Zone.

Pacific silver fir is the sole climax species (Table 12). Both western and mountain hemlocks are major associates although mountain hemlock is the more common. This is the only association where extensive mixing of the two hemlocks was encountered which is undoubtedly the consequence of the association's common occurrence in the transition between the two zones. Douglas-fir, western white pine, Alaska-cedar, and Engelmann spruce are several of the less common seral trees.

A tangle of shrubs 1 to 1 1/2 meters tall dominates the understory. Vaccinium membranaceum, Menziesia ferruginea, V. ovalifolium, Sorbus scopulina, and Rhododendron albiflorum are the most important members of this shrub layer. Rhododendron may replace Menziesia partially or entirely in some stands, particularly at high elevations. The herbaceous layer is relatively inconspicuous (Table 13). Characteristic herbs include Rubus pedatus, R. lasiococcus, Clintonia uniflora, Streptopus curvipes, and Erythronium montanum. Erythronium has only 40 percent constancy, but a coverage of 8 to 26 percent in those stands in which it occurs. The moss layer average 13 percent coverage, most of which is provided by Rhytidiopsis robusta, Dicranum fuscescens, and Brachythecium starkei.

The association is floristically very similar to the C. nootkatensis/Rhododendron/Gley Podzol Association (Table 12). Alaska-cedar is a climax codominant in the latter, however, and there are also differences in soil morphology that will be pointed out.

Soils developing on sites representative of the A. amabilis/Menziesia Association are Podzols of two types. On steeper slopes typical podzolic

profiles are present with relatively little evidence of mottling or gleization.

The Skate Mountain soil (Plot GP-89) is of this kind:

| Horizon | Description |
|---|---|
| 01 | 2 1/2 to 1 1/2 inches, matted layer of undecomposed twigs, needles, etc.; 1/2 to 1 inch thick; extremely acid (pH 4.1). |
| 02 | 1 1/2 to 0 inches, densely-matted, fibrous layer of partially decomposed and humified organic matter; 1 to 2 inches thick; extremely acid (pH 3.8). |
| A2 | 0 to 1 inch, dark gray (10 YR 4/1, moist) coarse sand ; single grain; 1/4 to 1 1/2 inches thick; extremely acid (pH 3.8); clear wavy boundary. |
| B2 | 1 to 2 inches, dark yellowish brown (10 YR 3/4, moist) coarse sand; single grain; 0 to 1 inch thick; extremely acid (pH 4.1); clear wavy boundary. |
| B3 | 2 to 8 inches, brown (10 YR 4/3, moist) coarse sand; single grain; 3 to 9 inches thick; very strongly acid (pH 4.6); abrupt wavy boundary. |
| II02b | 8 to 8 1/2 inches, discontinuous black layer of charcoal 0 to 1 inch thick; abrupt wavy boundary. |
| IIA2b | 8 1/2 to 10 inches, gray (10 YR 5/1, moist) loamy sand; single grain; 1/2 to 2 1/2 inches thick; charcoal common; very strongly acid (pH 4.9); abrupt wavy boundary. |
| IIB21irb | 10 to 12 inches, dark reddish brown (5 YR 3/4, moist) fine loamy sand; massive; 0 to 3 inches thick; charcoal common; very strongly acid (pH 4.6); clear wavy boundary. |
| IIB22b | 12 to 14 inches, yellowish brown (10 YR 5/3.5, moist) fine loamy sand; massive; 1 1/2 to 6 inches thick; 8 percent gravel by volume consisting of weathered pumice; common medium mottles of yellowish brown, orange, dark brown, and gray; patches and streaks of B21irb and iron staining common; very strongly acid (pH 4.9); clear irregular boundary. |
| IIIB23b | 14 to 25 inches, yellowish brown (10 YR 5/6, moist) coarse sand; single grain; 7 to 12 inches thick; 9 percent gravel by volume consisting of pumice; charcoal common; strongly acid (pH 5.2); abrupt smooth boundary. |
| IVA2b | 25 to 26 1/2 inches, gray (10 YR 5/1, moist) fine sand; massive; 1 to 2 inches thick; 8 percent gravel by volume consisting of hard rock; distinct common fine brown to orange brown mottles; strongly acid (pH 5.2); abrupt smooth boundary. |
| IVB2b | 26 1/2 to 31 inches, dark brown to dark reddish brown (7.5 YR 3/2 to |

5 YR 3/4, moist) gravelly sandy loam; weak fine to medium subangular blocky; 2 to 6 inches thick; 45 percent gravel and rocks by volume consisting of gravel-sized hard rock fragments; iron and manganese concretions present; very strongly acid (pH 5.0); gradual smooth boundary.

VB3b — 31 to 48+ inches, brown (10 YR 4/3, moist) rocky sandy loam; weak medium subangular; about 60 percent rocks and gravel by volume consisting mainly of gravel-sized hard rock; strongly acid (pH 5.1).

On gentle slopes or benches where drainage is impeded, soils usually have typical podzolic A2-B2 sequences at the top but have strongly mottled and sometimes gleyed B and C horizons. However, gleying is not so conspicuous as in the Gley Podzols of the C. nootkatensis/Rhododendron habitat type, and high organic matter contents in lower B horizons are absent. The Badger Peak profile (Plot GP-97) illustrates typical morphology on a poorly-drained A. amabilis /Menziesia site:

| Horizon | Description |
|---|---|
| 01 | 2 1/4 to 1 1/2 inches, freshly fallen and partially decomposed needles, leaves, and twigs; 1/4 to 1 inch thick; very strongly acid (pH 4.6). |
| 02 | 1 1/2 to 0 inches, matted layer of decomposed organic matter with abundant roots; 1 to 5 inches thick; extremely acid (pH 4.3). |
| A2 | 0 to 1 inch, light gray (10 YR 6/1, moist) sand; single grain; 1/2 to 1 1/2 inches thick; extremely acid (pH 4.5); abrupt wavy boundary. |
| B21 | 1 to 4 1/2 inches, very dark brown (10 YR 2/2, moist) sand; very weak fine subangular blocky; 3 to 7 inches thick; charcoal common; very strongly acid (pH 4.9); abrupt wavy boundary. |
| B22 | 4 1/2 to 5 inches, gray (10 YR 5/1, moist) loamy sand; weak fine subangular blocky; 1/2 to 2 inches thick; common distinct fine to medium iron stains; strongly acid (pH 5.0); clear wavy boundary. |
| IIB3 | 5 to 8 inches, brownish yellow to pale brown (10 YR 6/6 to 8/3, moist) fine gravel; single grain; 2 to 5 inches thick; occasional distinct fine iron stains; strongly acid (pH 5.1); abrupt wavy boundary. |
| IIIA2b | 8 to 9 inches, dark gray (10 YR 5/1, moist) sandy loam; structureless; 0 to 2 inches thick; charcoal common; strongly acid (pH 5.5); abrupt wavy boundary. |

IIIB2b 9 to 17 inches, brown (10 YR 4/3, moist) sandy loam; massive breaking to weak fine subangular blocky; 7 to 12 inches thick; abundant clear mottles of gray brown and yellowish brown; charcoal common; medium acid (pH 5.6); abrupt smooth boundary.

IV02b 17 to 17 1/2 inches, discontinuous layer of charcoal and rotten wood.

IVC1 17 1/2 to 27 inches, pinkish gray (7.5 YR 6/2, moist) to gray loamy fine sand; massive breaking to weak fine subangular blocky; 8 to 12 inches thick; roots common; medium acid (pH 6.0); clear smooth boundary.

IVC2 27 to 42 inches, light gray (10 YR 6/1, moist) loamy sand to sand; weak medium subangular blocky; 10 to 20 inches thick; consists of several layers of sand and loamy sand; common distinct fine to medium mottles of yellowish brown and orange brown; roots occasional; medium acid (pH 6.0); clear smooth boundary.

IVC3 42 to 45 inches, brownish yellow (10 YR 6/6, moist) fine gravelly sand; single grain; 2 to 5 inches thick; roots very rare; slightly acid (pH 6.1); abrupt smooth boundary.

VA2b 45 to 47 inches, gray (10 YR 4/1 to 5/1, moist) loamy sand; structureless; 1 1/2 to 3 inches thick; charcoal common, roots very rare; medium acid (pH 5.9); abrupt wavy boundary.

VB2b 47 to 60+ inches, yellowish brown (10 YR 4/6 to 5/6, moist) gravelly loamy sand; massive breaking to weak medium subangular blocky; roots very rare; medium acid (pH 6.0).

This association is widely represented in the study area. It has been observed throughout the Cascade Range in Washington and northern Oregon. Regarding the undergrowth, its relationship with the Picea-Abies/Menziesia Association found in northern Idaho (Daubenmire, 1952) is obvious.

Abies amabilis/Veratrum viride Association

The A. amabilis/Veratrum Association is an edaphic or topoedaphic climax on moist sites within the T. mertensiana Zone. It occurs on gentle to moderate slopes (20 to 42 percent), usually in a mid-slope position and on a southerly exposure. Elevations ranged from 4,600 to 5,300 feet.

Most of the areas studied were dominated by youthful stands of subalpine fir (Table 12). The occurrence of a similar understory under a dense canopy of Pacific silver fir indicates these communities deserve status as an

association, however. Pacific silver fir is the only climax tree species. Major seral species are subalpine fir, mountain hemlock, and lodgepole pine.

The outstanding feature of the A. amabilis/Veratrum Association is the presence of a relatively luxuriant herbaceous understory (Table 13). There are, however, very few diagnostic species of high constancy. Luzula parviflora, Arnica latifolia, Mitella brewerii, Osmorhiza purpurea, Bromus vulgaris, Veratrum viride, and Valeriana sitchensis are probably the most important. Xerophyllum tenax is often present (60 percent), but with low coverage. Vaccinium membranaceum is usually present (80 percent) and may have considerable coverage (up to 44 percent). Still, the conspicuous element of the understory is the herbaceous cover, and this distinguishes the association.

Soils are podzolic, but podzolization is not usually so pronounced as on adjacent zonal habitats. In some of the younger stands podzolization is scarcely detectable (Plot MR-1):

| Horizon | Description |
|---|---|
| 01 | 1 1/2 to 1 inches, thin layer of partially decomposed leaves, needles, and twigs; 1/2 to 3/4 inch thick; strongly acid (pH 5.1). |
| 02 | 1 to 0 inch, partially decomposed and humified organic matter; 1 to 2 inches thick; very strongly acid (pH 4.7). |
| A2 | 0 to 1/2 inch, gray (10 YR 5/1, moist) sand; single grain; 0 to 1 inch thick; 15 percent gravel-sized white pumice by weight; very strongly acid (pH 4.9); abrupt wavy boundary. |
| B21 | 1/2 to 3 inches, mosaic of very dark grayish brown, brown, and yellowish brown (10 YR 3/2, 5/4, and 4/3, moist) loamy sand; very weak medium subangular blocky; 2 to 5 inches thick; 17 percent gravel-sized brown pumice by weight; charcoal common, roots abundant; strongly acid (pH 5.2); abrupt wavy boundary. |
| II02b | 3 to 4 1/2 inches, charcoal and rotten wood; 0 to 1 1/2 inches thick. |
| IIB22 | 4 1/2 to 26 inches, dark brown (10 YR 3/3, moist) sandy loam; weak medium subangular blocky; 20 to 25 inches thick; 16 percent gravel by weight, mostly weathered brown pumice, some angular to subangular andesite; common fine to coarse indistinct mottles of dark brown (7.5 YR 3/2), common coarse indistinct mottles of grayish brown, and flecks of yellowish brown; charcoal common, roots |

abundant; medium acid (pH 5.6); gradual smooth boundary.

IIB3 26 to 39+ inches, brown (10 YR 4/2.5, moist) loamy sand; weak medium to fine subangular blocky; becoming rocky at 35 to 40 inches depth; few coarse distinct mottles of grayish brown and dark brown, common flecks of yellowish brown; roots common; medium acid (pH 5.8).

Under denser, older stands, podzolization may be much farther advanced with well-developed A2 and B2ir horizons.

The geographic distribution of this association is poorly known. Stands were difficult to locate, particularly older stands. The association was most common around Mount Rainier and Mount Hood (where two stands were analyzed). An open forest community of mountain hemlock and herbaceous species, especially Polemonium pulcherrimum, Luzula parviflora, Arnica latifolia, Mitella spp., and Valeriana sitchensis was encountered in several parts of the Goat Rocks Wilderness. All of these stands consituted fragments insufficient in size for analysis (elimination of edge effects, etc.). However, these communities are interpreted as successional stages of the Abies amabilis/Veratrum Association and suggest it has a fairly wide geographic distribution.

Chamaecyparis nootkatensis/Rhododendron albiflorum/Gley Podzol Association

This distinctive association represents a topoedaphic climax on cool, wet sites in the T. mertensiana Zone. The stands analyzed occupy a variety of landforms--slopes, bench, river terrace, depression--having in common a cool, wet character by virtue of north-facing slopes and areas of excessive cold air accumulation. Poor soil drainage is also characteristic. Elevations of the study areas ranged from 4,400 to 4,800 feet.

Alaska-cedar joins Pacific silver fir as a climax species on this habitat (Table 12). Mountain hemlock may also attain a minor place in the climax by taking advantage of the many openings typical of the association. Engelmann spruce is a seral species locally common though of low constancy for the

habitat as a whole.

A dense shrubby understory, 1 1/2 meters or more in height, characterizes this association (Table 13). R. albiflorum, Menziesia ferruginea, Vaccinium membranaceum, Vaccinium ovalifolium, and Sorbus scopulina are the constant and important members of the shrub layer. Rubus pedatus and R. lasiococcus, with a combined coverage of 7 to 12 percent, dominate the herbaceous layer in most stands. A few other herbs, e.g., Erythronium montanum and Valeriana sitchensis, have high frequency and coverage in individual stands.

Soils on habitats typified by this association are gleyed Podzols. The surface soils usually have a typical podzolic A2-B2 sequence, but this is underlain by mottled and dull colored horizons of high organic matter content. The Narada Falls soil (Plot MR-3) provides an example of this type:

| Horizon | Description |
|---|---|
| 01 | 3 1/2 to 2 1/2 inches, matted layer of freshly fallen needles, leaves, and twigs; 1/2 to 1 1/2 inches thick; very strongly acid (pH 4.7). |
| 02 | 2 1/2 to 0 inches, densely matted layer of decomposing and humified organic matter with abundant roots; 2 to 5 inches thick; extremely acid (pH 4.2). |
| A21 | 0 to 1 inch, gray (10 YR 5/1, moist) coarse sand; single grain; 1/2 to 3 inches thick; extremely acid (pH 4.1); abrupt wavy boundary. |
| A22 | 1 to 2 inches, very dark gray (10 YR 3/1, moist) coarse sand; single grain; 1/2 to 3 inches thick; extremely acid (pH 4.4); abrupt wavy boundary. |
| B21 | 2 to 6 inches, very dark brown (10 YR 2/2, moist) gravelly sandy loam; moderate medium subangular blocky; 3 to 9 inches thick; 26 percent gravel-sized pumice; 7.8 percent organic matter; distinct many fine to coarse mottles of very dark gray brown and few of dark reddish brown and dark gray; roots, rotting wood, and charcoal abundant; very strongly acid (pH 4.9); clear irregular boundary. |
| B22 | 6 to 8 inches, very dark gray brown to gray (10 YR 3/2 to 4/1, moist) sandy loam; weak fine subangular blocky; 1/2 to 3 inches thick; 16 percent gravel-sized pumice; many fine to coarse distinct mottles of dark reddish brown and few fine to coarse indistinct mottles of very dark brown; charcoal, roots, and rotting wood common; very strongly acid (pH 4.9); abrupt wavy boundary. |

IIB23 8 to 23 inches, mosaic of yellowish red (5 YR 4/6, moist) and dark brown (10 YR 3/3, moist) coarse sand; moderate medium to coarse subangular blocky; 12.8 percent organic matter; occasional indistinct coarse mottles of brownish yellow; charcoal common at top and bottom, roots occasional; very strongly acid (pH 4.9); abrupt smooth boundary.

IIIB24g 23 to 37 inches, very dark gray (10 YR 3/1, moist) sandy clay loam; massive breaking to moderate medium to coarse subangular blocky; 8.7 percent organic matter; abundant distinct coarse layers and mottles of very dusky gray (2.5 YR 2/2--organic matter) and black (charcoal), few distinct coarse mottles of dark gray brown or gray; few fine roots in upper inch of horizon; strongly acid (pH 5.1); abrupt wavy boundary.

IVB3 37 to 42+ inches, dark yellowish brown (10 YR 3/4, moist) very rocky loamy sand; massive, very firm; 85 percent rocks and gravel by volume, rocks andesitic breccia, subangular to rounded, and up to 14 inches long; rocks form line at top of horizon; 6 percent organic matter; many distinct fine to coarse mottles of dark reddish brown (rotting wood); iron staining around rocks; no roots; strongly acid (pH 5.3).

The Leech Lake soil (Plot SNO-3), on the other hand, has only a poorly dveloped podzolic sequence with the A2 horizons directly overlying mottled and gleyed horizons. At the time this profile was described the water table was at about 22 inches:

| Horizon | Description |
|---|---|
| 01 | 3 to 2 1/2 inches, matted layer of undecomposed needles, twigs, and branches; 1/4 to 1/2 inch thick; very strongly acid (pH 4.9). |
| 02 | 2 1/2 to 0 inches, matted fibrous layer of well decomposed litter with abundant fine roots; 2 to 4 inches thick; very strongly acid (pH 4.6). |
| A21 | 0 to 2 inches, gray (10 YR 4/1, dry) coarse sand; single grain; 1 to 3 inches thick; many of coarser particles light gray or white; very strongly acid (pH 4.9); abrupt smooth boundary. |
| II02b | 2 to 2 1/2 inches, decomposed organic matter and roots; 1/4 to 1/2 inch thick; abrupt smooth boundary. |
| IIA22 | 2 1/2 to 3 1/2 inches, gray (10 YR 5/1, dry) fine sand; single grain; very strongly acid (pH 4.7); abrupt wavy boundary. |
| IIA23 | 3 1/2 to 4 inches, gray (10 YR 6/1, dry) coarse sand; single grain; 1/2 to 3/4 inches thick; coarser particles pale brown or light gray; very strongly acid (pH 4.7); abrupt smooth boundary. |

IIIO2b 4 to 5 inches, rotten wood, charcoal and fine roots; 1 to 2 1/2 inches thick.

IIIB21 5 to 7 1/2 inches, grayish brown (10 YR 5.5/2, dry) fine loamy sand; massive; 2 to 6 inches thick; abundant fine to coarse distinct mottles of dark brown, dark reddish brown, and light gray; charcoal common; organic matter 7.7 percent; very strongly acid (pH 4.9); clear wavy boundary.

IIIB22 7 1/2 to 13 inches, light gray to brownish gray (10 YR 7/1 and 6/2, dry) fine loamy sand; massive; 2 percent gravel by volume consisting of weathered pumice; abundant, distinct fine to coarse mottles of yellowish brown, dark reddish brown, and black; stripes and patches of charcoal and rotten wood abundant; organic matter 5.4 percent; strongly acid (pH 5.2); clear smooth boundary.

IVO2b 13 to 14 inches, black discontinuous layer of charcoal; 0 to 2 inches thick.

IVB21hb 14 to 16 inches, dark reddish brown (5 YR 2/2, moist) or dark grayish brown (10 YR 4/2, dry) gravelly sand; very weak fine subangular blocky; 25 percent gravel by volume consisting of weathered pumice; organic matter 8.3 percent; strongly acid (pH 5.1); gradual wavy boundary.

IVB22hb 16 to 26 inches, yellowish brown (10 YR 3/4, moist) at top to yellowish brown (10 YR 5/8, moist) at bottom, loamy sand; massive but weak fine platiness appearing when dry; 2 percent gravel by volume; abundant distinct fine to medium mottles and stripes of yellowish red to dark reddish brown, most common in upper 4 inches; organic matter 8.4 percent; strongly acid (pH 5.1); abrupt wavy boundary.

IVB23hb 26 to 36+ inches, dark yellowish brown (10 YR 3/4, moist) rocky gravelly sand; massive at top but generally weak fine to medium subangular blocky; 70 percent rocks and gravel by volume, consisting of hard platy rock; few very fine indistinct mottles of dark reddish brown and black at top; organic matter 7.7 percent; strongly acid (pH 5.3).

The mottling and gleying are undoutedly caused by high water tables which characterize the C. nootkatensis/Rhododendron habitat throughout much of the year. These water tables result from inadequate internal drainage relative to the large water supply. Drainage may be impeded by topography or by impervious layers in the soil profile, as at Narada Falls.

The habitat typified by the C. nootkatensis/Rhododendron/Gley Podzol Association is relatively uncommon and not extensive where it does occur. Most

of the stands encountered were in the vicinity of the Goat Rocks and Mount Rainier. Stands belonging to this association were encountered in the Mount Baker area of northern Washington and the association may be more common to the north of the study area. The association has been found as far south as Mount St. Helens. Only scattered fragments have been found in the Mount Adams Province.

Other Communities

Two other types of forested communities were noted during the reconnaissance but not described quantitatively. These are the T. mertensiana/Xerophyllum/Lithosol and T. mertensiana/Vaccinium scoparium communities. The T. mertensiana/Xerophyllum/Lithosol community was found on high ridgetops or steep slopes covered by only a skim of lithosolic soil. Forested stands are relatively open, and mountain hemlock and possibly Alaska-cedar join Pacific silver fir as climax species. A wide variety of seral species is possible. Xerophyllum is the only understory species of consequence although Vaccinium membranaceum and Pyrola secunda are usually present. This community is obviously the upper-elevation analogue of the A. amabilis/Xerophyllum/Lithosol Association.

The T. mertensiana/Vaccinium scoparium community was found at scattered locations in the T. mertensiana Zone. Very little is known about successional relations in this community except that Pacific silver fir is at least one climax component. A variety of associated understory species may be present (or none at all) but V. scoparium is dominant. This community is most common near timberline and toward the eastern (drier) parts of the Mount Adams Province. A similar community, often without Pacific silver fir, is very common in the southern Oregon Cascade Range (Crater Lake Province of Franklin, 1965b).

Timberline Forests

Open stands and small groups of trees are interspersed with meadows at the zone's upper limits, thereby combining characteristics of forested and alpine communities. Undoubtedly, detailed study of this ecotone will reveal a spectrum of associations similar to those described in British Columbia by Peterson (1965) and Brooke (1965).

Though analysis of such associations was beyond the scope of this study, I observed tree species composition of timberline and krumholz forests sufficiently to justify comment. Mountain hemlock and subalpine fir are the most common of the wetter timberline species and Alaska-cedar occurs locally, particularly in the Goat Rocks. Pacific silver fir is also present at timberline on the westernmost slopes.

On slopes east (to the lee) of Mounts Rainier and Hood and in the more continental High Cascades around Mount Adams, whitebark pine and subalpine fir predominate at timberline. However, mountain hemlock is usually also present in this area.

The dynamic timberline on the north side of Mount St. Helens constitutes a special case. The advance of timberline up the youthful volcanic cone, though relatively rapid, is retarded primarily by coarse, loose pumice substrate rather than climate. Two facts lead to this conclusion. (1) Timberline's elevation is only about 4,500 feet compared to 6,000 to 6,500 feet typical of the Cascade Range. (2) Timberline groves occur immediately above forests dominated by lodgepole pine and commonly include only one typical timberline tree species--subalpine fir. Mountain hemlock is infrequent and whitebark pine is absent. Others commonly present are not typically timberline tree species: lodgepole pine, western white pine, Douglas-fir, noble fir, and black cottonwood (Populus trichocarpa).

## Communities of Unique Habitats

Within the study area are other types of forest communities which, because of unique characteristics resulting from specialized habitats, do not fit readily into the zonal organization. These are communities developed on (1) swamplands, (2) recent lahars, and (3) lava flows. Swamp communities were only reconnoitered; quantitative data were taken for some communities occurring on the other two types of habitat. All of these habitats deserve intensive study, for they not only are botanically interesting, but also offer special opportunities for relating community distribution to microenvironment.

### Swamp Communities

Swamplands occupy only a small fraction of the study area--depressions, bottoms of some broad stream valleys, and margins of wet meadows. Typical swamp communities are a mosaic of physiognomic units which present special sampling problems. Most trees grow on hummocks. Margins of hummocks and other slightly-raised sites are dominated by shrubs. The wettest parts of the swamp are densely covered by herbs with a scattering of stunted trees and shrubs.

Floristically, the picture is essentially the same regardless of province. Characteristic tree species are western redcedar, black cottonwood, Engelmann spruce, Alaska-cedar, western white pine, and red alder (Alnus rubra). Almost any species indigenous to the area may occur in small numbers. Characteristic shrub species include Spirea densiflora, Alnus sinuata, A. incana, Salix sitchensis (and other Salix spp.), Ribes bracteosum, and Lonicera involucrata. The list of ferns, monocotyledons, and dicotyledons is long, including, for example, Athyrium filix-femina and Equisetum arvense; many gramineae such as Glyceria elata, Fluminea festucacea, and Pleuropogon refractus; many Cyperaceae such as Carex rostrata, C. kelloggii, C. canescens, Scirpus microcarpus, and Eriophorum augustifolium; Lysichiton americanum; Stenanthium occidentale

and Tofieldia occidentalis; Habenaria saccata; and a wide variety of dicotyledons such as Trautvetteria carolinensis, Saxifraga arguta, Parnassia fimbriata, Mitella pentandra, Viola palustris, Epilobium glandulosum, Stachys ciliata, Mimulus moschatus, Veronica americana, and Senecio triangularis. Athyrium, species of Cyperaceae, and Lysichiton are particularly conspicuous dominants. At higher elevations there is a noticeable increase in subalpine elements such as Alaska-cedar, Stenanthium, Tofieldia, Parnassia, and Leptarrhena amplexifolia. A rich moss flora often develops including Sphagnum spp. on some of the boggiest sites.

In the Mount Rainier Province a distinctive Alnus rubra/Lysichiton community was found at lowest elevations in the A. amabilis Zone. This community represents a widespread association in the T. heterophylla Zone. Red alder is scattered through Lysichiton, sedge (Cyperaceae), and Athyrium-dominated wet areas, and western redcedar occupies the hummocks.

At South Prairie, in the A. amabilis Zone of the Mount Adams Province, black cottonwood characterizes raised portions and margins of a shallow perennial lake bed. This lake, formed by a lava dam, drains completely dry during the summer and refills during the winter. Kienholz (1931) described a similar situation at nearby Goose Lake, formed by the same lava flow. An annual fluctuation of 14 feet in the depth of this shallow lake resulted in black cottonwood communities analogous to those found at South Prairie. The reader is referred to Kienholz' paper for a thorough description of the zones and flora in these periodically flooded areas.

Lahars

Adjacent to Mount St. Helens are two lahars occupied by communities not clearly identifiable with any associations described previously. The larger lahar is in the Kalama River drainage on the southwest side of Mount St.

Helens (Fig. 2). Carbon dating of wood from snags in Blue Lake, which this lahar formed by damming several small drainages, indicates its age to be about 300 years. Communities vary from a climax stand of lodgepole pine (Fig. 9) to a mature stand of Douglas-fir, western hemlock, and Pacific silver fir in which the last two species are climax. A full range of stands intermediate in character between these two extremes is to be found somewhere on the lahar. The dominant control over community composition is the amount of soil mantle favorable for roots overlying the densely-compacted lahar assemblage (Fig. 10). Where the mantle is deepest hemlock and Pacific silver fir forests occur; where it is shallowest a climax community of lodgepole pine develops. Data for communities at each end of the spectrum are provided in Table 14.

Both communities are poor in species. The Pacific silver fir-western hemlock community has a well-developed shrubby layer dominated by Vaccinium ovalifolium and a high coverage of mosses. The only herb of consequence is Chimaphila umbellata. The soil mantle containing roots is 3 to 4 feet deep. The lodgepole pine community has only one major understory species, Arctostaphylos uva-ursi, but mosses and lichens are abundant. Roots extend 12 to 18 inches into the compacted lahar assemblage which lies about 7 inches below the ground surface.

In the lodgepole pine stand studied, the pine is the only species reproducing abundantly, although small numbers of western white pine and subalpine fir are present. Lodgepole pine stands on deeper soils are being rapidly replaced by other species such as western hemlock, Douglas-fir, and subalpine fir.

The second lahar is found along the timberline highway on the north slope of Mount St. Helens. Excepting a timberline ecotone which occupies the upper portions of this lahar, it has distinctive but better developed forest communities than the Kalama River lahar--mature forests of Pacific silver fir,

Table 14.--Vegetational and environmental data for two stands occurring on the Kalama River lahar

| Item | Plant Community | |
|---|---|---|
| | Tsuga heterophylla /Vaccinium ovalifolium (GP-20) | Pinus contorta/ Arctostaphylos (GP-94) |
| Elevation (in feet) | 2050 | 3250 |
| Slope (in percent) and aspect | 3 East | 10 South |
| Maximum depth of rooting (in inches) | 40 | 25 |
| **Trees**, reproduction[a] (number on plots): | | |
| Tsuga heterophylla | 139 | (+)[b] |
| Pseudotsuga menziesii | 15 | |
| Abies amabilis | 96 | |
| Pinus contorta | | 205 |
| Pinus monticola | | 23 |
| Abies lasiocarpa | | 10 |
| **Trees**, mature[a] (number on plot): | | |
| Tsuga heterophylla | 8 | (+) |
| Pseudotsuga menziesii | 5 | |
| Pinus contorta | | 4 |
| Pinus monticola | (+) | (+) |
| **Shrubs** (frequency/coverage): | | |
| Vaccinium ovalifolium | 50/30 | |
| Vaccinium alaskaense | 20/10 | |
| Gaultheria shallon | 16/4 | |
| Vaccinium parvifolium | 6/3 | |
| Menziesia ferruginea | +[b] | |
| Arctostaphylos uva-ursi | | 54/21 |
| Vaccinium membranaceum | | + |
| **Herbs** (frequency/coverage): | | |
| Chimaphila umbellata | 40/5 | |
| Corallorhiza mertensiana | 4/T | |
| Chimaphila menziesii | 2/T | |
| Hypopitys monotropa | + | |
| Gaultheria ovatifolia | + | |
| Xerophyllum tenax | + | |
| Lupinus albicaulis | | + |

Table 14,--Continued

| Item | Tsuga heterophylla /Vaccinium ovalifolium (GP-20) | Pinus contorta/ Arctostaphlos (GP-94) |
|---|---|---|
| Mosses and Lichens (frequency/coverage) | | |
| Rhytidiopsis robusta | 100/45 | + |
| Hylocomium splendens | 18/4 | |
| Calleriogonella schreberii | 24/2 | |
| Rhytidiadelphus loreus | 28/3 | |
| Dicranum fuscescens | 16/1 | + |
| Scapania nemorosa | 6/T | |
| Hypnum circinale | 2/T | |
| Cladonia sp. | 2/T | |
| Cladonia ecmocyna intermedia | | 40/11 |
| Cladonia rangifera | | 44/6 |
| Rhacomitrium canescens ericoides | | 20/3 |
| Polytrichum juniperinum | | 34/2 |
| Rhacomitrium heterostichum | | 40/1 |
| Cladonia bellidiflora | | 40/1 |
| Cladonia grayii | | 12/1 |
| Rhacomitrium sudeticum | | 20/T |
| Cladonia macrophylloides | | 20/T |
| Cladonia coniocraea | | 10/T |
| Polytrichum piliferum | | 10/T |
| Dicranum sp. | | 2/1 |
| Cladonia phyllophora | | 4/T |
| Lecidea quadricolor | | 2/T |
| Brachythecium velutinum | | + |

[a]Mature specimens are those over 8 inches d.b.h.; reproduction is less than 8 inches d.b.h.

[b]A + indicates a species occurred in the macroplot but not on any microplots; (+) indicates it occurred adjacent to but not in the macroplot.

noble fir, Douglas-fir, western hemlock, and western white pine. Pacific silver fir is the sole climax species. Vaccinium ovalifolium, V. alaskaense, and Menziesia ferruginea are typical shrub species. Rubus lasiococcus and R. pedatus are the only constant herbs. Quantitative study showed understories have differentiated depending on local differences in micro-environment. Communities with richer herbaceous understories appear related to the zonal A. amabilis/V. alaskaense Association. Poorer communities, on the other hand, appear related to the A. amabilis/Menziesia ferruginea Association. Still, neither community quite matches these suggested affiliates; perhaps they could be considered phases.

Lava Flows

Recent lava flows cover areas in the southern part of the Mount Adams Province, on West Crater in the Wind River Valley, and on the south side of Mount St. Helens. The largest is the Big Lava Beds which covers more than 21 square miles north of the town of Willard in the Mount Adams Province. This lava bed extends through three elevational zones; its upper edge is within the T. mertensiana Zone and the lower half within the T. heterophylla Zone. The various communities found on this flow depend on elevation and nature of the flow surface. Two forested communities were analyzed: (1) a Pinus contorta/Arctostaphylos community, typifying much of the flow within the A. amabilis Zone; and (2) an Abies lasiocarpa/Xerophyllum community which is restricted to the upper margins of the flow. Data for these communities are provided in Table 15.

The lodgepole pine community is an open forest stand having Arctostaphylos uva-ursi as the only major associated vascular plant. Exposed rock and shallow accumulations of loess provide a favorable habitat for a diversified moss and lichen layer, however. Compositions of this community and the Pinus

Table 15.--Vegetational data for the Pinus contorta/Arctostaphylos uva-ursi and Abies lasiocarpa/Xerophyllum tenax communities growing on the Big Lava Bed

| Species | Plant Community | |
|---|---|---|
| | Pinus contorta/ Arctostaphylos (GP-36) | Abies lasiocarpa/ Xerophyllum (GP-70) |
| **Trees, reproduction[a] (number on plot):** | | |
| Pinus contorta | 74 | 1 |
| Pseudotsuga menziesii | 4 | |
| Abies lasiocarpa | | 57 |
| Pinus monticola | | (+)[b] |
| Tsuga mertensiana | | (+) |
| **Trees, mature[a] (number on plot):** | | |
| Pinus contorta | 5 | (+) |
| Pseudotsuga menziesii | 1 | |
| Abies lasiocarpa | (+) | 11 |
| Pinus monticola | (+) | |
| Tsuga mertensiana | | (+) |
| **Shrubs (frequency/coverage):** | | |
| Arctostaphylos uva-ursi | 52/30 | |
| Pachistima myrsinites | 18/2 | + |
| Vaccinium membranaceum | 4/T | 32/13 |
| Holodiscus discolor | +[b] | |
| Juniperus communis | + | 8/3 |
| Sambucus melanocarpa | + | + |
| Vaccinium scoparium | | + |
| Rhamnus purshiana | | + |
| **Herbs (frequency/coverage):** | | |
| Xerophyllum tenax | 6/2 | 56/34 |
| Lupinus albicaulis | 8/2 | + |
| Penstemon fruticosus | 8/1 | |
| Apocynum androsaemifolium | 8/T | |
| Agrostis scabra | | 4/1 |
| Hieracium albiflorum | 5/T | 6/T |
| Arnica latifolia | + | 2/T |
| Cryptogramma acrostichoides | | 22/1 |
| Rubus lasiococcus | | 2/T |
| Juncus parryii | 6/T | + |
| Trisetum spicatum | | + |
| Gaultheria ovatifolia | | + |
| Erigeron acris debilis | | + |

Table 15.--Continued

| Species | Plant Community | |
|---|---|---|
| | Pinus contorta/ Arctostaphylos (GP-36) | Abies lasiocarpa/ Xerophyllum (GP-70) |
| Mosses and lichens (frequency/coverage): | | |
| Rhacomitrium canescens ericoides | 78/7 | 32/2 |
| Polytrichum juniperinum | 76/6 | 22/1 |
| Polytrichum piliferum | 46/1 | |
| Cladonia macrophylloides | 46/1 | 64/5 |
| Cladonia bellidiflora | 30/1 | 50/3 |
| Cladonia ecmocyna | 18/1 | 38/3 |
| Cladonia grayii | 18/T | 28/1 |
| Rhacomitrium sp. | 12/T | 2/T |
| Cladonia coniocraea | 10/T | 4/T |
| Stereocaulon paschale | 4/T | |
| Pohlia nutans | 4/T | |
| Cladonia sp. | 4/T | 28/3 |
| Rhacomitrium sp. | | 20/2 |
| Rhacomitrium sp. | | 24/1 |
| Lecidea quadricolor | | 46/2 |
| Grimmia sp. | | 16/2 |
| Rhizocarpon sp. | | 40/1 |
| Brachythecium curtum | | 6/T |
| Encalypta rhabdocarpa | | 4/T |
| Lescuraea sp. | | 4/T |
| Cladonia phyllophora | | 4/T |
| Brachythecium velutinum | | 4/T |
| Rhytidiopsis robusta | | 4/T |
| Cladonia sp. | | 2/T |
| Dicranum tauricum | | 2/T |
| Lophozia barbata | | 2/T |
| Cupspea sp. | | 2/T |
| Grimmia sp. | | 2/T |
| Grimmia sp. | | 2/T |
| Diplophyllum sp. | | + |

[a]Mature specimens are those over 8 inches d.b.h.; reproduction is less than 8 inches d.b.h.

[b]A + indicates a species was present in the macroplot but not in the microplots; a (+) indicates it occurred adjacent to but not in the macroplot.

contorta/Arctostaphylos community found on the Kalama River lahar are obviously similar, suggesting that a Pinus contorta/Arctostaphylos Association is characteristic of very dry, infertile habitats in the A. amabilis Zone of both provinces.

The Abies lasiocarpa/Xerophyllum community is confined to highest elevations on the Big Lava Beds and also occupies a different type of flow surface. The lodgepole community is found on relatively smooth surfaces; the subalpine fir community is found on very rough "lava block" areas (Fig. 11). Trees are clumped in this community. Several vascular plants have significant coverage--Xerophyllum tenax, Vaccinium membranaceum, and Juniperus communis. Mosses and lichens are also more varied than in the lodgepole pine community.

The Big Lava Beds are very interesting and deserve detailed study. The two communities discussed here barely indicate the habitat diversity and unusual botanical features. Almost every tree species in the adjacent forest is found at least sporadically on the flows, including Quercus garryana at lowest elevations. Species generally though to require extremely moist conditions are found in depressions and narrow crevices--e.g., Sambucus melanocarpa. Moreover, indigenous species not usually found on adjacent forest lands are there, e.g., Juniperus communis, Agrostis scabra, and Cryptogramma acrostichoides.

In the Mount Rainier Province only the West Crater lava flows were reconnoitered. These are occupied in part by open forest communities in which the dominant vascular plants are Douglas-fir, subalpine fir, Acer circinatum, and Xerophyllum tenax. These communities strongly resemble the Pseudotsugeto-Abietum lasiocarpae and Aceretum circinatum lavosum Associations described in the central Cascade Range of Oregon (Roach, 1952). The abundant subalpine fir in the West Crater flows is particularly interesting since it is generally absent from adjacent habitats and is well below its normal elevational range.

# DISCUSSION

## Environmental Relationships

### Soil Types

Since no soil survey has been carried out within the study area, relations between soil series and associations cannot be evaluated. Nevertheless, distinctive kinds of soils, which would almost certainly be recognized as series, were noted, and most profiles could be placed in a great soil group.

The only relatively consistent correlations between soil morphology and climax vegetation are found at the great soil group level (Table 16). Podzols dominate the Abies-Tsuga Zones, but soils belonging to other great soil groups are encountered, particularly near the wet and dry ends of the moisture scale. Furthermore, grouping the soils found under a large number of associations into the Podzol and Brown Podzolic groups tends to obscure some important differences. Many soils on herb-rich habitat types in the Mount Rainier Province are clearly marginal in podzolic features and, though classed as Brown Podzolics, might be considered podzolic-lateritic intergrades. Often A2 horizons are poorly developed but distinctive A1 horizons are present. In the Mount Adams Province Brown Podzolics are typical of seral communities in the A. amabilis Zone and are sometimes found under climax communities near the lower limits of the zone. Similarly, Podzols are characteristic but poorly developed on the moister habitats typified by the A. amabilis/Achlys and /Tiarella associations.

Interestingly, in both provinces development of A2 and B2ir horizons is most pronounced in the mid-elevation A. amabilis Zone and not in the T. mertensiana Zone.

Other great soil groups are relatively uncommon, being confined to one or two associations (Table 16). Gley Podzols were found only on C. nootkatensis/Rhododendron habitats. The high organic matter content of the continually wet gleyed horizons clearly marked these soils. Gley Podzol-Podzol intergrades marked a part of the A. amabilis/Menziesia habitat type. Mottling was apparent in one or more horizons, but dull gleyed horizons and high organic-matter content in the subsoils was not characteristic. Reddish-Brown Lateritic and Alluvial profiles were the only ones found under the A. amabilis/Oplopanax Association. Unfortunately all the higher elevation stands of this association were on alluvial soils, leaving a question as to the ubiquity of Reddish-Brown Lateritics as the genetically developed great soil group for this habitat. Sols Bruns Acides were found only at low elevations, on 2 out of 5 Gaultheria sites and one Vaccinium alaskaense site. The latter stand was clearly out of the normal altitudinal range (1,850 feet) for the association and this may have some significance. Finally, Lithosols were characteristic of the lithosolic associations.

Soils of other groups occur in the Abies-Tsuga zones on habitats not studied such as swamps and meadows. These doubtless include Ando, Bog, Humic Gley, and Alpine Meadow soils. Some soil scientists might consider some of the soils, classed as Brown Podzolic in this study, as Regosols.

Some distinctive soils were recognizable, occurring with little variability on as many as six plots; presumably a soil survey would recognize these as series. Many have been named and described earlier in this paper. These soils were often associated with a single habitat type although there were several marked exceptions involving widespread types. In no case, however, was an association confined to a single soil. Some associations occurred on distinctively different soils at every site studied, e.g., the A. amabilis/

Table 16.--Relation between great soil groups and plant associations on the sites studied. All great soil groups, except the Gley Podzol are as defined by the Agricultural Experiment Stations (1964)

| Great Soil Group | Province and Association | |
|---|---|---|
| | Mount Rainier Province | Mount Adams Province |
| Podzol, Brown Podzolic | A. amabilis/Vacc. alaskaense, A. amabilis/Oxalis A. amabilis/Berberis, A. amabilis/Gaultheria, A. amabilis/Streptopus | A. amabilis/Achlys, A. amabilis/ Tiarella |
| | A. amabilis-T. heterophylla/Vacc. membranaceum, A. amabilis/Veratrum, A. amabilis/Menziesia, A. amabilis-T. mertensiana/Vacc. membranaceum | |
| Gley Podzol | C. nootkatensis/Rhododendron | |
| | Gley Podzol-Podzol intergrade: A. amabilis/Menziesia | |
| Reddish-Brown Lateritic | A. amabilis/Oplopanax | |
| Sols Bruns Acides | A. amabilis/Gaultheria, A. amabilis/Vacc. alaskaense | |
| Lithosol | A. amabilis/Xerophyllum, T. mertensiana/Xerophyllum | |
| Alluvial | A. amabilis/Oplopanax | |

Oplopanax.

Lack of relation between associations and soils is certainly no cause for despair; it was to be expected. In the first place, most soils within the study area are young. The surface horizons, at least, are developing in recently deposited volcanic ejecta. The difficulties encountered in correlating plant communities with immature soil profiles have been thoroughly discussed by Dyrness (1960). The second reason is related to the first. Extensive layering of parent material produced a wealth of soil individuals within the study area. Their particular morphology reflects geographic position and prevailing winds in relation to sources of volcanic ejecta, as well as to local glacial, alluvial, and colluvial activity. Many of these soils differ in morphology, but not in biologic potential.

Distributions of the associations are correlated with other soil parameters as will be demonstrated. Also, when current productivity studies are completed, soil types may prove extremely useful for subdividing some of the more extensive habitat types. The A. amabilis-T. heterophylla/Vaccinium habitat type exemplifies particularly well those that could use further division for purposes of wildland management.

A final observation of soil-community relationships concerns how Mount St. Helens ejecta has profoundly influenced composition of plant associations in part of the study area. On the ridges immediately north and east of the present mountain, the T, W, and Y layers of Mount St. Helens ejecta (Mullineaux, 1964) consist of thick layers of pumiceous lapilli. On Mount St. Helens itself the T and W layers are about 30 feet thick; the Y layer predates the present mountain. Farther from the mountain, thicknesses decrease rapidly and the material becomes finer textured. Still, layers are typically at least 2 to 6+ feet in depth on the ridges northeast of Spirit Lake and 8 to 12 miles from

the mountain itself (Carithers, 1946). There, many soils are developing exclusively in coarse ejecta.

In such areas several important understory species are absent from communities in which one would have expected them on the basis of studies elsewhere. The best example is Xerophyllum tenax. Xerophyllum is completely absent from communities which have developed on soils composed entirely of gravel-textured ejecta. On ridges around Spirit Lake Xerophyllum grows only on rocky slopes from which much or all of the pumice mantle has been eroded. Stands obviously related to the A. amabilis-T. mertensiana/Vaccinium membranaceum Association occur in which Vaccinium is the only understory dominant and from which Xerophyllum is completely absent. Other species similarly affected include both herbs and shrubs. Tiarella unifoliata and Trillium ovatum, typically present in small numbers in the A. amabilis/V. alaskaense Association, are absent from stands representative of this association and are found instead only on the wettest habitats. Similarly, Berberis nervosa and Gaultheria shallon are absent from this association where deep, coarse ejecta is present.

Modification of community composition by the coarse pumice layers was not quantified in this study nor were the depth and texture of the layers limiting for individual species determined. Most of the 30- to 40-square-mile area affected north and east of Spirit Lake is accessible only by trail and a thorough study was not feasible in the time available. Enough observations were made during the reconnaissance to identify this phenomenon, however.

Other

Environmental factors will need detailed study before definitive relationships are established. The distribution of associations in relation to two important environmental gradients--soil moisture and elevation--is already apparent, however. These relationships are shown schematically in Figure 12.

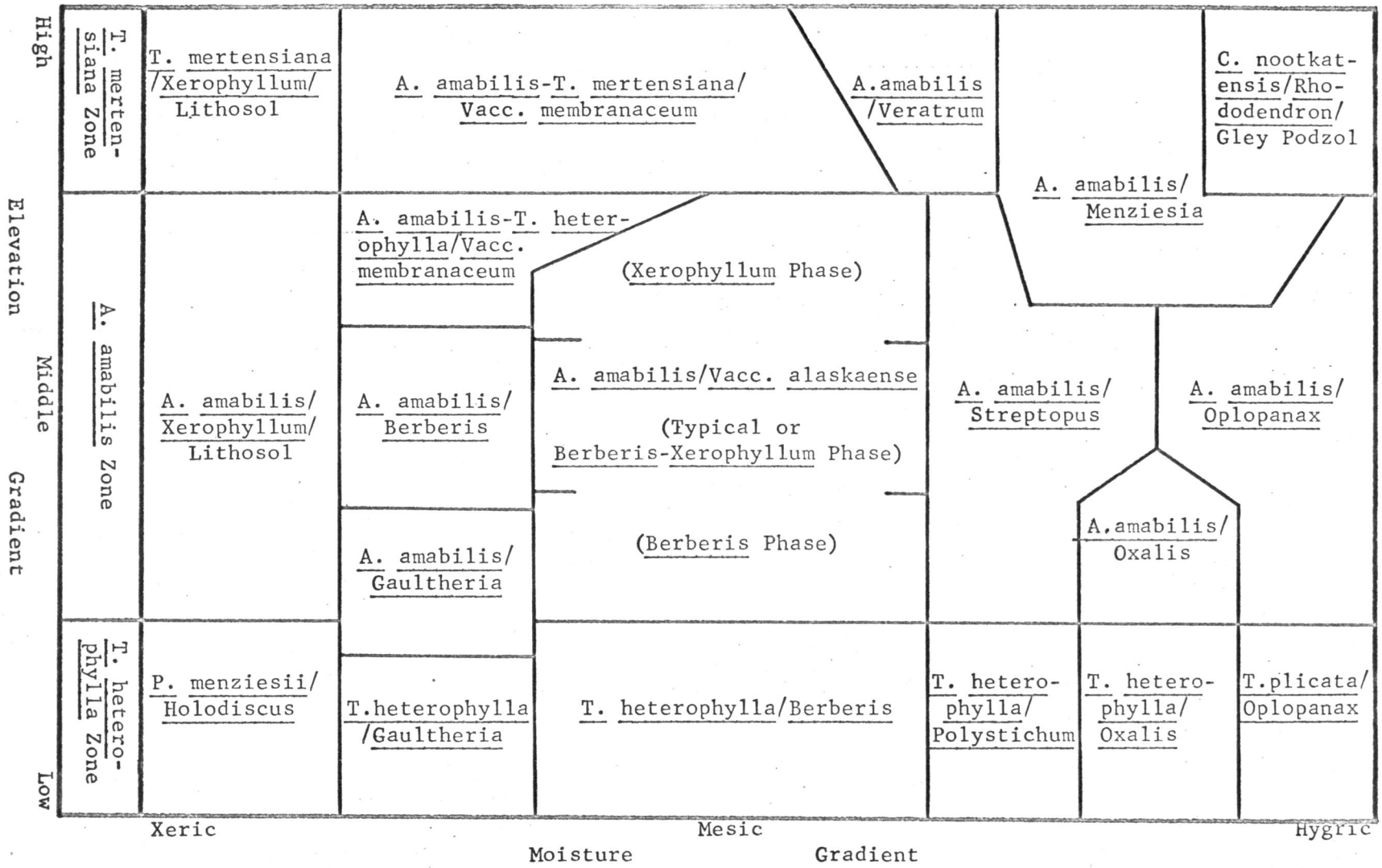



Fig. 12.--Distribution of plant associations in the Mount Rainier Province in relation to moisture and elevational gradients. Associations in the T. heterophylla Zone are hypothecated from notes taken during the reconnaisance.

In the A. amabilis Zone depauperate communities with very few herbs occupy the dry end of the soil-moisture scale, grading through a mesic zonal community of shrubs and herbs to herb-rich associations with increasing numbers of species at the moist end of the scale. At upper-elevations this sequence is modified by the appearance of shrub-dominated communities on wettest sites and an overall decrease in number of herbs at all points along the moisture scale. A similar pattern can be seen in the Mount Adams Province where dry site associations of lodgepole pine and subalpine fir are progressively replaced by the Vaccinium membranaceum, Achlys, Tiarella, and Oplopanax understory types as soil moisture increases.

The pattern is much the same everywhere at lower elevations. Figure 21 illustrates the relation of the Abies-Tsuga associations to communities (shown as hypothetical associations) observed during reconnaissance in the T. heterophylla Zone below. The same spectrum in relative dominance of shrubs and herbs is apparent there. Orloci's (1965) associations in the Coastal Western Hemlock Zone of British Columbia are comparable in physiognomy at different points along the moisture and elevational gradients.

Soil moisture seems to be one of the most important factors in determining distribution of plant associations in coastal North America. For example, Eis (1962) concluded that soil moisture regime was by far the most important of 16 topographic and edaphic factors studied. Morphology of the soil profile (soil type) may not correlate well with distribution of the associations; but measures of moisture regime will, if Figure 21 has any validity.

## Relation to Other Vegetative Studies and Synecological Methodology

Let us now look more broadly at: (1) how results of this study fit into existing knowledge of forests in the Cascades and adjacent regions; and (2) what light it sheds on the usefulness of different methods of vegetation analysis.

Vegetational Studies

The vegetation zones described in this study have been recognized to varying degrees by other authors (Table 17). The Abies amabilis Zone is roughly comparable to Merriam's Canadian Zone as it has been described in Washington. Brockman (1947) states, for example, that Pacific silver fir, Alaska-cedar, noble fir, and western white pine are the typical Canadian Zone species in Mount Rainier National Park, although Douglas-fir and western hemlock are common in the lower part of the zone. The difficulty in recognizing the Canadian Zone (commented on by several authors, e.g., Piper, 1906), is doubtless due to its basis on cover types. In contrast, Daubenmire's (1966) data and this study have shown that attention to climax tree species sharply delineates life zones obscured by attention to seral species.

Higinbotham and Higinbotham (1954), who considered vegetational dynamics, recognized the A. amabilis Zone (as the A. amabilis-T. heterophylla Zone) in their work at Mount Rainier. Likewise, the "Pacific silver fir-western hemlock wetter subzone" of the Coastal Western Hemlock Zone in British Columbia (Krajina, 1965) is homologous with the A. amabilis Zone described in this paper.

Similarly, the Tsuga mertensiana Zone is closely correlated with the Coastal Mountain Hemlock Zone in British Columbia (Peterson, 1965), even to its divisibility into a lower segment of continuous forest and an upper "parkland" segment. However, the Hudsonian Zone of Merriam's classification clearly takes in only a portion of the T. mertensiana Zone (Table 17) and overlaps the alpine zone, based as it is upon a physiognomic distinction rather than the climax tree species: "[The Hudsonian Zone is] Characterized by subalpine meadows in which are found groups of alpine fir and mountain hemlock . . . with an altitudinal range of from approximately 5,000 to 6,500 feet. . ." (Brockman, 1947). Higinbotham and Higinbotham (1954) recognized the T. mertensiana Zone as the

Table 17.--The vegetation zones described in this study in relation to the bioclimatic and life zones recognized by other authors

| Vegetation Zones | Bioclimatic Zones in Coastal British Columbia (Krajina, 1965) | Climax Plant Associations in Western Washington (Scott, 1962) | Merriam's Life Zones in Cascade Range (Piper, 1906) |
|---|---|---|---|
| TSUGA HETEROPHYLLA | Douglas-fir--Western hemlock (Drier Subzone) | WESTERN HEMLOCK-WESTERN REDCEDAR | HUMID TRANSITION |
| | COASTAL WESTERN HEMLOCK | | |
| ABIES AMABILIS | Pacific silver fir--Western hemlock (Wetter Subzone) | PACIFIC SILVER FIR-WESTERN HEMLOCK | CANADIAN |
| TSUGA MERTENSIANA | Subalpine Forest (Lower Subzone) | | |
| | COASTAL MOUNTAIN HEMLOCK | | |
| | Subalpine Parkland (Upper Subzone) | SUBALPINE FIR-MOUNTAIN HEMLOCK | HUDSONIAN |
| ALPINE | ALPINE | SAXIFRAGE-HEATHER | ARCTIC-ALPINE |

A. amabilis-T. mertensiana Zone in their work.

The zonal pattern in the Mount Rainier Province is exactly the same as that noted for the western slopes of the northern Cascade Range or Mount Baker Province (Franklin and Trappe, 1964).

Results of this study point out some similarities and major points of difference between zonation and associations in the southern Washington Cascade Range and those in the northern Rocky Mountains described by Daubenmire (1952). Many species are common to both areas and analogies may be pointed out, especially between the Mount Adams Province and northern Idaho--e.g., the Menziesia and Xerophyllum understory unions in the subalpine forests. However, occurrence of Pacific silver fir and ubiquity of mountain hemlock at high elevations in the Cascades produce a distinctly different zonal pattern. The T. mertensiana Zone replaces the Picea engelmannii-Abies lasiocarpa Zone in the highest forested areas. An A. amabilis Zone is interjected between the T. heterophylla Zone and the subalpine forest. Farther north, on the eastern slopes of the Cascade Range beyond the present range of Pacific silver fir, and often mountain hemlock, (Wenatchee Province of Franklin, 1965b), the zonal pattern is identical with that of northern Idaho (Franklin and Trappe, 1964). The importance of a single exceedingly tolerant species such as Pacific silver fir, in modifying the phytogeographic patterns of an area, is obvious.

Only two comprehensive vegetational studies (Becking, 1956 and Spilsbury and Smith, 1947) have been conducted in western Washington, both aimed at developing "Site type" classifications for Douglas-fir forests. Spilsbury and Smith examined only low-elevation second-growth Douglas-fir stands, so their work cannot be related to this study. Becking, on the other hand, used the Braun-Blanquet approach to classify all Douglas-fir forests on the western slope of the Cascade Range. Becking recognized four "associations" at higher

elevations: (1) Montane Salal-Douglas-fir Association; (2) Montane Sword fern-Douglas-fir Association; (3) Subalpine Salal-Douglas-fir Association; and (4) Subalpine Sword fern-Douglas-fir Association. He specified indicator species which, by their presence or absence, indicate one of the four Montane or Subalpine Associations. Becking's associations and those I describe can be compared only generally, since he has only four associations were I have 15. His Montane associations overlap the T. heterophylla and A. amabilis Zones. The Subalpine associations overlap the A. amabilis and T. mertensiana Zones. Each of Becking's indicator species occurs in two to as many as 12 of the associations I define. Reasons for these differences will be discussed later in this paper.

Krajina and his students (Krajina, 1965) have produced a classification of life or bioclimatic zones for coastal forests of British Columbia similar to my listing of zones, as has been pointed out. The similarity is not surprising since they consider vegetational dynamics as well as floristics. Individual associations are generally not comparable, probably because of differences in environment and flora between areas separated by a 150 to 200 mile gap. The same spectrum of associations is there, however--e.g., mesic herb-rich associations, Vaccinium-dominated climatic climax, and the shrub-dominated topographic or topoedaphic climaxes of the T. mertensiana Zone.

The only other relevant community studies have been the limited investigations of Higinbotham and Higinbotham (1954) and Carpenter (1961) in the Mount Rainier area. Only five sites above the T. heterophylla Zone were studied by Higinbotham and Higinbotham. These areas readily identify with associations described in this paper. Their moss data corroborate the results of my study. Carpenter's (1961) study was too limited and his "types" are too poorly described to permit correlation with associations I have distinguished.

The successional sequence in western Washington forests from Douglas-fir to western hemlock and, finally, Pacific silver fir has been studied by three authors (Hanzlik, 1932; King, 1961; and Munger, 1940) and recognized by others (Scott, 1962 and U. S. Forest Service, 1965). Hanzlik's (1932) description of succession on the western and southern slopes of the Olympic Mountains fits perfectly the situation in the A. amabilis Zone of southern Washington. Munger (1940) likewsie acknowledges this sequence in cooler, moister parts of the Douglas-fir region. King (1961) reported a 12-year study of growth and mortality in the Wind River Valley, a part of my study area. His primary interest was mensurational, but his data clearly show the successional trend from Douglas-fir to hemlock and, finally to Pacific silver fir.

The tentative separation of southern Washington Abies-Tsuga forests into Mount Adams and Mount Rainier Provinces (Franklin, 1965b) seems well justified by the results of this study. Although the A. amabilis Zone occurs in both provinces, (1) the climatic climaxes are different, (2) few associations bridge both provinces, (3) several important species, the most notable being Vaccinium alaskaense, are found in only one of the provinces, and (4) seral tree species vary more in the Mount Adams Province and reflect a continental influence.

It is apparent that past describers of Pacific coastal vegetation, zonation, and forest succession (e.g., Cooper, 1956; Hansen, 1947; Munger, 1940; Küchler, 1965) have failed to appreciate the importance of Pacific silver fir in zones and associations. This is at least partly due to the preoccupation of botanists and foresters with low-elevation conifer forests of the T. heterophylla Zone. The potential of Pacific silver fir for replacing other forest species and its use in identifying major phytogeographic units has not been recognized. Schmidt's belief that Pacific silver fir has not as yet inhabited

its full range because of poor migratory capabilities (Schmidt, 1957) is particularly relevant when the potential climax vegetation of the region is considered.

Synecological Methodology

This study was not designed to compare various "schools" of phytosociology. The value and validity of vegetation classification, using the polyclimax and ecosystem approaches, has already been demonstrated by Daubenmire (1952, 1966), Dyrness (1961), Krajina (1965), and others. However, this study does provide additional evidence of their value.

First, consider the individualistic concept of the plant community, the continuum viewpoint as developed by Curtis (1959) and his students. The continuity of vegetation is stressed by these workers, who feel that attempts at vegetative classification can be only subjective and arbitrary. In this study nearly three-fourths of the stands analyzed were sample prior to development of any classification scheme. The only criteria for selection were old age, a uniform area for plot location, and freedom from disturbance. Were community classification arbitrary, one might expect that stands would exhibit continuous variation in characteristics when analysis was attempted. In fact, however, attention to population structure, relative frequency and coverage of understory species, and occurrence of groups of species together (Daubenmire, 1966) readily revealed discontinuities. Communities distinctive in vegetative composition and, often, in obvious environmental characteristics, emerged. Only four of 120 plots turned out to be in ecotones. Occurrence of nearly identical communities a hundred miles or more from the study area further confirms the distinctive character of many of the associations.

Daubenmire (1966) has pointed out that he could have ordinated his data and produced a continuum by considering only species distribution and relative

abundance. I could also have done so, producing suites of overlapping bell-shaped curves when species distribution is plotted against environmental gradients. This brings me to my criticism of the strictly floristic approach of the Zürich-Montpellier ecologists as exemplified by Becking's (1956) work.

As pointed out earlier, Becking's montane and subalpine "associations" do not correspond to those described in this study; his key indicator species, supposedly of high fidelity, occur in as many as 12 of my associations. Becking's work indicates the difficulties of applying the classical Braun-Blanquet approach. First, he completely ignored successional relationships between tree species, a keystone of the classification presented in this paper. Second, Becking worked with seral stands in almost all cases. The understory in many may well have not stabilized to climax elements. Without data on stable associations, seral elements could not possibly be identified. Finally, Becking relied on indicator species, the presence of which purportedly indicate specific associations. Brief examination of my association tabulations makes obvious the fact that they could not be differentiated by presence or absence of one or even a few species. A species with high fidelity to only one association was invariably inconspicuous and/or of low constancy. A species with sufficiently high constancy and conspicuous enough to be diagnostic always occurred in other associations.

## Usefulness of the Classification in Land Management

The classification presented here is, of course, valuable for stratifying the Abies-Tsuga forests for research and resource management, since each association delineates portions of the landscape having similar biologic potential. The classification will undoubtedly find use mostly in research until detailed study has identified the management problems encountered on each habitat, e.g., insect, disease, and regeneration problems, relative

productivity of tree species, etc.

Observations made during the course of this study suggest how the results can be applied. For example, the stand tables for each association clearly show that the amount of advance regeneration present in old-growth stands varies widely depending on the association. In stands of Abies amabilis/Menziesia Association, care in logging and slash disposal could preserve enough of the 31,000 seedlings and saplings per acre to ensure adequate stocking. On other habitats, such as Abies amabilis/Streptopus, the relatively scanty advance regeneration is inadquate for restocking logged stands.

Vegetative development after logging also offers varied problems in regeneration. On some of the more productive sites, such as Abies amabilis/Oplopanax and A. amabilis/Streptopus habitat types, a dense shrub community develops soon after logging which is dominated by species such as Salix spp., Sambucus melanocarpa, and Rubus spectabilis. Competition from this dense shrub layer retards establishment of conifers, sometimes delaying full restocking of the site for many years. Similarly, on habitat types such as the A. amabilis/Xerophyllum/Lithosol, a dense ground cover of Xerophyllum may develop after logging, rendering restocking of the site difficult.

At present, lack of site index curves and other mensurational measurements for Abies-Tsuga forests prevents a quantitative rating of productivity by habitat types. However, the habitats can be generally categorized by the relative heights of dominant old-growth trees growing on them. Table 18 shows the relative productivity of habitat types in the A. amabilis Zone of the Mount Rainier Province.

Some protection problems are already known to vary by habitat type. Entomologists have pointed out the greater damage to Pacific silver fir on herb-rich habitats by balsam woolly aphid (Johnson, Mitchell, and Wright, 1963).

Table 18.--Relative productivity of habitat types in the A. amabilis Zone of the Mount Rainier Province

| Productivity[a] | Habitat Type |
|---|---|
| High to very high | A. amabilis/Oxalis, A. amabilis/Oplopanax, A. amabilis/Streptopus |
| Medium to high | A. amabilis/Vaccinium alaskaense |
| Low to medium | A. amabilis/Gaultheria, A. amabilis/Berberis, A. amabilis-T. heterophylla/Vaccinium membranaceum, A. amabilis/Menziesia |
| Very low to low | A. amabilis/Xerophyllum/Lithosol |

[a]Approximate values for these ratings are: very high = Douglas-fir Site I, high = Site II, medium = Site III, low = Site IV, and very low = Site V.

Observations of heart rot indicators during the course of this study have shown western hemlock is most severely affected on the A. amabilis-T. heterophylla/Vaccinium membranaceum, A. amabilis/V. ovalifolium, A. amabilis/Menziesia, and A. amabilis/Xerophyllum/Lithosol habitat types. Systematic study of root diseases and dwarfmistletoes may reveal additional correlations.

## SOME CONCLUDING NOTES

The study provides a classification of the Abies amabilis-Tsuga associations found in the southern Washington Cascade Range. It serves as a basic stratification for future ecological and silvicultural studies. It calls attention to an important phytogeographic unit that has been somewhat overlooked by plant geographers and ecologists.

Much work remains, however, before a complete phytosociological picture of the region emerges and the full value of the classification in land management can be realized. Already underway are studies of communities in adjacent regions and a thorough investigation of relatively accessible areas north and east of Mount St. Helens. These should lead to refinement of the characteristics for several associations. Another study aims to define the environmental limits of associations quantitatively. Successional studies following logging and burning will establish the seral communities encountered on each habitat type.

Additional comparisons are already underway of (1) regeneration following logging, (2) effects of different silvicultural techniques, (3) productivity of different species, and (4) protection problems, on different habitat types. These studies will result in the full fruition of the first, large step in understanding and managing the Abies-Tsuga forests reported in this paper.

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# APPENDIX A

# KEY TO THE MAJOR PLANT ASSOCIATIONS IN THE SOUTHERN WASHINGTON CASCADE RANGE

## KEY TO THE MAJOR PLANT ASSOCIATIONS IN THE SOUTHERN WASHINGTON CASCADE RANGE[1]

1 Pacific silver fir associated mainly with western hemlock or western redcedar 2

1 Pacific silver fir associated mainly with mountain hemlock or Alaska-cedar 18

2 Location in the Mount Rainier Province (Franklin, 1965b); Western Cascades 3

2 Location in the Mount Adams Province (Franklin, 1965b); High Cascades 14

### Abies amabilis Zone, Mount Rainier Province

3 Understory lacking a rich herbaceous layer, characterized instead by ericaceous shrubs and herbs and/or Xerophyllum tenax; Oplopanax horridum never present 4

3 Understory with a rich herbaceous layer, characterized by an abundance of species such as Oxalis oregana, Athyrium filix-femina, Tiarella unifoliata, Dryopteris linnaeana, Vancouveria hexandra, and Streptopus curvipes; a shrub layer dominated by Vaccinium alaskaense, V. ovalifolium, or Menziesia ferruginea may be present in addition; O. horridum may be present and conspicuous. 11

4 Understory dominated by Gaultheria shallon (30% coverage or more); at elevation of 3,000 feet or less, generally on river terrace or gently sloping area; X. tenax present but inconspicuous; Eurhychium oreganum, Rhytidiopsis robusta, Homalothecium megaptilum, and Hylocomium splendens form conspicuous ground moss cover

A. amabilis/Gaultheria Asso.

4 Understory not dominated by G. shallon 5

5 Stand occurring on shallow rocky soil (Lithosol) on steep ridgeslope (over 50%) or rocky ridgetop in which understory is dominated by X. tenax; associated species are typically G. shallon, Acer circinatum, Berberis nervosa, and Vaccinium parvifolium at low elevations and V. membranaceum at high elevations

A. amabilis/X. tenax/Lithosol Asso.

[1] Suitable for use in undisturbed stands of old growth.

5 Stand not as above; understory is not dominated by X. tenax or, if it is, soil is not a lithosol 6

6 High elevation stands (3,700 to 4,500 feet) in which the understory is dominated by V. membranaceum and X. tenax; V. alaskaense or ovalifolium may be present but, if so, much less important than the other 2 species; Menziesia ferruginea and Cornus canadensis always absent as well as many other species characteristic of low elevation associations

A. amabilis-T. heterophylla/V. membranaceum Asso.

6 Stands in which the understory is not dominated by V. membranaceum and X. tenax; V. alaskaense, V. ovalifolium, and/or M. ferruginea of equal or greater importance 7

7 High elevation stands (above 3,500 feet) with a dense shrubby understory of V. ovalifolium, M. ferruginea, V. membranaceum, and S. scopulina; mountain hemlock usually associated with the Pacific silver fir and western hemlock; V. alaskaense absent or subordinate to other shrub species, C. canadensis always and X. tenax usually absent (in the Mount Rainier Province); Rubus lasiococcus, R. pedatus, Clintonia uniflora, Erythronium montanum usually only conspicuous herbs

A. amabilis/Menziesia Asso.

7 Not as above, V. alaskaense present and usually a dominant, M. ferruginea usually absent or, if present, with low coverage; mountain hemlock absent; Cornus canadensis and/or X. tenax present 8

8 Understory dominated by B. nervosa, G. shallon, V. alaskaense, and X. tenax; stand occurs on steep (35 to 55 %) west or south facing slope; Pachistima myrsinites usually present; G. shallon with less than 15%coverage; X.tenax with 10 to 20% coverage (except in vicinity of Mount St. Helens); only conspicuous herbs are Chimaphila umbellata, C. menziesii, Linnaea borealis, and Gaultheria ovatifolia; C. canadensis usually absent, rare if present, T. unifoliata, Achlys triphylla, C. uniflora, Trillium ovatum, and Polystichum munitum always absent

A. amabilis/Berberis Asso.

8 Understory not as above on all points;e.g., G. shallon absent or inconspicuous, P. myrsinites absent, C.canadensis present with high frequency, T. unifoliata, A. triphylla, C. uniflora, T. ovatum, and/or P. munitum present 9

9 V. alaskaense and V. ovalifolium dominate the understory (coverage 27 to 64%), C. canadensis conspicuous with high frequency; X. tenax and B. nervosa absent, G. shallon usually absent, always inconspicuous; T. unifoliata, A. triphylla, and R. pedatus usually present; stands usually on gentle slope or on lower 1/3 of steep slope

A. amabilis/V. alaskaense Asso., typical phase

9 V. alaskaense a dominant member of understory and C. canadensis usually present but significant numbers of B. nervosa and/or X. tenax present in understory 10

10 V. alaskaense, B. nervosa, A. circinatum, and V. parvifolium important shrub dominants; X. tenax absent or, if present, inconspicuous (max. coverage 1%); T. unifoliata, A. triphylla, C. canadensis, and P. munitum usually present
A. amabilis/V. alaskaense Asso., Berberis phase

10 V. alaskaense, B. nervosa, V. membranaceum, and A. circinatum important shrub dominants, X. tenax and C. canadensis dominate herbaceous layer; T.unifoliata usually and P. munitum always absent
A. amabilis/V. alaskaense Asso., Berberis-Xerophyllum phase

10 V. alaskaense and V. membranaceum important shrub species, X. tenax, C. canadensis, and C. uniflora dominate the herbaceous layer; B. nervosa absent or present only in trace amounts; T. unifoliata, Viola sempervirens and P. munitum absent.
A. amabilis/V. alaskaense Asso., Xerophyllum phase

11 Oplopanax horridum and Athyrium filix-femina dominate members of the understory associated with a rich assemblage of herbs of which Dryopteris linnaeana, T. unifoliata, and A. triphylla are the most important; stands on moist benches, well-watered lower slopes, or margins of streams or wet meadows; western redcedar present and often represented in the reproduction
A. amabilis/Oplopanax Asso.

11 O. horridum and A. filix-femina absent or, if present, rare and inconspicuous 12

12 Oxalis oregana and Struthiopteris spicant conspicuous understory dominants associated with high coverage of many other herbaceous elements; Coptis laciniata present and important; occurs on well-watered lower slopes; if O. oregana is absent high frequency of S. spicant will indicate this association and vica versa
A. amabilis/Oxalis Asso.

12 O. oregana, S. spicant, and C. laciniata absent or inconspicuous; rich herbaceous layer dominated by other species 13

13 Shrub layer poorly developed (avg. coverage 16%), Erythronium montanum and R. pedatus absent or inconspicuous; T. unifoliata, A. triphylla, S. curvipes, C. uniflora, and T. ovatum always present and conspicuous; D. linnaeana and Vancouveria hexandra may be co-dominants locally; stands on middle and lower slopes, benches, and flats which are well watered
A. amabilis/Streptopus Asso., typical phase

13 Shrub layer well developed (avg. coverage 67%), V. ovalifolium, V. membranaceum, V. alaskaense, and M. ferruginea always present, the first three species each averaging 20% coverage; Erythronium montanum and R. pedatus always present and conspicuous, Luzula comosa and Pedicularis racemosa usually present;T. unifoliata, S. curvipes, C. uniflora, and R. lasiococcus are important constant herbaceous associates; stands on upper ridgeslopes, broad ridgetops, or benches with shallow soil

A. amabilis/Streptopus Asso., Erythronium phase

Abies amabilis Zone, Mount Adams Province

14 Understory dominated by X. tenax (10 to 50% coverage) and V. membranaceum (8 to 51% coverage); M. ferruginea always and V. ovalifolium usually absent, the latter always inconspicuous (max. coverage 3%); A. triphylla usually present but with coverage of 1% or less except in young stands at low elevations; T. unifoliata, A. filix-femina, and O. horridum always absent

A. amabilis-T. heterophylla/V. membranaceum Asso.

14 Understory not as above on all points, particularly X. tenax absent or inconspicuous, or a high coverage of V. ovalifolium and/or M. ferruginea 15

15 Understory dominated by rich assemblage of herbs, particularly T. unifoliata or A. filix-femina and O. horridum; other species often present are Rubus spectabilis, Viola glabella, Trautvettaria carolinensis, Valeriana sitchensis, Veratrum viride, Senecio triangularis, S. curvipes, Disporum oreganum, Mitella brewerii, Anemone deltoidea, and A. triphylla; M. ferruginea and X. tenax usually absent and always inconspicuous 16

15 Understory with shrub layer dominated by V. membranaceum and A. circinatum and herb layer dominated by A. triphylla; T. unifoliata absent or inconspicuous, A. filix-femina and O. horridum always absent; variety of herbs suchas Bromus suksdorfii, Penstemon nemorosus, A. deltoidea, and Pteridium aquilinum are always or nearly always present; herbs such as T. carolinensis, V. sitchensis, V. viride, S. triangularis, S. curvipes, D. oreganum, and M. brewerii always or almost always absent; V. ovalifolium and M. ferruginea usually absent, always inconspicuous; X. tenax usually absent, always inconspicuous

A. amabilis/Achlys Asso.

15 Understory without a well-developed herbaceous layer; shrubby layer dominated by V. ovalifolium, V. membranaceum, and M. ferruginea most important 17

16 Understory dominated by T. unifoliata, A. triphylla, C. uniflora, S. curvipes, V. hexandra and other herbs; V. ovalifolium and V. membranaceum most important members of reduced shrub layer (avg. shrub

coverage 13%); A. circinatum usually absent, if present only in trace amounts; A. filix-femina usually present but only in trace amounts, O. horridum usually absent

A. amabilis/Tiarella Asso.

16 Understory dominated by A. filix-femina, O. horridum, and dense assemblage of other herbs (especially T. carolinensis); western redcedar and Engelmann spruce usually associated with Pacific silver fir

A. amabilis/Oplopanax Asso.

17 Mountain hemlock usually not associated with Pacific silver fir and western hemlock; V. membranaceum, V. ovalifolium, and M. ferruginea dominant in the shrub layer, X. tenax always present and dominant in the herbaceous layer; C. canadensis always present and important, L. borealis and Gaultheria ovatifolia usually present; association restricted geographically to western margin of the Mount Adams Province

A. amabilis/V. ovalifolium Asso.

17 Mountain hemlock usually associated with Pacific silver fir and western hemlock; V. membranaceum, M. ferruginea, and V. ovalifolium shrub dominants; X. tenax usually absent (constancy 30%) and with low coverage (avg. 2%); C. canadensis, L. borealis, and G. ovatifolia usually absent; association widespread

A. amabilis/Menziesia Asso.

## Tsuga mertensiana Zone

18 Alaska-cedar present and its reproduction is associated with Pacific silver fir reproduction; understory composed of a dense tangle of shrubs always including Rhdodendron albiflorum (avg. coverage 38%), V. membranaceum, and V. ovalifolium; M. ferruginea usually present and important, Sorbus spp. usually present; mottled and gleyed soil horizons present

C. nootkatensis/Rhododendron/Gley Podzol Asso.

18 Alaska-cedar absent, or if present, not reproducing 19

19 Understory depauperate, V. membranaceum and X. tenax only important species; herbaceous components rare except scattered through small high-elevation stands interspersed with meadow vegetation or in very young stands

A. amabilis-T. mertensiana/V. membranaceum Asso.

19 Understory not dominated exclusively, if at all, by V. membranaceum and X. tenax 20

20 Understory dominated by dense tangle of shrubs usually including M. ferruginea, V. ovalifolium, and V. membranaceum

A. amabilis/Menziesia Asso.

20 Understory includes a rich component of herbs such as Luzula spp., Arnica latifolia, Mitella spp., Carex spp., Bromus vulgaris, Osmorhiza spp., Veratrum viride, and Luina stricta; X. tenax and V. membranaceum usually present but may be absent.

A. amabilis/Veratrum Asso.

# APPENDIX B

# LOCATION OF ANALYTIC STUDY PLOTS

## LOCATION OF ANALYTIC STUDY PLOTS

### Gifford Pinchot National Forest

| | |
|---|---|
| GP-1 | Northeast quarter of Section 20, Township 4 North, Columbia Base Line, Range 7 East, Willamette Meridian |
| " 2 | SW 1/4, SE 1/4, Sec. 13, T. 4 N., R. 6 E. |
| " 3 | SW 1/4, NE 1/4, Sec. 21, T. 5 N., R. 8 E. |
| " 4 | NW 1/4, SE 1/4, Sec. 35, T. 5 N., R. 6 E. |
| " 5 | NW 1/4, SE 1/4, Sec. 16, T. 5 N., R. 6 E. |
| " 6 | SE 1/4, NW 1/4, Sec. 35, T. 5 N., R. 6 E. |
| " 7 | SE 1/4, SW 1/4, Sec. 6, T. 4 N., R. 7 E. |
| " 8 | SW 1/4, SE 1/4, Sec. 16, T. 4 N., R. 7 E. |
| " 9 | SE 1/4, NE 1/4, Sec. 35, T. 6 N., R. 6 E. |
| " 10 | NW 1/4, SE 1/4, Sec. 35, T. 6 N., R. 6 E. |
| " 11 | SE 1/4, SE 1/4, Sec. 3, T. 5 N., R. 6 E. |
| " 12 | Center, Sec. 28, T. 5 N., R. 6 E. |
| " 13 | SW 1/4, NE 1/4, Sec. 28, T. 5 N., R. 6 E. |
| " 14 | SW 1/4, SW 1/4, Sec. 10, T. 5 N., R. 6 E. |
| " 15 | NW 1/4, SE 1/4, Sec. 17, T. 5 N., R. 6 E. |
| " 16 | NE 1/4, NE 1/4, Sec. 19, T. 5 N., R. 6 E. |
| " 17 | SE 1/4, SW 1/4, Sec. 27, T. 5 N., R. 6 E. |
| " 18 | SE 1/4, SE 1/4, Sec. 29, T. 8 N., R. 4 E. |
| " 19 | NW 1/4, Sec. 27, T. 8 N., R. 4 E. |
| " 20 | NW 1/4, NW 1/4, Sec. 33, T. 8 N., R. 4 E. |
| " 21 | NE 1/4, Sec. 20, T. 8 N., R. 4 E. |
| " 22 | SW 1/4, SW 1/4, Sec. 29, T. 8 N., R. 4 E. |
| " 23 | SE corner, Sec. 25, T. 8 N., R. 4 E. |
| " 24 | NE 1/4, Sec. 26, T. 8 N., R. 4 E. |
| " 25 | NE 1/4, Sec. 26, T. 8 N., R. 4 E. |
| " 26 | SE 1/4, SE 1/4, Sec. 14, T. 7 N., R. 6 E. |
| " 27 | Crossing Rd. 123 and Dry Cr., Sec. 22, T. 6 N., R. 9 E. |
| " 28 | SW 1/4, NE 1/4, Sec. 34, T. 6 N., R. 9 E. |
| " 29 | SW 1/4, Sec. 9, T. 6 N., R. 9 E. |
| " 30 | NE 1/4, NW 1/4, Sec. 6, T. 5 N., R. 9 E. |
| " 31 | Center, Sec. 36, T. 6 N., R. 8 E. |
| " 32 | Crossing Rd. 123 and S. edge Sec. 35, T. 8 N., R. 8 E. |
| " 33 | SE 1/4, NW 1/4, Sec. 28, T. 8 N., R. 8 E. |
| " 34 | SW 1/4, SE 1/4, Sec. 34, T. 8 N., R. 8 E. |
| " 35 | SW 1/4, SW 1/4, Sec. 25, T. 8 N., R. 9 E. |
| " 36 | SW 1/4, NE 1/4, Sec. 30, T. 5 N., R. 9 E. |
| " 37 | SE 1/4, NW 1/4, Sec. 17, T. 5 N., R. 9 E. |
| " 38 | SE 1/4, NW 1/4, Sec. 9, T. 4 N., R. 6 E. |
| " 39 | NE 1/4, Sec. 10, T. 4 N., R. 6 E. |
| " 40 | NE 1/4, NE 1/4, Sec. 11, T. 4 N., R. 6 E. |
| " 41 | SW 1/4, SE 1/4, Sec. 3, T. 7 N., R. 9 E. |
| " 42 | Center, Sec. 42, T. 7 N., R. 9 E. |
| " 43 | SE 1/4, NE 1/4, Sec. 25, T. 7 N., R. 7 E. |
| " 44 | SE 1/4, NW 1/4, Sec. 28, T. 7 N., R. 8 E. |

| | |
|---|---|
| GP-45 | NW 1/4, NE 1/4, Sec. 32, T. 8 N., R. 4 E. |
| " 46 | SW 1/4, Sec. 34, T. 8 N., R. 5 E. |
| " 47 | NE 1/4, NE 1/4, Sec. 16, T. 8 N., R. 6 E. |
| " 48 | Along Rd. 125, Center Sec. 24, T. 8 N., R. 6 E. |
| " 49 | Center, Sec. 36, T. 8 N., R. 6 E. |
| " 50 | Along Rd. 125, S. edge Sec. 24, T. 8 N., R. 6 E. |
| " 51 | NE 1/4, Sec. 28, T. 5 N., R. 5 E. |
| " 52 | NE 1/4, Sec. 28, T. 5 N., R. 5 E. |
| " 53 | NE 1/4, Sec. 33, T. 5 N., R. 5 E. |
| " 54 | SE 1/4, NE 1/4, Sec. 10, T. 5 N., R. 9 E. |
| " 55 | NE 1/4, SE 1/4, Sec. 10, T. 5 N., R. 9 E. |
| " 56 | NE 1/4, Sec. 17, T. 9 N., R. 5 E. |
| " 57 | SE 1/4, NE 1/4, Sec. 1, T. 9 N., R. 5 E. |
| " 58 | SE 1/4, NE 1/4, Sec. 6, T. 9 N., R. 5 E. |
| " 59 | SE 1/4, NE 1/4, Sec. 6, T. 9 N., R. 5 E. |
| " 60 | SW 1/4, SW 1/4, Sec. 5, T. 9 N., R. 5 E. |
| " 61 | SE 1/4, Sec. 1, T. 9 N., R. 4 E. |
| " 62 | SW 1/4, SW 1/4, Sec. 18, T. 9 N., R. 5 E. |
| " 63 | NE 1/4, NE 1/4, Sec. 22, T. 9 N., R. 5 E. |
| " 64 | NW 1/4, SE 1/4, Sec. 24, T. 6 N., R. 8 E. |
| " 65 | SE 1/4, NE 1/4, Sec. 18, T. 6 N., R. 9 E. |
| " 66 | NE 1/4, Sec. 29, T. 7 N., R. 9 E. |
| " 67 | South center edge Sec. 17, T. 7 N., R. 9 E. |
| " 68 | NW 1/4, SE 1/4, Sec. 5, T. 7 N., R. 9 E. |
| " 69 | SW 1/4, NW 1/4, Sec. 11, T. 6 N., R. 9 E. |
| " 70 | SE 1/4, NW 1/4, Sec. 22, T. 5 N., R. 8 E. |
| " 71 | SE 1/4, NW 1/4, Sec. 22, T. 5 N., R. 8 E. |
| " 72 | NW 1/4, Sec. 6, T. 5 N., R. 9 E. |
| " 73 | SE 1/4, NE 1/4, Sec. 18, T. 5 N., R. 9 E. |
| " 74 | SW corner, Sec. 8, T. 5 N., R. 10 E. |
| " 75 | SW 1/4, Sec. 13, T. 8 N. R. 9 E. |
| " 76 | SW 1/4, Sec. 13, T. 8 N., R. 9 E. |
| " 77 | NE 1/4, NE 1/4, Sec. 33, T. 8 N., R. 4 E. |
| " 78 | NW 1/4, NE 1/4, Sec. 31, T. 8 N., R. 5 E. |
| " 79 | SW 1/4, NE 1/4, Sec. 35, T. 8 N., R. 5 E. |
| " 80 | NE 1/4, Sec. 24, T. 9 N., R. 6 E. |
| " 81 | NW 1/4, NE 1/4, Sec. 20, T. 9 N., R. 7 E. |
| " 82 | N 1/2, Sec. 21, T. 5 N., R. 6 E. |
| " 83 | SE 1/4, NW 1/4, Sec. 27, T. 8 N., R. 11 E. |
| " 84 | SE 1/4, NE 1/4, Sec. 28, T. 8 N., R. 11 E. |
| " 85 | N 1/2, SW 1/4, Sec. 31, T. 8 N., R. 9 E. |
| " 86 | NW 1/4, NW 1/4, Sec. 18, T. 9 N., R. 10 E. |
| " 87 | Center, Sec. 23, T. 10 N., R. 9 E. |
| " 88 | NW 1/4, SW 1/4, Sec. 3, T. 10 N., R. 10 E. |
| " 89 | SW 1/4, SW 1/4, Sec. 33, T. 14 N., R. 8 E. |
| " 90 | NW 1/4, NW 1/4, Sec. 15, T. 13 N., R. 8 E. |
| " 91 | NE 1/4, Sec. 18, T. 9 N., R. 7 E. |
| " 92 | SW 1/4, SW 1/4, Sec. 13, T. 8 N., R. 4 E. |
| " 93 | NW 1/4, NW 1/4, Sec. 36, T. 8 N., R. 4 E. |
| " 94 | NW 1/4, Sec. 24, T. 8 N., R. 4 E. |
| " 95 | Center, Sec. 13, T. 8 N., R. 4 E. |
| " 96 | NE 1/4, Sec. 6, T. 9 N., R. 7 E. |
| " 97 | SE 1/4, Sec. 3, T. 9 N., R. 7 E. |

| | |
|---|---|
| GP-98 | SW 1/4, SE 1/4, Sec. 5, T. 13 N., R. 8 E. |
| " 99 | North center edge of NE 1/4, Sec. 4, T. 13 N., R. 8 E. |
| " 100 | NW 1/4, Sec. 9, T. 13 N., R. 8 E. |
| " 101 | SE corner, Sec. 27, T. 10 N., R. 6 E. |
| " 102 | SE 1/4, Sec. 14, T. 10 N., R. 6 E. |
| " 103 | SE 1/4, NE 1/4, SE 1/4, Sec. 36, T. 12 N., R. 10 E. |
| " 104 | NW 1/4, NE 1/4, Sec. 2, T. 11 N., R. 10 E. |
| " 105 | NE 1/4, SE 1/4, Sec. 8, T. 4 N., R. 6 E. |
| " 106 | Sec. 18, T. 6 N., R. 8 E. |
| " 107 | SW 1/4, NW 1/4, Sec. 1, T. 7 N., R. 8 E. |
| " 108 | NW 1/4, Sec. 22, T. 11 N., R. 10 E. |
| " 109 | NE 1/4, Sec. 10, T. 11 N., R. 10 E. |

## Mount Hood National Forest

| | |
|---|---|
| MH-1 | SW 1/4, SW 1/4, Sec. 8, T. 3 S., R. 9 E. |
| " 2 | NW 1/4 corner, Sec. 11, T. 3 S., R. 9 E. |
| " 3 | Center Sec. 27, T. 5 S., R. 9 E. |
| " 4 | SW 1/4, NE 1/4, Sec. 18, T. 3 S., R. 9 E. |
| " 5 | NE 1/4, NW 1/4, Sec. 15, T. 3 S., R. 9 E. |

## Mount Rainier National Park

| | |
|---|---|
| MR-1 | 2 1/2 miles below Sunrise Point on Yakima Park road |
| " 3 | 1/8 mile above Norada Falls parking area, Paradise road |
| " 4 | 1/2 mile west of Reflection Lakes, Stevens Canyon road |
| " 5 | 1/2 mile up Eagle Peak trail |
| " 6 | 1/4 mile north of Fish Creek Bridge, West Side Highway |
| " 7 | 1 1/2 miles south of Fish Creek Bridge, West Side Highway |
| " 8 | 3/8 mile east of Fryingpan Creek, Yakima Park road |
| " 9 | 1/2 mile north of Ohannapecosh Jct., State Highway 5 |

## Snoqualmie National Forest

| | |
|---|---|
| SNO-1 | NE corner, Sec. 2, T. 13 N., R. 11 E. |
| " 2 | SE 1/4, NE 1/4, Sec. 2, T. 13 N., R. 11 E. |
| " 3 | SW 1/4, SW 1/4, Sec. 9, T. 15 N., R. 12 E. |
| " 4 | Center Sec. 9, T. 15 N., R. 12 E. |

VEGETATION AND SOILS IN THE SUBALPINE FORESTS OF THE

SOUTHERN WASHINGTON CASCADE RANGE

ABSTRACT

by Jerry Forest Franklin, Ph.D.
Washington State University, 1966

Chairman: Rexford Daubenmire

Old-growth forest communities and soils were examined at more than 200 sites within the cool, moist Abies amabilis and Tsuga mertensiana Zones of the southern Washington Cascade Range which occur between 2,000 and 6,000 feet. About 120 stands were selected for detailed study of plant composition and coverage, population structure, and soil morphology. Fifteen distinctive plant associations were recognized. Their vegetational, edaphic, and topographic characteristics are reported and a key for their identification is presented.

Pacific silver fir is the major climax tree species in both zones. Western hemlock is its most common associate in the lower-elevation A. amabilis Zone but is either seral or only a minor climax component on most habitats. Mountain hemlock is the most common associate in the T. mertensiana Zone, but it also is either seral or a minor climax species. Western redcedar and Alaska-cedar are climax associates in an association in the lower and upper elevational zones, respectively. In the A. amabilis Zone Douglas-fir, noble fir, and western white pine are the common seral trees in the Mount Rainier Province, with Douglas-fir, western white pine, western larch, grand fir, noble fir, and Engelmann spruce typical seral species in the Mount Adams Province. In the T. mertensiana Zone subalpine fir, lodgepole pine, and western white pine are the major seral species.

The A. amabilis/Vaccinium alaskaense Association is the climatic climax in the A. amabilis Zone of the Mount Rainier Province. It is characterized by well-developed shrub, herb, and moss layers. On drier sites occur associations with depauperate understories dominated by shrubs such as Berberis nervosa and Gaultheria shallon and by Xerophyllum tenax. On moister sites herb-rich associations develop with understories dominated by Tiarella unifoliata, Streptopus curvipes, Achlys triphylla, Dryopteris linnaeana, Vancouveria hexandra, Oxalis oregana, and Smilacina sessilifolia. The wettest sites are typified by Athyrium filix-femina and Oplopanax horridum.

The A. amabilis Zone of the Mount Adams Province has a similar spectrum of associations. The A. amabilis-T. heterophylla/Vaccinium membranaceum Association is the climatic climax. Lithosolic associations occupy drier sites and associations progressively richer in herbs occupy moister sites. The flora of this zone, particularly the composition of seral forests, clearly show a mixing of Rocky Mountain and coastal floras.

The T. mertensiana Zone is essentially the same in both provinces. The A. amabilis-T. mertensiana/Vaccinium membranaceum Association constitutes the climatic climax. A dense tangle of ericaceous shrubs distinguishes the understory on the wettest sites. Associations within the forest-alpine ecotone were not studied.

The soils within the study area are predominantly podzolic, classed as either Podzols or Brown Podzolics. Degree of podzolization varies mainly with the plant associations and age of parent material. Other great soil groups encountered were Reddish-Brown Lateritic, Gley Podzol, Sols Bruns Acides, Lithosol, and Alluvial. These were associated with only one or two particular associations.

Layering of parent materials is a dominant morphologic feature in most

soil profiles. Ten or more layers may be encountered in a 60-inch pit, and three or four are typical. Aeolian deposits of volcanic ejecta, exhibiting a wide range in characteristics, are responsible for most layering. However, colluvial, alluvial, and glacial activity have been locally important.