TENTATIVE ECOLOGICAL PROVINCES *within the*

TRUE FIR-HEMLOCK forest areas of the PACIFIC NORTHWEST

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Introduction

True fir-hemlock forests occupy extensive areas at middle to high elevations in mountainous regions of Oregon and Washington. These forests are characterized by Pacific silver fir *(Abies amabilis)*, noble fir *(Abies procera)*, Shasta red fir *(Abies magnifica* var. *shastensis)*, subalpine fir *(Abies lasiocarpa)*, western hemlock *(Tsuga heterophylla)*, mountain hemlock *(Tsuga mertensiana)*, and western white pine *(Pinus monticola)*. True fir-hemlock forests constitute a major forest resource, covering approximately 3 million acres and containing about 100 billion board feet of timber. They occupy the upper reaches of many major drainages, occur within summer ranges of big-game animals, and in many areas receive heavy recreational use. Multiple resource aspects of the true fir-hemlock forests are important enough that an appreciable proportion of the area they occupy has been designated "High Mountain Area" (U.S. Forest Service 1962)[1] for which special objectives and policies have been determined.

True fir-hemlock forests are very diverse in character.[2] They occur on mountain habitats covering 7° of latitude and representing widely divergent geologic histories, climatic conditions, and topography. The forests themselves vary a great deal in species composition and stand characteristics and will require a variety of silvicultural prescriptions for intensive management. Thus, we need to subdivide the true fir-hemlock forest areas into as homogeneous and ecologically consistent units as present knowledge permits for purposes of both management and research.

This paper suggests useful geographic divisions of the true fir-hemlock forests within the mountainous regions of western Oregon and Washington. Divisions are based on differences in geology, topography, soil parent materials, climate, and forest composition. Because the regions or provinces are based on a consideration of several factors rather than just a single factor such as physiography or climate, they are considered ecological provinces. The provinces provide a geographic framework which, by reducing the variability of forests and habitats encountered within the true fir-hemlock zones, facilitates isolation and solution of management problems and provides an initial stratification for research purposes.

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[1] Names and dates in parentheses refer to Literature Cited, p. 30.

[2] Excluded from consideration in this paper are the grand fir *(Abies grandis)* forests, common on the eastern slope of the Cascade Range, and the extensive low-elevation western hemlock stands found on the western slopes in which a true fir is not a major constituent.

It is important to recognize that this is a broad, generalized classification of the true fir-hemlock forest area. Within each province, these forests occupy a spectrum of habitats resulting from different environmental conditions--soil types, topographic position, microclimate, etc.--and these habitats are typified by different forest types, understory plant communities and management considerations. In the author's opinion, the classification presented in this report is as detailed as presently possible. As increased information on vegetation (plant communities) and soils and their distribution become available, it will be feasible to develop an ecologic classification of the true fir-hemlock landscape based on individual habitat types which would have essentially identical biologic potential for management.

The province classification provided in this paper applies only to areas or elevation zones in which the climax forests are composed of true firs and hemlocks, except as noted in footnote 2. Significant ecological or geographical divisions of adjacent lower elevation forest types or zones may or may not be correlated with this subdivision of the true fir-hemlock forests.

The Provinces

The 11 tentative ecological provinces of the true fir-hemlock forests are:

Mount Baker	Three Sisters
Wenatchee	Crater Lake
Mount Rainier	Olympic
Mount Adams	Coast Range
Willamette	Siskiyou
Mount Hood	

Approximate boundaries of the provinces are illustrated in figure 1, page 17. Data collected throughout the geographic range of true fir-hemlock forests and available literature are the basis of the division into these provinces.

Geologic, topographic, climatic, edaphic, and vegetational characteristics of the various provinces are considered in following sections. Some characteristics are summarized in table 1.

GEOLOGY AND PHYSIOGRAPHY

Geology, and its expression in physiography, provides a good place to begin an ecologic stratification of our northwestern mountainous regions. The 11 ecological provinces occur within 6 areas of gross geologic uniformity[3] (fig. 2, table 1): Northern Cascades, Western Cascades, High Cascades, Olympic Mountains, Coast Ranges, and Siskiyou Mountains. Three of these units are parts of the Cascade Range which have previously been recognized as being biologically distinct (Campbell 1962, Molenaar 1956, Williams 1962). The other three, the Olympic Mountains, Coast Ranges (including the Willapa Hills), and the Siskiyou Mountains, will be considered, for our purposes, as single geologic units.

[3] Boundaries of provinces and geologic units do not necessarily coincide, however, because of the other factors (vegetation, soils, and climate) used in determining province boundaries. For example, the Wenatchee Province includes portions of both the Northern Cascades and Western Cascades geologic units because topographic, vegetational, and climatic similarities override differences in bedrock geology. Likewise, the Willamette Province (located mainly in the Western Cascades) includes a portion of the High Cascades geologic unit, and the Crater Lake Province (located mainly in the High Cascades) includes some of the Western Cascades geologic unit. Therefore, the 11 provinces are not simply a subdivision of the 6 geologic units as might be supposed.

Table 1.--Major environmental factors and extent of true fir-hemlock forests in the 11 ecological provinces

Ecologic province	Geologic unit	Topography
Mount Baker	Northern Cascades	Extremely rugged; deeply dissected
Mount Rainier	Western Cascades	Dissected, mature ridge and valley topography
Willamette	Western Cascades (mainly)	Dissected, mature ridge and valley topography
Mount Adams	High Cascades	Gentle, rolling
Mount Hood	High Cascades	Gentle, rolling
Three Sisters	High Cascades	Gentle, rolling
Crater Lake	High Cascades (mainly)	Gentle, rolling
Wenatchee	Northern Cascades and Western Cascades	Extremely rugged; deeply dissected
Olympic	Olympic Mountains	Rugged, complex systems of ridges and valleys
Coast Range	Coast Ranges	Mature ridge and valley topography
Siskiyou	Siskiyou Mountains	Rugged, complex systems of ridges and valleys

[1] Two aspects of parent materials are considered: (1) mode of origin, e.g., colluvial, residual; (2) parent rock, the material from which soil particles were developed, e.g., sedimentary. Residual parent materials originate by rock disintegration in place; they have not been transported. The other types of parent materials have been transported from other areas to their present location: colluvial, by gravity; alluvial, by water; and glacial (till), by glaciers.

Climate	Major soil parent materials[1]	Extent and continuity of true fir-hemlock forests
Cool, moist growing season; little or no summer drought	Colluvial, residual, alluvial, and glacial materials from metamorphic, igneous intrusive, and sedimentary rocks; local volcanic ejecta	Extensive, contiguous stands
	Colluvial, residual, and glacial materials from igneous extrusive rocks; volcanic ejecta as deposits or mixed with other materials	Extensive, insular stands
Increasing growing-season temperatures; summer drought	Colluvial, residual, and glacial materials from igneous extrusive rocks; volcanic ejecta as deposits or mixed with other materials	Extensive, insular stands
Decreasing annual and growing-season precipitation	Volcanic ejecta often over residual and glacial igneous extrusive materials	Extensive, contiguous stands
	Glacial, colluvial, and residual materials from igneous extrusive rocks	Extensive, contiguous stands
	Volcanic ejecta often over glacial, residual, and colluvial materials from igneous extrusive rocks	Extensive, contiguous stands
Warm, dry growing season; marked summer drought period	Volcanic ejecta often over glacial, residual, and colluvial materials from igneous extrusive rocks	Extensive, contiguous stands
Warm, dry growing season; marked summer drought period	Colluvial, residual, alluvial, and glacial materials from igneous intrusive or extrusive and metamorphic rocks; local volcanic ejecta	Limited, insular stands
Cool, moist growing season; no summer drought	Colluvial, alluvial, residual, and glacial materials from igneous extrusive, sedimentary, and metamorphic rocks	Extensive, contiguous stands
Cool, moist growing season; no summer drought	Residual and colluvial materials from igneous intrusive or sedimentary rocks	Extremely limited, insular stands
Warm, dry growing season; marked summer drought period	Colluvial and residual materials from igneous intrusive, sedimentary, and metamorphic rocks	Limited, insular stands

[1] Examples of the five categories of parent rock are: (1) igneous intrusive--granite, diorite, gabbro, peridotite; (2) igneous extrusive--andesite, basalt, pyroclastic rocks (e.g., tuffs and volcanic breccias); (3) sedimentary--sandstone, graywacke, shale; (4) metamorphic--gneiss, schist, slate; and (5) volcanic ejecta--defined in this paper as unconsolidated pyroclastic rock fragments, e.g., pumice, ash, lapilli, and cinders.

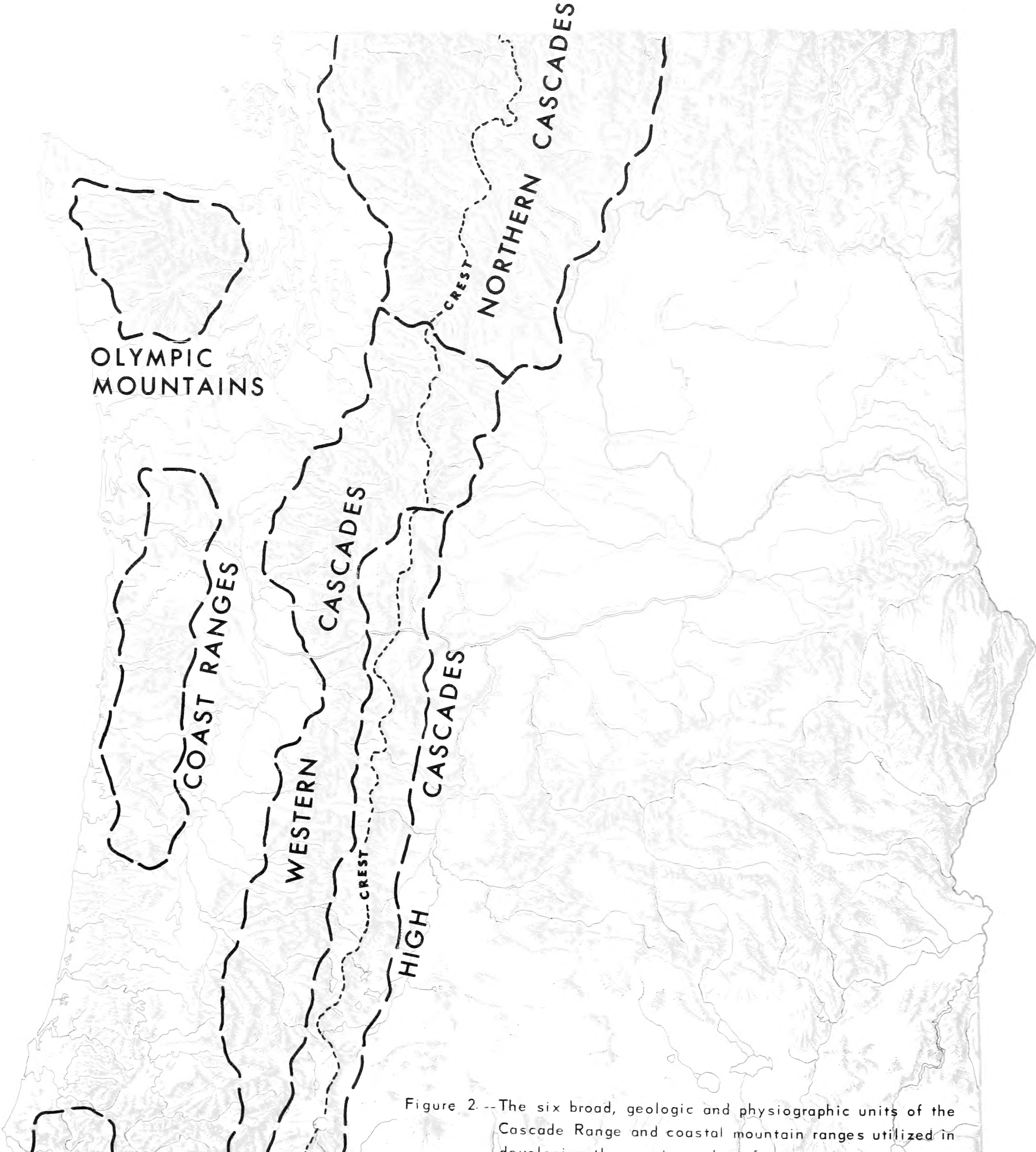

Figure 2.--The six broad, geologic and physiographic units of the Cascade Range and coastal mountain ranges utilized in developing the province classification.

North of Snoqualmie Pass (U.S. Highway 10) is the Northern Cascades, a complex geologic unit dating from the pre-upper Jurassic period (Molenaar 1956). This region is composed mainly of metamorphic, sedimentary, and intrusive igneous rock types. Extrusive igneous rock types are not extensive compared with other parts of the Cascade Range, although Mount Baker and Glacier Peak provide two major "islands" of volcanic materials. The Northern Cascades was the most heavily glaciated part of the range and during the ice age probably looked similar to heavily glaciated parts of Alaska today.

Much of the present Cascade Range was created by an upwarping in late-Tertiary time, but uplift was strongest in the Northern Cascades and decreased steadily to the south. Elevations of higher peaks and ridges are, therefore, greatest in this part of the Cascade Range--7,000 to 8,000 feet. The greater elevation and glaciation of the Northern Cascades are largely responsible for the present rugged topography. Matterhorn-like summits, jagged ridges, glacially carved valleys, and steep-walled cirques contrast with gentler topography in the remainder of the range (fig. 3).

The other two geologic units of the Cascade Range are composed almost entirely of volcanic materials--andesitic, basaltic, and pyroclastic rocks. Williams (1962) described major differences between the Western Cascades and the High Cascades in Oregon, where they lie parallel:

> The Cascade Range is divisible lengthwise into two belts, the Western and the High Cascades. The former consists of the tremendous volcanic accumulations of Eocene, Oligocene, and Miocene times. In this belt profound canyons are separated by narrow ridges, and no trace remains of the original volcanic landscapes. The landforms here are entirely the result of erosion. The High Cascades, on the other hand, are made up of Pliocene and younger volcanic cones whose original forms, even though modified by erosion, are easy to recognize.

Thus, the Western Cascades includes most of the range in Washington south of the Snoqualmie Pass (except for an area around Mount Adams and islands of more recent volcanic materials around Mount St. Helens and Mount Rainier) and the western flank of the range in Oregon. In Washington and northern Oregon, the dominant rock types are andesite and basalt, whereas, in the southern Oregon portion of the Western Cascades, pyroclastic rocks are the predominant type.

Most of the Western Cascades presents a mature ridge and valley topography which is rugged but generally not so precipitous as that typically found in the Northern Cascades (fig. 4). High-elevation tracts tend to be insular and limited in extent. In contrast, the larger volcanic cones of this geologic unit--Mount Rainier and Mount St. Helens--rise far above the generally concordant level of the numerous smaller peaks and ridges. One part of the Western Cascades is included within the Wenatchee Province because, among other reasons, the topography there is more similar to that found on the eastern slopes of the Northern Cascades.

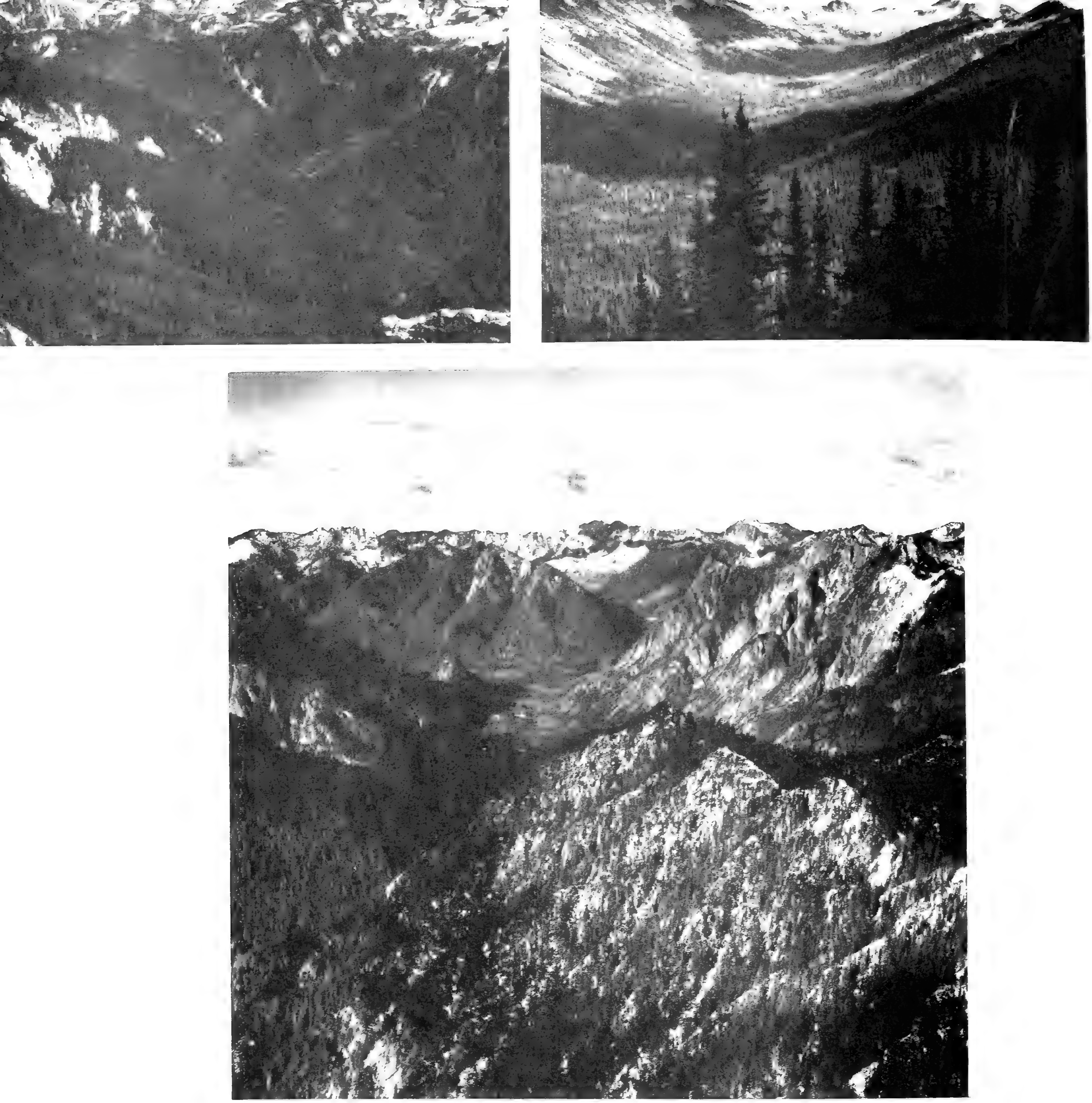

Figure 3.--Typical topographic conditions encountered in the Northern Cascades. Upper left: Chilliwack Creek drainage and Picket Range, Mount Baker National Forest. Upper right: upper Pasayten River drainage from Jim Peak, Okanogan National Forest. Bottom: view down Middle Fork of Snoqualmie River, Snoqualmie National Forest.

Figure 4.--Typical topographic conditions encountered in the Western Cascades. Top: north of Mount St. Helens, Gifford Pinchot National Forest. Bottom: near Carpenter Mountain and Wolf Rock, Willamette National Forest.

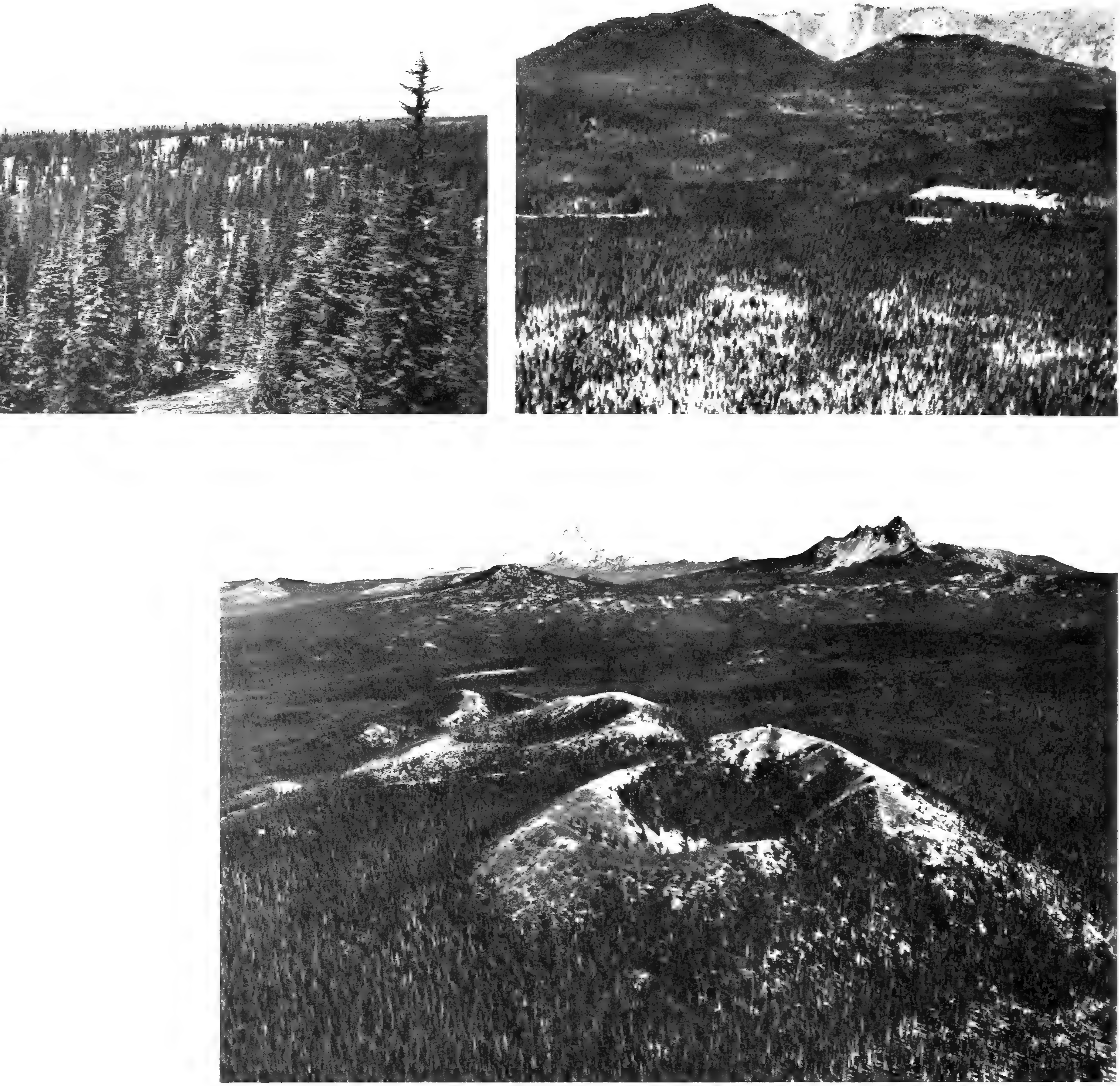

Figure 5.--Typical topographic conditions encountered in the High Cascades. Upper left and bottom: vicinity of Santiam Pass and Mount Washington, Willamette National Forest. Note the rolling topography broken by isolated volcanic peaks and cinder cones. Upper right: west of Mount Adams, Gifford Pinchot National Forest. Notice the mature ridge and valley topography of the Western Cascades in the distance.

The High Cascades is much younger than the Western Cascades and occupies the crest of the Cascade Range throughout the length of Oregon and an area around Mount Adams in southern Washington. Topography here is that of a gently rolling or sloping plateau with poorly defined drainage patterns and a minimum of precipitous topography (fig. 5). Isolated cinder cones and other volcanic landforms provide much of the relief, although glaciation has carved deep canyons in some areas and affected the major peaks. Surface deposits of pumice and other volcanic ejecta cover the bulk of the landscape and many (particularly in the Mount Adams and Crater Lake Provinces) have been subjected to little reworking since deposition. The crest of the High Cascades varies from 4,000 to 6,000 feet in elevation, and high-elevation tracts are, therefore, very extensive and contiguous.

The Olympic and Siskiyou Mountains are rugged mountain systems with complex patterns of valleys and canyons separating high peaks and ridges. The Olympic Mountains are composed mainly of metamorphic, extrusive igneous, and sedimentary rock types. They have been heavily glaciated. The Siskiyou Mountains are composed of metamorphic and intrusive igneous rock types. The Coast Ranges are relatively low mountains with a mature ridge and valley topography and few areas of sufficient elevation to support true fir-hemlock forests. Sedimentary rock types are most common, although higher peaks and ridges are often volcanic or metavolcanic in composition.

CLIMATE

Climatic variation in the Cascade Range is important in the delineation of ecological provinces (table 2). Some general features of the climate throughout the Cascade Range and coastal ranges are well known (U.S. Weather Bureau 1960a, 1960b). Annual precipitation normally increases with elevation of western mountain slopes and decreases rapidly on eastern leeward slopes. Precipitation is markedly seasonal, less than 10 percent of which usually falls from late June to September. At high elevations, much of the precipitation falls as snow and accumulates in winter snowpacks. The maritime climate is mild with cooler summers and warmer winters than at comparable elevations on inland ranges (continental climates).

Some broad variations in the general climatic pattern just described must be considered in a division of true fir-hemlock forest areas (table 2). Southward along western slopes of the Cascade Range, summers become progressively warmer and drier, a summer drought period develops, and total precipitation decreases at a given elevation. This change in climatic pattern necessitates subdividing the Western Cascades latitudinally into the Mount Rainier and Willamette Provinces to provide a greater measure of climatic homogeneity.

Table 2.--Climatic data from some representative stations in the Cascade Range and coastal mountains[1]

Ecological province and weather station	Elevation	In true fir-hemlock zone?	Precipitation: Total annual	Precipitation: June, July & Aug.	Precipitation: Annual snowfall	Temperature: Ave. annual	Temperature: Mean monthly Jan.	Temperature: Mean monthly July	Temperature: Ave. Jan. min.	Temperature: Ave. July max.
	Feet		Inches			Degrees F.				
Mount Baker:										
Mount Baker Lodge	4,150	Yes	111.08	12.32	550.3	40.1	27.3	53.8	21.8	63.5
Stevens Pass	4,085	Yes	65.79	5.10	354.1	39.9	22.8	57.9	16.9	71.1
Scenic	2,224	Yes	77.60	5.50	241.9	--	--	--	--	--
Snoqualmie Pass	3,020	Yes	104.57	8.94	386.5	41.9	26.3	58.0	20.1	70.0
Mount Rainier:										
Stampede Pass	3,958	Yes	93.60	7.34	473.4	46.8	23.7	56.9	19.8	67.2
Parkway	2,640	Yes	54.93	4.35	135.9	44.8	30.3	59.8	25.1	73.7
Mount Rainier, Longmire	2,762	Yes	79.44	6.37	179.4	45.2	30.0	61.1	23.6	74.9
Mount Rainier, Paradise	5,550	Yes	101.49	9.08	536.4	38.5	26.3	53.1	20.1	62.8
Spirit Lake R.S.	3,240	Yes	88.69	5.52	282.6	42.0	28.4	58.8	24.1	72.2
Willamette:										
Summit G.S.	3,900	Yes	84.09	7.12	301.5	42.2	29.0	57.8	22.0	72.4
Sundown Ranch	2,400	No	74.67	5.49	93.6	47.8	35.9	60.1	30.0	71.6
Oakridge R.S.	1,310	No	42.32	3.00	14.5	53.2	38.1	68.0	30.0	84.9
Detroit	1,730	No	74.22	3.25	67.1	48.5	33.0	63.5	25.3	81.2
McKenzie Bridge R.S.	1,375	No	68.93	4.23	39.8	50.5	34.5	66.8	27.3	85.1
Wenatchee:										
Blewett Pass	4,071	Yes	28.07	2.37	186.5	43.6	24.4	64.0	19.1	77.6
Holden	3,436	Yes	34.74	2.57	290.0	42.6	20.4	62.2	14.4	75.4
Chiwawa River	2,712	--	62.42	3.08	364.0	--	--	--	--	--
Lake Wenatchee	1,970	No	39.67	2.29	170.3	--	--	--	--	--
Bumping Lake	3,440	Yes	45.92	2.65	219.0	40.3	22.4	58.0	11.7	74.1
Lake Kachess	2,270	Yes	54.80	3.16	159.3	44.7	25.3	63.7	18.2	77.8
Mount Adams:										
Mount Adams R.S.	1,960	No	48.21	1.91	118.5	46.7	28.1	65.3	20.8	83.3
Mount Hood:										
Parkdale	1,740	No	45.11	1.91	95.9	47.3	29.8	63.5	22.3	80.6
Three Sisters:										
Odell Lake Land Pan	4,788	Yes	59.30	2.33	--	40.4	23.2	58.5	15.5	74.6
Wickiup Dam	4,330	No	20.08	2.53	78.4	41.2	21.8	59.6	7.9	80.0
Crater Lake:										
Crater Lake NPS Hq.	6,475	Yes	68.46	3.95	589.3	39.3	25.2	56.4	17.0	70.4
Cascade Summit	4,841	--	49.63	3.00	294.9	41.5	26.9	58.8	20.0	80.9
Fish Lake	4,687	--	45.47	2.97	171.7	44.1	28.4	61.1	18.9	78.0
Siskiyou:										
Siskiyou Summit[2]	4,480	No	22.70	1.74	104.4	46.8	31.8	64.0	25.4	75.6
Illahe 1 N[3]	300	No	85.79	2.64	14.9	55.1	40.2	70.4	34.6	79.7
Coast Range:										
Corvallis Water Bureau[2]	450	No	70.12	2.50	19.6	--	--	--	--	--
Valsetz[3]	1,150	No	124.02	5.80	15.5	50.1	37.2	62.2	29.8	77.4
Olympic:										
Forks[3]	350	No	115.87	8.35	15.0	49.2	38.5	59.7	32.6	70.3
Spruce[3]	410	No	123.80	9.80	20.5	--	--	--	--	--
Quilcene 2 SW[2]	123	No	48.10	4.04	6.2	50.3	36.7	63.5	29.3	77.4

[1] From U.S. Weather Bureau records for 1931 through 1952 (U.S. Weather Bureau 1956a, 1956b).

[2] East (inland) side of range.

[3] West (ocean) side of range.

Eastward from the crest of the Cascade Range in northern and central Washington, annual precipitation decreases (even at high elevation), summers become warmer and drier, and winter temperatures become colder (U.S. Weather Bureau 1960b). These differences in precipitation and temperature provide a climatic basis for separating the Wenatchee Province from the adjacent, geologically related, west slope areas.

The four High Cascades provinces (Mount Adams, Mount Hood, Three Sisters, and Crater Lake) straddle the crest of the Cascade Range. Summers are warmer and winters are cooler, and the climate is, in general, more continental than in adjacent provinces located in the Western Cascades. Both annual precipitation and that which occurs during the growing season are usually less at comparable elevations (U.S. Weather Bureau 1960a). Furthermore, there is a gradual decrease in precipitation and an increase in summer temperatures from north to south through the High Cascades, necessitating the division of this geologic unit because of climatic variation. Actual boundaries of the four provinces were determined by details of soil parent materials and vegetation because of the gradational change in climate.

Superimposed on this broader pattern of climatic variation are many localized macroclimatic variations within individual provinces. Localized effects of this type sometimes obscure the larger scale geographical shifts in macroclimate.

SOILS

Variation in soil parent material in the various provinces is closely related to the geologic regions. In the Northern Cascades, for example, colluvium, alluvium, and glacial till derived from sedimentary, metamorphic, and igneous intrusive rock types are the important parent materials except near Mount Baker and Glacier Peak where some deposits of volcanic ash and pumice are present.

In the Western Cascades, colluvial and residual parent materials derived from andesitic, basaltic, and pyroclastic rock types are most important, but they are often mixed with volcanic ejecta. In the vicinity of Mount Rainier and Mount St. Helens, soils may be developed entirely in deposits of pumice and lapilli.

In the High Cascades, the majority of soils are developed in recent surface deposits of volcanic ash, pumice, cinders, lapilli, and other unconsolidated pyroclastic materials, overlying either basic igneous rocks or buried profiles developed from these rocks. Over much of the area, particularly in the Mount Adams and Crater Lake Provinces, the most recent deposits have not been reworked by erosional processes and the various layers are readily apparent. Deposits of ejecta have been reworked, primarily by glaciation, around some major peaks. The Mount Hood Province provides a single large-scale exception where unconsolidated deposits of unreworked volcanic ejecta do not constitute a major soil parent material in this province. Most soils in the Mount Hood Province are developed in residuum and colluvium derived from andesite and basalt and in glacial till of varying composition.

Parent materials in the Olympic Mountains are usually residuum, colluvium, and glacial till derived from metamorphic, sedimentary, and igneous extrusive (e.g., basalt) rock types. The Siskiyou Mountains contain an even wider spectrum of parent rock types, and parent materials are mainly residual or colluvial in origin. Soils in the Coast Ranges are generally developed in sedimentary or igneous extrusive residuum or colluvium.

Great soil groups commonly found in true fir-hemlock forests are Podzols, Brown Podzolics, Regosols, Lithosols, Sol Brun Acides, and Yellowish-Brown Lateritics.[4] In the Cascade Range, Podzols attain maximum development at midelevations on western slopes of the Northern Cascades. Organic horizons sometimes attain thicknesses of 14 inches and A2 horizons may be 3 inches thick under Pacific silver fir-western hemlock stands. Podzols are the soil type found most often under true fir-hemlock stands regardless of the province. Degree of podzolization varies a great deal, however, decreasing from north to south and as one moves down the eastern slopes of the Cascade Range. Near the southern end of the Oregon Cascades and along eastern boundaries of the true fir-hemlock forests, podzolization is at a minimum, and zonal soils probably become Brown Podzolics except at the highest elevations.

It is important to note that many of the grey, ashy A2 horizons commonly encountered in podzolic profiles in the Washington Cascade Range are not primarily

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[4] The U.S. Department of Agriculture (1938) and Thorp and Smith (1949) define the first four great soil groups as follows: **Podzol** soils have an organic mat (usually mor or raw humus consisting of matted and compacted unincorporated organic matter) and very thin, organic-mineral layer above a gray leached layer (A2) which rests upon an illuvial dark-brown horizon (B2). Iron oxide, alumina, and colloidal organic matter have been removed from the A and deposited in the B horizon. **Brown Podzolic** soils have a thin mat of partly decayed organic matter over very thin, dark grayish-brown, humus-mineral soil and a trace of pale-gray, leached A2 horizon over a brown or yellowish-brown B horizon heavier in texture than the surface soil. **Regosols** consist of deep, unconsolidated rock (loess, sand, pumice, e.g.) in which few or no clearly expressed soil characteristics have developed. **Lithosols** are skeletal soils consisting of a fresh and imperfectly weathered mass of rock fragments which have no clearly expressed soil morphology. As recognized by soil scientists in the Pacific Northwest, Podzols generally lack the thin, organic-mineral layer above the A2, and Brown Podzolics have thin to thick mats of organic matter and often lack textural B horizons.

Sol Brun Acides and Yellowish-Brown Lateritics are reported to occur under true fir-hemlock stands (in a personal communication from Freeman Stephens and Jack S. Fisher, soil scientists, Region 6, U.S. Forest Service). **Sol Brun Acides** are deep, moderately to poorly weathered soils with indistinct horizons and containing primary minerals besides quartz (Harris 1963). **Yellowish-Brown Lateritics** have yellowish-brown, granular, friable surface horizons overlying yellow or reddish-yellow friable clay material and rest on parent materials usually not strongly mottled (U.S. Department of Agriculture 1938).

the result of podzolization, i.e., soil development in place. On the contrary, these horizons appear to have originated as recent depositions of volcanic ash and pumice, particularly by Mount St. Helens and Glacier Peak (Crandell et al. 1962; Carithers 1946). These pyroclastic materials had many of the characteristics of a podzolic A2 at the time of deposition (e.g., coarse texture, grey or white color, position in solum) and have since acquired additional features characteristic of A2 horizons (e.g., increase in acidity).

FORESTS

The climax species in the true fir-hemlock zones under consideration are true firs and hemlocks, but the exact composition, especially of seral species, varies considerably from province to province. This variability is important in dividing these mountain areas into provinces. The relative importance of the species is shown in table 3. All forest types occurring in the true fir-hemlock zones[5] are being considered, regardless of successional status or species composition.

Table 3.--Forest composition in the true fir-hemlock zones, by ecological provinces [1]

Species	Province										
	Mount Baker	Mount Rainier	Willamette	Mount Adams	Mount Hood	Three Sisters	Crater Lake	Wenatchee	Olympic	Coast Range	Siskiyou
Pacific silver fir	M	M	M	M	M	M	m	m	M	m	--
Noble fir	m	M	M	M	M	m	m	m	--	m	m
Shasta red fir	--	--	--	--	--	--	M [2]	--	--	--	M [2]
Western hemlock	M	M	M	M	M	M	m	m	M	M	--
Mountain hemlock	M	M	m	M	M	M	M	m	M	--	M
Western white pine	m	m	m	M	M	M	M	M	m	--	M
Douglas-fir	M	M	M	M	m	m	m	m	M	M	--
Western redcedar	M	M	m	m	m	--	--	m	M	m	--
Alaska-cedar	m	m	m	m	m	--	--	--	m	--	--
Lodgepole pine	m	m	m	M	M	M	M	M	--	--	m
Engelmann spruce	--	m	m	M	M	m	m	M	--	--	--
Subalpine fir	m	m	m	M	M	M	m	M	m	--	--
Western larch	--	--	--	M	M	--	--	M	--	--	--
Grand fir	--	--	m	m	m	M [3]	M [3]	M	--	--	M [3]
Incense-cedar	--	--	--	--	m	m	m	--	--	--	m

[1] The higher elevation forest zones in which true firs and hemlocks are the climax species (see text footnotes 2 and 5). Symbols indicate the following: M = major species; m = minor species.

[2] See text footnote 6.

[3] See text footnote 7.

[5] The higher elevation forest zones in which true firs and hemlocks are the climax species. These include the following life zones found in various parts of the mountain ranges: Pacific Silver Fir-Western Hemlock, Pacific Silver Fir-Mountain Hemlock, Shasta Red Fir, Mountain Hemlock, and Subalpine Fir-Englemann Spruce Zones. These life zones are based on the climax tree species. The zones and their geographic distribution will be discussed in future publications.


BELLINGHAM
Mt. Baker
MT. BAKER
WENATCHEE
OMAK
River
Columbia
Glacier Peak
Lake Chelan
EVERETT
OLYMPIC
SEATTLE
SPOKANE
WENATCHEE
TACOMA
ABERDEEN
Mt. Rainier
MT. RAINIER
YAKIMA
PASCO
Mt. St. Helens
Mt. Adams
ASTORIA
RANGE
MT. ADAMS
River
Columbia
PENDLETON
PORTLAND
THE DALLES

Figure 1.--The boundaries of the 11 ecological provinces of the true fir-hemlock forests recognized in this paper. These are based on differences in geology, topography, soil parent materials, climate, and vegetation.

Extensive forests of Pacific silver fir and western hemlock occupy the Mount Baker Province, not only at higher elevations but also at moderate to low elevations on slopes and valley bottoms (fig. 6). True fir-hemlock forests, the most important forest resource in this province, provide a large part of the raw material for the local pulp and paper industry. A recent inventory (MacLean and Hightree 1959) reveals that 65 percent of the sawtimber volume present in Skagit and Whatcom Counties is Pacific silver fir and western hemlock. At highest elevations, the major forest species are Pacific silver fir and mountain hemlock. Western redcedar and Alaska-cedar are common associated species on moist sites at lower and higher elevations, respectively. Seral stands of Douglas-fir are common on recently disturbed sites at low and moderate elevations. Noble fir is found in scattered stands and only in the southern half of the province.

Forests of the true fir-hemlock zone in the Olympic Mountains are very similar to those found in the Mount Baker Province. In mature stands, the major species are Pacific silver fir and western and mountain hemlocks.

Forests in the Wenatchee Province reflect less precipitation and a more continental climate than is found on the western slopes of the Cascade Range. Pacific silver fir and mountain hemlock occur only along the western edges of this province. Abundant species in the true fir-hemlock zone of this province are subalpine fir, Engelmann spruce, lodgepole pine, western white pine, western larch, and grand fir. Forests are very much like those described in the Engelmann spruce-subalpine fir zone of northern Idaho (Daubenmire 1952). They occupy high peaks and ridges, and sometimes valley bottoms due to air drainage patterns. Fire has been a more important factor than in the adjacent Mount Baker Province and seral stands of variable composition are extensive. Also, much of the high-elevation area is broken, rocky country along the summits and slopes of ridges and does not support closed forest stands.

True fir-hemlock forests of the Mount Rainier Province are more diverse in composition than those of the Mount Baker Province. Although extensive, they are more insular in character and tend to occur as disjunct stands on higher peaks and ridges. This is because areas of sufficient elevation to support true fir-hemlock forests (which do not extend to as low an elevation in this province) are usually not continuous as a result of the ridge and valley topography. Pacific silver fir, western hemlock, noble fir, and mountain hemlock are the most important species in mature stands. Douglas-fir forests are common in the true fir-hemlock zone, but are eventually succeeded by forests of Pacific silver fir and hemlock (fig. 7). Western white pine is only a minor constituent of the forests, but individual specimens attain excellent development. Alaska-cedar is locally abundant on cooler and moister sites where specimens compare favorably with associated species (fig. 8).

Forest stands in the true fir-hemlock zone of the Willamette Province are very similar to those in the Mount Rainier Province. They are even more insular in nature, however, because of the increased elevation at which the true fir-hemlock zone occurs.

Figure 6.--A Pacific silver fir-western hemlock stand in the Mount Baker Province.

Figure 7.--A nearly pure western hemlock forest growing at 4,500-foot elevation in the Mount Rainier Province. The understory regeneration is entirely Pacific silver fir. Note the noble fir on the right which is emergent above the western hemlock canopy.

Figure 8.--Pacific silver fir and Alaska-cedar are often associated at high elevations in the Mount Rainier Province. In this stand, fir averages 165 feet tall and cedar, 135 feet tall.

Figure 9.--Dense, young-growth stand of Pacific silver fir in the Willamette Province.

Figure 10.--Pure stand of old-growth noble fir in the Mount Hood Province. Dominant trees are 135 to 145 feet tall.

Figure 11.--This stand of western and mountain hemlocks, Pacific silver and noble firs, and Douglas-fir in the Mount Hood Province illustrates the highly variable nature of true fir-hemlock forests.

Important species in mature stands are Pacific silver fir (fig. 9), noble fir, and western hemlock; mountain hemlock is present in quantity only at the highest elevations. Douglas-fir, western redcedar, and western white pine are common as remnants in older stands or as major constituents of young stands.

True fir-hemlock forests occupy extensive contiguous areas in the rolling, high country of the Mount Adams Province. In the moister western parts of the province, mature forests are composed of Pacific silver fir and western and mountain hemlock. Toward the eastern edges of the province, mature forests of mountain hemlock predominate. Excellent stands of noble fir are common on certain localized habitats. The true fir-hemlock zone in this province has suffered from extensive wildfire over the last century and, for this reason, seral stands with various combinations of lodgepole pine, western white pine, subalpine fir, grand fir, Engelmann spruce, western larch, and Douglas-fir are common. Western white pine attains major importance in this province and in the High Cascades provinces of Oregon.

Forests of the true fir-hemlock zone of the Mount Hood Province are similar (figs. 10 and 11) except that Pacific silver fir is less important and the hemlocks more important than in the Mount Adams area. Old burned-over tracts are common at high elevations in this province (fig. 12).

Forests in the Three Sisters Province differ noticeably from those further north. Western hemlock is much less important and mountain hemlock relatively more important. Pacific silver fir, although still a major climax species, is less common. Noble fir is practically absent except in one or two localities. Stands of lodgepole pine, subalpine fir, and western white pine are common on old burns (fig. 10); Douglas-fir is less common as a seral species, and western larch is absent.

A major change in the character of true fir-hemlock forests takes place in the Crater Lake Province. Western hemlock and Pacific silver fir become relatively inconspicuous species with limited distribution. Major species are Shasta red fir,[6] mountain hemlock, western white pine, lodgepole pine, and grand fir[7] (fig. 13). In the absence of the tolerant Pacific silver fir and western hemlock, climax species are

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[6] Shasta red fir in southern Oregon is a morphologically variable complex, sometimes referred to as noble fir. Hybrid populations are probably present, having resulted from mingling of noble fir and California red fir *(Abies magnifica)*. For discussion of this complex, see Franklin (1964) and Parker (1963). Because of differences in ecological characteristics between the fir found in southern Oregon and noble fir found in Washington and northern Oregon, and until the identity of the former has been satisfactorily established by taxonomic study, the bulk of the southern Oregon fir will be referred to as Shasta red fir, and noble fir will be considered to be a minor component of these forests.

[7] The grand fir here is a morphologically variable complex, referred to by various authors as both grand fir and white fir *(Abies concolor)*. Populations exhibit characteristics of both species in variable proportions and may represent hybrids.

Figure 12.--Many high-elevation tracts within the High Cascades provinces have been burned by wildfires over the last century. Top: Sherar Burn in the Mount Hood Province, Mount Hood National Forest. Bottom: an old burn on slopes of Mount Washington, Willamette National Forest, which has regenerated very slowly following burning.

Figure 13.--In the Crater Lake and Siskiyou Provinces, Shasta red fir (trees in foreground on extreme right and left) and mountain hemlock (two trees in center foreground) are the most important species in the true fir-hemlock forests.

apparently mountain hemlock and Shasta red fir at high elevations and Shasta red fir and grand fir at lower elevations in the true fir-hemlock zone. Mountain hemlock attains its maximum importance relative to other upper-slope species in the high, rolling country of this province, and it forms dense, pure or nearly pure stands covering many square miles (fig. 14). Lodgepole pine also forms pure stands (mainly seral) over extensive tracts within the true fir-hemlock zone, expecially on eastern slopes of the Cascade Range.[8]

Forests of the Siskiyou Mountains are similar in composition to those in the Crater Lake Province. True fir-hemlock forests are not extensive, however, because most high-elevation tracts are highly insular and often not suited edaphically or topographically for closed forest stands. Shasta red fir, mountain hemlock, grand fir, and western white pine are the major species. Shasta red fir and mountain hemlock are typical of highest elevations and Shasta red fir and grand fir of lowest elevations in the true fir-hemlock zone.

True fir-hemlock forests in the Coast Ranges occur at very scattered locations, generally on the highest peaks and ridges. Occasional stands of Pacific silver fir and more frequently encountered isolated stands of noble fir in the northern Oregon Coast Ranges and in Washington's Willapa Hills represent the true fir-hemlock forests in this province.

Thus, four general groups of provinces can be recognized on the basis of forest composition in the true fir-hemlock zone: (1) Mount Baker, Mount Rainier, Willamette, Olympic, and Coast Range Provinces, where Pacific silver fir, western hemlock, and noble fir (in three of the five provinces) are the characteristic and important species and in which seral stands in true fir-hemlock zones are often typical, west-side Douglas-fir forests; (2) Wenatchee Province, where forest composition is very similar to the spruce-fir zone of the northern Rocky Mountains; (3) Mount Adams, Mount Hood, and Three Sisters Provinces, where climax species are the more mesic Pacific silver fir and hemlocks, but in which the important seral species indicate interior influences (subalpine fir, lodgepole pine, western white pine, western larch, e.g., in addition to Douglas-fir); and (4) Crater Lake and Siskiyou Provinces, where mountain hemlock and Shasta red fir are the most important species.

[8] Lodgepole pine stands may be climax on certain soils and physiographic positions within the true fir-hemlock zone. This is certainly the case at lower elevations (e.g., in the ponderosa pine zone) on the east side of the southern Oregon Cascade Range (Dyrness and Youngberg 1958).

Figure 14.--Mountain hemlock attains major importance in the true fir-hemlock forests of the Crater Lake Province, forming pure stands over extensive areas.

Application

This ecological province classification can be of immediate use to forest managers and researchers working in forests of the true fir-hemlock zone. For forest managers, the provinces provide a geographic basis for making generalized management decisions. For the researcher, classification provides a broad basis for stratifying study areas and identifying and isolating problems in true fir-hemlock forest management. Following are some examples of management problems which appear to be directly related to particular ecologic provinces.

The most acute regeneration problems in the true fir-hemlock forests are in the High Cascades provinces from Mount Adams to southern Oregon (fig. 15). On the other hand, regeneration tends to be easier to obtain in western slope provinces--Mount Baker, Mount Rainier, Willamette--provided cutting units are kept small enough to allow for adequate, natural seed fall.

Figure 15.-- Clearcut tracts in true fir-hemlock forests of the High Cascades provinces, such as this one near Crater Lake, are sometimes difficult to regenerate.

Figure 16.--True fir-hemlock forests in the High Cascades provinces occur on topography which allows for easy access and application of a variety of silvicultural systems.

Growth potential of true fir-hemlock forests are related to provinces. As one example, old-growth noble fir in the Mount Rainier Province attains heights of more than 250 feet on best sites but only 150 feet in the adjacent Mount Adams (High Cascades) Province, as indicated by preliminary data.

Protection problems are often related to provinces. Indian paint fungus *(Echinodontium tinctorum)* is a rot responsible for heavy cull in old-growth western hemlock stands in the High Cascades provinces but is of minor consequence in adjacent Western Cascades provinces. Destruction of Pacific silver fir by balsam woolly aphid *(Chermes piceae)* has been encountered only on high-quality Pacific silver fir sites in the Mount Rainier Province; none has been encountered in the adjacent Mount Adams Province in which Pacific silver fir is also widespread. Damage to mountain hemlock by *Poria wierii* has been noted only in the Three Sisters and Crater Lake Provinces.

Provinces may also provide a basis for species selection. For example, the Wenatchee Province and four High Cascades provinces appear to be favorable areas for the management of western white pine. In these areas, western white pine generally appears to be one of the fastest growing species in the true fir-hemlock zone.

Finally, the provinces provide a basis for comparing timber management potential of true fir-hemlock forests in various parts of the region. On western slopes of the Washington Cascades, these forests are extensive and appear amenable to management with no particularly difficult problems except in local areas. In the Wenatchee Province, the true fir-hemlock forests are much less valuable compared with the total timber resource and often occupy areas which are difficult of access and management. The High Cascades provinces contain extensive tracts of true fir-hemlock forests on topography which allows easy access and application of a variety of silvicultural systems (fig. 16), although the growth potential of these true fir-hemlock forests is somewhat below those found in the adjacent Western Cascades provinces.

Further Subdivision

Subdivision, simplification, or other refinements of this tentative classification may prove desirable as more data become available on vegetational and environmental characteristics of the true fir-hemlock forests. In the Mount Rainier Province, for example, comparatively recent creation of Mount St. Helens has greatly modified Western Cascades topography and soil parent materials over a considerable area in the immediate vicinity of the mountain, especially to the northeast where much of the volcanic ejecta was deposited. This type of variation within the broader geographic units must be considered when the vegetational and environmental features of provinces are studied or when management recommendations for provinces are made.

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