This is a study of the ecology of the timberline and alpine vegetation of the Three Sisters which are located in the central Oregon Cascades.

The Sisters are a close group of three 10,000-foot volcanic peaks. Volcanic activity within the last few hundred years as well as recent glaciation have produced a high degree of physiographic instability within the area.

The study area was divided into six zones based primarily on the physiography, and the vegetation of each zone was described.

A glacial maximum about 200 years ago produced large moraines and outwash which now cover much of the slopes. In addition large areas are covered by cinders, pumice and lava. These factors combined with climatic factors are holding the vegetation in a number of climaxes.

There is evidence for climatic fluctuations within the last 200 years or so. As a result of a decrease in average snowbank size the hemlock forest is advancing slowly into meadows and some other areas.

The timberline is at about 6500 feet and a number of factors are responsible for its limits. The treeline is about another thousand feet higher and a different set of factors limit the trees.
THE ECOLOGY OF THE TIMBERLINE AND ALPINE
VEGETATION OF THE THREE SISTERS, OREGON

by

GEORGE WENDELL VAN VECHTEN III

A THESIS
submitted to
OREGON STATE COLLEGE

in partial fulfillment of
the requirements for the
degree of

DOCTOR OF PHILOSOPHY

June 1960
ACKNOWLEDGMENTS

The writer expresses his appreciation to various persons who have helped him during the course of the field work and the preparation of this dissertation. Particular thanks are due my major professor, Dr. H. P. Hansen, Professor of Palynology, under whose supervision the work was done as part of a larger project in the Three Sisters Wilderness Area under a grant from the National Science Foundation. Thanks are due to the National Science Foundation for a Research Fellowship for three years which was supported by the grant.

I also express my appreciation to Dr. John Thomas Howell, California Academy of Science, for checking the species of Carex and to Dr. John Merkle, Flint Junior College, for determination of the species of Gramineae. I am grateful to Miss La Rea Dennis for her time in obtaining herbarium materials for me.
<table>
<thead>
<tr>
<th>TABLE OF CONTENTS</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>GENERAL PHYSIOGRAPHIC POSITION</td>
<td>3</td>
</tr>
<tr>
<td>GEOLOGICAL HISTORY</td>
<td>9</td>
</tr>
<tr>
<td>RECENT VOLCANISM</td>
<td>11</td>
</tr>
<tr>
<td>RECENT GLACIATION</td>
<td>13</td>
</tr>
<tr>
<td>TOPOGRAPHY</td>
<td>17</td>
</tr>
<tr>
<td>CLIMATE</td>
<td>21</td>
</tr>
<tr>
<td>HISTORY</td>
<td>24</td>
</tr>
<tr>
<td>METHODS</td>
<td>27</td>
</tr>
<tr>
<td>SURROUNDING VEGETATION</td>
<td>29</td>
</tr>
<tr>
<td>ZONATION OF THE STUDY AREA</td>
<td>31</td>
</tr>
<tr>
<td>Th e Peak Zone</td>
<td>31</td>
</tr>
<tr>
<td>Glacial Zone</td>
<td>31</td>
</tr>
<tr>
<td>Morainal Zone</td>
<td>34</td>
</tr>
<tr>
<td>Ridge and Outwash Zone</td>
<td>34</td>
</tr>
<tr>
<td>Pumice and Outwash Flats Zone</td>
<td>35</td>
</tr>
<tr>
<td>Woods and Meadows Zone</td>
<td>36</td>
</tr>
<tr>
<td>DESCRIPTION OF THE VEGETATION</td>
<td>37</td>
</tr>
<tr>
<td>Th e Peak Zone</td>
<td>37</td>
</tr>
<tr>
<td>The Glacial Zone</td>
<td>38</td>
</tr>
<tr>
<td>The Morainal Zone</td>
<td>38</td>
</tr>
<tr>
<td>The Ridge and Outwash Zone</td>
<td>41</td>
</tr>
<tr>
<td>Pumice and Outwash Flats Zone</td>
<td>53</td>
</tr>
<tr>
<td>Woods and Meadows Zone</td>
<td>63</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>Page</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>The Concepts of Succession and Climax in Alpine Areas</td>
<td>74</td>
</tr>
<tr>
<td>Successional Trends</td>
<td>82</td>
</tr>
<tr>
<td>Evidence for Climatic Fluctuations</td>
<td>83</td>
</tr>
<tr>
<td>The Timberline and Treeline</td>
<td>86</td>
</tr>
<tr>
<td>Notes on the Flora</td>
<td>88</td>
</tr>
<tr>
<td>SUMMARY</td>
<td>90</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>93</td>
</tr>
<tr>
<td>APPENDICES</td>
<td>96</td>
</tr>
</tbody>
</table>
ILLUSTRATIONS

<table>
<thead>
<tr>
<th>Plate/FIG</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plate 1.</td>
<td>Topographic map of Three Sisters Area</td>
<td>5</td>
</tr>
<tr>
<td>Plate 2.</td>
<td>Map of Cascades</td>
<td>7</td>
</tr>
<tr>
<td>Fig. 1.</td>
<td>Collier Glacier</td>
<td>16</td>
</tr>
<tr>
<td>Fig. 2.</td>
<td>The recently formed &quot;esker&quot;</td>
<td>19</td>
</tr>
<tr>
<td>Fig. 3.</td>
<td>Zonation on South Sister</td>
<td>32</td>
</tr>
<tr>
<td>Plate 3.</td>
<td>Diagram of Zones on South Sister</td>
<td>33</td>
</tr>
<tr>
<td>Fig. 4.</td>
<td>Moraines on Middle Sister</td>
<td>39</td>
</tr>
<tr>
<td>Fig. 5.</td>
<td>Ridges on the south slope of South Sister</td>
<td>42</td>
</tr>
<tr>
<td>Fig. 6.</td>
<td>Krummholz alpine fir</td>
<td>43</td>
</tr>
<tr>
<td>Fig. 7.</td>
<td>Ericaceous mat in seepage zone</td>
<td>46</td>
</tr>
<tr>
<td>Fig. 8.</td>
<td>Windswept ridge between Middle and South Sister</td>
<td>47</td>
</tr>
<tr>
<td>Fig. 9.</td>
<td>Rocky plateau at 7500 feet</td>
<td>49</td>
</tr>
<tr>
<td>Fig. 10.</td>
<td>Trees growing on outwash</td>
<td>52</td>
</tr>
<tr>
<td>Fig. 11.</td>
<td>A pumice flat</td>
<td>54</td>
</tr>
<tr>
<td>Fig. 12.</td>
<td>Edge of Rock Mesa Lava Flow</td>
<td>55</td>
</tr>
<tr>
<td>Fig. 13.</td>
<td>Obsidian flat</td>
<td>58</td>
</tr>
<tr>
<td>Fig. 14.</td>
<td>The cinder desert</td>
<td>60</td>
</tr>
<tr>
<td>Fig. 15.</td>
<td>A blocky, gray lava flow</td>
<td>61</td>
</tr>
<tr>
<td>Fig. 16.</td>
<td>A lupine meadow</td>
<td>65</td>
</tr>
<tr>
<td>Fig. 17.</td>
<td>A sedge meadow</td>
<td>67</td>
</tr>
<tr>
<td>Fig. 18.</td>
<td>A snowdrift clearing</td>
<td>69</td>
</tr>
<tr>
<td>Fig. 19.</td>
<td>A dry south slope within the forest</td>
<td>70</td>
</tr>
<tr>
<td>Fig. 20.</td>
<td>The effect of snow creep</td>
<td>81</td>
</tr>
<tr>
<td>Fig. 21.</td>
<td>Snow shear on white bark pine</td>
<td>85</td>
</tr>
</tbody>
</table>
THE ECOLOGY OF THE TIMBERLINE AND ALPINE VEGETATION OF THE THREE SISTERS, OREGON

INTRODUCTION

Timberlines are of particular interest to the ecologist because the environment is rigorous and limiting factors assert themselves until only a few well adapted plants persist. Griggs (10, p. 12) stated that timberline species are at the limit of their range because at least one environmental factor is at a critical minimum and it should be possible to determine. Usually, however, the interaction of numerous factors is responsible for the presence or absence of a plant and single factor reasoning cannot be used. While the competition between plants is not usually as great as in lowland communities the severity of other environmental factors is much greater. Such factors may include deep snow, a short growing season, high winds causing snow abrasion and desiccation, lack of soil, and unstable topography.

It has been the object of this project to make an ecological study of the timberline and alpine vegetation of the Three Sisters Peaks of Oregon. I am particularly fortunate in having had the opportunity to work in this area. No timberline study of a high Cascade peak had been made previous to this despite the need for such investigations. Furthermore, there is probably no other area in North America which exhibits such a profusion of recent volcanism combined with glaciation.
in a magnificent alpine setting.
The Three Sisters are located in the central Cascades of Oregon at about 44° north latitude and 122° west longitude. Instead of following the usual pattern of well spaced peaks in a north-south line along the Oregon Cascades the Three Sisters form a close group (Plate 2). The summit of Middle Sister is less than a mile and a half southwest from the summit of North Sister and is connected to it by a ridge 9000 feet high. The summit of South Sister is only four and a half miles south from the North Sister, and the broad ridge between Middle and South Sisters is over 7500 feet elevation (Plate 1). The average height of the Cascade Range between the higher peaks is usually about 5000 feet. Thus instead of the isolated roughly circular peaks rising up from about 5000 feet the Three Sisters form an elongate high region running north and south about nine miles in length and several miles wide from which the peaks rise to over 10,000 feet. North Sister has a height of 10,085 feet; Middle, 10,047 feet; South, 10,358 feet. They are surpassed in height by only two other Oregon peaks: Mount Hood, 11,245 feet and Mount Jefferson, 10,495 feet.

Plate 2. Map showing the position of Three Sisters in relationship to the other Cascade peaks.

(Adapted from Williams (28, p. 38))
The Columbia basalt plateau stretches eastward from the Sisters at an elevation of about 3000 feet. To the west the maturely dissected lower Cascades extend about 40 miles, sloping downward to the southern end of the Willamette Valley and the Pacific Ocean, which is about 120 miles distant from the Three Sisters.
GEOLOGICAL HISTORY

The history of the Three Sisters Mountains began in early Miocene times about ten million years ago when the Western Cascades began to rise (28, p. 37-41). This uplift cut off the flow of moisture into eastern Oregon and the forests of this region died out by the close of the Miocene (6, p. 51). As the original Cascades continued to be uplifted and folded, a fault line was formed on the eastern edge of the mountains, along which the high Cascades began to rise in the early Pliocene. Throughout the Pliocene continued eruptions of lava built large volcanic cones with gradual slopes. In many cases, steeper pyroclastic cones were then built upon the older cones and in some areas this activity has continued nearly to the present.

In the case of North Sister, the activity probably ceased in the early Pleistocene. This mountain was so severely eroded by the Pleistocene glaciation that little evidence of its former cone shape remains. It is rugged and steep and the internal structure is exposed.

The volcanic activity of Middle Sister continued until later in the Pleistocene or if it ceased for a while it then renewed its activity later on. As a result, the glacial erosion has been less severe and the original cone shape is evident on the west side of the mountain. The erosion has been
sufficiently severe, however, so that the east side is a steep cliff and the present summit does not represent the original top.

South Sister continued to erupt long after the other two volcanoes became extinct and is the only one with a well preserved crater. The present crater has been formed over the remains of several older cones and is thought by Williams (28, p. 51) to have erupted within the last thousand years.

Hodge (15) proposed the theory that a high mountain, Mount Multnomah, once stood on the present site of the Three Sisters and that its collapse or destruction by explosion formed a large caldera. He believed that North Sister and a number of lesser peaks in the area are part of its rim, and that Middle and South Sisters were built up upon its floor. This theory became quite popular among laymen familiar with the area despite the lack of substantiating geological evidence. Williams (28, p. 46-47) clearly demonstrated the fallacies in Hodge's hypothesis which is not even considered seriously by present day geologists.
Volcanic activity has continued in the Three Sisters region to within the last few hundred years. A number of small lava flows have issued from around South Sister. These range in size from a few acres to about six tenths of a square mile and were of a viscous, blocky nature. Their fresh appearance is startling to the observer and Williams concludes that they are not over two or three centuries old. Another flow starting near North Sister flowed west down the White Branch valley for seven miles and also flowed north until it mingled with the 65 square-mile McKenzie lava flow which is one of the largest recent igneous floods in the United States.

A pumice shower buried the southern end of the study area under varying depths of pumice and produced thousands of acres of pumice flats around South Sister, such as Wikiup Plain. According to Williams, the hummocky appearance of Wikiup Plain is due to an old lava flow which has been buried by the pumice fall. The source of the pumice was a vent which is now buried by the Rock Mesa lava flow and the eruption is presumed to have occurred just previous to the outpouring of this flow.

A number of scoriaceous cinder cones occur in the area, including such well formed comes as Le Conte Crater, Cinder Cone and Yapoah Crater (see map). A series of little scoria
cones extend between Cinder Cone and Yapoah Crater north of North Sister. They form the Ahalapam Cinder Field, a rolling black desert of cinders two and one half miles long and three quarters of a mile wide. Despite these numerous examples of recent volcanism there is now no sign of current activity.
RECENT GLACIATION

There is considerable evidence that after the Pleistocene glaciation, a warm dry period existed from about 8000 to 4000 years ago, and that the present mountain glaciers have formed since then (11, p. 119-120). Furthermore it appears that this glaciation reached a maximum only about 200 years ago. Studies of Eliot Glacier on Mount Hood (18, p. 91-94) show that a recent maximum advance occurred in 1740. This is confirmed by ages of trees at the trimline and by a tree actually scarred by the ice and partially pushed over before the ice retreated. Studies in the forest beyond the trimline show that no more extensive glacial advance had occurred for at least 650 years previous. Since the maximum advance 200 years ago the glacier has retreated 2000 feet and has left several ridges in its wake which represent slight hesitations or advances. Similar glacial maxima occurred in Alaska, Europe and other parts of the world. European records show that the advance became noticeable as little as one hundred years before it reached a maximum around 1750. This is confirmed by radiocarbon dating of overwhelmed and buried trees now exhumed in Alaska. Trees 600 years old growing below the trimline of Mendenhall glacier in Alaska are rooted on an older buried generation. This indicates that at least a thousand years and very likely several thousand elapsed since
a previous ice advance. Thus it seems that when the warm
dry period ended about 4000 years ago glaciers formed in the
mountains and that they recently underwent a sudden advance
reaching a maximum about two centuries ago. Since then a
retreat has been in progress. Such a glacial advance occurred in the Sisters area and although there is no trimline or
other evidence for exact dating it may have been concurrent
with the advance of Eliot Glacier on Mount Hood, 88 miles to
the north. As will be shown later, the influence of this
 glaciation has had a pronounced effect on the alpine vegeta-
tion of the Three Sisters.

There are about 15-18 glaciers in the area now, in-
cluding two on Broken Top, a severely eroded cone four miles
southeast of South Sister. The glaciers in the area have
not been studied accurately and the status of some large
snowfields is uncertain. The glaciers have a total area of
about 2260 acres and form the largest ice field in the United
States as far south as this. In addition, numerous permanent
snowfields, some many acres in extent are found in the area.
Unlike the glaciers of Glacier National Park which have
shrunk 40 to 75 percent in area since 1900 the glaciers in
the Sisters area have not retreated anywhere near this amount.
In some cases they are still within a hundred yards of the
moraines they formed at maximum advance two centuries ago.
Collier Glacier, the largest glacier in Oregon, is one and one half miles long and half a mile wide (Fig. 1).
Figure 1. Collier Glacier with Middle Sister in the background and the lower slopes of North Sister on the left. The lowest tongue of this mile and a half-long glacier is at about 7300 feet and its upper snowfields are at 9000 feet.
TOPOGRAPHY

One of the most striking features of the alpine zone of the Three Sisters is the geomorphic instability of the area. The silence of the wilderness is constantly being broken by the sound of falling rock, whether it be the rumble of a slide on one of the peaks as it sends a column of dust into the sky, or just the sound of a stone rolling down one of the many talus slopes. The recent glacial advance though of very short duration formed tremendous moraines. Even now erosion from the numerous glaciers and even the larger snow-fields is severe and rapid because of the loose unconsolidated materials of which the peaks are built. Much of the slopes are covered with moraines and outwash. The great fields of boulders and gravel in some cases extend to the edge of the forest.

The moraines of some of the glaciers contain buried ice and its slow melting causes periodic collapsing and sliding of the huge moraines which are 200 feet high in some cases. At the terminal moraine of Collier Glacier abutting against Cinder Cone, a large mass of deeply buried ice became exposed in the summer of 1959 as a result of a slide. This ice had been left there when the glacial maximum occurred 200 years ago. Not far away the melting of subterranean ice causes collapse of soil surface engulfing the vegetation.
Numerous sharp ridges and deep canyons whose walls are composed of loose materials radiate away from the summits frequently making travel very difficult. Crumbling precipitous cliffs frequently block one's way. The entire west face of North Sister is a talus slope and the east side is a series of cliffs and chutes largely too steep even for talus. Numerous cirques have gouged the slopes of all three mountains.

In some areas streams are causing severe erosion and in other places are depositing great loads. In the winter of 1957-1958 an esker-like formation was deposited in a small valley (Fig. 2). It was several hundred yards long and up to 15 feet high and contained boulders as large as 4 feet in diameter. It was apparently formed by deposition from a stream flowing in a channel over a deep snowpack in the valley. Later melting of the snow deposited the debris from the stream channel in a serpentine ridge down the valley. Where trees happened to be in the path of the esker they were damaged many feet above the surface of the esker while trees on either side were not damaged even at ground level, thus proving the mode of formation. No other such case has been recorded in the literature so far as the writer knows.

When erosion is not actively taking place as a result of glacial or stream action there is still movement due to the steepness and the unconsolidated nature of the slopes.
Figure 2. The "esker" which was formed in the winter of 1957-1958. Its height in the background is 10 feet above the surrounding ground.
Frost action, avalanches, and the creep of the heavy winter snowpack contribute to the downward movement of materials. Stable areas are largely confined to rounded ridgetops, benches, and other comparatively level areas which have not been covered by moraines or outwash.

There are a number of lakes in the area most of which are on the east side of the mountains. Many of the lakes lie between present-day glaciers and their terminal moraines. Most of them appear to be young. One lake was drained and re-formed twice in three years as a result of erosion and slides.

In summary it can be said that the physiography of the area is in a very dynamic state and although there has been very recent volcanic activity, the current processes involve degradation, and as a result there is a high degree of geomorphic instability.
The climate of Oregon is of a marine type, caused by the prevailing westerly winds off the Pacific Ocean. East of the Cascade range the continental influence is felt to a certain degree. Although the precipitation is largely cyclonic in origin (25, p. 1085-1086), its geographical distribution is greatly affected by topography. As the moisture-laden winds move across the Coast and Cascade Ranges, heavy precipitation is produced on their westward slopes. Annual totals reach 130 inches in parts of the Coast Range and at least 80 in the Cascades. There are no weather stations in the Cascades over 4000 feet and it is possible that precipitation totals might be higher in certain locations above this level. The precipitation in western Oregon is decidedly seasonal with only five per cent falling during the summer months.

In the study area, above 6500 feet, most of the precipitation falls as snow. Lack of weather stations at higher altitudes precludes reliable data on snow depths in the Three Sisters area. At Crater Lake, 70 miles to the south, the snowpack reaches an average depth of 12.5 feet in March at an elevation of 6500 feet. The average cumulative total there is over 50 feet and as much as 18 feet have been recorded on the ground. At Timberline Lodge (elevation 6000 feet) on

---

2 Personal communication with Fred. J. Novac, Assistant Superintendent, Crater Lake National Park, Oregon.
Mount Hood, 80 miles to the north, the snowpack normally reaches a depth of 21 feet and occasionally a 30 foot depth. It is quite probable that the snow depths in the Three Sisters area are as great as in these places and it is also likely that at higher elevations there is a considerably greater accumulation of snow. No noticeable differences in snow depth between the east and west slopes of the Sisters were noted. Although the precipitation decreases rapidly eastward from the summits this effect on the depth of the snowpack is not noticeable close to the Three Sisters, probably because snow is carried over the divide by the prevailing westerly winds.

The snowpack within the study area except on windswept ridges usually persists until late in June, but by the end of July it has largely melted. There may be considerable variation in the time of melting depending on location, snow depth, and spring temperatures. Snow may occur any month of the year even as low as 6500 feet.

Because of the modifying effect of the moist marine air, temperature extremes are rare. Days in winter with zero readings are infrequent and the lowest temperature at Crater Lake since 1927 was only minus 18 degrees. Temperatures frequently rise above freezing even in the coldest

---

3 Personal communication with Bryce Lausch, Assistant Ranger, Mount Hood National Forest, Oregon.
months and some rain occurs as high as 7000 feet in midwinter. As a result, the snowpack has a high moisture percentage and is well compacted. Summer temperatures frequently reach 70 degrees in the day although the nights are cool and occasionally reach freezing.

During the summer months the humidity is usually quite low. Although orographic fogs sometimes do occur, they usually are of short duration. Summer rainfall is slight and is usually limited to brief showers. In winter the humidity is quite high most of the time, and long periods of strong, cold, desiccating winds are almost nonexistent.
The study area lies within the Three Sisters Wilderness which is part of the Willamette and Deschutes National Forests. The national forests were created in 1908, from land that had been previously placed in "forest reserves" by President Cleveland in 1893. The eastern part of the Three Sisters Wilderness lies in the Deschutes National Forest which was named in 1908 and the western part of the area lies in the Willamette National Forest which was formed from the combination of the Santiam and Cascade forests in 1933.

The Three Sisters Primitive area was established by the Forest Service in 1937. It included 191,100 acres along the backbone of the Cascades and included Broken Top and the Three Sisters. The next year 56,000 acres west of Horse Creek were added to this area. This primitive area, and others, was established by the Forest Service to segregate and protect undeveloped primitive country pending further study as to its primary public value.

In 1955 the Three Sisters Primitive Area was reclassified as wilderness. At the same time the Three Sisters Game

---

4 Information on the history of the Three Sisters Area was obtained from Frank B. Folsom, Assistant Regional Forester, Pacific Northwest Division of U. S. F. S.
refuge, established in 1929, was eliminated. About 53,000 acres of that part of the primitive area that was west of Horse Creek was not included in the wilderness and was reclassified as a multiple use area. Minor changes were made on the remainder of the borders so that the total area now is 196,708 acres or about 307 square miles.

As a wilderness area it is protected from commercial development or exploitation. No roads may be built and no motorized equipment of any sort is permitted. Trails are maintained by the Forest Service in many parts of the wilderness area. The major use of this area is recreation. Climbers, fishermen, hikers, campers, and others who enjoy the benefits of the unspoiled outdoors now probably number several thousand per year and the numbers are increasing.

In addition, this area is ideal for scientific research and also is important as a watershed.

The only use made of this region other than recreation, before it became a primitive area, was grazing. Sheep grazing started in the Three Sisters area in the 1870's. The normal season was from about June 15 to September 15. There was also some cattle-grazing on the east side of the mountains. Overstocking was common prior to the formation of the national forests in 1908. From then on, livestock numbers were limited and seasons were established. Grazing continued
until about 1932 near North and Middle Sisters. In 1938 the area near the Skyline Trail was closed to grazing and finally in 1944 sheep-grazing was eliminated from the South Sister area. There has been a very limited amount of cattle-grazing in the Deschutes National Forest since the sheep were removed in 1932.
METHODS

The field work was done during parts of the summers of 1957, 1958, and 1959. In the first two summers only a limited amount of time was available in August and most of the field work for those two summers was done in the first half of September. In 1959 I was fortunate in having all of August to devote to the field studies, especially since bad weather limited the September work. Because the Three Sisters Mountains are in a wilderness area with no roads, it was necessary to spend considerable time backpacking in supplies and equipment. This was especially true in some of the more remote parts far from trails. Weekend trips were made in October of each year to observe late fall conditions and one trip was made in the middle of June, 1958, over deep snow. In June, 1959, an aerial reconnaissance trip was taken over the Three Sisters and photographs of snow drift patterns in relation to trees were made.

The study area is delimited by the 6500 foot contour line which surrounds the peaks enclosing about 35 square miles, much of which is above timberline. This line passes through some of the upper parts of the heavy forests which flank the mountains.

Over seven hundred sample plots of the vegetation were taken. These were one meter square quadrats in which the percent cover of each species was estimated. The elevation, soil,
slop, exposure, and any other pertinent data for each plot were recorded. The plots were placed every 75 feet along com-
pass lines of several miles in length which extended from in the forest to well above the tree line. It is realized that in so large and varied an area an analysis of the data from such plots would not have statistical significance. However, they do indicate trends and help prevent complete subjectivity in observations, and as Cain (5, p. 245) points out, "Plot studies serve to direct one's attention to less attractive but more important plants in a community."

The primary means of gathering data was by the use of reconnaissance trips into as many parts of the area as time permitted. Field notes were supplemented by numerous photographs in color and black and white.

A plant collection was made which, it is hoped, includes all, or nearly all the species of vascular plants found in the alpine regions of the Three Sisters. No extensive collect-
ing had been done previous to this although a few plants have been collected along the trails. This collection num-
bering about 800 specimens has been deposited in the Oregon State College Herbarium at Corvallis, Oregon. The floras listed in the bibliography were used in the determination of the plants. The grasses were checked by Dr. John Merkle and the species of Carex by Dr. John Thomas Howell.
SURROUNDING VEGETATION

A great belt of coniferous forest covers the western flank of the Cascade range extending down to the grasslands of the Willamette Valley. The lower part of this forest is coextensive with the Humid Transition zone of Merriam's life zone scheme. The predominant tree is Douglas Fir (*Pseudotsuga menziesii*), and other species such as hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*), and true firs (*Abies*) are common. The Canadian zone is characterized mainly by lodgepole pine (*Pinus contorta*) at 4500 to about 6000 feet. There is very little Douglas Fir in this zone and silver or lovely fir (*Abies amabilis*) and alpine fir (*A. lasiocarpa*) are often quite common. This is the most poorly defined of Merriam's life zones in this region. The highest forest zone is the Hudsonian which is characterized by stands of mountain hemlock (*Tsuga mertensiana*) in which there is frequently some lovely fir and a little alpine fir. Whitebark pine (*Pinus albicaulis*) is found in the upper part of this zone. It is the upper part of this zone and the still higher Arctic-Alpine zone with which this paper is concerned.

The forest belt on the east slope of the mountains is much narrower than on the west. Below the Canadian zone a band of ponderosa pine (*Pinus ponderosa*) defines the Arid
Transition zone, which to the east gives way to juniper woodland which in turn grades into the sagebrush of the Upper Sonoran Zone.
ZONATION OF THE STUDY AREA

The study area may be divided into six zones based primarily on physiographic features (Fig. 3, Plate 3). These are: 1. Peak Zone, 2. Glacial Zone, 3. Morainal Zone, 4. Ridge and Outwash Zone, 5. Pumice and Outwash Flats Zone, 6. Woods and Meadows Zone.

1. **The Peak Zone.** This zone occurs entirely above the glaciers and large snowfields. It extends from the cirque walls of the past and present glaciers to the summits of the mountains. It is mostly above 9500 feet elevation and there are steep ridges and cliffs in many places and the surface is covered with loose rock except where it is very steep. This zone lies largely above the effects of glacial erosion and the surface is a little more stable than in some of the zones below.

2. **Glacial Zone.** The glacial zone extends from the lower edge of zone one to as low as 7400 feet in places. Within it lie all the glaciers and many large snowfields. Between the glaciers are large rocky ridges extending in a radial pattern down from the peak zone. The ridges are frequently narrow and sharp although sometimes they are wide and may represent part of the original surface of the volcanic cone. This is especially true on the less dissected South Sister.
Figure 3. The southeast side of South Sister showing zones 1 through 5. Compare with Plate 3. Below the Peak Zone three glaciers are seen, Lewis Glacier on the left, Prouty on the right and a small unnamed one in the center. The pointed hills below the glaciers are the moraines which blend with the outwash below. The ridges sticking through the outwash are lighter in color. Trees are seen on the ridge tops but not on the talus-covered sides of the ridges or on the outwash. Beyond the hill in the foreground is an outwash flat visible at left. The vertical distance from this flat to the summit is 3800 feet and the horizontal distance is nearly two miles.
Plate 3. Zonation on the southeast side of South Sister. Compare with Figure 3. P, the Peak Zone; G, the Glacial Zone; M, Moraines; O, Outwash; R, Ridges. Beyond the hill (H) in the foreground is an aluvial flat (F) seen at left.
3. **Morainal Zone.** This is a narrow zone immediately below the Glacial Zone which consists of glacial till which was deposited in an irregular narrow band when the glacial maximum occurred about two centuries ago. This till is a mixture of materials ranging in size from dust to large boulders. The moraines are quite large, being up to 200 feet high in some cases. Some are underlain by stagnant ice whose slow melting causes periodic sliding. This is especially prevalent in the moraines of Collier Glacier. The slopes of most moraines are so steep and loose that travel over them is most tedious and sometimes impossible. Most of the present glaciers are within a few hundred feet of the large moraines. A notable exception is Collier Glacier which has retreated several thousand feet since its maximum of 200 years ago. The area between the ice front and the moraine frequently contains a lake and sometimes there are small moraines within the big one which have been formed more recently. The morainal zone is the most unstable of those in the study area.

4. **Ridge and Outwash Zone.** This is the widest zone and it extends down to 6500 feet in some places. A large amount of material has been carried down the sides of the mountains from the moraines above. Creep, avalanches, and stream erosion account for this action which is going on at the present time, and a mantle of boulders, gravel, and sand clothe much of the slopes except where the ridges protrude.
There is no soil development on this fresh unstable material. The ridges, in contrast, are much more stable and frequently have limited soil development and a much greater abundance of vegetation than on the outwash slopes to either side. Most of the outwash material appears to have been deposited since the recent glacial advance of the eighteenth century. The upper ends of the outwash valleys blend with the glacial moraines. In a few places logs occur in this material above where trees now exist and they are presumed to be from trees that were overwhelmed by outwash as a result of this recent glacial activity.

5. **Pumice and Outwash Flats Zone.** This zone lies between the steep upper slopes of the mountains and the forested lower slopes. Included in this somewhat discontinuous zone are thousands of acres of pumice flats which are especially prevalent around South Sister. In some places these flats extend well below the 6500 foot limit of the study area. Numerous outwash fans occur which are composed of finer materials and have a much more gentle slope than the outwash between the ridges in the zone above. They are covered with small boulders, cindery gravel, sand, and dust and may contain pumice or blend with pumice flats. Also included in this zone is the cinder field to the north of North Sister, and a field of obsidian chips northwest of Middle Sister. The majority of the recent lava flows are found within this zone although not considered
part of it. This zone is characterized by having finer materials than the above zones, by being flat or only moderately sloping and by having little woody vegetation.

6. Woods and Meadows Zone. The upper limits of this zone are a little over 6500 feet in places and it extends to well below the study area. Meadows, open areas in the forest covered with vegetation, are common at the edge of the study area but decrease in number as the elevation becomes less. There is a thin soil over most of this zone and a more or less continuous cover of vegetation unlike the zones above. The trees are well developed and the meadows are frequently quite lush. The greatest diversity of habitats and largest number of plant species are found in this lowest zone.
DESCRIPTION OF THE VEGETATION

The vegetation will be described in detail by zones. The lower zones will be classified into habitats and these described within the zone. The upper zones support little vegetation and the description will entail little more than a plant list. It will be noted that the species inhabiting each zone differ considerably. The number of species and the vegetation cover increase rapidly in the lower zones as the number of habitats increases and the environment becomes more favorable for plant growth.

1. The Peak Zone. Plants in this zone are small and occur mainly as small individuals or tufts which are seldom over ten centimeters high. The plant cover probably occupies less than one tenth of one percent of the surface and from a distance this zone appears to be lifeless. There is little moss and practically no lichen present. In little hollows and in the protection of rocks grow *Hulsea nana*, *Draba aureola*, and *Claytonia bellidifolia*, which are low, compact fleshy plants with large taproots. They frequently become nearly covered as the loose material in which they grow shifts down the steep slopes and around the plants. *Polemonium elegans* forms dense mats which will occasionally reach two decimeters across. It grows both on the loose cindery material and in cracks in rocks. *Phacelia hastata* was occasionally noted and
one tiny specimen of Achillea millefolium was found growing in a crack in a cliff at 10,000 feet. Two small tuft-forming grasses grow in loose material, Trisetum spicatum and Poa pringlei. The sedge, Carex breweri, occasionally occurs in moister spots.

2. The Glacial Zone. Very little vegetation occurs here, probably less than in any other zone. Here are found most of the plants of the Peak Zone except Claytonia bellidifolia and Polemonium elegans. The most typical plant of this zone, Oxyria digyna, grows on moist cliffs and cirque walls near glaciers and permanent snowfields, and is seldom found elsewhere. Arabia lemmonii and Penstemon davidsonii occasionally occur in this zone.

3. The Morainal Zone. Similarly to the above two zones the vegetation of the moraines is very sparse (Fig. 4). Although the Morainal Zone extends as low as 7000 feet on the north slope of North Sister there is little more vegetation here than on the moraines at 9000 feet on the south side of South Sister. This is due largely to the great instability of the morainal material.

Occasionally in scattered clumps on the moraines are Phacelia hastata, Senecio fremontii, Collomia larsenii, Hulsea nana, Epilobium clavatum, Sitanion hystrix, Trisetum spicatum, Poa pringlei, and Carex breweri. In moist, cold sites such as steep north facing slopes and under boulders there are often
Figure 4. Moraines on the east side of Middle Sister, North Sister in background. Krummholz white bark pine are seen on the ridge in the foreground.
found Cardamine bellidifolia, Saxifraga tolmiei, and occasionally Oxyria digyna. Penstemon davidsonii forms somewhat woody mats about a decimeter thick and up to several decimeters in diameter. In one place Juncus mertensiana and Mimulus lewisii grow at the edge of a glacial lake in which ice-bergs persist all summer.

South of Cinder Cone is an interesting area where nearly level, stagnant, glacial ice is covered with several feet of morainal material. The ground surface is quite hummocky here and slumps and cracks and ice caverns are evident in many places. As the ice slowly melts, the over-burden of till and its vegetation is engulfed into the enlarging caverns below. The vegetation here includes most of the species mentioned before as frequently occurring on moraines as well as Salix geyeriana, S. sitchensis, Juncus mertensianus, Mimulus lewisii, Arabis puberula, Phleum alpinum, and Smelowskia calycina.

Ice occurs under morainal material in several other places but this is the only location where vegetation is growing over a permanently frozen surface.

Of unusual occurrence in this normally treeless zone was a small Engelmann spruce (Picea engelmanni) at 8200 feet northwest of Middle Sister near Thayer Glacier. It was about 25 cm. tall, in healthy condition, and was growing on a ridge of till in a hollow entirely protected by large boulders.
This was far beyond the treeline and miles from the nearest known spruce which are usually limited to moist places in the forests far below the lowest zone of the study area.

4. Ridge and Outwash Zone. This is the highest zone in which trees are normally found (Fig. 5). They are usually restricted to the ridges and are either of a stunted or krummholz form. The highest trees in the area are white bark pine (Pinus albicaulis) which are found at about 8300 feet on the south slope of South Sister. The altitudinal limits of the trees vary considerably throughout the area and in general are below 8000 feet. The white bark pine is the most common tree on the upper parts of the ridges while mountain hemlock (Tsuga mertensiana) is the predominant tree on the lower parts of the ridges between about 6500 and 7000 feet. Alpine fir (Abies lasiocarpa) is found to a lesser extent along the ridges. It frequently has a krummholz form which often is about half a meter thick (Fig. 6). Layering or vegetative propagation occurs in these mats which frequently surround the base of a larger and less deformed tree. Timber atolls as reported by Griggs (9, p. 554) do not occur in this area.

Sometimes the ridges are narrow knife-like edges of rock exerted through the outwash and snow patches on either side. Under these conditions the following plants frequently grow in crevices in the rock and form dense tufts: Erigeron compositus, Silene suksdorfii, Penstemon davidsonii and
Figure 5. South slope of South Sister at about 7800 feet. Outwash is seen as a darker finer material between the talus-covered sides of the ridges. It is continuous with the moraines above out of the picture. Picture taken August 4.
Figure 6. Krummholz alpine fir growing on a ridge at about 7300 feet. The dense mats are mostly less than a meter high and spread by vegetative reproduction. The small upright stems are as much as 75 years or more old.
Trisetum spicatum. Also frequently found on the high ridges are stunted white bark pine, Phyllodoce empetriformis, Carex breweri, Anemone occidentalis, A. drummondii, and Lutkea pectinata. Where the ridges are wider and more rounded the number of species is greater. There are also more species with decreasing altitude. A thousand feet below the upper limits of the Ridge and Outwash Zone the following frequently occur on the ridges: Phyllodoce empetriformis, Vaccinium myrtillus, Carex breweri, Trisetum spicatum, Sitanion hystrix, Castilleja arachnoidea, Anemone occidentalis, Eriogonum marifolium, Lutkea pectinata, Aster alpigenus, Solidago spathulata, Penstemon davidsonii, Luzula glabrata, Achillea millefolium, Juniperus sibirica, Arctostaphylos nevadensis, Holodiscus glabrescens, white bark pine, mountain hemlock, and alpine fir. Not all of the above species are likely to be found in any one location. Also a number of plants appearing on ridges are not listed because they are not as generally distributed as the above species. An example of this is Sibbaldia procumbens which was noted only in four widely scattered places.

Ages of trees determined on one ridge ranged up to 300 years for a mountain hemlock fourteen inches in diameter, and 427 years for a 24-inch white bark pine. Many of the trees have large, twisted and often prostrate trunks from which numerous shoots arise. The centers are often decayed which prohibits age determination. The above figures indicate, however,
that the trees have occupied these ridges for a long time and were growing when outwash was being deposited on either side, sometimes within a few feet of the trees during the glacial advance about 200 years ago. On most ridges, seedlings, saplings and young trees are found as well as old trees and dead remains.

In some places the topography is such that rather extensive areas escaped being covered by outwash. Several such areas are on the south slope of South Sister. They are covered with pumice and support a flora somewhat similar to the pumice flats of the zone below. Such plants as *Eriogonum pyrolaefolium*, *Spraguea umbellata*, *Juncus drummondii*, *Carex breweri*, *Castilleja arachnoidea*, and *Lomatium angustatum* are common in these pumice areas. Trees are usually found on rises which become free of snow earlier than elsewhere. Hollows tend to have a greater plant cover and more *Carex* and *Juncus*.

Where hollows are large and snowbanks linger into late summer ericaceous mats may occur in the zone of seepage below the bank (Fig. 7). Here the ground is likely to be almost entirely covered with a layer of *Phyllodoce empetriformis* and *Cassiope mertensiana* in which grow a few herbs such as *Castilleja parviflora*, *Hieracium gracile* and several species of *Carex*.

Another large area free from outwash is the high windswept saddle between Middle and South Sisters (Fig. 8) which is from about 7200 to 7800 feet in elevation. Rounded, polished,
Figure 7. An ericaceous mat growing in the seepage zone of a snowbank. The plants in the foreground are mainly *Cassiope myrtillus* and *Phyllococe empetriformis*. Up-slope from the snowbank is dry pumice-flat type vegetation. This type of situation is uncommon since most draws where snowbanks remain are filled with outwash.
Figure 8. A windswept ridge north of South Sister at about 7500 feet elevation. The trees are mostly white bark pine. The treeless hollow to the left of center contains a large snowbank until midsummer. Moraines and outwash are visible at right.
and scratched rock outcrops and areas of boulders and gravel remain from the Pleistocene glaciation. The rocks here have weathered to a brown color unlike the rocks of the moraines and the outwash between the ridges which have a fresh gray appearance. The vegetation of this region is very sparse except in certain areas where stunted white bark pine trees grow (Fig. 9). These sites are usually on the tops and west sides of plateaus and ridges and observations from the air in June 1959, showed that these areas were free of snow while elsewhere there was still a deep cover. In the treeless expanses the following plants grow in scattered clumps: *Eriogonum pyrolae folium*, *E. marifolium*, *Aster alpigenus*, *Lomatium angustatum*, *Castilleja arachnoidea*, *Raillardella argentea*, *Lutkea pectinata*, *Polygonum newberryi*, *Phyllo doce empetriformis*, *Penstemon davidsonii*, *Antennaria alpina*, *Agrostis thurberiana*, *Trisetum spicatum*, and *Sitanion hystrix*. In moist microhabitats such as hollows where snow lingers late are sometimes found *Saxifraga tolmiei*, *Cardamine bellidifolia*, *Carex breweri*, *C. straminiformis* and *Juncus mertensianus*.

White bark pine and a smaller amount of mountain hemlock and alpine fir are the only arborescent species present. The pines frequently have trunk diameters of more than one foot but are almost uniformly about ten feet in height. This may represent the average snow depth in the more exposed places where the trees grow. Alpine fir frequently forms krummholz mats less
Figure 9. Plateau between North and Middle Sisters at about 7500 feet. This material was probably deposited in the Pleistocene. In the foreground are sedges. *Lutkea pectinata* is seen beyond them. The trees are white bark pine.
than a meter high. The mountain hemlocks are often stunted but not matted. Most of the plants of the open areas also occur among the trees. In addition, where a little soil and needle duff occurs Vaccinium myrtillus, Juniperus sibirica, and Sorbus occidentalis are found. Phylloco empetriflora and Penstemon davidsonii are much more abundant near the trees than elsewhere.

The outwash supports much less plant life than the ridges and other areas not covered with outwash. Usually there is no woody vegetation on this loose unconsolidated material between the ridges. Species common to the outwash include: Eriogonum pyrolaefolium, E. marifolium, Raillardella argentea, Senecio fremontii, Spraguea umbellata, Aster alpigenus, Hulsea nana, Castilleja arachnoidea, Lutkea pectinata, Polystichum lonchitis, Hieracium gracile, and Trisetum spicatum. Many large snowbanks occur on the outwash which persist well into the summer or exist permanently. Frequently the only plants growing near them are Cardamine bellidifolia and Saxifraga tolmiei. In moist draws such plants as Juncus mertensianus, J. drummondii, Luzula wahlenbergii, Carex breviflora, Castilleja parviflora, and Epilobium alpinum frequently occur.

A few trees are sometimes found on the outwash. They are usually mountain hemlock growing on outwash that is less steep at the lower edge of the Ridge and Outwash Zone. They are all quite young, being generally under 50 years. In one
unusual instance east of Middle Sister there are small trees growing on a gradually sloping wide outwash nearly to the foot of the moraines which come down to about 7000 feet here (Fig. 10). They are up to 30 feet tall and up to ten inches in diameter and have a maximum age of about 200 years which indicates establishment right after the deposition of the outwash. The outwash material here is quite stable because of a gentle slope and lack of large snowfields, or severe erosion. Most of the trees here are mountain hemlocks with a few alpine fir and white bark pines. In addition a few lodgepole pines (Pinus contorta) were growing in this area although they are normally found well below the study area. Some soil and needle litter has collected under the larger trees of this region in which the following plants are found: Phyllodoce empetriformis, Lutkea pectinata, Luzula glabrata, and Vaccinium myrtillus. There is quite a bit of open gravelly ground between the trees where plants typical of open outwash are found such as: Spraguea umbellata, Eriogonum marifolium, E. pyrolaefolium, Raillardella argentea, Lomatium angustatum, Juncus drummondii, and Trisetum spicatum.

In summary, the Ridge and Outwash Zone typically has much more vegetation on ridges and other outwash-free areas than on the loose outwash where plant life is sparse and woody plants usually are absent.
Figure 10. The area where trees growing on outwash approach the base of the moraines on the east side of Middle Sister. These trees started growing soon after the outwash was deposited about 200 years ago. The summit of Middle Sister (right) is about one mile beyond and nearly 3000 feet higher than these moraines. Part of Diller Glacier is visible (center).
5. **Pumice and Outwash Flats Zone.** The flats, composed of pumice or fine outwash or a mixture of the two, are characterized by their nearly level topography, their dry, porous, uniformly textured surface, and by the lack of woody vegetation (Figs. 11 and 12). The flats form a discontinuous zone between the Ridge and Outwash Zone above and the Woods and Meadows Zone below. Sometimes the flats are completely surrounded by the mountain hemlock forest with usually a sharp transition between. Although the composition of the vegetation of the flats is varied, the general appearance is quite similar. There are clumps or individuals which are fairly regularly spaced with a bare surface between, and with the plant cover usually not over 25 percent and frequently much less.

Some of the large pumice flats south of South Sister are predominated by *Juncus drummondii*, *Sitanion hystrix*, *Carex breweri*, *Eriogonum marifolium*, *E. pyrolaefolium*, and *Lupinus lepidus*. Also commonly found here are *Penstemon procerus*, *Raillardella argentea*, *Trisetum spicatum*, *Spraguea umbellata*, *Castilleja arachnoidea*, *Polygonum newberryi*, *Lomatium angustatum*, *Antennaria alpina*, *Aster alpigenus*, *Hieracium gracile*, *Microseris alpestris*, *Agrostis variabilis* and *Carex breweri*. In this area, in addition to the flats and very similar to them, there are wide flat-topped ridges covered with pumice. The west sides of these north-south oriented ridges are forested with mountain hemlock, while on the east sides where the
Figure 11. A pumice flat. The regularly spaced plants in the foreground are *Polygonum newberryi*. Some sedges are growing along the stream in the background.
Figure 12. The edge of the Rock Mesa lava flow with Le Conte Crater in the background. Part of the Wikiup Plain pumice flat is in the foreground where *Polygonum newberryi* and *Juncus drummondii* form the most noticeable clumps. Mountain hemlock grows only on the north side and rim of the 400 foot high pumice covered cinder cone.
snowbanks persist late in the season, trees are largely absent.

Nearer North and Middle Sisters there is less pumice and it is finer and of sand-like texture. It is often mixed with fine outwash material. These flats tend to have much less Juncus and Carex and more Polygonum newberryi. The latter is in fairly homogeneously spaced bunches and it is commonly associated with Eriogonum pyrolaefolium, Spraguea umbellata, Aster alpigenus, Castilleja arachnoidea and Microseris alpestris.

There are several lakes within the Pumice and Outwash Flats Zone including the Green Lakes and Moraine Lake. There are no plants visible in the water and the hydrarch succession so commonly associated with lakes of lower regions is absent here. Surrounding these lakes is a narrow beach of fine pumice often less than a meter wide. Above the beach there is usually a narrow band of dense vegetation growing on a mass of accumulated organic matter held together with roots. This may be several decimeters thick but is usually less. The vegetation decreases rapidly away from the lake shore and in some places as little as a meter or two from the beach there is the usual dry pumice-flats vegetation. The dense lakeshore band of vegetation is composed mainly of such plants as Carex spectabilis, C. breweri, C. nigricans, C. straminiformis, Juncus mertensianus, J. drummondii, Trisetum canescens, Agrostis variabilis,
Poa epilis, Luzula wahlenbergii, and Lutkea pectinata. Also found and sometimes having local dominance are Vaccinium occidentale, V. myrtillus, Kalmia polifolia, Phyllodoce empetrifolia, Gaultheria humifusa, and often some moss. Frequently present but only as scattered individuals are: Castilleja parviflora, Aster alpigenus, Agoseris glauca, Senecio subnudus, S. triangularis, Ligusticum grayi, and Veronica wormskjoldii.

About two miles northwest from Middle Sister is a glaciated plateau covered with black obsidian chips (Fig. 13). In numerous places glacially rounded outcroppings of pure obsidian are exposed and the dusty, sandy ground between them is covered with a layer of chips mostly less than a decimeter in size. These are scattered about or may occasionally form a layer up to about five centimeters thick on the surface. It appears as if the fine material containing pieces of obsidian was deposited as a ground moraine and then through erosion, probably mostly wind, dust was removed leaving a layer of obsidian on the surface similar to desert pavement. Here occur scattered plants typical of flats such as Eriogonum marifolium, E. pyrolaefolium, Polygonum newberryi, Castilleja arachnoidea, Aster alpigenus, Antennaria alpina, Spraguea umbellata, and Juncus drummondii. Also found, especially near the rock outcroppings, are Lutkea pectinata, Castilleja parviflora, Penstemon procerus, Epilobium alpinum, Hieracium gracile,
Figure 13. The Obsidian Plateau. Reflection of sunlight from the shiny black chips causes the light colored spots.
Phyllodoce empetriformis, and Cassiope mertensiana.

Another interesting area is the cinder desert north of North Sister (Fig. 14). It is a gently rolling expanse of hundreds of acres of black gravel-sized cinders at an elevation of about 7200 feet. As soon as the snow melts, the moisture becomes very limited because of the high porosity and the lack of summer rain. Although this is true for all the flats, the condition is more extreme in the cinder desert because of a greater porosity and better drainage. The only plant life of any significance here is widely scattered clumps of Eriogonum pyrolaefolium although occasionally found also are: Spraguea umbellata, Draba aureola, Smelowskia calycina, Hulsea nana, and Carex breweri. In hollows the plant cover increases considerably although it is still usually only a few per cent.

Lying mostly within the Pumice and Outwash Flats Zone are a number of lava flows. Several of these cluster about the base of South Sister covered with angular blocks (Figs. 12 and 15) and with no opportunity for moisture or soil to accumulate. As a result the vegetation is very sparse and it is usually limited to cracks or exposed gas bubbles in the rock. The plants occurring on this lava include Phyllodoce glanduliflora, P. empetriformis, Cardamine bellidifolia, Carex breweri, C. nigricans, and Cryptogramma acrostichoides. Very rarely
Figure 14. The cinder desert. Scattered clumps of Eriogonum pyrolifolium are on the cinders. The Cascade peaks in the background are, left to right, Mount Washington, Three Finger Jack, and Mount Jefferson.
Figure 15. A blocky gray lava flow south of South Sister. The dark areas are obsidian. Broken Top, a smaller companion of the Three Sisters outside the study area is in the background.
stunted white bark pine occurs where a pocket of soil has accumulated in areas protected by the slabs of rock.

The red, scoriaceous lava in the flow north of North Sister is composed of finer materials rather than large blocks and a larger number of species is present. Some stunted mountain hemlocks and white bark pine grow on the ridges while the gulleys between usually have less vegetation and no trees. Many depressions in the lava are filled with snow well into the summer. Plants growing on the lava include Penstemon davidsonii, Phylloco empetriformis, P. glanduliflora, Lutkea pectinata, Vaccinium myrtillua, Arctostaphylos nevadensis, Cassiope mertensiana, Juniperus sibirica, Hulsea nana, Epilobium alpinum, Antennaria alpina, Silene suksdorfii, Polygonum newberryi, Carex breweri, Juncus drummondii, Trisetum spicatum, and Sitanion hystrix. Saxifraga tolmiei and Cardamine bellidifolia frequently are seen in hollows where snow remains late and are often the only plants in such places. Several small specimens of ponderosa pine (Pinus ponderosa) were found on lava at about 6500 feet, west of Cinder Cone.

In summary it can be said that the vegetation of the Pumice and Outwash Flats Zone consists mainly of taprooted low perennials growing on loose dry surfaces. Usually the plant cover is less than 25 per cent and woody species are seldom present.
6. **Woods and Meadows Zone.** The upper reaches of the subalpine mountain hemlock forest extend into this lowest zone of the study area. Numerous meadows occur in the forest especially wherever the ground is flat or only slightly sloping. Unlike the other zones of the study area, there is a considerable vegetation cover in most places and stable, though often thin, soil covers most of the ground.

The forest is composed largely of mountain hemlock which often forms dense stands. The trees do not greatly diminish in size or become stunted as the timberline is approached. These trees are frequently several feet in diameter. The largest noted was 69 inches in diameter at breast height, about 100 feet high, and was within a few hundred yards of the timberline. Numerous ring counts made on trees of different ages indicate that growth is very slow. A cut stump with a diameter of 27 inches had 335 annual growth rings so that the 69 inch tree could be 800 or more years old and probably is not less than 600 years old.

Alpine fir occurs scattered through the hemlock forest and lovely fir, although rare above the 6500 foot lower limit of the study area, sometimes is quite common a short vertical distance below this line. White bark pine is seldom found in the hemlock forest on the west side but is quite common in the upper parts of this forest on the east side. In general the mountain hemlock forest is not as well developed on the
east side and the lovely fir is absent.

The hemlock forest is sometimes so dense that little vegetation grows under the trees. The forest floor is covered with a dense brown needle duff a few centimeters thick which has been severely compacted by the weight of the heavy snow cover. Where there is sufficient light under the trees *Luzula glabrata*, *Lutkea pectinata*, and *Vaccinium myrtillus* are frequently found associated with the mountain hemlock. These species, singly or as mixtures, frequently cover the ground and at least one of these is almost certain to be present if there are any plants at all. Also commonly found in the forest especially where there are numerous openings in the canopy are *Lupinus perennis*, *Rubus lasiococcus*, *Cassiope mertensiana*, *Phyllodoce empetriformis*, *Vaccinium membranaceum*, *Microseris alpestris*, *Aster ledophyllus*, and *Carex phaeocephala*. There is a marked tendency for the trees to grow on slight ridges and rises with small open areas between which often have a lusher vegetation consisting of the above species as well as a number of other plants which are more commonly found in the meadows.

There are several types of meadows; one of the commonest being the lupine meadow (Fig. 16). These most commonly occur along stream courses where the soil has been somewhat disturbed by flooding, although this is not always true. The soil in the meadows is thin and frequently bare sand or gravel.
Figure 16. A lupine meadow at the upper edge of the forest. The northwest face of Middle Sister is in the background. Many small mountain hemlocks are seen on the rocky north-facing slope at right. Many of these are 50 years old or older.
is exposed. Disturbance by gophers is common in these meadows. *Lupinus perennis* is the most noticeable plant and frequently it has the greatest ground cover. Also commonly occurring with the lupine are: *Castilleja parviflora*, *Potentilla flabellifolia*, *Epilobium alpinum*, *Aster ledophyllum*, *A. alpigenus*, *Senecio triangularis*, *Ligusticum grayi*, *Hieracium gracile*, *Microseris alpestris*, *Carex spectabilis*, *C. nigricans*, *Trisetum canescens*, and *Agrostis variabilis*.

Away from streams and where the soil is finer, the lupine may be absent and the meadow sometimes has a lawn-like appearance. The surface is stabilized by a mat of roots several centimeters thick, and there is evidence of heavy grazing by deer and sometimes elk in these meadows. Most common in such places are: *Trisetum canescens*, *Carex nigricans*, *Juncus drummondii*, *Aster alpigenus*, as well as many species of the lupine meadows. Where the ground becomes rocky, this type of meadow is likely to grade into a dense ericaceous mat composed of one or more of the following: *Cassiope mertensiana*, *Phyllochoce empetriformis*, *Vaccinium myrtillus*, and *V. ovalifolium*.

One other type of meadow common in this zone is the sedge meadow (Fig. 17). Such areas are usually quite flat and there is evidence that they are kept moist by seepage or poor drainage during the early part of the summer although by August they are usually quite dry. The ground is densely
Figure 17. A sedge meadow. The short species is Carex nigricans and the taller one is C. spectabilis. Several other species are also present in the dense cover. This valley is kept moist by seepage until midsummer by which time the sedges have formed their fruits.
covered by the sedges, and a soil as much as several decimeters thick is held together by a thick entanglement of roots. The dominant sedges are usually *Carex nigricans* and *C. spectabilis* which occur mixed or in patches. Frequently found growing among the sedges are: *Juncus drummondii*, *Trisetum canescens*, *Agrostis variabilis*, *Hieracium gracile*, *Epilobium alpinum*, and *Lutkea pectinata*. *Lycopodium sitchense* has also been found in a few sedge meadows.

Frequently found at the margins of the meadows are mountain hemlock thickets often not over two meters high which usually grow along the northern edge of the meadow or wherever the snow melts first (Fig. 18). A very few alpine firs grow with the mountain hemlocks. The trees in these thickets, though small, are quite old and slow growing, many being 50 years or more. One small sapling with a diameter of 2.5 mm. had 19 growth rings, and numerous trees about one centimeter through and several decimeters high were found to be about 30 years old. Not all growth is this slow however. One of these, five centimeters thick, was only 30 years old.

Several other habitat types exist in the Woods and Meadows Zone, including dry south slopes, rocky, moist north slopes, talus slopes, cliffs, and stream sides.

The dry south slopes occur along the east-west oriented ridges on both sides of the Three Sisters (Fig. 19). The south slopes of these ridges are often dusty and dry with
Figure 18. A snowdrift clearing in the mountain hemlock forest. The drift (right) remains until about the first of August. Small trees invading the north side of the opening indicate that the effect of the snowbank on maintaining the opening has decreased in the last half century. The large trees are several hundred years old and are growing on small ridges.
Figure 19. A dry south slope within the hemlock forest. *Lupinus perennis* and *Festuca viridula* predominate.
scattered large mountain hemlocks. The predominant vegetation on such slopes is usually *Lupinus perennis*, *Festuca viridula* or a mixture of the two. Associated with them are: *Sitanion hystrix*, *Aster ledophyllum*, *Agoseris glauca*, and often some of the plants common to the dry flats such as *Polygonum newberryi*, *Spraguea umbellata*, *Eriogonum pyrolaefolium*, and *E. marifolium*.

The north-facing slopes are usually moist and often have snowbanks persisting into early summer. The surface is loose and disturbed by snow creep and frost action. Quite frequently small mountain hemlocks are scattered about on these slopes. They are about the same age and size as those at the edges of the meadows but usually much more scattered, and often dead and dying trees are present. Plants that can often be expected to be found on such slopes are: *Cardamine bellidifolia*, *Saxifraga tolmiei*, *Lutkea pectinata*, *Castilleja arachnoidea*, *C. parviflora*, *Epilobium alpinum*, *Luzula wahlenbergii*, *Carex nigricans*, *C. spectabilis*, and *Juncus drummondii*. *Cassiope mertensiana* and *Phyllodoce empetriformis* and occasionally *Vaccinium myrtillus* frequently form mats, especially where it is quite steep and rocky.

Talus slopes support very little vegetation because there is little opportunity for moisture or soil to collect on the loose shifting slabs of rock. Occasionally the shrubs, *Arctostaphylos nevadensis*, *Holodiscus glabrescens*, *Juniperus*
sibirica, or Sorbus occidentalis are able to survive on the talus where they form mats.

There are frequently moist cracks in cliffs which will support a variety of species. Typically occurring on cliffs are: Penstemon davidsonii, P. rupicola, Phyllodoce empetriflora, and Polystichum lonchitis. The two penstemons frequently form mats on cliffs which are about a decimeter thick and several decimeters across. Also commonly found on cliffs are: Heuchera micrantha, Pectiantia breweri, Athyrium americanum, A. filix-femina, Viola orbiculata, Dicentra formosa, Agrostis scabra, and moss. A number of other species are occasionally present as a result of chance dispersal.

There are two distinct types of streams found in the study area, the spring-fed stream and the glacial- or snowfield-fed stream. The spring-fed streams have a rather constant flow throughout the year and are not subject to violent flooding. Their water is clear and their banks support lush vegetation. The flow of glacial- and snowfield-fed streams undergoes a considerable seasonal variation. In addition there is a marked diurnal variation in midsummer. There is much erosion and deposition along these stream courses and as a result there is little streamside vegetation. The vegetation along the spring-fed streams varies considerably although the most frequently occurring species are: Carex nigricans,
C. spectabilis, Juncus mertensianus, J. drummondii, Trisetum canescens, Agrostis variabilis, A. thurberiana, Lupinus perennis, Lutkea pectinata, Ligusticum grayi, Castilleja parviflora, Epilobium alpinum, Agoseris glauca, Senecio triangularis, Valeriana sitchensis, Phyllopoce empetriformis, Cassiope mertensiana, Vaccinium myrtillus, Salix commutata, and S. pennata. Usually around the springs at the head of the streams there is a dense moss mat five to ten centimeters thick and moss also frequently occurs along the streams.

In summary, the Woods and Meadows Zone, unlike the above five zones, provides a variety of habitats suitable for a nearly continuous vegetation cover. The soil surface is stable for the most part and the recent glacial maximum, about 200 years ago, had little effect in this zone. The meadows appear to be maintained at least in part by late-persisting snowdrifts, and some invasion by trees of these open areas in the part where the snow leaves first has been occurring for over 50 years, as indicated by the ages of trees in thickets at the northern edges of many meadows.
DISCUSSION

The Concepts of Succession and Climax in Alpine Areas

The total environment at any one site is not the impact of each factor acting independently but rather it is the resultant of an interaction of all its components. Some of these can be readily measured such as altitude, slope, exposure, light, precipitation, evaporation, temperature, pH, soil moisture, etc. Other factors of equal importance but less easily measured are the biotic influence, past history of the area, soil drainage and microorganisms, effects of microclimates, availability of seed sources, competition between plants. The numerous interactions of all these components of the environment are almost impossible to measure and may not even be obvious for a subjective description. The best expression of the total environment at any one location is the plant population present. The difficulty lies in the correct interpretation of the environment from the population.

In mountainous regions such as the study area, the numerous environmental components vary sharply in short distances because of the topography and sharp changes in climatic factors associated with differences in altitude. Frequently spatial changes of a few meters in the mountains may be equivalent to changes of miles on a plain. In addition, certain factors in the mountains may tend to be much more extreme than in the lowlands. Some factors of importance in the mountains such as
deep snow, short growing season, prolonged cold periods, slopes, and others may not even exist in the lowlands. As a result, the vegetational pattern in the mountains may be quite complex.

Succession of vegetation may be attributed to one or more of the following four causes: variations in rates of migration into the area, interaction of the plants and the environment, changes in one or more components of the total environment, and evolution. The first cause of succession is often the most important following a recent disturbance but it is soon largely replaced by the second cause. Examples of this might include soil accumulation, decrease in runoff and erosion, increase in shade, production of more ecological niches, etc. This modification of the environment by existing vegetation so that other vegetation replaces it is the most widely recognized cause of succession. It is the basis of the monoclimax theory of Clements (24). The third cause of succession, physical changes of the environment, normally occurs so slowly that it is usually neglected in a consideration of succession and climax. Changes in rainfall pattern, average temperature, elevation above sea level, or the reduction of mountainous terrain to more gentle slopes are examples of factors which could cause a slow change in the vegetation. These can normally be ignored in the discussion of succession. In a mountainous area, however, the effect of the external
environmental change on succession should be considered because changes usually occur more rapidly in mountains and their effect on the vegetation is more pronounced. Thus a slight decrease in snowbank-size in the last 50 years has resulted in trees invading areas previously unsuitable for them. The same is true concerning the glacial maximum of 200 years ago which profoundly affected much of the study area, while it is doubtful if this climatic fluctuation had much if any affect below the study area. As cliffs disintegrate into talus and slopes become more gentle, the vegetation changes. If we consider only migration and change of environment by plants as causes of succession, however, then the population of a cliff or the scattered taprooted perennials of a scree slope may be considered as climax.

The vegetation is considered to be climax where it is perpetuating itself with no replacement by different species and the environment is not being modified by it. The stabilized communities in the study area which make up the patterns corresponding to the patterns of the environmental gradients are considered climax. Small irregular changes which do occur in these communities are considered as being within the framework of the climax. This interpretation is in agreement with Churchill and Hanson (7, p. 181) and Whittaker (26, p. 46) (27, p. 38).
Some examples of communities being maintained by various environmental factors will now be discussed.

1. The scree slopes, moraines, and outwash. The sparse vegetation of these regions consists of a comparatively few species adapted to the rigorous conditions of the rocky unstable slopes. Most of these plants are low, often tuft-like, with large taproots, which help anchor them in the loose unconsolidated materials. Some of the environmental components which are maintaining this vegetation in a steady state are the instability of the soil, lack of organic material in the soil, short growing season, temperatures at or near freezing almost every night, wide diurnal range of temperature, and little rainfall over the summer.

Late-persisting snowbanks are common. In general the amount of vegetation decreases toward the snowbanks probably because of a greatly reduced growing season resulting from snow burial especially during years of heavy snow. Also in some cases the sparseness of the vegetation may be due to a greater instability in the soil surface close to the snowbanks. The vegetation zones surrounding the banks as noted by Billings and Bliss (4, p. 393-394) in the Medicine Bow Mountains of Wyoming generally do not occur here on the upper scree slopes, glacial moraines, or outwash. This is probably because of the geomorphic instability within this area. As was noted by Harshberger (12, p. 277) plants near snowbanks tend to have a
rapid development and early flowering and seed production after the snow has melted. The scree slope plant, Draba aureola, had the following year's inflorescence well developed by early September although it was completely protected by the overlapping leaves.

As mentioned before, many of the plants of these open rocky areas have a compact tuft-like growth form. This growth habit appears well adapted to this environment because:

(a) The plant is protected from desiccating winds of summer;

(b) The concentration of many leaves in a small area causes an increase in humidity immediately surrounding the tuft so that the gradient between the leaf surface and the atmosphere is more gradual and the transpiration is reduced;

(c) The prostrate form is favored by the sharp temperature gradient from the warm soil to the cool air above;

(d) There is less chance of the plant's being crushed by the snow or torn out by snow creep;

(e) The tuft tends to stabilize the soil in the immediate vicinity so that the plant is less likely to be overwhelmed by shifting soil.

Because there is no competition for light among the scattered plants in these high open areas the cushion growth form is not at a disadvantage as it would be in the meadows or woods below.
2. Flats. Lack of moisture is probably one of the most important factors in maintaining the present vegetation of the flats. Little moisture is retained by the porous materials covering these flats after the snow melts. Because of the low summer precipitation and the exposure of the flats to dry winds and long hours of sunlight they become quite dry. There is very little organic material in their soil. It is quite likely that the necessary mycorrhizae for tree growth are absent. Species of the flats without taproots usually mature quite early in the summer but those with large taproots may mature somewhat later.

3. The meadows. The meadows are maintained by late-persisting snowbanks which inhibit the growth of trees. The meadows within the forest tend to lie between ridges and are nearly flat. The snow may remain in them a month or more after it has melted elsewhere. It is possible that the growing season is too short for trees in such meadows. Also the meadows may not be free of snow at the time of germination of tree seeds. This is indicated by the fact that germinating fir seeds were found on four feet of snow in June 1958. As was shown by Shaw (23, p. 177-179) the presence of deep moist snow on poorly drained ground for long periods of time may exclude trees. The meadows beneath the snow are waterlogged for eight or nine months of the year, a condition which the trees apparently cannot tolerate. In addition, fungus mycelia (probably
Herpotrichia sp.) make brown cobwebby growths on the branches of trees buried by snow for long periods of time. This may kill part or all of the tree if the entire tree is buried. Where large drifts form on moderate slopes, snow creep may be an additional factor in inhibiting the trees (Fig. 20). Grazing by animals is probably also affecting the composition of the meadows.

Griggs (9, p. 51+9) found that some open meadows on Mt. Rainier were caused by fire as indicated by buried burned logs. No such evidence was found in this area, however. Fires within the study area have been infrequent, are generally lightning caused, and usually only affect a small area. Subalpine wet meadows as described by Ives (16, p. 90) where the water table is always within an inch or two of the surface do not occur in the study area.

4. Ridges. Trees grow on the ridges at much higher altitudes than on the outwash between the ridges because of greater soil stability and lesser snow. Exposure to wind and abrasion by ice particles, however, cause the trees to be progressively smaller and more krummholz in form with increasing altitude. Thus the treeline as distinguished from timberline is caused at least in part by wind. Trees growing in sheltered places, but where the snow does not become too deep, are taller than some cripples in the open at the same altitude. This indicates that wind is a controlling factor
Figure 20. The effect of snow creep on small mountain hemlock trees. The picture was taken in late June 1958. The trees frequently become damaged, especially on the uphill side, and may be broken off.
of the treeline.

Other factors which may be controlling the position of the treeline are decreasing stability of the substrate at the higher altitudes especially as the Morainal and Glacial Zones are approached, and decrease in the length of the growing season with an increase in altitude due to a longer lasting snow cover. The white bark pine appears to be slightly better adapted to the more rigorous conditions of the uppermost ridges and is found there in much greater proportions than on the lower parts of the ridges although the mountain hemlock and alpine fir extend almost as high as the pines.

5. The hemlock forest. The hemlock forest is a stable community and appears to be undergoing little if any change. Some trees are quite old and the reproduction is essentially of the same species. There are frequent interruptions in the continuity of the forest caused by meadows, cliffs, talus slopes and, at the upper edge, flats. Each one of these areas supports its own usually stable form of vegetation.

Successional Trends

Succession is evident in certain parts of the study area such as where a recently disturbed stream bank in a meadow is being invaded by the surrounding vegetation. In addition, as mentioned previously, there is an area east of Middle Sister where a hemlock forest is slowly establishing itself on a gradual slope of outwash. In this region plants
common to outwash such as *Eriogonum* sp. are being slowly shaded out. At the same time species common to the hemlock forest such as *Luzula glabrata* and *Vaccinium myrtillus* are found growing under some of the larger trees.

The most noticeable example of succession, however, is in the numerous places where young mountain hemlocks are invading open areas, often forming a thicket-like growth. Almost without exception this is occurring where trees were once excluded by snow drifts and where a reduction of drift size in the last 50 years or so is permitting this invasion. Where this occurs the trees are occupying a meadow, hollow, or slope and directly displacing the vegetation with no intermediate successional stages. Where there is a variation in size of these smaller trees the youngest ones are usually closest to the late-persisting drift, indicating that the reduction in drift size has continued until recently. There is in most cases a wide variation in the ages of the oldest trees in the thicket and those of the mature hemlock forest, indicating that the reduction in drift size has not been a continuous process since the origin of the hemlock forest.

**Evidence for Climatic Fluctuations**

In addition to the recent reduction in average snow-bank size there is further evidence for climatic change. On some of the ridges, especially between Middle and South Sister, a number of the white bark pines exhibit a sprout growth
extending above the snow-shear line (Fig. 21). These sprouts are mostly under 50 years of age and they may have resulted from a slight decrease in the severity of the climate.

Furthermore, near certain large stagnant ice masses and snowfields, dead sedges and other plants have been uncovered during the last few years. This indicates that sometime in the past it was milder or there was a period of lesser snowfall so that these plants became established and grew where none are now. Also the plants were buried by expansion of the snowbanks for an undetermined length of time, and finally that snowbanks are again shrinking because of climatic change as indicated by this and other evidence. Thus there is evidence of a past warmer period being uncovered by the effects of a present one. Because some of these snowbank areas occur on the outwash from the last glacial advance this warm - cool - warm cycle has evidently occurred within the last 200 years.

Some burial and exposure of plants might be expected from year to year fluctuation in the size and shape of the snow patches. Evidence indicates, however, that the exhumed plants were buried by a single enlargement of the snowbanks. The evidence includes, the wide band of dead plants surrounding the snowbanks, the lack of living plants among the dead ones, and the fact that the dead plants had been growing for some time in an area where now no plants grow because of proximity to the ice. That they had been growing for a number of years is
Figure 21. White bark pine growing on a windswept ridge. The shear line may indicate average winter snow depth. Although the trees are very old the sprouts extending above the shear line are less than 50 years old.
indicated by the thick caudexes of the sedges and thick woody penstemon mats uncovered. Lack of succession into the edges of the recently uncovered ground indicates that the present melting phase may be only a few years old.

The Timberline and Treeline

It could be expected that recent climatic changes might be reflected in a movement of the edge of the forest. The edge of the forest in Alaska is moving into area not previously occupied by forest while timberlines of the Rocky Mountains appear to be static (8, p. 80-96) (10, p. 278-279) (20, p. 11-14). This is indicated by the presence of very old trees and stumps close to the upper limit of the trees and by a lack of any evidence that trees once grew above where they are now found. Timberlines in the northeastern part of the country appear to be losing ground (10, p. 279-286) as indicated by the fact that few trees are coming in to replace those which are killed, remains of former trees are found which were much larger and less crippled than trees now growing in the vicinity, and tree seedlings in the upper regions are very scarce. Within the study area there appears to have been little migration of the trees except the invasion of certain meadows and slopes and to a slight extent the lower parts of some ridges in the wake of decreasing snowbanks. The upper edge of the hemlock forest is limited by meadows, flats and outwash. Thus the factors responsible for the timberline are
several and are those which are maintaining these vegetational
units. As mentioned previously, however, there is an area
where the forest is slowly advancing on the outwash because of
more favorable conditions than are found on most of the outwash.

The upper limit of the hemlock forest where the trees
have a normal growth habit is referred to as the timberline.
The timberline occurs at an average elevation of about 6500
feet, although the highly irregular edge of the forest makes
estimation difficult. The timberline extends higher south of
South Sister than on the north of North Sister. This is
probably not only a result of more rapid melting of the snow
on the south slope but also the presence of larger moraines,
large cirques, the Cinder Desert, and lava north of North
Sister. In general, differences in physiography over the area
are so great that it is unwise to try to correlate the posi-
tion of the timberline with such simple factors as slope and
exposure.

The upper limit of the stunted and krummholz trees on
the ridges is referred to as the treeline. As was pointed
out previously the factors controlling the upper limit of the
trees are wind, decreasing stability of the soil with higher
altitudes, and decrease in the length of growing season. It
can be expected that if the late-persisting and permanent
snowbanks continue to diminish the forest will slowly advance
until it is controlled only by such factors as the flats,
outwash and talus slopes. A slow invasion of these areas might then occur as geomorphic processes slowly render them more suitable for plant life.

Notes on the Flora

Most of the species start to flower within several weeks after they have been uncovered by snow. As a result, plants on ridges may be flowering while the area between is still covered with snow. The flowering period reaches its peak around the first of August but due to local microclimates and late uncovering by snowbanks it is possible to find flowering specimens of most of the species as late as early September.

With the exception of *Navarretia divaricata* all the species within the study area are perennials. This is of high adaptive significance because the growing season is very short and moisture is quite limiting in the latter part of the growing season. The perennials are able to flower soon after the snow disappears and their well-developed root system can obtain moisture from deeper in the soil when it becomes limiting near the surface.

It is interesting to note that spruce (*Picea* spp.), an important tree of most of the timberlines throughout North America is absent in the study area.

Some plants are highly specific to a particular type of habitat. One example is *Saxifraga tolmiei*, which grows on cool,
moist, north slopes where snowbanks persist. It is so com-
monly found in this type habitat and so rarely found else-
where that it can be called a snowbank indicator. Other plants
such as *Lutkea pectinata* have a wide ecological amplitude.
This plant occurs in numerous places such as in the forest
shade, in meadows, in open rocky area, and even on pumice
flats. Most species, however, are more specific to a particu-
lar habitat than this. A list of species and the habitat in
which each one is most frequently found has been prepared in
the appendix.
SUMMARY

The Three Sisters are located in the central Cascades of Oregon. They are a close group of 10,000 foot peaks of volcanic origin, and some activity has persisted in the area until recent times. Extensive areas are covered with pumice and cinders. There are about 17 glaciers in the region now and numerous snow-fields. Much of the area has been disturbed by a glaciation which reached a maximum about 200 years ago.

The climate is a marine type generally lacking in temperature extremes. Heavy precipitation falls in the winter months largely as snow. The summers are quite dry except for occasional showers.

Parts of the summers of 1957, 1958, and 1959 were devoted to field work. Several short trips were made in the fall and spring and an aerial reconnaissance was made in the spring of 1959. A plant collection was made and deposited in the Oregon State College Herbarium. The study area is delimited by the 6500 foot contour surrounding the peaks. This line which encloses about 35 square miles, is at the approximate height of the timberline.

The study area was divided into six zones based primarily on physiography, and the vegetation of each zone was described. These zones are: (1). the Peak Zone found entirely above the glaciers consists mainly of cliffs and scree slopes;
(2) the Glacial Zone in which are found the glaciers and many larger snow-fields; (3) the Morainal Zone below the glaciers largely deposited 200 years ago containing the most unstable soil in the area; (4) the Ridge and Outwash Zone which is the widest of the zones. The outwash is unstable with deep snow-banks much of the year and has a limited amount of vegetation. The ridges in contrast are more stable and have a greater number of species including trees; (5) the Pumice and Outwash Flats Zone consists of nearly level desert-like flats of porous material supporting rather sparse uniformly-spaced plants; (6) the Woods and Meadows Zone which is characterized by a stable soil, rich flora, and numerous habitats.

It was found that the glacial maximum of 200 years ago had an important effect on the vegetation of the study area by producing large moraines and much unstable outwash which is still subject to much erosional movement. A pumice fall a few hundred years ago has resulted in thousands of acres of pumice flats especially near South Sister. A cinder desert resulted from an eruption probably less than 500 years ago. Lava flows in the area are quite young and support a limited flora.

The meadows in the forest are being maintained by late-persisting snowbanks. The average size of the banks has diminished in the last half century permitting advance of the forest. Other evidences for climatic fluctuation are presented.
The timberline has remained essentially stationary for a long time although there is now some evidence of slight advance in relation to recent climatic trends. The timberline has remained static because of deep snow and the inability of the trees in most places to advance upon the flats and outwash. The upper limits of the stunted trees on the ridges representing the treeline are controlled mainly by wind, but other factors such as instability of the soil are important.
BIBLIOGRAPHY


APPENDICES
APPENDIX A

SUGGESTIONS FOR FUTURE STUDIES

There is ample opportunity for a number of scientific projects which could and should be started within the Three Sisters area. Just a few examples will be given.

1. Glaciology. The glaciers of this region have never been studied or explored to any great extent. The exact number of glaciers within the area is not even accurately known. Continuing studies of the glacier's size, depth, rate of flow, etc. could be inaugurated. Interesting comparisons could be made between the glaciers within this region. There is a wide variation in the size, shape, exposure, elevation and slope of these glaciers. It is also believed that a study of buried ice at the edge of and near Cinder Cone should be made as soon as possible.

2. Geology. The formation of the "esker" mentioned previously is just one example of the rapid erosion and deposition taking place in the area. Studies in this field might be very worth while. There are places where a buried soil surface under the Jerry lava flow has been exposed by stream erosion. Carbon 14 dating of organic matter in this soil could date the flow. Throughout the study area numerous rock outcroppings exhibit striae from the Pleistocene glaciation. From these the flow pattern of glaciers from the Pleistocene glaciation in the area could be mapped.
3. **Natural History.** An interesting project in this field might be to study the upper limits of certain animals and their behavior at these high altitudes. For instance, ground squirrels were observed at 9,000 feet where the only noticeable food was the fruit of *Saxifraga tolmiei*, on which they were feeding. Humming birds were seen feeding on *Penstemon davidsonii* nectar near glaciers. Butterflies were observed in large numbers migrating past the Three Sisters, crossing the glaciers at over 9,000 feet.

4. **Ecology.** Numerous studies of a smaller scope but with greater detail than this present study could be inaugurated. For instance, a careful study of the pumice flats might indicate just why they are treeless. A study of pollen from some of the higher peat deposits might yield some interesting information. Tree ring analysis might enable dating of the climatic fluctuations for which the evidence has been presented.

5. **Systematics.** Just one example will be given here. All of the species of lupine within the study area except for *Lupinus lepidus* exhibit a high degree of variability in all the characters used by different authors in separating them. This variability in key characters is among different areas within the study area, among plants in the same area, and often in between flowers of the same plant. As a result it was impossible to differentiate them using existing keys, and
therefore it was necessary to lump them together under the name *Lupinus perennis*. This species, according to Philips (22) is very widespread, highly variable, and fits the assemblage of lupines within the study area better than any other. A statistical study based on mass collections from the area, testing the key differentiating characters used by different authors, would yield interesting results. This is a good area to study hybridization and variation since numerous populations occupying different ecological habitats are located in close proximity with each other.
### APPENDIX B

**VASCULAR SPECIES OF THE TIMBERLINE AND ALPINE REGIONS OF THE THREE SISTERS AREA**

<table>
<thead>
<tr>
<th>No.</th>
<th>Species Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td><em>Abies lasiocarpa</em> (Hook.) Nutt.</td>
</tr>
<tr>
<td>2.</td>
<td><em>Achillea millefolium</em> L.</td>
</tr>
<tr>
<td>3.</td>
<td><em>Agoseris glauca</em> (Nutt.) Greene</td>
</tr>
<tr>
<td>5.</td>
<td><em>A. thurberiana</em> Hitchc.</td>
</tr>
<tr>
<td>7.</td>
<td><em>Anaphalis margaritacea</em> (L.) B. &amp; H.</td>
</tr>
<tr>
<td>11.</td>
<td><em>Antennaria alpina</em> (L.) Gaertn.</td>
</tr>
<tr>
<td>12.</td>
<td><em>A. rosea</em> Greene</td>
</tr>
<tr>
<td>15.</td>
<td><em>A. platysperma</em> Gray</td>
</tr>
<tr>
<td>16.</td>
<td><em>Arctostaphylos nevadensis</em> Gray</td>
</tr>
<tr>
<td>17.</td>
<td><em>Arenaria formosa</em> Fisch.</td>
</tr>
<tr>
<td>18.</td>
<td><em>A. nuttallii</em> Pax.</td>
</tr>
<tr>
<td>20.</td>
<td><em>Arnica diversifolia</em> Greene</td>
</tr>
<tr>
<td>22.</td>
<td><em>A. viscosa</em> Gray</td>
</tr>
<tr>
<td>23.</td>
<td><em>Aster alpinus</em> Gray</td>
</tr>
<tr>
<td>24.</td>
<td><em>A. fremontii</em> Gray</td>
</tr>
<tr>
<td>25.</td>
<td><em>A. ledophyllus</em> Gray</td>
</tr>
<tr>
<td>26.</td>
<td><em>A. shastensis</em> Gray</td>
</tr>
<tr>
<td>27.</td>
<td><em>Athyrium americanum</em> (Butters) Maxon</td>
</tr>
<tr>
<td>28.</td>
<td><em>A. filix-femina</em> (L.) Roth</td>
</tr>
<tr>
<td>29.</td>
<td><em>Calochortus lobbii</em> (Baker) Purdy</td>
</tr>
<tr>
<td>30.</td>
<td><em>Caltha leptosepala</em> DC.</td>
</tr>
<tr>
<td>31.</td>
<td><em>Cardamine bellidifolia</em> L.</td>
</tr>
<tr>
<td>32.</td>
<td><em>Carex ablata</em> Bail.</td>
</tr>
<tr>
<td>33.</td>
<td><em>C. breweri</em> Boott.</td>
</tr>
<tr>
<td>34.</td>
<td><em>C. halliana</em> Bail.</td>
</tr>
<tr>
<td>35.</td>
<td><em>C. inops</em> Bail.</td>
</tr>
<tr>
<td>36.</td>
<td><em>C. nigricans</em> C. A. Mey.</td>
</tr>
<tr>
<td>37.</td>
<td><em>C. phaeocephala</em> Piper</td>
</tr>
<tr>
<td>38.</td>
<td><em>C. rossii</em> Boott.</td>
</tr>
<tr>
<td>39.</td>
<td><em>C. scopulorum</em> Holm.</td>
</tr>
<tr>
<td>40.</td>
<td><em>C. spectabilis</em> Desv.</td>
</tr>
<tr>
<td>41.</td>
<td><em>C. straminiformis</em> Bail.</td>
</tr>
</tbody>
</table>
42. Cassiope mertensiana (Bong.) D. Don
43. Castilleja arachnoidea Greenm.
44. Castilleja parviflora Bong.
45. Cheilanthes gracillima D. C. Eaton
46. Chimaphila menziesii (R. Br.) Spreng.
47. C. umbellata (L.) Nutt.
48. Claytonia bellidifolia Rydb.
49. Collomia larsenii (Gray) Pays.
50. Cryptantha nubigena (Greene) Pays.
51. Cryptogramma acrostichoides R. Br.
52. Danthonia intermedia Vas.
53. Dicentra formosa (Andr.) DC.
54. Dodecatheon jeffreyi Van Houtte
55. Draba aureola Wats.
56. Epilobium alpinum L.
57. E. angustifolium L.
58. E. clavatum Trel.
59. E. lactiflorum Reich.
60. Erigeron compositus Pursh
61. E. foliosus Nutt.
62. E. peregrinus (Pursh) Greene
63. Eriogonum marifolium T. & G.
64. E. pyrolaefolium Hook.
65. Erysimum perenne (Wats.) Rossb.
66. Festuca viridula Vas.
67. Gaultheria humifusa (Gray) Rydb.
68. Gilia congesta Hook.
69. Haplopappus bloomeri (Gray) H. M. Hall
70. Heuchera micrantha Dougl.
71. Hieracium albiflorum Hook.
72. H. gracile Hook.
73. Holodiscus glabrescens (Green.) Hel.
74. Hulsea nana Gray
75. Hypopitys monotropa Crantz
76. Juncus drummondii E. Mey.
77. J. mertensianus Bong.
78. J. parryi Engelm.
79. Juniperus sibirica Burgsd.
81. Ligusticum grayi C. & R.
82. Lomatium angustatum (C. & R.) St. John
83. Lupinus lepidus Dougl.
84. L. perennis L.
85. Lutkea pectinata (Pursh) Hook.
86. Luzula glabrata (Hoppe) Desv.
87. L. wahlenbergii Rupr.
88. Lycopodium sitchense Rupr.
89. Microseris alpestris (Gray) Q. Jones
90. *Mimulus guttatus* DC.
91. *M. lewisii* Pursh
92. *Navarretia divaricata* (Torr.) Greene
94. *Oxyria digyna* (L.) Hill
95. *Pectantia brevicaulis* (Gray) Rydb.
96. *Pedicularis atrolineata* Gray
97. *P. racemosa* Dougl.
98. *Pentacemone nemorosa* (Dougl.) Trautv.
99. *P. procerus* Dougl.
100. *P. rupicola* How.
101. *P. davidsonii* Greene
102. *Phacelia hastata* Dougl.
103. *Phleum alpinum* L.
104. *Phyllocladus empetrifolius* (Sm.) D. Don
105. *P. glanduliflora* (Hook.) Cov.
108. *P. contorta* Dougl.
110. *Poa epilis* Scribn.
111. *P. lettermanii* Vasey
112. *E. pringlei* Scribn.
114. *P. elegans* Greene
115. *Polygonum newberryi* Small
116. *Polystichum lonchitis* (L.) Roth
117. *P. scopulinum* (D. C. Eaton) Maxon
118. *Potentilla flabellifolia* Hook.
119. *P. dentata* Smith
120. *P. secunda* L.
121. *Raillardella argentea* Gray
122. *Ranunculus eschscholtzii* Schlecht.
124. *Rubus lasioccoccus* Gray
125. *Sagina saginoides* (L.) Dalla Torre
126. *Salix caudata* (Nutt.) Hel.
127. *S. commutata* Bebb.
129. *S. pennata* Ball
130. *S. sitchensis* Sans.
131. *Sambucus callicarpa* Greene
132. *Saxifraga caespitosa* L.
133. *S. ferruginea* Graham
134. *S. tolmiei* T. & G.
137. *S. fremontii* T. & G.
138. *S. subnudus* DC.
139. *S. triangularis* Hook.
140. *Sibbaldia procumbens* L.
142. *Sitanion hystrix* (Nutt.) J. G. Sm.
143. *Smelowskia calycina* C. C. Mey.
144. *Solidago spathulata* DC.
145. *Sorbus occidentalis* (Wats.) Greene
146. *Spiraea densiflora* Nutt.
149. *Stipa occidentalis* Thurb.
150. *Tofieldia occidentalis* Wats.
152. *T. spicatum* (L.) Richt.
154. *Vaccinium deliciosum* Piper
155. *V. membranaceum* Doug.
156. *V. myrtillus* L.
157. *V. occidentale* Gray
158. *V. ovalifolium* Smith
159. *Valeriana sitchensis* Bong.
160. *Veratrum viride* Ait.
161. *Veronica wormskjoldii* R. & S.
162. *Viola orbiculata* Geyer
163. *Woodsia oregana* D. C. Eaton
APPENDIX C

LIST BY FAMILY

1. POLYPODIACEAE
   Athyrium americanum
   *A. filix-femina*
   Cheilanthes gracillima
   Cryptogramma acrostichoides
   Polystichum lonchitis
   *P. scopulinum*
   Woodsia oregana

2. LYCOPODIACEAE
   Lycopodium sitchense

3. PINACEAE
   Abies lasiocarpa
   Picea engelmannii
   Pinus albicaulis
   *P. contorta*
   *P. ponderosa*
   Tsuga mertensiana

4. CUPRESSACEAE
   Juniperus sibirica

5. GRAMINEAE
   Agrostis scabra
   *A. thurberiana*
   *A. variabilis*
   Danthonia intermedia
   Festuca viridula
   Phleum alpinum
   Poa epilis
   *P. lettermanii*
   *P. pringlei*
   Sitanion hystrix
   Stipa occidentalis
   Trisetum canescens
   T. spicatum
6. CYPERACEAE
   Carex ablata
   C. breweri
   C. halliana
   C. inops
   C. nigricans
   C. phaeocephala
   C. rossii
   C. scopulorum
   C. spectabilis
   C. straminiformis

7. JUNCACEAE
   Juncus drummondii
   J. mertensianus
   J. parryi
   Luzula glabrata
   L. wahlenbergii

8. LILIACEAE
   Calochortus lobbii
   Tofieldia occidentalis
   Veratrum viride

9. SALICACEAE
   Salix caudata
   S. commutata
   S. geyeriana
   S. pennata
   S. sitchensis

10. Polygonaceae
    Eriogonum marifolium
    E. pyrolaefolium
    Oxyria digyna
    Polygonum newberryi

11. Portulaceae
    Claytonia bellidifolia
    Spraguea umbellata

12. Caryophyllaceae
    Arenaria formosa
    A. nuttallii
    A. propinqua
    Sagina saginoides
    Silene suksdorfii
    Stellaria borealis
13. **RANUNCULACEAE**
   - *Anemone drummondii*
   - *A. globosa*
   - *A. occidentalis*
   - *Caltha leptosepala*
   - *Ranunculus eschscholtzii*

14. **FUMARIACEAE**
   - *Dicentra formosa*

15. **CRUCIFERAE**
   - *Arabis lemmonii*
   - *A. lyallii*
   - *A. platysperma*
   - *Cardamine bellidifolia*
   - *Draba aureola*
   - *Erysimum perenne*
   - *Smelewska calycina*

16. **CRASSULACEAE**
   - *Sedum spathulifolium*

17. **SAXIFRAGACEAE**
   - *Heuchera micrantha*
   - *Pectiantia breweri*
   - *Saxifraga caespitosa*
   - *S. ferruginea*
   - *S. tolmiea*

18. **RIBESACEAE**
   - *Ribes montigenum*

19. **ROSACEAE**
   - *Holodiscus glabrescens*
   - *Lutkea pectinata*
   - *Potentilla flabellifolia*
   - *Rubus lasiococcus*
   - *Sibbaldia procumbens*
   - *Sorbus occidentalis*
   - *Spiraea densiflora*

20. **LEGUMINOSAE**
   - *Lupinus lepidus*
   - *L. perennis*

21. **VIOLACEAE**
   - *Viola orbiculata*
22. ONAGRACEAE
   *Epilobium alpinum*
   *E. angustifolium*
   *E. clavatum*
   *E. lactiflorum*

23. UMBELLIFERAE
   *Ligusticum grayi*
   *Lomatium angustatum*
   *Camorhiza chilensis*

24. ERICACEAE
   *Arctostaphylos nevadensis*
   *Cassiope mertensiana*
   *Chimaphila menziesii*
   *C. umbellata*
   *Gaultheria humifusa*
   *Hypopitys monotropa*
   *Kalmia polifolia*
   *Phyllodoce empetriformis*
   *P. glanduliflora*
   *Pyrola dentata*
   *P. secunda*
   *Vaccinium deliciosum*
   *V. membranaceum*
   *V. myrtillus*
   *V. occidentale*
   *V. ovalifolium*

25. PRIMULACEAE
   *Dodecatheon jeffreyi*

26. POLEMONIACEAE
   *Colombia larsenii*
   *Gilia congesta*
   *Navarretia divaricata*
   *Polemonium californicum*
   *P. elegans*

27. HYDROPHYLLACEAE
   *Phacelia hastata*

28. BORAGINACEAE
   *Cryptantha nubigena*
29. SCROPHULARIACEAE
   Castilleja arachnoides
   C. parviflora
   Mimulus guttatus
   Mirabilis lewisii
   Pedicularis attolens
   P. racemosa
   Penstemon nemorosus
   P. procerus
   P. rupicola
   P. davidsonii
   Veronica wormskjoldii

30. CAPRIFOLIACEAE
    Sambucus callicarpa

31. VALERIANACEAE
    Valeriana sitchensis

32. COMPOSITAE
    Achillea millefolium
    Agoseris glauca
    Anaphalis margaritacea
    Antennaria alpina
    A. rosea
    Arnica diversifolia
    A. mollis
    A. viscosa
    Aster alpigenus
    A. fremontii
    A. ledophyllus
    A. shastensis
    Erigeron compositus
    E. foliosus
    E. peregrinus
    Haplopappus bloomeri
    Hieracium albiflorum
    H. gracile
    Hulsea nana
    Microseris alpestris
    Raillardella argentea
    Senecio canus
    S. fremontii
    S. subnudus
    S. triangularis
    Solidago spathulata
APPENDIX B

VASCULAR SPECIES OF THE TIMBERLINE AND ALPINE REGIONS OF THE THREE SISTERS AREA
AND THE HABITATS IN WHICH THEY ARE MOST FREQUENTLY FOUND

<table>
<thead>
<tr>
<th>Species</th>
<th>Peak Zone</th>
<th>Ridges</th>
<th>Outwash</th>
<th>Moraines</th>
<th>Scree</th>
<th>Talus</th>
<th>Lava Flow</th>
<th>Rock Outcrops</th>
<th>Snowbank</th>
<th>Plate</th>
<th>Ridge Heads</th>
<th>Lupine Meadows</th>
<th>Shady Woods</th>
<th>Open Water</th>
<th>Lake &amp; Streamside</th>
<th>Limited Distribution</th>
<th>Vodegrass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abies lasiocarpa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Achillea millefolium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agoseris glauca</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agrostis scabra</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. thumberiana</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. verbascoides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anemone drummondii</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. globosa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. occidentalis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aster alpina</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. rosea</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arabis lemannii</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. lyallii</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. platytera</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Areostaphylus nevadensis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arenaria formosa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. nuttalii</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. prostrata</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arnica diversifolia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. mollis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. viscosa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aster alpinus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. fremontii</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. ledophyllum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. shastenseis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Athyrium americanum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. filix-femina</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calochortus lobbianus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calypso leptosepala</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardamine bellidifolia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carex ablate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. breweri</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. halliana</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. inope</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. nigricans</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. phaeocephala</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. rosei</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. scopulorum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. spectabilis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. straminiformis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cassiope mertensiana</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Castilleja arachnoidea</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Castilleja parviflora</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cheilanthe gracillima</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chimaphila menziesii</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. umbellata</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Claytonia bellidifolia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collomia Larsonii</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cryptantha pubigena</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cryptogramma acrostichoides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Danthonia intermedia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dianthus formosus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dodecatheon Jeffreyi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Draba aureola</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epilobium alpinum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. angustifolium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. claratum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. lactiflorum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Erigeron compositus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. foliolosus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. peregrinse</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epilobium marifolium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. proalesifolium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

209
<table>
<thead>
<tr>
<th>Peak Zone</th>
<th>Bledges</th>
<th>Cutlakes</th>
<th>Naramus</th>
<th>Shore</th>
<th>Slope</th>
<th>Lost Flows</th>
<th>Rock Outcrops</th>
<th>Snowbanks</th>
<th>Flats</th>
<th>Sage Meadows</th>
<th>Lupine Meadows</th>
<th>Shady Woods</th>
<th>Open Woods</th>
<th>Lake &amp; Streamside</th>
<th>Limited Distribution</th>
<th>Widespread</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Erysimum perenne</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Festuca viridula</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gaultheria humifusa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gilia congesta</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Haplopappus bloomeri</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Heuchera micrantha</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hieracium altiformum</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>H. gracile</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Holocarpium glabrescens</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hulsea nana</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Erysimum monotrepa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>lenoc drummondii</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>J. mertensianus</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>J. perryi</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Juniperus alpina</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Kalama polifolia</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ligusticum grayi</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lomatium专辑mum</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>L. perenne</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lutkea pectinata</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Luzula glabrata</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>L. wahlenbergii</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Microseris alpina</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Himalayan polystichus</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>K. lewisii</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Navarretia divaricata</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Osmorhiza chilensis</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Oxypia digyna</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Polystichum breweri</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Peucedanum attolens</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P. racemosum</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P. prosera</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P. rupestris</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P. davidsonii</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Phacelia hastata</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Phleum alpinum</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Phyllodoce emettriformis</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P. glanduliflora</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Picea engelmannii</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P. abies</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P. contorta</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P. ponderosa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Potentilla spicata</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P. lettermanni</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P. pringlei</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Polemonium californicum</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P. elegans</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Polygnum novaebrugia</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Polystichum lonchitis</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P. scopulinum</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Potentilla fiabellifolia</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pyrola dentata</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>P. secunda</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Rhododendron argenteum</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Rhamnus euscobolii</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ribes montigenum</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Rubus lasiococcus</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sagina sagiroides</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Salix candida</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>S. cozmata</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>S. geyeriana</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>S. pennata</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>S. hitchensia</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>