Mount Multnomah

Ancient Ancestor of the Three Sisters

By
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Professor of Economic Geology
University of Oregon

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Figure 1. Looking northeast towards the Three Sisters, showing the caldera rim surrounding the Middle and South Sisters. The more or less intact original surface of Mount Multnomah is shown on the north and south, and its deeply dissected western face is in the foreground. Compare with figure 2.

MOUNT MULTNOMAH

Ancient Ancestor of the Three Sisters

INTRODUCTION

Centuries before the white man reached the fertile valleys "where rolls the Oregon," the prehistoric Indians worshipped the Tomanus of three snow-clad mountains, which were visible from all parts of central-eastern and western Oregon. A few of the more courageous (or perhaps mercenary and less religious) of these early dwellers visited the secret treasure chest of these exalted mountains, and obtained therefrom the valuable obsidian which they traded far and wide to the Indians of the plains, of the river valleys, and of the coast.

Perhaps a thousand years later the white man, urged westward by the same impulse which brought his Asiatic predecessors eastward, reached the yellow pine slopes of the eastern Cascades. Here at intervals between their labors and their conflicts, they gazed westward to three beautiful mountains, and in their admiration named them the "Three Sisters."

Later settlers in Oregon have always approved of this name and now the fame of the beauty of this region is known in all parts of the world.

Attracted by the beauty of the region, its glaciers and lava flows, the author selected it as the subject for actual field work during the Summer of 1924. While engaged in this detailed study it was discovered: that the Three Sisters mountains rest upon the worn remnants of Oregon's greatest Pre-historic mountain, Mount Multnomah; that this mountain once rose approximately a mile in height above the present snow-clad tops of the Three Sisters; that the top of this enormous mountain was lost by a gigantic explosion which left one of the largest calderas in the world; and that the Three Sisters and most of the adjacent peaks have acquired their present form as the result of later volcanic and glacial activity. It is the purpose of this book to present the evidence discovered in support of these facts and to trace the history of this ancient mountain.

In addition to the gigantic caldera, other interesting geologic features were studied. A lava flood covering over eighty square miles is perhaps the largest accessible recent lava in the United States (Figure 34, page 52). Within the vicinity of the Three Sisters there are about fifty young volcanic cones. One cinder field is over a mile long, one-half mile wide and five hundred feet deep. Miles of the surrounding country are strewn—like summer snow—with pumice. The South Sister, a young volcano, is 10,352 feet high and bears at its crest a crater lake (Figure 67, page 86). This lake is 10,200 feet high, about 1000 feet in diameter and is, as far as known, the largest crater lake at this extreme elevation in North America. Seventeen glaciers covering 2257 acres lie lodged in a comparatively southern portion of North America and cover the largest acreage of any ice-field as far south as this in the United States.

The author, however, has realized that a mere technical report of his findings would be of interest only to scientific men and he has therefore endeavored in writing the following pages to present his subject in language and form that can be understood by the average interested reader as well as by the trained scholar. In the effort to thus popularize the geology of this region and make the amazing facts revealed by this study as well as the reasons for the present topography and natural grandeur of this terrain available, understandable and useful to those who visit this territory, it has been thought advisable to also make this work a hand-book of reference describing in detail the present topography of the territory, its mountains, glaciers, lava flows, volcanic cones, lakes, streams, vegetation, floral and animal life. A topographic map in a pocket at the back of the book shows all the features described and will serve as a guide to those who choose to explore the fascinating area.

The Cascade Plateau

The Three Sisters area is located midway between the northern and southern boundaries of Oregon on the summit of the Cascade Plateau (Figure 27, page 44) which extends from northern Washington down into California. The average elevation of this plateau is about that of the McKenzie Pass, or 5000 feet. This elevation gradually increases southward to 6000 feet, above which Mt. Mazama (about Crater Lake) rises to an elevation of 8200 feet. This plateau presents two strongly contrasting sides. The eastern half has not been dissected greatly by streams but dips with a gentle slope to the east. Near Mt. Hood this slope rises from a surface of 4000 feet. On the McKenzie Highway[1] beginning at an elevation of 4000 feet, it ascends to 5200 feet. From the crest this eastern slope presents a slope so gentle that it might be interpreted as only sloping deceptively downward as a result of distant perspective (Figures 54, page 74, and 75, page 92).

In contrast to the eastern slope, the western slope is carved to a state of maturity (Figures 1 and 2). Thus, ten miles east of the Middle Sister, within the area of this map, the lowest elevation attained by any stream is 5000 feet, whereas on the west in the same distance some streams drop as low as 3700 feet. The slope of the plateau as a whole on the McKenzie Highway is from 5000 feet down to 400 feet, the level of the Willamette Valley. This abrupt western slope is due to outcropping edges of eastern dipping rocks which have been worn down by the vigorous dissection occasioned by the moist western winds. The line separating the rugged western side from the gently sloping eastern side will be spoken of in this report as the "break" of the plateau. This divide is a sinuous line which may be traced from Mt. Hood direct to the Three Sisters, thence with a change of direction to Mt. McLoughlin where it is again deflected slightly eastward to Mt. Lassen. The Skyline Trail follows this break closely for 250 miles to Crater Lake. The average breadth of the Plateau proper is seventy-five miles.

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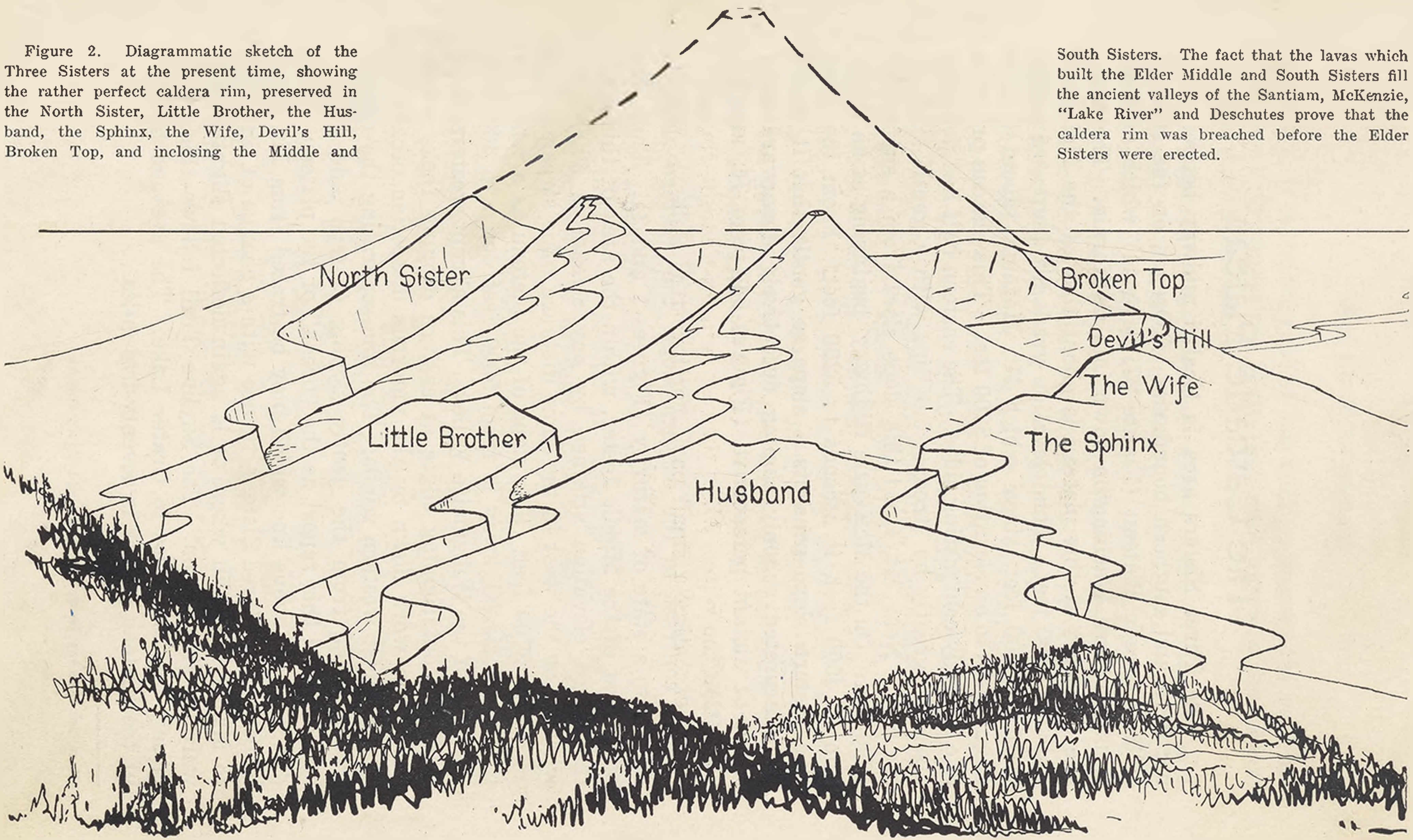
[1]Macadam highway between Eugene and Bend, Oregon.

Figure 2. Diagrammatic sketch of the Three Sisters at the present time, showing the rather perfect caldera rim, preserved in the North Sister, Little Brother, the Husband, the Sphinx, the Wife, Devil's Hill, Broken Top, and inclosing the Middle and South Sisters. The fact that the lavas which built the Elder Middle and South Sisters fill the ancient valleys of the Santiam, McKenzie, "Lake River" and Deschutes prove that the caldera rim was breached before the Elder Sisters were erected.



A series of volcanoes stand in linear formation along the break. Among the more important of these volcanoes are: Hood, 11,225 feet high; Olallie Butte, 7243; Jefferson, 10,523; Three Finger Jack, 7792; Washington, 7769; Belknap, 7000, and Black Crater, 7184; Three Sisters; Bachelor Butte; Packsaddle Mountain, 6000; Maiden Peak, 7750; Diamond Peak, 8792; Mounts Thielsen, 9178; Bailey, 8356; Mazama, 8200; Scott, 8938; Union Peak, 7698; and Mount McLoughlin, 9760; besides many craters and other centers of volcanic disturbance.

There are many lakes upon and close to the summit near Diamond Peak. Among them is Waldo Lake at the head of the North Fork of the Willamette; Odell and Davis Lakes on the West Fork of the Deschutes River; and Crescent and Summit Lakes which drain into the Deschutes.

The area included in this map embraces parts of three national forests. The Deschutes National Forest lies east of a boundary line passing through Belknap, the Sisters, and just east of the Wife. All of the rest is in the Cascade National Forest excepting a small part, northwest of Belknap, which lies in the Santiam National Forest.

History of the Cascade Plateau

STAGE I—EOCENE PERIOD[1]

The chronicle of the Three Sisters Region, in so far as history affects its present appearance, dates back about ten million years. To get a true understanding of its history, one must vision two great land masses, both named by Thomas Condon (Figure 3). One occupied the general vicinity of the present Blue Mountains and is called the Shoshone; the other lay in southwestern Oregon and is called the Siskiyou. These two land masses, portions of a once continuous chain of mountains, lay on either side of an arm of the sea called the Chico embayment. The rocks in Western Oregon indicate that, during the first stage, these mountains were being restored to their former elevation.

Nearly all mountainous uplifts are associated with vulcanism. We know that vulcanism occurred in the Cascades during this period because large amounts of volcanic ash are incorporated in the marine sediments of that age. The erosion of these mountains resulted in their being torn down and reduced almost to the level of the sea. The low plain formed by this erosion produced what is now known as the Klamath Peneplane, remnants of which are to be found in the tops of mountains of concordant elevation in southern Oregon. The streams which produced this peneplane carried their sediments into the Pacific Ocean and eventually filled the Pacific Ocean embayment. The conglomerates, sand stones, and shales which were deposited in the sea at that time are now known as the Eocene rocks, which at the present time make up the greater part of the bulk of the Coast Range.

A great break in the earth's crust which from this time on forever separated the *Shoshone* and *Siskiyou* land masses took place at the conclusion of this period and determined the site of the Cascades, not only in Oregon, but in Washington and California as well. At first this break was a simple rift extending north and south. This break or fault was brought about by an upward push which elevated eastern

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[1]See appendix "A" for an explanation of Epoch names.

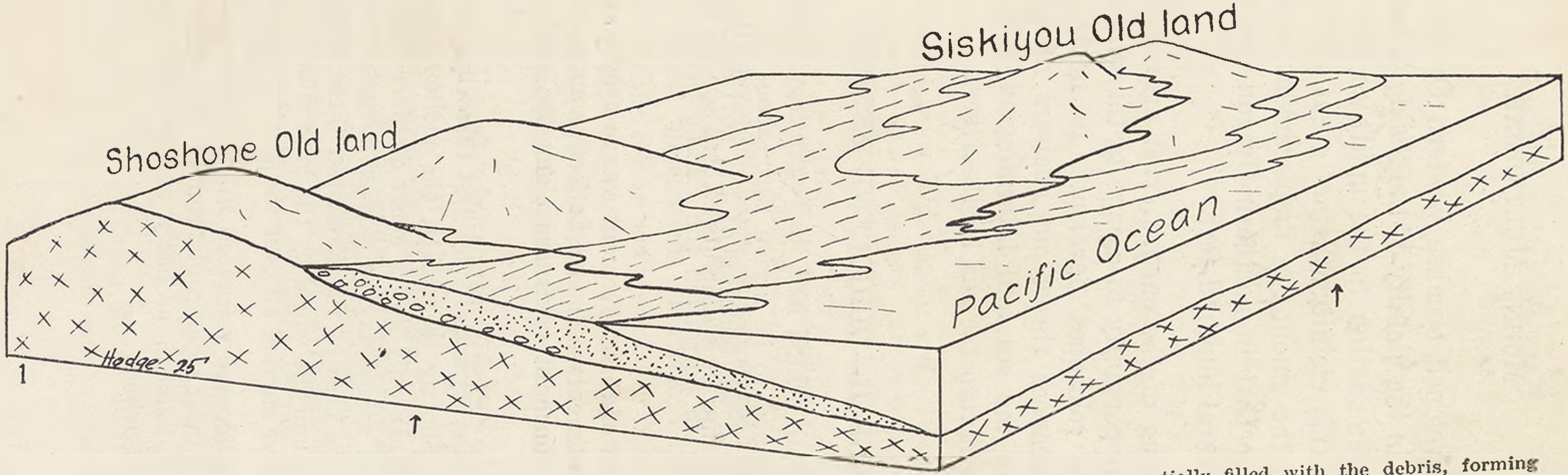


Figure 3. Oregon in the last part of Stage I (Eocene) showing the old land mass partially worn down and the sea partially filled with the debris, forming a broad coastal plain.

Oregon and developed because western Oregon did not join in this uplift. In the vicinity of the *Siskiyou* land mass, there was some accommodation to the uplift so that the slipping of the rocks in this vicinity was not great. North and south along the fault the amount of displacement became progressively greater so that in northern Oregon and California it amounted to several hundred feet.

This breaking of the earth's crust afforded deep-seated liquid rock an opportunity to escape to the surface. In consequence, small volcanoes developed in northern Oregon. These small volcanoes threw out showers of tuff and ash which settled in the sea and intermingled with the sands and muds brought into the sea by the rivers.

STAGE II—OLIGOCENE PERIOD

The great fault which had its beginning at the close of the Eocene continued to be active throughout the Oligocene (Figure 4). The down bending of the northern portion of the fault block again permitted the Pacific Ocean to spread to the east.

The first effect of this movement was to crowd and gently fold the Eocene sediments. The next effect brought into action the more or less dormant volcanoes along the ancient shore line.

A volcano begins its activity by first throwing out clouds of tuff and ash. Shortly thereafter, the molten rock pours out. Molten rock can only flow a short distance from a volcano, but tuffs and ashes may be carried to great distances by the wind. In the case of the Krakatau these ashes were carried entirely around the world by the high winds. In this period the ashes were carried all over the Pacific embayment.

Among these Oligocene volcanoes Mount Multnomah was destined to have the most significant future. The larger flows from the Mount Multnomah probably did not flow farther west than Belknap Springs.

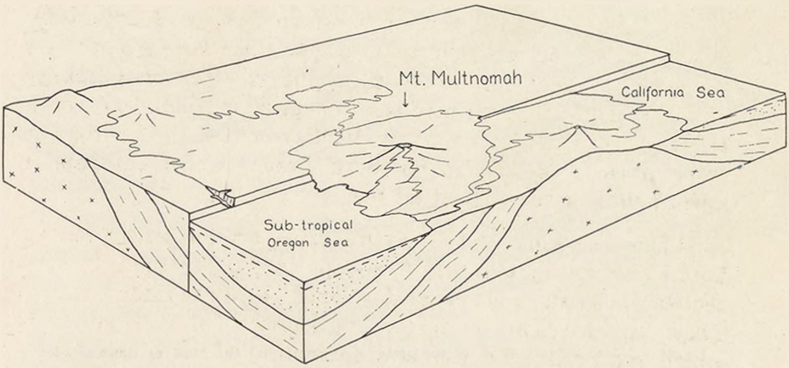


Figure 4. Oregon in the latter part of Stage III (Miocene) a stage much later than that shown in figure 3. The picture is slightly rotated clockwise in order to show that both the California and Oregon portions of the Pacific Ocean have been partially filled with Eocene and Oligocene sediments. The north-south fracture (fault) is being worn down nearly as rapidly as elevated as shown by the small valley on the left. Lavas from Mount Multnomah and other volcanoes are shown covering most of Oregon with great basaltic floods. The water draining eastward from the embryonic Cascades terminates in interior lakes. Mount Multnomah is only about half of its destined size.

While Mount Multnomah was being erected streams were active in tearing down the fault escarpment and in the destruction of Mount Multnomah. Material so eroded was carried into the Pacific Ocean and formed a thick series of deposits known as the Oligocene. These deposits naturally consist largely of volcanic materials. On the land during this period ferns, palms and fig trees flourished.

STAGE III—MIOCENE PERIOD

The Cascade fault continued to slip through all the Miocene to an amount of a few hundred feet. The warm western sea came inland to our present coast line. Into this sea the rivers continued to carry sandstones and mudstones, mingled with tuffs and ashes largely derived from Mount Multnomah.

By the middle of the period vulcanism reached its height. Down the slopes of Mount Multnomah, and from other fissures north and south, poured out great floods of basaltic lavas (Figure 5). These lavas did not pour out in one continuous stream, but were intermittent in character. Between each

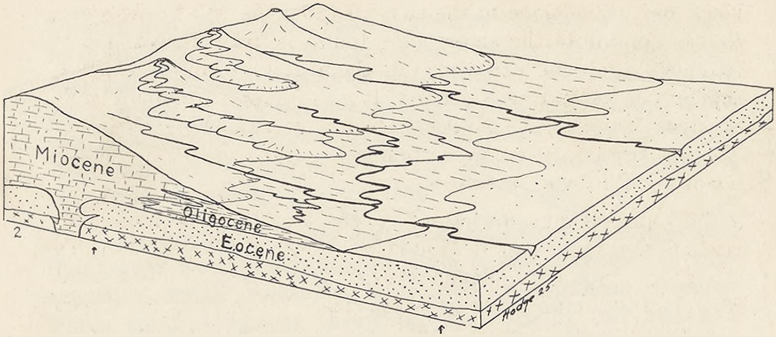


Figure 5. The western third of the state of Oregon from the crest of the Cascades to about 20 miles west of the present coastline. The position, arrangement, and extent of the Eocene sandstones, Oligocene volcanic ashes, and Miocene lava flows are shown. The Cascade Range, of which one-half is shown, at this time was a simple pile of volcanic flows with a few craters along its crest.

great period of active flow there were showers of tuff and erosion by streams of the previous flows and tuffs. The time between each flow was often long enough for deep soils to develop and forests to grow. We may now see in the deep river canyons between the successive flows, beds of tuff and ash or gravels or lateritic soils and often remaining fragments of forests, which were overwhelmed by volcanic showers or floods.

As many as thirty of these different flows may be counted in the Deschutes River Canyon. The flows from Mount Multnomah and adjacent peaks reached as far west as the present eastern slope of the Coast Range. Flows from this mountain and from many other volcanoes and fissures covered much of eastern Oregon, Washington, and parts of Nevada and Idaho. The lavas, ashes and gravels of this period are now known as the *Columbia River* formation, which is about 3500 feet thick.

During this period the high Cascade volcanic plateau was completed. The appearance of this plateau was, however, different from the appearance of the present Cascades. Instead of the present rugged and rather abrupt western slope, it then had a gentle slope. This gentle slope began at about the present western boundary of the Willamette Valley and extended eastward to the summit along the present line of volcanoes. The slope to the east was like the one to the west. It was similar to the slopes now found in Hawaii, which are so gentle that one can walk up them and hardly appreciate that one is ascending a grade. It was simply a plateau built of lavas from Mount Multnomah and neighboring volcanoes. The crest was much lower than now, and was reduced even lower by Pliocene erosion.

Emphasis must be placed on the fact that the main vulcanism centered around Mount Multnomah (Figure 4). To the north only low volcanoes existed. This vulcanism built Mount Multnomah to its greatest size. When fully developed it must have attained an elevation not less than fifteen thousand feet (Figure 23, page 28). The base of its steeper cone probably reached as far west as Belknap Springs, as far north as Mount Washington, as far east as Sisters and as far south as Elk Lake. Beyond the base, flows from this volcano spread radially for thirty or forty miles.

The closing days of this grand peak witnessed a decrease in the ejection with only occasional explosions of tuff and ash.

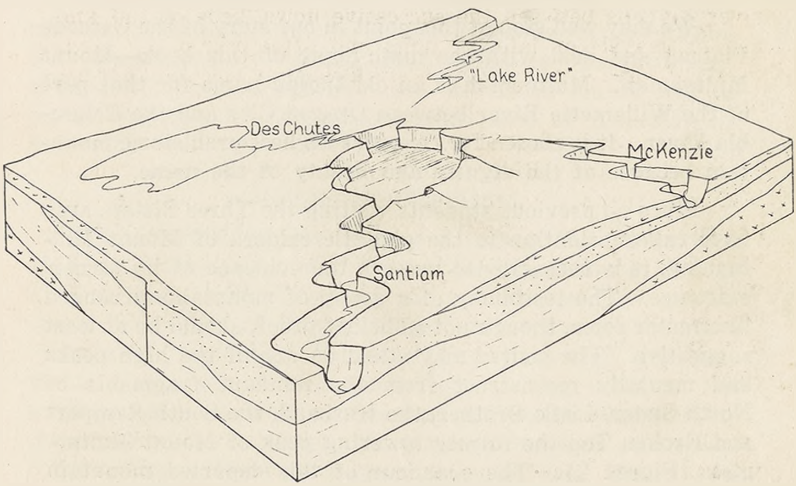


Figure 6. A detail of figure 5, showing Mount Multnomah at the close of Stage III or the beginning of Stage IV (Pliocene). Note that the lavas of this mountain bury the old Cascade fault and cover the old sediments. By this time the top of the mountain had been destroyed and four rivers had carved courses for themselves towards the caldera. The Santiam was the first to breach the caldera. "Lake River" and the ancient Deschutes probably supplied interior lakes with water.

This decrease in outward activity only portended a dire catastrophe—the entire top of the mountain was destroyed. As a result a gigantic caldera was formed at the close of the Miocene or at the very beginning of the Pliocene in Mount Multnomah (Figure 6). This caldera might have been produced by an enormous explosion such as that which produced Krakatau and Katmai, or it may have been formed like Crater Lake by subsidence. Evidence is not at hand to prove which took place. There is, however, abundant evidence to show that a caldera developed. The present rim could not have been produced by a simple erosion of a volcano. It is highly probable that the caldera was the site of a gigantic lake much larger than Crater Lake. Imagine standing on the rim of this caldera and looking out across the lake or down three to four thousand feet to the lake's azure waters. The flora and fauna of this period indicate a moist, warm, temperate climate. On the forested slopes and in the valleys roamed herds of camel and probably diminutive horses.

Evidence of Mount Multnomah

We may well stop at this point in our story of the Cascade Plateau and deal with the main topic of this book—Mount Multnomah. Multnomah is an old Indian name for that part of the Willamette River between Oregon City and the Columbia River. It is chosen for Oregon's highest prehistoric mountain because of the dignity and beauty of the name.

Since no previous students visiting the Three Sisters area have called attention to the gigantic caldera of Mount Multnomah, it is necessary to present the evidence of its former existence. The testimony of a group of mountains arranged in circular form, though not sufficient proof, should be at least suggestive. The visitor may stand on one of the high peaks and mentally reconstruct from the remnant fragments of North Sister, Little Brother, the Husband, the South Rampart and Broken Top the former towering peak of Mount Multnomah (Figure 2). The grandeur of this departed mountain and the immensity of its caldera will seize the mind of every one because, without especially noting the detailed evidence of its existence which follows, the obvious topographic evidence makes its former existence reasonable.

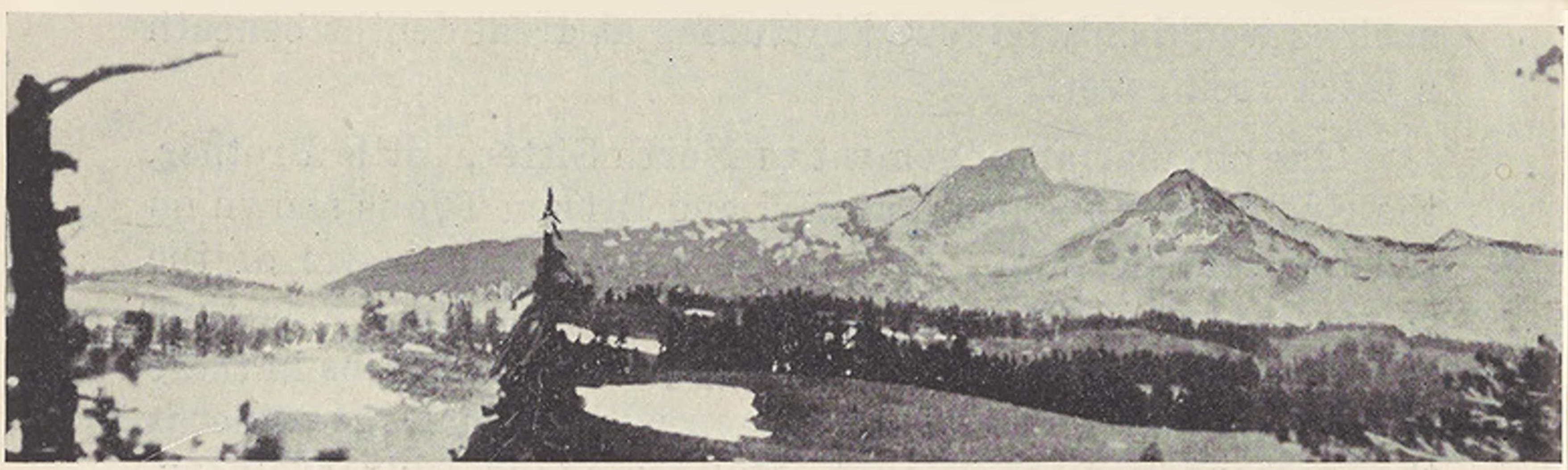
The geologist and many of the visitors to this area, however, will want further proof. The incontrovertible evidence can be summarized under eight heads: 1. The circular arrangement of the above named peaks. 2. The outward slope of the rocks from these peaks as well as the areas in between these peaks. 3. Proof that the interior peaks are younger. 4. The radial drainage determined by the old volcanic surface. 5. The annular streams and interior dissection. 6. The feeding dikes which cut the basement complex and many of the outward dipping rocks and terminate often in a visible flow. 7. The volcanic complex found beneath the outward dipping rocks, particularly where exposed at the inner base of the remnant mountains. 8. Deep seated intrusive rocks such as would only be found intruding at great depths beneath a thick rock cover.

The circular arrangement of North Sister, Little Brother, the Husband, the South Rampart and Broken Top is shown on the topographic map. In view of the enormous size of the caldera exposed to the vicissitudes of erosion for a long time a large percentage of the caldera rampart still remains in these remnant mountains. In comparison with other large calderas the preservation of Mount Multnomah is extraordinary. Because of this preservation, even the casual tourist will be more impressed by the caldera than those of Krakatau or Santorim.

Outward Dipping Rocks

The *outward dipping rocks* remnant of the old surface of Mount Multnomah surround all of the Three Sisters region. Thus on the North Sister the rocks of this surface can be traced from the top down the eastern and northern spurs (Figure 17, page 24). Those of the eastern spur dip eastward at an angle of about five degrees. The rocks of the northern spur extend down this spur and can be observed outcropping in the valleys to the east and west of Ahalapam Cinder Field. These rocks pass beneath Black Crater and can be found in the islands of the McKenzie Lava Field.

In those islands south of the McKenzie Highway, the rocks have been dissected so that they form a succession of cliffs and benches facing northward. Their northward dip



Figures 7, 8, 9, 10. See Footnote Page 15.

can be traced to the North Fork of the Santiam. The hogback-like ridge which forms the north pinnacle of the North Sister is a small remnant of one of these flows (Figure 41, page 57). The North Sister, when viewed from Collier Glacier, shows that these flows are slightly curved. This curvature gives an arc, the limbs of which extend north and south. The upper lava flows have a smaller radius of curvature than those which lie below and represent successive flows pouring out upon a slope, which became steeper and steeper with each successive emission.

All of these flows in the North Sister lie upon the complex beneath them. The north spur of the North Sister also shows that the lower lavas were dissected or their axial portions destroyed by an explosion before the later flows occurred. The younger flows truncate the inner ends of the older flows. In general all of the North Sister looks like a truncated spur from an old volcano (Figure 17, page 24).

To the northwest of Little Brother a small remnant of these outward dipping flows exists between the two forks of White Branch lying on either side.

On the Husband most of the westward dipping flows were long ago removed by streams and glacial action. However, looking to the west from this peak one can see the even horizon line formed by them, and they may be traced with conformable relationship down the west slope of the Cascades (Figure 8). In the vicinity of Mount Multnomah the inclination of such should gradually increase to one of about twenty degrees. However, on the west slope of the Cascades the old flows do not all dip westward for the simple reason that the successive hoists of the Oregon fault block tilted this block eastward so that their former westward inclination has been changed to a very gentle eastward one, except where the former westward consequent slope was too great to be overcome by the

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Figures 7, 8, 9, 10. (7) Looking north from foot of Cinder Cone showing eroded edge of old surface of Mount Multnomah (extending northward between recent lavas) and cut by the old Santiam. Belknap, Washington, Three Fingered Jack and Jefferson in distance. (8) Toward Husband from Middle Sister. On either side are portions of Mount Multnomah's surface. The peaks composed of deep-seated intrusive rocks surmount the middle glacially carved cirque. (9) South side of South Rampart showing Multnomah's surface dissected by tributaries of "Lake River" and ancient Deschutes. Devil's Hill on right, Wife in center, and in distance left Sphinx and South Sister within the Caldera. (10)—(U. S. F. S.) Looking east to Broken Top from Moraine Lake. Remnants of Mount Multnomah's surface shown on either side. The spires surmount a glaciated cirque. Morainal topography of pumice in foreground; the end of Miller Lava Flow on extreme left.

Figures 11, 12, 13 and 14. See Footnote, Page 17 eastward tilt. Hence, if we can find such flows within the area of the Three Sisters they should still retain a westward dip. Such remnant portions may be seen on the northwest spur and the south spur of the Husband. These flows dipping outward from old Mount Multnomah can be detected if this ancient remnant is viewed in profile from a distance. The northwest spur shows a slope gradually increasing in declivity to an abrupt cliff which faces inwards. This cliff is the inward eroded end of a series of flows which poured westward out of Mount Multnomah. A similar feature is plainly evident in the south spur of the Husband.

The Rampart[1] is formed by these flows. From the top of the Rampart, the surface and flows slope outward from about the center of the Three Sisters region. In the more prominent peaks of the Rampart, such as the Wife or the Sphinx, can be seen the eroded edges of these flows lying on top of the basal complex.

Broken Top shows similar features (Figure 10). The great eastern spur shows the same inward facing escarpment and the long eastern slope of the former lava flows. The northern spur is also made up of a remnant of the eastward sloping rock. To the southeast is a small hill, a remnant of a former spur which shows the flow rocks on top unconformable on the older flows below.

Traveling up the McKenzie Valley, or any one of the related valleys on the western slope of the Cascades, one observes that the principal cliffs face westward. From these cliffs gentle slopes extend eastward to the base of another cliff. These cliffs are determined by old volcanic flows which

[1]A name given to the continuous topographic feature on the south side, consisting of the Sphinx, Wife, Devil's Hill, and connecting land masses.

Figures 11, 12, 13 and 14. (11) A view of the south ends of Lane Plateau showing an unnamed plateau lying between the head branches of Linton Creek. On the right is Linton Valley and a portion of the south spur of the Husband. On the left are the Middle Sister, Renfrew Glacier and the beheaded lava flows. South Sister shows Clark, Lost Creek, and Eugene Glaciers; in the distance is the Sphinx, a part of the South Rampart. (12—U. S. F. S.) The Middle Sister from the top of the third bench where the Hudsonian Zone changes over to the Alpine Arctic Zone. (13) Looking north to Mount Washington from the east side of Belknap. In the foreground is a part of the great McKenzie Lava Flow. On the left the lowlands formerly occupied by the Santiam are shown. A portion of the undissected eastern slope of the Cascades is on the right. (14) Looking west down the ancient McKenzie Valley. In the foreground is that portion of the Elder Middle Sister which once poured down this valley as a series of lava flows and now dissected into benches of which Obsidian Plateau is one. The right hand wall of the valley continues to the base of Scott Mountain. On the left is shown the maturely dissected western edge of the Cascade Plateau. Note its even crest line.

now dip gently to the east. Superficial examination leads one to believe that they are horizontal. Detailed investigation reveals them to descend gently to the east, passing finally into the depths of the Cascade plateau. The McKenzie Valley exposes many of these old lavas which once poured westward down the west slope of Mount Multnomah.

Further evidence of this old surface will be given under "Present Topography."

Interior Younger Mountains

The younger interior group of mountains of Pliocene and later age lying within the old slope of Mount Multnomah is further proof of the caldera. In this discussion we need only consider those of the Middle and South Sisters. An examination of the topography of the McKenzie and Lost Creek Valleys shows a major valley related to the plateau surface within which there has been carved, upon two successive occasions, additional valleys. The surface, into which the McKenzie and Lost Creek[1] Valleys have been cut, truncates the flows from Mount Multnomah as they emerge one after another in regular succession to the west. The later lavas lie uncomformably upon the lavas into which the ancient McKenzie cut its valley.

Below the high surface, mentioned above, and in the old valley of Lost Creek, one finds a lower surface which terminates in the vicinity of Belknap Springs. This surface was formed by lavas which poured down the older valley from the Elder Middle Sister and the Elder South Sister proven because the rocks of this older valley filling are the same rocks which constitute the Elder Middle Sister.

The lavas which filled this old valley and built up the Elder Middle Sister have in turn been vigorously dissected. The streams have cut the various flows into a succession of benches of which Obsidian and Lane Plateaus are typical examples. In these lavas of the Elder Middle and South

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[1]Lost Creek must not be confused with Linton Creek which formerly held that name. The upper end of Lost Creek proper enters our area, as shown on the topographic map, just north of Linton Lake and receives White Branch as a tributary. Lost Creek is also shown as a tributary of the McKenzie River in figure 15. Linton Creek ends in Linton Lake and is shown but not named in figure 15.

Sisters which fill the McKenzie Valley, the Pliocene streams have cut a second set of smaller valleys.

Much of the erosion which has taken place since the outward dipping rocks of the ancient mountain were laid down is concealed by recent vulcanism and by the flows and cinders of the present Middle and South Sisters. Only the eroded top of the Elder South Sister protrudes through the eastern side of the present South Sister (Figure 68E, page 86).

The peak of the Elder Middle Sister has been entirely destroyed, but its location is indicated by the beheaded lava flows which now form Black Hump and Cirqued Rock.

In recent times lavas issued from Cinder Cone, the Ahalapam Cones, Belknap and other craters, and flowed down the Pliocene or second valleys. In these recent lavas the streams are now beginning to cut a third set of very small valleys.

In summary we may say that the topography and rocks show two periods of lava pouring down the old McKenzie Valley and two periods of dissection affecting these lava flows. The succession of events described in detail for the McKenzie and Lost Creek Valleys may be found in the other radial valleys cut in the old surface. These facts prove that an old surface was once extensive and intact, has since been dissected, and since then the interior group of mountains and their attendant features formed.

As an alternate theory we may assume that the central group of peaks represent the top of Mount Multnomah. By this theory we would assume that a circular fault marked by the present rampart permitted the inner part of the mountain to drop to its present position. This theory, however, is untenable, because of the clear-cut evidence indicating two successive periods of lava ejection lying in the old McKenzie valley, and two periods of erosion affecting these lava flows.

Radial Drainage

The radial drainage is equally conclusive evidence of the former existence of Mount Multnomah. A careful examination of this area proves that the streams now, and in former times, radiated outward from the Three Sisters area (Figure

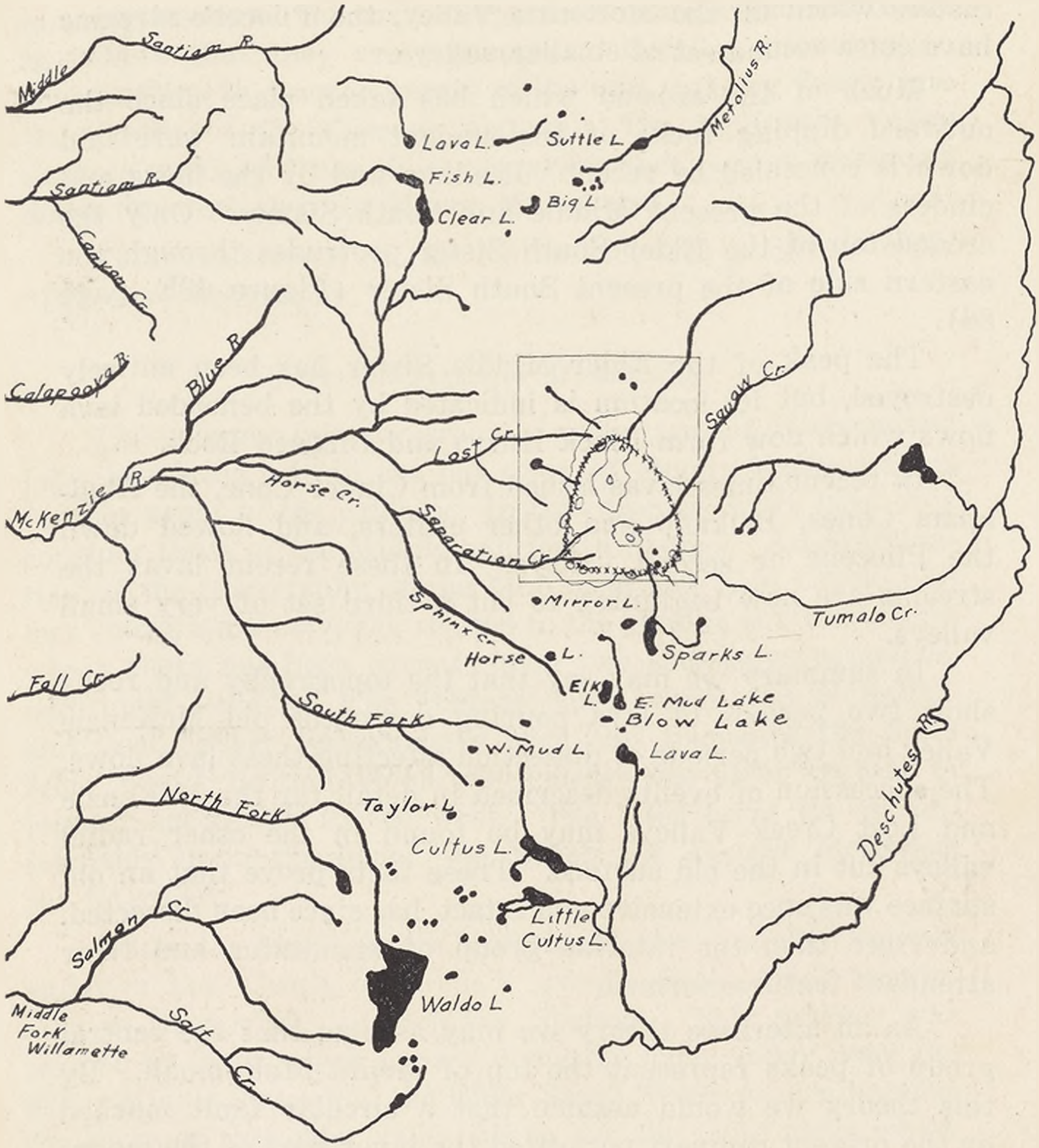


Figure 15. The radial pattern formed by the various streams flowing outward from and on the old surface of Mount Multnomah. Many of these streams have been captured and their waters turned northward since that time. On the north and south lava damming has disturbed the drainage, but the old river courses are plainly shown by the linear arrangement of the lakes.

15). The valleys of these streams are very large—too large to have been cut within the last geological period. These large radiating valleys must have been carved by streams which had their beginning on the slopes of Mount Multnomah, and a long time ago at the close of the Miocene.

These streams, like all streams, were born on the lower slopes of Mount Multnomah and by headward erosion and slow growth worked up the steeper slopes until they reached the rampart of the caldera. Inasmuch as the Miocene was a period of constructive vulcanism and these valleys are now occupied by lavas derived from the Middle and South Sisters which are pre-Pleistocene in age, the conclusion is plain that the radial streams effected an entrance into the caldera in the Early Pliocene. There is a little evidence to prove that the breaching of the south caldera walls took place at a later time—perhaps in the late Pliocene.

From the north a branch of the Santiam worked headwards past the site where now stands Mount Washington (Mount Washington did not come into existence until much later) and excavated the valley now occupied by the great McKenzie Lava Flood. By continued headward erosion this stream cut an entrance into the caldera from the north side at a point between the North Sister and Little Brother.

The valley created by this stream is not fully occupied by lava and is clearly shown on the topographic map or from the hills located along its border (Figure 13). The bottom of the valley and many of the details of its tributary system, however, have been obliterated by the great McKenzie lava flood. Though the valley form is preserved, streams do not follow it (except subterranean streams) because of the irregular surface of the great McKenzie Lava Flood. The best proof, perhaps, of this former valley depends directly on the fact that the lava poured northwest to the vicinity of Fish and Lava Lakes because lava, like water, flows down a perfered gradient and channel. Most of the world's lava streams are now found resting rigid and cold in the chamfer of a water course. Because this lava took a northwestward course obviously following a former valley it is apparent that the McKenzie did not reach into this area. In fact the present slope of this lava is such that streams, arising upon it, move northwestward until they disappear within its porous body. The alignment of Lava Lake, Fish and Clear Lakes, due to damming of the headward portion of the Santiam, indicates the position of the former valley. One effect of this lava damming was to reverse the drainage, southward over a low divide, of waters unable to take their former northwestward course. This southward diversion was assisted by a head-on capture on the part of a branch of the McKenzie working its way northward.

The McKenzie could not affect a northward entrance into the caldera, because between two streams, the one with the shortest course to the sea has the greatest power of erosion. It is apparent that streams flowing northwestward to the Willamette afforded their waters a shorter course to the sea than those which first took a westward course and later a northern one—that is, around the two legs of a triangle.

At the northwest the Lost Creek Branch of the McKenzie by a similar process of headward erosion cut a large gap in the rampart between Little Brother and the Husband. Together these two streams cut the area on the north side of the Three Sisters so low that, despite the great McKenzie Lava Flood, it still remains one of the low passes in the Cascades.

On the southwest the caldera was breached between the Husband and the Sphinx by Separation Creek. This creek, like all the others on the southwest side, had a course to the sea along a direction radiating from Mount Multnomah. All these streams were controlled by the master stream, the Willamette. The tributaries of the Willamette at an early stage captured the southward and southwestward flowing streams and diverted them into the shorter channels to the sea. Thus Separation Creek was captured by Horse Creek and Horse Creek in turn by the McKenzie. The headward portion of these streams, however, as well as those to be cited later, show a radiant pattern.

The Middle Fork of the Willamette likewise shows the same pattern as though controlled by some central uplift.

Thus on the south between the Wife and the Sphinx a small breach was cut in the rampart by the Sphinx Creek branch of Horse Creek, which was later captured by Separation Creek. At first Sphinx Creek had an outlet to the southwest along the line now marked by Mirror Lake, Bowl Lake, Horse Lake, Taylor Lake and other unnamed lakes to Salt Creek of the Middle Willamette. The upper end of this ancient

Sphinx Creek was successively captured by North Fork of the Middle Willamette, South Fork of the McKenzie and fianlly by Horse Branch of the McKenzie.

Between Devil's Hill and the Wife a stream flowed outward through a break in the caldera wall, following a course marked by Elk Lake, Mud Lake, Blow Lake, the Lava Lakes, and the upper part of the present branch of the Deschutes. This ancient stream we will now call "Lake River" (Figure 78, page 92). On the southeast a branch had a course between Devil's Hill and Broken Top, now marked by Falls Creek and Sparks Lake, which debouched into Lake River. Lake River probably fed one of the large extinct and fossil lakes in eastern Oregon.

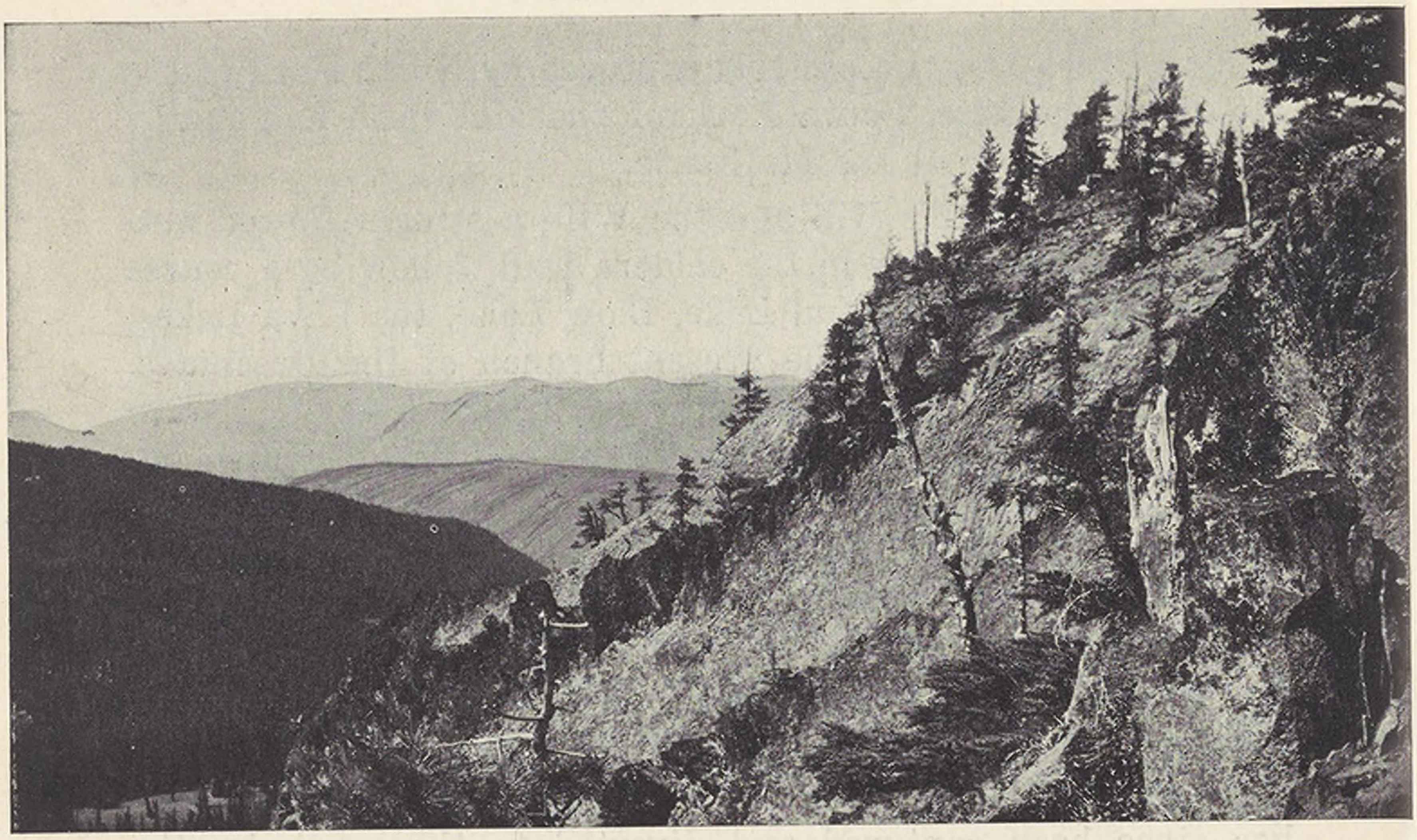
The former courses of Sphinx Creek and Lake River have been greatly deranged by recent lava floods and morainal damming. Lake River, marked by the long chain of lakes, has since been captured and diverted to the north by the Deschutes River.

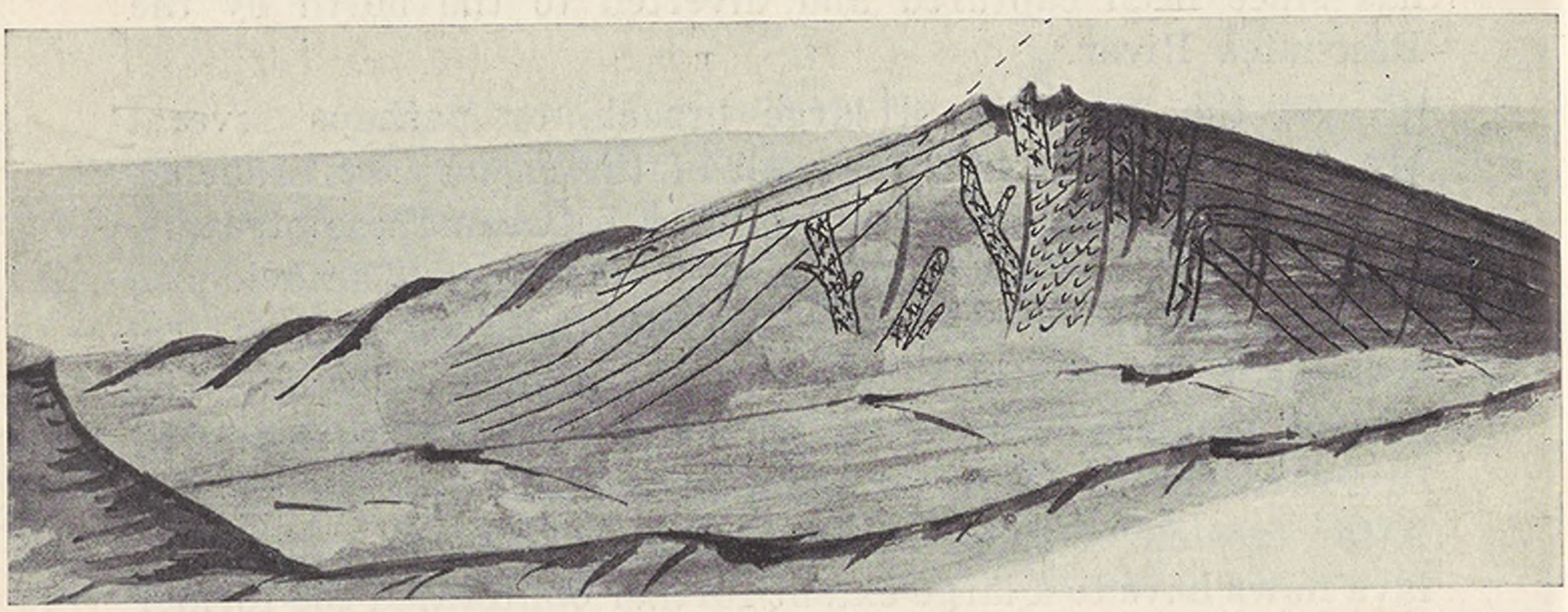
At the northeast a large breach, or perhaps several breaches, were cut into the wall of the caldera by branches of the Deschutes River. The divides between these streams, if there were several of them, were very low. The evidence we have of this break is the large gap between Broken Top and the North Sister now occupied by Squaw Creek. The great lava floods of the Elder Middle and South Sisters poured eastward for many miles and now conceal the old surface. After erosion of these Pliocene flows, glaciation and recent lava flows have to a large extent further obliterated the former topography.

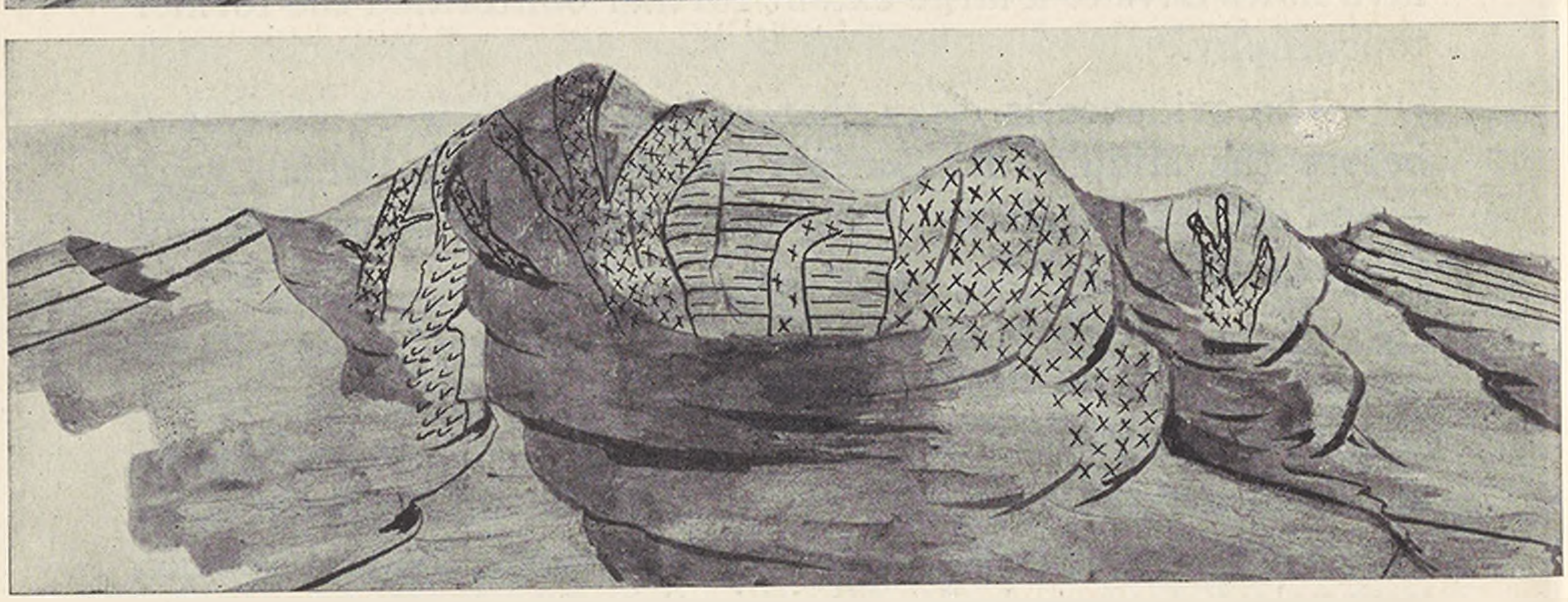
The evidence is clear that radial valleys were developed before the Middle and South Sisters were born which were —and still are—related to a central axis—the focus of Mount Multnomah.

Annular Branches and Interior Dissection

The above radial streams, after gaining entrance to the caldera basin, quickly drained the caldera and deployed upon the more or less irregular floor of the caldera. Soon, however, new volcanoes were built up within the caldera. If the caldera contained a lake, then, perhaps, vulcanism began before







Figures 16, 17 and 18. See Footnote, Page 25.

the lake was tapped, and formed, when very young, islands similar to the young volcano, Wizard Island, in Crater Lake. During and after the development of these interior volcanoes consisting of the Elder Middle and South Sisters, two additional stream types appeared. Down the slopes of these two new volcanoes, imitating the history of their departed parents, were developed small radiating streams. These streams, upon reaching the foot of the rampart, followed annular courses to the nearest outlet. Thus annular streams developed to which we may now assign the modern names of White Branch, Linton Creek, Separation Creek, Falls Creek, Pork Creek, Squaw Creek, Soap Creek and Alder Creek.

It is thus apparent that the great main valleys represent consequent valleys determined by an ancient slope. Their radial character could only have been created by streams radiating outward from a volcanic slope. The upper parts of these streams turn abruptly and follow annular courses around the base of the Middle and South Sisters. These annular courses were not determined alone by the soft rock lying within the caldera rim of Mount Multnomah. These latter streams could not have developed unless a caldera rim were present to obstruct the course of the new radial streams.

Feeding Dikes

To the evidence of form, old surface, caldera remnants, interior young mountains and stream dissection, we may add the structural evidence within the caldera as proof of Mount Multnomah's historic past. Feeding dikes are quite common on the great sheer face of the North Sister as seen from Collier Glacier, two of which are particularly well exposed. From the top of the North Sister hundreds of these feeding dikes may be seen outcropping on each of the spurs, which strike

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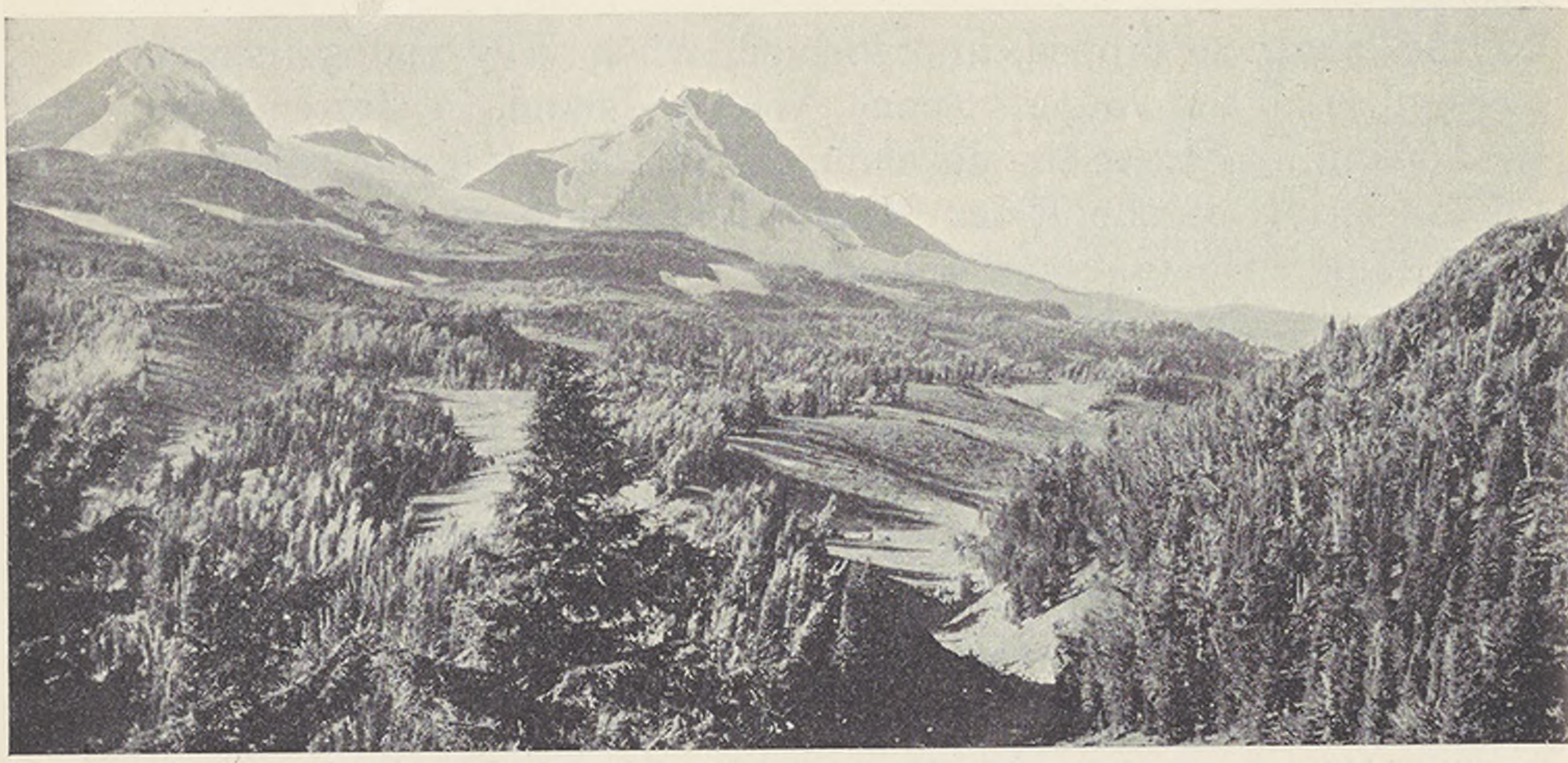
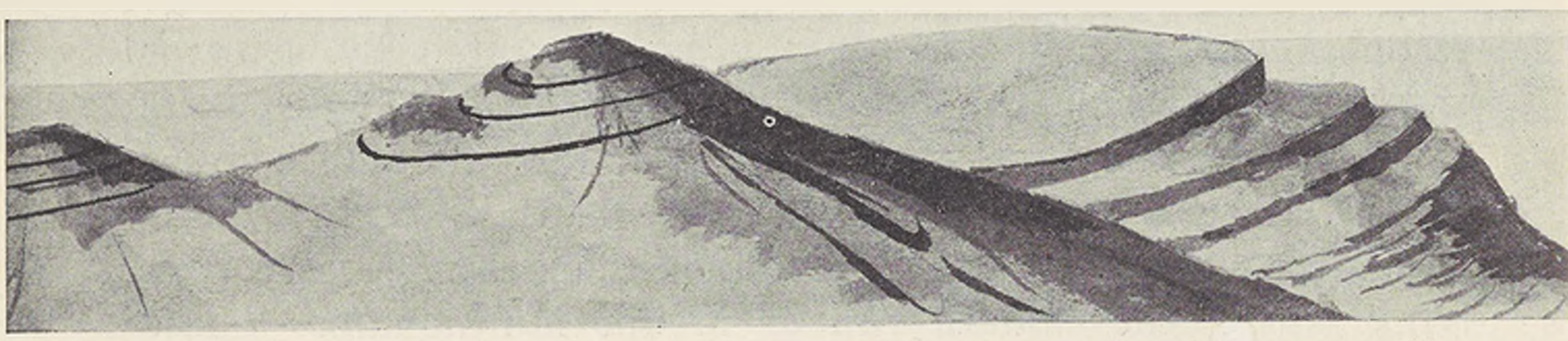
Figures 16, 17 and 18. 16—U. S. F. S.) West down McKenzie Valley from steep south Lane Plateau composed of trachyte lavas. Linton Valley in foreground. Center lava flows from Middle Sister; distance even crest line of Cascade Plateau; compare with Figure 14. (17) North Sister from west moraine of Collier Glacier. Little Brother on left, eroded edges of the northward dipping flows from Mount Multnomah on the left of North Sister. Truncated edges of flows from Mount Multnomah extending to the east in center and right. Later flows unconformable on the earlier ones because between lava emissions there were periods of erosion. Feeding dike bends over and becomes a surface flow on right. Pyroclastic material (V); Coarse-grained dikes (X) pentrating the flows and forming the middle pinnacle prove that deeper portions of Mount Multnomah are now laid open to view. (18) East toward the Husband, (compare Figure 8) showing edges of flows of Mount Multnomah's old westward surface. Three large cirques show large bodies of coarse grained intrusive rocks (X) exposed by decapitation of Mount Multnomah and small body of pyroclastic (V) material.





Figures 19, 20, 21 and 22. See Footnote, Page 27.

in a direction between South Sister and Broken Top. The lava flow rocks lie on top of these vertical rocks (Figure 17). These vertical rocks are dikes frozen in the fissures through which the molten lava from the depths reached the surface and then spilled down Mount Multnomah's eastern slope. Some dikes may be found which turn and continue as flows. Their great number indicates that flows were poured from the side walls of this volcano at many different times. In fact Mount Multnomah was built up by a succession of such outflows.

Similar dikes are found cutting the flows of the Husband. On the southwest spur of Broken Top many similar dikes, which cut through the flows and pyroclastics or fragmental volcanic material, may be found. The distribution and arrangement of these feeding dikes show a relationship to the central axis of Mount Multnomah.

Central Fragmental Rocks

The inner cone of an explosive type of volcano not only shows feeding dikes, but is usually composed of fragmental rock. Thus beneath the outward dipping lavas of Mount Mazama and Krakatau one finds volcanic tuff, ash and agglomerate. The same may be found beneath the outward dipping beds of Mount Multnomah. Such beds of red and yellow tuff cut by many dikes may be seen on the west side and between the spurs on the east side of the North Sister (Figure 17). The term "bed" is slightly inaccurate. As a matter of fact, one finds difficulty in detecting any structure beneath the upper lava flows. Little Brother is too deeply immersed by Collier Glacier and the flows from the Elder Middle Sister to show this basal structure except beneath the upper flows. In the large northeast cirque of the Husband

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Figures 19, 20, 21 and 22. (19—U. S. F. S.). A view from the pass between Broken Top and the South Sister looking north. The eastern half of the Middle and North Sisters has been completely cut away by glaciers. Between the middle and North Sister is shown Black Hump, a beheaded flow which once issued from the Elder Middle Sister. To the east of the Middle Sister is shown Diller and Hayden Glaciers. (20) Looking north to Little Brother, an erosional remnant carved out of the old surface of Mount Multnomah which extends to the northwest. (21) Looking south towards the Wife. On the right is shown the old surface of Mount Multnomah. In the center the edges of the flows, which formed this old surface, are cut by coarse-grained intrusive rocks. (22) Looking southeast toward Broken Top. On the left are shown the succession of flows which poured down to the east and formed the old surface of Mount Multnomah. The main mass of Broken Top is formed of pyroclastic material (V) proving that this mountain was located close to the ancient conduit. A few intrusive dikes or coarse-grained rocks prove that this mountain is a portion of the inner body of Mount Multnomah.

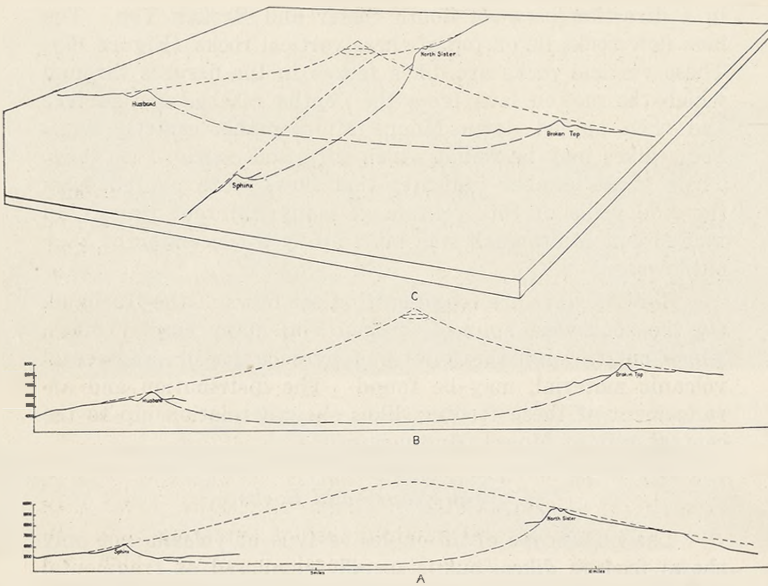

Figure 23. Showing probable elevation of Mt. Multnomah as determined by remnants of old surface preserved in North Sister, Broken Top, Sphinx, and Husband. Scale divisions are 1000 feet, the lowest division in A being 5500 feet above sea level and in B, 4500 feet.

similar fragmental volcanic material can be seen. None is found along the Rampart, because the later lava flows from the South Sister bury all but their upper portions.

Broken Top (Figure 22) like North Sister, shows, beneath the upper flows, great quantities of fragmental rocks. The present core of the mountain is made up entirely of large agglomerates and smaller fragmental rocks. To the west these pyroclastics enclose the feeding dikes. Some of these pyroclastics have a horizontal structure; others are structureless.

In all cases the fragmental rocks are towards the ancient conduit and beneath the outward dipping rocks. Wherever found they point to an "inward" source.

Deep Seated Rocks

The feeding dikes and central fragmental rocks are important, but the most significant proof is given by the coarse-grained dikes to be found at the inner base of the caldera rim. In themselves, these dikes simply prove that dissection has exposed rocks which were cooled and crystallized at great depths. When one adds this fact to the others mentioned above, it is evident that such deep seated rocks could only be found at the base or far within the body of a great volcano. These coarse-grained rocks, formed only under deep cover, demand that some explanation be given for the process which has exposed them to view. Since this area has not been deeply dissected by stream erosion, their exposure must be due to some other cause, as, for instance, the submergence of a volcanic cone or its destruction by a great explosion.

The Husband affords the best display of these rocks (Figure 18). The northernmost portion of the Husband is composed of an enormous dike of olivine monzonite. This dike once penetrated several hundred feet of overlying rock. In the great northeast cirque are several apophyses which look like the giant limbs of a winter tree, the branches of which do not quite reach the top of the mountain. In the southeast cirque are several dikes which cut the basement complex and the horizontal flow rocks. These rocks must have intruded this side of Mount Multnomah at a time when the mountain had reached its maximum size and while they were buried beneath several thousand feet of rock cover.

Several similar dikes, but not so accessible for close inspection, may be seen on the west base of the North Sister and on the South and Middle Horns (Figure 17). At various places along the South Rampart these deep-seated intrusive rocks may be found. The Wife is determined by at least four such dikes of a medium grained rock similar to those of the Husband and the North Sister (Figure 21).

These dikes serve to hold together the loose mass, much in the same manner as the main mass of Krakatau Island is bound together. Since such rocks formed only at great depths have not been exposed by erosion, they must have been exposed by explosive or submerged destruction of the great mountains once standing above them.

STAGE IV—PLIOCENE PERIOD

The Cascade volcanic plateau was completed by the beginning of the Pliocene. The events of the Pliocene were determined by the development of a new fault line a few miles west of and parallel to the present coast line of Oregon which hitherto, i. e. during the Eocene, Oligocene and Miocene, had been much farther east (Figure 27). The inland block consisting of most of the state of Oregon was lifted and tilted eastward relative to the seaward block with the chief hoist of the inland block on the seaward side. The east tilt brought the former western slopes of the volcanic plateau, built up by Mount Multnomah and other mountains, to a horizontal position or to a slight eastern dip. The westward block, submerged below the level of the sea, permitted the waves of the Pacific Ocean to dash against a great fault face.

The effect of this lift was to rejuvenate all the streams. Short new streams developed upon the face of the fault scarp and flowing westward over the coastal plain and the peneplane were able to maintain their courses through the fault block as rapidly as it was elevated and formed delta deposits. These streams and all others developed north-south tributaries upon the softer rocks.

Because the newly born Coast Range was composed of resistant Eocene sandstones beneath non-resistant Oligocene tuffs, the streams trimmed the over-lying soft Oligocene beds down to the more resistant Eocene beds. The union of these tributaries gave a north-south stream which was the original Willamette. After the Oligocene beds were trimmed back some distance a valley was formed which was farther west than at the present time. Continued erosion of the Oligocene beds has impelled the valley eastward until its eastern wall is formed by the edge of the Cascade lava plateau.

The climate of this time was practically the same as that of today. Ancient bears searched out succulent bulbs and gigantic sloths pulled down, with their hairy, clawed arms, the limbs of the deciduous trees and stripped them of leaves.

The calderon of Mount Multnomah, developed at the very close of the Miocene, was dissected during all this time, by streams flowing down its surface in all directions. Those which flowed eastward must have spread out onto the plains of eastern Oregon and formed lakes since they were shut off from the ocean by a volcanic mountain range. Some of those flowing north and south bent westward and joined the Willamette River.

By headward erosion these streams cut a passage to the actual rim of the caldera of Mount Multnomah. After they had breached the rim they turned and developed annular courses inside the caldera rim.

The streams which flowed westward down the lava slopes dissected it into great canyons which were enlarged after the uplift of the Oregon fault block. The courses then developed persist to a large extent to the present time. Some of these streams cut their valleys to such a width that only a small part of the lava flow surface remained. These interstream divides, therefore, formed parallel ridges running east and west (Figure 16 F., page 24). The present upland is formed by these ridges of concordant height and represent remnants of the former westward lava slope brought almost level by the Pliocene tilt. The character of this valley surface north of the McKenzie has been more greatly modified by recent lava flows than that to the south. In the vicinity of Mount Hood much of the older topography has been buried by later lavas. Therefore, as one looks south from the Middle Sister one sees a much older topography than that observed to the north. The tops of many of the mountains on the west side of the Cascades are lava mesas—erosional remnants—of the old lava surface of the west side of the Cascade volcanic plateau.

In the walls of the McKenzie and Lost Creek Valleys, especially in the latter, the slight eastward dip due to early Pliocene uplift and the bevelling of later Pliocene is well shown.

EARLY VULCANISM WITHIN THE CALDERA

Contemporaneous with the coast line fault, activity along the Cascade fault resulted in renewed vulcanism within the caldera of Mount Multnomah. The Elder Middle and South Sisters were erected. The Elder Middle Sister was built about five hundred feet higher and 1000 feet farther east of the present Middle Sister. Also a little east of South Sister was built up the Elder South Sister to about the same height. These two volcanoes did not entirely fill the caldera and may be compared to the young volcano "Wizard Island" within the caldera of Crater Lake.

Though discussed above under "Interior Younger Mountains," a certain amount of additional data is here desirable. The structure of the present Middle Sister is three-fold in character. On the top rests a black basaltic cone composed of scoriaceous and loose angular boulders which appear to have come from a vent at a period not farther back than the Pliocene.

Below this cone extended radially a number of flows. These flows apparently poured down the mountainside at periods previous to that which poured out the lava of the top-most cone. The series of lava plateaus on the south side also represent flows which issued from the Middle Sister. The distal ends of these flows have been eroded away so that when one descends he alternately walks over the gently sloping surface of a flow and climbs down its clifted edge. Some of these flows are much smaller than others, and where the eroded end of such a small flow is found it has a semi-circular cross section. On the west side these flows have been vigorously eroded by streams so that they give rise to great alluvial fans extending clear to the base of the mountain. On the northwest Renfrew Glacier cuts diagonally across a series of these flows and at one time this glacier spilled westward between these flows. At the present time these flows serve as an abutment for the west edge of this glacier and serve to hold in place its west moraine (Figure 79, page 95).

The third feature of the structure of the Middle Sister is not so obvious but if one looks at Black Hump he will see that its eastern edge is clifted and that its surface extends northward and disappears beneath a snow field. Farther northward on the west edge of Collier Glacier stands Cirque Rock which has an upper surface similar to that of Black Hump. It is apparent that these two masses of rock are parts of a former lava flow, which could not have had its source in the present top of the Middle Sister. This flow must have come from a source further east. When it poured out of some orifice to the east the basal portion of Middle Sister must have been in existence in order to afford the surface upon which these rocks now rest and upon which their parental lava once flowed.

If one restores to these beheaded flows their lost portion he must reconstruct a mountain of greater height than Middle Sister and standing at least four thousand feet farther east. The key to this situation is shown when one views the Middle Sister from the top of the North Sister. The great cirque on the east side is composed of a successive series of flows all dipping to the west. Black Hump is also composed of a similar series of flows dipping to the same angle. The conclusion is forced upon one that there once existed an Elder Middle Sister whose conduit arose from a site now occupied by the terminal moraines of the eastern glaciers and the orifice of which was in a crater rising to an elevation of at least twelve thousand feet. The Middle Sister is only a sporadic cone of more recent date built on the west surface of the Elder Middle Sister.

The South Sister shows two components of structure. The present mountain, probably in part, Pleistocene in age is wrapped around the skeleton of an ancient peak erected within the caldera. This Elder South Sister exposes the family skeleton on the east slope where the gaunt, stark head protrudes through the otherwise graceful slope of the South Sister (Figure 46, page 63). This peak, like the Elder Middle Sister, stood farther east and suffered severe erosion before the present South Sister clothed its aged figure.

The erosion of the Elder Middle and South Sisters producing extensive benches and valleys was accomplished in the Pliocene. The completion of these two mountains took place in the Pleistocene Age which we will now consider.

STAGE V—PLEISTOCENE PERIOD OR ICE AGE

The uplift which characterized the Pliocene continued into the early Pleistocene. This brought about a rejuvenation of vulcanism which built the present cone of the Middle Sister about two thousand feet further west of the Elder Middle Sister. A little later the present South Sister was built by flows and cinders which buried all but the very top of the Elder South Sister. However, not all of the vulcanism of this time took place within the caldera, for Black Crater and Scott Mountain on the north and Bachelor on the south were then raised. Many of the major peaks along the "break" of the Cascades were erected at this time, among which we may include: St. Helens, Hood, Jefferson, Washington, Diamond, and Mount Mazama.

The construction of the Elder Middle and South Sisters in the Pliocene and the mantling of them in the Ice Age by the Present Middle and South Sisters produced the main elements in the topography. Outside was the caldera rim with the North Sister, Little Brother, Husband, Sphinx, Wife, Devil's Hill and Broken Top. Except for minor changes the topography was completed. Such changes as will now be discussed are erosional modifications.

During the early Pleistocene the erosion of the Three Sisters region was of utmost severity. The vigor of this attack was due to the amount of precipitation occasioned by the new uplift. The "break" of the western edge of the Cascade Plateau was elevated so high that it intercepted the moist Pacific winds. The early effects of this precipitation were simple stream erosion and the enlargement of the radial valleys. These valleys determined the course of the glaciers which developed on the crest and the volcanic peaks of the Cascade Plateau.

The waters shed from the western slope of the Cascades cut into deeper relief the "ridges" and widened the valleys. The crests of these divides were not reduced below the general plateau level and may now be seen as ridges of even height. Thus from Saddle Mountain and elsewhere they present an even table land above which the volcanic peaks arise abruptly. From Lane Plateau the level crests are clearly shown (Figure 14, page 16).

The uplift which characterized the beginning Pleistocene continued with the result that glaciers were developed along the entire summit of the Cascades. The presence of these glaciers does not indicate a colder climate. The glaciers simply prove that so much water fell in the form of snow during the winter seasons that it could not entirely melt during the summer. The repeated addition of the annual residue of the unmelted snow at the end of each summer eventually gave rise to glaciers. These glaciers grew so large that they could no longer remain lodged in the upper portions of the mountain valleys, but flowed downward into the low lands to the east and west. On the west side, they moved down into a comparatively warm atmosphere, which for the most part was like that of today. There, at the lower end of the glaciers, was fought a battle between the mild temperature and the supply of ice sent down from the mountain tops. All through the Middle Pleistocene this battle raged unceasingly. All through the Middle Pleistocene the supply of ice was greater than could be melted. The glaciers crept farther and farther westward, reaching the McKenzie Valley at least as far west as Belknap Springs, and in the Santiam Valley as far west as Cascadia.

One of the most striking features regarding the Pleistocene is the evidence of intense glaciation on the east side (Figure 24, page 41). This is in strong contrast with the fact that at the present time the main glaciers are on the northwest. The presence of the glaciers at the present time is determined by the fact that the moist winds striking these mountains come from the north and west. During the Ice Age the prevailing winds were undoubtedly from the same direction. The cause of the ice mantle or glacier was the superior altitude of the Cascade block during the middle Pleistocene. This theory states that the cessation of glaciation was due to the depression of the Oregon fault block at the close of the Pleistocene and all through the Recent geological period. The crest was so high that the winds were robbed of practically all their moisture. This moisture falling from the chilled winds rising over the crest was carried over much in the same way as one now frequently sees the principal snow bank on the leeward side of a peaked roof. Snow, because dry, will drift over the peak of the roof, while rain will not. Further, the higher the mountain the further leeward the cloud banner will soar. Hence, if a range is high enough, all precipitation will be in the form of snow which will drift over the divide. The winds striking the western slope were chilled, but the velocity of these winds was so great that the snow was carried over and dropped on the lee side of the mountains.

EXTENT OF GLACIATED ROCKS

Evidences of this former intense glaciation are extensively found over all the Three Sisters area. The evidence of this glaciation consists of terminal moraines[1], lakes formed through glacial damming, roche moutonnées, polished rock surfaces, glacial scratches and transported glacial boulders.

Thus the obsidian which flowed from the west base of the Middle Sister has been extensively glaciated. This is not surprising where found on the upper benches, but the entire surface of the obsidian plateau likewise shows intense glacial scratching and polishing.

The black and white basalt boulders, found over an extensive area on the eastern and western slope of the Middle Sister, are in nearly all cases polished and scratched, showing that they were carried by glaciers. The trachyte rocks about the Middle Sister also show striations. The olivine basalt of Black Hump and Cirqued Rock were sculptured by glacial action. The stream valleys, cut between them, were enlarged by the Pleistocene glaciers. This evidence may be traced down Lost Creek Valley as far west as Alder Springs.

In general it may be said that all the rocks for many miles surrounding the Sisters region are glaciated. Thus on the north wherever "islands" rise through Belknap[2] and Jerry Flows, the surface of these "islands" show glacial striæ. If one could remove the great McKenzie Lava Flood which covers most of this area one would find beneath it roche moutonnées, polished rocks, striations and glaciated boulders. It is only where islands protrude through this flood that this glaciated surface may be seen. These islands, without exception, prove that glaciers moved over their surfaces.

On the east side glaciers of Black Crater, North Sister, Middle Sister, South Sister and Broken Top extended as far east as the present timber line. Over this area the rocks are intensely scoured and heavily mantled with glacial deposits (Figure 56, page 74).

All of the area on the south side between the South Sister and the Rampart shows evidences of glaciation. Here again much of the glaciated surface is concealed by the present

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1For definitions of glacial terms see page 64.
2See page 51

lava flows of Rock Mesa, Devil's Hill, and Newberry Flow[1]. Around the base of Rock Mesa one can see where the lava poured over glaciated rock.

NUMBER OF GLACIAL PERIODS

The glaciated rocks give some evidence of more than one period of extensive glaciation. This evidence, however, may be due to temporary periods of advancement during the retreat of the glaciers. Jerry Flow must have poured out during the closing stages of intense glaciation. On the west side of Cinder Cone there appear to be several successive glaciated surfaces of this rock separated by several inches of lava. In one place four such layers were noted. The formation, Jerry Flow, however, must have taken place after the glaciers had retreated back to the base of Little Brother because below this point Jerry Flow lies on morainal material and stream boulders of White Branch. On the McKenzie highway there are several localities where glaciated lavas lie on earlier glaciated surfaces.

One interesting bit of evidence pointing to the occurrence of vulcanism when the ice was much more extensive than at present is found near the upper edge of Renfrew Glacier. Here there is a fine development of pillow structure, a structure usually thought to be caused by lava cooling under water. Since there was no water at this point this structure would suggest that some of the lava from the present cone of Middle Sister escaped under ice during the Middle Pleistocene.

EFFECTS OF PLEISTOCENE GLACIATION

The existence and repeated glaciation did not entirely submerge the Three Sisters region beneath a sea of ice (Figure 24). Nowhere were the glaciers as extensive as those at present in existence in northern British Columbia and Alaska. The great masses of ice were more or less local, leaving a large part, perhaps half, of this area exposed. The glaciation of the Three Sisters was contemporaneous with that which profoundly affected the whole northern part of the United States. In this discussion, the modern names of the glaciers are applied to the pre-historic glaciers since the present glaciers are only remnants of the original ones.

1See page 56.

North Sister

North Sister was severely carved on its east side where rises its largest cirque. On the northeast are two small cirques, one simple and the other double-headed (Figure 54, page 74). These glaciers were confluent and deployed northeast and eastward. The west side was too steep to hold a glacier, except perhaps at the very base of the pinnacle. The south side was glaciated by the ancestral Hayden Glacier.

Collier Glacier was then twice as thick as at the present time. It deployed far to the north and to the northwest, and probably moved northwest over the area now occupied by the north lava plains, past the site of Belknap Crater and down the Santiam Valley. Cinder Cone erupted when Collier Glacier was shrinking.

The ice was so thick that a branch extended westward over the pass between Cirqued Rock and Little Brother, united with Renfrew Glacier, and moved westward over Obsidian Cliff and down the valley of White Branch to Lost Creek (Figure 48, page 68). It is believed that the glacier which passed over Obsidian Cliff was at least sixty feet thick, because it was able to fill not only the two branches of White Branch but covered the Cliff at the same time. The striæ on Obsidian Cliff point to a source between North and Middle Sisters and down Linton Creek.

Middle Sister

Middle Sister, like North Sister, shows the most extensive glaciation on the eastern side. All of the eastern and central parts of the Elder Middle Sister were removed, as well as the eastern half of the cone of the present Middle Sister. These glaciers beheaded all the lava flows sloping westward. Thus Cirqued Rock and Black Hump are parts of a late flow from the Elder Middle Sister which has lost its upper end (Figure 53, page 70). As entities, Hayden and Diller Glaciers were not in existence during the period of maximum glaciation. In their stead was one great glacier with perhaps a small nunatak projecting through its center. This great glacier extended eastward at least six miles and spread its outwash for many miles further. This glacier probably united with the larger of the glaciers on the east side of the North Sister and perhaps with the glacier from South Sister and Broken Top.

The northern slope of Middle Sister was covered by Renfrew Glacier. It is not probable that any rocks on this slope projected through the glacier when it was thickest. This glacier covered the surface now occupied by the small snow field between Black Hump and Cirqued Rock. It spread westward and, uniting with the overflow glacier from Collier, extended over the benches on the west side of the Middle Sister far beyond Lane Plateau and down into the valley of Linton Creek. The radial lava flows from Middle Sister were beheaded so that only the lower portions of them now remain. Some of the ice from the north slope of the South Sister probably united with Renfrew Glacier because on the third and fourth benches the glaciated surfaces show striæ which point to the south side of Middle Sister. When individuality was restored to Renfrew Glacier, Black Hump and Cirqued Rock emerged as nunataks, and the peculiar curling rock which forms a spire on the west end of Black Hump was sculptured.

The small ancestral glaciers of Irving on the south slope united with the glaciers from the South Sister.

South Sister

The South Sister, like the Middle, formerly bore the largest glaciers on its north side. During the Ice Age we would have seen but one great glacier on this slope, where today we find five glaciers. This glacier surrounded the cone near the top just as the thumb and fore finger of one's hand might surround a ball. This glacier entirely filled the valley between the North and Middle Sisters and moved eastward to a distance of about five miles. Most of the ice moved westward down the head of Linton Creek and divided into two parts. One part, which moved down Linton Creek, received tributaries from the Husband and from Renfrew. Just beyond Linton Creek it united with a great stream of ice coming down from Collier.

Clark Glacier reached down as far as Separation Creek and joined with a stream of ice coming from the head of

Linton Creek and the Husband. On this slope there are enormous roche moutonnées and many terminal moraines. Lodged between these moraines are several small lakes. The explorer traveling through the thick woods of this slope comes upon these little beautiful lakes in the most unexpected places. Their small circular shape, azure blue waters, and the reflection of the dense forests in their depths, entice the traveler to camp beside them (Figure 51).

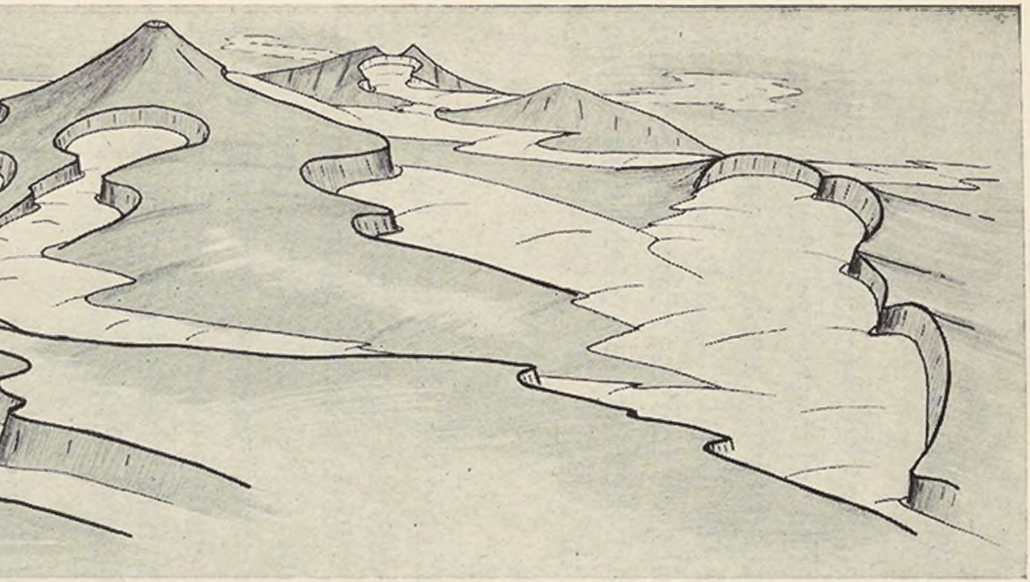
On the south side of the South Sister, glaciers must have reached as far as the valley now occupied by Rock Mesa (Figure 42) because on the higher benches the great tuff showers are heaped into morainal deposits. Lewis Glacier reached down at least as far as Green Lakes and there united with a glacier from Broken Top. For the most part this mass of ice passed east of Devil's Hill. Part of it, however, moved down the valley on the west side of Devil's Hill, for there at the base we find a moraine which dams a pre-glacial valley and is the cause of Moraine Lake.

The east side of the South Sister, like the east side of the other Sisters, shows the most extensive glaciation. The glaciers on this side were not able, as in the case of the Middle Sister, entirely to cut away the Elder South Sister. These eastern glaciers were perhaps confluent with the northern glaciers of the South Sister. At any rate they were extensive and reached many miles to the east. They were undoubtedly confluent with the glaciers from Broken Top.

Husband

Unlike the South Sister, the Husband has lost all of its former glaciers. The most characteristic features of the Husband as seen from a distance are the three large cirques which have been cut into its eastern face (Figures 10, page 14, and 18, page 16). The larger of these cirques rises between the prominent north and south horns. When the glacier occupied this great cirque it had to pass around a great central mass, which at the present time lies some distance to the east and at the very center of its basin. Morainal hills and the topography extending some distance to the northeast, indicates that this glacier passed northward down Linton Valley.

Figures 24 and 25. (24) An airplane view during the Ice Age looking east towards the Three Sisters. On the left is the ancient Collier Glacier passing down the old Santiam Valley and in part spilling over the divide between Little Brother and Cirqued Rock. Glaciers at that time headed from Cirque Rock and between Cirque Rock and Black Hump. These glaciers and the ancient Renfrew Glacier moved downwards over Obsidian Plateau into the ancient McKenzie Valley. In the foreground are shown the prehistoric glaciers moving westwards towards Proxy and Honey Creeks from the Husband. The eastern side of the Husband was occupied by glaciers, some of which moved toward Separation Creek Valley. The north side of the South Sister at that time was occupied by three large glaciers which moved northward and divided. Part moved westward into Separation Creek, and the other part moved eastward and joined the great mass of ice from the east side of the North Sister, Middle Sister, South Sister and Broken Top and deployed eastward for miles over the eastern slope. Glaciers from the south side of the South Sister joined with the glaciers from the Wife and moved westward down Separation Valley. Glaciers on the southeast side of the South Sister and from the west side of Broken Top joined and then separated around the impediment of Devil's Hill. (25) The glacially fed waters of the modern streams from the Three Sisters abound in trout.



The south pinnacle is formed by the remnant left between two westward-facing cirques. The glaciers on the east and those on the west headed directly toward each other, and, by their erosion cut that portion of the Husband into two narrow walls. One of these narrow walls, or arêtes, starts southward from the south turret, and the other arête extends between the south pinnacle and the north one.

Wife

Glaciation in the ice age existed on the north side of the Wife, as shown by the well developed cirque, capped by two peaks with a chimney between. This glacier united with the glacier coming down Separation Creek and those from the south side of the South Sister, and passed westward down Separation Creek. This entire valley shows morainal topography and everywhere one may find the evidence of striated rock and glaciated boulders (Figure 21).

Broken Top

Broken Top shows three enormous cirques, each of which was host to a glacier during the Ice Age. The westernmost glacier united with Lewis glacier from the South Sister and passed down Fall Creek Valley. The Cook Glacier must have extended as far as Soda Creek Trail because the entire area is now covered by morainal material. The Bend Glacier was very extensive and reached far to the north and east for a distance of about five miles. (Figure 69, page 88).

In addition to the glaciers already described there were small glaciers on Black Crater and perhaps small local glaciers on many of the surrounding mountains. These glaciers, did not create prominent cirques and therefore their existence is not so well established.

STAGE VI—CLOSE OF THE ICE AGE

The Pleistocene was brought to a close by a sinking down of the Oregon fault block. This downward movement, which perhaps has continued to the present time, permitted a large part of the moisture-laden winds to pass over the break of the Cascade Plateau. The winds gradually pre-

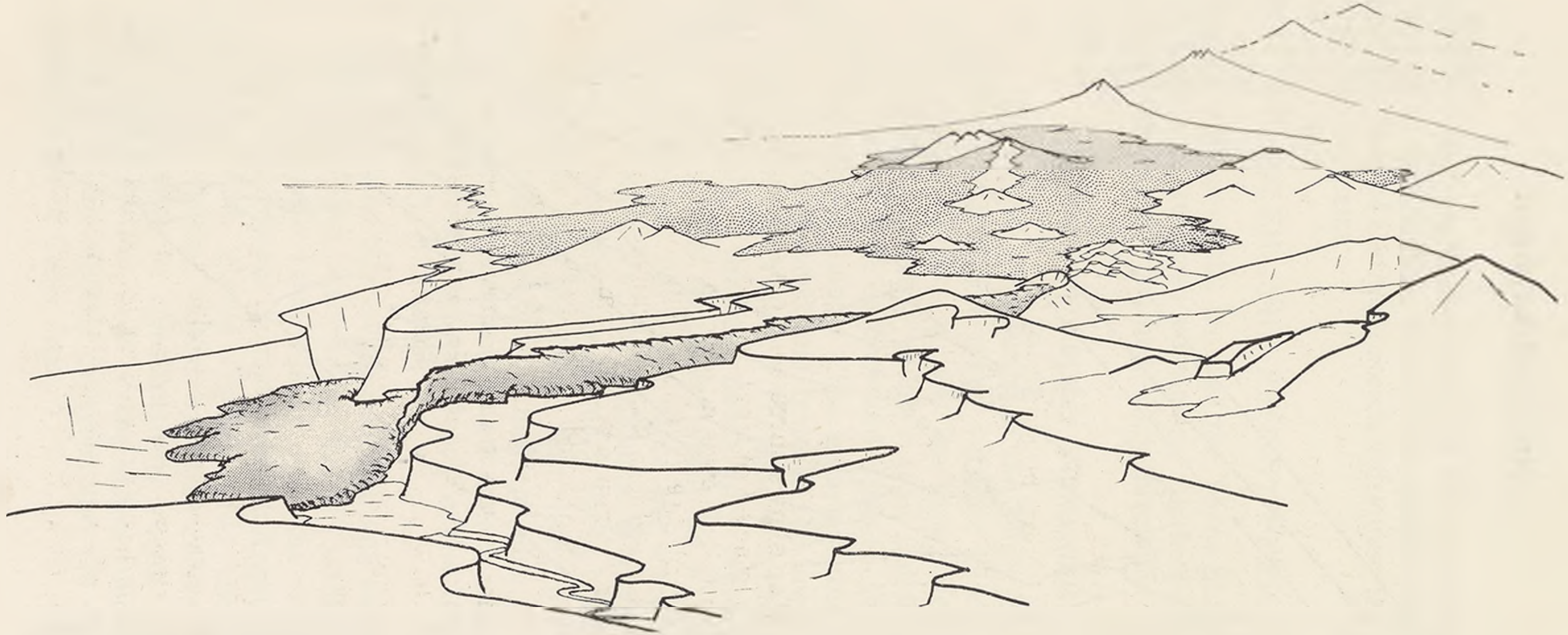


Figure 26. Looking north from the Husband, showing the great McKenzie Lava Flood pouring out of Little Belknap, surrounding the Cinder Cone of the Belknap and the "Islands," pouring down the old Santiam Valley and damming the same. Jerry Flow is shown issuing from Cinder Cone at the south end of Ahalapam Cinder Field, moving westward over the benches of the Middle Sister to Lost Creek Valley. The McKenzie Lava Flows lie north of Scott Mountain, extend around the west base of Black Crater and reach as far north as Mount Washington.

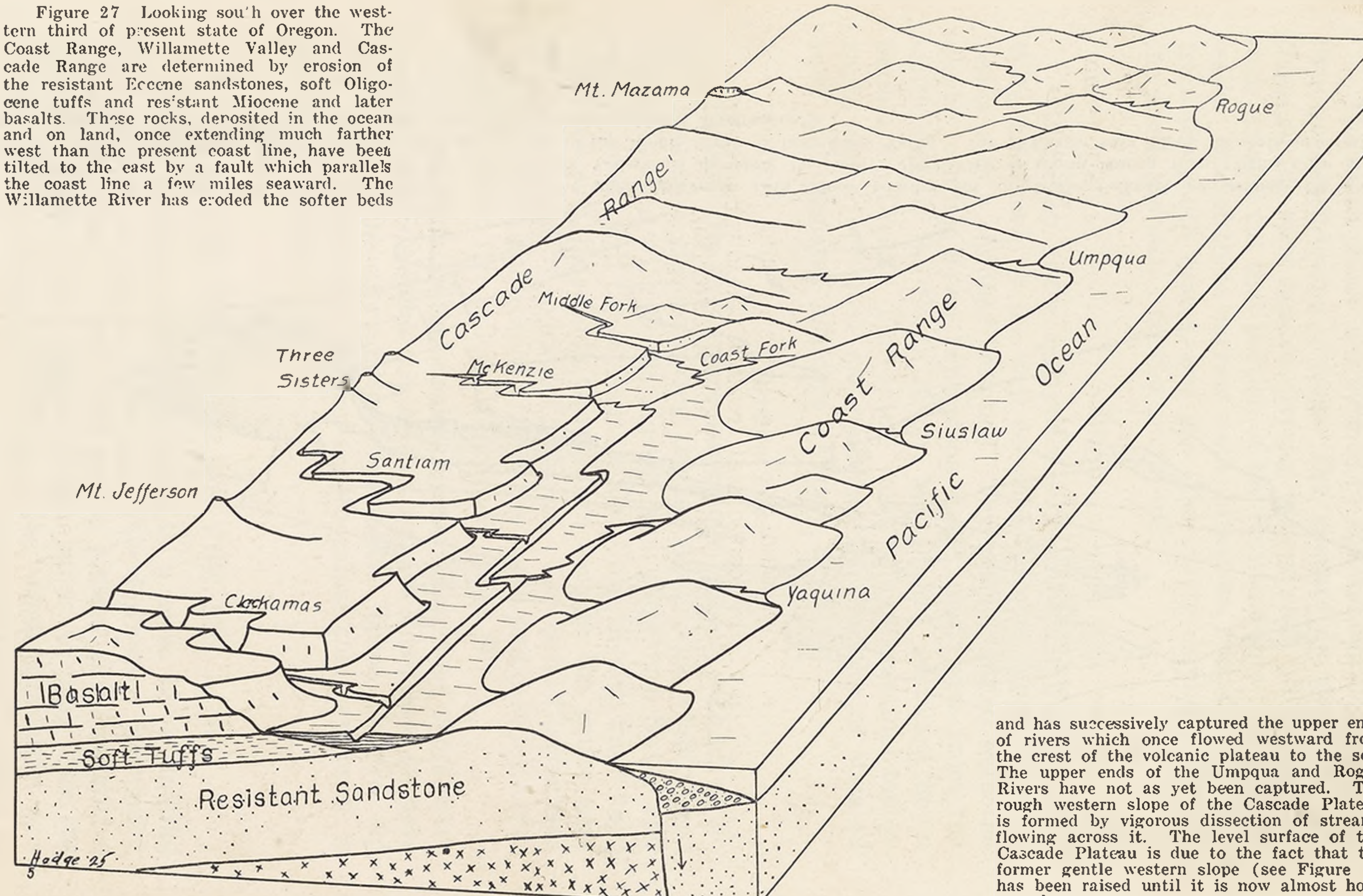


Figure 27 Looking south over the western third of present state of Oregon. The Coast Range, Willamette Valley and Cascade Range are determined by erosion of the resistant Eocene sandstones, soft Oligocene tuffs and resistant Miocene and later basalts. These rocks, deposited in the ocean and on land, once extending much farther west than the present coast line, have been tilted to the east by a fault which parallels the coast line a few miles seaward. The Willamette River has eroded the softer beds and has successively captured the upper ends of rivers which once flowed westward from the crest of the volcanic plateau to the sea. The upper ends of the Umpqua and Rogue Rivers have not as yet been captured. The rough western slope of the Cascade Plateau is formed by vigorous dissection of streams flowing across it. The level surface of the Cascade Plateau is due to the fact that the former gentle western slope (see Figure 5) has been raised until it is now almost horizontal.

cipitated less and less moisture, with the result that the glaciers began to disappear. When these glaciers had retreated to within the base of the more recent volcanoes, the Pleistocene period came to an end.

STAGE VII—THE RECENT PERIOD

Since the close of the Ice Age the Three Sisters area has been subjected to renewed vulcanism, further glaciation and the present topography has been fully developed (Figure 27).

EVIDENCES OF RECENT VULCANISM

The most striking peculiarity of the Three Sisters region is the obvious youth of the many volcanic floods, volcanoes, and cinder fields. In fact, it was the great McKenzie Lava Field, over which the early pioneer road builders carved a laborious union between eastern and western Oregon, which first made the region famous. The lavas pouring down from the young volcanoes flooded and froze in the lower areas and in the upper Santiam Valley. Though diverting the water courses of the valley, the lava floods only veneered the low pass which the earliest explorers chose as a possible way to cross the Cascades. No better route has since been found, and the summit section of the McKenzie Highway is at the present chiseled through these lavas. These black, scoriaceous, volcanic rocks look so young that many are convinced that they have congealed within historic time. These congealed lavas in total cover seventy-eight square miles and form one of the largest recent igneous floods in the United States (Figure 34, page 52).

The evidence that this lava inundation and volcanic explosion is of recent origin is shown by (1) the undisturbed surface of the McKenzie Lava Field; (2) the superimposed streams; (3) the presence beneath the McKenzie lavas of a glaciated surface and glacial deposits; (4) the filling and damming of older radial valleys by these recent flows; (5) the existence of dams in comparatively young valleys; (6) the absence of vegetation, even of the lichen which will grow on a rock surface only slightly decayed; and (7) the presence of submerged trees in Clear Lake.

McKenzie Lava Field

It is apparent that Belknap Crater forms the very center of this flood area (Figures 26, page 43, and 34, page 52) from which these lavas flowed northward to Mount Washington, northwest down the Santiam Valley beyond Clear Lake, while to the east they spread as far as Blue Grass Butte and to the south they reached Little Brother.

South of the McKenzie Highway the lavas were furnished chiefly from Cinder Cone. It is impossible to determine the point at which these two lavas actually met, because they are both composed of the same type of rock, and when they met each other the liquid rock from their respective craters intermingled. The extent of these McKenzie lavas, sixty-five square miles, was not sufficient to bury all of the older topography. The later lavas, together with those from Belknap Crater filled in the area to the west of Black Crater. Several peaks now called islands which lie to the west of this were not submerged, such as Chief Joseph Island, Huckleberry Butte, Abernethy Island, and Winthrop Island. These lavas were controlled in their flow by the surface of the valley in the vicinity of the McKenzie Pass. One stream of lava poured westward down the former valley of White Branch to beyond Linton Lake, but the greater part of incandescent rock deluged the entire upper valley of the Santiam.

This lava is largely of the "aa" type. Here and there the ropey and billowy "pahoehoe" lava ocurs. All of this lava is characterized by an exceedingly scraggly, fractured and broken surface (Figures 28 and 31). One traveling over this lava notes that it is arranged in long parallel ridges. Some of these ridges show a half circular cross section such as one would expect to find resulting from the freezing of streams of viscous liquid. Other ridges are double in character and look as though someone had split a long lava flow longitudinally and wedged the two halves apart. The inner edges are bounded by perpendicular cliffs. This split appearance is due to the collapse of lava flows (Figure 31F, page 50).

Let us visualize a lava stream during its active period. Such a stream of lava might pour out of the crater of a cinder cone, but because of its liquid character and weight, it is more likely to soak or break through the porous side of a cinder cone, or perhaps even burst the walls of a volcano made of solid rock. In most cases, therefore, the lava did not issue from a crater, but poured out from one side of a crater. Thus in the case of Belknap we would have seen first the blowing out of a great pile of cinders caused by the first escape of the volcanic gases (Figure 33, page 50). Later the lava rent the southwest side and poured out innumerable streams in all directions. Continued emission of the lava from this point built up a low cone, Little Belknap, composed entirely of lava.

This lava gushed out in individual streams, perhaps two hundred feet wide and thirty to fifty feet high. These streams flowed until obstructed by some topographic features or until their viscosity became so great that further movement was impossible. The distance that any one of these streams of fluid rock extended (that is, to where it was stilled by viscosity) depended on its initial temperature and the surfaces over which it moved. Those which moved to the northwest, following a large valley, flowed the greatest distance, thirteen miles. The streams moving to the northeast, on a gentler surface, flowed only about six miles. The flow north from Cinder Cone extended at least five miles. Jerry Flow poured down White Branch Valley for seven miles.

In the northern region six great lava streams may be recognized. One, covering twelve square miles, starts at a point about four miles southwest from Three Finger Jack and extends to Lava Lake, thence southerly along the valley of the McKenzie River to the waterfalls below Clear Lake where it is joined by another stream from the side of Belknap Crater.

Streams of lava did not, as a whole, remain liquid until they had reached their greatest length. Crusts of frozen lava immediately formed on top similar to the little crusts of slag which one may see on a stream of pig iron as it issues from a molder's furnace. If only crusts were formed, the lava moved beneath the fractured crusts and they were floated along like blocks of ice on a river. Blocks carried along in this manner were turned over and over and finally came to rest in disordered position (Figure 38, page 57).

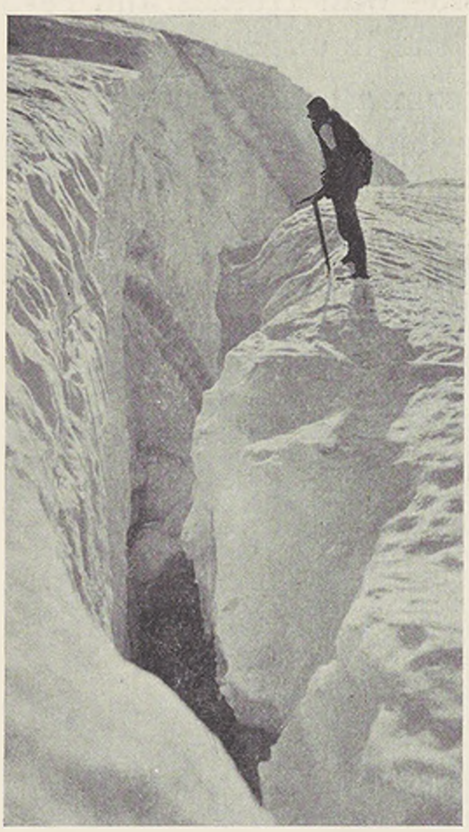
Figures 28, 29 and 30. See Footnote, Page 49.

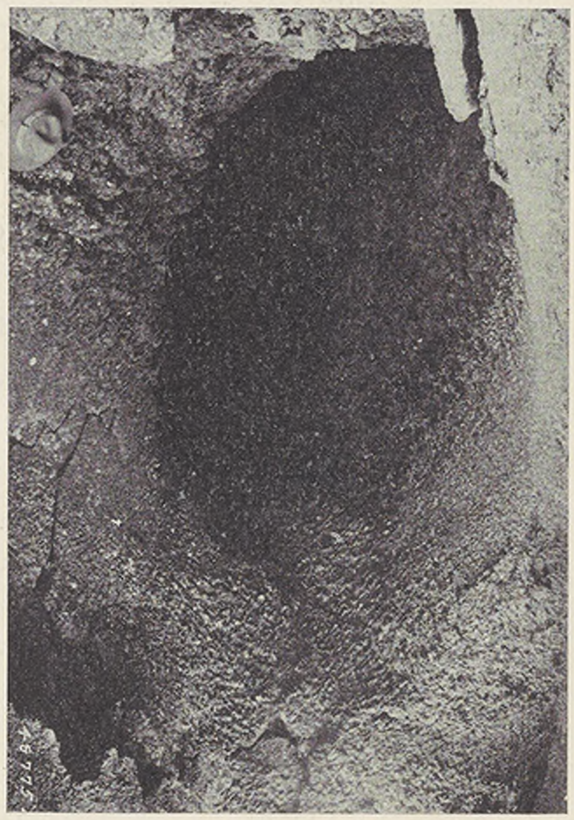
Lava streams—like a thick sirup and unlike water—do not have a level surface. Along the sides of such slowly moving streams rock splatters out and immediately freezes, and there, along their edges, a rampart is built of frozen material (Figures 29 and 40, pages 50 and 57). This lateral crust grew until finally a solid crust was formed on top. This crust formed a continuous coating over the lava particularly close to the volcano. Through this crust the later rock issuing from the volcano flowed as water might flow through a conduit. If the amount of lava issuing was not sufficient to fill up the entire valley, or if the crust was thick enough to prevent the lava beneath from freezing, then the lava flowed out from this conduit and left it standing alone. Such arches of lava were unable to support their own weight, and collapsed. It was the collapse of such conduits which gives the double ridged flows.

In some cases a revival of vulcanism permitted new flows to flow down between the side walls. The steep walls of these flows prove that the lava must have been very viscous to retain such steep walls and still continue to flow. To some extent, however, these steep walls are not due to viscosity, but to the fact that the liquid rock on the side wall freezes and remains as dikes between which flows the liquid lava.

In cases where the lava did not form a conduit, long and often wide fractures due to contraction resulted from the cooling. The rock at the time of fracture was not entirely solid but slightly plastic. Movements, such as sliding, pushing and crowding of portions of such a flow upon one another, caused the adjacent parts to iron out and groove their neighbors (Figure 38, page 57).

Figures 28, 29, and 30. (U. S. F. S.) (28) The rugged scoraceous McKenzie lava surface. (29) Jerry Flow upon alluvium and glacial gravels and impinged against Obsidian Cliff where it once dammed White Branch and formed a lake, where the man stands, which overflowed and cut a new channel. (30) Looking north to Cinder Cone and terminal moraine of Collier Glacier.





Figures 31, 32 and 33. (U. S. F. S.) (31) Collapsed lava caves and scoreaceous surface of McKenzie Lava Flow. (32) Crevasses in Collier Glacier. (33) Gas conduit on west side of Little Belknap. Gas escaping from below maintained an opening in the liquid lava until it froze.

Volcanic Cones

Belknap

Belknap is the most prominent of the numerous cones related in part to the great McKenzie Lava Flood (Figure 52E, page 70). This is a cone built of cinders, ash and volcanic bombs. This mountain, not at all difficult to climb, repays the visitor for his labor. The top of the mountain shows three distinct craters, all in a row, with the largest to the west. Apparently the gases which threw out the cinders forming these cones either escaped at three different times; or else, when the pile of cinders had been built to this elevation, the gases sought an unrestrained escape through the porous side wall to the east and there successively built new craters.

On the top of this crater one finds semi-consolidated ashes and tuffs. These have a horizontal stratification, indicating either the presence of water in the craters, or stratification resulting from the ashes settling gently down out of the air after the final explosion. The large amount of gas which rushed out during the escape of lava blew aloft drops of liquid lava. These drops of lava consolidated in the atmosphere and fell back as a shower of cinders. Only a small fraction of the total mass of liquid rock was hurled into the air as coarse drops and rock mist.

No visitor to this region should fail to climb to the top of Little Belknap, and see for himself the stalactites, the stalagmites, the splatter cones, the conduits through which the lava poured, and other details of this marvelous crater. One standing on this crater can imagine himself looking down upon it from the safety of an airplane and restore this crater at its period of activity. He can see the lava spluttering out and pouring down in streams in all directions. He can see the earlier lava streams buried beneath the later overflows. Finally he observes that the effect of all was to flood all the previous valleys and bury them deep beneath a mantle of volcanic rock.

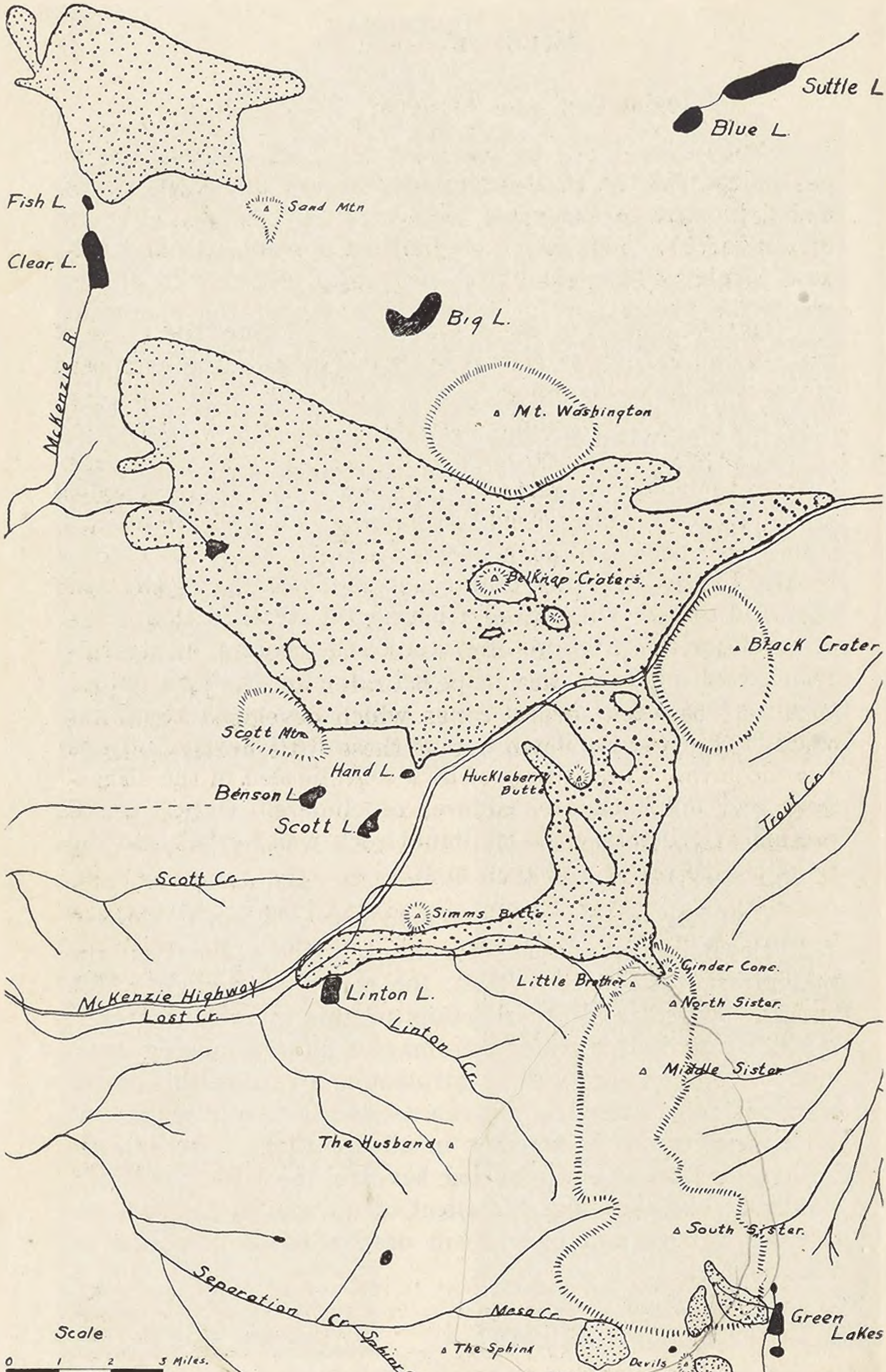


Figure 34. See Footnote, Page 53.

Cinder Cone and Ahalapam Cinder Field

Cinder Cone, one of the most accessible of these cones, lies at the foot of Collier Glacier between the North Sister and Little Brother at 7500 feet elevation. Its shape is that of a horseshoe with the rear of the shoe facing to the southwest (Figures 59, page 76, and 72, page 90).

This Cinder Cone came into existence near the close of the Glacial Period, as shown by the little moraine composed entirely of cinders on its south side, and by the fact that Jerry Flow rests upon morainic material. Its western half was carried away by Jerry Flow. Extending northward from Cinder Cone, the largest, are two rows of volcanoes called the Ahalapam[1] Cinder Field terminating in a perfectly-formed cinder cone called Yapoah[2] Crater around which Scott Trail bends (Figure 39). At a distance these volcanic cones have the appearance of morainal topography. This is due to the nob and kettle, or the hill and basin character of the surface. The basins, however, are in part crater and in part depressions left between several cones which developed simultaneously. The cinders blown out of these little craters were at one time spread east and west for perhaps a mile. All of these cinders have been swept away by the streams on the east and west side of the North Sister. These volcanoes arise from—and have spread their cinders on—the northward sloping surface of North Sister, the edges of which are exposed beneath the cinders on the east and west sides. The Ahalapam Cinder Field is two and one-half miles long and three-fourths of a mile wide and about 500 feet thick. It is the largest cinder pile in the area (Figure 36).

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[1]Ahalapam, an old Indian name, presumably the true one for the Santiam River—chosen for this immense cinder field because of its beauty and because the area where it now lies was once the source of the Santiam River.

[2]Yapoah, a beautiful Indian name signifying an isolated outstanding hill.

Figure 34. A map of the lava flows of the Three Sisters. Note that Jerry Flow not only moved westward toward Lost Creek but flowed northward and mingled its liquid rock with that of Belknap. On the south side of the South Sister are four lava flows. These latter are composed of white to cream colored silicic lavas of the great McKenzie Lava Field. This is remarkable since these two lava floods came to the surface at about the same time and probably from the same magmatic reservoir.

Figures 35, 36 and 37. See Footnote, Page 55.

Evidence of Recent Vulcanism on the South Side

The south side lavas and volcanoes are also Recent in age. These flows have obstructed post-glacial drainage channels, lie on glaciated surfaces and young stream gravels, afford no hospitality to vegetation, and the superimposed streams have not had time to cut a perceptible channel.

Rock Mesa

The most interesting of these volcanic features is Rock Mesa (Figure 37), composed of trachytic vitrophyre and pitchstone lavas which have broken out from the south side of the South Sister since the Ice Age. From a broad plain it rises from all sides to a central elevation of 6700 feet with an elongation from northwest to southeast. The lava manifestly came from some central orifice and moved outward in all directions over a pumice covered and, in places, glaciated valley floor. This lava must have had a consistency similar to that of building plaster, since it did not flow rapidly outward in all directions like basaltic lava but moved with so slow a motion that the later lavas rolled over the earlier emanations (Figure 43, page 60). The amount of material which poured out came in contact with one spur from the South Sister and almost reached to the Wife; it covered two-thirds of a square mile and was just sufficient to block the valley. It is an excellent illustration of sticky, viscous lava rising to the surface through a small conduit and spilling out on the surface in all directions. The rock is so young that it does not show the slightest decay (Figure 40, page 57).

Just south of Rock Mesa is another youthful and perfect cone covered with trees called Le Conte Crater, after Professor Joseph LeConte, an outstanding geologist of the Pacific Coast

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Figures 35, 36, and 37. (U. S. F. S.) (35) Looking into one of the Twin Craters northeast of Scott Mountain. (36) Looking north from North Sister over the great Ahalapam Cinder Field. (37) Looking north from the Wife toward South Sister over the irregular surface of Rock Mesa lava flow. The surface of this flow is so young and fresh that no vegetation of any kind grows on its surface. The top of the South Sister shows Clark Glacier on the left and Lewis Glacier on the right. Note the symmetrical profile of the South Sister.

Miller and Devil's Flow

in the early days. Near Rock Mesa are several similar mesas of smaller size among which, one-half mile east, is Rose Mesa.

Miller Flow (Figure 64, page 80), at an elevation of about seven thousand feet, also issued from the very base of the South Sister and flowed toward—but did not entirely reach—the base of Devil's hill. It covers about one-third of a square mile. The lava came to the surface, soaked through glacial moraine and then debouched over a glaciated surface. In so far as I know, this is the only described case of a lava flow reaching the surface by soaking through a recessional moraine. It was named after Miller, a deceased member of the party which assisted me in the preparation of this report. Devil's Flow extends eastward from Devil's Hill and covers about one-fourth square mile.

Newberry Flow

One of the most bewitching flows on the south slope of South Sister was named after Professor J. S. Newberry of Columbia University, who examined it in 1854-55 and described it for the United States government in a "Report on an Exploration for a Railroad from the Mississippi to the Pacific Ocean." The first name given by the writer to this flow was Disappointment Flow, because of the fact that after an arduous trip around the South Sister he found his way obstructed by this impassable flow lying athwart his route to Green Lakes. This is the largest of the recent trachytic flows and covers six-tenths of a square mile (Figure 64, page 80).

The vent through which this lava issued must have been a sort of slit in the mountain side extending southeastward. It is apparent that the lava squeezed out through this slit at an elevation of 8000 feet and even more abundantly at about 7700 feet, and oozed slowly upward and outward, and then downward. The pressure of lava from below and the viscosity made possible the piling up of the lava to an elevation of 8100 feet.

Figures 38, 39, 40 and 41. (38) To show the huge angular, grooved trachytic lava blocks lying at all angles over the surface of Newberry Flow. Part of Lewis Glacier is shown in the distance. (39) Looking north from the top of Ahalapam Cinder Field to Yapoah Crater. In the distance is shown Washington, the tip of Three Fingered Jack, and Mount Jefferson. Note the gentle eastern slope of the Cascade Plateau extending eastward from these mountains. (40) Looking eastward to the divide between South Sister and Rock Mesa Lava Flow; (41) Looking north from the middle peak of the North Sister to its north peak. This peak is an erosional remnant of the old surface of Mount Multnomah. In the distance is Black Crater.

The surface of the flow is exceedingly jagged and jumbled. It is composed of small fragments at its base, but near the top great angular blocks rest in complete confusion. These blocks were formed by the upper portion of the flow freezing to a depth of ten to fifteen feet. The lava beneath, kept viscous by the heat-nonconducting overcoat, moved down the slope and fractured the upper solidified crust just as ice is ruptured on the surface of a stream. Unlike ice blocks on the surface of a winter stream, however, these blocks of lava did not float gently down, but were rolled over and over and in some places squeezed and hoisted up into jagged piles. Some of these massive blocks were not frozen rigid, but retained enough plasticity so that as they were jostled along they gouged each other and left in their sides enormous grooves (Figure 38).

Despite the rough character of this flow it affords one of the most interesting rock climbs in the area. By taking reasonable care and plenty of time one can reach the topmost rock of the mass. Such a trip will yield the explorer many samples of trachytic vitrophyre, some of which are full of bubble holes, some contain tiny crystals, and some are found to be pure glass. The explorer will vividly realize how the upper frozen surface of this flow was cracked and then the fractured blocks jostled along over the slowly-moving surface of red-hot lava.

Little Broken Top

In addition to the flows of the South Side some of the volcanic cones should be mentioned. After going over the rugged pass between Rock Mesa and the South Sister into the valley beyond, one may ascend the first valley in the slope of South Sister to the first plateau. The surface here is covered by a mantle of pumice, from six to twelve inches thick, through which the other rocks project (Figure 60F, page 78). At an elevation of about 6700 feet is a small volcanic field on which appears Little Broken Top. It is about five hundred feet in diameter, perhaps one hundred feet high, and is composed of basaltic rock—which is exceptional for the South Side. This basic lava welled and formed a little symmetrically shaped pile. During the cooling period the top of this tiny volcano split and fractured.

Cayuse Cone, of the same type, composed of red scoriaceous lava, lies on the southwestern spur of Broken Top. Around its base are abundant volcanic bombs, and to the south a flow of porous trachyte extends down about 1000 feet.

As one looks south from the Three Sisters toward the eastern profile extending out from Bachelor, he can see dozens of little craters standing on the eastern slope of the Cascades. The lavas from these Recent cones bury much of the old east surface of Mount Multnomah.

In addition to these cones there are about fifty others in the vicinity of the Three Sisters. Nearly every peak in the vicinity shows one or more craters around its base. There are four of these cones around the base of Black Crater. A double crater on the north east slope of Scott Mountain is called Twin Crater. Figure 33 is a view looking down into one of the craters of Twin Crater.

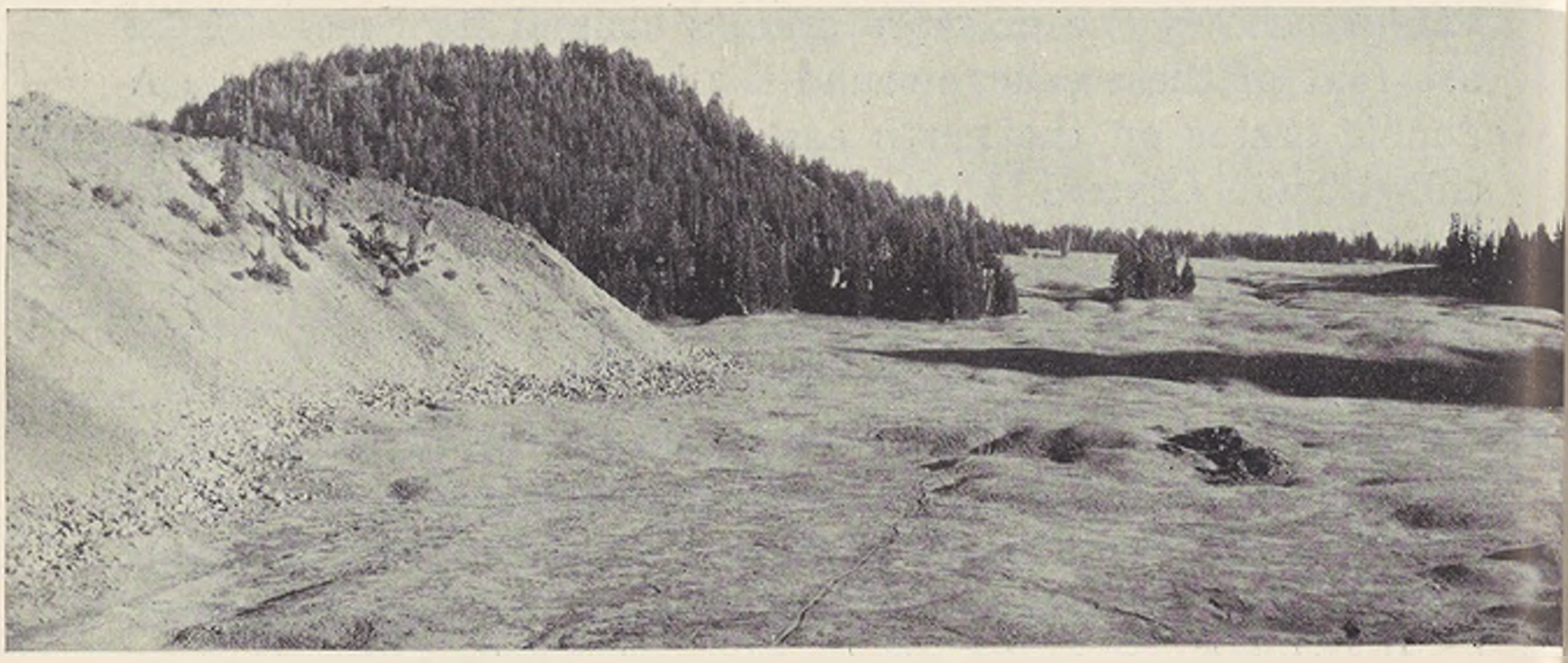
Old Sub-Lava Surface

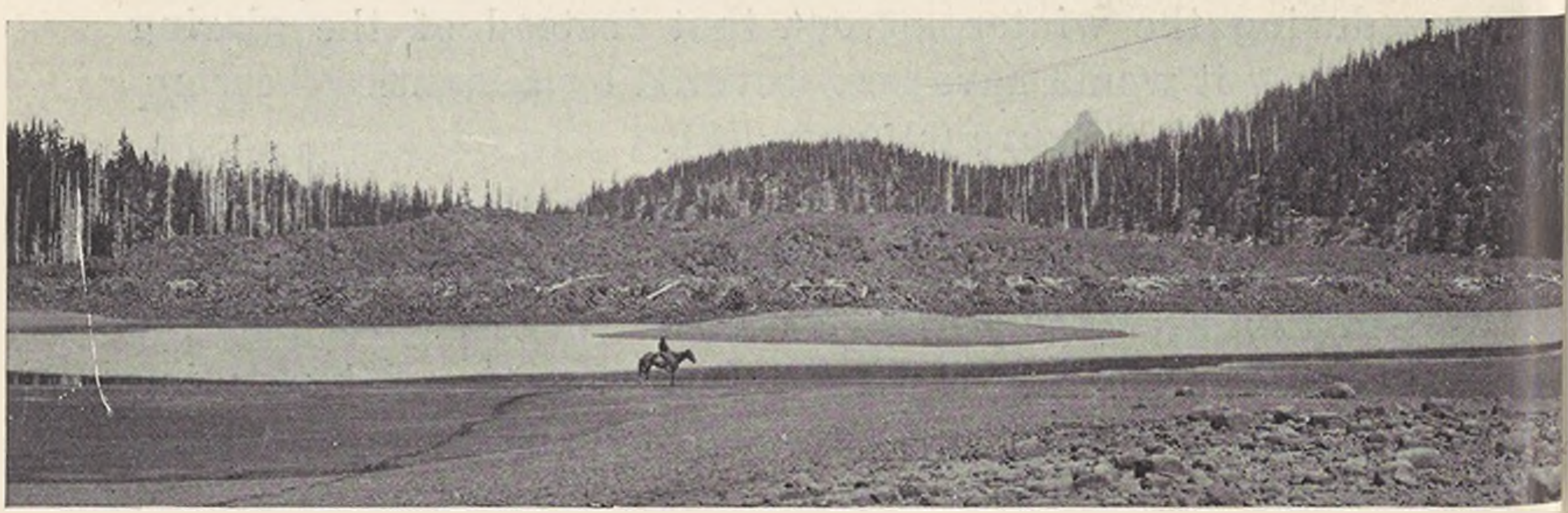
The glaciated surface over which lie the McKenzie lava and other "Recent" lavas is everywhere found to be that of an old surface eroded to maturity (Figure 7F, page 14). This mature surface was once covered by glaciers, as shown by the striations, roche moutonnés and erratics.

Pumice Showers

It is also patent that before these lavas spread over any portion of this surface, it was buried deep beneath a canopy of cinders and pumice. The expulsive gases which brought to the surface the lava floods threw out for miles in all directions great pumice showers. If one could have seen this surface at this time, it would have looked very much as it does now during the winter, except that instead of the glaring white snow it would have been covered by a mantle of cream-colored pumice (Figure 60, page 78).

On the south side the pumice covers the entire surface up to an elevation of about 7500 feet. As one goes south or east of this area the pumice becomes thicker. Much of the area from the Sisters to Crater Lake is covered by an immense quilt of pumice. On the immediate slopes of the South





Figures 42, 43, 44 and 45. See Footnote, Page 61.

Sister it is heaped into morainal ridges. This pumice was not hurled from a single volcano, but was blown out from numerous craters, active during and since the glacial period. Most of the pumice is on the south side of the Three Sisters and also on the south side of Mount Hood. This evidence points to northwesterly winds during the period of eruption. The gases escaping from these volcanoes were entangled in the viscous silicic lava. Thus lightened, it was hurled high in the heavens, then fell slowly to the ground. In this parabolic journey it was drifted by the winds far away from the volcano from which it erupted.

Superimposed Streams

The superimposed streams prove the youthfulness of these volcanic features.

Figure 29, page 48, shows clearly that Jerry Flow poured down the older valley of White Branch. At the edge of the flow old stream gravels, some six inches in diameter, and alluvium lie beneath it. This lava impinged against the northwest side of Obsidian Cliff and so dammed White Branch. These glacial waters piled up behind two walls until it finally escaped by flowing over the surface of Jerry Flow along the channels formed by collapsed flows. This happened so recently that the superimposed White Branch has not cut into Jerry Flow more than a few feet and near Linton Lake must cut at least forty feet to reach the bottom rock (Figure 89, page 138).

White Branch is not the only stream which has superim-

Figures 42, 43, 44 and 45. (42-U. S. F. S.). One of the Mirror Lakes typical of the many park areas surrounding the Three Sisters formed by morainal damming on the south side of the Wife. (43-U. S. F. S). Looking eastward from the pass between Rock Mesa and the Wife. The picture shows that Rock Mesa poured out over a ground moraine of pumice. All the surface south of the South Sister is deeply covered with pumice. (44) Looking southward from the northwest slope of Broken Top. On the left is the Bachelor, in the distance the even crest of the Cascade Plateau. Newberry Flow which issued from the east side of the South Sister is shown to overlie the alluvial fans from the South Sister, to dam Fall Creek, and form the green lakes in the foreground. The Green Lakes were much larger but eventually found an outlet around the left hand end of Newberry Flow and drained outward to Spark's Lake, shown in the distance. In the center of the picture is shown the conical peak of Devil's Hill. To the left of Devil's Hill is Devil's Flow. Between Devil's Hill and Newberry Flow is Miller's Flow. (45-U. S. F. S.). Looking east toward Mount Washington over the surface of the McKenzie Lava Flood, Hand Lake occupies a depression in the surface of this flood.

posed in this manner. Careful study of this lava field will reveal many other streams similarly superimposed. Thus the drainage from Patjenes Lake is superimposed in the vicinity of the upper falls of the McKenzie River. The drainage from Clear Lake is in like manner superimposed over the top of the McKenzie Flow.

Falls Creek is a stream whose course has been seriously deranged by Newberry Flow. This stream at one time followed down its valley a few thousand feet to the west. Newberry Flow for a time dammed the stream and created a large lake over the Green Lakes area (Figure 64, page 80). When these lakes overflowed their waters took a new course around the eastern edge of Newberry Flow where they have not had time to cut a well-defined channel and now tumble over the rough lava in a series of cataracts. Some of the water escapes from Green Lakes beneath the lava dam on the southern side in the form of large springs. Eventually Fall Creek will cut a channel deep enough to completely drain the lakes

PRESENT GLACIERS

In the Three Sisters area, seventeen separate glaciers still survive from the "Great Ice Age." No other region in the United States contains in so limited an area so many accessible glaciers as the Three Sisters. These glaciers cover 2257 acres and form the largest ice field in the United States at so southern a latitude.

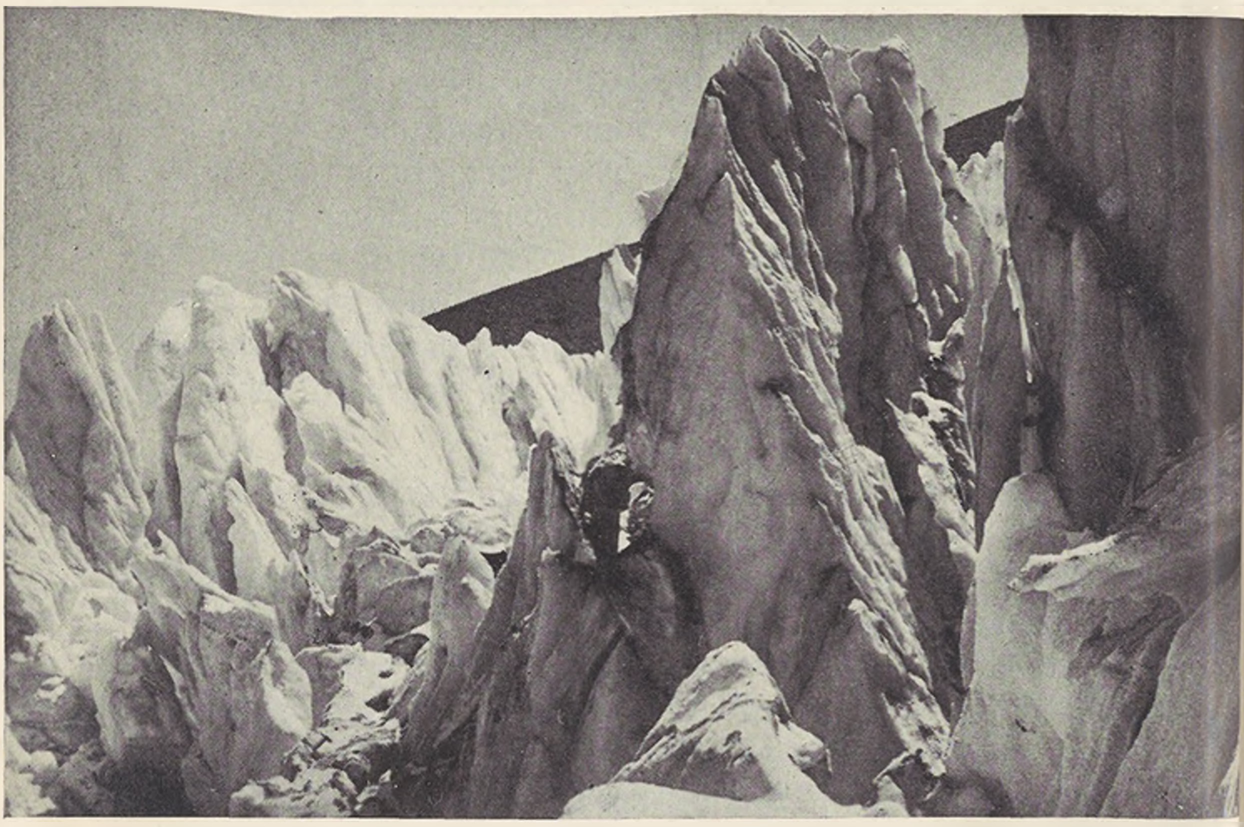
Glacial Features

Those who visit the glaciers of the Three Sisters will be interested in the many fascinating features which they display. The science of Geology largely had its beginning in the interest aroused in studious men who visited the Alpine playgrounds of Europe. These early intellectuals could not fail to observe the definite evidence of glacial work. Stimulated by the obvious, they sought the reasons for the less apparent results. From these beginnings, resulting from a summer's outing, has grown the science of geology.

One does not need to visit Europe, however, to see great glaciers nor to observe their work. The Three Sisters region contains as beautiful glaciers as any of those found in Europe and, like some of the more famous playgrounds of Europe, the glaciers of the Three Sisters are easily accessible by motor car within a few hours from large cities. In fact the glacial playground of the Three Sisters is exceptional because of its accessibility.

This chapter, however, is not devoted to the sports of the glaciers, but to a brief description of the features which may be found in and around the glaciers themselves. All the glaciers except Collier and Hayden take their origin in a *cirque*, (Figure 8, page 14, and 69, page 88). These cirques form an amphitheatrical area (hence the name "circus") carved by the headward erosion of a glacier. Glaciers carve cirques and cut headward by freezing to the rock at their upper ends and then pulling it away from the mountain wall as they move down hill, thus creating there a steep wall called a *bergschrund wall* (Figures 62 and 63, page 80). Because the Sisters have greatly diminished in size, these bergschrund walls stand as perpendicular cliffs overlooking th glaciers. Between the bergschrund wall and the head of the glacier, there is often found a yawning chasm called *bergschrund* or mountain rip. This bergschrund is often a source of danger, especially to climbers seeking to ascend or descend a mountain on a glacier. The top of such a bergschrund or chasm is frequently bridged by new snow. Many a mountaineer, unconscious of this danger, has broken through the weak snow bridge and fallen to his death in the bergschrund.

A glacier moves downward along its valley by a process of melting and freezing. This melting and freezing of each névé or ice granule is microscopic in character but in the aggregate reaches a considerable volume. Though only an insignificant amount of water produced by pressure is released and moves downward to a place of less pressure, where it freezes and expands, yet the net result of billions of névé and glacial ice particles so reacting give the glacier as a whole a considerable and visible movement. Since only a mere fraction of the ice is water at a time, it is possible for the ice as a whole to freeze onto chunks of rock and hold them firmly and remain rigid. The rocks thus grasped by the glacier are



Figures 46 and 47. (46-U. S. F. S.). Looking north from the morainal dam between Devil's [illegible] and the rest of the South Rampart. This moraine and much of the surface of the South Sister is [illegible] up of a light colored pumice. Moraine Lake has resulted from this morainal dam. The Lewis and [illegible] Glaciers are shown on the south side of the South Sister. Lewis Glacier is shown to extend eastwar[illegible] the south side of the projecting top of the Elder Sister. The hump on the right is the head of Newb[illegible] Flow. (47) Seracs on Prouty Glacier.

used as *tools*. With these tools the glacier cuts, carves and gouges into the rocks over which it rides. Not only does a glacier carve a valley for itself, but by freezing to the loose rock "*plucks*" it from its bed and carries it along.

The material carried by a glacier is held until the ice melts, and then is dropped. Unless this material is carried away by water it remains as a huge pile called a *moraine* (Figures 30, page 48, and 55, page 74). Moraines are built along the sides and at the ends of glaciers. These moraines are frequently built higher than the glaciers themselves because of the shove given to them by the glacier. The material composing these moraines is derived from the mountain over which the glacier travels. Thus the moraines on the north and south of the South Sister are red and yellow in color, while those of Collier are a blue-gray. The material of the moraine is not sorted in any way. Hence they are composed of large, angular, scratched, and polished boulders called *till*, heterogeneously intermingled with muds and ground-up rocks called *glacial flour*. The largest moraine of course is formed at the end of the glacier.

The glaciers of this region were once more extensive than at the present time. In retreating, the former glaciers formed at their temporary termini *recessional moraines*. Such morainal country is extensively developed on the east side of the Three Sisters Region.

Glaciers riding over the surface rock scratch and polish it. All around the Three Sisters region these scratches or *striæ* may be observed (Figure 56, page 74). On the polished rock surface these striæ point in the direction from which the glacier came. Where the former glaciers rode over nobs of rock, they rode over and polished the *stoss* sides of these rocks, and left, in many cases, the *lee* sides unharmed. Such rocks, some only a few inches across and others as large as a house, occur extensively over the Three Sisters region and are known as *roche moutonnées*. In some cases the glaciers have scoured out the bed rock leaving *rock basins*.

The morainal material left along the sides or at the ends or on the bed of a former glacier disturbs the drainage of an area over which the glacier has passed. Thus in such a region small *glacial lakes* may be found, which are the result of this deranged drainage. There are many such lakes on the east side of the North Sister and on the southwest side of the South Sister. A pretty example is Valerie Lake on the southwest side of the South Sister (Figure 51, page 68).

The mountain side over which the glacier passes is gnawed away. Where several glaciers are working on several sides of a single mountain, they destroy the symmetrical profile of the mountain and leave in its stead a mountain faceted by glacial scars. The effect of these scars is to produce a more or less pyramidal shaped mountain, or, as it is commonly called, an *Alpine peak* (Mt. Washington in figure 52, page 70). The Middle Sister partakes to a large extent of this Alpine character. The South Sister has been cirqued only to a limited extent. Black Crater and Scott Mountain have hardly been touched.

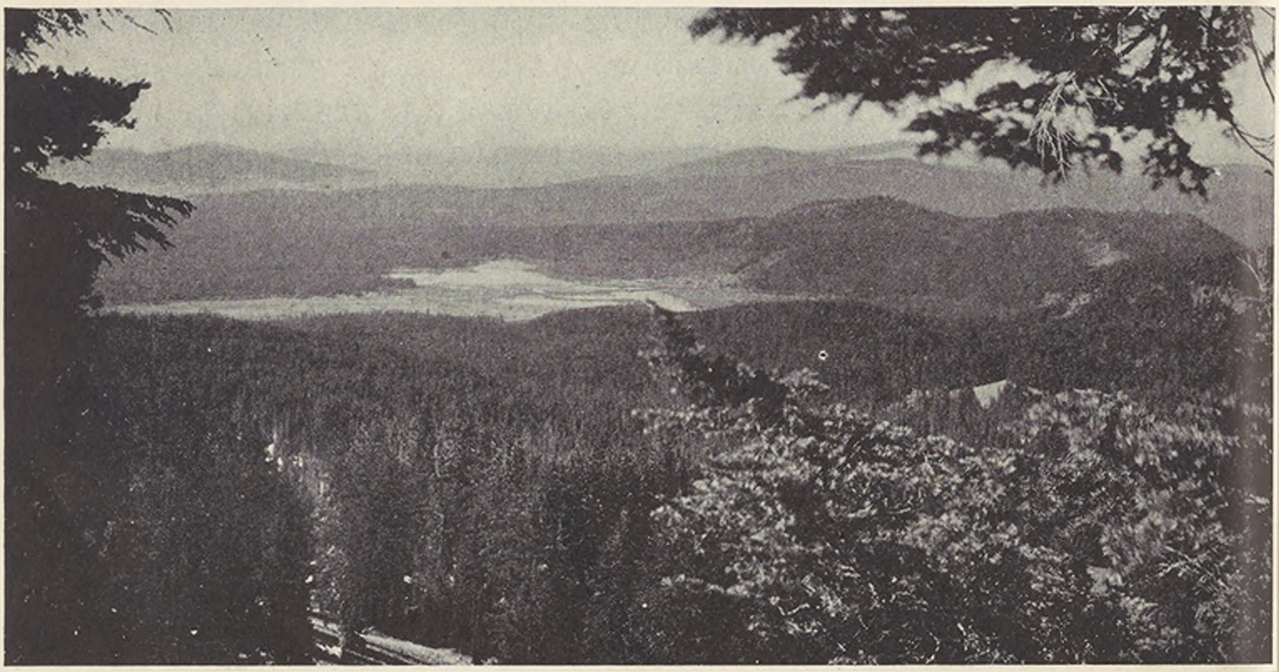
When several glaciers work toward each other, they gradually reduce the rock between them to narrow walls. Such walls are called *arêtes* (Figure 54, page 74). The long spur usually followed in climbing the North Sister from the south side is such an arête. The extensive glaciation which has taken place on the peaks of the North Sister, the Husband, and the Broken Top, has left narrow arêtes standing between cirques of these mountains.

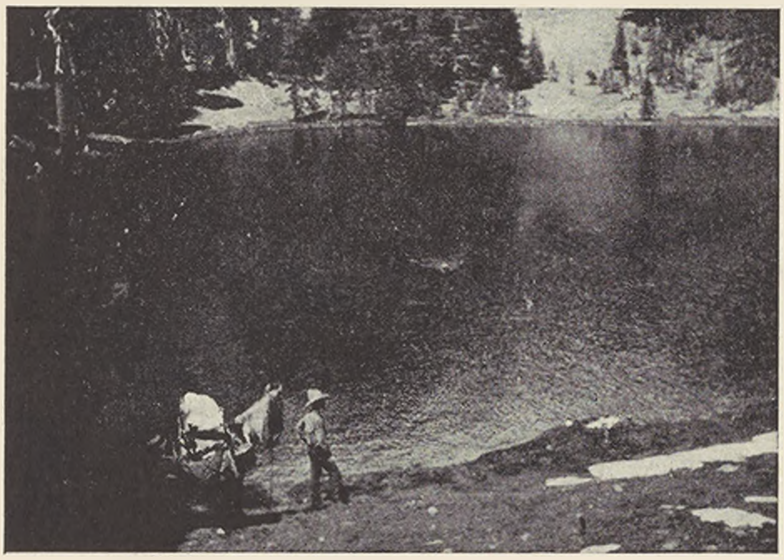
The surface of a glacier is equally interesting. A glacier is composed of three types of material. On the top is the newly fallen *snow*, which may entirely melt away during the long summers. Beneath the snow are little granules composed of many congealed snow crystals. These *névé* particles range in size from those comparable to rice grains to fragments the size of a marble. Beneath the névé layer is the solid *glacial ice*. This ice differs from that found on rivers and lakes in its lack of cleavage. In most cases it is impossible to split or cleave it with an axe. This is due to the fact that the snow crystals from which it is formed lie at every possible orientation and have given to the ice no uniform crystalline structure. Glacial ice chops like a piece of knotty wood. It does not split along a uniform grain like a bolt of shingle cedar. Because of this structure glacial ice lacks the transparency and color commonly found in river ice. Glacial ice moves down a mountain side not like a mass of liquid tar or molasses, but as a rigid body.

Glacial movement is such as never to destroy the rigidity of the ice; hence when the ice passes over a cliff or around a sharp turn great cracks will develop within it. These cracks are called *crevasses* (Figure 32, page 50). Crevasses are also due to the fact that the central portion of a glacier moves faster than its edges. Hence one will find crevasses along the central zone of a glacier, along its edges where it is retarded by its valley walls and wherever a glacier *steps* over a cliff (Figure 82, page 107). These crevasses are a source of great danger in traveling over a glacier, particularly after newly fallen snow. Such snow simply bridges a crevasse and does not fill it. A person falling into such a crevasse usually falls to his death. It is therefore advisable to travel over the surface of a glacier roped together in parties of four or more so that if, perchance, one member breaks through into a crevasse, he may be pulled out again by a companion (Figure 91, page 138). When the surface snow of a glacier has melted, or after it has solidified, as the result of frequent thaws, glaciers are no longer dangerous, although explorers should exercise caution when traveling in a crevassed region. The writer, in all of his explorations of this region, took his pack horses over the surface of the glaciers. This fact is cited to show that with a reasonable knowledge of the crevasses they can be traveled with safety and confidence.

The rock over which the glacier rides is rarely of uniform character. Soft rocks are cut away much more easily than hard rocks. Hence below a hard rock a cliff is carved much in the same manner as a river cuts a falls. Such cliffs beneath a glacier are called *steps*.

The surface of a glacier is commonly covered by boulders which roll onto it from the neighboring cliffs, by land slides which plunge onto it from its valley walls, and by material carried onto it by streams and by the wind. This material covers more or less of the glacier with a *surface moraine*. If the boulders are small in size, the heat which they attract is conducted through and melts the ice beneath them; hence such boulders serve to melt *holes* and *pockets* in the surface





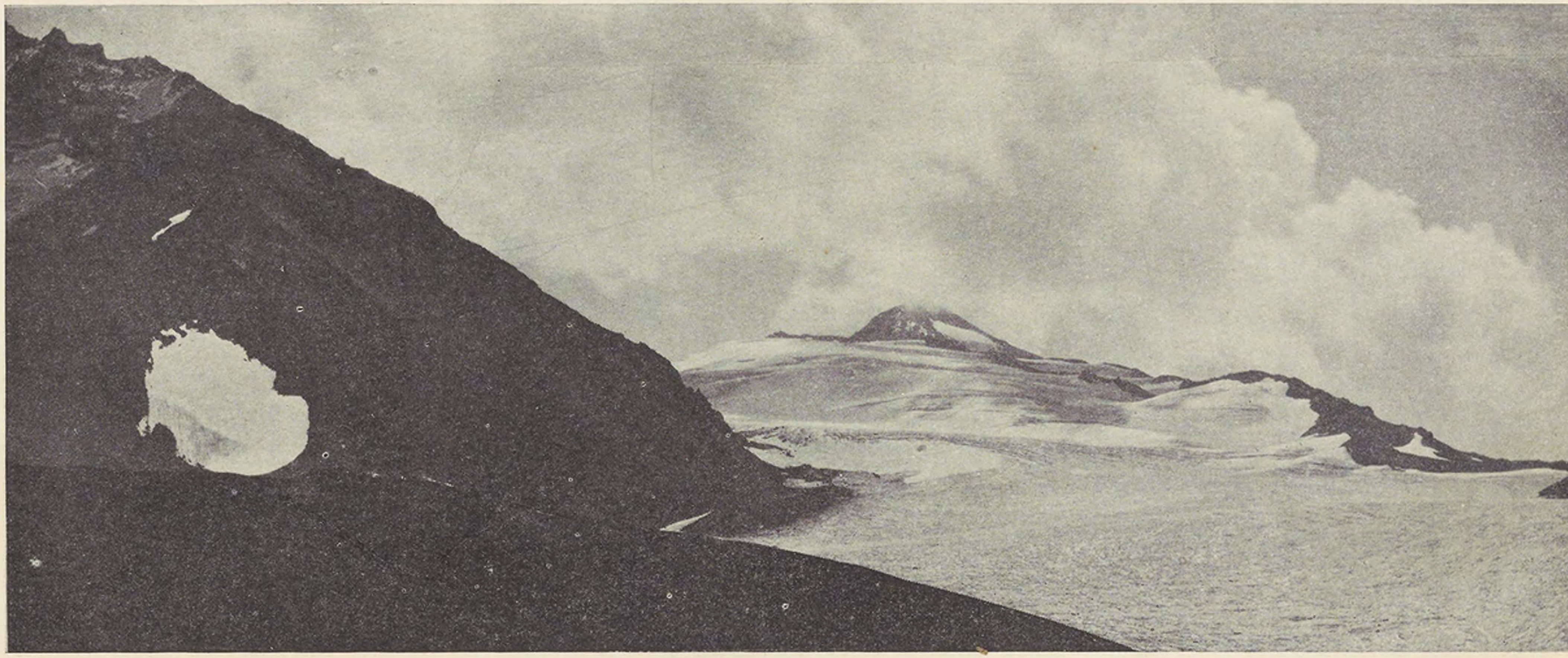
Figures 48, 49, 50 and 51. (48) Three Sisters from Camp Riley with Little Brother on left, North Sister next, then Cirque Rock, Black Hump in center, Middle and South Sisters on right, all covered by a light fall of snow. Obsidian Plateau in foreground and a part of the second plateau level which extends entirely around the west side of the Sisters covered with glacial deposits and scooped out basins. (49) The same view after the snow has melted. (50-U. S. F. S.). Looking south from Devil's Hill down the old valley of the ancient Deschutes. It is dammed at several places by lavas and moraines forming a series of lakes, of which Sparks Lake is one. (51) One of the delightful little lakes surrounding the Sisters, formed by morainal dams.

of the glacier. Heat is not conducted through large boulders, but on the contrary the boulder serves to prevent the warm rays of the sun from reaching the ice beneath it. The ice all around such boulders melts, leaving the boulders perched on a *pedestal* or *table* of ice. If the glacier is highly fractured by crevasses, blocks of ice are shoved and jostled about by the moving glacier. Such blocks of ice give rise to a very jagged and broken surface. These sharp ice pinnacles are known as *seracs* (Figure 47, page 64).

Streams flowing onto the surface of the glacier, or resulting from the melting of the surface of a glacier, travel over the body of the glacier and perform the same work as do streams of water on the land. They cut for themselves little beds, build levees, deposit flood plains, and create deltas. Such a stream rarely travels the entire length of a glacier. Sooner or later it plunges into a crevasse and then follows a course underneath the glacier or on through the body of ice. One may hear the roaring of the water rushing beneath the glacier, and one may hear the pounding of boulders hurled against each other and against the walls of ice as they are carried along the glacial conduit. These streams debouch at the end of the glacier in a tunnel called a *moulin.* Upon their emergence the streams rapidly lose their transporting power. The material which they carry is spread out in a great delta called an *outwash plain.*

The Snow Fields

Much of the higher ground not covered by glaciers retains a blanket of snow. In winter this snow reaches to a depth in places of twenty to thirty feet. The high, dry altitude combined with this enormous snow field gives a playground where visitors may seek relaxation, sport, and a pleasant relief from the rainy lowlands. In this snow and on the lakes all the winter sports may be enjoyed. The wonderful slopes in this season of the year provide opportunities for tobogganing, skiing and glissading not surpassed by any of the winter resorts of Europe. Unlike many of the European winter resorts, this winter playground is accessible within a few hours. In the summer season, the snow fields decrease in size, and in the later summer almost entirely disappear. Nevertheless,



Figures 52 and 53. (52) Looking north to Belknap, on east side of which rises lava cone of Little Belknap. On left is old Santiam Valley, now partially filled by McKenzie Lava Flow. On right is line of volcanoes marking "break" of Cascade Plateau; Washington, Three Fingered Jack, Jefferson and Hood. (53) South from Cinder Cone toward Middle Sister. On left is North Sister; in center, Collier Glacier. Right of center is Cirque Rock and at the top, partially obscured by clouds, is Black Hump.

throughout the entire summer vast stretches of snow exist upon the surface of the mountains where all of the snow sports may be enjoyed in a summer climate. One may spend the forepart of a half day glissading on one of these snow fields, and finish the half day by a swim in one of the many mountain lakes (Figure 48).

Size of Cascade Glaciers

North and Middle Sister Area		
Linn	39.50	acres
Villard	20.20	"
Thayer	56.10	"
Collier	442.00	"
Hayden	230.10	"
Renfrew	184.70	"
Dillar	193.80	"
Total	1,166.40	"

Between Middle and South Sister		
Irving	61.60	acres

South Sister		
Lost Creek	187.50	acres
Eugene	99.30	"
Skinner	94.70	"
Carver	152.60	"
Prouty	164.50	"
Clark	38.60	"
Lewis	26.70	"
Total	763.90	"

Broken Top		
Bend	247.20	acres
Crook	18.40	"
Total	265.60	"

Total for Three Sisters area, 2,257.50 acres.

Mt. Hood		
Ladd	134.90	acres
Coe	166.70	"
Eliot	295.70	"
Newton Clark	234.20	"
White	124.00	"
Zigzag	354.08	"
Reed	112.02	"
Sandy	185.85	"
Unnamed (three glaciers)	220.48	"
Total	1,828.11	"

Mt. Shasta		
Whitney	305.20	acres
Bolam	460.90	"
Konwakiton	87.30	"
Hotlum	965.30	"
Winton	186.80	"
Total	2,005.50	"

Glaciers of the North Sister

Collier Glacier

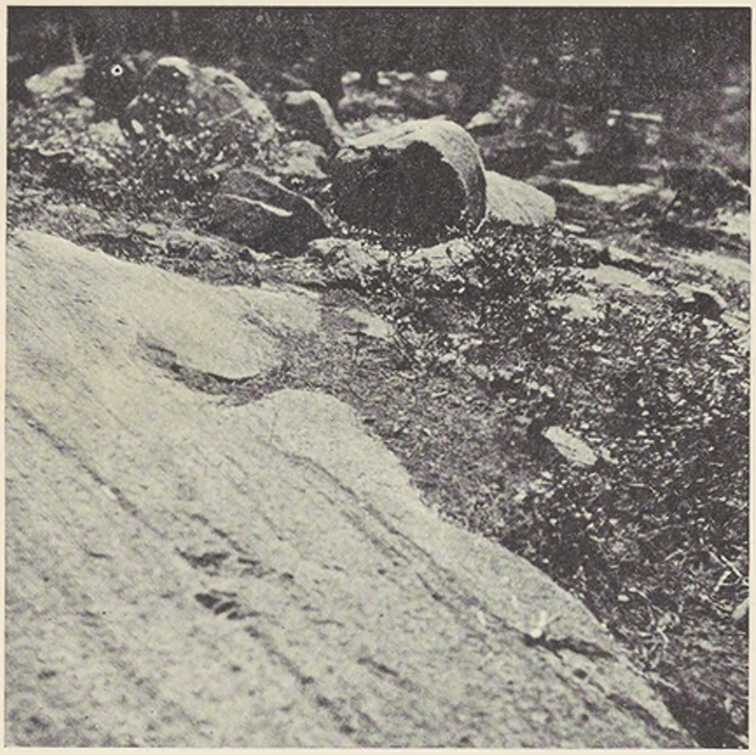
The North Sister contains four glaciers, the largest of which is Collier, named after George H. Collier, a former Professor at the University of Oregon. Collier Glacier covers 442 acres and is the largest in the state of Oregon and has perhaps been visited by more people than any other one in the state. It rises from a col between the North Sister and the Middle Sister (Figure 53) and extends northward over seven thousand five hundred feet. Over most of its length it maintains an average width of three thousand feet, but reaches a maximum width in the central part of three thousand five hundred feet. The actual thickness of this glacier in the central portion is unknown, but cannot be less than five hundred feet. At its source it joins Hayden Glacier, which descends the slope of the Middle Sister to the east.

Collier Glacier forms the east route by which to climb either the North or Middle Sisters. The Glacier may easily be reached from White Branch Crossing by ascending White Branch to its source in the glacier (Figure 55, page 74); or from the Skyline Trail, where it crosses Obsidian Cliff Plateau, by climbing a series of cliffs and then going eastward to a low pass over the west moraine just south of Little Brother. This route puts one on the glacier at an elevation of about 7600 feet. Others prefer to swing southward after passing over these cliffs and by climbing over the West Moraine to reach the glacier at a higher elevation. It is not practical by this latter choice to reach the glacier at an elevation exceeding 7700 feet. From the east the glacier may also be reached by ascending Hayden Glacier; or from Scott Trail, by following along the Ahalapam Cinder Field and passing over the divide between Cinder Cone and the north slope of the North Sister to the terminal moraine.

A day may be spent to great advantage and pleasure in examining the many features in the immediate vicinity of Collier Glacier (Figures 55 and 58, page 76). Its eastern boundary is formed by the North Sister, which rises as a steep and inaccessible cliff from beneath it. One should not try to crose the glacier close to this cliff because great boulders frequently bound down its slope and at frequent intervals great slides of rock descend upon the glacier. The boundary along the north half of its eastern side is formed by the north-west spur of the North Sister. A large crecentic moraine closes in the glacier at its north end, except at the point where water issues from under and off the glacier. This terminal moraine, not as high as the west moraine, but is built of great angular blocks and soft "till" derived from the Middle and North Sisters. Behind the first and largest moraine, are several smaller recessional moraines. A small recessional moraine, composed entirely of cinders, stops at the foot of the Cinder Cone. This last moraine proves that Collier Glacier has never over-ridden nor even pushed deeply into the slopes of Cinder Cone. Climbing over these recessional moraines, one may reach Cinder Cone, or by going a little farther eastward one may reach the great Ahalapam Cinder Field.

Since the piling up of Cinder Cone, the glacier extended to a point lying between it and Little Brother (Figure 59, page 76). In the Ice Age this glacier pressed north-westward, between Little Brother and the North Sister, to the Santiam and carved the north slope of Little Brother into steep cliffs. Little Brother is now separated from Collier Glacier by the eastward curve of the great west moraine. Little Brother still forms the abuttment below upon which the bottom portion of the glacier rides.

The west moraine forms a continuous rampart extending from Little Brother southward to the face of Cirqued Rock and thence to Black Hump. This moraine is made up of huge angular blocks, some of them ten feet in diameter, which have broken from the glacier. The height of this moraine above the glacier varies, but averages about fifty feet. At a distance it looks a smooth, blue-gray ridge. Climbing over it, one is likely to change his opinion, not only of its soft texture, but also of its height. The great slabs of rock roll and slide when stepped upon. The finer rocks and *till* creep and sink beneath the traveler. The exhausting climb to the crest calls for a stop to breathe, even though one is not held in amazement by the great stream of ice dazzling before him. The height of this moraine is not proof that the glacier was at one time thick enough to be level with its crest. The side-ward pressure of the glacier shoved the rocks to a height much higher than its own surface.



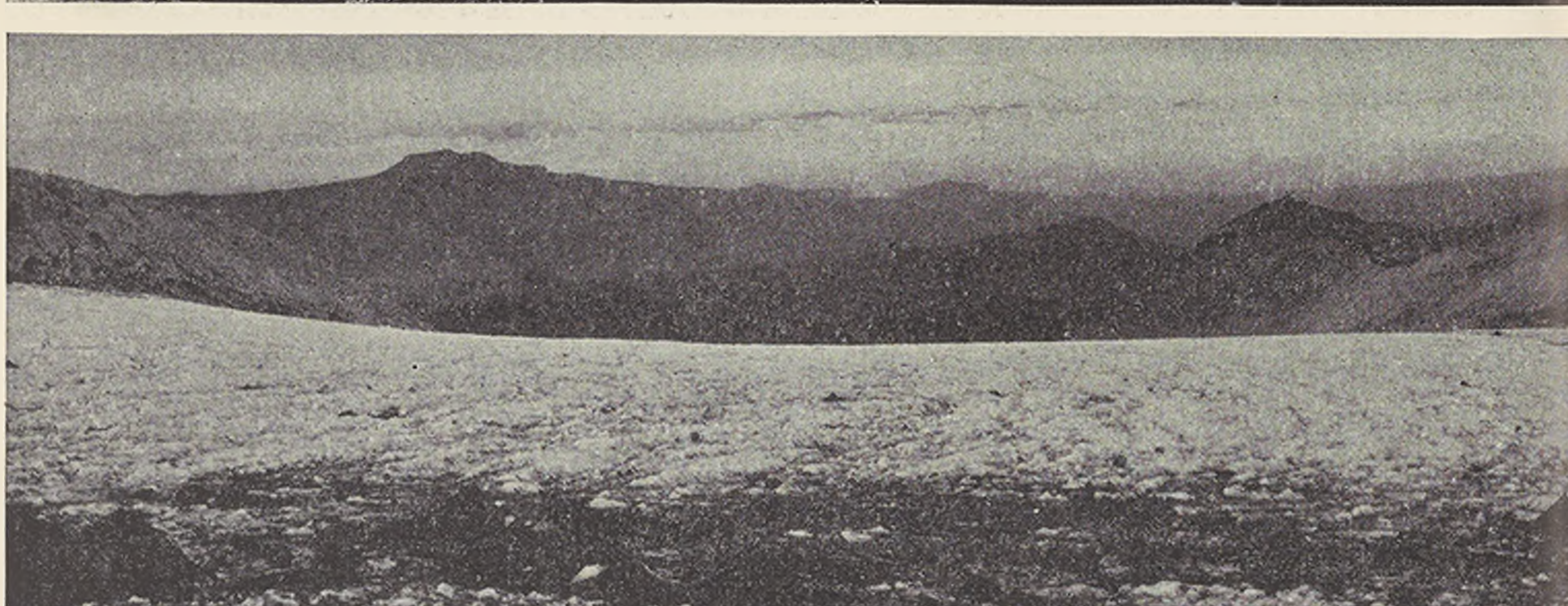
Figures 54, 55 and 56. (54) A view from Black Crater looking south. On the left in the distance is Broken Top, showing a profile of a part of the former surface of Mount Multnomah • between the eroded western edge of the old surface and Broken Top may be seen Bend Glacier. Next to the right are the two peaks of South and Middle Sisters. In the center is North Sister showing three cirques occupied from left to right by Thayer, Villard and Linn glaciers. Extending eastward (left) from the Three Sisters is the long gentle slope of the Cascade Plateau. Extending northward from the North Sister is the eroded portion of the north slope of Mount Multnomah. The smallest peak on the skyline to the right is the Husband from which extends westward (right) the old surface of Mount Multnomah. (55) (U. S. F. S.) looking south towards the snout of Collier Glacier. On the left is the lateral moraine behind which may be seen a part of Cinder Cone. (56) Grooved and polished roche moutonnees and glacial boulders lie in the forests 10 miles east of the Three Sisters.

One surface feature, the great steps, demand special notice. The surface of the glacier from its terminus to its source, does not present a continuous smooth slope. At about its center the ice cascades over a great rock cliff submerged beneath the ice. Above this cliff there are two additional steps of similar character. The ice, in passing over these submerged rock cliffs, presents in a gigantic way the appearance of a great fall in a river. (For explanation see Obsidian Plateau).

Thayer, Villard and Linn Glaciers

Three other glaciers exist on the North Sister (Figure 54). The largest (56 acres) is called Thayer Glacier, after Eli Thayer, a congressman from Massachusetts who worked vigorously and fought valiantly for the admission of Oregon into the Union, which was finally consummated February 14, 1859. It rises from the bottom of the great eastern cirque and forms a body of ice practically occupying the entire basin of this gigantic amphitheater. Only a small part of this glacier extends up the bergschrund wall to an elevation of about 8600 feet. The glacier ends in a terminal moraine, the largest of a succession of recessional moraines, which extend eastward far beyond the present timber line. The last moraine, formed by the present remnant glacier, is being built on the cirque basin at an elevation of 7400 feet.

Two smaller glaciers lie on the northwest slope. The north one (39 acres) is called Linn Glacier, after Lewis Shields Linn, foremost champion of Oregon in the United States Senate between 1833 and 1843. The south one (20 acres) is named Villard Glacier after Henry Villard, a pioneer railroad builder in Oregon and the West. They begin at a lower elevation than the Thayer Glacier—that is, 8000 feet—and extend down to about 7700 feet elevation. These two glaciers were not long since united, in the same manner in which Hayden and Diller Glaciers are now joined, in their upper parts. The two lobes of this former glacier were separated by a small nubbin of rock, which rests like a prominent hump on the northeastern spur of the North Sister. At a still earlier period this mass of rock stood up in a continuous sea of ice as a nunatak.



Figures 57, 58 and 59. See Footnote, Page 77.

Glaciers of the Middle Sister

Renfrew Glacier

The Middle Sister bears on its slopes three large and one small reminant glaciers. The best known of these is Renfrew Glacier (185 acres), so often traversed by those climbing the Middle Sister. Renfrew Glacier (Figure 79, page 95), usually deeply covered with snow, rises on the northwest slope of the Middle Sister at an elevation of about nine thousand feet. Its southeastern portion coalesces with the upper ends of Collier and Hayden Glaciers. The northern edge of this glacier is bounded by the great rock abutment of Black Hump. On the west end of Black Hump ridge is Curved Rock, around which the glacier bends and moves northward. The southwest edge of the glacier rides successively over a series of flows which extend down the old surface of Middle Sister. At, and just below, each of these ribs of rock the morainal material spills down the Middle Sister in a series of talus slopes. The glacier reaches down almost to an elevation of 7500 feet.

Hayden Glacier

Hayden and Diller are the largest glaciers on the Middle Sister. Hayden (230 acres), the northernmost one, heads at the col between North and Middle Sisters, and at the base of a cirque wall at the northeastern portion of Middle Sister (Figure 61). Its northern edge is provided by a terminal moraine which flanks the southern spur of North Sister. Its southern edge is formed by a great medial moraine, reinforced by pinnacles of rock projecting upwards from the solid mass of the Middle Sister. This glacier, as well as its brother to

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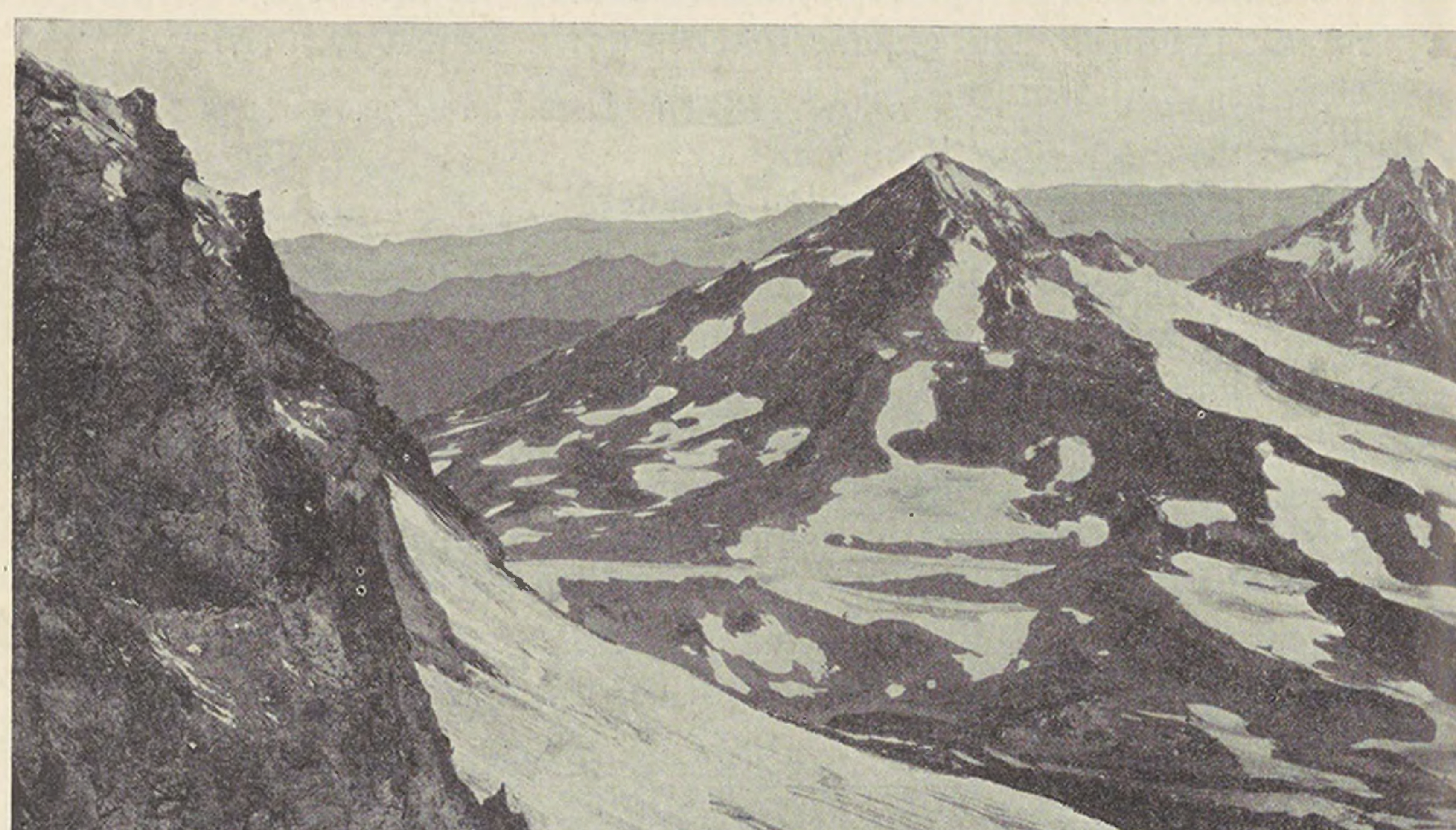
Figures 57, 58 and 59. (57) Looking north from the west slope of the South Sister towards the Middle and North Sisters. Canyon of Linton Creek in foreground. Renfrew Glacier between Middle Sister peak and Black Hump. North Sister in distance with its two horns and steep western or inner caldera face. (Compare figure 17). (58-U. S. F. S.). South from the terminal moraine of Collier Glacier looking south. On right is Little Brother, Black Hump and Cirque Rock and lateral moraine on right. (Compare figure 53). Elk horn found buried in the terminal moraine. (59-U. S. F. S.). North from the lower end of Collier Glacier, lateral moraines on either side; Cinder Cone in middle, the south end of the Ahalapam Cinder Field; Belknap and gentle eastern slope of the Cascade Plateau in distance.



Figures 60 and 61. See Footnote, Page 79.

the south, owes its size to the fact that the moist winds from the northwest are able to pass between the North and Middle Sisters and deposit much of their snow on the eastern slope. This sufficient supply of ice enable it to reach down to an elevation of about 7300 feet, where it terminates against a large recessional moraine.

Diller Glacier

The upper portion of Hayden Glacier joins with Diller Glacier (Figure 61, page 78). Both find lodgement against the great east bergschrund wall of the Middle Sister. Since the time when this bergschrund wall was cut, the two glaciers have gnawed their way westward so that each of them has developed a recess for itself in the bergschrund wall. Diller Glacier (194 acres) takes its origin in the southernmost recess, at an elevation of about 9200 feet. It descends the mountain southeastward to an elevation of about 7300 feet. A medial moraine forms its northern boundary, but its southern boundary is against the southeast spur of the Middle Sister.

Both Diller and Hayden Glaciers at one time were much more extensive, as is shown by the fact that the east half of Middle Sister is completely cut away. At that time they were so extensive that the ground now occupied by the middle moraine was probably buried in ice.

Irving Glacier

Irving Glacier (61 acres) is a mere remnant of a once extensive glacier on the south slope.

Glaciers of the South Sister

South Sister is the proud possessor of seven glaciers remaining from the Ice Age. Five of these are on the north side (Figure 66, page 84), and two small ones still exist on the south side (Figure 83, page 131). The great peaks of the Cascades for the most part are free of broad stretches of ice on their south sides.

Figures 60 and 61. (60—U. S. F. S.) Looking north from Wickiup Plain to the South Sister, showing the pumice strewn ground and in the foreground the park-like surface and on the South Sister Lewis and Clark Glaciers. The hump on the right of the South Sister is the top of the Elder Middle Sister. (61) Looking north from the southeast slope of the South Sister. In the foreground is the bergschrund wall and head of Prouty Glacier. At the foot of the South Sister may be seen Chambers Lakes. Lying between the South and Middle Sisters is Carver Glacier, on the near slope of the Middle Sister is Irving Glacier. The lobate glaciers on the east side of the Middle Sister are Diller and Hayden glaciers. Note the strongly dissected eastern slope of the Middle and North Sisters and the even crest and maturely dissected surface of the western side of the Cascade Plateau.

N.E.

Figures 62, 63, and 64. (62) Looking ~~southward~~ from the head of Renfrew Glacier, showing Hayden and Diller Glaciers separated by a large medial moraine. The ~~northwest spur of Broken Top~~ looms up in the distance. (63) (U. S. F. S.) Looking west from the crest of the bergschrund wall of Prouty Glacier. Prouty Glacier has carved deeply into the northern side of the Elder Middle Sister. (64) Looking southwest from the northwest side of Broken Top. In the left foreground are Miller and Newberry Lava Flows arising from the southeastern slope of the South Sister. To the right of Newberry Flow are the Green Lakes. The two glaciers on the South Sister are Lewis and Prouty glaciers and the black mass this side of Prouty Glacier is the top of the Elder South Sister. To the left of the South Sister is shown the South Rampart of the Caldera rim. The position of Diller and Hayden Glaciers on the Middle Sister are well shown. Note the severe glacial sculpturing shown on the eastern side of all three Sisters and observe the gentle eastern slope of the Cascade Plateau.

Prouty Glacier

This glacier was named after H. H. Prouty, one of the foremost mountaineers of the northwest, who for a number of years held the record of being the only one to ascend the North Sister unassisted.

Prouty Glacier (164 acres) arises close to the present crater of South Sister and from the cirqued north wall of the Elder South Sister. Beginning at an elevation close to ten thousand feet, it spreads out northward between two prominent spurs of the South Sister, and reaches down to an elevation of about 7500 feet. It descends the mountains over a series of gigantic steps whose great height make it impossible for one to travel over its surface. Because of the uneven bed over which this glacier moves, its surface is broken by many gapping crevasses. Much of the dissection of the cone of the Elder South Sister was due to the action of this glacier in the Ice Age.

Carver and Skinner Glaciers

North of Prouty Glacier is Carver Glacier, named after Jonathon Carver, in whose book, "Interior Travels,' 'the name "Oregon" first appeared. Carver Glacier (153 acres) is thought by some to be the reconstructed portion of Prouty. It rises at 8300 feet, and extends to 7100 feet, where it has built an enormous moraine. West of Carver Glacier and occupying a cup-shaped cirque is the small Skinner Glacier. This glacier (194 acres) is almost circular in shape, and rests on the mountain slope between 8800 and 7500 feet.

Eugene Glacier

West of Skinner Glacier is Eugene Glacier. This glacier (99 acres) occupies only a small part of its former elongated cirque. It begins at an elevation of 8500 feet and reahes down to an elevation of 7100 feet. Both Eugene and Skinner Glaciers are named after Eugene Skinner, who took up a land claim near Eugene, Oregon, in 1846 and whose wife was the first white woman in Lane County.

Lost Creek Glacier

Lost Creek Glacier (187 acres) on the northwest slope of the South Sister, is commonly used in climbing the South Sister. It is reached by a trail branching off from the Skyline Trail just east of the Husband. Because of the heavy snow which lodges on this slope of the South Sister, it is commonly believed that the glacier has its origin on the rim of the crater. This, however, is not a fact, as may readily be observed during long, dry summers. This glacier, like all others, occupies only a small part of its former cirque and valley. It begins at an elevation of about 9500 feet, where its bergschrund, in 1924, was 12 feet in width. At 8500 feet it is constructed by the outlet of its former cirque. From this elevation it deploys down the slope of the Middle Sister to an elevation of 7500 feet. This deployment is for the most part to the east, so the glacier has the appearance of making a sharp turn eastward.

These five glaciers are cut into the red volcanic tuffs and scoria which form the upper, and probably Recent, cone of the South Sister. The material has been carried down the mountain slope and piled up in huge terminal moraines of bright yellow, green and maroon colored rock. Even the streams pouring off from these glaciers for several miles west are colored red.

Lost Creek Glacier was named by Williams in 1916 after Lost Creek. The name of this creek has since been changed, by order of the National Geographic Board, to Linton Creek.

These five glaciers were at one time confluent, and spread as far north as the base of the Middle Sister, whence a part of the ice moved eastward and joined with the ice from the Middle and North Sisters. Some of the ice moved westward and joined with the glaciers moving southward from the Husband. The recession of the glacier has produced many intermorainal lakes, to which are given the name Chambers Lakes after James B. Chambers, who after his arrival in Oregon in 1887 was a prominent merchant and enthusiastic advocate of the McKenzie country.

South Slope—Lewis and Clark

The smallest glacier (27 acres) on the south slope of the South Sister called Lewis Glacier, arises from the south rim of the crater. It is bounded on the south by a moraine undoubtedly reinforced by the upper edge of a former flow. This glacier moves eastward down the slope to an elevation of 9000 feet. People desiring to climb the South Sister from the Green Lakes vicinity will find it to their advantage to make this glacier their objective (Figure 68, page 86).

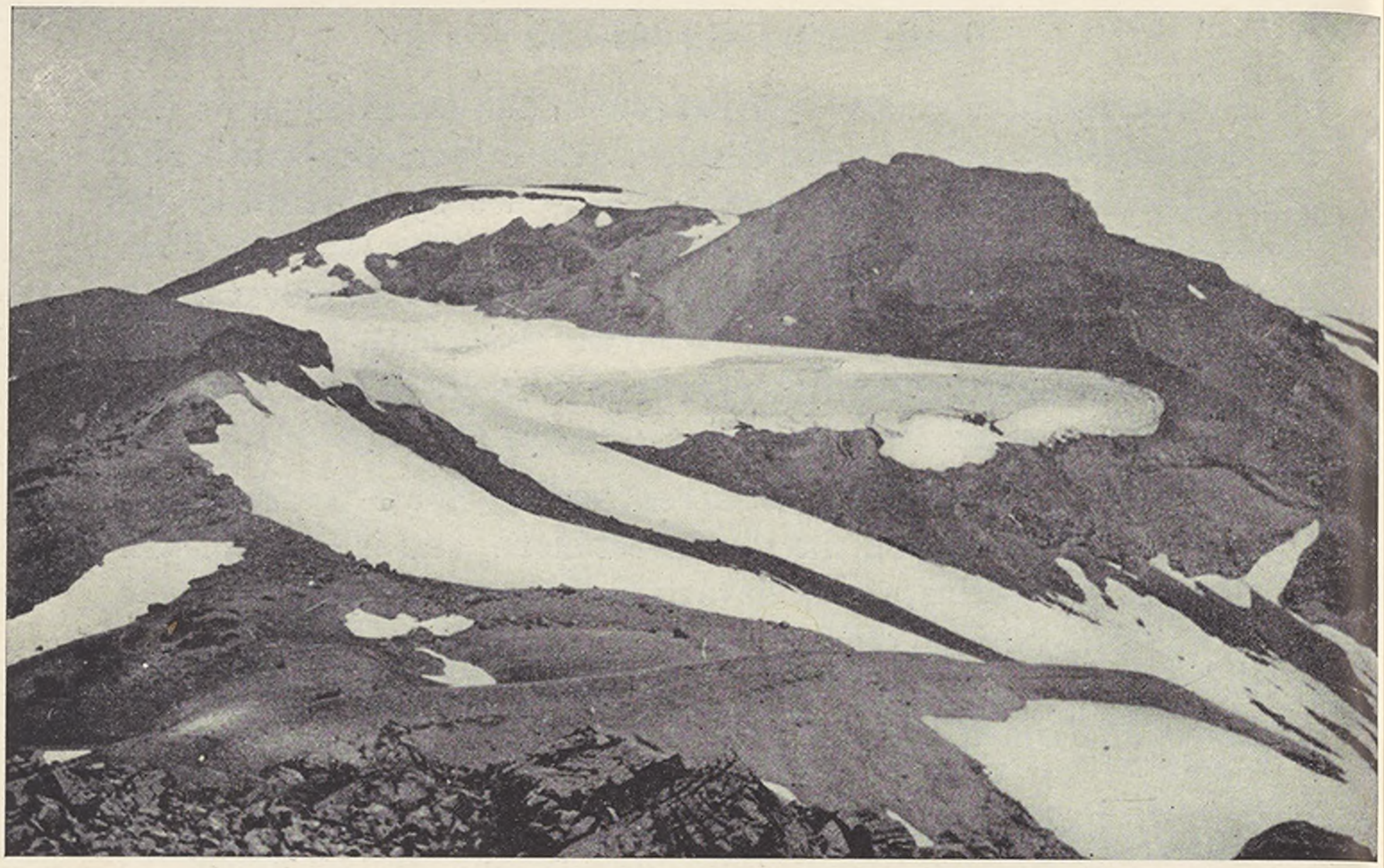
The largest glacier (39 acres) on the South Sister arises in the small cirque on the southwest slope, and is called Clark Glacier. It begins at an elevation of 9500 feet and descends to an elevation of 8900 feet (Figure 37, page 54). These two glaciers are named after M. Lewis and W. Clark of the Lewis and Clark Expedition.

The Glaciers of Broken Top—Bend and Crook

Broken Top is the only other mountain in this area containing glaciers. The largest glacier (247 acres) exists on its north slope, and is called Bend Glacier after the city of that name (Figures 69, and 70, page 88). This glacier takes its origin at 8500 feet and spreads out to a great field of ice with a nearly level surface, terminating in an immense moraine at 7500 feet. A very tiny glacier (18 acres) exists in the southeast cirque of Broken Top between the elevations of 8300 and 8600 feet, and is called Crook Glacier after Crook County, and named after George Crook, a prominent military man in the early days.

LANDSLIDES

Landslide activity strictly "Recent" in character will impress the visitor. Rocks are on instable slopes everywhere over this area. They constantly break loose and slide down steep slopes. The west face of the North Sister sends down landslides almost daily. The noise made by these slides is awe-inspiring. First is heard a sharp crack, then a rolling rumble, which increases in volume reaching a maximum when the main mass descends upon the glacier. The rumble then decreases in intensity as the main stream of rocks entrain



Figures 65 and 66. See Footnote, Page 85.

and rush down the mountainside. This thunderous noise may last for several minutes. At places these slides have built up great alluvial fans, which afford an interesting and exciting way of descent for the more experienced mountaineers returning from the top of the North Sister.

Alluvial fans and talus slopes thus formed surround all the major peaks. One might easily mistake some of the apparently stratified rock of these slide deposits for true bedded structure. Thus on the western slope of the North Sister are slump deposits which have in part been dissected. They look very much like a structure which one would expect to find surrounding an old volcanic field. Such in interpretation, however, is incorrect, since they are merely slide deposits formed long after any vulcanism took place near this ancient peak.

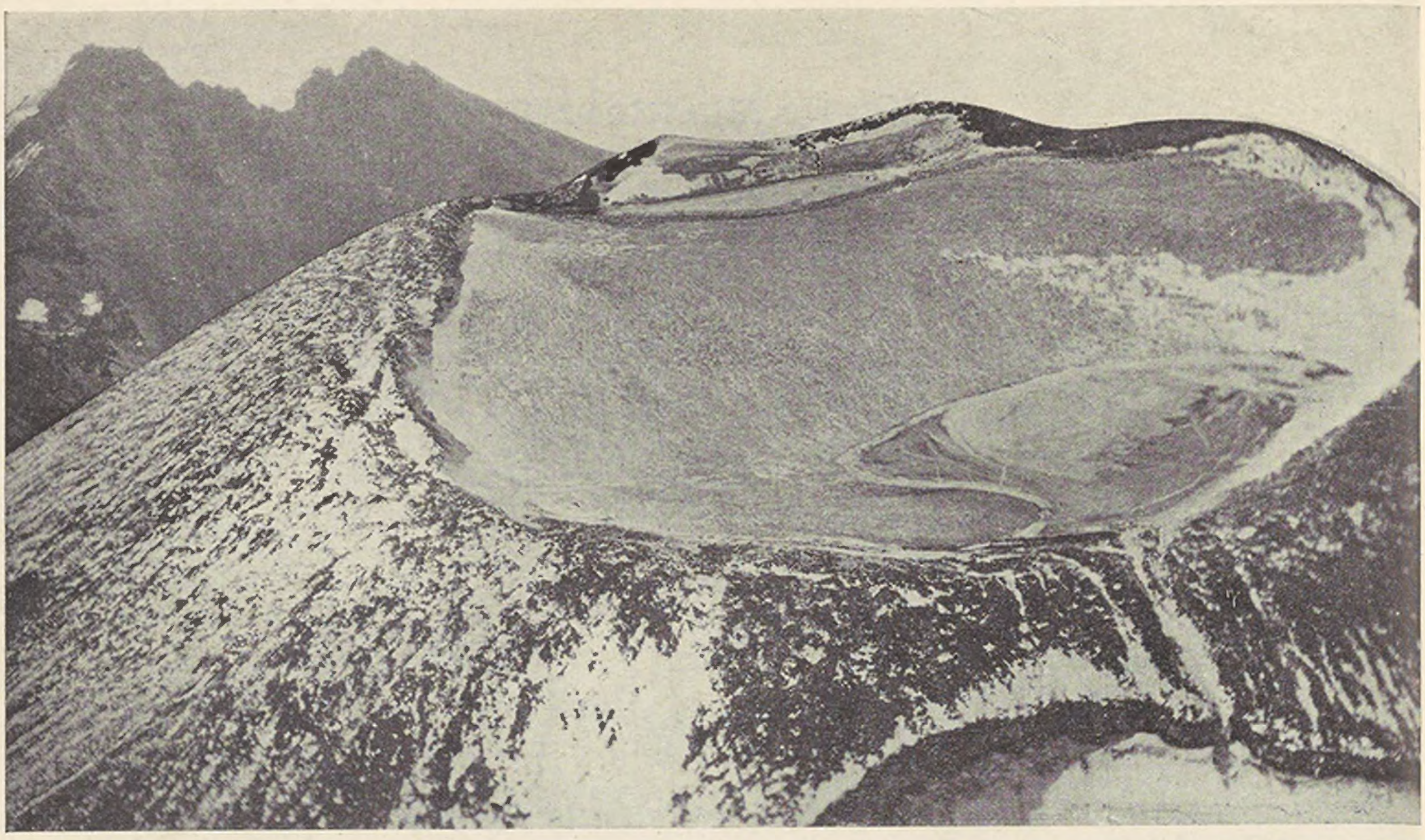
PRESENT TOPOGRAPHY

A chapter on the present topography is introduced to serve as a summary of the discussion given above, and as a ready reference to those wishing a detailed description of any part of the area. The features described in the main will follow an outline based upon the history of the origin of the various scenic features.

North Sister

North Sister, because of its rugged appearance, has been frequently spoken of as the oldest mountain of the Three Sisters group. In this case the appearance of the mountain leads only to a half-truth. As has been shown under "Mount Multnomah" it is exactly of the same age as Little Brother, the Husband, Sphinx, Wife and Broken Top.

Figures 65 and 66. (65) Looking east from top of Newberry Flow toward South Sister. In the foreground is Lewis Glacier, bounded on the left by a large lateral moraine and rock buttress and on the right by the badly time-scarred top of the Elder South Sister and well preserved top of the present South Sister. (66) Looking south from Middle Sister to South Sister. In spite of the early spring mantle of snow many features are well shown. At the foot of Middle Sister is Irving Glacier and beyond is one of the Chambers Lakes. The large glacier on the left side of South Sister is Prouty, showing well developed terminal moraines. Below Prouty's terminal moraine, considered by some to be a reconstructed glacier, is Carver Glacier. To the right of Carver Glacier is Skinner Glacier. The next little glacier west (right) is Eugene Glacier and the large glacier is the Lost Creek Glacier. All of these glaciers except Prouty have cut into the comparatively young cone of South Sister. Prouty Glacier is lodged between the present South Sister and the Elder South Sister. In the distance is the youthful figure of the Bachelor.



Figures 67 and 68. See Footnote, Page 87.

With the exception of Mount Washington, climbed for the first time in 1922, the North Sister is generally accepted as being the most difficult peak on the Pacific Coast to climb. John A. Lee, veteran Mazama and mountaineer, in "A chron-icle of the North Sister" which appeared in the 1922 Mazama, says:

"Imagine some four uprearing knife-like ridges converging to a common center surmounted by two well-defined pinnacles, the whole mass composed of black, rapidly disintegrating lava, each face with a precipice so steep that neither snow nor talus can find lodgment on it, with the ice stream of Collier glacier sweeping about its base. The North Sister may well be styled the *bete noire*, the black beast of the Cascades. It has a fascination that has caused a few venturesome spirits to accept the challenge and to essay to place iron-shod feet upon its crest.

"In the consumption of foot-pounds of energy the North Sister is no more exacting than the ascent of any other of our major peaks, but in point of treacherousness, in the requirement of continued tension and nervous strain, the North Sister furnished the writer the most difficult climb in his experience."

The first well authenticated climb of the North Sister was made during the course of the Mazama outing in 1910, by the late H. H. Prouty, past president of the club, whose ashes repose beneath a bronze tablet imbedded on the face of Obsidian cliff.

Up to the summer of 1924 only seventeen people had been able to scale the North Sister. The ascent may be made from the north, beginning where the Ahalapam Cinder Field passes over the North spur, then climbing to the base of the north pinnacle, thence passing around to the west on a snow

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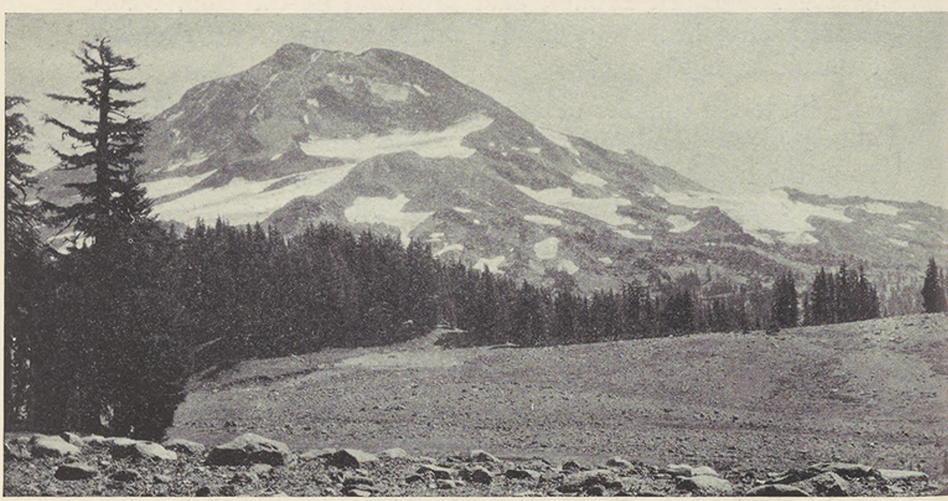
Figures 67 and 68. (67) An airplane view of the crater of the South Sister looking toward the east capping a scoriaceous lava of comparatively recent origin. The crater, when this picture was taken, late in the fall of a long dry summer, contained a lake of not over one thousand feet in diameter. Commonly the lake completely fills the crater and spills over the lip shown by the small groove in the foreground onto the bergschrund wall of the Lost Creek Glacier. In the distance is shown the northwest and southwest spires of Broken Top. (68-U. S. F. S.). A view from the upper edge of Newberry Flow looking west across Lewis Glacier, which is usually chosen by those climbing the South Sister from the east side. The picture shows in detail the time-worn top of the Elder Middle Sister and the steep profile of the bergschrund face of Prouty Glacier.



Figures 69, 70 and 71. See Footnote, Page 89.

field, which is almost always present, to a chimney between the south and middle pinnacles, and there climbing to the top. An easier ascent may be made by ascending Collier Glacier to the col, then following the knife-edge arête to the base of the north pinnacle, thence passing around to the west over the snow field to the chimney. The author and two students are the only climbers who have ever made the summit from the east side. They accomplished their ascent by working around the base of the pinnacle over the snow field to the saddle between the north and middle horns and then scaling the middle spire from the east side. This is an ascent that will test the ability of the experienced mountaineer, and is not advisable for anyone who has not proved his climbing ability. In ascending over the north or south spurs, one should not attempt to go over the large rocks which rest on the crest of these two arêtes. On the contrary time will be saved, and perhaps limbs, by taking the more arduous course over the creeping talus around their base. On the snow fields one should have an ice-pick or some other instrument with which to cut steps. These snow fields stand at angles so steep that they would not be safe to traverse unless secure footing is cut into the snow.

From the top of the North Sister splendid views may be seen. Figures 72 and 76, page 92, give the direction of the most important objects of interest. To the west, immediately below, rises the irregular mass of Little Brother. Extending eastward from it is an upland surface similar to that which extends east from Broken Top, thus proving that it is the upper surface of an old volcano. To the north, beginning with the Cinder Cone, extends a double row of recent volcanoes, called the Ahalapam Cinder Field. The northernmost and most perfect of these volcanoes is the Yapoah Crater. It is surrounded on the west and north sides by the Jerry portion of the Great McKenzie Lava Field. The great Jerry Lava Flow can be seen extending from Cinder Cone to the west and to the north where it joins with the great floods of

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Figures 69, 70 and 71. (69) East to Broken Top from South Sister. Green Lakes in foreground. Cirqued western slope of Broken Top; Bend Glacier on north. Old surface of Mount Multnomah extending eastward from Broken Top. (70—U. S. F. S.) East to Bend Glacier. Only a few hardy forms of life exist here in the Alpine Arctic Zone. (71—U. S. F. S.) East to South Sister from near Indian Camp. Foreground shows typical surface of the high park levels where the Hudsonian changes to the Alpine Arctic Zone. Lost Creek Glacier northwestern side. Part of Clark Glacier high on the slopes to right.

Figures 72, 73 and 74. See Footnote, Page 91.

lava which descend from Little Belknap. To the northeast is the great cone of Black Crater. The sporadic cones of Lotta, Harlow and Millican on its slopes are plainly evident. To the north and east, rough terminal moraine topography extends far to the east. The western side has been undercut to such an extent that the rocks on its upper portion are overhanging, unstable and produce continuous landslides. See "Glaciers" for the cirques and glaciers.

The top of the North Sister is formed by two horns of equal height composed of coarse igneous rock of a deep seated origin (Figure 17, page 24).

To the south of the horns is a mesa-like peak. If one ascends to this peak, the mesa surface is found to be a sharp ledge along which one must walk with care or else be catapulted down the mountainside. It is a small erosional remnant of a flow which once descended northward on the flank of old Mount Multnomah (Figure 41, page 57).

Little Brother

Little Brother, named by the Mazamas in 1910, is a part of the old rim of Mount Multnomah and lies between the two branches of White Branch and extends westward to White Branch Crossing (Figures 20, page 28, and 74, page 90). The uppermost flow rocks of this caldera reminant have a gentle slope to the northwest, which increases at Little Brother. Their slope and direction is that of flows pouring down from a crater to the southeast. The eastern and southern face of Little Brother has been largely dissected away by Collier Glacier, and by a former branch of Collier Glacier which passed westward toward Obsidian Cliff. The eastern side is flanked by the west moraine of Collier Glacier.

Little Brother is an interesting peak to climb and may be reached from the Obsidian Cliff by ascending over the plateaus to the north pass of Collier Glacier, or may be reached from White Branch by ascending Collier Glacier. The only

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Figures 72, 73 and 74. (72) North from the Middle Sister to Little Brother in left foreground. End of Collier Glacier and terminal moraine; Cinder Cone and Jerry Flow; McKenzie Lava Flood, arising from Belknap in center and beyond Washington, Three Fingered Jack, Jefferson and Hood. (73—U. S. F. S.) North from the Husband. Linton Creek Valley in foreground. Obsidian Plateau, and Belknap, Washington, Three Fingered Jack, Jefferson and Hood, in the distance. Contrast between mature lower surface on the west (left) (old Santiam Valley, now partially filled by McKenzie Lava) and gentle, undissected eastern slope. (74—U. S. F. S.) Southeastward from White Branch to North Sister, left, and Little Brother, right.

Figures 75, 76, 77 and 78. See Footnote, Page 93.

feasible way to climb Little Brother is from the west, by ascending its comparatively gentle western face. It is surmounted by a double peak, the higher of which reaches 8200 feet. From it may be obtained a magnificent view of Collier Glacier, Middle Sister and the country to the north.

Husband

The Husband is the only western fragment of Mount Multnomah (Figure 2, page 4). The mountain is easily accessible from the Skyline Trail. Despite its low elevation of 7550 feet it is not an easy mountain to climb. Its cragged slopes afford many interesting climbs for those who enjoy working out different passages up chimneys, around cornices, and along sharp ridges. As far as is known only the south pinnacle has been scaled. This mountain extends in the form of a ridge between the waters which drain into Linton Creek and those which flow westward into Proxy and Separation Creeks. Though much dissected by these streams a large portion of its former extensive westward slope remains. Glacial carving has revealed on the east side the internal structure of old Mount Multnomah (Figure 8, page 14).

From the summit of the Husband may be seen magnificent views in all directions. To the east the Three Sisters, their benches and Linton Creek Valley may be closely studied. To the west extends the rugged mature surface of the Cascades. The nearer of the hills to the west appear to have an elevation approximating that of the Husband. As a matter of fact the nearer of these mountains forms a secondary divide which extends north and south along the Cascades. This peculiar character of the Cascade Plateau is more clearly evident when

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Figures 75, 76, 77, and 78. (75) Looking south from Scott Mountain to show the gentle eastern (left) slope of the Cascade Plateau and the maturely dissected western slope. The valley to the right is the old McKenzie Valley now occupied by ancient flows from the Elder Middle and South Sisters as well as by recent lava flows. (76) Looking north from the North Sister. On the left is the eroded eastern edge of the old surface of Mount Multnomah which dips under the McKenzie Lava Flood coming to the surface only in occasional "islands." One of these "islands" is shown just beneath the cloud bank. The valley fog bank occupies the valley cut by the old Santiam and now partially filled by the McKenzie Lava Flood. The McKenzie Highway follows this valley in part and extends eastward around the north side of Black Crater. Belknap, Washington, Three Fingered Jack are shown in the distance. (77) Timber killed by heavy snows on Obsidian Plateau. (78—U. S. F. S.) Looking south from the Elder South Sister showing part of Lewis Glacier and the head of Newberry and Miller Lava Flows. Note the old river channel extending south and now marked by a string of lakes. This is part of "Lake River" now dammed by lava flows.

one examines the topography to the south. There one may see parallel ridges defiinitely succeeding one another far to the south. These ridges represent divides between streams which are working their way eastward.

These ridges coalesce on the east at the break of the Cascade Plateau. East of the Secondary Divide the regularity of these ridges disappears. They give way to irregular hills of decreasing size extending down to the level of the Willamette valley. Along the line of this break may be seen the high volcanoes of this Cascade plateau as far south as Diamond Peak. If one in imagination completes a surface from these crests the surface so formed descends with a gentle slope to the Willamette River and everywhere lies well below the level of the Middle Sister. The eastern edge of this surface would just graze the top of the Husband and strike at the base of the Middle, North and South Sisters.

The South Rampart

An examination of the topographic map or a view of this area as seen from the Husband, South Sister or Broken Top shows that the Sphinx, Wife, and Devil's Hill are portions of the Caldera rampart which extends entirely around the base of the South Sister (Figures 2, page 4, and 9, page 14). They form the inward-looking face of the slope of old Mount Multnomah. These peaks rise through the younger rocks derived from the South Sister and vicinity. The escarpment and more or less flat upland surface are broken by several old southward flowing streams, now blocked or captured, which once dissected the south slope of Mount Multnomah. An old Indian trail passes through one, just west of Devil's Hill.

Sphinx

The Sphinx is a prominent peak of the South Rampart. This peak, together with the spur extending southward from the Husband, form the gate posts through which Separation Creek passes to the outside world. The term "gate post" is not merely a figure of speech, but has been definitely chosen to express the U-shaped profile of Separation Valley at this point. The shape of the valley at this point is due to the

Figures 79, 80 and 81. See Footnote, Page 96.

glacier, which, in passing down the valley, rode against the abutment of the Sphinx on the south and the spur from the Husband on the north and cut their faces into perpendicular cliffs.

Wife

The shape of the Wife, with its greatest length from west to east, and with its steep face on the north and comparatively gentle slope on the south, is an indication of its origin. The Wife is tenanted by two small nobs at about 7300 feet. It joins the Sphinx on the west and is separated from Devil's Hill by a low pass.

The Wife is easily accessible from the Skyline trail, which passes on the east between it and Rock Mesa. The Wife may have at one time been a host to a small glacier near its summit. Its northern face shows plainly that it has been scoured by some great glacier passing westward along its face.

Devil's Hill

At the northwest side of the Sparks Lake and at the southeastern part of the rampart is Devil's Hill. This hill is a prominent landmark because of its height of over 6500 feet and its thimble-like shape (Figure 44, page 60). It represents a part of the South Rampart, which has been preserved from dissection by its favorable position between several streams.

The west face of Devils Hill is buried under morainal material, which dammed the stream that once reached southward down Mount Multnomah's surface to Sparks Lake and beyond. The upper parts of these streams are now without outlet, and pour their waters into Moraine Lake (Figure 46, page 64). The lake waters escape in part beneath the moraine, gush out in hundreds of springs on the south slope, and enter Sparks Lake. To the east of Devils Hill extending almost to Fall Creek a great mass of trachytic lava has recently issued.

Figures 79, 80 and 81. (79) Looking southeastward from the third bench east of Obsidian Plateau. Black Hump and Renfrew Glacier and the cone of the Middle Sister are shown. The moraine on the near side of the Renfrew Glacier is held in place by the beheaded ends of old lava flows which once issued fro mthe Elder Middle Sister, that is to say, Black Hump and these beheaded flows were once continuous. In the distance is the South Sister. (80—U. S. F. S.) Looking northwest from the position of the above photograph showing Obsidian Plateau. Note that this plateau is surrounded by a rampart which rises higher than the central surface. (81) An airplane view of the South Sister looking towards the east. The head of Lost Creek Glacier on the left and Clark Glacier is on the left. Note the lava flow which in comparatively recent time poured over this side of the lip of the South Sister Crater. On the left in the distance is Broken Top and the Bend Glacier and in the distance on the right is the Bachelor.

Broken Top

This appropriately named mountain, Broken Top, is a remnant of the former rim of Mount Multnomah. The three jagged spires in almost any direction are easily discernible. The three spires terminate the main mass which may be divided into the northwest, the northeast and the southwest parts, from each of which spurs extend outward. Between each of the spires and spurs, present and former glaciers have cut enormous cirques. The northwest spur is truncated and forms the east boundary of Green Lakes. This spur shows a remnant of a flow which comes from a point higher than this peak and must have extended at one time far to the northeast (Figures 10, page 14, and 54, page 74). On the northern portion of the southwest spur rests the small sporadic Cayuse Cone of recent origin.

The eastern spur displays a series of elevations, the highest, 8000 feet, is broken by a sharp westward-facing cliff just outside the limits of the main mass. This cliff is the eroded upper end of a flow which once poured down the eastward slope of Mount Multnomah.

Broken Top may be reached from the north by Alder Creek Trail, or from the west by going over the pass between the North and Middle Sisters. The former trail is an excellent one for pack horses.

The latter trail can be traveled by a pack horse at certain seasons of the year. This latter trail is an exceedingly interesting one. It permits an intimate acquaintanceship with the glaciers on the north side of the South Sister. Those coming in by the Skyline Trail will find it convenient and advisable to take the detour to the south of Rock Mesa, coming north to Moraine Lake and thence east to Fall Creek. Visitors coming in from the south will find an excellent trail both for pack horses and men from Sparks Lake. All of these trails lead to the beautfiul Green Lakes which afford a magnificent camp site from which to explore the surrounding area.

Broken Top can be climbed by ascending any of its three great spurs to its respective pinnacle. One should decide which pinnacle he intends to climb and ascend the spur that leads directly to it, since it is very difficult to pass at the top from one pinnacle to another. The southwest pinnacle is the highest and can be conveniently reached from Green Lake. All of these climbs require just enough rock tactics and skill to make them interesting either to an experienced mountaineer or to a novice of moderate experience.

Broken Top repays the climber with views not to be obtained from any other peak. To the northwest loom the Three Sisters whose severely eroded eastern sides face the rising sun and stand out in sublime dignity. To the east of them lies the great eastern slope of the Cascade plateau. To the southeast one may see a series of erosional remnants dissected out of the southeastern slope of Mount Multnomah. To the south, in cold celibate isolation, stands the handsome peak of Bachelor. Farther to the south may again be seen the eastern slope of the Cascade plateau, dotted here and there with Recent volcanoes. To the southwest, the great lake region, formed by damming of the two old river valleys, extends to Diamond Peak (Figures 78 and 88). In the immediate foreground to the west, can be seen the various recent volcanic flows which have broken out of the side of South Sister since the Ice Age. To the west, more or less hidden by the great South Sister, the broken and eroded western face of the Cascade may be studied.

East Side

Now that the peaks existing as remnants of the caldera have been described, we will view the eastern slope of the caldera. The best view of the Three Sisters is obtained from Bend. Looking across the great lava plains one observes a gentle change in grade which rises steadily to an even crest line. If it were not for the occasional peaks rising above this crest line the top of the Cascades would be uniformly level, with only a few low sags. Arising above this level crest are numerous peaks such as the Three Sisters. As viewed from Bend, the North and Middle Sister appear grouped together. Between the Middle and South Sisters is a low broad bench extending southward from the Middle Sister, the top of which is barely visible.

In traveling from Bend to the Three Sisters one ascends a long, steady even grade. If the road did not pass over lava flows and through some canyons, but followed the undissected surface of the lava, it would have a perfectly even grade. This grade does not change abruptly to the grade of the lava plains of eastern Oregon, but blends into them with almost no change of dip.

The same appearance of the country is obtained when viewed from a commanding peak near the east side of the Three Sisters. Thus from Broken Top the Sisters appear to arise abruptly out of a sloping surface (Figures 19, page 26, and 64, page 80). As far as the eye can reach this surface continues unbroken and without change of grade to the east. It is impossible to tell where the eastern slope of the Cascades ends and the great plateau of eastern Oregon begins. As a matter of fact there is no sharp line separating these two physiographic provinces.

The eastern slope of the Cascades is a young surface formed by recent lava flows, broken only here and there by small volcanic cones and incised canyons of young streams. Between these canyons are vast stretches of unbroken surfaces. Strong evidence as to the comparative youthfulness of this eastern slope is shown by the lakes. With the exception of Waldo Lake, all the large lakes are on the east side of the divide. Some of these lakes are Trout, Deer, Davis, Odell, Crescent, Summit and Fish Lakes. These lakes are for the most part formed by lava or glacial damming of older streams, carved on the eastern slope of the Cascades.

This eastern surface, traced in imagination to the west, continues gradually rising in height above all the mountain peaks to the west. The crest of the Cascades is evidently just the point of contact between the remaining portion of this surface and the new surface cut by westward flowing streams. In other words the Cascades consist of an old "consequent" surface dipping to the east, and an erosional remnant of a similar surface to the west (Figure 75) .

North Spur of North Sister and "Islands"

The eastern slope shows the youthfully dissected side of Mount Multnomah and the north slope a more maturely carved slope. Extending northward the rocks composing the North Spur of the North Sister may be traced beneath the great

McKenzie Lava Flood. From the top of the North Sister it is easily traced to the pass on Scott Trail. Beneath the Recent Ahalapam Cinder Field it outcrops as an eastward facing cliff composed of white colored rock which forms a lower bench, and lying on this bench is the eroded edge of a red colored rock (Figures 7, page 14, and 76, page 92). Related to the lower bench are erosional remnants lying somewhat to the east and a small bench close to the North Sister. Both of these two rocks can be traced into the walls of the North Sister. Close to the base of the North Sister these rocks are cut by feeding dikes, through which later flows, now removed, must have issued. Coming out from the base of the North Sister are other flow rocks older than the white rock which disappears in the great morainal field to the north and east of the Sister. These rocks have a steeper tilt to the east than they do to the north.

On the west side of Ahalapam Cinder Field the upper red rock appears just beneath the lavas and cinders and below the light colored rock is divided into two benches. These rocks can not be traced further westward because eroded and for the additional reason that their inclination would carry them to a high elevation, that is, far up on the slope of the old Mount Multnomah. Older rocks beneath these two, and younger ones on top are plainly displayed by the section on the west side of the North Sister. Just beyond Scott Trail Pass these rocks disappear beneath the lavas to reappear at the base of Black Crater and there pass beneath the crater and the flows which surround it. It is evident that Black Crater is a volcano which erupted upon the surface afforded by these rocks long after they had been maturely dissected.

The various islands are composed of these old flow rocks which formed the garment of Mount Multnomah. Thus in traveling westward from Black Crater one comes to an island called Chief Joseph Island[1], composed of light colored olivine basalt. Continuing to the west side of this island, one sees stretching westward toward Huckleberry Butte a series of benches, which face northward. The uppermost bench,

[1]Named after Chief Joseph, who resisted to the last efforts of the white invaders to wrest from him his inherent rights dedicated as "the home of the free and the land of the brave."

formed of gray olivine basalt, passes beneath Chief Joseph Island at an elevation of about 5600 feet, and is, therefore, the next flow beneath the light basalt. To the west this rock and all others are buried beneath that branch of Jerry Flow, which passes northward close to the base of the Huckleberry Butte. In traveling northward from this gray olivine basalt bench one descends over a series of benches or cliffs formed by the eroded edges of old flows. The drop over these benches, about five in number, amounts to over five hundred feet. Near the McKenzie Pass these rocks are again buried by the McKenzie Lava Flow.

These rocks represent former fragments of extensive and continuous lava flows which issued from Mount Multnomah and spread eastward and northward. Dissection since that time has molded the upper ones to maturity, but the deeper ones have not as yet been exposed except perhaps in the deep canyons of the Santiam.

West Side of the Caldera

Along the McKenzie Highway here and there exposures of these elder rocks may be seen. Everywhere they show severe erosion and their outcrops are determined by hills which arise above the lava surface. In following them westward their dip gradually decreases until it is horizontal or perhaps slightly eastward. To the west of the break of the Cascades these rocks make up the Cascade Plateau (Figure 14, page 16). The even skyline of this plateau is determined by the uppermost series of rock.

The westward surface of the Cascade Plateau represents the dissected face of a fault block which extends from the vicinity of the coast to the "divide." This sculptured fault block face shows a steep declivity between the crest of the Cascades and the Willamette Valley cut in the Miocene lava series. The Willamette Valley represents the erosion on this face of the Oligocene formations (Figure 27, page 44). The Coast Range is that portion of the face which has withstood erosion because of the Eocene sandstones.

Middle Sister

Middle Sister is usually the first peak to be climbed by the experienced mountaineer who visits this area, in order that, at an elevation of 10,038 feet, he may get his bearings and lay out a program of trips to the more inaccessible and the more difficult climbs. It is the peak that the novice in mountaineering should pit his skill against in his first attempt to climb a high mountain since it may be scaled with comparative ease, with the exception of the east slope (Figures 19, page 26, and 79, page 95), from almost any side. The average person reaches this peak by ascending over Collier and Renfrew Glaciers. If one prefers rock climbing, the west and south sides should be chosen (Figure 61, page 78).

Because the Middle Sister was built within the Caldera, the area which can be allotted to it is large. Its north slope underlies Collier Glacier; its western slope extends far out beyond the Obsidian and Lane Plateaus around the Husband as a sea surrounds an island. The southern slope passes beneath the area belonging to South Sister, and the eastern slope extends far beyond the limits of the map.

Only a half-cone of the Middle Sister with the flat face to the east remains over from erosion during the Ice Age. All of the Elder Middle Sister was cut away, with the exception of that standing beneath the cone of the present Middle Sister. The bergschrund wall cut by the former glaciers rises almost perpendicular for twelve hundred feet (Figure 61). This wall is so steep that when one rolls boulders off the top of the Middle Sister they disappear over the edge of this cliff and lodge below on the glacier out of the line of vision. Only an exceptional one gains sufficient impetus to bound or glissade over the surface of the glacier to a distance again to be visible.

Collier Glacier on the north, Renfrew on the northwest, and Hayden and Diller Glaciers on the east unite at the col or base between the North and Middle Sister (Figure 53, page 70). In the midst of their common source arises an island or nunatak of rock, called Black Hump.

Standing on the summit of the Middle Sister on clear days, one may see magnificent panoramas of the surrounding country. Rainier on the north and Shasta on the south are often visible. From this elevation it is apparent that the Sisters are in line with the great chain of volcanoes stretching north and south.

Benches and Middle Sister

The later features of the western side are in contrast to those of the eastern side of the Middle Sister, and are marked by a succssion of lava benches too small to be clearly shown on the scale to which the map is drawn. A careful inspection however, will show that some of the contour lines are close together and others are far apart, thus indicating a succession of benches—five in number. The largest bench abuts against the Husband, extends out Linton Creek Valley, and is the site of Linton Creek and Separation Creek Valleys (Figure 16, page 24). The rise from this bench, marked by a cliff about four hundred feet high, gives a broad dissected bench, of which Obsidian and Lane Plateaus are important parts (Figure 80). Back of this second bench are four additional benches, reaching up to an elevation of 7500 feet. The Skyline Trail follows for the most part an area between the second and the cliff of the third bench. The only two difficult places to build a modern roadway making use of this bench will be in ascending up to it over Obsidian Cliff and descending from it west to the Husband (Figure 71).

Just beyond the limits of the trail there is a slight cliff facing inward toward the Sisters. This cliff forms the east edge of old flows which at one time poured out of the Middle Sister. Obsidian Cliff Plateau and Lane Plateau are fashioned from these former extensive flows.

Obsidian Plateau

Obsidian Plateau is the best known bench on the west side of the Middle Sister. Inasmuch as the Skyline Trail climbs its north edge, travelers are sure to be impressed by the enormous occurrence of volcanic glass of which the plateau is largely composed. This semi-circular bench extends like an inverted flat iron out into the valley of Linton Creek (Figure 80). The plateau is bound on the north, west and south by a steep, almost inaccessible cliff three hundred feet high.

Obsidian Cliff is composed of rhyolite, rhyolite vitrophyre, and black obsidian. These rocks, which are simply different cooling phases of the same lava, can be traced far up the side of the Middle Sister. This lava flowed down the side of the Middle Sister and far down the valley of the old McKenzie River. At the base of the cliff parts of older trachyte flows may be found. Later erosion has cut in these flows Lost Creek Valley and the benches and plateaus on the west side (Figure 16).

Around the edges of Obsidian Plateau—that is, where the obsidian and rhyolite are not concealed by morainal material—the wonderful banding of these rocks may be observed. It looks as though the rocks might have spilled over the edge of the cliff; but since the banding is not definitely related to the edge of the cliff, such a theory cannot be sustained. The banding occurs wherever the rocks outcrop. In appearance it is identical with the contorted structure found in the ancient rocks of the pre-Cambrian shield surrounding Hudson's Bay, which have suffered contortion and especially squeezing. If one stands back a short distance from the outcrop, these rocks look like ancient contorted gneisses and schists.

If this glassy rock were to suffer static metamorphism so that the feldspathic materials were altered to muscovite or biotite and the siliceous bands were to crystalize to quartz, we would have a rock which we would call biotite or muscovite gneiss. Such a rock would appear to give evidence of severe crumbling and folding. Perhaps many of the highly compressed and overturned folds found in metamorphic areas have resulted in this way, and do not indicate severe dynamic movement, but simply static metamorphism.

The great sheet of ice which descended from the North and Middle Sisters in Pliocene time over-rode Obsidian Plateau. The ice has left evidences of its presence in the roche moutonnéed surface moraine, and eratics derived from the Middle Sisters. The glaciers have retreated so lately from this cliff that recent dissection has not destroyed nor profoundly distributed the effects of the ice.

One of the most striking results of this glacial work is the rampart which surrounds Obsidian Plateau (Figure 80). The fringe of trees around the edge practically mark this rampart. This rampart averages about thirty feet higher than the general level of the plateau. It is a remarkable thing that the great thick sheet of ice which passed over this plateau did not more severely erode its edge. It almost looks as though the glaciers extended to the very edge of the plateau and then stopped. This theory is untenable because it would be unreasonable to expect the outer limits to the glacier to coincide so accurately with the edge of the plateau. Further, we find on the sides of this plateau and for a long distance beyond, striking evidence that the glacier reached far down the valley of White Branch.

It would appear upon first thought that the ice would have been able to pluck the rock from the edge of the cliff more easily than from any other place, since on the edge of the cliff the rock has two unsupported surfaces against which the ice could work. The cliff, it would seem, should be more easily rounded or destroyed for the same reason that we find it easier to knock the corner off a block of stone rather than break a chunk out of the center of one of its surfaces. In the case of Obsidian Plateau the upper surface has been scooped out while the edge of the Plateau has been left with but little erosion.

This apparently anomalous condition can be easily explained if we stop to think of the mechanics of a glacier in passing over a cliff. A glacier in traveling over a surface performs its work as a result of three factors: (1) The tools in the form of rocks frozen to the bottom of the ice; (2) the speed with which the ice moves; and (3) the weight of the ice. The tools would be no more abundant while the ice was on the surface than upon the slopes, and may be disregarded. The velocity of the ice would only slightly increase in passing over the edge of the plateau or down its slopes because the velocity of the ice on a surface is dependant not only on the slope of a particular surface but upon the average slope of the entire glacier. The ice behind can move no faster than the ice in front. The speed of the ice in going down the cliff and over the edge of the cliff is determined by the velocity of the ice on the surface of the cliff and the velocity of the ice beyond the cliff. This principle may be illustrated by a train of freight cars in which the middle car in a long train, though moving down a small steep grade, can move no faster than the cars in front or behind. This factor, also can be omitted.

The difference in the erosion, therefore, must be due to the thickness or the weight of the ice. The weight working upon a particular square foot of surface is determined by the mass of the ice, weighing about 60 pounds to the cubic foot, vertically above it. The weight of this column of ice, shod more or less uniformly with tools of rock, gouges into the rock below. This gouging is carried along by the velocity of the glacier.

The weight of the ice passing over a comparatively flat surface rests directly upon the surface. Ice resting upon an inclined surface does not bear down perpendicularly upon that surface, but works upon an inclined surface. The effect of the weight is to assist the ice in slipping over the surface rather than digging into it. The pressure of this ice is not upon the surface, but upon the ice in front of it. The effect of this pressure is to accelerate the velocity of the ice on the surface and in front. The more rapid movement of this ice as a result of this cause enables the ice to move away from the ice behind it, and creates cracks and fractures in the glacier. These cracks and fractures will occur along a line transverse to the length of the glacier where this acceleration first begins. Thus we may see upon Collier and Prouty Glaciers enormous transverse crevasses at those portions of these glaciers where they descend over steps.

Imagine a block of ice one hundred feet high in such a glacier separated by two transverse crevasses. Let this block of ice reach the edge of a cliff. Here it will be tipped over the edge as a result of the pressure of the ice from behind (Figure 82). It is evident that this block will continue its eroding up to the edge of the cliff; but when it starts to cant, the ice will bear down only upon the axis of overturn. The fore end of the block will not erode because the upsetting process has lifted it from the surface. The erosion along the axis will not be severe because, though the pressure may be great, the movement of the block is a movement of rotation rather than of transition. The block will rotate over the edge of the cliff

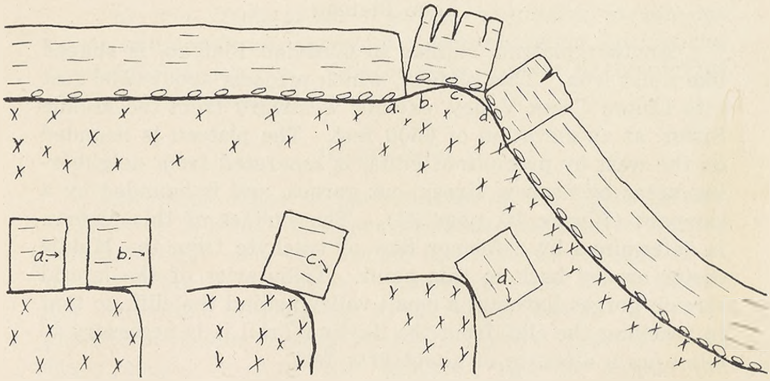


Figure 82. This figure is to show that a glacier riding over the edge of a cliff actively erodes up to the edge of the cliff where its erosive power is lessened due to the fracture and tilting over the edge of the blocks of ice.

and then drop onto the top of the ice below. When this block has settled upon the forward body of ice, it will then again begin to pluck and gouge.

Thus it will be seen that a glacier, in passing over a cliff, is steadily at work up to the edge of the cliff, where it greatly loses much of its power of erosion, and does not resume this activity until it is well over the cliff edge. The rocks on the edge of the cliff will not be cut down, but will be left standing as a ledge or rim.

The height of this rim is determined by the thickness of the ice. When the difference in elevation between the rim and the surface of the approaching ice becomes too large, the ice from behind will push against rampart and cause it to be eroded. Such erosion of the rim will be from the stoss side. Thus the elevation of such a rampart is definitely limited to the thickness of the ice. The thicker the ice, the lower the rampart. The elevation of the rampart of Obsidian Plateau or of Lane's Plateau appears to have been limited to about thirty feet.

Lane Plateau

Another plateau, similar to Obsidian Plateau, is shaped like a flat iron. This plateau, which projects about 6500 feet into Linton Creek Valley, extends westward from the Middle Sister, at an elevation of 6300 feet. The plateau is bounded on the west by precipitous cliffs, is separated from neighboring areas by narrow stream-cut gorges, and is bounded by a rampart (Figure 16, page 24). The surface of this plateau is determined by a former flow of trachyte from the Middle Sister eroded back to this point. Tributaries of the lateral stream gorges have cut a small valley behind the cliff, so that in reaching the cliff from the Skyline Trail it is necessary to climb up a distance of about fifty feet.

In descending over the edge of the cliff, a complete section of the rocks from the trachyte, the principal rock, down to the basement rocks of Linton Creek may be seen. On the southwest cliff are a series of rocks which, though they appear to be dikes, are the peculiar result produced by weathering upon this platy trachyte.

From the edge of this cliff interesting and instructive views into the surrounding country may be obtained. To the south one sees a number of benches all definitely related to the Middle Sister, having the same elevation as that of Obsidian Plateau. To the west may be seen the even crests of the distant mountains and the old valley of Lost Creek incised in the old surface. Within this valley a lower surface is apparent, formed by the same lava flows from the Middle Sister which gave body to Obsidian and Lane Plateaus. The surface of the Pliocene flows may be traced from the foreground down into Lost Creek Valley. Figure 16 shows on the right side the end of Lane Plateau. A prominent ridge in the center of the valley is almost the same general elevation as that of Lane Plateau, except for the difference in the elevation due to the surface formed by a lava flow extending down the former valley. This lower surface has itself been channeled by numerous courses such as the present valley of Lost Creek, and, in the distance, the valley of the McKenzie. In both of these latter valleys Recent lava flows have descended. We may thus prove three definite stages in the history of this area by observations made from the edge of Lane Plateau.

The even crests of the west side mountains though maturely sculptured, are not proof of peneplanation, but are due to an original surface. This original surface is the surface of Mount Multnomah.

South Sister

The South Sister is the youngest of the Three Sisters. It, however, is not a unified peak, but is a comparatively young mountain built upon and around the wrecked remains of an ancient Elder South Sister. Neither of these South Sisters are comparable in great age to the North Sister. If it were possible to rename these peaks at the present time, the North Sister should be called the "Mother," and the Middle and South Sisters "Daughters." The South Sister, by reason of its youth, is the most symmetrical mountain in the group. The Elder South Sister, which protrudes through its eastern slope, disfigures its almost perfect shape (Figure 37, page 54). Here we see that a mountain, like a human being, contains within itself part of its ancestors.

The South Sister has not been severely eroded. The lava flows which poured down its sides may still be seen, one flow having poured over the lip almost within historic time (Figure 81). Though streams have cut radiating valleys in these flows and glaciers have cut deep scars into its sides, only a small percentage of its total mass has been removed.

The area belonging to the South Sister extends to the Husband on the west, the Rampart on the south, to Broken Top on the east, and for a mile out on the northeast. Lavas from this mountain, which once abutted against the southern slopes of the Middle Sister, have largely been removed by the glaciers and the head waters of Squaw and Separation Creeks.

The Elder South Sister shows only its top. If we could remove the lavas and cinders of the present South Sister, the Elder South Sister would show a structure resembling the present Middle Sister. Much of the north, east and south side of the Elder South Sister has been removed by Prouty Blacier (Figure 68, page 86).

On the South Sister at 10,200 feet, is a crater lake approximately one-fourth of a mile in diameter—one of the highest crater lakes of the North American continent. During the summer in this crater lake over 10,000 feet high and around its shores one can enjoy on any one day swimming, skiing and skating. The inner walls of this crater are rather steep and one must take care in descending to the edge of the lake. If, however, one is provided with skiis or a toboggan, great sport can be had in sliding from the crest of the crater down to its pit (Figure 67, page 86).

It is apparent that this is an extremely youthful crater, and it is quite possible that its latest period of activity has been since the glacial age. It does not appear to be eroded any more than the present crater of Vesuvius, which is only twelve years old. Except for the vulcanism characterizing the present crater at the summit, the recent vulcanism about the base of the South Sister is confined to the South Side, where Newberry, Miller, Mesa, Little Broken Top, LeConte craters and Rock Mesa have breached its sides (Figure 64, page 80).

The South Sister is one of the high mountains in Oregon, and the highest one of the Three Sisters Group. The climb to the summit of this mountain can be made from any side but the north. From the Skyline Trail one is advised to use the surface of Lost Creek Glacier and from the Fall Creek Trail the Lewis Glacier. From its summit, magnificent views in all directions may be seen. This peak gives the best view of the country to the south. The gentle eastern slope of the Cascade Plateau, the break line decorated by a long line of volcanoes, and the rough westward slope of the plateau are clearly seen. In addition to seeing recent lava flows and enormous glaciers during the ascent, one is finally rewarded by the giant volcanic pit at its top (Figures 81 and 84). In the course of a circuit around the rim, one may look out upon the magnificent scenery of the Cascade plateau.

Scott Mountain

On the slopes of Old Mount Multnomah are some mountains formed at the close of the Glacial Period (Figure 26, page 43). Scott Mountain is named after Felix Scott, a sub-Indian agent in southern Oregon in the early days and promoter of the McKenzie Wagon Road in 1861. He first made the pass en route to Canyon City mines, following the mail route from Windy Point to Meacham. During the winter there was only one way to get across—on foot—and Thomsons relayed the mail for 15 years across the divide, making the complete round trip daily, except Monday. Felix Scott's opening of the first trail dates back to 1863, but it was not until 1872 that the road was first opened to wagons, as a toll thoroughfare, with a toll bridge where the McKenzie Bridge is now.

It is a symmetrical peak rising from about the five thousand foot level to an elevation of sixty-five hundred feet. Its east, north, and south slopes are the steepest. Its western slope extends gradually downward to the confluence of Lost Creek and the McKenzie River. Cupola Rock, one of the landmarks observed coming up the McKenzie Road, is a spur on this southwest slope truncated by the McKenzie River.

Scott Mountain rises to a height of 7000 feet and is bounded on the west by the McKenzie River, which flows south from Fish, Lava and Clear Lakes. On the northeast slope of Scott Mountain at an elevation of 5100 feet are two volcanoes, Twin Craters, each of which rises about one hundred feet (Figure 35, page 54). The presence, in these craters, of trees does not prove that the craters are ancient, but simply shows the effect of lower altitude and exposure to the moisture of the west winds on vegetation. On the southeast side of Scott Mountain are three beautiful lakes, all of which may be reached by short trails from the McKenzie Highway (Figure 90, page 138).

Black Crater

Black Crater is of about the same age as Scott Mountain. It is a tremendous mountain, much larger than any of the other surrounding peaks (Figure 26, page 43). Its regular symmetrical slopes rise gradually on the north from the highway, on the east from Trout Creek, on the south from Scott Trail, and on the west from the great Belknap Lava Flood. This mountain rises to an elevation of 7184 feet, according to the U. S. F. S.

Five subsidiary volcanic cones rise from its slope. These volcanic cones may easily be recognized at a distance because their red color stands out prominently against the Black slopes of this crater. All of these minor volcanoes contain well developed craters. The northernmost cone is named after John Lotta, who discovered Lost Creek Canyon sometime in 1865-66 (and thus made possible a feasible road over the Cascades via the McKenzie River. The southwest cone is named after M. H. Harlow, president as well as one of the incorporators, in 1871, of the McKenzie Pass Toll Road. The southeast cone received its name from George Millican, who, with John T. Craig, originally conceived the idea of creating a wagon road across the pass. The road began from the Willamette Valley and terminated at Camp Polk, Crook County.

Standing on the top of Black Crater one sees at its base the immense lava flood which issued principally from Little Belknap. Looking northward beyond the McKenzie Lava Flood one can see the line of early Pleistocene volcanoes erected upon the break of the Cascade Plateau. A few miles beyond Belknap is the triangular peak of Mount Washington (Figure 13). This triangular peak sits upon a comical mountain like a small three sided pyramid set on top of an inverted tea cup. Beyond this arises the magnificent peak of Mount Jefferson. On clear days, or when the atmospheric conditions are right, there may be seen the glacier-clad slopes of Mount Hood, and, with good luck St. Helens, Adams, and in the faint distance the peaks of Rainier and Baker. One may reach the very base of Black Crater by saddle horse on a trail from the McKenzie Highway on the east; and the top, then, is easily attained over a good Forest Service Trail. At the very top of this mountain is a crater. Around the base are the several small Matthieu Lakes, made by morainal and lava dams and named after Francois Matthieu, who, at the Champoeg Convention in 1843 rendered a decision which gave the United States its present northwest boundary.

The more adventurous explorer will find much of interest in the features exhibited by frozen liquid rock, and a thrill as well, in a trip from the base of this mountain westward over the lava flood to McKenzie Highway (Figures 28, page 48, and 31, page 50). This trip can be varied by going over the lava to the various islands.

Hydrography

Streams

The elevated uplands of the Three Sisters area are being destroyed by the energetic streams. Some streams, active for only a part of the year, are not shown on the topographic map. Many of the streams shown are not continuously active. In addition to the annual variation in volume of water due to the melting snows and winter rainfall, there is also daily variation. Thus many of the streams flowing immediately off the Three Sisters are dry early in the morning and by eight or nine o'clock they become little trickles of water, but about five or six o'clock in the evening they become roaring torrents. Unless one is prepared to ford such a stream, it is wise to plan the day's journey so as to avoid them late in the afternoon. White Branch shows this great daily variation (Figures 86 and 87, page 134).

White Branch receives its name from the fact that its waters are colored by rock flour furnished it by the glacial mill, where one rock is ground against the other to a white rock powder. The streams flowing down the head of Linton Creek canyon are red in color, due to the fact that the South Sister glaciers grind up red lava rocks.

Springs

Many of the streams are fed by springs. In addition to the springs below Newberry Flow and west of Devil's Hill, there are numerous springs about the base of the Three Sisters. These springs are formed wherever waters due to melting snow or ice find a course possible through fractured or porous rock, as along the north walls of Linton valley. About three thousand feet along the Skyline Trail south of the Husband, the water gushes out beneath a lava flow in several streams four or five inches in diameter. This spring gives rise to a number of little lakes and ponds which dot the meadow surface of the valley at this point and create a quaking bog over the whole surface of the valley. The elastic ground gives the effect of walking over a great thick green Brussels carpet.

Lakes

The lakes are among the most beautiful features of the Three Sisters (Figure 88)—even more beautiful than the springs. Since the lakes have frequently been discussed in earlier parts of this book, an attempt will be made here merely to mention the larger ones and a few typical illustrations of the various types of small lakes (Figure 15, page 20).

Clear Lake is a very important lake located just beyond the limits of this area. It is famed for its fishing, and for the fact that it appears to have no definite inlet or surface outlet. It is a lake formed by the damming of the Santiam by the Great McKenzie Lava Flood. This damming took place so recently that the submerged trees may still be seen around its borders. Much of the water entering this lake comes into it from unknown sources beneath the lavas and escapes in the same manner. This lake has been considered as a possible source of water supply for the towns of the Willamette Valley. Because of its uncertain supply it is not practical from a few years' observation to attempt a judgment of the amount of water this lake will afford, but only after many years of careful gauging. Further, were a dam established at the outlet of this lake in an effort to raise it and to make it a more desirable reservoir for water supply, it is doubtful whether such a dam would be successful. The raising of the water level would undoubtedly afford these waters an opportunity to spread over some other divide under the porous lava rocks. Any consideration of this lake as a source of water supply for the towns of the Willamette Valley must include these facts. Fish, Lava and Big Lakes, formed by lava dams, teem with mountain trout.

Linton Lake is another lake of the same type, formed by the damming of the waters of Linton Creek by Jerry Flow. Linton Creek, which drains the area between the west Rampart, i. e., the Husband ridge and the newer volcanoes, flows over a valley cut in old lavas poured out of the Middle Sister in Pliocene times and then plunges over the edge of this old flow in the highest falls in the district and into Linton Lake (Figure 89). The waters of this lake have an outlet underneath Jerry Flow and appear in springs about one mile west. The waters of White Branch are carried over this subterranean stream by Jerry Lava Flow, much as an irrigation flume is carried by a trestle bridge over a river. The level of this lake was at one time, and indeed before the coming of Jerry Flow, much higher than it is now, as shown by the silt deposits on its eastern side. The stream was dammed apparently by some other flow at an earlier date, which was eroded, and much of the silt removed before the coming of Jerry Flow.

The group of beautiful lakes around the base of Scott Mountain is in part due to lava damming, in part to morainal damming, and in part to natural depressions in the surface of the McKenzie Lava Flow (Figure 90). Sparks Lake and Elk Lake are also illustrations of such deranged drainage formed on the south slope of Mount Multnomah.

Several small lakes, called the Mirrors (Figures 42 and 83), south of the Wife, were formed by the damming of former streams by small flows, such as Rock Mesa. Beyond the pass between South Sister and Rock Mesa is an enclosed basin. At certain seasons of the year, this interior valley contains a small body of water derived from the South Sister. This water has no outlet except that which it can find from seeping through the pumice underlying the Mesa.

On the east side of the Three Sisters, on the surface of the various plateaus, and around the southwest base of the South Sister are a group of picturesque morainal lakes. It will be left to the tourist to find and describe these numerous and beautiful lakes.

To the south of the Three Sisters is a large group of lakes famed for the beauty of their shores, their general accessibility and their fine fishing. The average visitor will be more interested in the size and number of the trout they contain, but the author mentions them in this connection because they also owe their origin to morainal and lava damming. Further than that they offer an attractive place for the tourist to visit in his journey from the Three Sisters down the Skyline Trail to Crater Lake.

Parks

Most of the lakes rest in beautiful parks (Figure 42, page 60). A park is a comparatively flat timbered and meadowed area located in a mountainous region. This definition, employed by mountaineers, is not identical with that used by the unfortunate city-dweller. A mountain park is an exceptional place in the mountain in which one finds relief from arduous travel and assuagement to the eyes in the simple idyllic surroundings afforded by level surfaces, flower-carpeted meadows, and open timber, after the rugged grandeur of high mountain peaks.

The Three Sisters area is surrounded by a string of parks as beautiful as jewels. There are many parks, all different, wherein one may camp for weeks at a time and enjoy the benefits of high mountain altitude, and the exaltation that comes with free, out-of-door movements, and the satisfactions to be derived from the surroundings of trees, flowers and magnificent mountain scenery (Figure 60, page 78).

The varied scenery which surrounds them, the great variation in trees and flowers and in the sharp contrast of those on the west to those on the east, make each one worthy of special visit. A month could be spent delightfully in the Parks alone.

In the vicinity of the lakes at the base of Scott Mountain and on the south side of the road near Frog Camp and Pole Bridge, are beautiful parks in which one can establish a base and from which the entire area can be explored. These are easily reached by the tourist who has but a small time at his disposal, or for those who do not feel disposed to expend the energy required to reach the higher and finer mountain peaks. On the west side beginning above the falls at Linton Creek and continuing southward in Linton Valley to its divide with Separation Creek and thence to Separation Valley is one continuous park area.

Here one finds the last stand of the trees which characterize the western side of the Cascades. Just to the east of this valley the timber and flora changes to the high Alpine type (Figure 71, page 88). In this long and continuous park are many lakes, springs and streams. The main part of it is covered by a dense growth of meadow grass and mountain flowers. East of Linton Creek are the parks of Obsidian Cliff and Lane Plateau. Their top is covered by a moderate growth of trees, the density of which is such as to afford abundant shade and picturesque scenery and yet not so dense as to prohibit easy rambling on foot or on horseback.

On the surface of these plateaus are a number of small lakes where one may skate in the colder seasons or swim in the summer. Above these is a succession of smaller parks, each characterized by a smaller amount of timber and more limited flora. In exchange for the plants and flowers, however, they afford small lakes and interesting rock-strewn areas over which one may ramble for days in thorough enjoyment.

The park area continues around the base of the South Sister. Just south of McArthur Hill and close to the trail, is perhaps the most beautiful area in the district, in which are located the pretty Mirror Lakes. McArthur Hill was named after L. L. McArthur, a prominent judge of the Oregon Supreme Court, who died in 1897.

On the east side the parks show the effect of a dry, high elevation. On the west they show the effects of high elevation plus a humid climate. Southeast of Devils Hill the character of the flora and fauna begins to change. The soil surface also changes to one strewn with pumice. In the lower valley of Fall Creek and on the bench on the east side of upper Fall Creek are equally delightful parks characterized by the flora of eastern Oregon. The area around Green Lakes is such that it looks as though it had been designed by an expert gardener. North of this area along the Alder Creek Trail to the McKenzie Highway are a series of parks not very large in size but each offering new and delightful attractions.

Summarized History of Mt. Multnomah

The history of Mount Multnomah will help to correlate the evidence of its former presence. Oregon's greatest mountain was born in Stage "II," or the Oligocene (Figure 4, page 9), when an eruption started along the Cascade fault. During all of this period a tuffaceous cone, remnants of which are found in the fragmental rocks, was piled up. Beginning in the Middle Miocene and continuing into the late Miocene, Stage "III," an enormous flood of basic lava poured out. As a result of this intense volcanic activity Mount Multnomah was built into a gigantic cone over 15,000 feet high and with a base extending from the vicinity of Belknap Springs on the west to Three Sisters, on the east to beyond Mount Washington on the north and to Elk Lake on the south. The lavas from this crater poured out far beyond the base of the cone in all directions for seventy or eighty miles. On the west these lavas reached to the western border of the Willamette Valley. On the east these lavas now lie buried beneath later volcanic flows, though, in some of the deeper canyons such as that of the Deschutes, these lavas may be seen. Wherever found they show an outward dip from the axis of Mount Multnomah.

At the close of the Miocene the entire top of this mountain either collapsed or was blown off. If a collapse, it was due to the inability of the earth beneath the cone to support the enormous weight. The top of this mountain might have sunk into the liquid rock below in much the same manner as the stone neck of a jug would sink were it broken by a down crushing weight. The cause of the subsidence was the cessation of upward pressure, which had forced the lavas to the surface. The support was only that which could be afforded by the subjacent rocks, and since this was liquid rock, it is evident that with the cessation of explosive pressure, the top of the mountain would drop into the resurged liquid magma below.

The top might have been blown off much as was that of Krakatau. Since practically all of the world's great calderas have been due to decapitation by explosion, we may conclude that Mount Multnomah lost its top by such a catastrophe. Whether due to caving in or to explosion, the destruction of the top of the mountain created a circular fault around its entire edge. The location of this fault was fairly close to the present caldera rim which gives a diameter of about eight miles. It is thus evident that the caldera was of gigantic proportions (Figure 6, page 11). The diameter of a few of the world's greatest calderas are given below for comparison.

Lage di Bracciano, Italy—Diameter in miles, 6½; depth, 300 to 500 feet.

Lage di Bolsena, Italy—Diameter in miles, 10¼ by 9.

Gulf of Santorin, Grecian archipelago — Diameter in miles, 6.

Krakatau, Straits of Sundra, between Java and Sumatra, East Indies—Diameter in miles, 5; depth, 3000 feet.

Crater Lake, Oregon—Diameter in miles, 5; depth, 500 to 2000 feet.

In the early part of Stage "IV," or the beginning Pliocene, streams working their way headwards from the east and west eventually cut into the walls of this caldera (Figure 6). When these streams cut their channels low enough, they afforded perfected outlets which drained completely. If one could have visited this area away back in the distant Pliocene, he would have found a high mountain meadow surrounded on all sides by sheer walls rising three or four thousand feet and cut through midway between the four points of the compass by narrow canyon walls.

In the Middle Pliocene volcanic activity was again renewed, the result of movement along the Cascade fault. Two new volcanoes were formed within the caldera, the Elder Middle and Elder South Sisters. The close of the Pliocene produced a dissection of these two peaks to a state of maturity.

Continued upward movement again revived vulcanism with the result that the present Middle and South Sisters, Black Crater, Mount Scott, Bachelor, and the whole chain of peaks along the Cascades were developed. A continuation of this uplift brought about glaciation in the Ice Age, or Stage "V" (Figure 24F, page 41). The sinking down of the Oregon fault block which brought about the close of glaciation reopened the Cascade fault and revived vulcanism again. The vulcanism of this last period gave birth to Belknap, with its great sea of lava and of the smaller flows around the base of the South Sister (Figure 25).

Climate

The climate will permit the tourist, properly prepared, to examine all the interesting features so far described at any season of the year. The eastern and western slopes of the Cascade Range differ widely in their general climatology, the eastern being dry with extremes of temperature, while the western is wet and with a comparatively even temperature. The maximum depth of snow on the summits is about twenty feet, except about the immediate base of the Three Sisters. The maximum depth at an elevation of 3000 feet is five feet. Upon hills having an elevation of from 5500 to 6500 feet small patches of snow, if well compacted and sheltered from the warm Chinook winds, may remain as late as August first.

The moist westerly winds ascending in the western valleys are chilled, and produce either clouds or rain; hence these valleys are not uncommonly filled with long valley clouds (Figure 76, page 92), or the valleys receive more rainfall than the upper slopes. The winds, striking against the higher elevations such as the Sisters, are chilled, and produce large cloud caps, which surround the mountains more or less completely. These huge clouds are rather common throughout the winter, and may even occur for parts of a day during the summer. When the heavy fogs hang over the mountains, the trees serve to condense their moisture which falls to the ground beneath the trees. It is not an uncommon thing to find in the early morning a small layer of snow beneath a tree, and the surrounding vicinity completely dry.

Flora and Fauna of the Three Sisters

In this varied climate, and because of diverse geologic conditions, trees, flowers, animals and birds of many varieties abound. Because of the elevation, the direction of the prevailing winds, the topography of the country, and its location in the central temperate zone, the flora and fauna may be divided into three distinct zones, each with its arid and humid phase. A description of these zones for Oregon was first published in 1917 by Alfred C. Shelton of the University of Oregon. These three zones consist, first of the Cascade Canadian, extending from the foothills of the Cascade Mountains to the timber line; second, the Hudsonian, including that area along the timber line zone; and finally, the Alpine Arctic, which includes the region definitely above the timber line.

To students of nature the Three Sisters area should be particularly attractive because within this single area the flora and fauna of all three distinct zones may be found. Thus the lower limit of the Arctic Alpine scarcely occurs in southern California, and only begins at an altitude of 10,000 feet in the southern Sierra Nevada. To the north it is found at lower elevations, for instance, at 9500 feet on Mount Shasta; at 8000 feet in Three Sisters; and at about 6500 feet in Washington. The other zones are likewise restricted on the north and south. Within the area of this study, all three are fully developed and under most favorable conditions. Moreover, because of the height and proximity of the Three Sisters and adjacent mountains the moist western winds are shut off from the east side. Therefore, each zone shows a humid phase on the west and an arid phase of the east, with an intermingling of the two around the south side of the South Sister. The area is an ecological laboratory for the nature student.

The Cascade Canadian Zone extends from the western boundary of the Park to the level of Linton Park. The Hudsonian includes the plateau area, including the Obsidian and Lane plateaus up to about 7500 feet, and the Alpine Arctic, covering a large area above this elevation.

In addition to the zones established more or less definitely by elevation, the central chain of mountains—i. e., Black Crater, The Sisters, and Devils Hill—definitely divide the area into two parts. To the east the flora and fauna are characteristically arid; to the west of this line they are typically humid. In passing over from one side to the other the dividing line is sharp and distinct. Extending up the eastern side, the three above mentioned zones show the changes wrought in the flora and fauna of arid eastern Oregon because of higher elevation. Up the slope of the western side, the flora and fauna of the humid Willamette Valley area of Oregon is gradually changed to that adapted to higher elevations. Thus on the western slopes is a heavy forest of Douglas fir, western hemlock, western red cedar, and, at higher elevations, mountain hemlock, mountain white pine, Englemann spruce, and true firs with an undergrowth of salals and Oregon grape; while on the eastern slope is pine and juniper and an undergrowth of bunch grasses. If the two slopes were not separated by snow or cinder cones and volcanoes at the summit, there would be a merging of the two types of vegetation.

TREES AND SHRUBS

Cascade Canadian Zone

In the Cascade Canadian Zone is the mountain flora which includes, in the mountainous districts, part of the Transition, so named because here the boreal, or northern, and the southern elements of the flora meet. It coincides in general with the yellow and jack pine belt. Here, during the summer months, the botanical traveler will find a delightful and exhilirating climate. If he comes from the eastern states, most of the genera and some of the species will be already familiar to him, but if from the north, or from northern Europe, he will feel more at home, botanically, in the higher zones.

From the eastern edge of the Willamette Valley floor, where the flat country of the lower valley disappears imperceptibly, the hills becoming higher and more rugged, extending up the western slopes of the Cascades, the timber becomes heavier and heavier, and on these slopes the Normal Transition zone attains perfection, sweeping for miles upon miles in unbroken forest. The McKenzie Highway traverses this thick forest.

This vast forest consists of DOUGLAS FIR *(Pseudotsuga taxifolia)* and in some localities, especially in the McKenzie valley above Blue River, are more or less extensive stands of WESTERN HEMLOCK *(Tsuga heterophylla)* and Red Cedar. Scattered over these slopes, especially along the streams and rivers, are many scattered Grand Fir, WESTERN WHITE PINE, and INCENSE (or WHITE) CEDAR.

The GRAND FIR *(Abies grandis)* is a large dark gray and very tall ornamental tree with dark green foliage and light colored wood. The WESTERN WHITE PINE *or* LITTLE SUGAR PINE *(Pinus monticola)* in tree and wood resembles the white pine of the East, and is found all over the Cascades. It is a very tall and symmetrical tree with a cone six to twelve inches long and is very valuable for lumber.

The INCENSE (or WHITE) CEDAR *(Libocedrus decurrens)*, very abundant in southern Oregon, occurs to the south and west of the Three Sisters and is valuable because of its durability. Its flattened fan-like foliage of a light green color and delightful fragrance make it a beautiful and ornamental tree.

The YELLOW or RED CEDAR *(Thuya plicata)*, abundant all over Oregon, is the largest cedar known. It is found twenty-two feet in diameter and two hundred feet high. It is easily worked and is highly prized for its lightness and durability as finishing lumber and for shingles.

In this zone, which stretches in a vast expanse along the entire summit of the Cascades, below the higher peaks, is found the typical LODGEPOLE or JACKPINE *(Pinus contorta var. murrayana)*, forests as exemplified at Frog Camp meadow and other points along the summit at the corresponding altitude. It covers the entire belt in heavy stands on both slopes of fairly large trees in full growth. This species, in these coniferous forests, is more widespread and abundant than any other. It is characterized by two needles and small cones. Its tough and light, tall, slender, bamboo-like trunks served as admirable poles for the tent dwellings of the plains Indians. Unlike most other western conifers, it has a very thin bark and suffers severely under fire, but its abundant cones, often remaining closed for several years, provide a safe-guard against excessive mortality by forest conflagrations.

Throughout the stands of Lodgepole Pine are many scattered individuals or small clusters of NOBLE FIR *(Abies Nobilis)*, sometimes called LARCH, this being another and very characteristic tree throughout this zone. The stands of Abies are heaviest at and near many high mountain meadows scattered throughout this region of the Cascades. Here the individual trees attain their greatest size, many of them reaching a height of a hundred feet or more. The noble fir is indeed a noble tree, and the most beautiful of all the fir family. As an ornamental tree it can hardly be equalled. The tree, straight as an arrow, with smooth, light-colored bark, silvery blue foliage, large cones that stand upright with pointed depressed bracts, can easily be identified. The lumber is very valuable for inside finishing because the soft white wood is easily worked.

This is also the belt of the ENGLEMANN SPRUCE *(Picea Englemanni)*, a tall tree with hard and tough wood, indigenous to high altitudes where it occurs along the summit of the Central Cascades everywhere in the vicinity of lakes. In spots of abundant moisture, are many scattered individuals or more or less extensive stands.

On the rolling foothills along the edge of the Willamette Valley are a few scattered OREGON or WESTERN YELLOW PINE *(Pinus ponderosa)*, WHITE FIR *(Abies concolor)*, and other species. The first named species is remarkable in that it is accommodated to a greater variety of soil, exposure and climate than any other North American coniferous tree. This pine flourishes all over Oregon. The famous lumber tree of the Oregon mountains is a cosmopolitan in character and flourishes in all climates and elevations, but reaches its greatest perfection at about 1000 to 4000 feet above sea level, being a rapid and beautiful grower, and extremely hardy. Good marketable timber is made from this pine. The supply of this timber is especially great in eastern Oregon, where magnificent forests are found. Here and there these are replaced by thickets of mountain balm, alder and vine maple, with occasional madroñna, dogwood, and White-Bark-Pine.

The OREGON ALDER *(Alnus oregana)*, abundant all over the Coast, and the MOUNTAIN ALDER *(Alnus rhombefolia orteninfolia)*, a much smaller tree with very red wood, occur in or near the meadows. VINE MAPLE *(Acer circinatum)* is a small, beautiful maple with light green leaves and green bark, which for foliage, has few equals. In the fall the foliage turns blood-red, yellow and pink. The wood is very strong and tough and can be used for anything that requires great strength.

Underbrush

There is relatively little underbrush in the Cascade Canadian Zone, especially in the vicinity of the Three Sisters Mountains and the higher slopes, save thickets of young Lodge-pole pines. In favored spots, mainly with a southern exposure, these vast forests may be underbrushed throughout with a fairly heavy stand of MANZANITA and MOUNTAIN LILAC *(Ceanothus velutinus)*, Rhododendron, salal, Vine Maple, OREGON GRAPE *(Berberis nervosa)*, and ferns. SALAL *(Gualtheria shallon)* is a small evergreen tree or shrub bearing an edible berry. RHODODENDRON *(Rhododendron californicum)* is one of the most beautiful plants to be found in abundance in the Cascades and along the Coast. Its large, glossy leaves, and lovely rosy pink flowers give it great beauty. It is sometimes found twenty-five feet high and is very bushy.

Litter

The litter common only in the Cascade Canadian zone is the graveyard of the forest, and as such is a constant menace to the living trees. It is composed of the fallen limbs of living trees and the trunks and limbs of the dead ones lying as they fell upon the forest floor. In the late summer or fall the western forest is a potential conflagration, with the humus for tinder, the litter for kindling, and the standing forest for the fuel. All that is needed is the match and the wind.

The litter is at its minimum in the most easterly of the yellow pine areas, where there is only here and there a tree fallen from old age. On the high exposed summits it is composed of broken limbs and saplings whose root hold was not secure against the storms or weight of snow. In the thick forests of the western slopes it is generally composed of immature trees killed by overshading or windshake, and it covers the floor to a depth of five to six feet. Seldom have fires been so severe as to entirely destroy this covering, and therefore the restocking has been rapid.

HUDSONIAN ZONE

The Hudsonian zone, above the Cascade Canadian zone and below the Alpine-Arctic zone, may be called the timberline zone, or very roughly, the zone of the higher peaks, ranging above the Cascade Canadian. This zone is very extensive and clearly distinct on the higher slopes of the Three Sisters. It extends from Linton Meadow at an altitude of about 6,000 or 6,500 feet around the base of Obsidian and Lane plateaus to the timberline at about 8,000 feet. The major timber association all through this zone is one of MOUNTAIN HEMLOCK *(Tsuga Mertensiana)*. On the higher slopes of the North, Middle and South Sister Mountains, around the bases of the actual peaks, this tree forms heavy forest stands in full growth. Higher up the slopes of these peaks this tree rapidly diminishes in size until it becomes dwarfed and stunted, to die out entirely at timberline. This tree makes fine lumber and its bark may be used for tanning. This hemlock, with its slender steeple-like top resting on a broad base, is one of the delightful trees of the sub-Alpine zone.

Next to Tsuga mertensiana in abundance as a Hudsonian form is the WHITE-BARK PINE *(Pinus Albicaulis)*, another characteristic timberline tree, which is scattered in some abundance among the forests of Mountain Hemlock, but is more abundant nearer timberline, where it becomes dwarfed and stunted, wind-whipped, and grotesque in form. Here it often assumes a semi-prostrate condition, as it struggles for a foothold, only to die out at timberline, at an altitude of about 8,000 feet.

The SUB-ALPINE FIR *(Abies Lasiocarpa)*, rare on high peaks in the Cascades, is a tall, very straight, ornamental tree with dark green foliage. A form characteristic of this zone, often seen in the mountains, is the DWARF or CREEPING JUNIPER *(Juniperus Communis)*, which is a fairly common, prostrate timberline shrub at the upper limits of tree growth on the Three Sisters Mountains. It is a beautiful, ornamental variety, one plant frequently growing over one hundred square feet.

TREES OF ALPINE ARCTIC ZONE

Above the Hudsonian Zone is the highest of the Boreal zones, the Alpine Arctic Zone, and it is confined to the extreme summits of the peaks of the North, Middle and South Sisters, and Broken Top. On these peaks, it ranges from timberline at about 8,000 feet, to their summits at an altitude of from 10,000 to 10,300 feet. It lies entirely above the limit of tree growth in the region of living glacier, snow field, lava ledge and cinder cone.

Here there are many modifications of the former zone, due to certain condition such as protection from storms, slope exposure, richness of soil, and other causes which result in tongues and spurs of Hudsonian extending up some distance into the higher zone, while in unfavored spots, similar tongues of the Alpine Arctic Zone extend down into the lower zone. Because of these modifications, the upper limits of timberline —hence the upper edge of the Hudsonian Zone—follows a contour which is very broken and irregular, and here local conditions control the extent to which Hudsonian forms may range into higher altitudes.

Along upper edges of the Hudsonian belt, at extreme timberline where it merges into the higher, treeless, Alpine Arctic Zone, the Black Alpine Hemlock and White-Bark Pine become dwarfed and stunted, prostrate and often grotesque in form, and above wind-whipped and distorted, dying out entirely. Here also along the timberline border is the characteristic crawling prostrate form of dwarfed and stunted Alpine Juniper. The Hudsonian Zone also extends down into the Cascade Canadian Zone.

RARE TREES

The following trees are found, but not in sufficient quantity to exceed one per cent. They are, however, worthy of mention because in other parts of the Cascades they are abundant.

The SILVER or LOVELY FIR *(Abies Amabilis)* is a wondrously beautiful tree with silvery green foliage and large, upright, purple cones. It is a large tree which reaches a height of over two hundred feet. The wood is soft and white, and is valuable for many purposes.

SUGAR PINE *(Pinus Lambertiana)*, whether in youth or old age, is the largest and most beautiful pine known. Trees are sometimes found ten feet in diameter and three hundred feet high. The young trees are very symetrical and have a decidedly trim appearance. Old trees are strikingly picturesque and ornamental, with their long branches, silvery green foliage, and, depending therefrom, immense cones, sometimes eighteen inches long. The Sugar Pine is the most valuable lumber tree on the Pacific Coast because of its white, very soft, highly scented, and easily worked wood, which does not check or warp. A very delicious sugar exudes from the tree, and the seed or nut of this pine is edible and very delectable.

A prevailing sub-Alpine species of the timberline slope of Mount Rainier and Hood is the ALASKA CEDAR *(Chamaecyparis Nootkatensis)*. It has a creamy yellow, very hard and strong wood, which takes a fine polish and is very valuable for fancy work.

WHITE OAK *(Quercus Garryana)*, is a beautiful oak found everywhere east and west of the Cascades from the Columbia River to Southern Oregon.

BIRCH *(Betula Occidentalis)*, a small ornamental tree with a very tough wood, is found along streams east of the Cascades.

While the forests of the eastern United States are largely deciduous, those of the Pacific Coast are coniferous. It is significant that these areas have only two species in common —namely, the ASPEN *(Populus Tremuloides)* and the BLACK WILLOW *(Sali Nigra)*, neither common to the Three Sisters country. The former grows at high altitudes in the mountains; the latter in the great valley of California and southward. Both of these species belong to the same family and both are furnished with light hairy seeds, which insure wide dispersal.

DISTRIBUTION OF TIMBER

The amount of timber is a factor not only of time and of elevation, but also of the direction of the prevailing winds. The sparsity upon the great McKenzie Lava Flow at once suggests the idea that these lavas have just recently poured out of young volcanoes. In the main this conclusion is correct, because studies made upon the youthfulness of the trees and the freshness of the lavas indicate that some of the flows are not much more than 100 years old. On the other hand, many of these flows are of great antiquity and the absence of timber upon them in a factor of their elevation and location rather than their youth. Thus, on Jerry Flow west of Simms Butte there is an abundance of timber; but east of there the timber rapidly decreases in amount until in the vicinity of White Branch Crossing no trees grow upon it at all. In Figure 77, page 92, on Obsidian Plateau, the effect of heavy snows in winter is strikingly shown. This figure shows mature trees that have been killed by unusually cold winters and heavy snows. If mature trees can be thus killed, it is obvious that tree seeds and seedlings will likewise be killed. Hence on lava flows at high elevations trees cannot get started and their absence is not an argument for the youthfulness of the lavas.

Except for the original distribution already described, no evidence was found showing distribution based upon the type of rock. Thus for instance the Alpine Fir grows on the fresh lavas as well as on the older gray andesites.

Southward from the international boundary at latitude 49°, the western flora "overflows" the summit of the mountains eastwardly until the latitude about the vicinity of the Three Sisters is reached, where this overflow ceases, and farther to the southward the eastern flora overflows westward. This intersection, close to the Three Sisters and within the summit of the Cascade Mountains, is the "critical point" at which a line bounding the typical western slope tree species crosses the summit. It is interesting that this point should be midway from the equators to the pole.

The west slope lies in two of the heaviest timbered countries of the United States.

Mr. N. F. Macduff, supervisor of the Cascade National Forest, says, "The Cascade Forest contains one of the largest bodies of Virgin Douglas Fir—24 billion feet— enough timber to build two and one-half million homes."

On the whole, the forest diminishes southward, owing to diminishing rainfall, which is particularly noticeable on the west side of the range, the average stand maintaining itself much more successfully east of the range. Furthermore, there is a change in the distribution of species southward, also owing to the reduction in rainfall. In the northern part of the range, yellow pine occurs chiefly and becomes common on the west side about twenty-five miles south of the Three Sisters; thence southward it increases upon the west side of the range, and in the southern part of the state becomes quite an important component of the forest. Associated with it, south of the Sisters, is a small proportion of sugar pine. The incense cedar comes up from California, and extends into the state half way up the range in commercial quantity. The divide between these two flora runs along the crest of the Sisters. The two sides present a striking contrast in the timber and other flora.

FLOWERS

Cascade and Canadian Zone

The luxuriant display of flowers will appeal to some more than the trees. That part of the Cascade Canadian Zone which extends into the Three Sisters area has flowers in common with the Hudson Zone. Space does not permit the discussion of the almost illimitable flora of the Cascadian just to the west.

Hudsonian Zone

Above the Cascade Canadian Zone in the open forests will be found a scattering growth of flowering herbs, which increase in abundance as the trees become better spaced, thus admitting more light. In these favored forest openings one finds flowering plants in profusion, especially on gravelly slopes along rocky outcroppings and on exposed ridges. PENSTEMON (*Penstemon Menziesii var. Davidsonii*) are plentiful and ANEMONE *(Anemone Drummondi)* and many other genera

Figures 83, 84 and 85. U. S. F. S. (83) Looking north from Mirror Lake to the South Sister. Many lakes of this character abound in the park lands surrounding the Three Sisters. Lewis and Bend Glaciers on the south side of the South Sister are shown. (84) Looking southeastward across the crater of the South Sister to show the immense size of this crater. The crater of the South Sister across to Bachelor; (85) To show the character of the young lava which makes up the present cone of the South Sister.

are also rather common. Such localities may be yellow with Trigonum and Eriophyllum, both of which western genera are represented by many species, or blue with Erigerons or Asters, but always with an admixture of many species belonging to other genera.

Two varieties of JACOB'S LADDER *(Polemonium, Viscosum Pilosum)* and (*Polemonium Elegans* in Washington) also occurs with showy blue flowers and on the higher rocks, golden sedum are to be found.

There are thousands of CAT'S EARS *(Calachortus Lobii).* One climbs over vast beds of heather, true and false, SWAMP LAUREL (*Kalmia Polifolia*) and (*Bryanthus Empetriformus*) red, yellow and white. The Mazamas report that from their first Linton Creek expedition they brought in seventy-seven distinct varieties of flowers, not mere botanical varieties, but such as the amateur might easily distinguish.

Thick-stemmed saprophytes like Pterosplora, Pleuricospora, Corallorhiza, and Pyrolaaphylla force their way through the carpet of pine needles in the open forest. The most popular of these saprophytes is the SNOW PLANT (*Sarcodes Sanguinea*), the thick red stalks of which appear soon after the snow has melted and remain as conspicuous elements until autumn. Although not abundant, it may be expected anywhere in this zone from southern California to Oregon.

But the more entrancing flower of the upper water of Linton Creek is the glacier lily. This differs from the AVALANCHE LILY (*Erythronium Montanum*) both in color and size. Myriads of its blossoms, slender, golden, and dancing, grow not only through melting snow, but actually push their delicate scapes through the ice—a very miracle of strength made perfect in weakness. The latter flower is not long lived, but quickly droops after a few days.

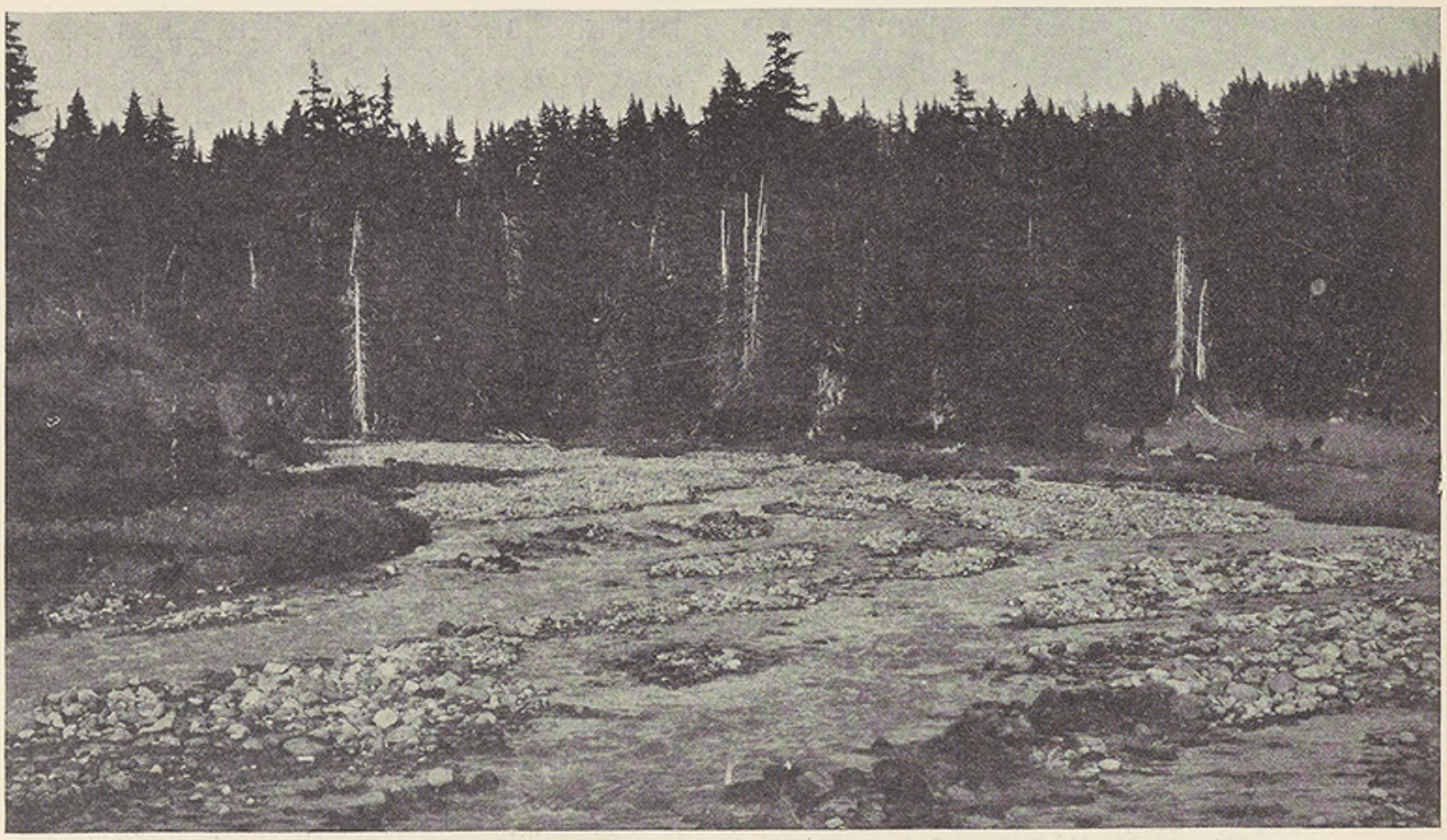
Here and there the forests open up to make room for a mountain meadow, the composition of which will vary with the moisture content of the soil as well as with geographical position. Where the ground begins to be boggy, one finds all around white marsh marigolds, buttercups, and larkspur. Along the creek, these are intermingled with the great white saxifrage, very stately; and along the water's edge is to be found a fine fringe of tiny many-colored gentians. The glowing *(Castelleja Miniata)* blooms on every side. This INDIAN PAINT BRUSH" of the Cascades is found in many varieties and in color from palest yellow to orange, from pink to flaming crimson, the numerous spikes of which impart warm color to the vegetation. These castillejas show great hardihood, sometimes found pushing through six inches of snow to daylight. Overtopping all else the blue racemes clumps of lupine. Common on gentle southerly slopes or in a marshy meadow near Linton Lake are many tall spikes and the conspicuous ELEPHANT HEADS *(Pendicularis Contorta)*.

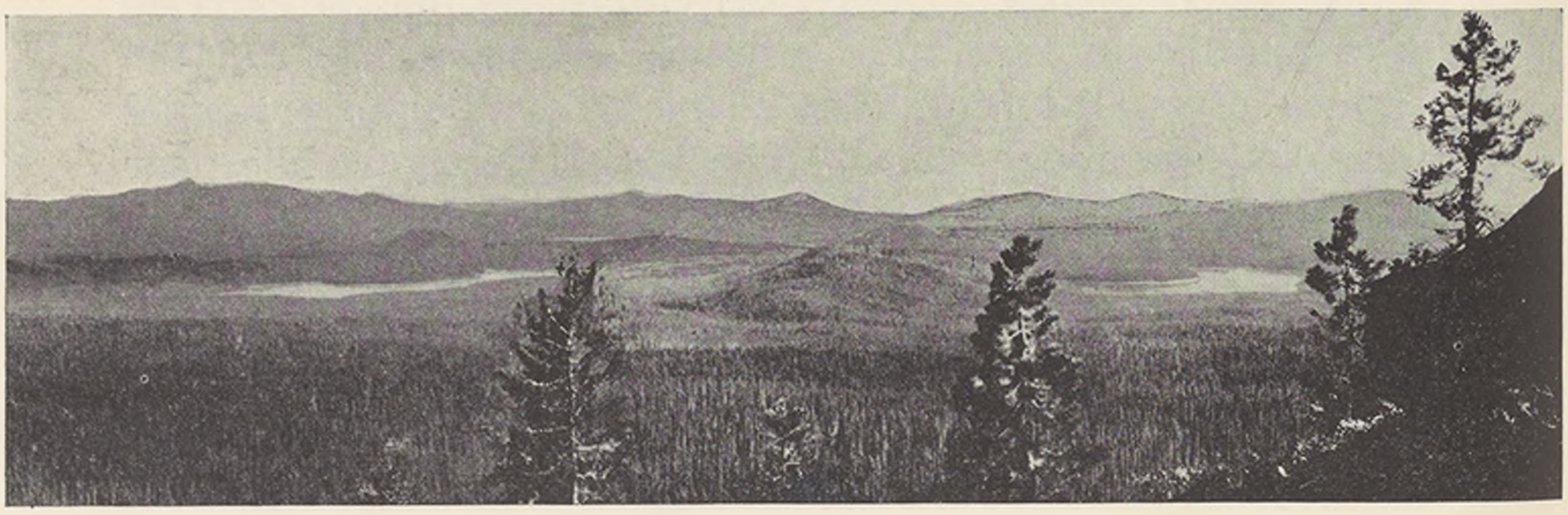
Upon the marshy flat above Linton Lake are found Indian pond lilies in bloom. Limnorchis, the great white bog orchid, beguiles the visitor with heavenly sweetness, and every summer yields a few rare blossoms but in the average mountain it is a fortunate flower-finder who finds half a dozen in a season, and here are hundreds, thousands, tall and gleaming white, and sweet beyond all other fragrances. Here also is the beautiful, flower-stalk of the buckbean. Its flowers are not only exquisitely white, but they gleam as with hoar frost at the center.

Below along the creek of Linton Lake where it begins to fall precipitately, and the valley narrows to a bare channel between the mountains, are small bushes along its course—vacinium in all its puzzling varieties, and the thimbleberry; and farther down the creek, a perfect foam of elk grass may be found.

ALPINE ARCTIC ZONE

The Alpine Arctic Zone, as defined above, contains only a few hardy plants. Their restrictions are due to extreme of temperature—long snow periods, strong winds, and the absence of soil. In this zone all plants have deep perennial roots and low tough stems. The leaves closely huddle near the base or along the short stems, and are heavily cutinized. Among the characteristic species, all of boreal origin, may be mentioned the ARCTIC *Willow* (*Sali Artica var. Petrea*) with stems only two or three inches high; *Cassiope Mertensiana,* with thick overlapping leaves and dainty pendant flowers; the ALPINE S*orrel* (*Oxyria Digyna*), well known in





Figures 86, 87 and 88. See Footnote, Page 135.

Arctic and Alpine districts around the world; *Polemonium Eximium,* with showy blue flowers (replaced in Washington by P. ELEGANS), and a number of composites, mostly with yellow flowers. This is only the beginning of a long series of species which might be enumerated.

The large number of forms, the remarkable adaptation to so rigorous a habitat, and the brilliancy of the colors displayed, all conspire to make a study of the Alpine flora an exceedingly attractive occupation. The highest summits are beyond the reach of seed plants, but the rock supports meager lichen flora.

In the lower part of this zone, late in summer may be found the plants of the Hudsonian Zone in belated bloom. There are phloxes, polemonium or valerian, crucifers, and soft, shining Pussy-paws (*Spraguea Multiceps*). Here orchids and lilies are multiplied. Here, too, may be found betony, and Elephant Heads *(Pedicularis Groenlandica)* and chimaphila and pyrola. A belated cluster of rhododendron may bloom among the scattered trees. Undiscouraged by the bigger, brighter flowers, the delicate orchids, the tway blade holds up its tiny spike; the long-spurred green orchids are everywhere beneath. Even wild roses are found; also the clear shining of white bunchberry blossoms, and on the face of a cliff, Romanzoffia, may be seen.

ANIMALS

CASCADE CANADIAN ZONE

Animals, unlike trees and flowers, will reveal their presence only to the more observant visitors. The animals, naturally, are more plentiful in the Cascade Canadian Zone, only a small portion of which extends into the Three Sisters area. The summit country in the region of the Three Sisters is the scene of extensive trapping during the dead of winter, when

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Figures 86, 87 and 88. (86, 87-U. S. F. S.) Looking east from near the foot of Obsidian Plateau across White Branch to show the daily change in the amount of water which this stream carries. The upper picture was taken about 9 o'clock in the morning and the lower one about 3 o'clock in the afternoon of the same day. (88) Looking south from the South Sister showing the old river channels of the ancient Deschutes on the left and "Lake River" on the right. The two lakes in the foreground are Sparks Lake on the left and Elk Lake on the right.

small mammals have sought safety in hibernation, and when most of the birds, save a few hardy forms, have been driven to milder climates, and when snow, ten to twenty or more feet in depth, covers the summit for mile upon mile in an unbroken blanket.

Porcupines, with their many good points, feed on the bark, especially of the saplings and younger trees, especially in the jack pine forests. The streams produce beautiful mink and otter, with their glossy and lustrous pelts, and the forests along the crest of the range furnish excellent marten, and some fisher. The skunk, here, finds plenty to occupy his busy little mind. This is the home of the snowshoe rabbit and weasel, which like the Arctic hare of the north, turns pure white in winter, to resemble more closely the snow in which he lives. Bob-cats, or lynx cats, are among the most abundant fur bearers of the region, and hundreds of the "kittens," as the trappers call them, are taken each year.

Among the larger predatory animals, wolves still range as scattered individuals or small packs through the high mountains, and cougar are widely, though sparingly, scattered throughout the region. Both of these are a serious menace to the game of the region, destroying annually many deer and elk. Bear may be said to be plentiful still in certain remote sections of the high Cascades, and coyotes are of widespread and universal distribution, though by no means so abundant as in Eastern Oregon. Mink, otter, beaver and marten are rigidly protected by law; bear go unprotected, making their way as best they can, while government trappers wage continual warfare on such predatory beasts as cats, coyotes, cougar and wolves.

Hudsonian Zone

Mammals are plentiful in the high Hudsonian Zone. During a normal summer the meadows are fairly alive with Alpine chipmunks, golden-mantled ground squirrels, and gophers. The rank growth of grass, flowers, and other Alpine vegetation in the meadows harbors an abundance of meadow mice, jumping mice, white-footed mice, shrews, water-shrews, and other small, night-roving mammals which are, as a rule, overlooked by any save the most observant. One of the most interesting mammals of the high mountain regions is the cony, or pika, or Little Chief hare, as he is variously called. This little beast spends the greater part of his life beneath the lava, coming out for a short period during the summer months. He is the very soul of industry. No sooner does the snow melt than the little fellow is out looking for the first tender shoots of Alpine plants or grass. These are cut and piled in the sun to dry. As soon as the "hay" is thoroughly cured, it is carried beneath the lava ledges and stored for use during the long months of winter.

Marmots, cousins of the woodchuck, and often so called themselves, may be found in any of the large lava flows along the summit, where they forage through the summer, and spend the long months of winter in hibernation in the depths of the snow-covered lava.

ALPINE ARCTIC ZONE

In the Alpine Arctic Zone squirrels, chipmunks and a few gophers nose about in the exposed patches of earth, or a cony or a marmot may be seen whistling or listening under some ledge of lava. Occasionally other forms wander up into this higher zone, to the regions of ice and snow, often to meet a tragic end.

THE BIRDS[1]

WEST SIDE CASCADE CANADIAN ZONE

Birds will, perhaps, afford visitors to the Three Sisters more pleasure than the animals.

The bird fauna of the Cascade Canadian Zone is more typically characteristic and abundant than that of any of the other life zones of West-Central Oregon. It is the breeding home of such birds as the Mountain chikadee, Red-breasted Nuthatch, Mountain Bluebird, Oregon Jay, and varied Thrush.

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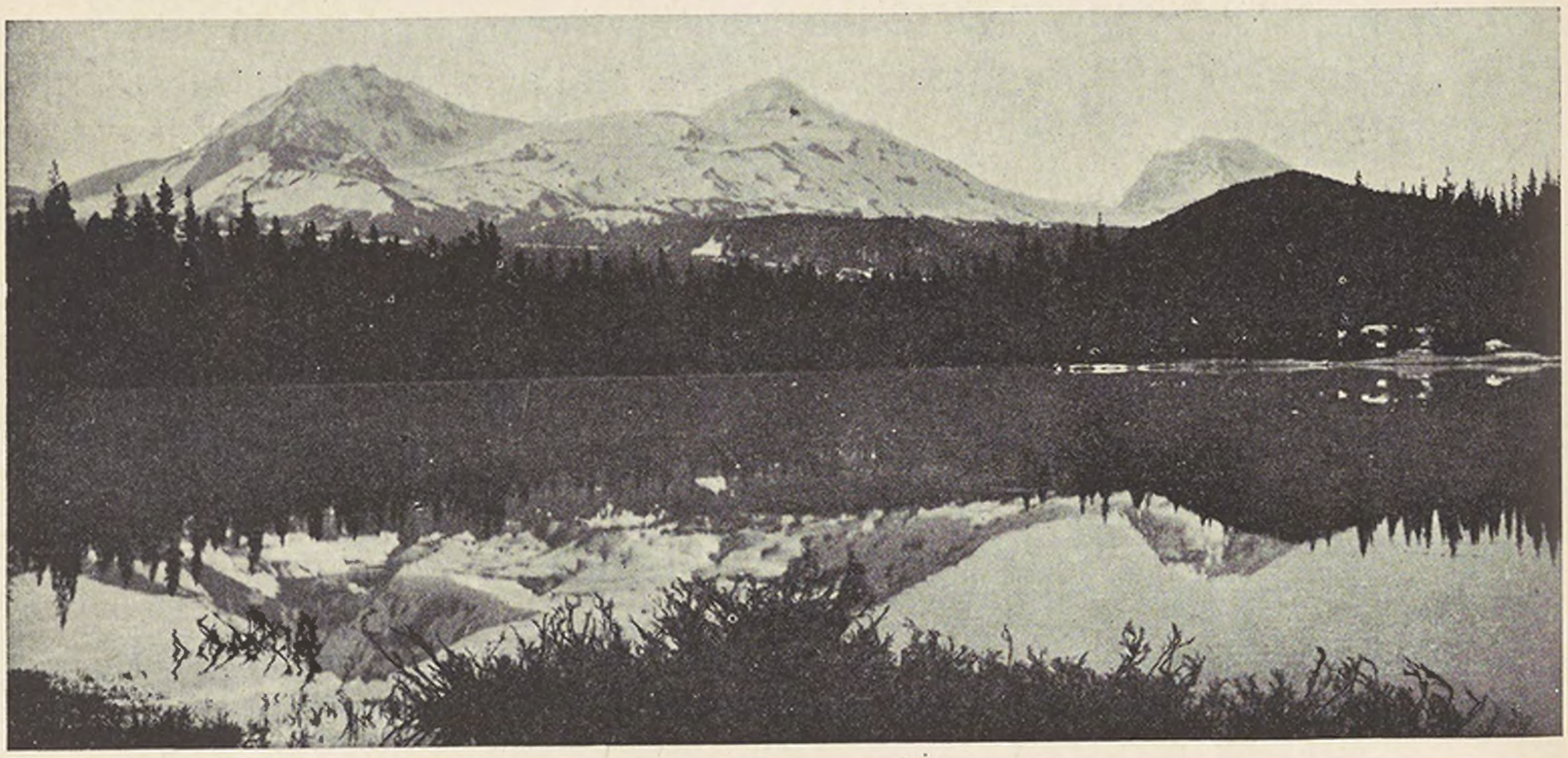
[1]No attempt at description of the bird life will be made. Visitors are advised to carry the little pocket manual "Western Bird Guide—Birds West of the Rockies and West to the Pacific" by Reed, Harvey and Brachen, or "Handbook of Birds of the Western United States" by Bailey.

This list offered as a suggestive guide, has been obtained by checking a list originally published by Shelton on the birds of Western Oregon. Those mentioned here are birds which the writer has personally observed during the examination of this area or in the country closely contiguous.



Figures 89, 90 and 91. See Footnote, Page 139.

Here large flocks of pine siskins are always on hand as they nest everywhere throughout this region, and the same may be said of the Audubon warblers, robins, chipping sparrows, and stellar jays.

All through these belts of heavy timber along the summit, woodpeckers of various species are more or less plentiful. SIERRA *Woodpecker* (*Dryobates Villosus Oius*) is an abundant resident in all the Boreal zones of the Cascades and is recorded breeding commonly in Canadian and Hudsonian zones from the Three Sisters Mountains and Diamond Peak regions. In the winter it ranges lower into Normal Transition in forests of western slopes of Cascades. The HARRIS *Woodpecker* (*Dryobates Villosus Harrisi*) is found fairly abundantly on the lower slopes of the Three Sisters. The NORTHERN RED-BREASTED SAPSUCKER (*Sphyrapicus Ruber Notkensis*) may be found in some numbers on the lower slopes of the Three Sisters within the Cascadian Zone. The RED-SHAFTED FLICKER (*Colaptes Cafer Collaris*) may be found on the lower slopes of the Three Sisters within the Cascadian Zone. The OLIVE-SIDED FLYCATCHER *(Nuttalornis Borealis)* is found along the summit.

The OREGON JAY (*Perisoreus Obscurus Obscurus*) is an abundant resident breeding commonly throughout Boreal and higher Transition zones aong the Cascades, especially from the lower Hudsonian down through the Cascadian Zone. On bright sunny days, Oregon Jays, "camp robbers," "whiskey jacks," or "summit birds," as they are variously known, are the most characteristic birds of the summit, and their local name of "summit bird" is indeed appropriate. They come foraging around camp to pilfer and to steal, or honestly search for discarded scraps from the commissary. They are the first to discover camp, and in their greed for plunder will often enter the tents and pilfer from every nook and corner. One occasionally mounts to the topmost spray of some tall tree and favors those who were so fortunate as to hear him with a burst of melody surpassed by none save possibly the water ouzel. In the winter months, when snow lies deep

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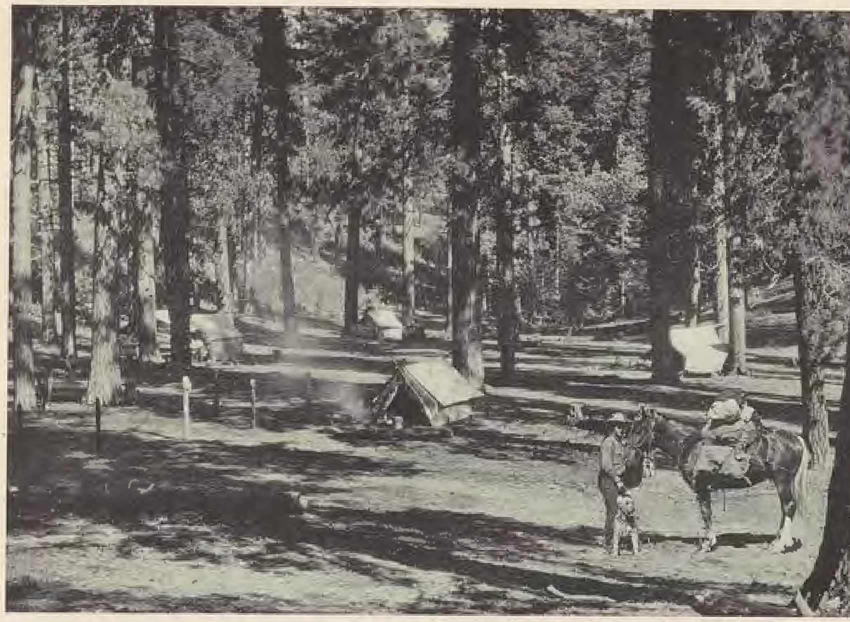
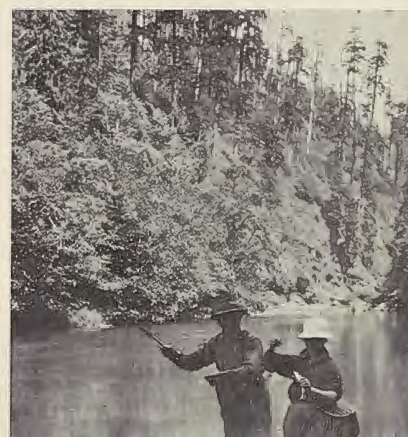
Figures 89, 90 and 9-. (89—U. S. F. S.) Looking south. Linton Creek drops over the edge of the first bench at about the edge of the shadow. Linton Lake results from Jerry Flow dam upon which the man is standing, escaping only beneath the flow. (90) Scott Lake, one of the fishing lakes around the Three Sisters. (91) Climbing a glacier.





Figures 92, 93 and 94. See Footnote, Page 141.

over all this summit country, these birds become a source of endless trouble to the high mountain trappers, robbing the bait from the trap sets, and often springing the traps. At this season of the year, driven by hunger, they become very gentle, and will eat crumbs from the hand of anyone who will feed them.

The CLARKE NUTCRACKER (*Nucfraga Columbiana*) is resident and breeds in the higher Boreal zones of the Cascades from the lower edge, rarely lower, of the Canadian Zone to the timberline, especially where the hemlock forests and white-bark pines form the Hudsonian Zones. The Clarke Nutcrackers are among the largest of the mountain birds, conspicuous by their noisy calls, and the striking black and white plumage of their wings. Because they feed on the soft green cones of the white-bark pines, the gray feathers of their heads and throats are often stained a brilliant purple by the sap from the cones.

The WESTERN EVENING GROSBECK (*Hesperiphona Vespertina Montana*) is apparently confined in summer to scattered individuals and small flocks in the higher Transition and Boreal Zones, where it doubtless breeds.

The CASSIN PURPLE FINCH (*Carpodacus Cassini*) is a fairly abundant summer visitant to Boreal Zones (especially Canadian) of the Cascades, and is recorded from the Three Sisters and from the east slopes in the Canadian Zone between Diamond Peak and Crescent Lake.

The SIERRA CROSSBILL *(Loxia Curvirostra Bendirei)* is fairly numerous in summer, breeding in Boreal Zones of the higher Cascades. It is found especially abundant in the Canadian Zone in the vicinity of the Three Sisters. The flocks of Crossbills feed in the hemlocks, and white-bark pines, wrenching the seeds from the cones with their peculiar crossed mandibles, which nature has so admirably adapted to this purpose.

The PINE SISKIN (*Spinus Pinus Pinus*) is very common in summer in Cascade Canadian or Boreal Zones, where it

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Figures 92, 93 and 94. (92) A forest camp on the west side of the Sisters. (93) Snow sports in winter or summer. (94) Speckled beauties at home.

breeds in abundance, especially from the lower Hudsonian down through the Canadian.

The WESTERN CHIPPING SPARROW (*Spizella Passerina Arizone*) is an ubiquitous summer visitant. It is very common through all zones from Coast to Boreal during the summer months, especially from lower Hudsonian down through the pine and fir forests of the Cascadian.

The OREGON JUNCO (*Junco Hyemalis Oreganus*) in summer is found in the Canadian and Hudsonian Zones of the high Cascades, breeding most plentifully throughout the latter region.

The SLATE-COLORED FOX SPARROW (*Passerella Illiaca Schistacea*) is a rare bird found breeding in the Boreal Zones, high Canadian of the Cascades, and at the base of Diamond Peak.

The MOUNTAIN BLUEBIRD (*Sialia Curro*) is an abundant summer visitant of Boreal Zones along the Cascades. It breeds somewhat commonly in Canadian and Hudsonian.

The GREEN-TAILED TOWHEE (*Oreospiza Chlorural*) is also found in the upper Normal Transition (to lower edge of Canadian) on the slopes west of the western base of the Three Sisters.

The RED-BREASTED NUTHATCH (*Sitta Canadensis*) is a resident throughout all zones from the Coast to upper Boreal in the Cascades, especially from lower Hudsonian down through Canadian.

The AUDUBON WARBLER (*Dendroica Auduboni Auduboni)* is an abundant resident, breeding at suitable localities from the coast up through Boreal Zones of the Cascades, and from lower edge of Hudsonian down through great belt of pines and fir of Canadian.

The GOLDEN PILEOLATED WARBLER (*Wilsonia Pusilla Chryseola*) is fairly plentiful in summer in the Canadian Zone of the Cascades between Diamond Peak and Crescent Lake. It is recorded from the Coast to the Boreal Zones of the Cascades.

The WESTERN PIPIT (*Anthus Rubescenes*) is recorded in early fall migration (September) in Boreal Zones in the Cascades at the north base of Three Sisters Mountains.

The MOUNTAIN CHICKADEE (*Penthestes Gambeli Gamboni)* is an abundant resident, breeding at suitable localities extreme upper edge of the Normal Transition, in the high Cascades. It is resident, and doubtless ranges into lower zones in severe winters from lower Hudsonian down through Cascadian.

The WESTERN RUBY-CROWNED KINGLET (*Regulus Calendual Cineraceus*) breeds somewhat sparingly in Boreal Zones of the high Cascades, especially in Canadian Zone in the vicinity of Diamond Peak and Cowhorn Mountain.

The TOWNSEND SOLITAIRE *(Myadestes Townsendi)* is found breeding in Boreal Zones in the vicinity of Diamond Peak. The hemlock white pine are the true home of the Townsend Solitaire, most beautiful songster, and yet possible the least known of the West. From some lofty tree or tall dead snag in the wild fastnesses of his mountain home, he pours forth his wondrous song where there are but few to hear.

The SIERRA HERMIT THRUSH (*Hylocichla Guttata Sequoiensis*) is rarely found in the Canadian Zones along the summit in the vicinity of Diamond Peak, Cowhorn Mountain, and Crescent Lake, and in the Boreal and higher Transition Zones in the region of the Three Sisters. Hermit Thrushes are wild and shy and rarely seen, though present, for they seek seclusion in the deep ravines and heavy forests.

The WESTERN ROBIN *(Lanesticus Migratorious Propinquus*) is a very numerous resident. It breeds through all zones from the Coast through Boreal in the high Cascades. In winter, it is of irregular and erratic abundance everywhere below the heavy snows of the higher Cascades.

The VARIED THRUSH or ALASKA ROBIN *(Ixoreus Naevius*) is a resident and breeds sparingly in the upper Normal Transition on the western slopes of the Cascades, and in the Boreal Zones along the summit. Most of these birds, which come south in such vast numbers during the winter, return north in spring to nest, but a few remain with us and these seek seclusion in the deeper recesses of sombre forests of the higher mountains. Here they may be found feeding their young in some bright sunny meadow, or calling out in their shrill mysterious tones from some deep ravine.

Game birds are rare at these high altitudes. Mountain quail seldom range above the jack-pine Canadian belt, and the same is true of the ruffed grouse, or native pheasant.

EAST SIDE CASCADE CANADIAN ZONE

The WHITE-HEADED WOODPECKER (*Xenopicus Albolarvatus*) breeds in the yellow pine forests of Arid Transition on the eastern slopes of the Cascades.

The TRAIL FLYCATCHER *(Empidonax Trailli Trailli)* is found breeding in some abundance in the Canadian Zone on the east slope of Cascades between Diamond Peak and Crescent Lake.

The Cassis Purple Finch (Carpodacus Cassini) and the Hammond Flycatcher (Empidonax Hammondi) have been described above.

HUDSONIAN ZONE

The typical breeding birds of the Hudsonian Zone are the Clarke Nutcracker (see Cascade Candian Zone) and the Arctic and Alpine Three-Toe Woodpeckers.

The TURKEY VULTURE (*Catharthes Aura Septentrionlis*) is a resident and breeds in suitable localities throughout west central Oregon and in the Normal Transition of the McKenzie Villey. It is widely distributed through all the zones, except possibly the higher Boreal, where it now and then may be seen circling slowly high overhead.

SOOTY GROUSE, BLUE GROUSE, or HOOTERS (*Dendragapus Obscurus Fuliginosus*) may be very abundant along the summit at certain seasons of the year.

WESTERN GOSHAWK (*Astur Astricapillus Striatulus*) is confined to the Boreal Zone along the higher ridges of the Cascades in the summer.

WESTERN RED-TAILED HAWK (*Buteo Borealis Calurus*) is an abundant resident and often seen throughout all zones from Coast to Boreal as they wheel and circle high in the air in search of prey.

The PACIFIC NIGHTHAWK (*Chordeiles Virginianus Hesperis*) may be seen sailing and swooping back and forth over the meadows, in their endless quest of insect prey in the dusk of evening.

RUFOUS HUMMINGBIRD (*Selasphorus Rufus*) ranges up the mountain sides to the limit of trees, and may often be seen over glacier and snowfield far above timberline. The commonest one is the rufous hummingbird, though the CALLIOPE HUMMER (*Stettula Calliope*), a typical high mountain Alpine bird, found at many points along the crest of the Cascades, may be seen in the Three Sisters regions.

The ARCTIC THREE-TOED WOODPECKER (*Picoides Articus*) and the ALPINE THREE-TOED WOODPECKER (*Picoides Americanus Dorsalis*) both breed in the Boreal Zones along the summits of the Cascades and are recorded from the lower edge of the Hudsonian on the Three Sisters.

The NORTHERN PILEATED WOODPECKER or COCK-OF-THE-WOODS *(Phloeotomus Pileatus Abieticola)* is a fairly common resident from the humid Coast Transition up at least through Cascade Canadian, being most abundant in the Normal Transition on the lower western slopes of the Cascades. It breeds through Humid and Normal Transition throughout fall and winter. Stragglers remain throughout the early spring. This large flame-crested pileated woodpecker is very rarely seen in the Three Sisters Country.

The WILLIAMSON SAPSUCKER (*Sphyrapicus Thyroideus*) is recorded from Boreal Zones in the high Cascades near the Three Sisters Mountains, and a few may be found in the timber on the higher slopes.[1]

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[1]In addition to the above birds certain birds common to both the Hudsonian and Cascade Canadian Zones (and described under the latter may be found. They are:

Sierra Woopecker (Dryobatus Villosus Ornis).
Oregon Jay (Perisoeus Obscurus Obscurus).
Pine Siskin (Spinus Pinus Pinus).
Oregon Junco (Junco Hyemalis Oreganus).
Mountain Bluebird (Sialia Currocoides).
Red-breasted Nuthatch (Sitta Canadensis).
Mountain Chickadee (Penthestes Gambeli Gambeli).
Audubon Warbler (Dendroica Auduboni Auduboni).

ARCTIC ALPINE ZONE

The Alpine Arctic fields of snow and ice are inhabited by but a single bird, the HEPBURN ROSY FINCH (*Leucosticte Tephrocotis Littoralis*) though others may be seen there at times. In the ledges of lava, jutting from the snow fields far above the timber line, this bird makes its home. It wanders widely through eastern Oregon in winter, but only on the Middle Sister in the lava ledges near the summit has it ever been found nesting in this state. (Shelton 1914 and again in the summer of 1917). One was in a lava ledge near the extreme summit of the Middle Sister, and another was watched as it flitted in an out of crack and cranny in the edge of a big crevasse, near the upper end of the Collier glacier. This bird is doubtless to be found at other points at a corresponding altitude, but so far authentic summer records from other arctic regions in Oregon are lacking.

In the summer a few species of birds wander up into the snowpeaks of the Alpine Arctic from the forested slopes below. The WHITE-CROWNED SPARROW (*Uonotrichia Leucophrys Leucophrys*) is noted sparingly in high Cascade Canadian along the summit just north of the Three Sisters Mountains where the fortunate may find one along the lava ledges of the higher ridges or at the edges of the meadows.

BIRDS OF GENERAL RANGE

The following birds have a less restricted range, but seek the high and cool Alpine-Arctic, Hudsonian, Cascade Canadian, the zones of the Arctic and semi-Arctic regions of far northern latitudes, and the higher snow-capped peaks and summit country of our Cascade range at high altitudes, in southern latitudes:

The BALD EAGLE (*Haliaeetus Leucocephalus Leucocephalus*) breeds at suitable points along the Coast, and sparingly around the Boreal lakes along the Cascades. In winter it is irregularly distributed throughout West-Central Oregon at large.

The HAMMOND FLYCATCHER (*Empidonax Hammondi*) is found in the lower Boreal along the west slopes of the Cascades and on the east slope of the Cascades between Diamond Peak and Crescent Lake.

The BREWER BLACKBIRD (*Euphagus Cyancephalus*) is a very common resident, from the Coast to lower Boreal on the western slopes of the Cascades.

The ALASKA PINE GROSBEAK (*Pinicola Enucleator Alascensis*) is an irregular migrant to Boreal and higher Transition Zones of Cascades in vicinity of the Three Sisters in winter, and may range lower in severe winters.

The LINCOLN SPARROW (*Melospiz, Lincolni Lincolni*) is recorded breeding in Boreal Zones of the Cascades in the vicinity of Diamond Peak and Crescent Lake.

The WESTERN TANAGER (*Piranga Ludoviciana*) is an abundant summer guest in forested areas from the Coast to the Boreal Zones of the higher Cascades.

The TREE SWALLOW (*Iridoprocne Bicolar*) is an abundant summer tourist and breeds throughout its range from the Coast to the Boreal Zones of the higher Cascades.

The CHESTNUT-BACKED CHICKADEE (*Penthestes Rufescenus Rufescenes*) is a very abundant resident where it ranges through all zones from the Coast to the Boreal in the high Cascades.

The WESTERN GOLDEN-CROWNED KINGLET (*Regulus Satrapa Olivaceus*) is an abundant dweller where it commonly breeds in the high Cascades.

RARE BIRDS

These birds may be found:

The MOUNTAIN QUAIL (*Oreortyx Picta Picta*).

The GOLDEN EAGLE (*Aquila Chrysaetos*) is reported of irregular occurrence throughout westc entral Oregon.

The GREAT GRAY OWL (*Scotiapter Nebulosa Nebulosa*),

The WESTERN BELTED KINGFISHER (*Ceryle Alcyon Caurina*).

The WESTERN FLYCATCHER (*Empidonax Difficilis Difficilis*).

The WRIGHT FLYCATCHER (*Empidonax Wrighti*) is found breeding in some abundance in the Canadian Zone along the summit between Diamond Peak and Crescent Lake.

The COAST JAY (*Cyanocitta Stelleri Carbonacea*) is probably most plentiful on the heavily forested slopes of the Cascades.

The SHARP-SHINNED HAWK (*Accipiter Velox*Q is resident and breeds throughout West-Central Oregon from the Coast to the Cascades, in winter probably not ranging higher than the lower edge of the Canadian.

The COOPER HAWK (*Accipter Cooperi*) is an abundant resident and breeds throughout all sections of West-Central Oregon. Cooper and sharp-shinned hawks may often be encountered among the heavy timber near the Three Sisters where they are a source of constant terror to the smaller birds.

The DUSKY HORNED OWL *(Bubo Virginianus Saturatus)*, the largest of the tribe and found everywhere in the mountains, is a resident throughout West-Central Oregon from the Coast up at least to the lower edge of Cascade Canadian.

Accessibility

The Three Sisters is one of the most accessible of the regions of natural wonder, scenic beauty, and delightful playground opportunities in the United States. Four transcontinental railway lines, the Union Pacific, the Northern Pacific, and the Great Northern railroads terminate at the city of Bend. On the west the Oregon Electric, a subsidiary of the Great Northern, reaches Eugene and the north and south main line of the Southern Pacific passes through Eugene. From Eugene an excellent macadamized road, passing through Springfield, extends for 77 miles through beautiful forests and along the picturesque McKenzie River to Frog Camp.

MILEAGE TABLE OF THE U. S. NATIONAL FOREST SERVICE

From	To	Road Miles	Trail Miles
Eugene	McKenzie Bridge	56	....
McKenzie Bridge	Castle Rock	1	4
" "	McKenzie Bridge Homesite Tracts	1	....
" "	Belknap Springs Resort	6	....
" "	Linton Lake and Falls	14½	2½
" "	Scott Lake	21	....
" "	Lava Fields	22	....
" "	Obsidian Cliffs	18	4
" "	Three Sisters	17	8
" "	Foley Springs Resort	4½	....
" "	Horse Lake	4	18
" "	Elk Lake	5	22
" "	Horsepasture Mountain		9
" "	Town of Sisters	40	....
" "	Clear Lake	6	22
Bend	Sisters	26	....
"	McKenzie Road Summit	42	....
"	Broken Top	50	....

From the east, on the recently completed McKenzie Highway, Frog Camp is 45 miles from Bend. One may also reach this area via the Century Drive from Bend to Spark's Lake, just outside the southern limits of the map. The Pacific Highway, extending from British Columbia to Mexico, the main line of motor car traffic along the Pacific Coast, passes through Eugene. Just east of the Cascade Mountains, there is another north and south line from California to Washington, which passes through Bend. Tourists crossing the continent by way of the Yellowstone Route or the Salt Lake Route may reach this area over good highways which, passing through Bend, extend over the McKenzie Pass at the Three Sisters and continue on to Eugene. The McKenzie Highway is kept open during the winter so that winter sports in this area are available the year around.

Acknowledgments

The author of this book wishes to express his deep appreciation to many people without whose valuable aid and kind assistance its publication would have been impossible.

First, the author is deeply indebted to the members of his party: Don Fraser, Morrison Miller, Ralph Tuck, Gene Goodrich, Alex Shipe, Reuben Young, Don Zimmerman, and Howard Powers, whose loyal and efficient field service made it possible to gather the large amount of data necessary to the preparation of the map and to the writing of the book.

To the University of Oregon and the Research Committee of that institution, the author is indebted for assistance and finance for field and laboratory work.

Much of the manuscript has been gone over critically by various authorities and the confidence the author has in placing it before the public rests in a large part upon the high opinion which he holds for their advice. Among those who should receive particular credit are: Professor Lewis Henderson and Professor A. R. Sweetser, who have examined the botanical portion; Dean John Bovard, who has examined the biological portion; Mr. Lewis A. McArthur, Oregon representative of the National Geographic Board, who has criticized the map, and Professor E. L. Packard and Professor W. D. Smith, who have examined the geological portion of the manuscript.

Work in the field and subsequent preparation of the report would not have been possible without the valuable co-operation of Mr. N. F. Macduff, supervisor of the Cascade National Forest. In addition, the North Pacific District of the Forestry Service of the United States Department of Agriculture has furnished every possible aid. Of these Mr. C. M. Granger, District Forester, and Mr. C. J. Buck have given valuable co-operation. Many beautiful photographs, indicated by "U. S. F. S.," were taken by Mr. F. M. Cleator of the United States Forestry Service. Mr. A. H. Hodgson and Mr. Victor H. Flack have rendered valuable assistance in particular in regard to the topographic map.

Valuable data has been obtained from the pages of the Mazamas' Annual. The Mazamas, because of the great interest in this region, have visited it on three different occasions—1903, 1910 and 1916.

The publication of this manuscript has been made possible by a generous gift to the University by the Eugene Chamber of Commerce. Because of this the author is indebted to Mr. Frank Chambers, president of the Eugene Chamber of Commerce, and to a Chamber of Commerce Committee, whereon Mr. L. L. Ray, chairman, and Mr. Joseph Koke have given unstinted service.

The final publication of the book is due to the valuable assistance of the Publication Committee of the University of Oregon, of which Dean Eric W. Allen is chairman, and to the assistance of Professor Robert C. Hall, who served thereon.

There is a rather extensive literature bearing on the Oregon Cascades. A careful examination of this has shown that it consists almost entirely of popular descriptions of scenery. Only the following references contain any information of importance bearing directly upon the geology of the Three Sisters region:

Mazama Annuals of 1903, 1910 and 1916, published by the Mazamas, Portland, Oregon.

Salient Features of Oregon Geology, W. D. Smith and E. L. Packard, Journal of Geology, Vol. XXVII No. 2, Feb.-March, 1919.

Forest Conditions in the Cascade Range, Forest Reserve, Oregon House Document 217, Vol. 69, Professional Paper No. 9, by Langille, Plumer, Rixon and Leiberg.

Some Little Known Scenic Pleasure Places in the Cascade Range of Oregon, Oregon Bureau of Mines, Vol II, No. 1, 1916, Ira Abraham Williams.

A Distributional List of Land Birds of West Central Oregon, University of Oregon Bulletin, New Series, Jan., 1917, Vol. XIV, No. 4, Alfred C. Shelton.

Report on Exploration for a Railroad from the Mississippi to Pacific Coast, House Document, 1857, J. S. Newberry.

A bibliography of other literature referring to the Oregon Cascades is given in Appendix D.

APPENDIX A.

PRINCIPAL DIVISIONS OF GEOLOGIC TIME (a)
AFTER UNITED STATES GEOLOGICAL SURVEY (b)

Era	Period	Epoch.	Characteristic Life	Duration, according to various estimates
Cenozoic (recent life.	Quaternary.	Recent. Pleistocene (Great Ice Age).	"Age of man." Animals and plants of modern types.	Millions of years. (d) 1 to 10
	Tertiary	Pliocene. Miocene. Oligocene. Eocene.	"Age of mammals." Possible first appearance of man. Rise and development of highest orders of plants.	
Mesozoic (intermediate life).	Cretaceous.	(c)	"Age of reptiles." Rise and culmination of huge land reptiles (dinosaurs), of shell-fish with complexly partitioned and coiled shells (ammonites), and of great flying reptiles. First appearance (in Jurassic) of birds and mammals; of cycads, an order of palmlike plants (in Triassic); and of angiospermous plants, among which are palms and hardwood trees (in Cretaceous).	10 to 20
	Jurassic.	(c)		
	Triassic.	(c)		
Paleozoic (old life).	Carboniferous.	Permian. Pennsylvanian. Mississippian.	"Age of amphibians." Dominance of club mosses (lycopods) and plants of horsetail and fern types. Primitive flowering plants and earliest cone-bearing trees. Beginnings of backboned land animals (land vertebrates). Insects. Animals with nautilus-like coiled shells (ammonites) and sharks abundant.	20 to 50
	Devonian.	(c)	"Age of fishes." Shellfish (mollusks) also abundant. Rise of amphibians and land plants.	
	Silurian	(c)	Shell-forming sea animals dominant, especially those related to the nautilus (cephalopods). Rise and culmination of the marine animals sometimes known as sea lilies (crinoids) and of giant scorpion-like crustaceans (eurypterids). Rise of fishes and reef-building corals.	
	Ordovician.	(c)	Shell-forming sea animals, especially cephalopods and mollusk-like brachiopods, abundant. Culmination of buglike marine crustaceans known as tribolites. First trace of insect life.	
	Cahmbrian.	(c)	Trilobites and brachipods most characteristic animals. Seaweeds (algae) abundant. No trace of land animals found.	
Proterozoic (primordial life).	Algonkian.	(c)	First life that has left distinct record. Crustaceans, brachiopods, and seaweeds.	
	Archean.	Crystalline rocks.	No fossils found.	50+

(a) The geologic record consists mainly of sedimentary beds—beds deposited in water. Over large areas long periods of uplift and erosion intervened between periods of deposition. Every such interuption in deposition in any area produces there what geologists term an unconformity. Many of the time divisions shown above are separated by such unconformities—that is, the dividing lines in the table represent local or widespread uplifts of the earth's surface.

(b) Bulletin 612 U. S. Geological Survey.

(c) Epoch names omitted; in less common use than those given.

(d) These figures are conservative. Many authorities lengthen them considerably, giving a total of nearly a billion years for the age of the earth.

APPENDIX B.

Origin of Names on the Topographic Map of Three Sisters Region.

Abernethy Island, after George Abernethy, first governor of Oregon, June 3, 1845.

Ahalapam, see pags 53.

Alder Creek, source unknown, an old name.

Bear Creek, an old name.

Belknap Crater, an old name after Belknap, an early settler.

Bend Glacier, named after the town of Bend.

Benson Lake, an old name, source unknown.

Big Island, named by United States Forest Service.

Black Crater, an old name, given in reference to the appearance of this striking volcano.

Black Hump, a descriptive name.

Broken Top, an old descriptive name, source unknown.

Camp Riley, the name of Frank Branch Riley, one of the leaders of the Mazama camps.

Carver Glacier, see page 81.

Cayuse Crater, name given because in every area at least one topographic feature should be called Cayuse.

Chambers Lakes, see page 82.

Chief Joseph Island, see page 100.

Cinder Cone, an old descriptive name of this cone.

Cirque Rock, a name given in reference to the appearance and origin of this outstanding feature.

Clark Glacier, see page 83.

Collier Glacier, see page 72.

Condon Butte, after Professor Thomas Condon, an early preacher, scientist and evolutionist.

Craig Lake, after John T. Craig, who froze to death in his cabin in the winter of 1878 while in pursuance of his duty in carrying the mails across the pass. Craig was also one of the original founders of the toll road.

Crook Glacier, see page 83.

Devil's Hill, an old figurative name, source unknown.

Diller Glacier, an old name after J. S. Diller, a United States geologist who contributed extensively to the interpretation of Oregon geology.

Eugene Glacier, see page 81.

Fall Creek, an old descriptive name in reference to the many falls on this creek, source unknown.

Frog Camp, named by the Mazamas.

Green Lakes, an old descriptive name, source unknown.

Hand Lake, an old name, source unknown.

Harlow, see page 112.

Hayden Glacier, named after F. V. Hayden, pioneer geologist and explorer of the West.

Honey Creek, an old name, source unknown.

Huckleberry Butte, an old name, source unknown.

Indian Camp, name given by Cleator of U. S. F. S. to an obsidian locality where the Indians manufactured arrow heads and other implements.

Irving Glacier, after Washington Irving, who wrote "Astoria" in 1836 and "The Adventure of Captain Bonneville" in 1837, which writings brought the Oregon country to the attention of the people in the Eastern states.

Lane Plateau, named after Joseph Lane, who as a reward for his valiant work in the Mexican war was made territorial governor of

Oregon April 3, 1892, later provisional governor and afterwards senator. He was also a candidate for the vice-presidency of the United States.

Lava Camp, source unknown.

Le Conte Craters, see page 55.

Lewis Glacier, see page 83.

Linn Glacier, see page 75.

Linton Creek, name given in 1924 by Forest Service to replace name of Lost Creek.

Linton Lake, name given in 1924 by Forest Service to replace name of Lost Lake.

Little Brother, a name probably assigned by the Mazamas.

Lost Creek Glacier, see page 82.

Lotta, see page 112.

Matthieu Lakes, see page 112.

McArthur Hill, see page 117.

McKenzie, an old name, probably after McKenzie of the Hudson Bay company.

Mesa Creek, named after Rock Mesa, where it heads.

Millican, see page 112.

Mount Multnomah, see page 12.

Moraine Lake, a genetic name given by Cleator.

North Sister, an old name, source unknown.

Obsidian Cliff, an old name given in reference to the rock which composes the cliff.

Park Creek, an old name, source unknown.

Pole Bridge, an old name, source unknown.

Pole Creek, an old name, source unknown.

Prouty Glacier, given by the Mazamas in honor of Mr. H. H. Prouty, one of the most zealous and successful mountain climbers of his day.

Proxy Creek, an old name, source unknown.

Renfrew Glacier, an old name, after P. C. Renfrew, one of the incorporators of the McKenzie Toll Road.

Rock Mesa, a descriptive name of a mesa-like, vitrophyric volcano.

Scott Lake, after Felix Scott, Jr.

Scott Mountain, see page 110.

Scott Trail, after Feliz Scott, Jr.

Separation Creek, an old name,, source unknown.

Simm's Butte, an old name.

Skinner Glacier, see page 81.

Skyline Trail, name of some years standing, given by the U. S. F. S. to the trail which extends from Mount Hood along the Skyline to Crater Lake.

Soap Creek, an old name, in reference to the white silt which characterizes its water.

Soda Creek, an old name in reference to the alkali character of its water.

South Sister, old figurative name.

Sphinx Creek and *Sphinx*, old figurative names, source unknown.

Squaw Creek, old name, source unknown.

Thayer Glacier, see page 75.

Trout Creek, source unknown.

Twin Craters, named by F. M. Cleator of the U. S. F. S.

Villard Glacier, see page 75.

White Branch, see page 113.

Wickiup Plain, named by Cleator.

Winthrop Island, after Theodore Winthrop who wrote "The Canoe and the Saddle," a book which called attention to the state of Oregon.

Yapoah Crater, see page 53.

APPENDIX C.

GLOSSARY

aa—very rough surface of a lava flow.

agglomerate—a rock containing volcanic boulders and pebbles of all sizes and shapes, formed by mud flowing down a mountain and enclosing all the lose rock in its path or by the accumulation of these materials upon a surface direct by volcanic shower.

alluvium—a soil and sand formed in a stream or lake bed.

alluvial fan—the outspread sloping deposit of bowlders, gravel, and sand left by a stream where it passes from a gorge out upon a plain.

annular stream—stream flowing around a circumference.

aretes—see page 66.

apophyses—see page 29.

basalt—a common fine grained lava rock, usually black or dark gray, containing much calcium, magnesium and iron and the minerals plagioclase and olivine.

basic—containing calcium and magnesium in excess and low in silica, sodium and potassium.

bench—a comparatively narrow strip of level land on the side of a hill. The down hill edge of the bench is usually a cliff.

bergschrund—see page 64.

biotite—a variety of mica (isinglass) containing much iron and little potassium. It is black or dark brown in color.

bomb—a rounded mass of lava thrown in the air while liquid which is rounded and solidified while falling through the air. Often they are are pear or gourd shaped.

breccia—a mass of naturally cemented angular rock fragments.

caldera—the bowl-shaped top of a beheaded volcano. It is the depression found by the top being blown off or engulfed within the center of the volcano.

capture—the process whereby a swiftly cutting stream cuts through a divide and steals the water from a nearby stream. This is called stream capture or stream piracy.

cirque—the cup-shaped valley at the upper end of a glacier. The sides are always very steep cliffs. See page 64.

col—See page 66. A pass between adjacent peaks in a mountain range.

conglomerate—a rock composed of gravel and boulders formed either in river beds or near the shore of lakes or ocean.

consequent stream—a stream whose course is determined by the slope of the original surface. The stream flows directly down the greatest slope.

delta deposits—deposits of mud and sand formed at the mouth of a stream where the current is so retarded that the river can no longer carry the mud and sand in suspension.

dike—a "wall-like" mass of igenous rock which has solidified in a wide crack in the earth's crust.

dip—the slope of a rock layer expressed by the angle which the top of the layer makes with a horizontal plane.

dissected—cut by erosion into hills and valleys.

distal end—the far end of a thing.

erosion—the wearing away of materials at the earth's surface by the mechanical action of running water, waves, moving ice, or winds, which use rock fragments and grains of sands as tools and abrasives.

erratic—a boulder carried by a glacier and which is dropped a long distance from the place it was originally found.

escarpment—a steep cliff formed by a fault or other cause.

fault—a fracture in the earth's crust accompanied by movement of the rock on one side of the break past the rock on the other side.

fault block—a part of the earth's crust bounded wholly or in part by faults.
fault scarps—the cliff formed by a fault. Most fault scarps have been modified by erosion since the faulting took place.
feeding dikes—lava rock in large cracks or fissures through which the liquid lava formerly passed to the surface and issued as flows.
feldspathic—having aboundant feldspars, minerals which are light colored and contain much aluminum, silica, and alkalies, but are very low in iron and magnesium.
fauna—the animals that inhabit a certain region at a given time.
fissure—a crack or fracture in a mass of rock or a glacier.
flora—the plants that inhabit a certain region at a given time.
gneiss (pronounced nice)—a rock resembling granite, but with its mineral constituents so arranged as to produce a banded effect. Gneisses are rocks which have been changed by heat or pressure from some other original rock.
headward erosion—the process of erosion by which a stream lengthens its valley by cutting back from its source. The mouth of a stream is the oldest part of a valley, the source is always being cut back farther into the hillsides.
incised—cut in or carved as with a sharp tool.
mesa—a hill composed of bedded rocks in nearly horizontal position, usually flat on top, which stands alone and is not definitely joined to other hills nearby.
moraine—a mass of rocks and dirt piled up by a glacier. A terminal moraine is formed at the extreme end of the glacier, lateral moraines are formed along the sides, a medial moraine is formed down through the center where two glaciers have flowed together and is really the combination of two lateral moraines. Recessional moraines are terminal moraines left at different places as the ice melts back or the glacier recedes.
muscovite—a white mica which contains no iron or magnesium but is rich in potassium.
nunatak—a hill or rocky point which is formed by a glacier passing around on all sides but not over the top. It might be considered an island in the glacier.
obsidian—an acid lava which has cooled so rapidly that the minerals did not have time to crystallize. A volcanic glass. It is very hard and brittle and has a very shining appearance.
olivine monzonite—a coarse-grained igneous rock containing olivine and which is intermediate between granite and diorite.
outcrop—the exposure of bed rock at the surface.
pahoehoe—surface of a lava flow which is smooth or ropey, in contrast to the sharp, jagged surface called 'a'a.
peneplane—a land surface which has been reduced nearly to a level by erosion. Almost a plane.
peneplanation—the process of reducing to a peneplane surface.
pitchstone—a volcanic glass which differs from obsidian in that it is dull and not shinging in appearance.
pumice—volcanic glass which is full of air bubbles. It resembles a sponge and is very light, in fact it will float on water.
pyroclastc—having its origin in a volcano. "Pyro" means "fire."
recent—since historic time.
reconstructed glacier—a glacier formed from ice furnished by another glacier which precipitates it over a cliff.
roche moutonn'ees—see page 65.
sandstone—a stone formed of sand which has been cemented by silica, lime or iron oxide.
schist—a transformed rock which has been changed in such a way by pressure or heat that the rock splits easily in certain directions,

comparable to the grain in a block of wood. The minerals are all arranged in parallel positions.

scoria—lava which is full of large bubble holes.

scoriaceous—having the appearance of scoria. Full of large holes, rough surface.

shale—a rock made up of hardened layers of mud or clay.

silica—one of the components which is most important in the formation of rocks and minerals and having the chemical composition of SiO^2. More than half the bulk of the earth's crust is silica. Quartz is pure silica.

striations—scratches or grooves made by a glacier.

talus—a pile of rock fragments at the foot of a cliff.

trachyte—a lava which is light colored and contains no basic minerals or quartz. A fine grained rock composed chiefly of orthoclase with or without some dark minerals.

truncate—cut off at an angle to the longest dimension.

tuff—rock composed of layers of lava particles blown from a volcano.

vitrophyre—a volcanic glass in which there are small areas in which the

viscous—having the ability to flow but only slowly like molasses.

minerals have had time to crystallize. This gives the rock a spotted appearance.

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Topographic Map of Three Sisters

BY

EDWIN T. HODGE

Explanation of the Topographic Map

The features shown are (1) water, (blue) including lakes, rivers, glaciers, and other bodies of water; (2) relief, (brown) including mountains, hills, valleys, and other elevations and depressions; (3) culture (works of man), (black) such as roads, and boundaries.

Relief is shown by contour lines. A contour on the ground passes through points that have the same altitude. If one were to walk along a contour he would neither go uphill nor downhill but remain at a constant level. The contour lines on the map show not only the shapes of the hills, mountains and valleys but also their elevations. The line of the sea coast itself is a contour line, the datum or zero of elevation being mean sea level. The contour at, say, 20 feet above sea level would be the shore line if the sea were to rise or the land to sink 20 feet. On a gentle slope this contour is far from the present coast; on a steep slope it is near the coast. Where successive contour lines are far apart on the map they indicate a gentle slope; where they are close together they indicate a steep slope; and where they run together in one line they indicate a cliff.

The contour interval, or the vertical distance in feet between one contour and the next is 100 feet. Every fifth one is made heavier than the others and is accompanied by figures stating elevation above sea level. The heights of many points, such as road corners, summits, surfaces of lakes, and bench marks, are also given on the map in figures, which express the elevations to the nearest foot only. The horizontal scale is 1:5000, that is in walking over the surface of the ground one traverses one inch on the map. This scale is practically one mile on the ground to one inch on the map.

Persons intending to use this map in the field should have it mounted on linen.

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TOPOGRAPHIC MAP
OF
THE THREE SISTERS
OREGON
By
EDWIN T. HODGE Professor, Economic Geology, University of Oregon
Assisted by
Don Fraser, Morrison Miller, Ralph Tuck,
Gene Goodrich, Alex Shipe, Reuben Young,
Don Zimmerman, Howard Powers
Legend
Contours
Roads
Trails
Streams
Lakes
Glaciers
Existing Craters
Approximate Rim of Caldera of old Mt. Multnomah
XXXXX
SCALE IN FEET
JANUARY 1925
R.7½ E.
R.8 E.
R.7 E.
121°50'
44°10'
T 15 S
T 16 S
T 17 S
Belknap Crater 7000 U.S.F.S.
Little Belknap
Big Island
Latta Crater
Black Crater
McKenzie Pass 5200 U.S.F.S.
Lava Camp
Craig Lake
Winthrop Island
Twin Craters
Mc Kenzie Highway
Harlow Crater
Millican Crater
Scott Mtn
Hand L.
Chief Joseph Island
Matthiew Lakes
Huckleberry Butte
Abernethy Island
Pole Bridge
Scott Lake
Scott Trail
Alder Creek
Yapoah Crater
Condon Butte
Frog Camp
Simms Bu.
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