THE GEOLOGY OF THE NORTHWEST PORTION OF THE

MT. AIX QUADRANGLE, WASHINGTON

by

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INTRODUCTION

Abstract

The area under consideration comprises approximately
300 square miles on the crest and eastern slopes of the Cascade
Range immediately east of Mt. Rainier National Park. It is
predominantly a volcanic province, and is of particular interest
because it offers an unusually complete stratigraphic sequence
of Tertiary sedimentary and volcanic rocks.

The oldest rocks are sediments. They consist of
sandstones and argillites of the Puget Group with a total
exposed thickness of over 800 feet. The base of the sedimentary
series is not exposed. The sandstones are concordantly and
possibly conformably overlain by several thousand feet of

slightly to moderately altered andesitic flows, tuffs, and breccias that have previously been named lower Keechelus. In this paper the term lower Keechelus is replaced by the name Keechelus. The name upper Keechelus is eliminated entirely as explained below.

A gently eastward dipping unaltered series of andesitic flows, ash beds, volcanic breccias and tuffs unconformably overlies the Keechelus formation. These unaltered andesites were called upper Keechelus by early workers, but this terminology was discarded by Warren (28) who introduced the name Fifes Peak andesite. Warren's use of the name Fifes Peak andesite for the upper Keechelus is heartily endorsed, and his terminology is followed in this report.

The Yakima basalt flows disconformably overlie the Fifes Peak formation. The basalts are restricted to the eastern part of the area where their total thickness is approximately 500 feet.

Early Pleistocene andesitic to basaltic flows described by Smith (25) and Becraft (4) in the Tieton Valley occupy the valleys of upper Bumping River, Cougar Creek, and Cedar Creek. These flows are approximately 200 feet thick and unconformably cover the older rocks. Tumac Mountain, a post-Wisconsin cinder cone, is the most recent expression of vulcanism. The Tumac cone is unusual because it is the first post-glacial cone reported in the Washington Cascades and also because its lavas are basaltic

in composition.

An elongate body of granite and associated agmatitic[*] breccia which is intrusive into the Puget Group sandstone and the lower portions of the Keechelus formation trends northwest through the area. These granitic rocks are here given the names of Bumping Lake granite and Granite Lake breccia respectively. Other intrusive rocks, which are rather limited in extent, are Snoqualmie granodiorite, a quartz monzonite porphyry stock, and small plugs of diorite. Dacite porphyry comprises a major intrusive unit which penetrates the granitic rocks and parts of the Keechelus andesite in the form of large dikes and sills.

Metallization is all of the vein or disseminated type. Small mining ventures have been attempted; most of them were unsuccessful. Metals whose ores were identified include copper, tungsten, molybdenum, arsenic, and gold.

Alpine glaciation sharpened a pre-glacial topography of rolling upland into scenery of precipitous assymetrical slopes, cirque basins, arretes, and other associated glacial features. Three main glacial tongues flowing eastward off the Cascades Range imparted the distinctive U-shape to the valleys of American River, Bumping River, and Deep Creek.

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[*] After Wegmann--A breccia composed of dark fragments which are embedded in light-colored granitic rock.

Location

The most prominent reference point in designating the location of the Mt. Aix quadrangle is Mt. Rainier, the world-famous, 14,408 foot volcanic cone. The Mt. Aix quadrangle lies immediately to the east of Mt. Rainier National Park quadrangle and its principal feature, Mt. Rainier. The point in the Mt. Aix quadrangle that is closest to Mt. Rainier lies on the western boundary one mile south of Chinook Pass. At this place the base of the Rainier cone is approximately six and one-half airline miles to the west. The northwest portion of the Mt. Aix quadrangle constitutes the area studied in this thesis.

The northern boundary of the thesis area is latitude 47°-00' north, the southern boundary, latitude 46°-23' north. The western boundary is longitude 121°-30' west, the eastern boundary is approximately longitude 121°-10' west although the eastern line is irregular as shown on the accompanying index map.

Although most of the area is included in the northern tip of Yakima county, a few square miles on the western side are contained in corners of Lewis and Pierce counties. The entire region lies in the Snoqualmie National Forest.

From view points within the area prominent landmarks that are visible in addition to Mt. Rainier include Mt. Adams to the south, the Goat Rocks and Mt. St. Helens to the southwest, and the Mt. Stuart massif to the northeast. The eastern skyline

WASHINGTON

SEATTLE

MOUNT AIX
QUADRANGLE

SCALE

0   20   40   60   80   100

MILES
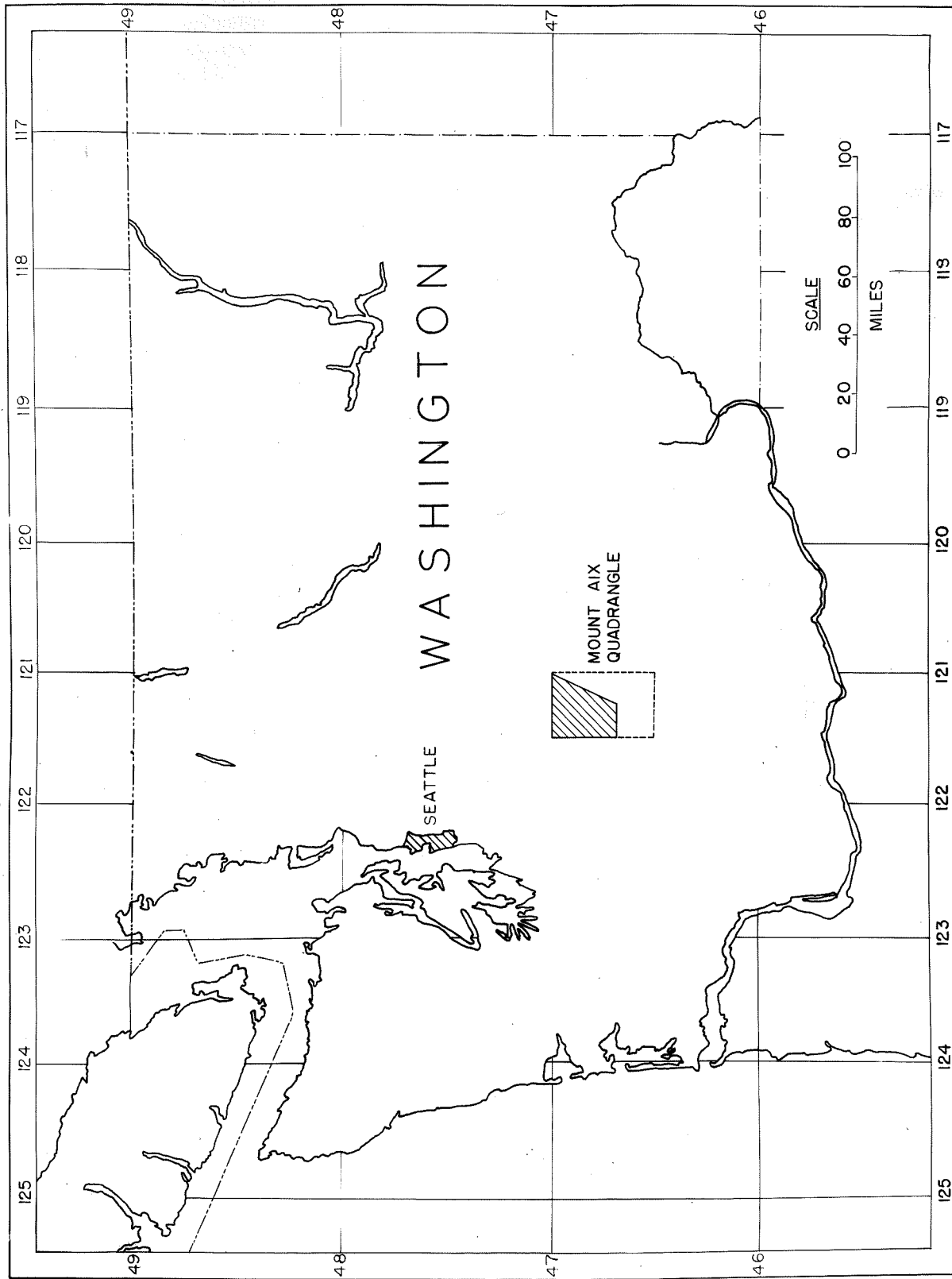
Fig. I   INDEX MAP MT. AIX AREA, WASH.

is dominated by the high, flat Columbia River basalt plateau.

Purpose and Plan

This investigation was undertaken to fulfill, in part, the requirements for the degree of Doctor of Philosophy in Geology at the University of Washington.

The principal contribution of this work is further clarification of Tertiary stratigraphy in the eastern Cascades.

It is planned to treat first the sedimentary and meta-sedimentary rocks which constitute only 5% of the total area but are very important chronologically and historically. This is the first report of Eocene sediments east of the Cascade crest. Next, the extrusive rocks, which occupy approximately 75% of the area, will be discussed. This will be followed by consideration of the intrusive rocks including possible explanations of their genesis. The intrusive rocks make up approximately 20% of the total area.

Discussion of the physiography and topography will include description of the present landscape and glacial features. A brief physiographic history of the area will also be given.

Most of the mines and prospects are abandoned. Many of the workings are completely blocked or in such condition to make entry unsafe. The area as a whole contains little

indication of untapped economic deposits. A discussion of the economic aspects will, however, be presented.

Access and Culture

A paved arterial highway, U.S. 410, which connects Enumclaw and other cities on the western side of the Cascades to Yakima on the eastern side, runs through the north central part of the area. The road crosses Chinook Pass at an elevation of 5314 feet and then descends into and follows the valley of American River eastward. From the junction of U.S. 410 and the Bumping Lake road at American River Crossing it is twelve miles along the Bumping Lake road to Bumping Lake. From the lake, unimproved and often unmaintained roads lead to the Copper City mine townsite, to Miner's Ridge, and part of the way to upper Bumping River Falls.

Newly constructed State Highway 5 from Yakima Junction on U.S. Highway 410 to Ohanapecosh follows the Tieton Valley and crosses the Cascades through White Pass at an elevation of approximately 4600 feet. This highway is three miles south of the area and provides a means of access to its southern extremities.

Within the area after leaving the roads the only routes of travel are along U.S. Forest Service foot trails, some of which are maintained and some are not.

The Great Northern Railroad and Northwest Airlines serve the city of Yakima, Washington, which is the Yakima county seat and the nearest large city. By road it is approximately sixty miles from Bumping Lake to Yakima.

The U.S. Post Office at Goose Prairie, four miles east of Bumping Lake, is the only settlement. Accommodations are available at the Double K Mountain Ranch at Goose Prairie. There are tourist cabins at American River Crossing, Goose Prairie, and Bumping Lake.

The principal industry of the region is providing services for visitors, fishermen, and hunters.

Acknowledgments

Sincere thanks are due to Dr. Howard A. Coombs and Dr. Peter Misch of the Department of Geology, University of Washington who, as members of the writer's thesis committee, offered guidance in this project and were exceedingly generous with their time, valuable criticisms, and suggestions.

Professor G. E. Goodspeed, executive officer of the Department of Geology, has afforded continuous inspiration to the writer throughout his three years of graduate study. Dr. J. Hoover Mackin suggested the Mt. Aix area for a thesis project and thanks are due to him for his interest in the writer's progress.

Every member on the staff in the Geology Department

Plate 1. Bumping Lake, looking west from the
lower slopes of Nelson's Ridge. Mt.
Rainier towers in the background above
American Ridge.

has given a full measure of his knowledge and experience. Their help and encouragement has been greatly appreciated.

For all their kindness in the writer's behalf during the field seasons, special thanks are due to Misses Patricia Kane and Kathryn Kershaw, owners of the Double K Mountain Ranch at Goose Prairie.

The polished section of the ore from the Black Jack prospect was made and photographed by Clarence A. Bloomster, mining engineering student at the University of Idaho.

Information of the flora and meteorological measurements in the Bumping Lake district was furnished by Mr. Horace G. Cooper, district ranger, of the Snoqualmie National Forest.

To my wife, Paula, goes a multitude of thanks for her patience and understanding while the writer was engaged in this work and in the academic study that preceded it. Without her encouragement and faith the project might never have reached completion.

Previous Work

One of the difficult and yet intriguing features of the northwest portion of the Mt. Aix region is that it has previously remained virtually untouched geologically. Warren (28,29) worked along the eastern margin of the Mt. Aix topographic sheet in connection with mapping the various

volcanic flows, determining the western edge of the Columbia
River basalt, and rearranging the stratigraphic sequence in
the eastern parts of the Cascades. His investigation carried
him westward in the valleys of American River and Bumping
River. Consequently, there has been some overlap with his
work in these places. The writer is in general agreement with
Warren's conclusions but some changes and additions to the
earlier study are in order.

Within most of the actual area covered in this project
no previous comprehensive geologic mapping has been done.
Geologic investigations were limited to local areas surrounding
mineral deposits. The State of Washington Department of Mines
and Geology issued a report on the Copper City mine in 1945 in
connection with a survey of tungsten resources (10). Hobbs
(18) conducted a confidential examination of the Copper City
mine for the U.S. Geological Survey during World War II. That
report is now on open file.

In the summer of 1951 the Haile Mining Company examined
the meager zinc showings in the Blackjack Mine near Twin Sisters
Lakes with negative results. Other reports have been made on
the mines and prospects within the area. However, most of them
are promotional in nature and are so misleading that discussion
of them will be short.

The quadrangles on the west, north, and east of the Mt.
Aix sheet have been mapped. These are in the order mentioned:

Mt. Rainier National Park, Coombs, (1935); Snoqualmie, Smith
and Calkins, (1906); and Ellensburg, Smith, (1901). The Mt.
Adams quadrangle to the south remains unmapped.

The only paleontological find close to the area was
made by Grant (17) who discovered the jaw of an oreodont in
Keechelus rocks on the north side of the Tieton Reservoir.
The age of the fossil was determined as Oligocene.

Field Work

Five and one-half months were spent in the field during
the summers of 1950 and 1951. The work was primarily of a
reconnaissance nature because, as stated above, little geologic
mapping of most of the area had been done previously. Heavy
forest cover, particularly in the lower elevations, constituted
an annoying obstacle that impeded progress and lessened the
accuracy of rock correlation and the location of contacts. The
field map was made, nevertheless, showing the probable rock
types that underlie the vegetation, although many times only an
occasional outcrop was visible. An outcrop map of the area
would present a picture of little significance and would be
difficult to read.

Mapping was done on 9 x 9 contact aerial photographs
which were taken by the U.S. Department of Agriculture in 1949.
Results were transferred from the photographs to the Mt. Aix
topographic map. The aerial photographs were a valuable aid in

mapping, in locating position, and in showing outcrops in forested areas that otherwise would never be found.

Topography and Climate

The general trend of the Cascade Range in the Mt. Aix region is north-south. The eastern side of the Range is cut up into high, transverse, east-west ridges that form divides between the eastward flowing streams.

Mt. Aix, a matterhorn peak, lies on one of these transverse ridges. It is the highest point in the area reaching an elevation of 7,805 feet. The lowest point with an elevation of 2,800 feet, is in the American River gorge below its confluence with Bumping River. Total relief is approximately 5,000 feet.

All slopes are steep to precipitous. Alpine glaciation produced an exceedingly jagged landscape particularly on the north-facing slopes. Most of the landforms are in a mature stage of development, relief at the present time being at a maximum.

Carleton Pass crosses the Cascade crest at an elevation of 4,100 feet. This is the lowest pass across the Cascades in the region. Chinook Pass and White Pass are 5,314 and 4,600 feet respectively.

The valleys of American River and Bumping River are fairly wide and flat-bottomed. The average gradient for the two streams is approximately 75 feet per mile except near the headwaters of American River where the gradient is much higher.

Small tributary streams usually have very steep gradients.

Hundreds of lakes formed directly or indirectly by glaciation add to the scenic beauty of the region. The largest body of water is Bumping Lake, a natural lake that is now controlled by a U.S. Bureau of Reclamation dam at its east end. Bumping Lake is three miles long, three-fifths of a mile across at its widest point, and reaches a depth of 90 feet.

The only area of low relief in the region is a high plateau in the southern part. The plateau is in a youthful stage of dissection. Its monotony is broken only by Tumac Mountain.

The summer season is temperate and dry. During the fall, winter and spring, low temperatures prevail and snow accumulates to great thickness particularly in the higher elevations. Although there are no permanent snow fields, patches of snow are often found as late as September.

The total annual precipitation at the Bumping Lake weather station is 44 inches. The average annual snowfall is 300 inches. The annual mean temperature is 40.9 F.

Flora and Fauna

Heavy stands of virgin timber mantle the valleys and mountain slopes below 5,000 feet elevation. Above this level the vegetation rapidly thins until at 6,500 feet only scrub varieties will grow. Over 6,500 feet there is no vegetation

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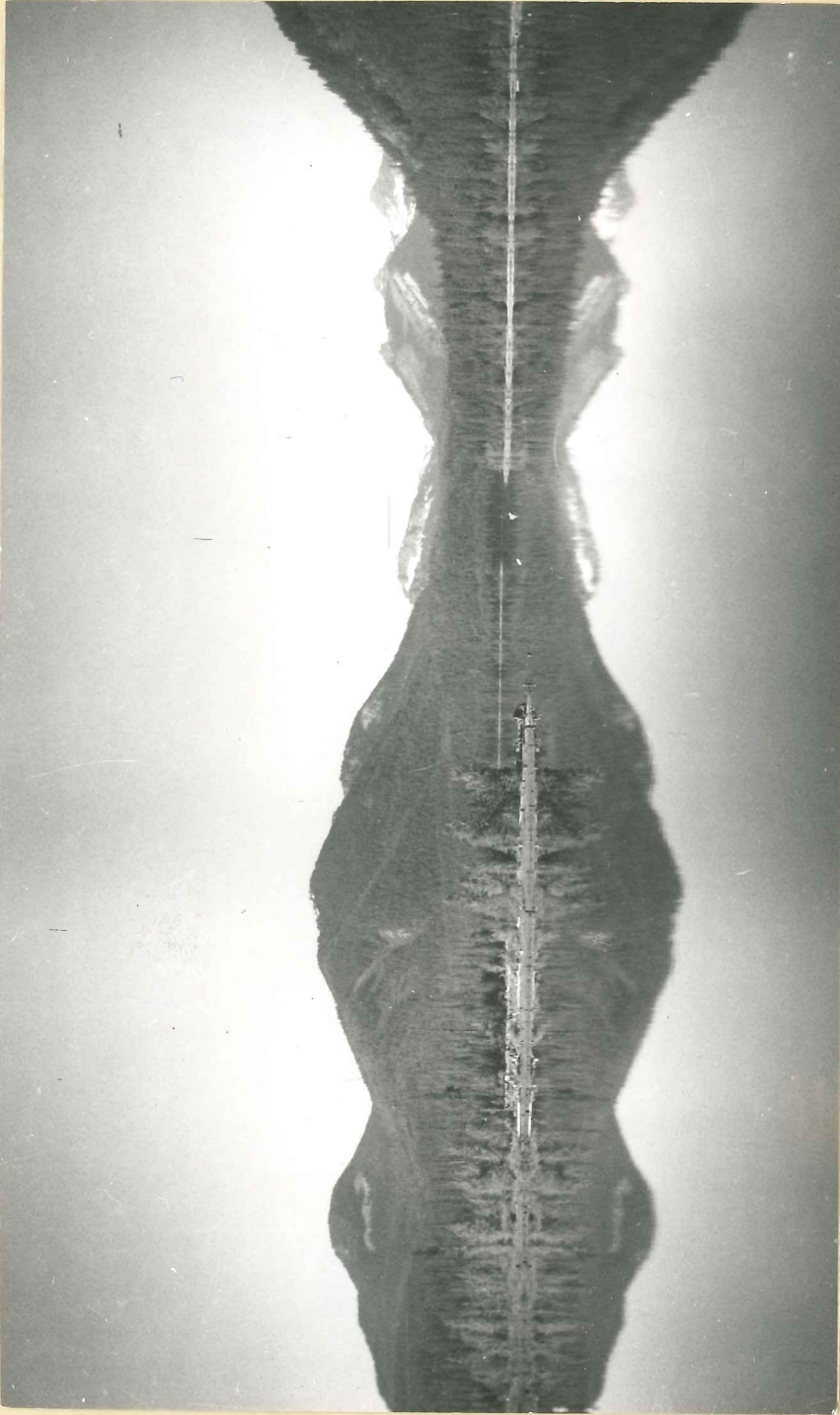
Plate 2. Looking west across Bumping Lake. The hill on the far
left is Sugar Loaf (Deep Creek andesite). Miner's Ridge
in the center is composed of Granite Lake breccia
(front hill) and Bumping Lake granite (rear hill).
Landscape in the background is composed of Keechelus rocks.
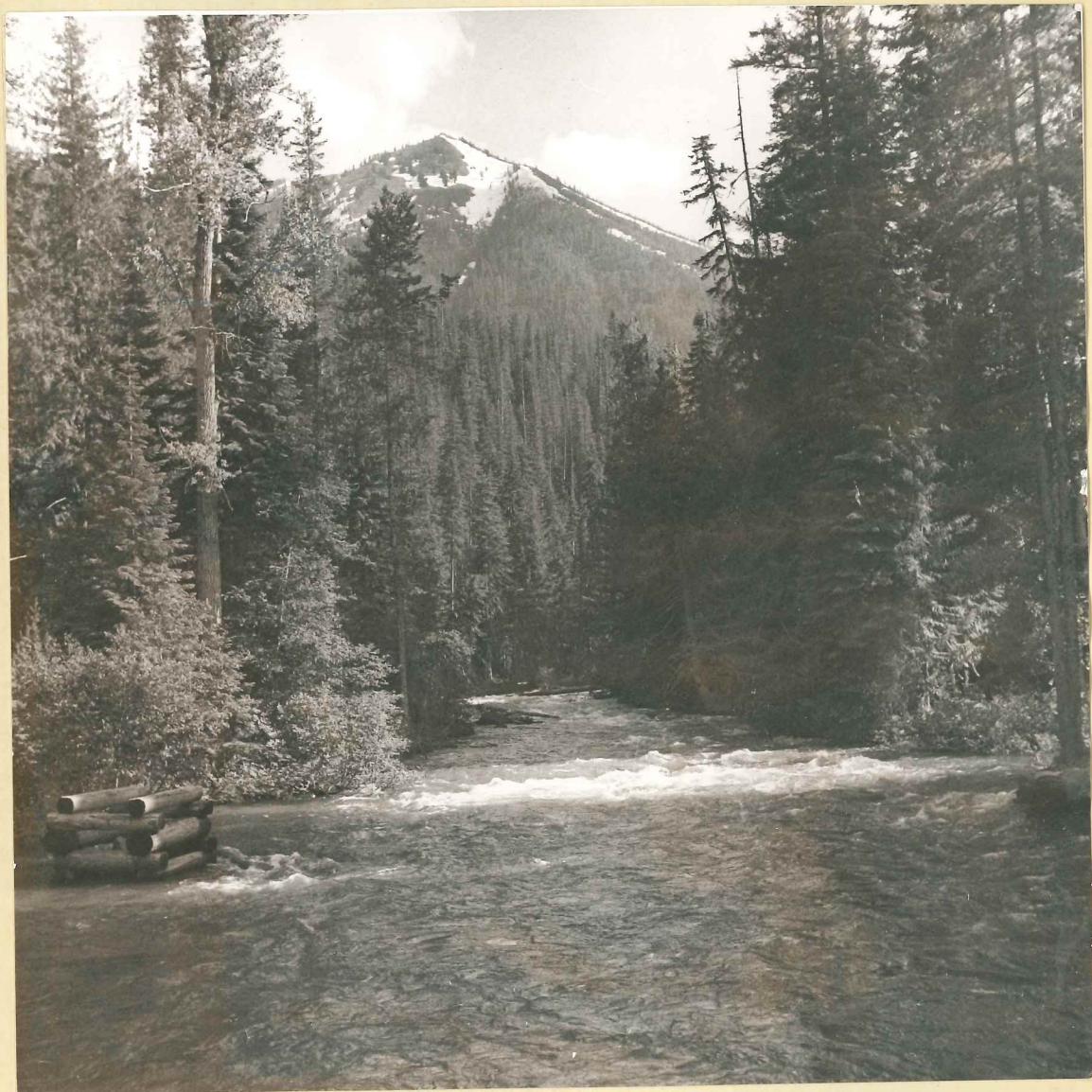
Plate 3.   Typical stretch of swift water in
           Bumping River.   Old Scab Mountain
           in the background.

except for sturdy bunch grasses, wild flowers, and an occasional weather-beaten shrub.

From a non-geological standpoint the flora provides a never-ending source of beauty and enjoyment. Out of the dark, quiet, moist, forest of gigantic firs and cedars one may climb into mountain meadows brilliant with wild flowers and waving grass surrounding clumps of wonderfully symmetrical alpine fir.

Trees in the lower elevations include western larch, white fir, Douglas fir, Engleman spruce, white pine, and lodgepole pine. At somewhat higher elevations there is balsam fir, noble fir, and mountain hemlock. Alpine fir and alpine white pine grow slightly below timber line.

The animals in this region are deer, elk, black bear, cougar, and a variety of small creatures. In the very high country the shy mountain goat is sometimes seen.

SEDIMENTARY AND META-SEDIMENTARY ROCKS

Puget Group

Carbonaceous Sandy Argillite and Argillaceous Sandstone

A wedge-shaped body of banded, carbonaceous, sandy, argillite and argillaceous sandstone forms the ridge between and north of Twin Sisters Lakes. The argillite and associated sandstone cover approximately two and one-half square miles, which constitutes about two percent of the total area mapped. Very heavy forest growth obscures most of this formation. It is, however, fairly well-exposed along the last few hundred feet of the trail from Copper City to Twin Sisters, and along the steep east bank of Big Twin Sister Lake. Mapping of the covered parts of the formation was done on the basis of float, and float in glaciated country can be misleading.

The argillite is dark-colored, highly indurated, and dense-textured. Light colored laminae and lenses composed of very fine quartz sand lend the rock a dark and light banded appearance. The percentage of quartz sand increases considerably from the dark, dense, banded argillites on the Copper City trail to the argillaceous sandstones on the other side of the ridge.

This is a lateral rather than vertical change of facies. Sills and dikes of light colored, highly altered porphyry intrude the sandstones east of Big Twin Sister.

Most of the banded argillite is dipping south at approximately 20°. Locally, however, the argillite has been crumpled into small tight anticlines, synclines, monoclines, and drag folds. Under the microscope these structures are very evident.

The wedge of carbonaceous argillite and sandstone is foreign to the rocks which surround it. Unfortunately, because of the thick forest, only the contact on the south side can be observed. This is the contact between argillite and basaltic Valley Flows that cap the Tumac Plateau. The argillites and sandstone lie unconformably beneath vesicular basalt lavas. The lavas, which are nearly horizontal, rest on an eroded surface of southerly dipping sedimentary beds. Other contacts, whose exact location and genetic nature can only be inferred, include the argillite-Deep Creek andesite contact on the west, and the argillite-dacite porphyry contacts on the north and east. Because the argillites and argillaceous sandstones are definitely out of their genetic environments, the most probable explanation of their present position is that the wedge-shaped body is an upraised fault block. As stated above, however, no contacts, fault or otherwise, that would prove the method of emplacement, could be observed.

Assuming tentatively, then, that the argillite and sandstone body is a fault block, the age of the faulting must be considered. The unconformable contact with overlying Valley Flows leaves no doubt that the faulting took place prior to these Pleistocene lavas, thus providing an upper age limit of pre-Pleistocene Valley Flows. No lower age limit for the faulting can be determined.

The date of deposition of these carbonaceous sandy argillites is also in doubt. In the Mt. Rainier quadrangle near the snout of the Carbon Glacier, Coombs (7) described an outcrop of dark, carbonaceous, highly indurated argillite, similar to that in the Twin Sisters wedge, that he tentatively assigned to the Eocene Puget Group. In the Mt. Aix quadrangle, although nearly 800 feet of Puget Group sandstone is exposed along the north wall of upper Bumping River, nowhere in that section are there any significant amounts of argillite. It must be understood, however, that along Bumping River the base of the Puget Group sandstone is not visible, and therefore it is possible that carbonaceous argillites and argillaceous sandstones lie beneath the exposed section. If this is so, the Twin Sisters wedge of argillite may be the lower part of the Puget Group that was faulted upward into its present position. Erosion has removed the upper part of the section.

Coombs (7) reported that immediately northwest of Mt. Rainier National Park there is a 10,000 foot section of Eocene

Puget Group carbonaceous argillites and sandstones. The
regional trend of these sediments is southeast through the
Park toward the Mt. Aix area. Because the lithology of the
argillites in the Twin Sisters wedge is similar to that
described by Coombs, and because the trend of the Puget Group
sediments is toward the area mapped, it is probable that the
Twin Sisters carbonaceous argillites and sandstones belong to
the Puget Group and are, therefore, Eocene in age.

Petrographic Description of Carbonaceous Sandy Argillite and Argillaceous Sandstone

Megascopic description. The carbonaceous sandy
argillite is black or very dark slate-gray in color with light
gray lenses and bands composed of very fine, light-colored
quartzose sand or silt. The argillite is highly indurated and
may be scratched with a knife only with difficulty. The surface
is dull and lusterless, suggesting that sericite is not present
in any quantity. Some sericite is seen, however, in thin
section. The lighter colored bands are helpful in displaying
local wrinkling, folding, and drag folding.

The argillaceous sandstone is a medium brown color and
may be flecked with specks of orange limonite. The sandstone
is fine-grained and contains varying amounts of argillaceous
and carbonaceous material. Folding in the sandy facies is not
so evident as in the banded argillite.
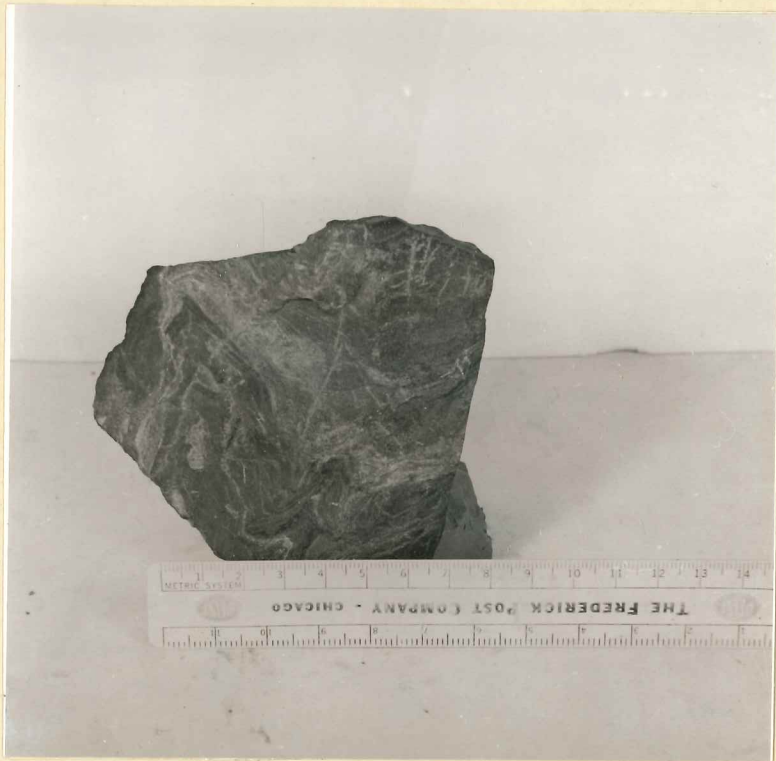
Plate 4.   Carbonaceous argillite showing
           local folding. The specimen is
           from the body of phyllite and
           argillite north of Twin Sisters
           Lakes. Its age is probably
           Eocene.

Microscopic description. The banded, carbonaceous, sandy, argillite is distinctly bedded. The bedding is accentuated by alternating light and dark laminae which are caused by segregation of very small grains of clastic quartz in the light bands and argillaceous and carbonaceous material in the dark bands. Often the contact between laminae is particularly black with carbonaceous matter.

Although most of the rock is undeformed, locally there are small flexures. Tension fractures along the fold crests are commonly present. In the most strongly deformed zones folds have been overturned and faulted with the development of miniature examples of decollement.

The argillite was not sufficiently metamorphosed for the development of porphyroblasts; only the incipient formation of sericite was observed and chlorite was never present. Quartz grains show a tendency to be flattened and rotated in the direction of foliation. The many thin laminae are probably original bedding. It is doubtful that any chemical phase of metamorphic segregation took place, however, mechanical segregation of clastic quartz grains according to their physical habit probably rearranged some particles. Locally the argillite may be slightly phyllitic.

The quartz sand or silt particles are very small. Their average size is .004mm. Specks of orange limonite are scattered through most thin sections.

The average percentage of constituents in the sandy, carbonaceous, banded argillite is as follows: argillaceous material, 40; carbonaceous material, 30; quartz, 25; sericite, 3; limonite, 2. The more sandy facies of the Twin Sister occurrence of Puget Group rocks is definitely foliated but differs from the argillite in several ways. In the sandstone the folia are less distinct, coarser, less crumpled, and dark and light banding is not conspicuous. Clastic quartz is the main constituent and the argillaceous and carbonaceous materials are present in subordinate amounts.

The grains of quartz are larger and more angular than in the argillite, but some flattening of the grains was observed. The average size of the quartz grains is .15mm.

Orthoclase and plagioclase, with orthoclase predominant, are present as clastic grains in the sandstone. They are approximately the same average size as the quartz grains and are also angular in shape. The feldspars show only slight alteration.

Granules of magnetite and its alteration product limonite are scattered throughout the rock.

The incipient development of sericite in argillaceous zones may be seen under high power. Chlorite, however, is absent.

Except for the foliation, which is caused by fairly abundant carbonaceous and argillaceous material, this sandy

facies of the Twin Sisters occurrence of the Puget Group is microscopically not markedly different from the Puget Group sandstone exposed along Bumping River.

The average percentage of constituents in the argillaceous sandstone is as follows: quartz, 60; orthoclase, 10; argillaceous material, 10; carbonaceous material, 10; plagioclase, 3; sericite, 3; calcite, 2; magnetite, 2.

Summary of Twin Sisters Puget Group Argillites and Sandstones

The following points are significant in connection with this relatively small exposure of clastic sediments:

1. The exposure indicates a lateral, east to west, facies change from argillaceous to sandy.

2. The wedge-shaped block may have been faulted upward into its present position.

3. The date of faulting was pre-Pleistocene Valley Flow, but more precise dating is not yet possible.

4. The sediments may be a lower portion of Eocene Puget Group, and are tentatively classified as such.

Sandstone

The Puget Group, which is comprised of sandstone, shale, and carbonaceous argillite, was first described by White (32) in widely scattered localities in the Puget basin on the west side of the Cascades. From fossil evidence he dated the Puget Group
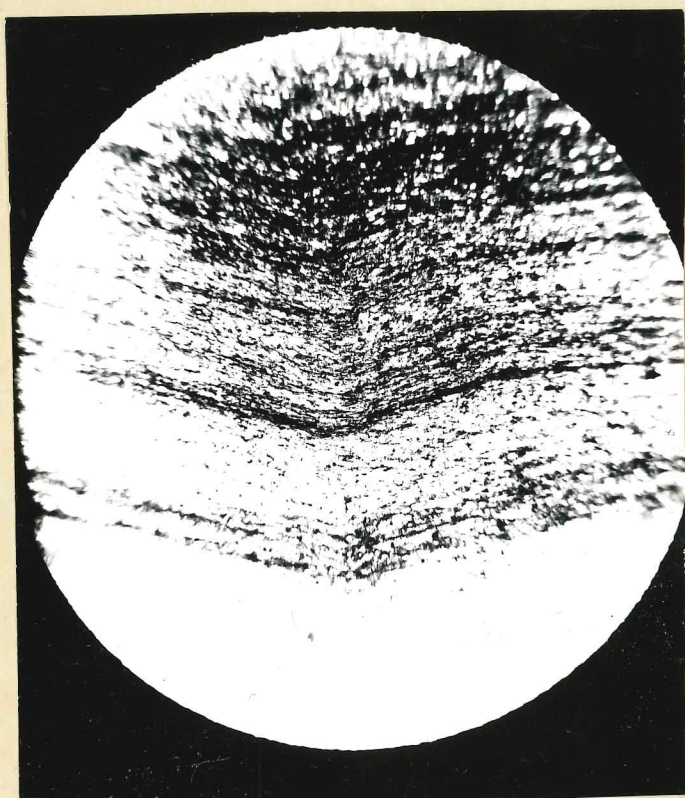
Plate 5. Photomicrograph of slightly folded carbonaceous, sandy, argillite from the Twin Sisters Wedge. x 15, Plain light.

rocks early Tertiary. Impressed by the 12,000 feet of section
of the Puget Group, by its large areal extent, and by the fact
that fossils in the formation indicated a fresh or brackish
water environment, White stated:

> Certain unique features of the fauna...show that
> the strata in which the remains were found were
> deposited in a body of water which was quite separate
> from that in which was deposited any one of the coal-
> bearing formations in the Pacific Coast region or
> elsewhere. Its zoological character indicates that
> the body of water in question was an estuary; and the
> extent of the district within which the deposits have
> been found shows that the estuary was a very large one.

White continues:

> This is surely a remarkable deposit for one of
> estuary origin, but it is so regarded in consideration
> of the following facts: No trace of an open sea
> fauna has been found in it, while all the molluscan
> remains that have been found in it are related to
> estuary forms. These remains embrace species of
> CORBICULIDAE, the members of which family are known to
> range from brackish to fresh water.

Although the facts indicated the Puget Group was an
estuarine deposit, it is evident that White had difficulty
explaining how so large an estuary existed because he further
states:

> The known area within which strata of that group
> occur shows that the Puget estuary was of such great
> extent that it is difficult to understand how so large
> a body of water could have kept so uniformly nearly
> fresh as to afford a congenial habitat for such a
> molluscan fauna as it is known to have possessed, and
> was necessary for the accumulation of the great
> thicknesses of strata in which the remains of that
> fauna are found during so long a period of time.

Except for a seam of coal, the writer found no organic
remains in the Puget Group sandstone of the Mt. Aix area. The

basin of deposition for Puget strata in this area most probably
was nearer the mouths of the rivers which emptied into the
estuary than any of the areas of deposition in the Puget basin
studied by White. Whether environment, or geographical
position, or both were responsible for the lack of fossils in
the Mt. Aix area is not known.

Discovery by the writer of thick deposits of Puget Group
sandstone in western portions of the Mt. Aix area extends the
shores of the estuary farther east than they had hitherto been
known to exist. (see Culver, 1919) In the Ellensburg quadrangle Smith (25) noted,
north of Bald Mountain, that Yakima basalt rested unconformably
on Eocene sandstone, but he did not propose that the sandstone
was part of the Puget Group. In the Mt. Rainier quadrangle
Coombs (7) found several exposures of Puget Group sandstones
and argillites.

The lower portions of steep cliffs that form the north
walls of upper Bumping River, which drains east from Carleton
Pass, and Carleton Creek, which drains west from Carleton Pass,
are composed of Puget Group sandstone which is at least 800 feet
in thickness. The cliffs extend for about six miles. The upper
portions of the cliffs are composed of Keechelus andesite. On
the east side of Carleton Pass sandstone exposures are good
although they are not continuous; on the west side of the Pass
heavy forest mantles the slopes and the contacts, as mapped, had
to be inferred. Three smaller outcrops east and north of the

Bumping River complete the exposures of Puget Group rocks in
this area. Together, the four occurrences comprise approximately
3 percent of the total area mapped.

Because the base of the Puget Group sandstone is nowhere
exposed, its relationship to older rocks cannot be described,
nor can the true total thickness be given.

Along the north wall of upper Bumping River the sandstone
is concordantly overlain by basal Keechelus andesite (Cougar
Creek andesite). Both formations dip approximately 15° north-
ward. The surface of the sandstone upon which the flows rest
is essentially flat. Relief on the sandstone surface when the
Keechelus flows were laid down was apparently very low. This
suggests the possibility that the start of Keechelus volcanic
activity followed closely the cessation of sedimentation in the
estuary. That Keechelus deposition may have started even before
the end of Puget deposition is indicated by intercalation of
andesite flows within the sandstone.

The sandstone varies from light buff to dark brown in
color. It is massively bedded and no distinct bedding planes
are visible in outcrop. Cross bedding or deltaic bedding is
entirely absent. Except for small lenses of shale in the
sandstone north of Bumping Lake and argillaceous material with
sand in the Twin Sisters wedge, the sediment is a moderately
clean arkosic sand. Small flakes of muscovite are abundant
locally, but most of the sandstone is not micaceous. The sand

Plate 6.   Looking west across upper Bumping River valley.
Opposite wall exposes concordant contact of
Puget Group sandstone and Keechelus andesite.
A line of trees about one-half way up the
slope marks the contact. Mt. Rainier appears
in the distance.

grains are uniform in average size from bottom to top of the
exposures, but there is a slight suggestion of increase in
grain size as the formation is followed eastward.

From a thickness of at least 800 feet in the western
portion of the area mapped, the visible section of Puget Group
sandstone decreases to about 50 feet near the east end of
Bumping Lake. Because the base of the formation is never
exposed, there is no evidence of thinning of the formation
eastward.

It is reasonable to assume that most of the sediments
were contributed to the estuary from highlands somewhere to the
east. The exact location of these highlands is not known, but
it is possible that the Okanogan region contributed some of the
material.

One surprising feature of the Puget Group rocks is the
lack of conglomerates; in fact there is not even an occasional
pebble embedded in the sandstone. If this area were near the
apex of the estuary, conglomeratic beds or lenses should appear;
but they do not. The lack of coarse material suggests that the
outlets of the rivers contributing the clastic sediments were
some distance east of the area mapped.

Because the sandstone is arkosic, it is probable that
the topographic relief of the area contributing the sediments
was fairly great. In this regard Pettijohn (23) discusses the
use of feldspar grains in a sediment as an index to the rate of

erosion and deposition:

> Feldspar is the mineral index of relief (and
> therefore of the rate of erosion and deposition).
> The feldspar content reaches a maximum under
> conditions of highest relief; it is reduced to
> zero at base level. The effects of climate are
> at a minimum under conditions of highest relief,
> and feldspar is contributed to the sediment
> regardless of climate. At base level climate plays
> a major role, and under normal conditions feldspar
> is eliminated and therefore is absent from the
> sediment.

The Puget Group sandstone is intruded by Bumping Lake granite north and west of Bumping Lake. The best exposure of the contact relationship is in the bottom of Cougar Creek one-half mile east of Cougar Lake. Here the intrusion converted the sandstone to a quartz biotite hornfels near the contact, and displaced the sandstone, causing it to dip rather steeply away from the granite mass. Apophyses of granite cut through the sandstone several hundred yards away from the contact (cf. Bumping Lake granite). On the east side of the Bumping Lake granite, where it is in contact with sandstone along the walls of Boulder Creek north of Bumping Lake, the sandstone started to recrystallize (cf. Microscopic description Puget Group sandstone).

Two diorite plugs intrude the Puget Group sandstone. One small plug, whose contact with the sandstone is obscured by heavy forest, breaks through the sandstone on the north shore of Bumping Lake; the other and larger plug forms the peak known

as Mt. Baldy which is two and one-half miles east of Bumping Lake. Around the Mt. Baldy intrusive there is a discontinuous rim of sandstone. The sandstone rim does not exceed 50 feet in total thickness. On the north side of the diorite the sandstone strata are standing nearly vertical, whereas on the south side the sandstone is only slightly tilted. Around Mt. Baldy the sandstone is a lighter color than in other exposures, sometimes being nearly pure white. In this occurrence there is a slight increase in grain size as compared to the sandstone along upper Bumping River.

If this sandstone belongs to the Puget Group, it is definitely out of place, because the last occurrence of the Puget Group to the west was at an elevation of 3,395 and was dipping beneath the waters of Bumping Lake. The Mt. Baldy sandstone, however, is found between 5,500-6,000 feet elevation. Microscopic examination of the sandstone showed that it is composed of abundant quartz and orthoclase, which indicates that the sandstone is a portion of the Puget Group arkose. The sedimentary beds were forced upward by the diorite intrusion.

A few hundred yards north of Carleton Pass and several hundred feet higher than the Pass elevation, a seam of coal was discovered in Puget Group sandstone. The coal seam was exposed only in a gully that cut deeply into the sandstone. The seam was covered on either side of the gully, consequently its linear extent could not be measured. In the gully the coal bed is

about ten feet in thickness. It is not a good grade coal
because it contains a large admixture of shale. Slight
deformation of the coal bed was evidenced by small folds and
buckling of the weak carbonaceous material. The presence of
the coal seam proves that for part of the time a swamp
environment existed. Renewal of sand deposition resulted in
burial of the organic material.

Although 800 feet of sandstone is exposed on the north
side of upper Bumping River, none is exposed on the south side.
Projecting the formation to the south on the basis of its
northerly regional dip, it is evident that an even greater
thickness of sandstone should be exposed on the south side of
the river. This discrepancy suggests the presence of a major
fault running approximately east-west in the valleys of upper
Bumping River and Carleton Creek. This fault would cut directly
across the trend of the Cascades. Vertical displacement of the
many hundreds of feet along this fault raised the north block,
thereby exposing the Puget Group sandstone on the north side of
the river. One factor which suggests faulting and elevation of
the north block is the striking dissimilarity in the
physiographic development on the two sides of the river. On
the south side the hills have steep but smooth slopes and
rounded crests. The topography on the south side is in a stage
of late maturity. Topography on the north side of the river is
one of high jagged peaks, and towering vertical cliffs. The

topography here is in a stage of late youth or early maturity.
Possibly rejuvenation of the north block by faulting was
responsible for this pronounced difference in landscape.
Unfortunately, there is no direct evidence of a fault in the
river valleys.

The upper age limit of the inferred fault is probably
pre-Pleistocene because Pleistocene Valley flows in upper
Bumping River valley are not displaced. The lower age limit
cannot be determined, however, it probably was not much earlier
than Pleistocene judging from the very precipitous topography
of the north block.

Petrographic Description of the Puget Group Sandstone

Megascopic description. The sandstone is uniformly
medium-grained and varies in color from light buff to dark
brown depending upon the local concentration of iron oxide
minerals. In lighter-colored specimens scattered dark specks
of iron oxide provide a salt and pepper effect. The sandstone
forms massive thick beds, but close inspection of the hand
specimen reveals local thin discontinuous darker-colored layers.
Muscovite is not a common constituent but in certain outcrops
it is quite abundant. The mica is usually associated with the
darker-colored sandstones.

Microscopic description. The sandstone is composed of
sub-angular to sub-rounded grains of quartz and orthoclase with

minor amounts of muscovite, plagioclase (calcic oligoclase),
and heavy minerals. The terms sub-angular and sub-rounded
are used according to Pettijohn's (22) classification which
is as follows:

> Sub-angular--showing definite effects of wear. The
> fragments still have their original form, and the
> faces are virtually untouched; but the edges and
> corners have been rounded off to some extent.

> Sub-rounded--showing considerable wear. The edges
> and corners are rounded off to smooth curves and the
> area of original faces is considerably reduced, but
> the original shape of the grain is still distinct.

Willis (33) noted during his study of the Swauk sandstone that
the degree of rounding of sand grains cannot be used directly
to estimate the distance the grains have been transported.
That is, grains of sand size may have been carried for
considerable distances and still retain sub-angular to sub-
rounded shapes.

The larger clastic grains are cemented by clay, iron
oxide, silica, and calcite in order of their relative abundance.

The texture is fairly uniform throughout the formation
with a slight increase in grain size noted in thin sections of
specimens from the eastern outcrops. Average grain sizes are
apt to be misleading, however, because, if the specimen taken
for microscopic examination had been collected a few feet from
where it was, the grain size might be quite different.
Measurement of average grain sizes from all sandstone thin
sections produced these results:

Average grain size from sandstones near
    Carleton Pass   .20mm
Average grain size from sandstones near
    Bumping Lake   .30mm
Average grain size from sandstones near
    Mt. Baldy   .40mm

The mineral content of the Puget Group sandstone is quite uniform. Quartz and orthoclase are always predominant. Muscovite is present in small amounts in rocks from some areas and absent in others. Biotite is a common constituent near granite contacts, but otherwise it is absent. Epidote and tourmaline were found in a few thin sections but only in small quantities. Other heavy minerals that were conspicuously absent include garnet, rutile, zircon, and kyanite.

The orthoclase is only slightly altered except when it occurs as very fine grains in the cement in which case it is kaolinized. Plagioclase is somewhat more altered than orthoclase and some grains have partially gone to sericite and calcite. Quartz is unaltered, but some grains show strain shadows which probably resulted from forces acting on the mineral before it became a sediment.

An interesting texture was noted in that sandstone near the granite-sandstone contact on the east side of the Bumping Lake granite mass. Contact effects of the granite caused partial recrystallization of the clastic grains of quartz and feldspar. As a result the fabric of the sandstone is one of partially interlocking grains and sutured boundaries between grains. Under the microscope the formerly sub-angular grains

of quartz and feldspar now resemble miniature, intermeshed
cog wheels.

An average percentage of mineral constituents in the
sandstone is not to be taken too seriously. It is as follows:
quartz grains, 55; orthoclase grains, 20; plagioclase grains,
1; cementing material (including clay, iron oxide, silica,
calcite, and finely divided quartz and feldspar), 23; all other
accessories, 1.

Summary of the Puget Group Sandstone

The most significant points gained from this study of
the Puget Group sandstone are as follows:

1. As proposed by White, Puget Group rocks were probably
deposited in a large estuary of fresh or brackish water. By
discovery of the sandstones of Puget age on the east side of
the Cascades the limits of this estuary have been expanded
eastward.

2. The arkosic sandstones were probably derived from
highlands to the east. The exact location of the source or
sources is not known, although the Okanogan highlands may have
contributed some material.

3. The sandstones around the flanks of the Mt. Baldy
diorite plug belong to the Puget Group and were pushed into
steeply dipping folds by the intrusion of the plug.

4. A bed of coal in the sandstone indicates swampy
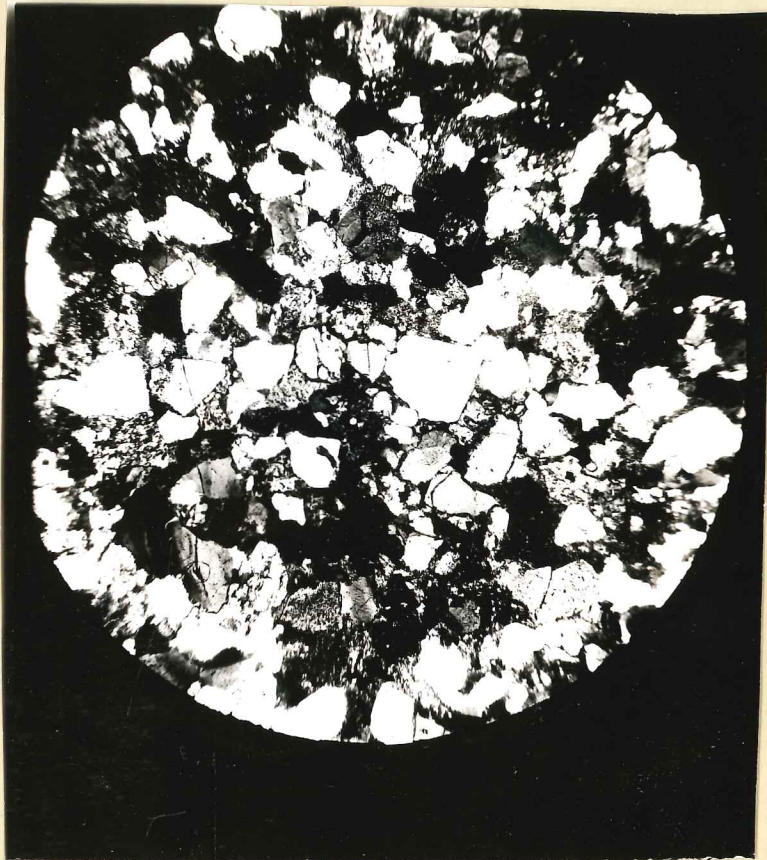
Plate 7. Photomicrograph of Puget Group
          sandstone. The white angular
          fragments are quartz and ortho-
          clase. The cementing material is
          clay, silica, and iron oxide.
          x 15, Plain light.
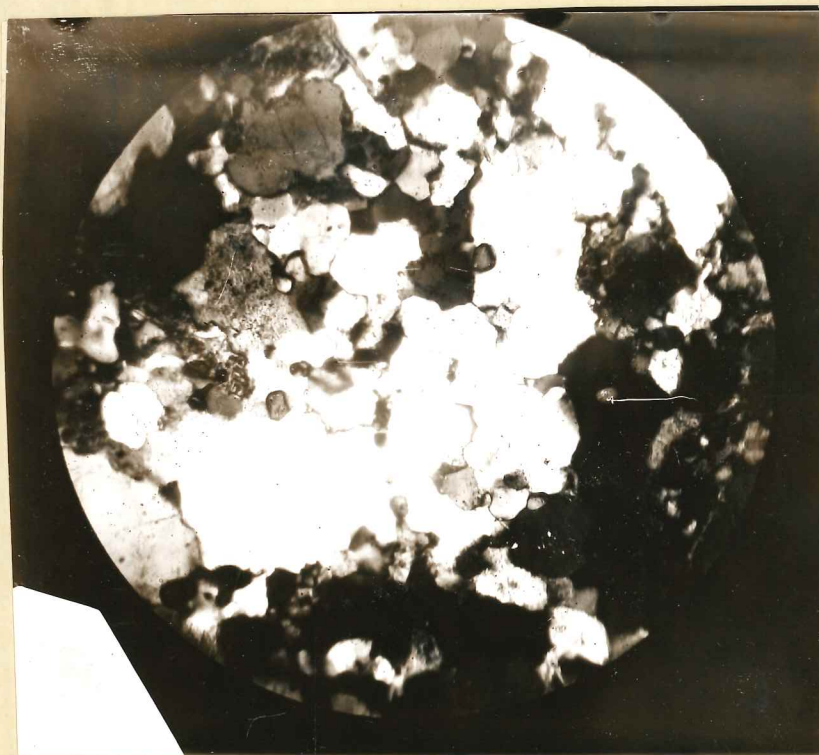
Plate 8.   Photomicrograph of recrystallized
           Puget Group sandstone east of its
           contact with Bumping Lake granite.
           Note the cogwheel effect. Most of
           the sand particles have lost their
           original shape. x 65, Crossed nicols.

conditions for a time followed by renewed deposition of sand.

5. The base of the sandstone is not exposed, therefore its total thickness cannot be determined.

6. The Puget Group sandstone in this area is concordantly overlain by basal Keechelus andesite.

EXTRUSIVE ROCKS

Keechelus Andesite Series

The Keechelus andesite series, which comprises
approximately forty percent of the area mapped, is a vast
heterogeneous assemblage of volcanic rocks that are dominantly
andesitic in composition and attain a thickness of 3,500 feet
or more. This estimate of thickness, which is greater than
that of one-half mile made by Coombs (7) in Mt. Rainier National
Park, may indicate an eastward thickening of the Keechelus
series. This thickening cannot definitely be proved, however,
because the true base of the Keechelus in the Park was not
observed. The principal rock types are indurated volcanic tuffs
and breccias, and various kinds of porphyritic extrusives. Also
included within the Keechelus, but in subordinate amounts are
sediments, basaltic flows, and hornfels. Weak to moderate
alteration in varying degrees pervades nearly the entire
assemblage.

Smith and Calkins (26) described and named the Keechelus
series at its type locality near Lake Keechelus in the
Snoqualmie quadrangle. Coombs (7) described the Keechelus
andesite series in Mt. Rainier National Park where it forms a

platform upon which the Rainier cone was built. Keechelus
rocks comprise eight-tenths of the Park area. The actual
extent of the Keechelus to the west of the Mt. Rainier region
is not known.

How far south of the Mt. Aix quadrangle rocks of the
Keechelus series extend is not definitely known, but they will
certainly be found in parts of the Mt. Adams quadrangle.

To the east, in the Ellensburg quadrangle, the Keechelus
is covered by Fifes Peak andesite and Yakima basalt.

The total extent of the Keechelus is undoubtedly
several thousand square miles. The conditions under which such
an enormous volume of heterogeneous extrusive rocks were
distributed over a vast area in western Washington are difficult
to imagine. Theories concerning the origins are beyond the
scope of this work. Unravelling the history of the entire
Keechelus presents a challenge to future workers in the Cascades
who may benefit from the results of local studies, such as this
one, in formulating the regional picture.

Smith and Calkins (26) dated the Keechelus as Miocene
because they interpreted its stratigraphic position as overlying
Yakima basalt and underlying Ellensburg sediments which are both
Miocene in age. They also stated that the Keechelus
unconformably overlies the Guye formation which they dated
Miocene. Later discovery of fossil leaves in the Guye, however,
places its age earlier than Miocene, probably Eocene. This

relationship was definitely proved in error by Warren (29) in his work in the Mt. Aix quadrangle, where he demonstrated that the Yakima basalt overlies the Keechelus. The present investigation fully substantiates Warren's observations.

A great deal of uncertainty accompanied Smith and Calkins' attempts to separate the Keechelus series into its stratigraphic components. They realized that there were two major distinct phases of the Keechelus series, but their efforts to map them separately were unsuccessful and they finally were forced to map the series as an undifferentiated unit. If these workers had extended their study southward into the Mt. Aix quadrangle, they would have found the lithologic and structural differences that distinguish the "lower" from the "upper" Keechelus. Warren (28) assigned the name Fifes Peak andesite to the "upper" Keechelus in the Mt. Aix quadrangle. He named the formation for its type locality near the towering spindles of andesitic breccia that form Fifes Peaks two miles north of American River. The writer has adopted Warren's name Fifes Peak andesite to replace the name "upper" Keechelus, and proposes that the name Keechelus be restricted to the former "lower Keechelus". This nomenclature will eliminate the terms "upper" and "lower" Keechelus for two rock assemblages that are so distinct in the Mt. Aix area that they must not bear the same name. In this work any mention of upper or lower parts of the Keechelus will refer only to upper or lower portions of the

Keechelus as restricted above.

Until Grant (17) discovered the jaw of an Oligocene oreodont in the Keechelus series north of the Tieton reservoir, dating of the Keechelus was based on its stratigraphic position. As mentioned above Smith and Calkins were certain that the Keechelus was Miocene in age, but they were working on a mistaken premise that the Keechelus lay between Yakima basalt and Ellensburg sediments. Coombs (7) recognized that there was insufficient evidence for dating the entire Keechelus series as Miocene and wisely cautioned against full acceptance of this age until more definite data could be collected. He predicted that the true age of the Keechelus would probably be older than Miocene. Warren (29) dated the Keechelus as Oligocene because it lay unconformably between Eocene Guye sediments in the Snoqualmie quadrangle and Miocene Fifes Peak volcanics.

Grant's important fossil discovery verified Warren's dating. The fossil was the jaw of an oreodont, which was identified by Stirton of the University of California as being closely allied to the genus EPOREDON which is found in the John Day beds of Oregon.

Although the writer is in agreement with the assignment of most of the Keechelus series to the Oligocene, he is still in some doubt that sufficient evidence has been presented to justify dating the entire Keechelus series Oligocene. In the

first place, Warren (29) used the Guye formation, which was
mistakenly dated Miocene by Smith and Calkins, in the
Snoqualmie quadrangle to determine the lower age limit of the
Keechelus in the Mt. Aix quadrangle. The fact that it is
quite a number of miles between the two localities reduces the
accuracy of this correlation. Secondly, there is evidence of
intertonguing of lowest Keechelus andesite flows and Eocene
Puget Group sandstone in the upper Bumping River canyon (cf.
below). Coombs (8) and Misch (21) indicated orally that they
have seen evidence of this intertonguing at other localities.
Consequently, if the Puget Group is Eocene, lower portions of
the Keechelus may also be Eocene. In the third place, Grant
stated that the oreodont jaw was found in the lower third of
the Keechelus series. From the writer's experience with the
Keechelus it is often very difficult to determine what part of
the Keechelus one is in. Unless Grant had good marker beds to
determine his position within this vast series it is doubtful
that his discovery of one fossil can be safely used to date
the entire assemblage.

For a distance of more than two miles along the north
wall of the upper Bumping River gorge and high above the river
the main contact between the base of the Keechelus andesite
series and the Puget Group sandstone is well exposed. The
Keechelus series overlies the Puget Group concordantly and
probably conformably. Their contact dips gently northward

about 15°. This gentle inclination of the contact is probably
caused by regional tilting to the north subsequent to the
Keechelus deposition, rather than representing the initial
slope of the surface of Puget Group sandstone. The surface of
the sandstone was apparently one of low relief when the
Keechelus flows were extruded upon it. There is no evidence
of hilly or even rolling topography beneath the Keechelus
contact.

One-half mile west and several hundred yards above
Carleton Pass on the north wall of the valley at least one
andesite flow is interbedded with the sandstone. This suggests
that the relation between the Puget Group sandstone and the
Keechelus may be truly conformable in this area. The andesite
is strongly altered to epidote, sericite, and calcite to such
an extent that in the field the flow could not be positively
identified. Under the microscope its true identity is
revealed by outlines of plagioclase feldspar phenocrysts that
have undergone alteration. The groundmass is also strongly
decomposed. Whether this flow is a phase of the Eocene Puget
Group, or whether it is a tongue of Keechelus andesite could
not be determined.

In Mt. Rainier National Park, Coombs (7) described the
contact between Puget Group sandstone and Keechelus andesite as
unconformable, but he has indicated to the writer orally (8)
that near the Mowich Lake road in the Cascades he has observed

a conformable relationship.

The upper contact of the Keechelus is marked by an angular unconformity with the overlying Fifes Peak andesites. The structural and lithologic differences that separate these two great masses of volcanic rock may best be seen in the walls of tributary canyons north of American River, near the headwaters of Crow Creek, and along the crest of Buffalo Hump Mountain south of Goose Prairie.

Structurally, the Keechelus differs from Fifes Peak in that the Keechelus has suffered considerably greater deformation. The general trend of folding in the Keechelus is northwesterly. Dips as high as 65° have been read on the limbs of folds, although this intensity of folding is observed at only one place--about two miles north of Mt. Aix. More commonly dips range from 15°-40°. Much of the Keechelus shows the effects of a northward tilting uncomplicated by local flexures. This type of structure is well seen in the vicinity of Crystal Mountain and Silver Creek and Norse Peak. The overlying Fifes Peak formation, on the other hand, rarely exceeds a 10° easterly dip except for local broad synclines. There is no tight folding and no dip over 20° was recorded. Distinct bedding is rarely found in the Keechelus, whereas the Fifes Peak rocks are characteristically well bedded.

Lithologically, the Keechelus and Fifes Peak series are both predominantly andesitic, but there the similarity ends.

The tuffs and breccias of the Keechelus are strongly indurated,
but Fifes Peak tuffs and breccias are poorly consolidated.
The Keechelus andesites exhibit general, widespread, low grade
alteration, but the Fifes Peak andesites are virtually
unaltered. Although Keechelus rocks are seldom vesicular,
Fifes Peak rocks are commonly vesicular. Columnar jointing is
never found in Keechelus flows, but many Fifes Peak flows are
textbook examples of this type of jointing.

The eroded surface of Keechelus upon which the later
Fifes Peak volcanics were extruded was broken and rugged--total
relief probably being about 1,000 feet although this figure
must be considered only an approximation.

The Keechelus is variable in the extreme. The writer
was in the field for nearly a month before finding an exposure
of Keechelus rocks that resembled any he had examined previously.
Heterogeneity is not restricted to variations on a grand scale.
Often within the distance of a few feet along a given
stratigraphic horizon a marked lithologic change will occur.

The subdivision of such a rock assemblage, if feasible
at all, must be based on very general features. Four rudely
stratigraphic subdivisions of the Keechelus seemed justified,
and although there is considerable variance within each group,
an over-all similarity of rock types, degree of alteration, and
textures characterizes each. No estimate of the thickness of
any of the divisions is attempted because such estimates would

Plate 9.   Thinly bedded flows of Keechelus andesite on
American Ridge.   Structure is rarely this
well displayed in Keechelus rocks.

suggest a degree of accuracy that is not intended.

The four subdivisions of the Keechelus andesite series in the Mt. Aix region listed stratigraphically from bottom to top are: Cougar Creek andesite, Morse Creek andesite, Richmond breccias, and Mt. Aix andesite porphyries. Breccias and tuffs are more abundant in the middle parts of the Keechelus, whereas dense and porphyritic flows predominate in the lower and upper portions. The most severe alteration occurs in the middle portions of the Keechelus. Each of the four divisions will be discussed below.

Cougar Creek Andesite

This member is composed predominantly of slightly porphyritic relatively fresh andesite flows. The Cougar Creek andesite is worthy of special attention for two reasons. First, it is that portion of the great Keechelus series that is in contact with the Puget Group sandstone. Second, it was probably this lowest part of the Keechelus that was severely brecciated by intrusion of Bumping Lake granite, and the fragments now visible in the Granite Lake breccia are probably fragments of Cougar Creek andesite (cf. Bumping Lake granite and Granite Lake breccia below).

In addition to its type locality in upper Cougar Creek, the Cougar Creek andesite is well exposed at the following places: on the west side of an unnamed north-flowing creek

that enters upper Bumping River at Carleton Pass; in the high cliffs north of the northeast end of Bumping Lake; on the east bank of Boulder Creek about one mile north of Bumping Lake; and on top of a large granite exposure about one mile east of Cougar Lake.

Although the Cougar Creek andesite is the lowest member of the Keechelus series it is one of the least altered. Except for a narrow zone near the contact with the granite where the andesite has sometimes been converted to massive amphibolite by contact metamorphism, the usually abundant alteration products that characterize most of the Keechelus series are not prominent in Cougar Creek andesite. This fact is extremely important because it demonstrates that the widespread alteration of Keechelus rocks may not be primarily caused by the effects of igneous intrusion. Smith and Calkins (26), Coombs (7), and Warren (29) have maintained that the Snoqualmie granodiorite that intruded the Keechelus was responsible for the widespread alteration in the Keechelus and for the formation of minerals such as chlorite, epidote, serpentine, iddingsite, actinolite, hornblende, biotite, and magnetite even though in the Mt. Aix quadrangle these minerals were found in abundance several miles from any intrusive body.

Smith (26) offered a feasible but unproven solution to this situation by suggesting that groundwater in the Keechelus rocks was heated by the igneous intrusion and caused to

circulate. This heated ground water migrated great distances
and was responsible for the formation of the alteration
products. A fact that Smith overlooked was that the lower
portions of the Keechelus, i.e. the Cougar Creek andesite, is
only slightly altered, although it is possible, of course, that
these andesites were either too dense to allow the passage of
much water, or that they were too deeply buried to contain
abundant ground water.

However, the reason for only slight alteration of the
Cougar Creek andesite, which is the member that should be
affected most strongly if igneous intrusion were the principal
cause of metamorphism, cannot be dismissed easily. It is
possible that deuteric action was stronger in certain parts of
the Keechelus and weaker or incomplete in others, and consequently
the degree of alteration caused by deuteric processes varies
considerably from one portion of the formation to another.

Megascopic description. The Cougar Lake andesite is a
dense to fine-grained rock that is usually dark gray to black
in color. In contrast to the Keechelus rocks that overlie the
Cougar Creek andesite, it is homogeneous in composition and
uniform in texture. The greenish tinge that is prevalent
throughout most of the Keechelus rocks is seldom prominent in
this member. The weathered surfaces are customarily a light
brown color. There are no volcanic breccias in this member, in
fact fragmental textures of any kind are rarely seen. Also

lacking are the porphyritic textures that are so common in
higher members, although microscopically a fine porphyritic
texture may be present.

Microscopic description. Thin sections of Cougar Creek
andesite show a remarkable uniformity of texture and mineral
composition, even though the rock specimens from which the
sections were cut came from widely separated localities. A
typical thin section shows phenocrysts of euhedral to subhedral
blocky-shaped plagioclase feldspar and euhedral to subhedral
pyroxenes embedded in a felt-like matrix composed of small
plagioclase laths and finely divided intersertal pyroxene and
magnetite.

A striking feature of this rock under the microscope is
the lack of moderate to strong alteration that is so prevalent
in most of the Keechelus rocks. The feldspars are fresh and
clear with virtually no alteration to sericite, kaolinite, or
calcite. Even more notable is the fact that the pyroxenes,
namely pigeonite and hypersthene, have only slightly altered to
uralitic hornblende and chlorite.

The two types of plagioclase feldspar, i.e. the large
blocky phenocrysts and the small laths in the groundmass must
be considered separately. The large grains range in composition
from sodic labradorite to calcic andesine, Ab45 to Ab55.
Individual grains are seldom over 1.5mm in length although
glomerporphyritic clusters which are not common, are somewhat

larger. Albite and combined albite-carlsbad twinning are well
developed. Oscillatory zoning is rarely present. Lines of
magnetite dust that follow the outline of the grain, may be
seen inside the periphery of some crystals. Ragged inclusions
of matrix materials are common.

The lath-like plagioclase feldspars in the groundmass
vary in length from very small specks to .05mm in the finer
textured specimens up to .25mm in the more coarsely textured
rocks. The composition is not readily or well determined on
the small feldspars but most tests indicate a composition of
calcic-andesine, Ab5 An5. Carlsbad twinning is more common
than albite twinning. Zoning is absent. Specks of magnetite
and ferromagnesian minerals sometimes form inclusions in the
feldspar. Flow structures are indicated in some sections by
orientation of the small laths, but in other sections the laths
are in random orientation.

Hypersthene and pigeonite which occur in approximately
equal amounts form euhedral to subhedral phenocrysts up to
.5mm in length and also appear as small specks in the ground-
mass. Barth (3) and Hodge and Bogue (20) have stressed the
fact that the monoclinic pyroxene in Pacific lavas is much
more commonly pigeonite than augite. The present investigation
substantiates their findings. Pigeonite is most readily
identified by its small 2V, which in most grains is about 10°.
Many grains, of course, are not oriented to give a good

interference figure, but those in which a satisfactory figure
could be observed, pigeonite was definitely identified.
Twinning is common in the pigeonite, and twinning, according
to Hodge and Bogue (20), is strongly suggestive that the
pyroxene is pigeonite rather than augite. Hypersthene, which
forms small phenocrysts, is more abundant in the Cougar Creek
andesite than in some of the higher members of the Keechelus.
The hypersthene is weakly pleochroic and rarely displays
Schiller structure.

The intensity of alteration of the pyroxenes varies to
a certain extent in different parts of the Cougar Creek
andesite, but at no place, except possibly at the contact with
Bumping Lake granite, is alteration severe or complete. In
fact the pyroxenes often show no alteration. Sometimes
incipient chloritization or uralitization on the rims and
along cleavage traces are observed. The small intersertal
grains of pyroxene may be partly altered to epidote. Near the
contact with Bumping Lake granite secondary biotite and uralite
are abundant, but these minerals are not common away from the
granite contact.

Magnetite is invariably present. It occurs as sub-
microscopic dust in the groundmass and as scattered particles
up to .3mm in diameter. The size of the magnetite grains seems
to vary directly with the size of the feldspar and pyroxene
grains.
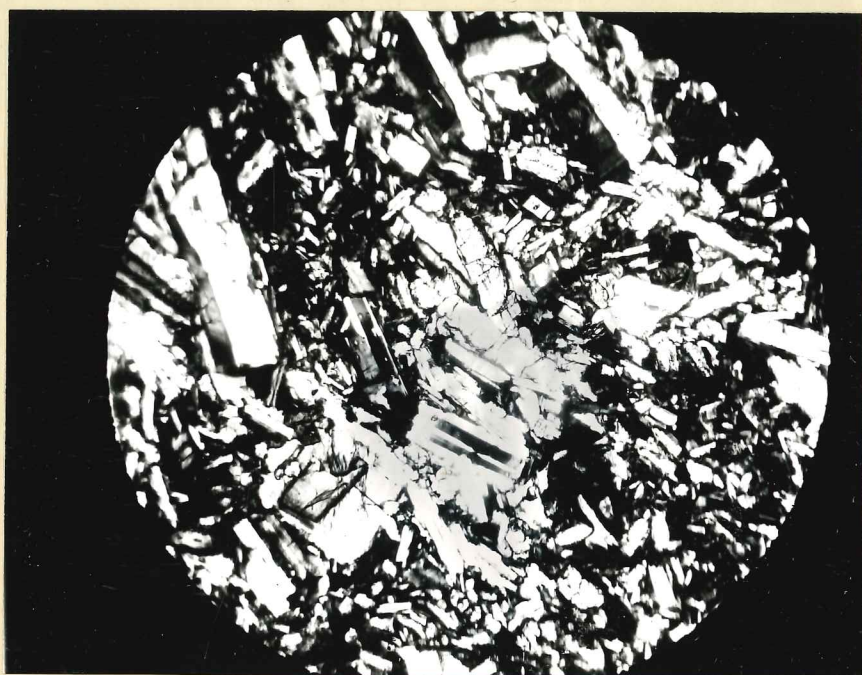
Plate 10. Photomicrograph of Cougar Creek
andesite of the Keechelus.
Note the lath-shaped, subhedral
unaltered plagioclase (labradorite)
and the fresh pyroxene (high
relief) set in a matrix of smaller
plagioclase grains and intersertal
pyroxenes. x 65, Crossed nicols.

Only near the contact with Bumping Lake granite are orthoclase and quartz major constituents of the Cougar Creek andesite. Specimens taken a hundred feet from the contact contain abundant orthoclase and quartz, which are clearly later than the other minerals. The orthoclase often exhibits a sieve texture due to inclusions of magnetite, pyroxene, and plagioclase. Quartz is usually clearer than the orthoclase and occurs as small anhedral grains in the groundmass.

The mineral assemblage and textures just discussed in the rocks near the granite contact are somewhat similar to those in the dark andesitic fragments of the Granite Lake breccia. It seems probable that most of the fragments in the Granite Lake breccia were derived from the Cougar Creek andesite member, or from flows equivalent to it.

The mineral percentages in the average Cougar Creek andesite are as follows: Plagioclase phenocrysts, 30; Groundmass, including plagioclase laths, pyroxene, magnetite, chlorite, epidote, 45; Hypersthene phenocrysts, 10; Pigeonite phenocrysts, 10; Magnetite grains, 5.

Morse Creek Andesite

The next higher division of the Keechelus, although the stratigraphic relationship of this member is not entirely clear, is made up of fine-grained flows named here the Morse Creek andesite for its type locality along U.S. Highway 410 east and

west of Morse Creek. Other places where Morse Creek andesite
is well exposed include Mesatchee Creek Falls, which is a few
hundred yards north of the contact with Bumping Lake granite;
in the huge cirque basin at the head of Morse Creek; and on
the west slope of Gold Hill.

Inspection of the topographic map will show that the
area of outcrop does not exceed five or six square miles. It
may seem that this is a small area on which to establish one
of the four main divisions of the Keechelus. Nevertheless,
the Morse Creek andesite is a distinctive part of the Keechelus
and will undoubtedly be identified at other places within the
province of the Keechelus. It was tentatively identified by
the writer on a saddle north of Mt. Baldy.

Exposures of Morse Creek andesite are dark brown or
reddish in color due to the oxidation of pyrite which
impregnates all Morse Creek rocks. The rock is dense and
brittle. Breakage usually occurs along tiny mineralized
veinlets often making it difficult to obtain a fresh surface.
When a freshly broken surface is obtained, cubes of disseminated
pyrite are easily seen without a hand lens.

Structure in Morse Creek andesites could not be
determined, either because the rock is practically structureless
or because structures that were present have been obscured by
fracturing and pyrite mineralization and oxidation. A
luxuriant growth of timber is of no great aid either. From

what observations could be made, the rocks of this member participated in the regional northerly dip of the Keechelus series.

Megascopic description. Megascopically the rock shows a compact, dense texture. Fresh surfaces are light to dark gray in color, the lighter colors predominating. Thin rims of reddish iron oxide on the borders of the specimen indicate weathering along fractures. The rock is so dense-textured that seldom can any determination of mineral composition be made in hand specimen.

Microscopic description. Without exception the Morse Creek andesite is strongly altered to calcite and sericite with subordinate amounts of ferromagnesian alteration products such as chlorite, epidote, actinolite, etc. Magnetite is excessive in this group. It occurs as irregular grains, as pseudomorphs after pyrite, and as dust that fills calcitized phenocrysts of plagioclase feldspar. The Morse Creek andesite includes some fragmental textured rocks, but in comparison with the Richmond breccias (cf. below) the percentage of broken material is very small. Apparently the andesite was rather low in primary ferromagnesian minerals, judging from the scarcity of their alteration products. Although secondary chlorite, hornblende, and epidote were observed in most thin sections, this type of alteration mineral is much less abundant than in most of the other Keechelus rocks. Remains of the original

mafic minerals are seldom seen, but they were found in one or two sections and were identified as titanaugite and hypersthene.

Under plain light the rock appears as a confused dense matte of tiny feldspars, calcite, and sericite, with minor chlorite, hornblende, actinolite and sometimes biotite. Magnetite dust may outline former crystals. Under crossed nicols outlines of plagioclase phenocrysts that have completely gone to granulitic calcite and sericite are well defined. The composition of the feldspar phenocrysts cannot be determined. Their average length is .04mm. The average length of the tiny feldspars in the groundmass, when enough of their outline is left to measure, is .01mm.

All sections are copiously spotted with pyrite and magnetite. Replacement of pyrite by magnetite is common and occurs in all degrees from incipient to complete.

Specimens taken near the contact with Bumping Lake granite are always high in granulitic biotite, whereas that mineral is a very minor constituent or absent entirely in specimens collected away from the contact.

Quartz is abundant along the numerous small fractures and occurs also in cryptocrystalline pods in the groundmass. It is often associated with pyrite and belongs, like pyrite, to a late phase of mineralization.

The average mineral percentages of Morse Creek andesite not including that part affected by contact metamorphism are:

matte, including feldspar, calcite, sericite, chlorite, magnetite, and quartz, 80; plagioclase phenocrysts, 10; pyrite, 5; magnetite, 5.

Richmond Breccias

This is by far the thickest member of the Keechelus series and encompasses a great variety of indurated, fragmental volcanic rocks and associated flows. The majority of the rocks in this division show the effects of fragmentation. Regional weak to moderate alteration produced abundant chlorite, hornblende, antigorite, and epidote. These minerals lend the Richmond member a distinctive greenish tinge, that is also found in the other members of the Keechelus but not on such a grand scale.

The type locality for this great suite of indurated, fragmental, slightly metamorphosed volcanic rocks is one-half mile west of Richmond Lake in cirque walls that rise vertically for nearly 1,000 feet. There are other excellent exposures of the Richmond breccia. Some of these are House Mountain west of Cougar Lake; in Bear Gap north of Morse Creek and also in the massive cirque basin that forms the headwaters of Morse Creek; in the vicinity of Dewey Lake; and along American River west of the Fourth Crossing.

It may seem unusual that this member which is composed largely of fragmental rocks should be such an excellent

cliff-former. The reason, of course, is that the tuffs and breccias are highly consolidated and form very resistant outcrops. It is difficult to scratch these rocks with a knife, or even to dislodge any fragments from the containing matrix with a hammer.

Andesitic and dacitic flows comprise quite a substantial part of the Richmond breccia member, and it must not be inferred from the name that the formation is composed entirely of breccia. The flows have similarly been altered and display the characteristic greenish colors.

Heterogeneity is the keynote of the Richmond breccias, which can be compared but not correlated with the Sheepskull Gap tuffs, the Sourdough Mountain breccias, and the Starbo altered tuffs as described by Coombs (7) in Mt. Rainier National Park. The Richmond is probably typical of deposits formed during times of widespread explosive volcanic activity followed by periods of relative quiet. Consequently, the initial structural relations may be exceedingly complex in one locality and relatively simple in another.

South and west of Cougar Lake structural altitudes may be easily recorded on moderately dipping beds of indurated pyroclastics and intercalated flows (cf. below). In the Richmond cliffs, however, even though 1,000 feet of section is exposed, it is impossible to distinguish a single structural feature except jointing. These cliffs are cut in a massive,

greenish, directionless pile of volcanic breccias and flows. Southwest of Mt. Baldy, although individual flows and beds of pyroclastics could be distinguished, their structural relationships were so completely jumbled that attempts to interpret the structure in that area were abandoned.

In the Cougar Lake region block-shaped mountains of Richmond breccia with east facing cliffs and stripped structural backslopes dipping west up to 25° suggest block faulting and tilting. Further study indicates, however, that these mountains are west limbs of large north-south trending anticlines. Headward working alpine glaciers on the east slopes removed the east limbs and crests of the anticlinal structures leaving only the west limbs. The steep cliffs on the east side are cirque cliffs rather than fault or fault line scarps. Large scale folding of the Richmond breccias is more pronounced in the vicinity of Cougar Lake than in any other region in the northern part of the Mt. Aix quadrangle.

The widespread alteration in Richmond breccias may be explained by Smith and Calkins' theory (cf. above) of far-reaching circulation of waters heated by igneous intrusion of Snoqualmie granodiorite, or in this specific area by the Bumping Lake granite. Whether the alteration was caused by this mechanism, or by strong deuteric action in this member is not clear. However, alteration on a regional scale, such as is found in the Richmond, cannot be explained simply by the

intrusion of granite, although this has been done by Smith
and Calkins (26) in contrasting the relatively unaltered Fifes
Peak andesite, which was not intruded by granite, with the
Keechelus. In the Mt. Aix area there is no significantly
greater alteration in the Richmond breccias toward the granite
than away from it. In fact the granite in this area is not
in contact with the Richmond, probably because the granite
did not intrude high enough into the Keechelus series to reach
the Richmond breccias.

Megascopic description. The description of one or
even a dozen hand specimens of Richmond breccia would hardly
suffice to illustrate the hundreds of variations that are
found in this member. Consequently, this description will
attempt to point out features that are common to most Richmond
rocks.

Except for some massive flows, a fragmental texture in
varying degrees is universal. The typical color is greenish or
greenish gray. The fragments are often a darker green than the
matrix, but they may be black, gray, white, or purple. There
is usually no orientation of fragments and often a large range
of fragment sizes is observed. The large fragments measure
about twelve inches in their greatest dimension, and the
smallest go beyond the megascopic range. Fragments are always
angular. There are water laid tuffs, but there has been no
widespread reworking by streams and rounding of fragments.

This fact would indicate a rapid and rather continuous deposition of volcanic materials that was uninterrupted for any great length of time by cycles of erosion. The fragments are frequently porphyritic, diabasic, or pilitic in texture. The source of these porphyritic fragments is not definitely known, but they were probably derived from the Cougar Creek or Morse Creek andesites or their equivalents.

Irregular and sometimes rather large grains of white quartz up to 1cm. in length may occur in the matrix between fragments. In some of the Richmond rocks quartz is a minor constituent. Therefore, rocks of this member vary in composition from dacite to andesite. Basaltic flows also occur, but they are of minor importance.

Vesicular textures are not common, although fragments within the breccia are sometimes vesicular.

Microscopic description. If there is any item of uniformity in the Richmond breccias, it is best displayed in the similarity of some of the fragments dispersed throughout this member. The fragments in question are porphyritic, pilitic, or diabasic textured andesites, and they seem to enjoy a rather general distribution in the Richmond breccias. The feldspar in these fragments ranges in composition from labradorite, Ab4 to andesine, Ab6. The plagioclase laths vary in length from .02mm to 1.5 mm. Carlsbad twinning is common. The plagioclase is in various stages of alteration to calcite
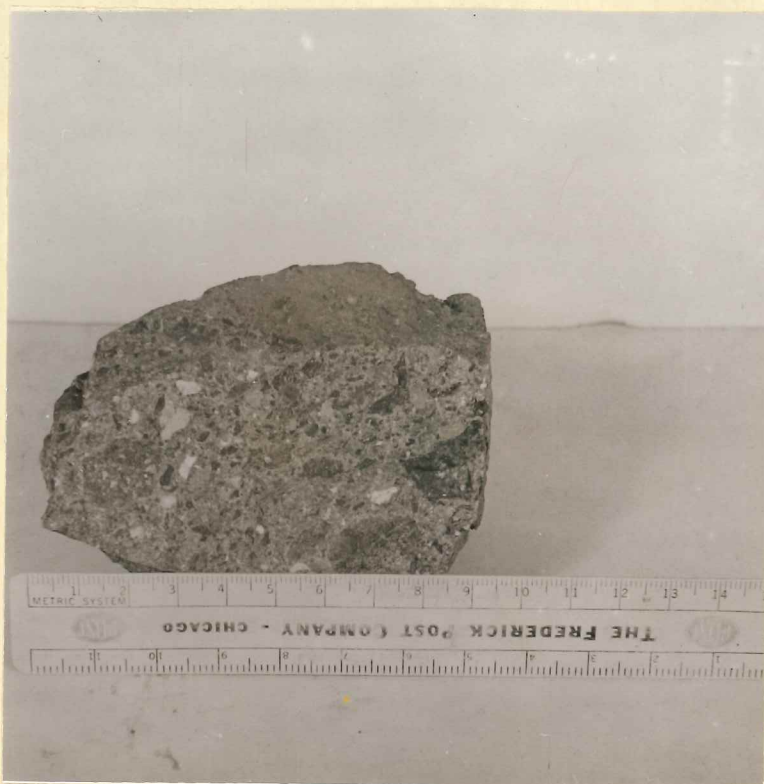
Plate 11.   A specimen of the highly indurated
            Richmond breccia from the Keechelus.
            Dark green and white fragments are
            embedded in a light green matrix.

and epidote. Magnetite dust often rims the laths of plagio-
clase. The groundmass of the fragments is usually composed
of very fine intersertal chlorite, epidote, actinolite,
magnetite, and remnants of pyroxenes that were probably
pigeonite and hypersthene. Some fragments are slightly
amygdaloidal. The amygdules are commonly chlorite or calcite.

In addition to the type of fragments mentioned above
there is, of course, a great variety of all kinds of volcanic
ejecta including ash, glass, pumice, chips and blocks of
diversified volcanic rocks.

In the hypocrystalline groundmass between fragments,
phenocrysts of quartz and plagioclase feldspar commonly provide
a subordinate porphyritic texture to the tuffs and breccias.
The phenocyrsts may reach 3mm. in length. Replacement of the
plagioclase by calcite, epidote, and quartz frequently occurs.
In fairly fresh feldspar grains oscillatory zoning is evident;
the zones always becoming more sodic toward the outside of the
phenocryst. Some feldspars are replaced by cryptocrystalline
quartz and feldspar. The quartz phenocrysts are deeply
corroded. Embayments of matrix material into the quartz grains
give a ragged, moth-eaten appearance to the mineral. Quartz
usually shows undulatory extinction.

The rock material forming the matrix of the breccia is
a confused mass of tiny fragments, ash, glass, magnetite, and
the familiar alteration products of the ferromagnesian minerals.
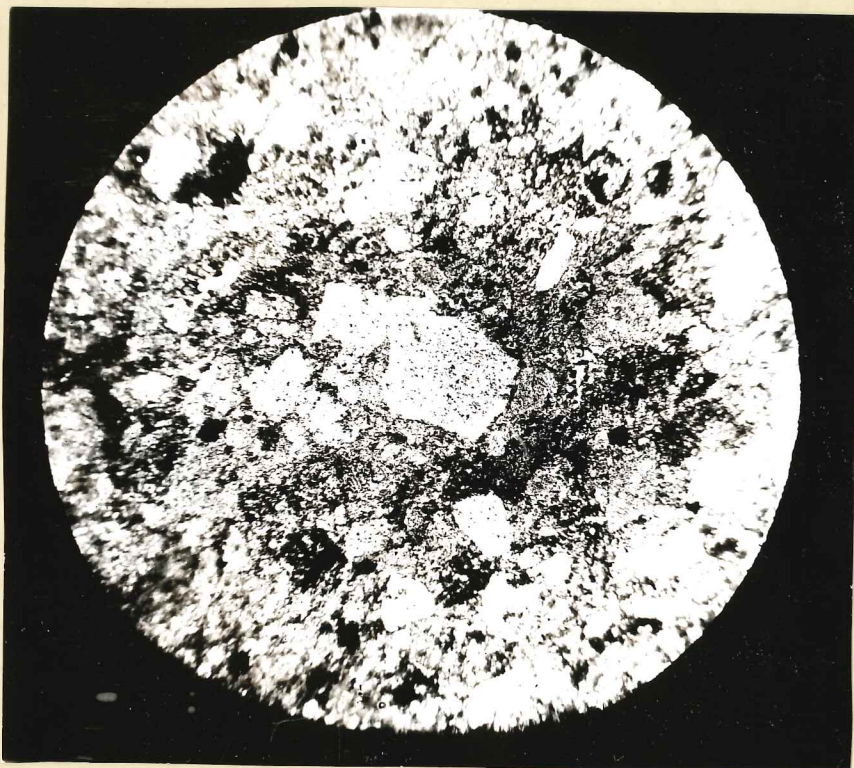
Plate 12.   Photomicrograph of the Richmond
            breccia of the Keechelus.
            x 15, Plain light.

In some thin sections subhedral biotite granules are very
abundant around grain boundaries of decomposed quartz and
feldspar. The biotite is light in color. These are not the
ragged remnants of biotite that are so frequently seen in this
area, but are recrystallized grains probably formed by deuteric
action. This generation of biotite shows no alteration to
chlorite.

Magnetite in the form of dust or specks is a consistent
ingredient of the Richmond breccias. It does not, however,
occur in excess. Titanite, when present, is usually partly
altered to leucoxene.

A rough approximation of the percentage of constituents
in the Richmond breccias is as follows: matrix, including
chlorite, calcite, epidote, antigorite, biotite, magnetite,
glass, ash, and very small fragments, 40; fragments with
porphyritic texture, 15; other fragments, 15; plagioclase
phenocyrsts, 10; quartz phenocrysts, 3; magnetite specks, 2;
miscellaneous, 15.

Mt. Aix Andesite and Dacite Porphyries

The upper member of the Keechelus series, the Mt. Aix
porphyries, are distinguished from the lower portions by two
main criteria. One is the outstanding porphyritic texture of
the flows, and the other is the distinct decrease in intensity
of alteration. Fragmental rocks are intercalated with the

porphyritic flows, but they are of minor importance. The flows consist of both andesites and dacites, although the andesites are probably predominant. Surfaces exposed to weathering display many colors which are principally shades of brown, red, and gray, although greenish gray, bluish gray, and purple are also fairly common. Phenocrysts of quartz and feldspar which often prove to be glomeroporphyritic clusters under the microscope measure up to 8mm. in length.

The type locality for these porphyries is the high barren peak of Mt. Aix which exhibits along its flanks a great diversity of porphyritic flows. Other localities where Mt. Aix porphyries form good outcrops are all high topographically and stratigraphically. Two of these are Norse Peak, which is in the north-west corner of the topographic sheet directly on the Cascade crest line and marked with an elevation of 6,862 feet, and Nelson Butte north-east of Mt. Aix.

Structure in this member is more easily recognized than in some of the lower members for two reasons. One, the more thinly bedded flows reflect structure better than the massive ones, and second, the Mt. Aix porphyries are usually found in the highest elevations where forest cover does not obscure the structure. Homoclinal structure typifies the Mt. Aix member. Along the steep north face of Mt. Aix and Nelson Butte the flows are dipping northeasterly between 15° and 20°. There are few local flexures and faulting, if any, is very

minor. Near the summit of Norse Peak the dips are also
gentle and homoclinal. In this area northerly dips of
approximately 15° prevail.

At no place was the writer able to locate the contact
or zone of transition between the top of the Richmond breccias
and the bottom of the Mt. Aix porphyries. This unsatisfactory
result is at least consistent, because the transition of any
of the Keechelus members into a higher or lower member was
never definitely located.

Megascopic description. Volcanic flows with large
phenocrysts of chalky feldspar and/or clear quartz set in a
dense textured, dark-colored matrix characterize most Mt. Aix
porphyries. The rocks have a generally fresh and unaltered
appearance that is quite different from the altered Richmond
rocks described above. Fragmental textures are not altogether
lacking, but they are subordinate to the prevailing porphyritic
textures. Megascopic flow structures in the finer-grained
porphyries are sometimes seen. Open vesicles, although they
are not abundant, are found in some flows.

Microscopic description. Large, euhedral to subhedral,
blocky plagioclase grains are embedded in a finer, hypo-
crystalline matrix of plagioclase, pyroxenes (pigeonite and
hypersthene), glass, magnetite, chlorite, and biotite. The
feldspar phenocyrsts are usually fresh, although some are
partially sericitized. Albite twinning and carlsbad twinning
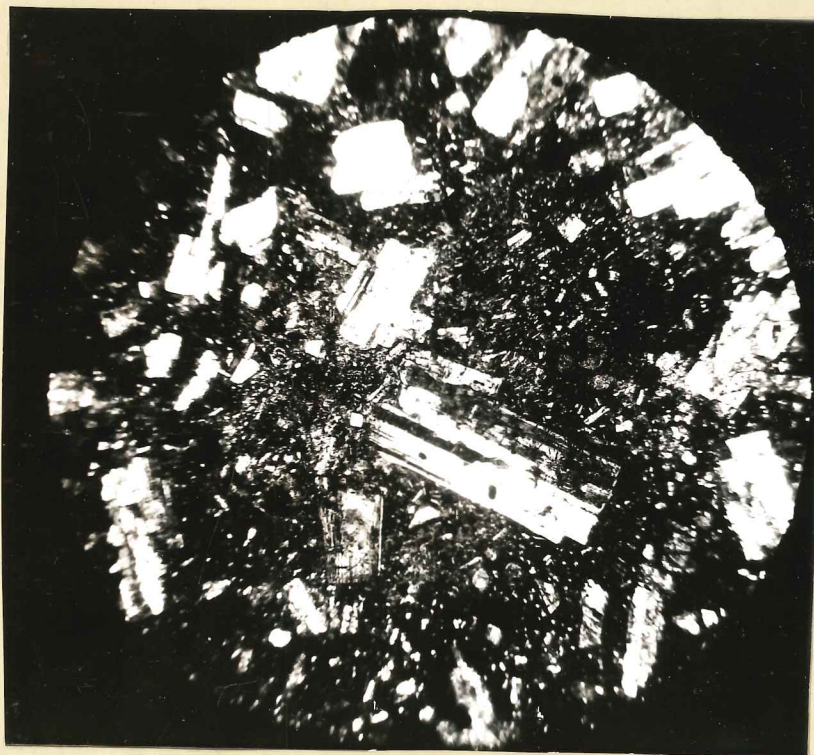
Plate 13.   Photomicrograph of the Mt. Aix
            andesite porphyry of the Keechelus.
            Note the euhedral, large, blocky
            phenocrysts of plagioclase (ande-
            sine), set in hypocrystalline matrix.
            x 15, Crossed nicols.

both occur, but the albite twinning is predominant. The
plagioclase phenocrysts range in composition from labradorite
Ab 48 to andesine Ab 65. Glomeroporphyritic clusters of
plagioclase with associated grains of pyroxenes and magnetite
are very common. Most of the larger phenocrysts observed in
hand specimen are glomeroporphyritic. Oscillatory zoning in
plagioclase is exceptionally well-developed. The change of
composition is always from more calcic centers to more sodic
rims. In most zoned grains the zone boundaries are regular,
sharp cornered, and evenly spaced. Some plagioclase phenocrysts
are broken by cataclastic shattering. Many thin mylonitic
zones composed of cryptocrystalline quartz, feldspar, and
calcite in the groundmass are also indicative of rather severe
cataclasis.

The pyroxenes, which are pigeonite and hypersthene,
occur as small phenocrysts and as fine grains in the groundmass.
Alteration to hornblende, chlorite, epidote, and magnetite is
fairly well advanced in the smaller particles of the groundmass,
but alteration of the phenocrysts is incomplete and is
restricted to cracks in the minerals and portions of the rims.
The pyroxene phenocrysts vary in length from .1mm to .5mm.
Twinning in the pigeonite is very common. The hypersthene is
only slightly pleochroic, and Schiller structure is seldom well-
developed.

An approximate percentage of the constituents in the

Mt. Aix porphyries is as follows: matrix, including feldspar,
magnetite, hornblende, chlorite, epidote, pyroxenes, and glass,
70; plagioclase phenocrysts, 15; pigeonite phenocrysts, 5;
hypersthene phenocrysts, 5; magnetite grains, 5.

Summary of the Keechelus Andesite Series

Coombs (7) stated in his summary of the Keechelus in
Mt. Rainier National Park that:

> After examining several hundred thin sections of
> Keechelus rocks, the writer was impressed by three
> characteristics that were almost unfailingly present.
> One of the most constant characteristics is a
> porphyritic texture.... Another distinguishing trait
> is the presence of abundant opaque minerals. In the
> vast majority of cases magnetite may be seen as dust,
> small granules or moderately sized grains...the size
> being roughly proportionate to the dimensions of the
> other minerals in the groundmass.... The green color
> of so many of the Keechelus rocks is undoubtedly
> related to the presence of chlorites, serpentines,
> actinolite, and, to a smaller extent, the pyroxenes.

To Coombs' suite of Keechelus rocks the writer can add
nearly a hundred thin sections and specimens. Results gained
from the present study verify Coombs' observations in nearly
every detail. The only point of difference is that in the Mt.
Aix area the highest member of the Keechelus series, the Mt.
Aix porphyries, do not prominently display the characteristic
greenish colors.

As a minor point, Coombs mentions that:

> The feldspars are zoned more often than not and
> usually contain inclusions of material identical to
> that in the groundmass.

Although zoning in plagioclase is common in the
Keechelus rocks in the Mt. Aix quadrangle, unzoned feldspars
predominate.

The most significant features of the Keechelus in the
Mt. Aix quadrangle as determined in this study might be summed
up as follows:

1. Possible thickening of the Keechelus series to
the east of Mt. Rainier National Park.

2. A concordant and apparently conformable contact
with underlying Puget Group sandstone.

3. An unconformable contact with overlying Fifes
Peak andesite.

4. The tentative stratigraphic division of the
Keechelus into four members.

5. Stronger alteration concentrated in the middle
members and weaker alteration in the lower and upper members.

Fifes Peak Andesites

The Fifes Peak formation, formerly called "upper"
Keechelus, constitutes a tremendous accumulation of andesitic
flows with intercalated trachyitic to andesitic pyroclastics.
The pyroclastics are perhaps more abundant than the flows, but
no measurements to determine their relative percentages were
taken. The estimated thickness of the Fifes Peak series in

this area is 3,000 feet. This figure is conservative. Warren
(29) had a thickness of 2,700 feet of Fifes Peak section in
the Tieton River valley.

Whereas the greens and grays are predominant colors
in Keechelus outcrops; brown, yellow, reddish, and buff
characterize the Fifes Peak series. This difference in color
between Keechelus and Fifes Peak is an excellent but not
infallible guide in differentiating the two series. It is due
to the degree of alteration, the Keechelus being the more
strongly altered of the two. Whereas the Keechelus rocks
contain abundant green alteration products such as chlorites,
epidote, antigorite, actinolite, and hornblende, the Fifes
Peak rocks show only the incipient formation of these minerals.

One of the most helpful criteria in recognizing Fifes
Peak rocks is a sub-resinous luster of the freshly broken
surface. Both the vitric pyroclastics and the andesitic flows
display this luster, which is imparted to the rock by its high
content of pyroxenes, particularly hypersthene.

The Fifes Peak andesites occupy roughly 25 percent of
the total area mapped. The northward extent of this formation
in the Snoqualmie quadrangle has not been established, nor is
its full extent in the Cedar Lake quadrangle known. That it
will be identified in the southwest corner of the Cedar Lake
quadrangle is certain, because Castle Mountain, an excellent
exposure of 2,000 feet of Fifes Peak series, continues from the

northwest corner of the Mt. Aix quadrangle into the Cedar Lake
quadrangle.

Warren (28,29) found Fifes Peak andesites in the eastern
most part of the Mt. Aix quadrangle and also in the western
part of the Ellensburg quadrangle.

The Fifes Peak series disappears beneath Yakima basalt
in the southern portion of the Mt. Aix quadrangle, but reappears
in the Mt. Adams quadrangle. Warren (29) suggests a possible
correlation of Fifes Peak andesite with Miocene Eagle Creek
formation which was described by Hodge (19) in the lower
Columbia River valley. Judging from Hodge's description and
the stratigraphic position of the Eagle Creek formation, which
is directly under the Yakima basalt, the possibility that these
two andesitic series are contemporaneous should receive careful
consideration from workers in the Mt. Adams quadrangle.

The Fifes Peak series is one of the three major masses
of extrusive rocks in the northern Mt. Aix region. The others
are the Keechelus, which lies unconformably below the Fifes
Peak, and Yakima basalt which disconformably overlaps the Fifes
Peak andesites. The stratigraphic position of the Fifes Peak
andesites was not properly interpreted by Smith and Calkins (26)
in the Snoqualmie quadrangle or by Smith (25) in the Ellensburg
quadrangle. In the Snoqualmie quadrangle Smith and Calkins
placed this formation, which they called Keechelus, above the
Yakima basalt. In the Ellensburg quadrangle Smith mapped Fifes

Plate 14. The contact between Keechelus breccia (right)
and Fifes Peak andesite (left) passes through
the saddle in the central part of the photograph.
This may be a fault contact although direct
evidence of faulting could not be found. The
highest peak in the far background is Mt. Aix.

Peak andesites as Pleistocene Tieton andesites. These errors were corrected by Warren (29) when he traced the Fifes Peak-Yakima contact along the eastern parts of the Mt. Aix quadrangle.

The Fifes Peak andesites overlie the Keechelus series with definite angular unconformity. This contact was described in the chapter on the Keechelus. Localities where this relationship may be observed are: near the headwaters of the North Fork of Union Creek; along Goat Creek in the northwest corner of the quadrangle; and along North Fork Creek. Fifes Peak volcanics also rest with angular unconformity upon the large dacite porphyry dike or sill that intruded the Keechelus. An excellent exposure of this contact may be seen on the nose of a hill between Union Creek and American River about two miles west of Pleasant Valley.

Only three erosional outliers of Fifes Peak andesite on Keechelus were identified, and these are so close together that they might better be classified as one erosional outlier. This remnant of the Fifes Peak series is composed of coarsely porphyritic andesite which dips gently eastward. The outlier forms three buttes which tower at least 150 feet above the general crest line of Buffalo Hump Mountain. It is these three peculiar buttes that caused the mountain to be called, "Buffalo Hump". They are extraordinary features and immediately attract the attention of any observer studying the skyline in this area.

Plate 15. Angular unconformity between dacite porphyry, light-colored rock, and Fifes Peak andesite, dark-colored rock exposed on ridge north of American River and east of Union Creek.

Although the actual contact is obscured by talus, it is
certain that the gently dipping Fifes Peak flows unconformably
overlie the Keechelus. The Keechelus below the contact is
dipping approximately 30° north.

No definite age for the Fifes Peak andesitic series
was determined in this work because, except for bits of charred
wood, no fossil remains were found. The most probable age is
lower Miocene. As indicated in the chapter on Keechelus
andesite, insufficient evidence has been presented to justify
dating the entire Keechelus series as Oligocene; therefore an
exact lower age limit for the Fifes Peak series is lacking.
Furthermore, there is no indication of the length of time that
elapsed between the folding and subsequent weathering of the
Keechelus prior to the deposition of Fifes Peak volcanics. In
considering an upper age limit for the Fifes Peak series it is
not known what stratigraphic part of the Miocene Yakima basalt
flows overlapped Fifes Peak, however it seems likely that the
later and upper Yakima basalt flows would have extended farthest
west.

The Ellensburg formation fills synclinal valleys in the
folded Yakima basalt several miles southeast of the area mapped.
The Ellensburg is considered late Miocene in age. This suggests
that the extrusion of Fifes Peak volcanics did not occur near
the close of Miocene time, but more probably in lower Miocene.

Warren (29) noted a striking lithologic and stratigraphic

similarity between Fifes Peak andesite and Taneum andesite
of Miocene age, which outcrops in the Snoqualmie quadrangle.

It is often difficult to definitely locate the contact
between Fifes Peak andesite and Yakima basalt. Although the
basalt disconformably overlaps the andesite, the brownish
weathered surfaces of the two rocks are very similar. In
addition both formations dip about 10° east with no angular
unconformity to mark their contact.

On the southeast side of Bumping River upstream from
its confluence with American River a steep 500 foot cliff of
black columnar andesite follows the river for five or six miles
finally culminating in Bald Mountain (usually called Little
Bald Mountain) and then diminishing in height to the west.
The top of the cliff is a flat plateau dipping gently east.
Warren mapped these flows as Yakima basalt, which they closely
resemble. The writer also mapped them as Yakima from a distance
during the first field season, but during the second field
season a close inspection of the hand specimen showed that
these cliffs were Fifes Peak andesite. This was confirmed by
microscopic examination. The black andesites that form these
prominent cliffs are underlain by buff-colored Fifes Peak
pyroclastics and overlain disconformably by the true Yakima
basalt.

The ridge that forms Little Bald Mountain resembles a
hogback with the backslope dipping 25° southeast. It is

Plate 16. Massive andesite flows overlying pyroclastics.
Both members belong to the Fifes Peak formation
although the massive flows have been mistaken
for Yakima basalt.

composed of Fifes Peak andesite. This ridge, which may be
followed eastward by eye, outcrops as a high rugged knob called
Edgar Rock on the west side of the Naches River. Structurally
the ridge may be a dike or sill of Fifes Peak andesite, or it
may be a more resistant flow on the south limb of an eroded
east-west anticline in folded Fifes Peak andesite. From field
relations it could not be determined which interpretation is
correct.

Some flows, notably those near the top of the Fifes
Peak series are extremely vesicular. Along the crest of
American Ridge--east of its high point, Goat Peak, the rocks
are at least 30 percent void space. Other flows in the Fifes
Peak series may vary from this extreme degree of porosity to
dense, low-porosity andesite. As indicated above the dense
andesite may easily be mistaken at a distance for Yakima basalt.

The pyroclastics vary in degree of consolidation from
beds of loose particles that become almost free-running when
struck with a pick, to moderately well-indurated tuffs and
breccias. In no case, however, does the consolidation and
induration of the fragmental volcanics approach the highly
indurated condition of the Keechelus rocks. Two good examples
of the unconsolidated pyroclastics include the large exposures
near the top of the Hall Creek trail which ascends Fifes Ridge
just downstream from Hells Crossing, and the vertical cliffs
one-half mile north of Little Bald Mountain. At the latter

place weathering processes and surface wash are rapidly removing
great amounts of the unconsolidated material. Easily accessible
exposures of the more indurated pyroclastics occur in road cuts
along the Bumping River road about four miles east of Goose
Prairie. Many fragments of charred wood in these tuff and ash
beds indicate that deposition of Fifes Peak volcanics was not
entirely continuous, but that enough time elapsed between
floods of lava and showers of ash and tuffaceous material for
soils to form and forests to grow.

In one place reworking of the Fifes Peak volcanics by
running water is well shown. This is on the north side of the
Bumping River road approximately two and one-half miles up
Bumping River from American River Crossing. A thirty-foot bed
of very coarse conglomerate, which is composed of rounded Fifes
Peak andesite cobbles, dips 25° north. Stratification and
bedding although present are not well-developed. Branches of
carbonized wood and even small stumps occur in bands and seams
in the conglomerate. The smaller pieces of these woody materials
have been transformed to lignite. All the cobbles are composed
of Fifes Peak andesite. They are weathered but not rotten, and
are coated with thick, sticky manganese oxide. Volcanic ash
is the principal cementing matrix. The bed of conglomerate can
be followed for one hundred yards along the strike. It ends
rather abruptly to the east against a slide of fine powdery
volcanic ash, and to the west it dips into the hill and

Plate 17. Fifes Peak andesite on north side of Bumping
           Lake road. Columnar jointed flow overlies
           moderately well-consolidated bed of volcanic
           tuff, which contains many fragments of
           charred wood.
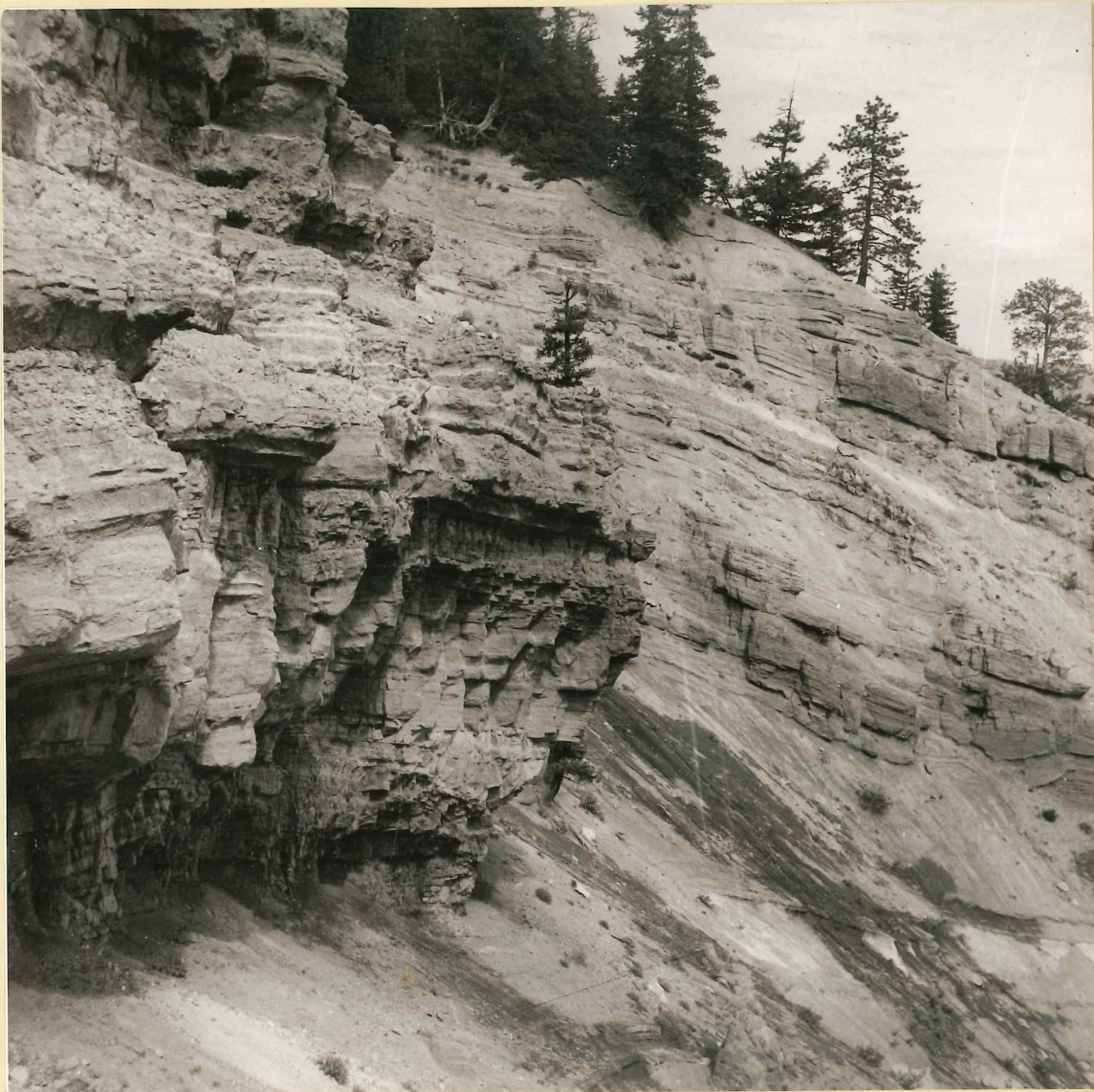
Plate 18. Well-bedded, loosely consolidated pyroclastics
of the Fifes Peak formation along the north
side of American River canyon.

Plate 19.   Unconsolidated pyroclastics of the Fifes Peak
            formation along the ridge north of American
            River. Note the slump in the beds in the middle
            of the photograph. Note also the abrupt change
            in fragment size from the lower to the upper beds.

disappears beneath a mantle of soil and vegetation.

Warren postulated that the groups of needles and
pinnacles north of American River which collectively are called
Fifes Peaks, and for which he named the Fifes Peak formation,
are remnants of a Miocene volcano. The peaks are composed
almost exclusively of volcanic breccia and agglomerate. The
writer does not agree with Warren's conclusion for several
reasons. As seen looking north from the crest of American
Ridge the Fifes Peaks needles are contained within a large,
synclinal, rudely saucer shaped, structural basin of Fifes
Peak (formation) flows and pyroclastics. This synclinal
structure indicates no displacement or interruption in continuity
that would be evident if a volcanic disturbance had penetrated
such a structure. Secondly, the enormous thickness of breccia
and agglomerate, of at least 1,200 feet, and also the areal
extent of approximately seven square miles restricts the
possibility that Fifes Peaks are the remnants of a volcano
unless it was unusually large. Thirdly, the breccias and
agglomerates are moderately well-bedded and dips are gentle.
In the southernmost part of the Snoqualmie quadrangle towering
cliffs of Fifes Peak breccia and agglomerate expose well-defined
bedding which is dipping gently northeast. These beds may be
traced directly to Fifes Peaks. If these fragmental rocks were
formed in the throat of a volcano, or volcanoes, no such
continuous bedding and gentle dips could be expected. Instead
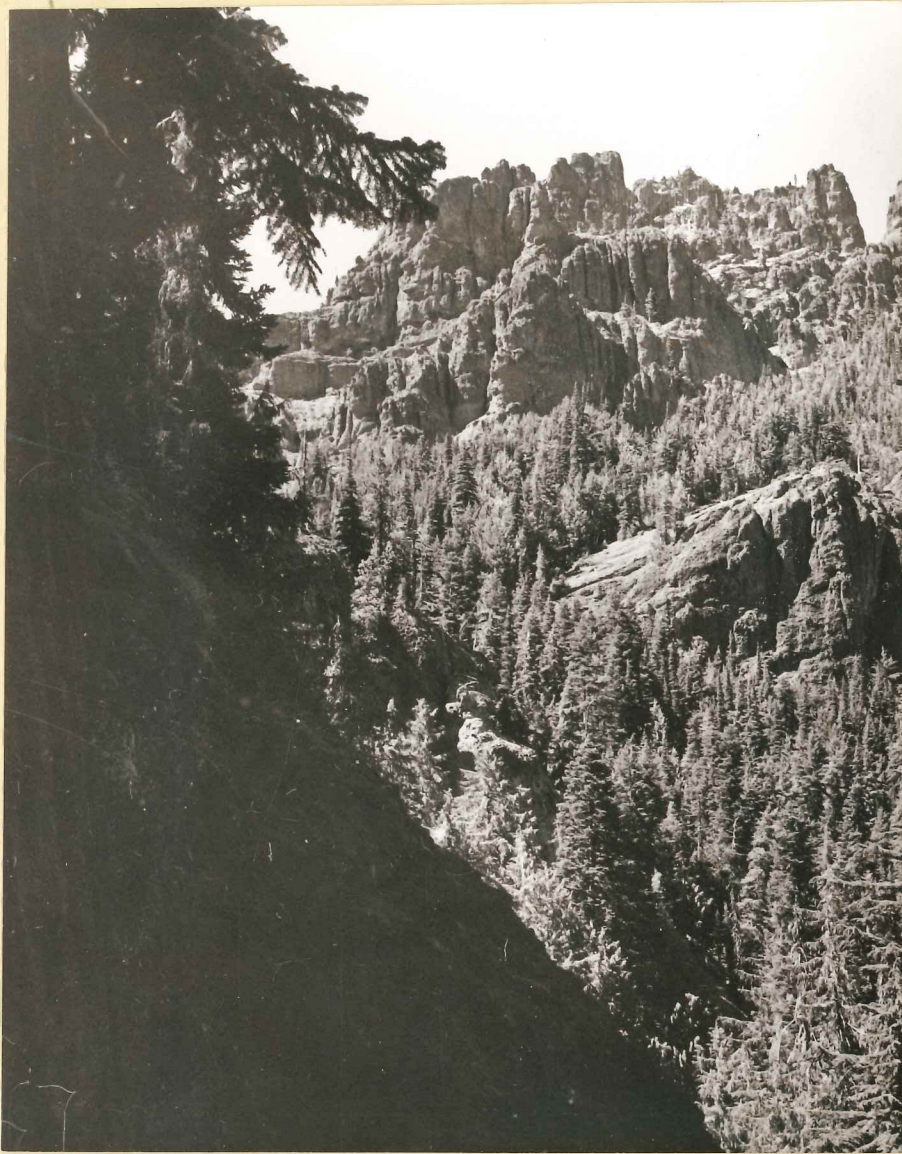
Plate 20.   Looking north toward one cluster of Fifes
            Peaks pinnacles. Note the strong north-
            south jointing in the volcanic breccias
            and agglomerate.
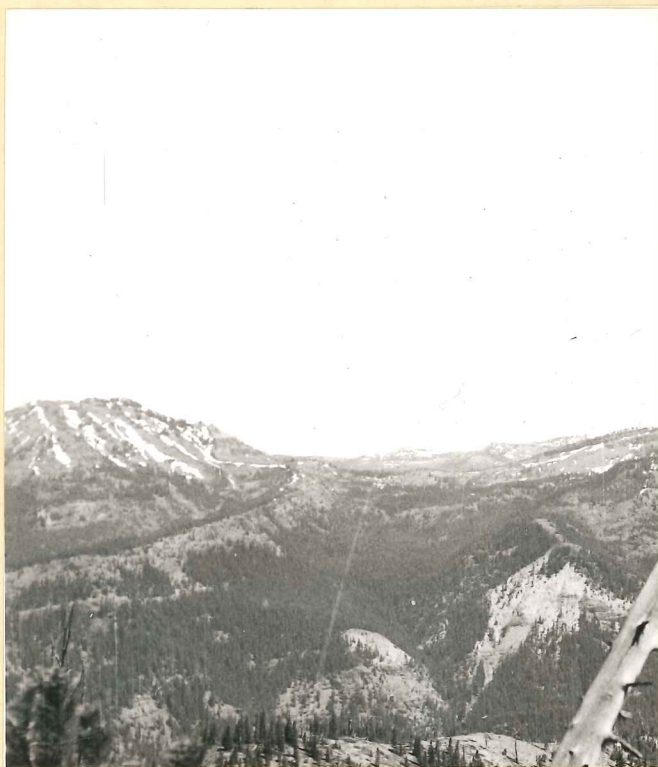
Plate 21.   East limb of the syncline composed
             of Fifes Peak flows that passes beneath
             the volcanic breccias and agglomerates
             that form the spindles and pinnacles of
             Fifes Peaks (mountain). Photograph is
             taken looking north from American Ridge.

poorly defined structure and steep dips would predominate.
The structure of fragmental rocks within a volcanic vent
customarily is at a wide divergence with the regional structure.
The breccias and agglomerates of the Fifes Peaks, however,
conform rather closely to the dips in the rest of the Fifes
Peak formation. The bedding in the central portion of the
rugged Fifes Peaks pinnacles lies nearly flat or is inclined
moderately southward.

The writer's explanation of the Fifes Peak breccias
and agglomerates is that they filled a broad synclinal warp in
the Fifes Peak flows. The source of this great volume of
fragmental rocks is not known, but it was probably a volcano
somewhere near the site of the present deposits of breccia and
agglomerate. Evidence of the existence of such a volcano has
been destroyed or not yet discovered.

The pyroclastics that comprise Fifes Peaks are very
coarse, sub-angular to sub-rounded breccias and agglomerates
which are firmly cemented by small amounts of volcanic ash.
The large fragments, which vary from three to eight inches in
diameter, account for 80 percent of the pyroclastic material.
Smaller pyroclastic fragments down to the size of ash are in
the minority. The terms breccia and agglomerate are used here
in accordance with their definition by Wentworth and Williams
(31).

They define volcanic breccia as:

More of less indurated pyroclastic rock consisting chiefly of angular ejecta 32mm or more in diameter.

Agglomerate, as defined by Wentworth and Williams is:

A contemporaneous pyroclastic rock containing a predominance of rounded or sub-angular fragments greater than 32mm in diameter lying in an ash or tuff matrix and usually located in volcanic necks (in which case the term vent agglomerate should be used) or at a short distance from them.

According to the latter definition the term "agglomerate" is appropriate here if it is understood that these rocks are not vent agglomerates.

Great amounts of the breccias and agglomerates that composed Fifes Peaks have been removed by the action of two alpine glaciers that headed in the highest portion of the peaks and flowed northward to join the glacial tongue flowing eastward down the Crow Creek valley. If the volume of breccias and agglomerates that were removed from the Fifes Peaks area were restored, these fragmental rocks before glaciation would have had an average thickness in excess of 1,000 feet and would have covered approximately seven square miles.

A notable feature of Fifes Peaks is the strong northwest jointing in the breccias and agglomerates. In aerial photographs the northwest trending joint pattern is remarkably well shown. Weathering along the continuous and often open parallel vertical joints is responsible for the needles and spindles and the castle-like skyline that characterizes Fifes Peaks. Weathering

Plate 22.   Typical outcrop of the coarse agglomerate
            and volcanic breccia that compose Fifes
            Peaks.

Plate 23. Typical coarse volcanic breccia and
agglomerate of Fifes Peaks.

processes attacking along the joints cause slabs to break off
in huge sections. House-size boulders of breccia and
agglomerate that are fragments of these slabs are strewn in
confused heaps around the base of the peaks.

Petrographic Description of Fifes Peak Rocks

Megascopic description of andesite flows. The andesite
flows of the Fifes Peak series are much more consistent in
appearance than those of the Keechelus. The rock is invariably
a light to dark brown color on the weathered surface. Light-
colored plagioclase laths and vitreous, sometimes iridescent
hypersthene crystals are often large enough to be detected with
the naked eye. On the fresh surface a characteristic sub-
resinous luster and color is distinctive of the Fifes Peak
rocks. A sugary texture is frequently present on the freshly
broken surface. The rock is usually finely vesicular, but
certain flows are highly and coarsely vesicular. The vesicles
are commonly coated with red iron oxide. Quartz and opal
sometimes occur as vesicular filling.

Microscopic description of andesite flows. For the
purpose of microscopic description, the andesite flows must be
divided into two general categories on the basis of texture.
The first category includes those porphyritic andesites with
a holocrystalline to hypocrystalline matrix and medium sized
phenocrysts, and the second category includes those andesites
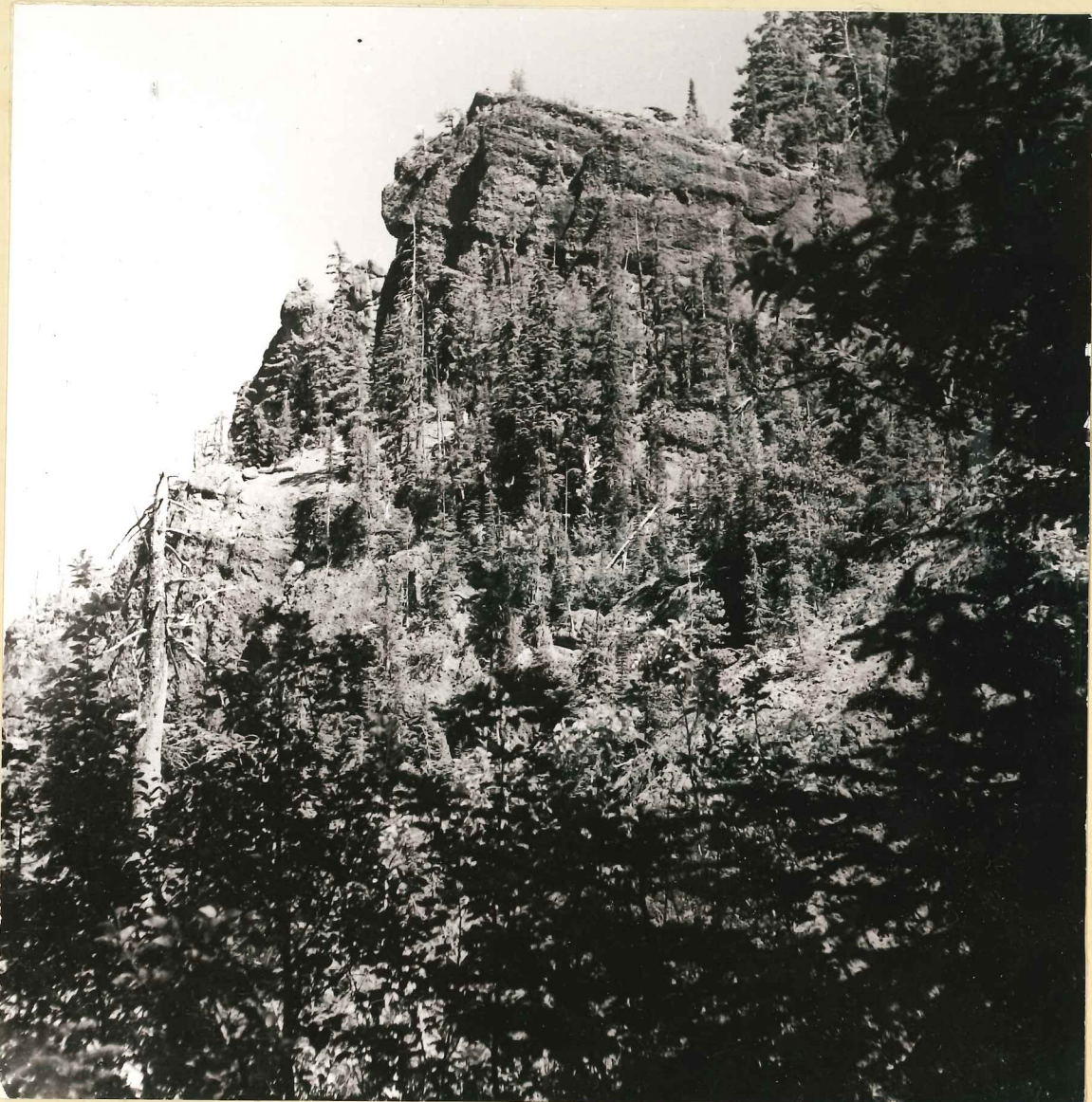
Plate 24.   Well-bedded volcanic breccia and agglomerate
south of Fifes Peaks. The gentle dip is
typical of the volcanic materials composing
Fifes Peaks.

Plate 25.   Looking southeast down Quartz Creek. Cliffs
            are bedded, gently dipping breccia and
            agglomerate identical to that that composes
            Fifes Peaks several miles to the west.
            The Columbia Plateau forms the skyline.

Plate 26. Looking southwest toward pinnacles of Fifes Peaks which are composed of volcanic breccia and agglomerate. The cliffs in the foreground are composed of the same materials.
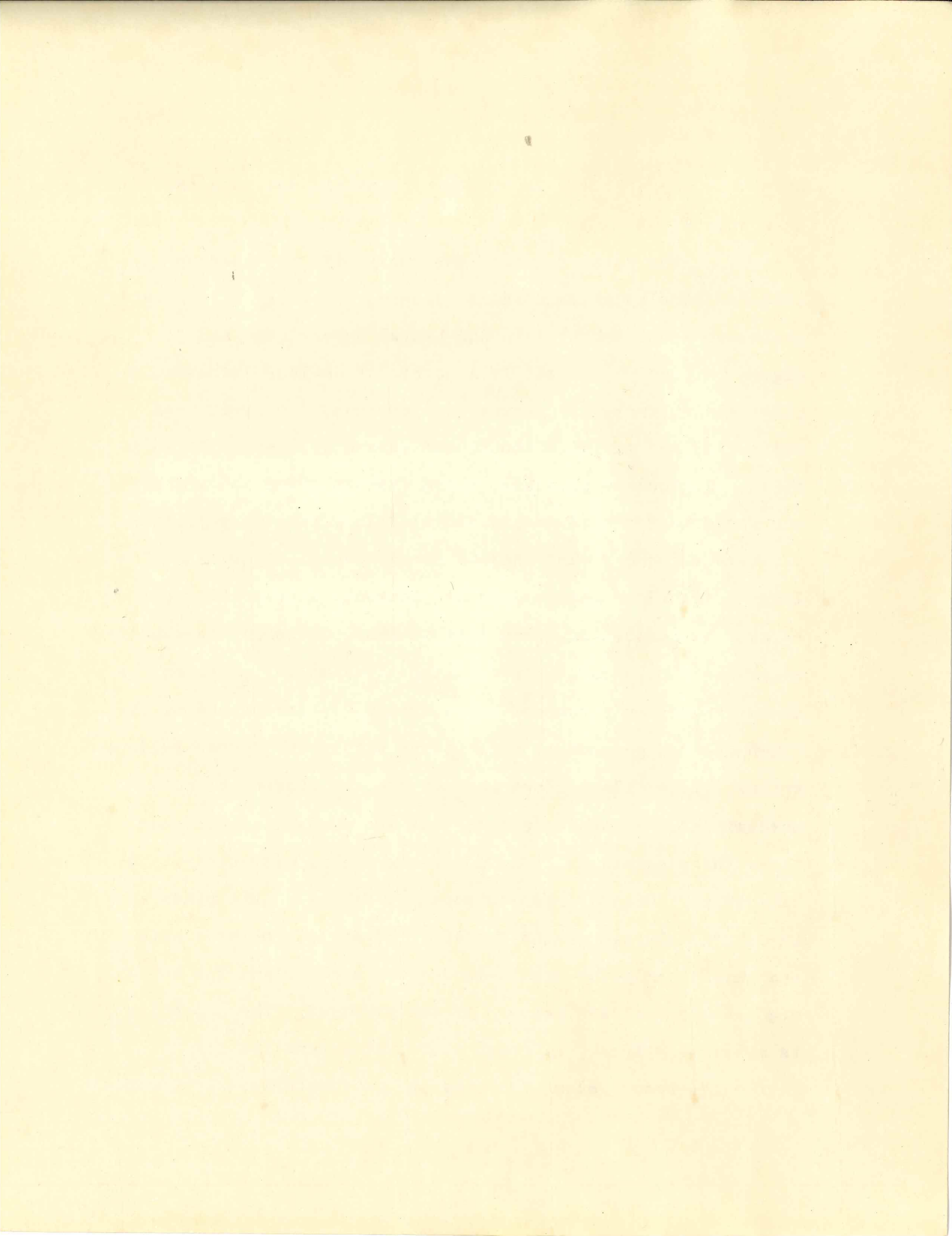
is subordinate in amount to pigeonite, however, like the pigeonite, it forms euhedral to sub-hedral grains and is very slightly altered. Magnetite in the form of granules or dust is scattered throughout the rock, but tends to concentrate in the glomeroporphyritic clusters.

The groundmass of the coarsely textured andesite porphyries may be composed entirely of small crystals of plagioclase, pyroxenes, and magnetite, or it may contain these minerals embedded in varying amounts of dark volcanic glass. The groundmass is made up primarily of small euhedral laths of calcic andesine, irregular small grains of intersertal pigeonite and hypersthene, and specks of magnetite. The small andesine feldspar laths average .15mm in length. They are fresh and frequently twinned according to the Carlsbad law, although albite twinning also occurs. These small feldspars are often oriented by flowage. This is well seen near the large phenocrysts of labradorite around which the andesine laths pass in perfect alignment like chips on a stream. The fine-grained pigeonite and hypersthene in the groundmass occupy the spaces between the small laths of andesine. These pyroxenes show incipient alteration to chlorite. A few scattered grains of quartz are probably derived from devitrification of the volcanic glass in the groundmass.

A tabulation of percentages of constituent minerals is as follows: plagioclase phenocrysts, 25; plagioclase in

groundmass, 35; pigeonite, 25; hypersthene, 10; magnetite, 3; chlorite, 2.

Fifes Peak andesite porphyries in the second category are much finer-grained than those just described and contain a higher percentage of volcanic glass. The mineral assemblage is, however, nearly identical in both types. Small grains of plagioclase, pigeonite, and hypersthene are set in a felted matrix of tiny feldspar needles, minute specks of pyroxenes, magnetite dust, and dark glass which sometimes constitutes nearly the entire matrix. The larger plagioclase phenocrysts are euhedral to sub-hedral, and average .25mm in length. They may be untwinned or twinned according to the Carlsbad or albite laws, although Carlsbad twinning is the more common. The composition of the plagioclase phenocrysts is approximately labradorite, Ab46. The plagioclase may occur in glomeroporphyritic clusters which also include grains of pyroxenes and specks of magnetite. The largest grains of pigeonite and hypersthene reach .25mm in length.

The felted groundmass which is predominantly glass heavily charged with magnetite dust contains very small needles of plagioclase whose composition could not be determined. The needles average .01mm in length and are as small as .005mm. In the thin sections examined these small needles of feldspar are unoriented and therefore do not indicate flowage as clearly as the somewhat larger plagioclase laths in the more coarsely

grained porphyries. In the dense glassy matrix very tiny specks of pyroxene may be detected only by their birefringence which is higher than that of the encompassing material.

The percentage of constitutent minerals in the fine-textured andesite porphyry flows is as follows: felted matrix (includes plagioclase, glass, magnetite, pyroxenes and miscellaneous), 70; plagioclase phenocrysts, 10; magnetite specks, 9; hypersthene, 8; pigeonite, 3.

<u>Megascopic</u> <u>description</u> <u>of</u> <u>loosely</u> <u>consolidated</u> <u>tuff</u>. This buff-colored material which occurs as moderately well-stratified beds between andesite flows is a difficult substance to collect because it crumbles when disturbed. The individual fragments are poorly rounded, but are never sharply angular. They are poorly cemented by small amounts of volcanic ash. The fragments are fairly consistent in size which ranges from that of a pea to that of a marble. No thin sections were cut of this material because it is so friable.

<u>Megascopic</u> <u>description</u> <u>of</u> <u>consolidated</u> <u>tuff</u>. Consolidated tuff which has a brownish buff color contains fragments of andesitic porphyries, pumice, glass, charred wood cemented in volcanic ash and glass. The larger fragments average 1-2mm in diameter. Flow structures are frequently present. Around the fragments of charred wood there is always a gray aureole several centimeters in width that was formed by bleaching of ash particles that were in contact with the burning
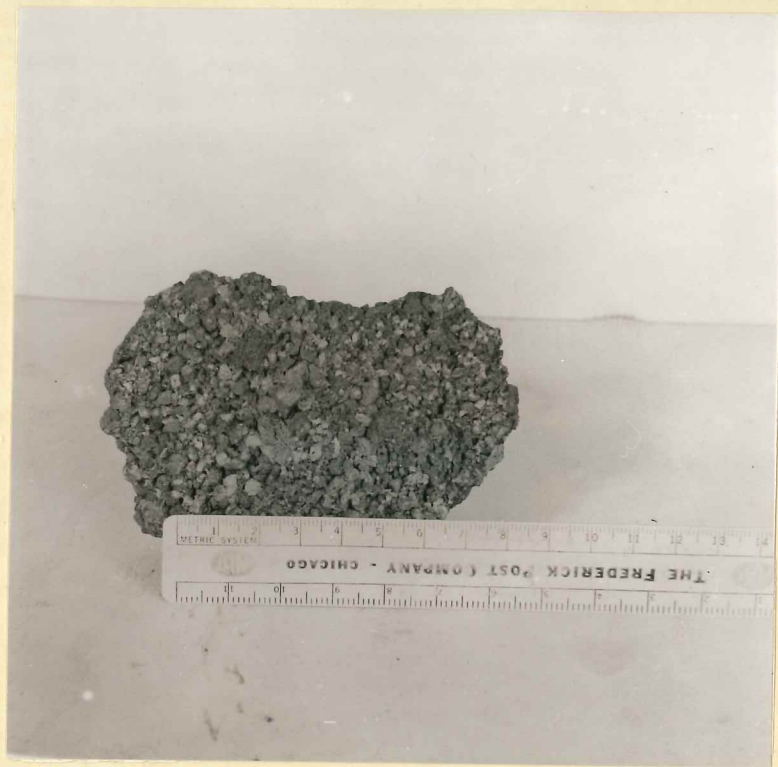
Plate 27.   Loosely consolidated pyroclastics
            from the Fifes Peak formation.

Plate 28.   Fragment of charred wood embedded
             in ashy tuff of the Fifes Peak
             formation.

wood. When specimens of the consolidated tuff are broken the fresh surface is quite smooth and imperfectly conchoidal. There is no evidence of sorting in these consolidated tuffs.

Microscopic description of consolidated tuffs. Angular fragments of a variety of volcanic rocks and intratelluric phenocrysts of feldspar are contained in a glassy pumaceous matrix. The fragments consist of andesitic porphyries, volcanic glass, pumice, and carbonaceous material. In thin sections examined the fragments reach about 1.5cm. in length, although in the field they range up to several centimeters. Phenocrysts of intratelluric plagioclase (oligoclase) and sanidine are embedded in the glassy matrix. The feldspars are exceptionally clear, fresh, and unaltered. Albite twinning is present in the plagioclase, but it is usually imperfectly developed. A few plagioclase grains display oscillatory zoning, the zones becoming more sodic toward the rim. The sanidine occurs as euhedral, square, very clear phenocrysts that are devoid of any alteration effects.

The matrix is yellowish brown volcanic glass. Crystallites, glass shards, and flow structures are features typical of the glassy matrix in all the thin sections examined. The glass has locally altered to palagonite, which in turn sometimes alters to chlorite. The chlorite occurs as pencil-like crystals in the cloudy, yellow, palagonite.

This tuff, in accordance with the Wentworth and
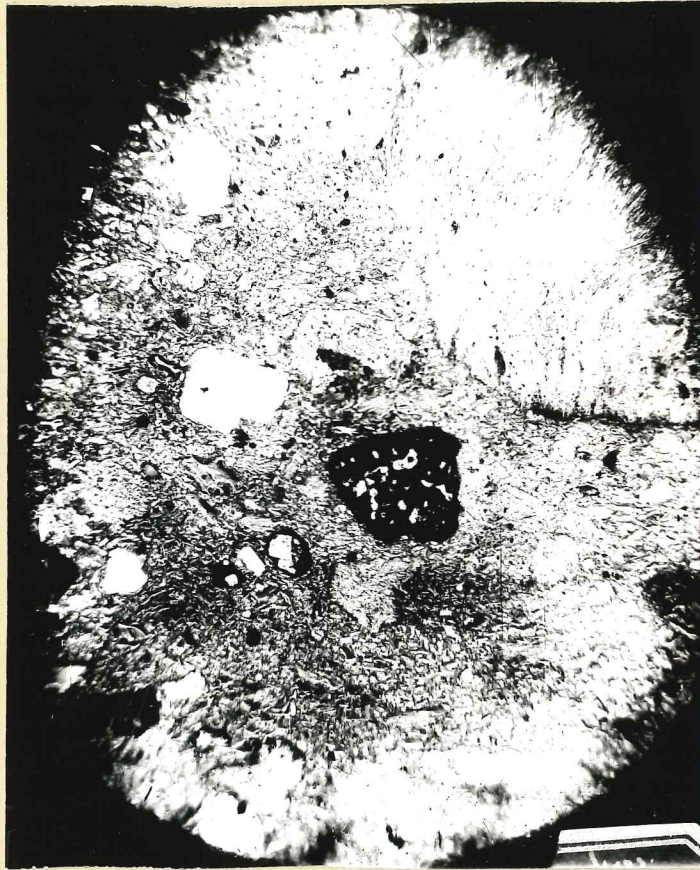
Plate 29.   Photomicrograph of glassy tuff from
the Fifes Peak andesite. Note the
variety of fragments, the crystallites
and shards in the glassy matrix, and
the euhedral grain of sanidine (white,
low relief) to the left of the large
dark fragment. x 15, Plain light.

Williams (31) nomenclature for pyroclastics, is a trachyitic
vitric-crystal tuff.

Approximate percentages of constituents present in the
tuff are: volcanic glass (and associated alteration products),
60; rock fragments, 25; oligoclase, 10; sandine, 5.

Summary of the Fifes Peak Andesite Series

The most significant points to be summarized from this
study of the Fifes Peak series are as follows:

1. This series will probably prove to be one of the
major volcanic units east of the Cascades.

2. It lies unconformably on Keechelus andesite and on
dacite porphyry dikes which are intrusive into the Keechelus.

3. Tectonic deformation of the Fifes Peak series is
much weaker than in the Keechelus series.

4. It is overlapped discomformably by Yakima basalt.

5. The Fifes Peaks are not remnants of a Miocene
volcano as proposed by Warren.

6. Alteration in Fifes Peak rocks is much less than
that in the Keechelus. Such minerals as chorite, epidote,
antigorite, hornblende, and iddingsite are not common.

Yakima Basalt

Parts of the western margin of the immense Miocene
basalt flows that form the great Columbia plateau lie within
the Mt. Aix quadrangle along its eastern border. Russell (24)
named these basalt flows the "Columbia lavas" during a ground
water survey in central Washington. The name, "Columbia River
basalt," is favored by many workers. Hodge compounded the
name, "Coriba," for the formation by using the first two letters
of each of the words, "Columbia River basalt," in an attempt to
shorten the name. The writer prefers the name, Yakima basalt,
for this formation because that was the term used by Smith (25)
in the adjoining Ellensburg quadrangle and by Smith and Calkins
(26) in the Snoqualmie quadrangle. The nearness of the city of
Yakima to this region also lends a certain geographic advantage
to the use of this name. Smith (25) dated the basalt early or
middle Miocene.

The Yakima basalt comprises approximately 3 percent of
the area under investigation. The outcrops of Yakima basalt in
this region mark the westernmost extent of these famous flows
in this area. The lavas are relatively thin as compared to
their tremendous thickness measured in thousands of feet in
central Washington. The basalt does not attain a thickness
over 500 feet in the Mt. Aix quadrangle and more usually does
not exceed 200-300 feet.

The Yakima basalt lies disconformably over Fifes Peak

andesite. The writer agrees with Warren's (29) statement
that, "it is very doubtful that the Yakima basalt once covered
all the Fifes Peak formation." It is probable that the lava
flows did not extend westward much farther than their present
margin. No erosional outliers of Yakima basalt on Fifes Peak
were found testifying to the fact that the basalt flows
probably thinned very rapidly to the west from the position of
their present margin. It is difficult to determine how deeply
the Fifes Peak andesites were eroded before deposition of the
Yakima basalt. It is certain, however, that the Fifes Peak
surface which the Yakima lavas covered, was one of low relief.
This relationship presents two possible interpretations.
Either the surface of the Fifes Peak series over which the
Yakima lavas flowed had been subject to erosion for a long
period of time and had been reduced to a rather featureless
plain, or the interim period was very short and the basalts
flooded over a fairly smooth virtually initial surface of the
Fifes Peak rocks.

The writer favors the second interpretation for several
reasons. First, there are no sedimentary deposits composed of
Fifes Peak rocks in this vicinity except for one small bed of
conglomerate that was mentioned previously. Second, the
surface of Fifes Peak flows upon which the Yakima basalt was
laid down was a structural surface and is parallel to the
structure in the lower Fifes Peak volcanics. In other words

there was no truncation of structure by erosion. Third, the Cascade uplift, (Pliocene), had not yet occurred and stream gradients were probably low. Consequently, the corrasive ability of the streams was weak and base leveling would have required a great length of time. There is no field evidence of a long erosion interval between Fifes Peak and Yakima depositions.

Nowhere was there observed an intertonguing of Fifes Peak andesite with Yakima basalt. However, as mentioned previously (cf. Fifes Peak andesite), the massive, dark, columnar andesite flows of the Fifes Peak series may easily be mistaken for basalt, so an intertonguing relationship might escape detection.

The Yakima basalt forms impressive dark cliffs that are almost invariably faced with hexagonal columns. The columns usually stand vertically, but in road cuts through the Dalles on American River, the columns approach horizontal and occur in conjugate sets that intersect at nearly right angles. The usual color of the weathered surface of the basalt is brown, but when the rock is broken the fresh surface is black and very dense. Porphyritic textures are absent in this formation. The broken surface may show imperfect conchoidal fracture.

The Yakima basalt forms the high cliffs along U.S. Highway 410, two miles east of American River Crossing. At this place the river has cut a narrow gorge known as the Dalles

Plate 30.   Yakima basalt exposed in road cut on U.S.
Highway 410 east of American River Crossing.
Note conjugate sets of columnar joints.

which was mentioned above. The basalt flows also occur as thin eastward dipping sheets lying on the top of Fifes Peak andesites on the gentle backslopes north and south of the Dalles. It forms the rugged cliffs along the east bank of the Naches River.

A relatively small, irregular body of basalt is exposed in road cuts along the Bumping River road about two miles west of American River Crossing. This outcrop is the most westerly exposure of Yakima basalt in the area. This body of basalt, unlike the rest of the formation, exhibits a porphyritic texture under the microscope. This fact might indicate that the body of basalt belongs to the Fifes Peak series, but evidence is incomplete.

In the area studied the Yakima basalt is not covered with any later rocks except scattered recent alluvial deposits. Farther south, however, in the Nile River valley clastic sediments of the Miocene Ellensburg formation fill synclinal valleys in the basalt.

Petrographic Description of the Yakima Basalt

Megascopic description. Distinctive features of the Yakima basalt are its uniformly dense texture and very dark color. By naked eye the rock is so dense that identification of any constituent minerals is impossible. Under a hand lens tiny needles of plagioclase feldspar are sometimes visible. The

weathered surface is usually brown. Minute vesicles are commonly present.

Microscopic description. The rock is composed of small, lath-shaped, euhedral grains of plagioclase feldspar set in a hypocrystalline matrix of dark glass, specks of magnetite, and minute, anhedral grains of augite and olivine. The composition of the plagioclase is labradorite, Ab45. The average length of the plagioclase laths is .2mm. The plagioclase is fresh, usually twinned after the albite law, shows no zoning, and occasionally contains inclusions of augite. The plagioclase laths lie in random orientation and seldom indicate any flowage direction.

Augite, which is more abundant than olivine, occurs in small anhedral grains between the plagioclase laths. The average size of the augite grains is .1mm. Twinning is very common. Some alteration to chlorite is evident, but for the most part the augite is fresh.

Olivine forms small rounded anhedral grains between the laths of labradorite. The average size of the olivine grains is .06mm. Like the augite it is only slightly altered, although incipient alteration is indicated by serpentine and iddingsite which occur in fractures and cleavage traces in the olivine.

The glassy matrix is black and opaque. The opacity is probably caused by an abundance of magnetite dust in the glass and the presence of chlorophaeite and sideromelane as described

by Fuller (12,13) in the Yakima basalts of central Washington.

Average percentages of constituents in the Yakima basalt are as follows: glassy matrix (including magnetite), 45; labradorite, 30; augite, 15; olivine, 8; serpentine and iddingsite, 2.

Summary of the Yakima Basalt

Significant points concerning the Yakima basalt as gained from this study are as follows:

1. In this region the Yakima basalt, which in some outcrops may be mistaken for columnar Fifes Peak andesite, does not occupy as great an area as formerly thought by Warren and by the writer.

2. The basalt disconformably rests on a relatively flat surface of Fifes Peak andesite.

3. There was probably a fairly short erosional interval between the end of Fifes Peak activity and Yakima deposition.

4. The Yakima basalt flows never completely covered the Fifes Peak series.

Deep Creek Andesite

A very distinctive andesitic flow forms the west side of Deep Creek valley from the Bumping Lake glacio-fluvial plain upstream to an unnamed tributary that joins Deep Creek at the

word "Deep" on the topographic map. This flow, or more
probably, this series of flows is entirely different in
appearance and structural setting from any other volcanic
flows in the area, which fact made early attempts to correlate
it with the Keechelus, Fifes Peak, or Valley flows difficult.
It appears certain now, however, that the Deep Creek andesite
is not a member of any of these other volcanic groups, but
represents a separate and distinct volcanic generation in this
region. It comprises about 3 percent of the area.

The Deep Creek andesite flows are predominantly a
peculiar light bluish gray color, but in addition contain bands,
streaks, lenses, and spots with a pinkish hue. The pink
portions are composed of the same rock material as the bluish
portions. The pink color is caused by the selective oxidation
of the disseminated magnetite to hematite. The flows reach a
maximum thickness in this area of 2,000 feet. They constitute
the entire eastern slope of Sugar Loaf mountain which is the
high knob directly south of "Lake House" which is shown on the
topographic map. The thickness diminishes rapidly to the north
as the result of removal of great quantities of the rock by
alpine glaciation. The flows lie practically horizontal.
Columnar jointing is usually absent or is imperfectly developed.
The andesite is usually finely vesicular. Along the base of
the cliffs there is always a thick accumulation of fissile
talus fragments. The tablet-like rocks that comprise the talus

produce a musical tone when they are struck or dropped.

Deep Creek andesite outcrops at localities other than along Deep Creek, but because the flows reach their maximum thickness in that area, Deep Creek was selected as the type locality. Other masses of Deep Creek andesite include the large unnamed hill west and slightly south of Carlton Pass, the saddle and portions of the valley south of Swamp Lake, a small exposure on Bumping River one and one-half miles downstream from Bumping Lake, and Big Peak. Big Peak is actually outside the southern limit of this work, but it is necessary to mention Big Peak because it demonstrates two different ages of lavas, namely the Deep Creek andesite that forms the mountain, and the later Valley flows that surround it.

Definite dating of the Deep Creek andesites is not possible from field relations in this area. In the bed of Deep Creek just below its confluence with Copper Creek, the Deep Creek andesites lie unconformably on a rugged erosional surface of Bumping Lake granite and dacite porphyry dikes that were intrusive into the granite (cf. Bumping Lake granite). The actual contact between granite and andesite is always hidden by an apron of talus. The lowest age limit of the andesite is then, post-dacite porphyry. However, the freshness of the andesite and the deeply eroded surface of the granite and dacite porphyry indicate that a long interval of time elapsed before deposition of the andesite. Consequently, the lower

age limit of the Deep Creek andesite is v

upper age limit may be determined somewha

in the vicinity of Big Peak and on the so

Lake where Deep Creek andesites are over

Valley flows. This relationship provide

of pre-Pleistocene for the Deep Creek an

In the Snoqualmie quadrangle Smi

described andesitic flows that are ident

andesite in the Mt. Aix quadrangle. Sm

these flows, which rest unconformably o

"Howson andesite," and dated them late

Although evidence for assigning a late

date to the Howson andesite was rather

is convinced that the Howson andesite

andesite are parts of the same volcani

consequently accepts, at least tempor

Calkins' late Late Miocene to Pliocen

There is a remarkable accord

the three high knobs composed of Deep

area. The summits of Sugar Loaf, th

Big Peak lie at

suggestive as to its lithology.

The outcrop pattern of the Deep C

geologic map might indicate a former nort

valley cut in the older rocks that was f

andesite flows. Subsequent offsetting b

partial coverage by Pleistocene flows le

the former valley exposed. These segmen

mentioned above.

It is interesting to speculate

absence of Deep Creek andesite on the e

whereas the flows are 2,000 feet thick

explanation is that the valley glacier

valley removed all the Deep Creek ande

This is not plausible, however, becaus

andesite should remain at high levels

they do not. Another explanation is

Copper Creek, which have been activel

since the retreat of the glacier, ren

the eastern part of the valley, but

task on the west side. Again, remna

boundaries of the andesite. Hence, the c

between Deep Creek andesite and Bumping L

actually that of the side of the andesite

valley wall of granite, rather than the

flows upon a granite floor.

Petrographic Description of the Deep Cre

Megascopic description. The roc

distinguished from the great variety of

region by its bluish gray color and irr

of pink color. The texture of the ande

dense, but megascopic examination somet

needles of hornblende and specks of mag

surface is usually light gray with rus

Vesicles are not prominent, but small

contain quartz crystals, are found thr

Frequently each vesicular opening is

of pink.

Microscopic description. Thi

taken from widely separated areas sho

myriads of magnetite granules, and brownish

Minor anhedra of quartz and orthoclase are

present in the matrix. The plagioclase ne

85 percent of the matrix are euhedral, unt

according to the Carlsbad law, and unalter

small inclusions of glass. Their average

The composition of these small plagioclas

to determine but appears to be basic ande

Outstanding are the euhedral to

of basaltic hornblende with resorption be

The basaltic hornblende occurs as spindl

to the c axis, or as pseudo-hexagonal pr

angles to the c axis. The brown hornble

the interior of the spindles or prisms

or the hornblende may be completely rep

elongate phenocrysts average .25mm in l

maximum of 1mm. The diameter of the cr

considerably. The brown hornblende is

with X yellow brown, Y darker brown, Z

sometimes observed in the basaltic hor
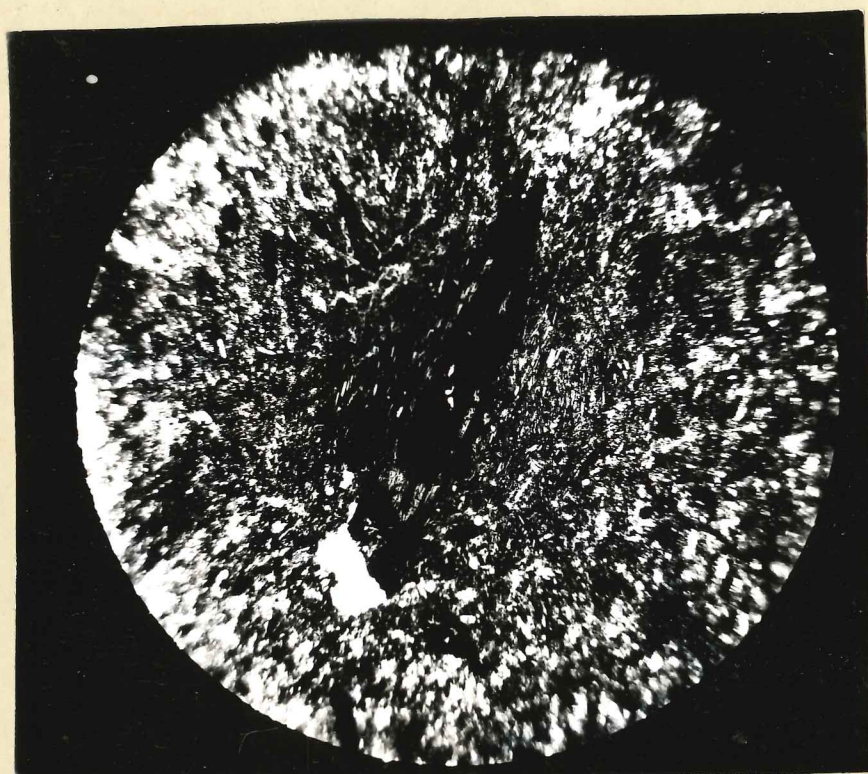
Plate 31.   Photomicrograph of Deep Creek andesite.
The black, cigar-shaped grain in the
center of the photograph is a prismatic
section of basaltic hornblende that has
gone almost completely to magnetite.
Note, however, small remnants of the
amphibole within the magnetite.
x 15, Plain light.

from the Deep Creek outcrops it is an acc

The hypersthene is euhedral to sub-hedral

moderately pleochroic. The average lengt

about .2mm.

Only one large grain of augite,

observed in the sections studied. It wa

and fairly fresh. Tiny specks of augite

magnetite in the resorption borders of

Thin sections of the pink varie

andesite are identical in texture to th

but differ in two ways in mineral comp

difference is the abundant hematite in

the hematite, of course, that produces

hematite occurs as thin rims around th

magnetite which surround the basaltic

very fine dust throughout the matrix.

the magnetite resorption rims are not

hematite, but rather that the hemati

their peripherys. The production of

these flows is probably caused by st

oxidizing the magn

The one exception to general textu

in thin sections cut from a small outcrop

andesite on the north side of Bumping Riv

miles east of Bumping Lake. Megascopical

resembles the rest of the formation, but

differs in that blocky phenocrysts of pla

as prominent as the basaltic hornblende.

phenocrysts are euhedral to subhedral, u

.2mm in length. The composition of the

Ab62.

The average percentages of const

andesite are as follows: plagioclase,

basaltic hornblende, 10; hypersthene, 5

variable; augite, variable.

Summary of the Deep Creek Andesite

The principal points to be sum

Deep Creek andesite are as follows:

1. It closely resembles the H

Snoqualmie quadrangle.

2. The age of the flows is n

to the Deep Creek andesite in this area.

Valley Flows

The series of basaltic flows that

in the present valleys are, in this repor

They may be correlative with the Pleistoc

described by Smith (25), and Becraft (4)

The Valley flows are, however, basaltic

this reason a definite correlation is no

further study can be made.

The Valley flows comprise approx

the area mapped. It is anomalous, perha

exposure of the "Valley flows" occurs on

plateau, which contains approximately 20

the Tumac plateau by the writer after Tu

glacial cinder cone that rests on Valle;

plateau (cf. Tumac Mountain). The name

however, because many of the valleys ra

plateau contain remnants of lava tongue

from the plateau area. Only remnants o

away from the central portions of the plat

the initial dip of the flows conforms more

gradient of the valley in which they occur

The flows are not always uniform i

color. On Tumac plateau the basalt is dar

banded, and highly vesicular. In the vic

River Falls, however, the basaltic flows

banded, not vesicular, and extremely fiss

joints and a tendency to fracture conchoi

to break in thin plates with razor-sharp

Other localities where the Valley

include: the upper portion of Summit Cre

of an unnamed creek that drains Frying Pa

Bumping River at Carlton Pass, portions

other than the waterfall, the lower part

Cougar Creek which drains Cougar Lake, i

Cedar Creek which joins upper Bumping Ri

Bumping Lake, and in a saddle on the Cas

Swamp Lake.

The exact age of the Valley flow

more likely. That the Valley flows were

is, however, undeniable (cf. Physiography

data, which is given below, the lower age

Deep Creek andesite and the upper age lin

glaciation.

Big Peak, which is composed of D

(cf. Deep Creek andesite) lies unconform

vesicular, massive type of Valley flow b

Deep Creek andesite that form the west

Bumping Lake lie unconformably beneath

unvesicular, fissile type of the Valley

structural relationship is inferred fro

southwest end of Bumping Lake, but the

Deep Creek andesite and Valley flows in

by very dense forest.

The rather striking dissimilar

color in different parts of these flow

Do these two types of outcrops represe

flows? If the two types of basalt la

part of the same flow or series of fl

these reasons the writer classified both

Valley flows.

It must be clearly understood th

flows was not Tumac Mountain cinder cone

showed to be post-Wisconsin in age. A s

flows may have been on the Tumac plateau

site of the present cinder cone. The c

however, a feature of the Valley flow l

discussed further in the chapter on Tum

Petrographic Description of the Valley

Megascopic description. Becau

two distinct textures and colors, each

separately. First, the dark basalt t

and forms the saddle west of Swamp La

This basalt is medium to dark gray in

never approaches the dead black of t

is commonly vesicular with a dense t

specimens specks of olivine are larg

recognized with the aid of a hand le

color and dense textured. Under the hand

magnetite, which are very abundant, provid

effect on the freshly broken surface. No

are visible megascopically in this type.

are absent.

Microscopic description. Althoug

of the two types of basalt is similar, th

difference. Therefore, the two types wil

separately.

The dark gray, vesicular type fo

and on the saddle west of Swamp Lake sho

olivine set in a dark hypocrystalline ma

volcanic glass, lath-shaped plagioclase

of olivine and augite.

The olivine phenocrysts are sub

and very fresh. The only alteration pr

may occur along cracks in the olivine.

present. The phenocrysts are quite la

diameter. The olivine phenocrysts cry

plagioclase in the groundmass.
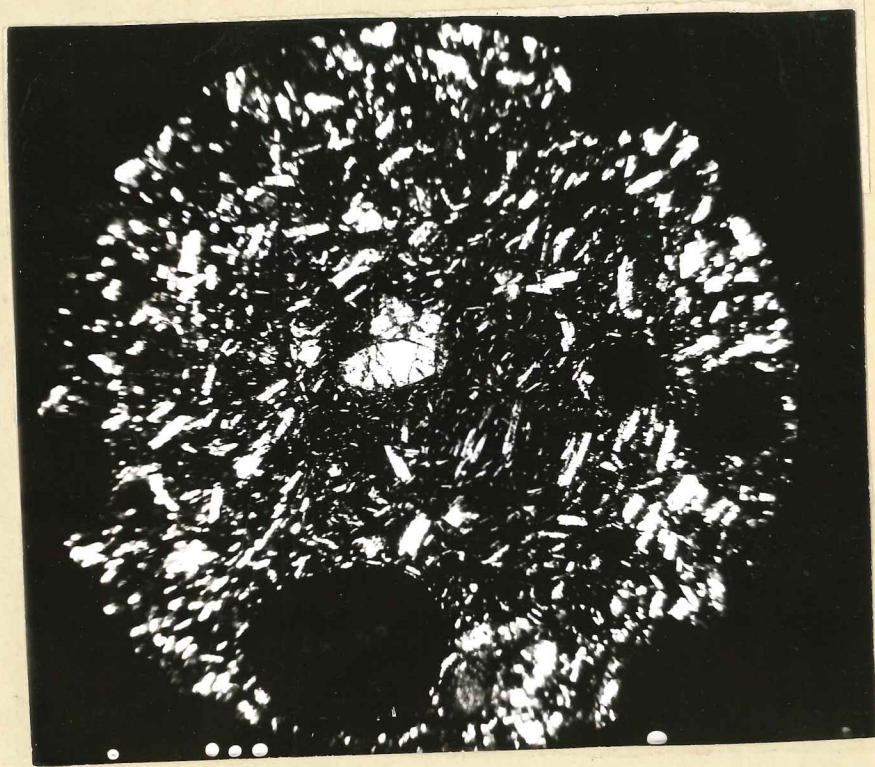
the plagiocl

Plate 32.   Photomicrograph of Valley flow basalt
            from Tumac plateau. The grain in the
            center of the photograph is olivine
            which is set in a matrix of plagioclase
            (labradorite), augite, magnetite, and
            glass. Note the vesicles.
            x 15, Crossed nicols.

a large part of the matrix. The opacity is probably due to
magnetite dust with which the glass is heavily charged. Specks
of olivine and augite are common but minor constituents in the
matrix.

The average percentage of constituents in this type of
Valley flow basalt is: labradorite, 40; olivine, 20; volcanic
glass and magnetite, 30; augite, 8; limonite, 2.

The brown, non-vesicular type of basalt contains olivine
phenocrysts embedded in a holocrystalline matrix. The matrix
is composed of small laths of plagioclase and specks of olivine
with lesser amounts of augite. The groundmass is heavily
charged with magnetite granules.

The olivine phenocrysts are anhedral or occasionally sub-
hedral and very fresh with incipient development of limonite
along fractures. Antigorite is never present. The average
size of the olivine phenocrysts is .3mm, although the largest
grain measured was .8mm in diameter.

In the groundmass plagioclase is the most abundant
mineral. The plagioclase, which has the composition of
labradorite, Ab4 An6, is lath-shaped, euhedral, unaltered,
twinned according to the albite law and averages .2mm in length.
Olivine specks are also abundant in the matrix as fresh anhedral
grains with an average size of .015 mm. Augite also occurs in
the groundmass, but it is not so abundant as the olivine. The
matrix contains excessive amounts of magnetite in the form of

granules which average .008mm in diameter.

The average mineral percentages in this variety of the
Valley flows is as follows: labradorite, 45; olivine, 30;
magnetite, 20; augite, 3; limonite, 2.

Summary of the Valley Flows

The most significant points to be summarized concerning
the Valley flows are as follows:

1. The composition of the Valley flows is basaltic
which is not common in the Cascades of Washington.

2. The flows may be correlative or contemporaneous
with the Pleistocene Tieton andesite.

3. One source of these flows may have been on the
Tumac plateau from where the basaltic lavas spilled down
adjoining valleys.

4. The Valley flows have undergone severe Wisconsin-
age glaciation, and may have been subject to earlier glacial
periods.

5. The two types of basalt in these flows were
probably roughly contemporaneous and should be considered as
variations of the same formation.

lon

Keechelus

Generally up to 10 to config Under- beneath formably. from Tuma onform-	Regional dip north and east, usually not over 25 degrees. Complicated by many local folds and faults. Under- lies Fifes Peak unconformably. Over- lies Puget Group s.s. conformably.
Occurs a sembles Tumac pl is tongu scarps e	Forms steep slopes and scarps- broken by benches and platforms.
No colum pro- spaced j Found edges to te flows. exposure common.	No columnar jointing.
Weathers ight tan. blue-gra uff.	Weathers light gray, gray, greenish, and purple.
May be v ar. Often sugary. pyroxene brown or Fresh d sub-	Not vesicular. Great variety of colors and textures on fresh surface.
Not asso dated to except 1 d volcanic , and with	Abundant pyroclastics, especially volcanic breccia. All pyroclastics highly consolidated.
Unmetamo ly	Low grade metamorphism nearly throughout. Development of chlorite, epidote, and iron oxide very common.
No fossi rich nts.	No fossils except one occurrence of petrified wood.

PETROGRAPHIC RELATIONSHIPS

Valley flows	Deep Creek	Yakima	Fifes Peak	Keechelus
Lath-like blades of plagioclase in fine matrix of plagioclase needles and mafics. Labradorite-Bytownite.	Tiny needles of plagioclase in dense, brownish glass. Needles may be oriented by flowage. Andesine?	Minute, lath-like blades of plagioclase in dense, black glass. Labradorite-Bytownite.	Medium to large size, blocky, euhedral to subhedral plagioclase in matrix of fine plagiocloase and mafics. Andesine-Labradorite.	Lath-shaped blades of plagioclase. Great range in size. Usually in hypocrystalline matrix. Andesine.
Olivine abundant. Forms large phenocrysts. Occasionally has rims of pyroxene. Also occurs in matrix.	Olivine absent.	Olivine abundant. Fine grained.	Olivine rare	Olivine rare.
Hypersthene present as phenocrysts.	Hypersthene locally abundant. Forms phenocrysts.	Hypersthene rare.	Hypersthene abundant. Occurs as large and small grains.	Hypersthene locally abundant as intersertal grains and as large, subhedral phenocrysts.
Pigeonite abundant. Occurs as large phenocrysts and as small grains in the matrix.	Only one grain of pigeonite observed.	Augite common. Forms small grains.	Pigeonite abundant. Forms large and small grains.	Pigeonite (or augite) abundant. Large euhedral to subhedral grains and as small intersertal grains.
Flow structures common.	Flow structures common.	Flow structures common.	Flow structures common in hyaline rocks.	Flow structures present in some members.
Magnetite very abundant.	Magnetite very abundant.	Magnetite common. Glassy	Magnetite common. Glassy matrix charged with magnetite dust.	Magnetite common.
Porphyritic texture common.	Porphyritic texture common.	Porphyritic texture absent.	Porphyritic textures common. Often associated with fragmental textures.	Porphyritic textures common. Often associated with fragmental textures.

Tumac Mountain Cinder Cone

The outstanding topographic feature on the Valley flow-capped Tumac plateau is Tumac Mountain, a 700 foot breached cinder cone which lies exactly on the crest of the Cascade Range at a summit elevation of 6,300 feet. The two most important features of Tumac Mountain are: first, the basaltic composition of its cinders and lava, and second, a post-Wisconsin age of the formation of the cone.

The cinders and thin beds of lava that compose the Tumac cone are not greatly different in mineral content from the basaltic Valley flows described in the last chapter. Basalt, as lava or cinders, is somewhat foreign to the andesite-rich Cascades of Washington. The writer has no explanation for the localized occurrence of two basaltic formations which were deposited at two different times, i.e. the Valley flows are pre-Wisconsin in age, and Tumac cinder cone is post-Wisconsin in age.

The cinder cone rests on a gently domed surface of Valley flow lavas. The Valley flow basalts show the effects of severe glaciation by a high altitude ice cap that covered the plateau with hundreds of feet of moving ice. Tumac Mountain, a cone of unconsolidated cinders, stands nearly in the center of this ice-swept plateau, but shows no effects of glaciation. Indeed, the very survival of the cone would have been impossible

Plate 33. Tumac Mountain cinder cone. Crater lies this side of breach in the cone. Mountain is approximately two miles distant. Little Twin Sister Lake in the foreground.

through a glacial period. Therefore, it is certain that the Tumac cone formed after the withdrawal of Pleistocene ice.

A more complete description of the interesting effects of glaciation on the Tumac plateau will be given in the chapter on Physiography.

Tumac Mountain is the first post-glacial cinder cone to be described in Washington. In Oregon there are many recent cinder cones, and in British Columbia post-glacial cones have been described by Burwash (5) in the Mt. Garibaldi area. Well known Washington volcanoes such as Mt. Rainier, Mt. Baker, and Mt. St. Helens have shown renewed activity in post-glacial times, but Tumac cone is unusual in that it represents the formation of an entire volcanic unit after the retreat of Wisconsin age ice.

The cone rises about 700 feet above its base. The base is approximately circular in cross section and measures three-quarters of a mile in diameter. A deep crater is assymetrically located on the northwest side of the cone. The bottom of the crater lies 550 feet below the highest point of the rim and 150 feet below the lowest portion of the breached rim. The bottom of the crater is approximately 100 feet across, and the top of the crater is over 1,000 feet wide.

The mountain is composed almost entirely of unconsoli-dated red and black cinders with minor amounts of interbedded vesicular basalt. Volcanic bombs are scattered over the surface

Plate 34.   A portion of the crater of Tumac cinder cone.
Spillway for melt waters is shown on the left
side.   Most of the water, however, seeps through
the unconsolidated cinders and issues around the
base of the cone.   Photograph taken looking north.
Twin Sisters Lakes are in the middle ground.
House Mountain west of Cougar Lake is the
prominent feature in the background.

of the cone, but are found most abundantly near the crater.
One large bomb measured over six feet in length. The cinders
are loose inside the crater and on the flanks of the cone
where scrub vegetation does not grow. The angle of repose of
the cinders is 33 degrees. It is nearly impossible to walk
straight up the slope of the cone on the east and south sides
because the cinders and ash slide beneath one's feet like a
treadmill. On the north and west sides scrub pine has taken
root and holds the pyroclastics in place and climbing is not
difficult.

The Valley flow basalt around the base of the cone is
higher on the west side than on the east side as indicated in
Figure 2. The reason for this is not entirely clear, but there
are at least two possible explanations. First, the force of
volcanic extrusion forced the Valley flow basalts aside and
tilted the basalt beds more steeply to the west than to the
east. Second, the extrusion might have occurred near the base
of a cliff formed in Valley flow basalt where the volcano built
an assymetrical cone with the bulk of the pyroclastics falling
to the east. Strong prevailing westerly winds off the Pacific
Ocean might be partially responsible for this kind of assymetry.

The Tumac eruption was evidently not violently
explosive. No bombs or volcanic fragments were found far beyond
the base of the cone. Although the forest is very thick on the
plateau, if the eruption had been explosive, scattered fragments

Plate 35.   A winged volcanic bomb from near
the summit of Tumac Mountain
cinder cone. The color of the
bomb, like most of the cindery
material, is brick red.

Plate 36.   A large volcanic bomb near the summit of Tumac cinder cone.

Plate 37.   A portion of the southeast side of the Tumac
cinder cone showing the angle of repose of
the unconsolidated cindery material.

should be found on the Tumac plateau.

Tumac Mountain can be reached only by trail. The shortest route is by a U.S. Forest Service trail from Copper City Mine on Deep Creek to Twin Sisters Lakes and then to Tumac Mountain, a total distance of about five miles. The trail is good and may be travelled on horseback. A second and longer route over an unmaintained trail from the Tieton Reservoir is not recommended.

Petrographic Description of Tumac Mountain Cinders

Megascopic description. The cinders that compose Tumac cone are either red or black in color, and are very vesicular with high porosity and permeability. Mineral crystals are seldom visible in the cindery material. Thin beds of dark-colored dense-textured basalt may show a slightly porphyritic texture.

Microscopic description. Some specimens are so highly vesicular that microscopic examination of them is not satisfactory. In less vesicular specimens the rock is a matte of unoriented plagioclase laths which are embedded in dark, magnetite-rich volcanic glass. In much less quantity than the plagioclase, small anhedral to sub-hedral grains of olivine, hypersthene, and augite are scattered through the matrix. Some grains of the mafic minerals show the effects of cataclasis. The feldspar, however, is usually not broken.

The composition of the feldspar laths is labradorite, Ab4. The plagioclase laths are unaltered, twinned according to the albite and less frequently according to the Carlsbad law, unzoned, average .03mm in length, and may contain inclusions of the glassy matrix. Apatite, a conspicuous accessory mineral, frequently occurs as inclusions in the labradorite.

Olivine is a less abundant constituent in the Tumac basalts than in the Valley flow lavas. It occurs as small anhedral specks between laths of plagioclase and averages .05mm in diameter. There are no alteration products of the olivine.

Hypersthene is more plentiful than augite. Both pyroxenes occur intersertally as small anhedral to sub-hedral grains. Neither shows any alteration.

Magnetite forms small granules and is also incorporated in the glassy matrix. The alteration of magnetite to hematite probably by steam is responsible for the reddish color of the cinders.

The average percentage of constituents in the basaltic cinders is as follows: labradorite, 50; volcanic glass and magnetite, 25; olivine, 5; apatite, 5; hypersthene, 4; augite, 1; magnetite and/or hematite, 10.

Plate 38.   Photomicrograph of basaltic cinder
            from Tumac Mountain cinder cone.
            Inclusions of apatite in the plagio-
            clase laths cause the mottled effect.
            Several small particles of olivine
            are visible in center of the large
            white patch. The matrix is black
            glass. x 65, Plain light.

Summary of Tumac Mountain Cinder Cone

Although Tumac Mountain is a rather small feature, it is an important and interesting one for two reasons.

1. It is post-Wisconsin in age and therefore the first of its kind to be reported in Washington.

2. It is basaltic in composition.

INTRUSIVE ROCKS

Bumping Lake Granite and Granite Lake Breccia

General Statement

There are in the area studied two distinct but
contiguous bodies of granitic rocks. One is the main mass of
homogeneous, inclusion-free granite which is called here the
Bumping Lake granite. The other is an agmatitic mixed breccia,
(Wegmann (29)) composed of dark andesite fragments in a
granite matrix. The agmatite is named in this thesis the
Granite Lake breccia. No final decision will be made concerning
the origins of these bodies because of their limited extent
within the area, and because they form poor and unconnected
outcrops that are not adequate for a conclusive genetic study.

Field Relations

The two granitic bodies mentioned above occupy roughly
6 percent of the total area, or about 15 square miles in its
central portion. In much of this area, however, the granitic
rocks are not exposed. Of the two bodies the Bumping Lake
granite is the larger. Its shape is irregular with the long

dimension in a northwest-southeast direction. The Granite Lake breccia forms a discontinuous marginal belt around the Bumping Lake granite and also occurs as large isolated masses within the homogeneous granite.

Megascopically the Bumping Lake granite is a coarse-grained rock containing quartz, orthoclase, plagioclase, and biotite. The granite weathers a light reddish brown or tan color and crumbles easily on weathered surfaces.

The Granite Lake breccia is composed of fragments of dense, dark gray to black, andesite which are embedded in a granite matrix that closely resembles the Bumping Lake granite, megascopically and microscopically (cf. below). The fragments vary in size from one-quarter-inch to twelve inches. The breccia weathers to a medium gray color and decomposes less readily than the Bumping Lake granite.

Contact Relations of the Bumping Lake Granite

The contact between the Bumping Lake granite and the Granite Lake breccia is always sharp. The two kinds of rocks have been followed at many places to within a few yards of their mutual contact without any sign of a gradation. This relationship holds true along the marginal belt and also around the isolated breccia masses within the granite.

Contacts of the two granitic bodies are best seen at the following places: on Miner's Ridge one-quarter mile northeast

of the Forest Service lookout, on the west slope of Nelson's
Ridge below the old Keystone mine, on American Ridge one-
quarter mile west of the junction of the Mesatchee Creek
trail and the American Ridge trail, and less typically but
more conveniently in a road cut on U.S. Highway 410, two miles
west of the Morse Creek bridge.

On its west side the Bumping Lake granite is in
contact with the Puget Group sandstone and also with the
Keechelus formation which overlies the Puget Group rocks.
The granite-sandstone contact will be considered first.

The contact is best exposed in upper Cougar Creek in
the creek floor and intermittently along the banks. The granite
is definitely later than, and intrusive into, the sandstone.
Apophyses of the granite which have the same composition as the
main granite extend into the sandstone for at least 100 yards
from the contact. These tongues vary in size from dikes
several yards in width to stringers only a fraction of an inch
across. They frequently cut across bedding planes in the
sandstone. Local control by jointing in the sandstone causes
abrupt pinching and swelling of the dikes.

The contact between the main body of granite and the
sandstone is sharp and distinct. Where the sandstone is
adjacent to either the main granite body or its apophyses, it
has been altered by contact metamorphism to a quartz-biotite
hornfels. Small slivers of hornfelsized sandstone are included

Plate 39. Apophyses of Bumping Lake granite cutting Puget Group sandstone. Picture taken several hundred feet west of main contact, in the bed of Cougar Creek. Granite is light-colored, sandstone is dark.

Plate 40.   Contact between Bumping Lake granite (light-
colored rock on the right and bottom) and Puget
Group sandstone (dark-colored rock on the left).
Note the sharpness of both the vertical and
horizontal contacts.
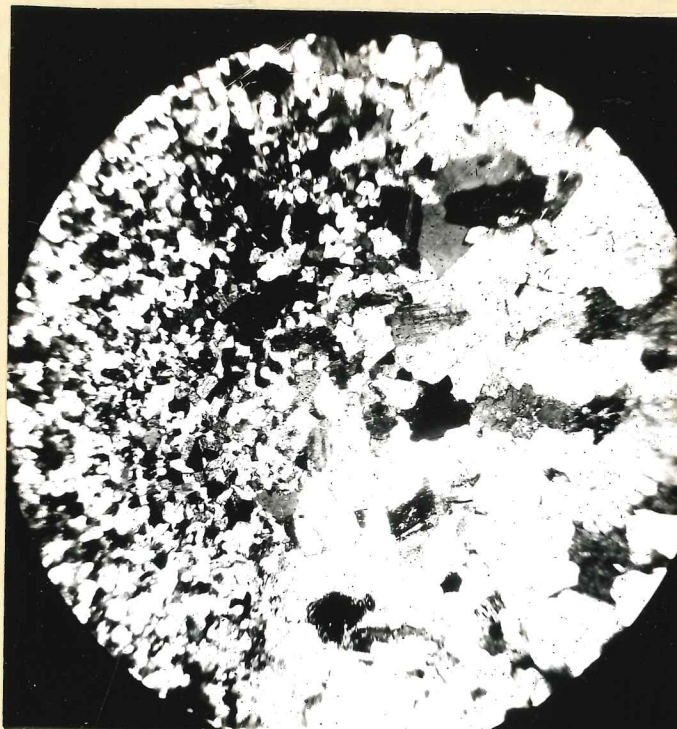
Plate 41.   Photomicrograph of the contact
            between Bumping Lake granite (on
            the right) and Puget Group sandstone
            (on the left). The coarse-grained
            granite is composed of quartz,
            feldspar, and biotite. The sandstone
            has been metamorphosed to a quartz-
            biotite hornfels. Note the sharpness
            of the contact. x 15 Crossed nicols.

in the granite several inches from the contact. These are
usually in parallel orientation with the contact.

Because of limited exposures it is difficult to
determine what structures have been caused in the sandstone
by the forceful intrusion of the granite. In two small outcrops
near the granite contact bedding planes in the sandstone dip
40° northwest, i.e. away from the contact. The regional dip of
the Puget Group in this area is much less, namely 15° north.
This strongly suggests that the greater dips near the granite
were caused by the intrusion of the granite.

At other places the Bumping Lake granite is in contact
with the Keechelus formation which overlies the Puget Group.
This contact is exceedingly irregular. As noted above there
is frequently a marginal zone of agmatite between the granite
and the Keechelus. In many places the Bumping Lake granite-
Keechelus contact is obscured by a later dacite porphyry
intrusion. The best exposure of the contact between the main
granite body and the Keechelus formation lies on the northeast
side of the granite on the crest of a ridge that forms the
west side of Boulder Creek near its headwaters in Big Basin.
On the topographic map this is about one-half inch south of the
first "A" in the words, American Ridge. The contact in this
area is sharp but highly irregular. The Keechelus (Cougar
Creek andesite member) is altered to massive amphibolite. There
is a marked decrease in grain size of minerals in the granite
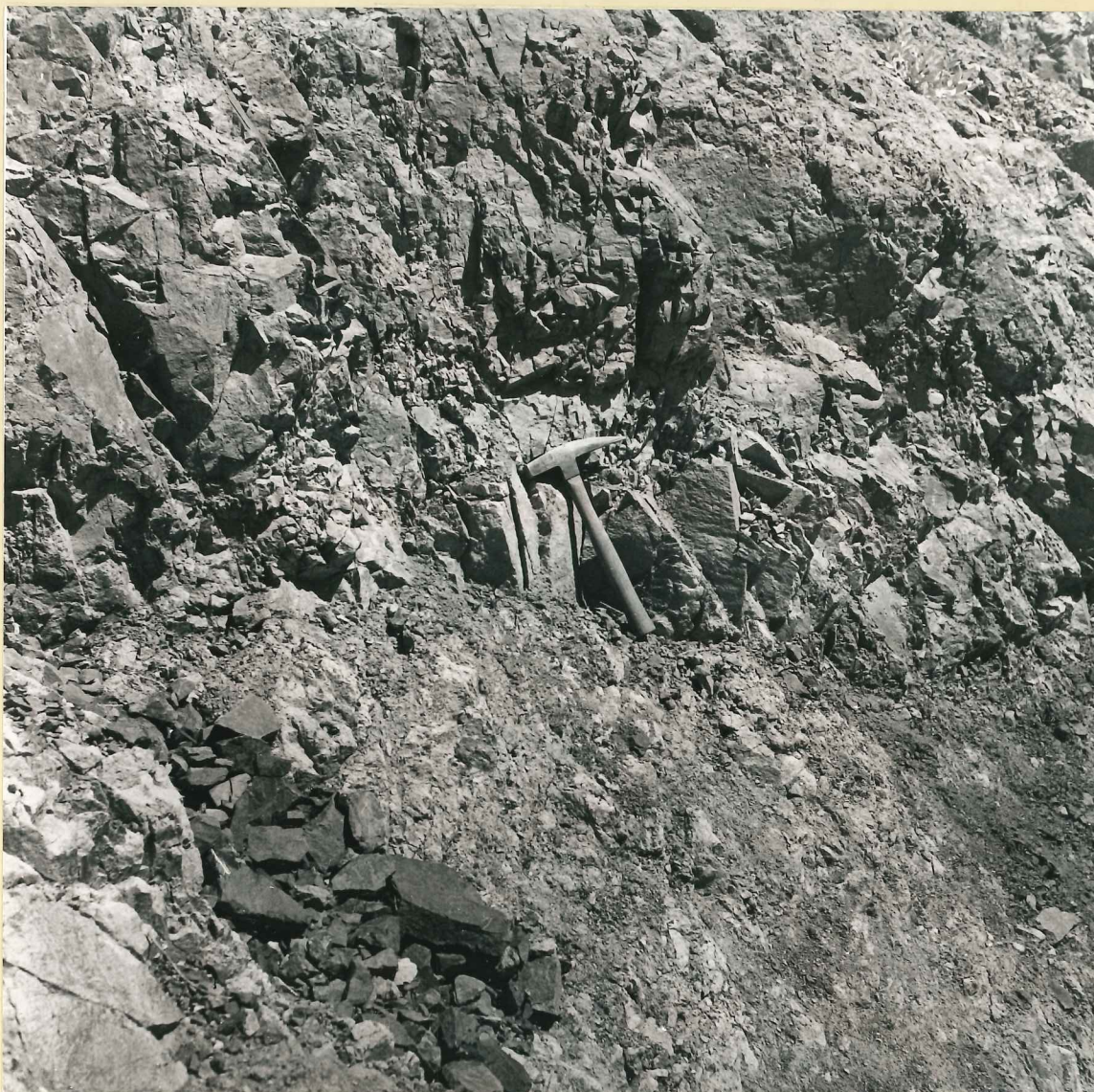
Plate 42.   Contact between Bumping Lake granite (below)
             and the Cougar Creek member of Keechelus
             andesite (above). Note the strong decomposi-
             tion in the granite, whereas the andesite is
             practically unweathered. Note also the
             sharpness of the contact.

near the contact. A thin band of manganese oxide, one inch
or less in width, follows the contact in this area.

A recent landslide one-half mile northwest of the west
end of Bumping Lake exposes a vertical section of the contact
between the granite and the overlying Keechelus. Although the
granite is rather severely weathered the contact is clearly
seen. In this place as in other localities the contact between
granite and andesite is sharp. Small granite dikes extend
upward short distances into the andesite and are weathered in
the same way as the main granite. Only one small inclusion
of the andesite in the granite was found. Contact metamorphic
effects in the Keechelus are weak. The andesite is only
slightly altered by weathering.

Contact Relations of the Granite Lake Breccia

The contact between Granite Lake breccia and Bumping
Lake granite has been described above.

The Granite Lake breccia is in visible contact with
the Keechelus andesite at only one locality, namely in a road
cut on U.S. Highway 410 approximately two miles west of the
Morse Creek bridge. In all other places where the agmatite-
andesite contact should be present intrusive bodies of dacite
porphyry obscure the contact. In the road cut the line of
contact is unfortunately not well-exposed because slope wash
mantles the crucial area. Even so, the change from Keechelus

andesite to Granite Lake breccia occurs in a short distance
and at least a fairly sharp contact is indicated. In this
area disseminated pyritization of the Keechelus has occurred
on a large scale. The mineralization is probably related to
the formation of the Gold Hill ore deposits to the east.
Andesite fragments in the breccia do not contain pyrite,
suggesting that the introduction of pyrite was later than the
brecciation and the introduction of the granite, and also that
pyritization was restricted to the andesites.

Petrographic Description of Bumping Lake Granite

Hand specimen description. The rock is a light tan or
locally light greenish gray, coarse-grained granite composed
of quartz, feldspar, and biotite. The high percentage of
quartz and potash feldspar in the Bumping Lake granite makes
it easily distinguishable from the Snoqualmie granodiorite
(see page 194). Weathered samples are a light reddish brown
color.

Microscopic description. The rock is coarse-grained
and contains in order of relative abundance quartz, plagioclase,
orthoclase, and biotite. The amounts of orthoclase and
plagioclase are often nearly equal. Alteration products which
vary in abundance in different parts of the granite body are
sericite and kaolinite from the feldspars; chlorite and
magnetite from the biotite.

Biotite and plagioclase are the earliest minerals.
In every slide they are at least partially replaced by later
quartz and orthoclase.

Plagioclase generally forms the largest grains. Its
average composition as determined from many thin sections is
oligoclase, Ab7An3. A few plagioclase grains are euhedral,
many are subhedral, and some which have been almost completely
replaced by quartz and orthoclase are exceedingly irregular
in shape. Small inclusions of plagioclase in quartz and
orthoclase show simultaneous extinction indicating that they
are relics of single large plagioclase crystals that have been
almost completely replaced by the later feldspar and quartz.
Zoning is present in some plagioclase grains. The change in
composition is from calcic-oligoclase in the central portion
to sodic-oligoclase near the rim of the grain.

Primary biotite is more or less euhedral and occurs in
independent grains as well as in occasional inclusions in
plagioclase. However, few such euhedral grains of biotite
remain. Varying stages of replacement by quartz and orthoclase
leave most of the biotite very ragged. Some biotite occurs as
remnants within the later orthoclase. Some biotite also forms
small usually irregular flakes at and near the grain boundaries
of quartz and orthoclase. These flakes might be remnants of
almost completely replaced primary biotite, but could also be
interpreted as due to secondary recrystallization of biotite
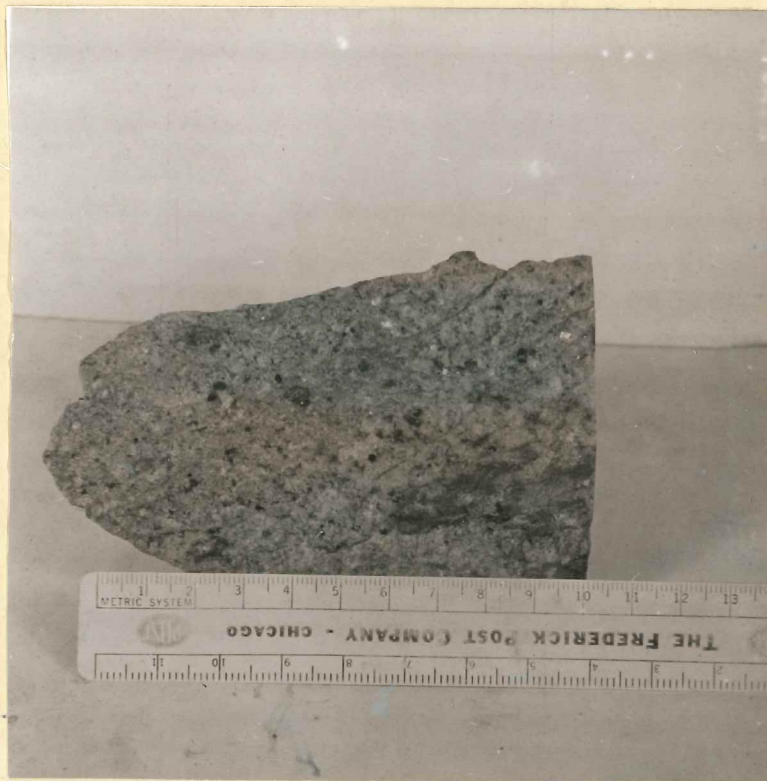
Plate 43. Bumping Lake granite. This
rock is composed of relatively
large grains of quartz, feldspar,
and biotite. Quartz is very
predominant.

Plate 44.   Photomicrograph of Bumping Lake
            granite. Light-colored minerals are
            quartz and orthoclase. Twinned
            feldspar is oligoclase, dark mineral
            is biotite. Deuteric replacement of
            plagioclase and biotite by later
            orthoclase and quartz is shown. Note
            the sutured contacts. Compare with
            photomicrograph of Snoqualmie granodi-
            orite. x 15, Crossed nicols.

which was later replaced by deuteric orthoclase and quartz. Some biotite is also included in plagioclase.

Alteration of biotite to chlorite and magnetite is common in the vicinity of the Copper City Mine, and in other localized areas where the granite has undergone slight alteration.

The orthoclase is uniformly anhedral. Being one of the later, deuterically introduced minerals the orthoclase had its shape determined by its reaction with the earlier minerals during the replacement process. The boundaries of the orthoclase are irregular and sutured. Plagioclase, biotite, and minor quartz form inclusions in the potash feldspar.

Quartz is the most abundant of all minerals in the granite, although its quantity varies in different parts of the granite mass. It is the latest mineral. Nearly all of the quartz is highly irregular in outline. Most quartz grains have complexly sutured contacts with the minerals it has replaced. Inclusions of plagioclase and orthoclase in the quartz frequently give it a sieve texture. Biotite inclusions are much less common in quartz than in orthoclase and plagioclase. The quartz is relatively free of gas and liquid inclusions. Some quartz grains show slight undulatory extinction.

Seritization is more advanced in the plagioclase than in the orthoclase.

Thin sections of granite specimens taken within one-quarter mile of the contact commonly contain cataclastic and

mylonitic zones. In the crushed zones quartz and orthoclase
are the principal minerals. This fact would suggest that the
crushing and mylonitization occurred before the last deuteric
replacement by quartz and orthoclase and that the replacement
proceeded more easily and therefore more completely in the
shattered zones.

Petrographic Description of the Granite Lake Breccia

Hand specimen description. The breccia is an agmatite,
(Wegmann (29)), with dark-colored, angular to sub-rounded,
dense to fine-grained fragments of andesite which are contained
in a coarse-grained, light tan to gray granite matrix that is
identical to the granite of the central mass. Some of the
fragments are unaffected by the granite, whereas others are
copiously spotted with large crystals of quartz and feldspar
that were introduced from the granite. Some of the larger
quartz crystals in the fragments are rimmed with feldspar. A
few fragments have been so completely replaced that only a
shadow-like suggestion of their original shape remains.

The largest fragments measure up to ten inches in their
longest dimension; the smaller fragments may be only a fraction
of an inch in diameter.

No bridges or septa cross between fragments in any of
the specimens or outcrops examined.

Microscopic description of the granite matrix. The

Plate 45.   Outcrop of Granite Lake breccia at the
            type locality west of Granite Lake.

Plate 46. A relatively large fragment of andesite in the
Granite Lake breccia. Partial replacement of the
andesite by the granitic material has caused the
borders of the fragment to be indistinct. Many
fragments, like the one at the upper right, have
sharp borders. Septa are never observed between
fragments.
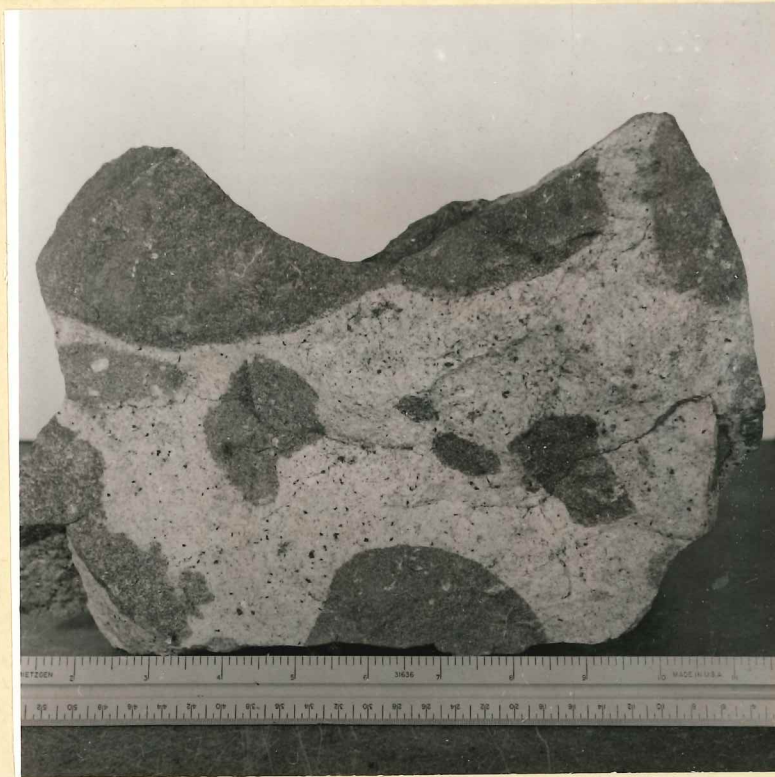
Plate 47.   Agmatitic Granite Lake breccia.
            The dark fragments are probably
            Keechelus andesite; the granite
            matrix is identical in composition
            to the Bumping Lake granite. Note
            the porphyroblasts of quartz and
            feldspar in some fragments.
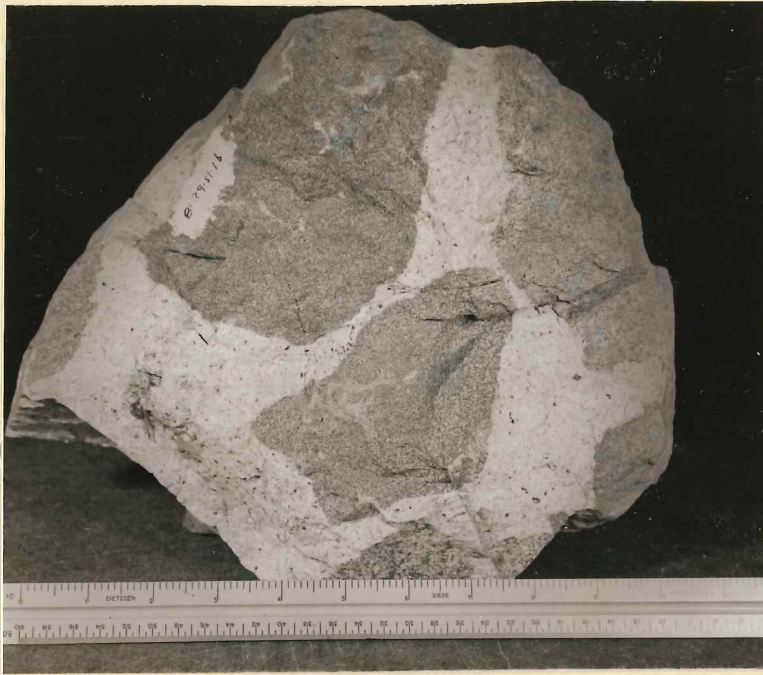
Plate 48.   Agmatitic Granite Lake breccia.
Note the sharp contacts between
andesite fragments and granite
filling and the lack of septa
between fragments. Incipient
silicification and feldspathiza-
tion of the fragments has taken
place.

granite matrix resembles the Bumping Lake granite except that it is less coarsely-grained. Most of the quartz and orthoclase, as in the Bumping Lake granite, are later than the plagioclase and biotite and are of replacement origin. Mylonitic zones of fine quartz and orthoclase occur more frequently than in the Bumping Lake granite central mass.

Inclusions of small, lath-shaped plagioclase (andesine?) and biotite typical of that found in the andesite fragments speckle the quartz and orthoclase of the granite matrix. These inclusions are particularly abundant near the contact between granite matrix and andesite fragments.

Microscopic description of the fragments. The dark fragments consist of a dense matte of plagioclase laths (andesine?), biotite, hornblende, and magnetite. Occasional large sub-hedral crystalloblastic grains of plagioclase which are similar in appearance and composition (oligoclase, Ab7An3) to the large early plagioclase in the Bumping Lake granite are scattered through the dense groundmass. These large plagioclases contain inclusions of biotite, but do not contain inclusions of the stubby laths of andesine.

Quartz and orthoclase are definitely later than, and replace or surround, all the other minerals in the fragments, including the oligoclase grains. Quartz and orthoclase are abundant in some fragments and the replacement is strong. In other fragments there is less quartz and orthoclase and

replacement is weak and incomplete. The paths that the replacing solutions followed through the fragments are usually easily traced because of the greater concentration of quartz and orthoclase in these zones.

Mylonites occur in the fragments but they are not as common as in the granite.

Microscopic description of the contact between the fragments and the granite matrix. The contact between the fragments and the granite matrix is quite sharp. Except for some inclusions in the quartz and orthoclase of the matrix near the contact, the biotite and andesine of the fragments terminate abruptly at the granite. However, quartz and orthoclase from the granite enter and replace minerals in the fragment to varying degrees as noted above.

There is no flow structure in the granite along the contact. A slight decrease in grain size of the minerals in the granite along the contact is evident. There are no optalic effects along the edges of the andesite fragments where they are in contact with the granite matrix.

Age Relationships of the Granitic Rocks

The clearest age relationship among the rocks mentioned above is that between the Puget Group sandstone and Bumping Lake granite. The granite is definitely later than and intrusive into the sandstone. The age of the Puget Group in
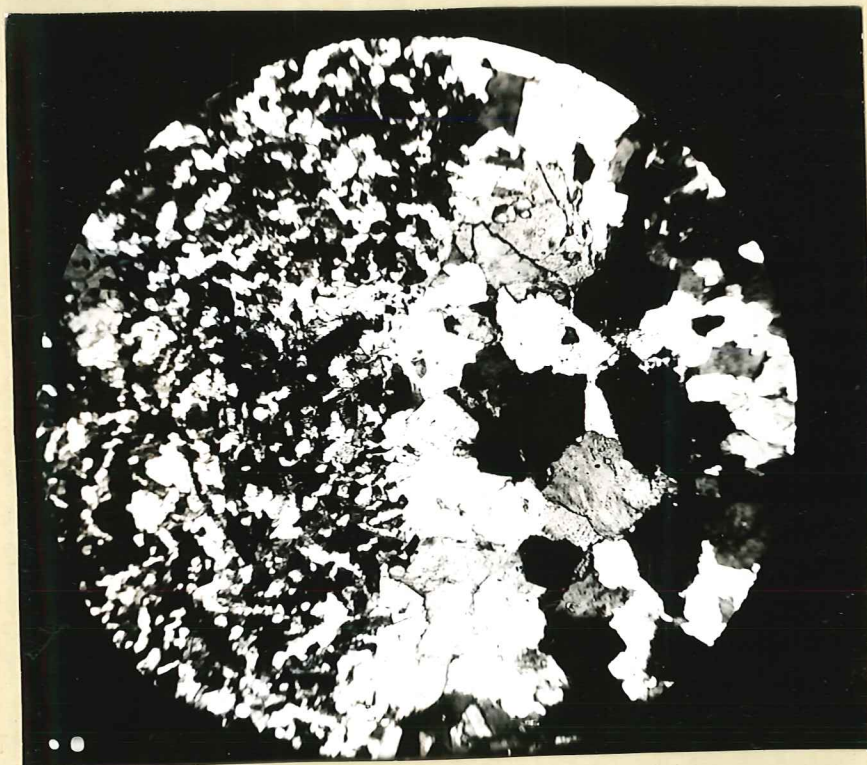
Plate 49.   Photomicrograph of the contact between
            granite matrix and andesite fragment
            in the agmatitic Granite Lake breccia.
            The granite is composed of quartz and
            feldspar. The andesite is composed of
            andesine laths and biotite with minor
            pyroxene. Silicification and felspathi-
            zation of the fragments has taken place,
            but is not well shown. x 20, Crossed
            nicols.

its main areas of distribution has been established as Eocene
by White (31). Even though no fossils have been found in the
Puget Group sandstones in the Mt. Aix region, the writer
considers that these sandstones are probably also Eocene in
age. If that is true, the lower age limit for the emplacement
of the granitic rocks must be very late Eocene, or more
probably, post-Eocene.

The granite is also later than the andesites of the
lower portion of the Keechelus series (Cougar Creek andesite)
which was brecciated by the intrusion. Parts of the Keechelus
have been established as Oligocene in age by Grant (17);
however it appears very probable that there exists an inter-
tonguing relationship between parts of the Keechelus with the
Puget Group. Therefore, the lower age limit of the granite
intrusion cannot at present be fixed more exactly than latest
Eocene.

The Bumping Lake granite is probably slightly older
than the Granite Lake breccia, at least according to the
writer's interpretation of their contact relationship (cf.
below).

The Bumping Lake granite, Granite Lake breccia, and
lower portions of the Keechelus are older than dacite porphyry
dikes and sills that intrude all three. No definite date can
be assigned to the intrusion of the dacite porphyry, but the
time of its intrusion may be used as an upper age limit for

the emplacement of the granite and breccia, i.e. the granitic
rocks are pre-dacite porphyry, which is pre-Fifes Peak
andesite. Therefore, the upper age limit for the emplacement
of the granitic rocks is pre-early Miocene. This dating,
although it is not exact, is probably more nearly correct than
that determined by a second method based on the position of the
Deep Creek andesite. The second method is given below.

The Deep Creek andesite (cf. chapter on Deep Creek
andesite) lies unconformably upon a rugged erosional surface
of Bumping Lake granite, Granite Lake breccia, and dacite
porphyry dikes mentioned above. This contact is evident in the
valley of Deep Creek a few hundred yards downstream from its
confluence with Copper Creek. The Deep Creek andesite is
identical to the Howson andesite in the Snoqualmie quadrangle.
Smith and Calkins (25) dated the Howson andesite as late
Miocene or Pliocene, and the writer tentatively accepts this
dating for the Deep Creek andesite. Consequently, this provides
a possible upper age limit of late Miocene or Pliocene for the
intrusion of the granitic rocks. This upper age limit is
unsatisfactory, however, because a long period of erosion
intervened between the intrusion of the granite and deposition
of the Deep Creek andesite. It is also unsatisfactory because
Smith and Calkins did not have conclusive evidence for dating
the Howson andesite. Therefore, by this method, the upper age
limit for the intrusion of the granitic rocks cannot be

definitely set.

Conclusion and Genetic Interpretation

As indicated in the opening paragraph of this chapter definite conclusions on the genesis of the granitic rocks in the Bumping Lake district will not be reached. The assembled facts from the field and from microscopic study suggest, however, a genetic interpretation of these rocks that is given below.

An intrusion of more or less dioritic composition penetrated the Puget Group sandstone and the andesitic flows of the lower portion of the Keechelus formation at some time later than the consolidation of these flows. The dioritic material came up through the underlying Puget Group sandstone and invaded the overlying lower Keechelus lavas. The effects of the rising dioritic material in the underlying sandstone must have been quite different from those in the andesite, because there was little or no brecciation of the sandstone, whereas the andesite was severely brecciated. However, no evidence of the emplacement of the dioritic material in the sandstone is actually preserved because a second intrusive phase (cf. below) has obscured this earlier stage.

In the lower portions of the Keechelus, which was intensely shattered, there was very little assimilation of the andesite, and replacement and assimilation were weak and

incomplete. Apophyses of the intrusive mass did not penetrate beyond the zone of brecciation into unbrecciated Keechelus rocks. The principal mechanism in the formation of the agmatitic breccia was that of filling the room between the fragments of andesite by intrusive material.

After consolidation of the agmatite a second partially crystallized intrusive dioritic body, probably with the same source at depth as the first, penetrated the central portion of the already solid breccia. The second intrusion acted like a giant piston and pushed out of the way most of the central portion of the breccia with the exception of a few isolated bodies. This type of intrusion would account for the sharp contact between Bumping Lake granite and Granite Lake breccia and for the lack of andesite inclusions in the Bumping Lake granite.

Strong protoclastic shearing in the plug-like body and the breccia near their contact was caused by the forceful intrusion of the plug. Evidence of this shearing is seen in thin sections as mylonitic zones in both granite and breccia. This second intrusion is in sharp contact with the Puget Group sandstone into which it has injected apophyses for several hundred feet.

Following the intrusion of the plug-like mass of dioritic rock, deuteric orthoclase and quartz replaced the early minerals, namely biotite and plagioclase in varying

degrees. The deuteric replacement process was active
throughout the entire complex; that is, in the central plug,
in the dioritic matrix of the breccia, and in the andesite
fragments of the breccia. As mentioned previously the deuteric
replacement was most complete in the cataclastic zones near
the granite-breccia contact. This deuteric replacement
converted a more or less dioritic rock into a granitic one.

The petrographic evidence may be summed up as follows.
The small, stubby plagioclase laths (apparently for the most
part andesine) hornblende, augite, biotite, and magnetite in
the dark fragments of the Granite Lake breccia are the primary
and contact metamorphic minerals in the flows of the lower
portion of the Keechelus. The biotite in the hornfelsized
Puget Group sandstone near the granite contact was produced
by contact metamorphic action on argillaceous material in the
sandstone.

The oligoclase and biotite grains which are frequently
replaced by orthoclase and quartz represent the approximate
composition of the initial intrusion at the time of its
emplacement. The oligoclase porphyroblasts in the andesite
fragments of the breccia belong to this same period.

The original composition of the second, or plug-like
intrusion, was probably mainly oligoclase and biotite. Most of
the orthoclase and quartz, however, are principally deuteric,
although a certain percentage of orthoclase and quartz present

may be primary constituents.

Dacite Porphyry

An extensive intrusive body that is predominantly dacitic in composition, but that locally may be andesitic, trends in a general north-south direction through the central portions of the area. No specific name is assigned to this body other than its rock-type classification. This intrusive mass of dacite porphyry is nearly 1,000 feet thick in some localities and occupies approximately 10 percent of the area mapped. It is intrusive into Bumping Lake granite, as relatively small finger dikes and dike swarms, but it reaches its greatest development as a huge dike or sill that intrudes the lower and middle portions of the Keechelus series, i.e. the Cougar Lake andesite, Morse Creek andesite, and Richmond breccia. The dacite porphyry did not penetrate the Mt. Aix andesite porphyries, probably because the intrusion did not extend high enough into the Keechelus series to invade Mt. Aix andesites, and probably not because the intrusion occurred before deposition of the Mt. Aix phase. The dacite porphyry intrusion definitely does not penetrate the Fifes Peak andesite or Yakima basalt, in fact the gently dipping Fifes Peak flows rest with angular unconformity upon the eroded surface of the steeply dipping dacite porphyry dike.

The dacite porphyry has a very distinctive appearance. It is fairly coarsely-grained; feldspar and quartz grains are easily recognized with the naked eye. The most characteristic feature of the rock is the large hexagonal phenocrysts of biotite. Some of these flakes of biotite may be a quarter of an inch across. The rock weathers a light gray color, although outcrops that have been exposed for long periods of time support the growth of a brownish lichen. This type of lichen is peculiar to the dacite porphyry, and does not grow on other types of rock. The lichen growth is found only in the higher elevations.

The dacite porphyry is a poor cliff-former, but it does form extensive talus slopes composed of small tabular fragments. The appearance of these talus slopes is distinctive and provides a fairly reliable means of identifying the dacite porphyry outcrops from a distance.

The dacite porphyry has not been described in the Mt. Rainier or Snoqualmie quadrangles.

In a predominantly volcanic province such as the Mt. Aix quadrangle with a great variety of extrusive rock types a problem exists, namely to distinguish extrusive from intrusive porphyritic rocks. Such a problem arose concerning the dacite porphyry. In this heavily-wooded country exposed contacts are few, and exposures that produce positive evidence are at a minimum. The writer is certain, however, that enough data was

collected from scattered points along the trend of this body
to classify it as intrusive. The most conclusive of these
data are presented below.

The observable fact that dacite porphyry dikes that
closely resemble and are geographically adjacent to the main
dacite porphyry mass cut through Bumping Lake granite is an
excellent indication that the dacite porphyry is intrusive.
Localities where this relationship may be seen are, in road
cuts along the old road from the Copper City mill site to the
mine and in the vicinity of the Copper City mine, in the valley
of Deep Creek below its confluence with Copper Creek, one-half
mile east of Swamp Lake where the dacite porphyry is in the
form of a n intrusive stock or plug.

A second criterion to show the intrusive nature of the
dacite porphyry is its contact effect on the country rock.
Contacts between dacite porphyry and Bumping Lake granite are
not diagnostic because the contact metamorphic effects on the
granite are very slight. Contact phenomena are well shown,
however, in some Keechelus rocks. Along the crest and on the
east slopes of Nelson Ridge the Keechelus breccias and flows
are bleached and baked for several yards from the contact. The
contact is not so notable for the production of alteration
products from minerals in the Keechelus as for the optalic
effects, perhaps because most of the mafic minerals in the
Keechelus were already moderately to strongly altered before

the intrusion of the dacite porphyry.

Displacement and tilting of the country rock by the dacite porphyry is the third significant indication of intrusion. Near the Keechelus-dacite porphyry contact on the north side of American River, Keechelus beds dip 35° west away from the contact, although the regional dip in this area is about 10° northeast. In addition the dacite porphyry in this area cross cuts the bedding planes in the Keechelus.

Inclusions of country rock in the dacite porphyry are not common, but they are found occasionally (see Plate 50).

These contact phenomena, although they are geographically widely separated, and often imperfectly displayed, are sufficiently characteristic of an intrusive mass to designate the dacite porphyry as intrusive.

In the Copper City mine post-mineral dikes in the Bumping Lake granite are probably related to the dacite porphyry. These dikes have been described by Barry (2), DuBail (11), Hobbs (18), and others. Although the appearance of these post-mineral dikes is not identical to the dacite porphyry, their mineral composition is similar.

A definite date for the intrusion of dacite porphyry cannot be determined. The intrusion is post-Bumping Lake granite and pre-Fifes Peak andesite. This provides a probable lower age limit of late Eocene or early Oligocene and an upper age limit of late Oligocene or early Miocene. It will have to

Plate 50. Dacite porphyry with inclusion of Keechelus andesite. Note the large biotite grains in the dacite porphyry.

suffice to date the dacite porphyry intrusion as Oligocene until additional evidence for dating can be assembled.

Petrographic Description of Dacite Porphyry

Megascopic description. The rock is medium-grained, light gray in color and has especially large phenocrysts of biotite. Weathering out of some biotite grains leaves angular cavities on the exposed surface. Feldspar and quartz also form fairly large grains. The feldspar is commonly euhedral in shape and chalky in color. Hornblende, which is not so abundant as biotite, occurs as scattered crystals. Under the hand lens granules of magnetite are plentiful. Green alteration products occur as small specks, but they are not sufficiently numerous to give the rock a greenish tinge.

Microscopic description. The rock is always porphyritic with large phenocrysts of plagioclase, quartz, orthoclase, biotite, and hornblende set in a holocrystalline mosaic of very fine-grained feldspar and quartz with minor amounts of biotite and magnetite. The phenocrysts are rather widely separated and glomeroporphyritic textures are absent. Alteration in the rock as a whole is slight, although some hornblende and biotite grains may alter to chlorite.

The plagioclase phenocrysts are large and blocky. They are euhedral to sub-hedral in shape, but some grains are cataclastic. The average length is 1mm. although some of the

Plate 51.   Photomicrograph of dacite porphyry.
The mafic mineral near the center of
the photograph showing good cleavage
is hornblende. The white grain in
the upper right is quartz. The large
euhedral grain on the left is plagio-
clase (andesine). Note the zoning in
the plagioclase. x 15, Crossed nicols.

Plate 52.   Outcrop of Snoqualmie granodiorite near the
headwaters of Morse Creek. Note the many
inclusions. In the photograph this rock
resembles the Granite Lake breccia to some
extent, but actually their lithology is quite
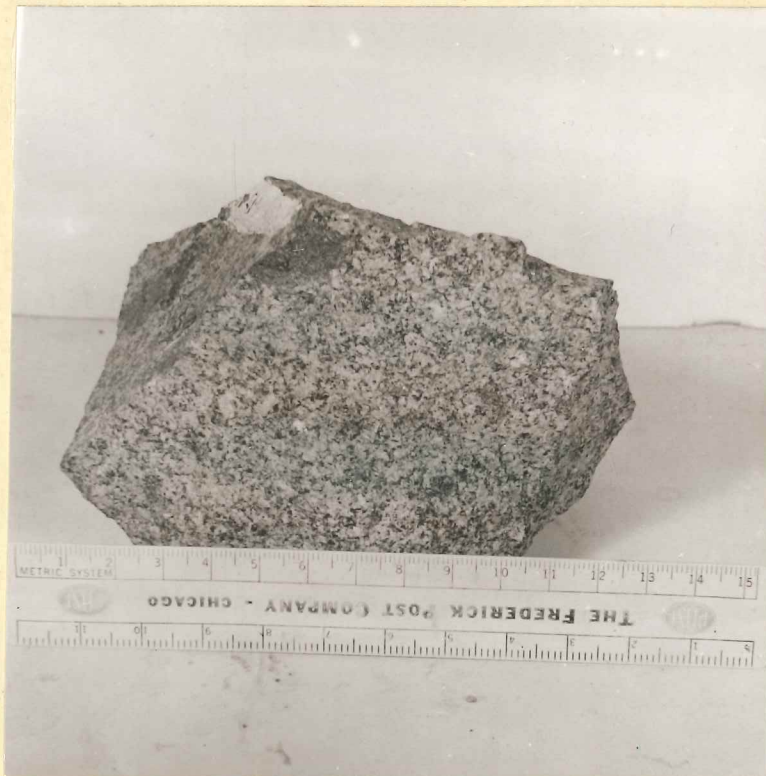different (see text).

Plate 53. Snoqualmie granodiorite. Microscopic
           examination of this rock indicates
           that it was probably formed by meta-
           somatic replacement processes.

larger grains measure several millimeters. The composition of the plagioclase is andesine, Ab52 to Ab64. Oscillatory zoning is very common, and in fact most of the plagioclase phenocrysts are zoned. The zonal boundaries are usually sharp and regularly spaced. In some grains a dozen or more zones were visible. The centers of the zoned plagioclase phenocrysts are more calcic than the rims. Albite twinning is well-developed and may occur with Carlsbad twinning. Alteration of plagioclase to calcite occurs locally, but kaolinization of the feldspar is very minor.

Quartz forms prominent phenocrysts. The quartz is commonly clear and free of inclusions except for needles of apatite. The boundaries of the quartz grains are not corroded. The grains vary a good deal in size, but they average about .5mm in diameter.

Orthoclase is less abundant than plagioclase. It forms a few large phenocrysts that are irregular in shape. The orthoclase is unaltered, frequently untwinned, and measures approximately 1.5mm in its greatest dimension.

Biotite occurs as small ragged grains and also as very large hexagonal plates. During grinding of the rock section, however, the large grains were usually dislodged and lost. Most biotite phenocrysts are fresh or show only slight alteration to chlorite and magnetite. A few grains of biotite are completely chloritized. There were no pleochroic haloes

in any biotite flakes examined.

Hornblende is usually subordinate in abundance to biotite, but in parts of the dacite porphyry it is the principal mafic mineral. Outcrops along American River are rich in large hornblende grains that are very fresh and strongly pleochroic. In other areas hornblende commonly alters to biotite, chlorite, and magnetite. The alteration products may form an outer rim around an enclosed hornblende crystal or the hornblende may be completely replaced and only its crystal outline remain. The pleochroism in the hornblende is, X light brown, Y greenish brown, Z green. The average length of longitudinal sections is .3mm.

Magnetite occurs as scattered granules of primary origin and as an alteration product around the mafic minerals, or in clusters pseudomorphic after hornblende.

The groundmass is finely divided or cryptocrystalline mosaic of plagioclase, orthoclase, quartz, magnetite, and biotite. The groundmass shows only slight alteration effects. Needles of apatite are included in some of the grains of feldspar and quartz.

The average percentage of minerals in the dacite porphyry is as follows: plagioclase, 40; quartz, 15; orthoclase, 10; biotite, 10; hornblende, 10; magnetite, 5; chlorite, 5; calcite, 3; apatite, 2.

Summary of Dacite Porphyry

The most significant points in connection with the dacite porphyry are as follows:

1. The dacite porphyry is a thick and extensive unit.

2. It is intrusive.

3. It intrudes Keechelus andesite and Bumping Lake granite.

4. It is unconformably overlain by Fifes Peak andesite.

5. The probable date of intrusion is Oligocene, but the age cannot now be more definitely fixed.

Snoqualmie Granodiorite

Only a relatively small body of Snoqualmie granodiorite, which is a common intrusive rock in the central Cascades of Washington, is exposed in the Mt. Aix quadrangle. There is some question whether the granodiorite in this area is truly an intrusive body. The single occurrence of granodiorite trends north-south for approximately two miles near the western margin of the Mt. Aix sheet. The maximum width of the body is approximately 2,000 feet. The contacts between Snoqualmie granodiorite and Keechelus andesite are indistinct and gradational and cannot definitely be located. A transverse section of the granodiorite is exposed in road cuts on U.S. Highway 410 beginning about one mile east of Chinook Pass. These exposures

extend intermittently along the road for about 1,500 feet.
The granodiorite constitutes approximately 1 percent of the
total area mapped, but only a fraction of that amount is
exposed.

Smith and Calkins (26) named the rock for its type
locality in upper Snoqualmie River. Coombs (8) described
several occurrences of Snoqualmie granodiorite in the Mt.
Rainier quadrangle.

The granodiorite is a light to medium gray color, has
a coarsely grained texture, and is always rich with inclusions
of dark colored andesite. Often the percentage of included
material is greater than the percentage of granodiorite. The
inclusions vary in size from blocks six feet or more in length
to small specks that go beyond the megascopic range. The
outlines of some inclusions are difficult to distinguish and
the inclusions deserve the name, skialiths, as defined by
Goodspeed (15). Indistinct septa between fragments may
occasionally be visible. The weathered surface is mottled
light gray with dark patches, the dark patches being inclusions.

In the Mt. Aix area Warren (29), Hobbs (18), and others
identified Bumping Lake granite and its associate, Granite Lake
breccia, as Snoqualmie granodiorite. The writer does not agree
with this interpretation. Results of the present study show
that Bumping Lake granite and Granite Lake breccia have a
uniform and typically granitic composition and are probably

intrusive masses, whereas the Snoqualmie granodiorite is not
granite, but, as the name implies, granodiorite, and in the
Mt. Aix area probably owes its origin to the partial replacement
of Keechelus andesite by metasomatizing solutions. A table
showing contrasting field and microscopic features of Bumping
Lake granite and Snoqualmie granodiorite is given in the
summary of this chapter.

Near Lake Keechelus in the Snoqualmie quadrangle
Goodspeed and Coombs (16) described breccias in the Keechelus
series that were formed by partial replacement of arenaceous
shales by hydrothermal solutions. The rock had the megascopic
appearance of an intermediate igneous rock with inclusions of
dark volcanic fragments. Microscopic examination revealed,
however, that the dark inclusions were clastic sediments and
that the grained matrix was the result of recrystallization
replacement of portions of the sediment. Goodspeed and Coombs
state that:

> There are many exposures in the Cascades of
> Washington where the Snoqualmie granodiorite has
> invaded the Lower Keechelus, and in this immediate
> vicinity (along the eastern shore of Lake Keechelus)
> the granodiorite can be expected at the depth of a
> few hundred feet. It is, therefore, logical to assume
> that emanations came from the granodiorite mass.

The Lake Keechelus breccias and the Mt. Aix-Snoqualmie
granodiorite mass cannot be compared directly because the
inclusions in the granodiorite are dark andesitic rock and not
clastic sediment. However, the processes by which the two

"breccia-like" bodies were formed may have been somewhat analogous. From thin sections studied it is likely that the granodiorite is the result of partial replacement of Keechelus andesite by hydrothermal solutions. These emanated from the main mass of Snoqualmie granodiorite which is probably not far beneath the present surface.

Because only Keechelus is in contact with the granodiorite, the date that must be assigned to the introduction of the granodiorite is post-Keechelus.

Petrographic Description of the Snoqualmie Granodiorite

Megascopic description. (See the first page of this chapter).

Microscopic description. Thin sections show a disordered fabric of turbid plagioclase grains which are usually sub-hedral, in a fairly coarsely-grained confused matrix of plagioclase, orthoclase, quartz, hornblende, biotite, epidote, and chlorite. Except for a few idiomorphic plagioclase grains the minerals are exceedingly irregular in shape and imperfectly formed. The original mafics, hornblende, and biotite, are exceedingly irregular and ragged due to their replacement in part by plagioclase, orthoclase, and quartz. The rock is filled with inclusions that are best identified as concentrations of ragged hornblende and biotite grains. The borders of the inclusions are gradational with the matrix. It is often

difficult to determine the contact between inclusion and matrix because much of the included material is strewed through the matrix.

Plagioclase is the most abundant mineral. It is more commonly subhedral than euhedral due to later replacement by orthoclase and quartz. Zoning in the plagioclase is common. The zones are not, however, sharply defined or angular. The rims are more sodic than the central portions. Albite twinning is poorly displayed and fuzzy, in fact it is often obscured by swarms of inclusions and turbidity in the plagioclase. The mineral inclusions that commonly give plagioclase grains a sieve texture are hornblende, epidote, biotite, magnetite. The larger plagioclase grains average .6mm in length. The composition of the plagioclase, although determination was difficult with the turbid grains, is andesine Ab6. Porphyro- blasts of plagioclase sometimes occur in the clusters of hornblende and biotite.

Orthoclase, which is subordinate in quantity to plagioclase, is interstital, anhedral, and frequently choked with mafic inclusions. The orthoclase grains vary greatly in size and shape. Like plagioclase, it occurs as porphyroblasts in the dark andesitic inclusions.

Quartz is found in minor amounts as a later mineral with exceedingly irregular outlines. It replaces the mafic minerals, plagioclase and orthoclase. The quartz anhedra are usually

Plate 54.   Photomicrograph of Snoqualmie granodi-
            orite.   Note the preponderance of
            plagioclase over orthoclase; the con-
            fused texture; and the remains of a
            fragment in the lower left that can
            scarcely be distinguished from the
            matrix.   Compare with Bumping Lake
            granite.   x 15, Crossed nicols.

relatively free of included material.

Hornblende, the major mafic constituent, sometimes
shows evidence of former euhedral shape, but it usually occurs
as irregular ragged grains between feldspars and quartz or as
inclusions in the feldspar. Some hornblende has altered to
biotite, which in turn has altered to chlorite. Epidote is
also an alteration product of hornblende. The hornblende is
the common green variety, moderately pleochroic with X very
pale brown, Y pale brownish green, Z green.

Biotite, like hornblende, is ragged and invariably
replaced by the later feldspars and quartz.

Magnetite is abundant as granules and dust in all thin
sections examined.

Summary of Snoqualmie Granodiorite

In summary there are two important concepts involved
in the Mt. Aix mass of Snoqualmie granodiorite.

1. Although the outcrops are few and poorly exposed,
the evidence collected suggests a metasomatic origin for this
inclusion rich body of granodiorite.

2. Bumping Lake Granite and Granite Lake breccia are
not, as has been stated in the literature, parts or correlatives
of the Snoqualmie granodiorite. Lists of comparative field and
microscopic features follow:

FIELD RELATIONS

Bumping Lake granite and Granite Lake breccia	Snoqualmie granodiorite
Sharp contacts with all country rocks.	Indistinct and gradational contacts with Keechelus andesite.
Light tan color, highly glassy surface.	Gray color with dull surface.
Decrease in grain size near contacts.	No decrease in grain size observed.
Displacement of country rock very evident in some areas.	Displacement of country rock not observed.
Inclusions usually less than one foot in length.	Inclusions may be six feet in length.
No septa observed between any inclusions.	Indistinct septa connect some inclusions.
Contact metamorphic effects noted in country rock.	No contact metamorphic effects observed in Keechelus rocks surrounding the granodiorite body.

MICROSCOPIC RELATIONS

Excessive quartz	Minor quartz
Plagioclase and orthoclase in approximately equal amounts.	Plagioclase more abundant than orthoclase.
Plagioclase is oligoclase, occasionally zoned and usually clear.	Plagioclase is andesine, usually zoned, and turbid.
Biotite is principal mafic mineral. Sometimes chloritized.	Hornblende is principal mafic mineral. Goes to biotite and chlorite.
Magnetite present but in minor amounts.	Magnetite present in considerable quantity.

MICROSCOPIC RELATIONS (continued)

Bumping Lake granite and Granite Lake breccia	Snoqualmie granodiorite
General texture is mosaic of interlocking grains.	General texture is of a confused crystalloblastic character.
Poikiloblastic textures in larger, late-deuteric feldspar grains found occasionally.	Poikiloblastic textures in feldspar grains is very common.
Contact between andesite inclusions and matrix is sharp.	Contact between andesite inclusions and matrix is indistinct and transitional.
Degree of mineral alteration slight.	Degree of mineral alteration moderate.
Mylonitic zones are common near contact granite and country rock.	No mylonitic zones observed anywhere.

N.B.   Because these two types of rocks are nowhere in contact, in observed exposures their relative ages cannot be determined.

Diorite Plugs

Two intrusive plugs of diorite are found in this area. The largest of these plugs forms the 7,000 foot peak known as Mt. Baldy, the other forms a relatively small outcrop on the north side of Bumping Lake. Together these plugs constitute approximately 1 percent of the total area mapped. Mt. Baldy and vicinity afford the better exposures, therefore this occurrence will be described in detail.

The Mt. Baldy diorite forms an irregularly-shaped mass with the long axis trending northwest-southeast. The dioritic body is approximately one mile long and one-half mile wide. Diorite composes the eastern slopes and the summit of Mt. Baldy, the southern end of Buffalo Hump, and the upper portion of Thunder Creek valley. The rock is an excellent cliff-former and steep-walled cirques are prominent in this locality. The diorite displays a widely spaced joint pattern that is responsible for the massive blocky appearance of the outcrops, and for the great rock abutments that give Mt. Baldy a bulky, broad-shouldered appearance.

There is no doubt that the diorite is an intrusive body. Keechelus andesite and dacite porphyry, into which the diorite is intrusive, are strongly tilted by the intrusion and contact metamorphic effects extend for a hundred feet or more into the country rock. These contact effects are principally optalic. Bleaching and baking of the dacite porphyry and andesite is very evident. In addition the country rock is hornfelsized and silicified. Both Keechelus andesite and dacite porphyry dip away from the intrusive diorite at angles up to 65°.

Almost circling the Mt. Baldy diorite plug is a bed of light gray arkosic sandstone that is approximately 100 feet thick. Microscopic examination of this sandstone, which is composed almost entirely of quartz and orthoclase fragments,

Plate 55. Looking southwest toward Mt. Baldy from Thunder
           Creek. The entire mountain mass is a plug of
           diorite. The summit is barely visible on the
           skyline. Note the blocky jointing in the
           diorite. Evidence of a fairly recent landslide is
           seen in the foreground.

indicates that it belongs to the Puget Group. Because the
Puget Group sandstone should be several hundred feet beneath
the area in which it outcrops around Mt. Baldy, the sandstone
must have been carried upward by the force of the diorite
intrusion. On the north side of the intrusive body the
sandstone member is standing nearly vertically, but on the
south side near Richmond Lake the sandstone is only slightly
tilted. The Mt. Baldy area marks the easternmost exposure of
Puget Group sandstone in this region. A more detailed
description of the unusual occurrence of the sandstone is
given in the chapter, Puget Group Sandstone.

The diorite is coarsely-grained, massive, and dark
gray in color. Porphyritic textures are absent.

Although the diorite is unquestionably intrusive into
Puget Group sandstone, Keechelus andesite, and dacite porphyry,
its relationship to Fifes Peak andesite, that forms three
erosional outliers on the crest of Buffalo Hump, is not clear.
The Fifes Peak outcrop is small and the contact between diorite
and Fifes Peak andesite is obscured by brush and talus.

The lower age limit for intrusion of the diorite is
post-dacite porphyry, but because definite evidence is lacking
concerning the contact between diorite and Fifes Peak andesite,
the upper age limit remains undetermined. The writer assumes
it temporarily to be pre-Fifes Peak. This would date the
intrusion as later Oligocene. Further work may uncover evidence

that will advance the upper age limit of the diorite into the
Miocene. Similarity with Oregon diorite plugs mentioned below
suggests, but does not prove, emplacement in the Miocene.

Buddington and Callaghan (6) described diorite and
quartz diorite plugs, stocks, and dikes along the crest of the
Cascades in Oregon. Many of these bodies are nearly identical
in general appearance, structure, and mineral content to the
two masses in the Mt. Aix quadrangle. Buddington and Callaghan
dated the Oregon diorites as Miocene because the intrusive
body of diorite at Shellrock Mountain, Oregon penetrated the
Yakima basalt. These workers described mineralized veins in
or around some of the Oregon diorites. The two dioritic stocks
in the Bumping Lake area are associated with no mineralization,
unless a small sulfide vein in the Richmond Mine on North Fork
Creek is related to the diorite intrusion. The mine is,
however, a mile south of the diorite contact.

Petrographic Description of Diorite Plugs

Megascopic description. The diorite is a dark gray,
evenly textured, massive rock with no structural peculiarities
in hand specimen. The weathered surface is gray and slightly
pitted. Under the hand lens a fresh surface shows fairly
prominent phenocrysts of plagioclase feldspar in a coarse-
grained matrix of feldspar and mafic minerals. Quartz is not
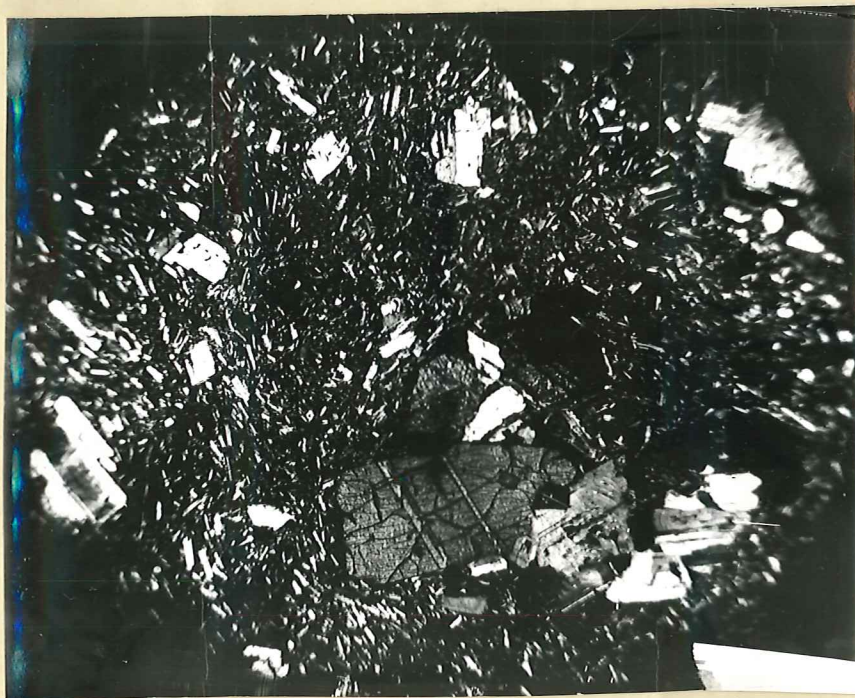visible.

Plate 56. Photomicrograph of diorite from
Mt. Baldy plug. Note the large
twinned pigeonite grain which is
set in a matrix of medium to small
plagioclase grains. x 15, Crossed
nicols.

<u>Microscopic description</u>. The rock is holocrystalline and composed principally of plagioclase, pigeonite, uralitic hornblende, chlorite, and magnetite. The plagioclase forms a fabric of interlocking grains some of which are slightly larger than others. Quartz and orthoclase occur as very minor and perhaps secondary constituents. They are not present in sufficient quantities to warrant calling the rock quartz diorite.

Plagioclase is the most abundant mineral. It occurs as moderately large euhedral to subhedral phenocrysts and as smaller grains in the matrix. The phenocrysts average .5mm in length but they may reach 2mm. The composition, which is the same for the large and small plagioclase grains, varies from labradorite, Ab48 to andesine Ab56. Some thin sections show rather severe cataclasis of the plagioclase. Oscillatory zoning is present but is not nearly so well developed as the dacite porphyry. Sieve textures in the larger plagioclase grains are very common. Some plagioclase crystals contain many inclusions of pyroxene, uralitic hornblende, and chlorite. Most plagioclase grains have relatively clear margins but the central portions are clouded with kaolinite.

Pigeonite is the principal pyroxene in the diorite. A small 2V in pyroxene grains indicates pigeonite rather than augite. The pigeonite forms large subhedral to anhedral grains that average .5mm in diameter, but some individuals may reach

2mm. Twinning is very common and well developed. More grains are twinned than untwinned and some show lamellar twinning. Although a few pigeonite grains are fresh, except for uralitization around the edges and in fractures, most of the pyroxene has gone to uralitic hornblende or chlorite.

Hornblende is all of secondary origin being derived from pyroxene. Because uralitization of the pyroxene was widespread, hornblende is a major constituent of the rock. The hornblende may form rather large pseudomorphic grains after pigeonite, or it may occur interstially as small irregular grains.

Magnetite is found as primary granules and as an alteration product of the mafic minerals.

Quartz and orthoclase are nearly always present but they occur in minor amounts. They occur as anhedra between crystals of plagioclase.

The average percentage of constituent minerals in the diorite is as follows: plagioclase, 65; pyroxene, 10; uralitic hornblende, 10; chlorite, 10; magnetite, 3; quartz, 1; orthoclase, 1.

The petrographic description by Buddington and Callaghan (6) of the intrusive body at Shellrock Mountain in the Oregon Cascades is very similar to the description above. They named the rock augite diorite. Perhaps a more accurate name for the Mt. Baldy mass would be pigeonite diorite.

Summary of Diorite Plugs

The following points are the most significant concerning the diorite plugs in the Bumping Lake area:

1. The diorite is intrusive into Puget Group sandstone, Keechelus andesite, and dacite porphyry.

2. Its rock classification is pigeonite diorite.

3. The country rocks show displacement by intrusion and contact metamorphic effects.

4. The diorite intrusion may be Oligocene in age but a clearer understanding of its relationship to Fifes Peak andesite might change the date of intrusion to Miocene.

Quartz Monzonite Porphyry

An elongate stock or dike of quartz monzonite porphyry, striking approximately east-west, is intrusive into Keechelus andesite on the east slope and crest of Crystal Mountain. The mass is at least one mile in length and averages 1,000 feet in width. Its extent to the west in the Mt. Rainier quadrangle is not known because the body is obscured on the west slope of Crystal Mountain by heavy forest. The monzonitic intrusion occupies approximately 1 percent of the total area mapped.

The most striking feature in the field of the quartz monzonite porphyry is its light color. From view points several miles from the outcrop the observer is immediately

attracted to this light gray outcrop which at certain times
of the day is almost white. The light color is especially
striking because the Keechelus rocks are all uniformly somber
in color. Another unusual feature of this rock is the
sheeting, or low angle convex upward jointing which has
prepared the outcrop for spalling. This has resulted in the
accumulation of large amounts of talus.

The intrusive quartz monzonite porphyry cuts across
the bedding of the Keechelus which is dipping about 8° north.
Displacement of the Keechelus by the intrusion was not severe,
but contact metamorphic effects are evident. These are notably
the formation of massive amphibolite in Keechelus rocks near
the contact.

The age of the quartz monzonite porphyry intrusion
cannot be determined more accurately than that it is post-
Keechelus, because there are no younger rocks overlying the
Keechelus in this district.

Buddington and Callaghan (6) described an intrusive
granodiorite porphyry in the Oregon Cascades that is somewhat
similar to the quartz monzonite porphyry, however in the
granodiorite porphyry orthoclase and quartz are comparatively
minor constituents whereas in the quartz monzonite porphyry
they are abundant. The quartz monzonite porphyry intrusive
may, nevertheless, belong to the post-Keechelus, or Miocene,
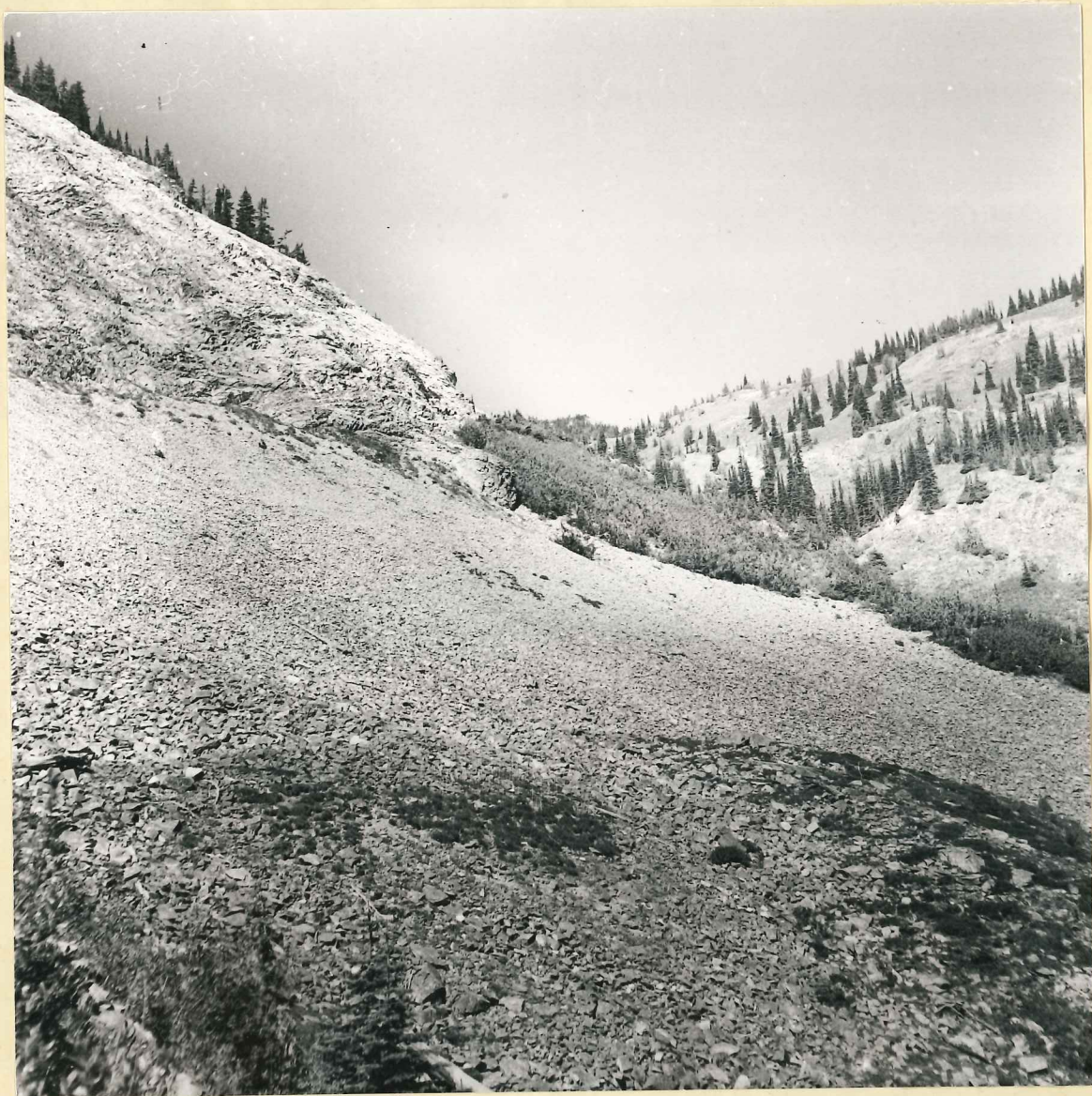sequence of small intrusions of intermediate composition that

Plate 57. The light-colored exposure on the left is
composed of quartz monzonite porphyry, which is
intrusive into the Keechelus. Their contact
lies in the gully to the right. Note the
sheeting in the monzonite and the abundant talus.

trend northwest along the flanks of the Cascades. It is
possible that the quartz monzonite porphyry was more or less
contemporaneous with the diorite plugs which were described
in the last chapter.

On the south and east sides of the quartz monzonite
porphyry stock there are small veins of gold and silver bearing
sulfide ores in Keechelus andesite. To the writer's knowledge
there are no veins, or at least no prospect holes, in the
quartz monzonite body itself. It is probable that the
formation of mineralized fissure veins in the Keechelus
andesite was concomitant with the quartz monzonite porphyry
intrusion.

Petrographic Description of the Quartz Monzonite Porphyry

Megascopic description. The rock contains large,
square, chalky phenocrysts of feldspar and glassy grains of
quartz set in a dense light greenish gray matrix. It is the
large and abundant feldspar phenocrysts that give the outcrops
a distinctive light color. Most quartz occurs as visible
individual grains, but under the hand lens some quartz grains
may be seen included in feldspar phenocrysts. Black specks
of magnetite are scattered throughout the rock. One lath of
hornblende was seen megascopically, but under the microscope
all the hornblende has altered to epidote.

Microscopic description. The rock is composed of large
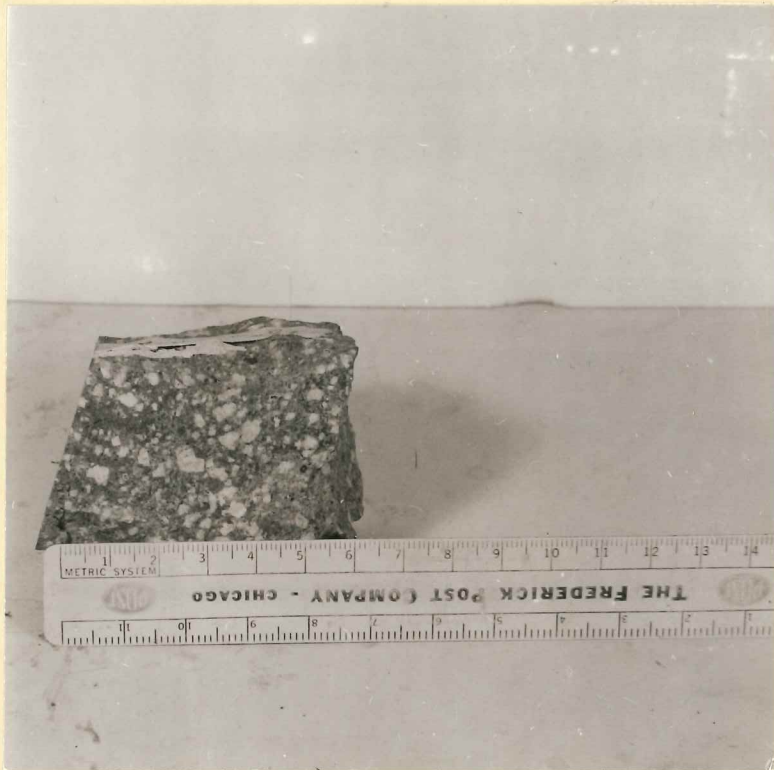
Plate 58.   Quartz monzonite porphyry from the
            Silver Creek area. The large, chalky
            feldspar phenocrysts lend a distinctive
            light color to outcrops of this rock.

euhedral to subhedral phenocrysts of orthoclase, plagioclase,
and quartz, with smaller grains of epidote, set in a very
fine-grained holocrystalline matte of feldspar, quartz, and
various alteration minerals.

Orthoclase, which is slightly more abundant than
plagioclase, occurs as phenocrysts that average 1.5mm in
length, but some individuals may reach 3mm. The orthoclase
is usually untwinned, although some smaller grains may show
Carlsbad twinning. Alteration to sericite and kaolinite varies
in intensity, but most grains of orthoclase are only partially
altered.

Plagioclase forms large euhedral to subhedral
phenocrysts that show albite twinning and may or may not be
zoned. The composition of the plagioclase is sodic andesine,
Ab62. Alteration of plagioclase is more severe than that of
orthoclase; some plagioclase grains have gone completely to
calcite and sericite. In other grains inclusions of sericite
and calcite give the feldspar a moth-eaten, ragged appearance.
Epidote and chlorite are occasionally found as small inclusions
in the plagioclase.

Quartz forms moderately large subhedral, unaltered, and
virtually inclusion-free crystals. These average .75mm in
diameter.

Epidote is the principal mafic mineral, and is an
alteration product of hornblende. However, there is none of
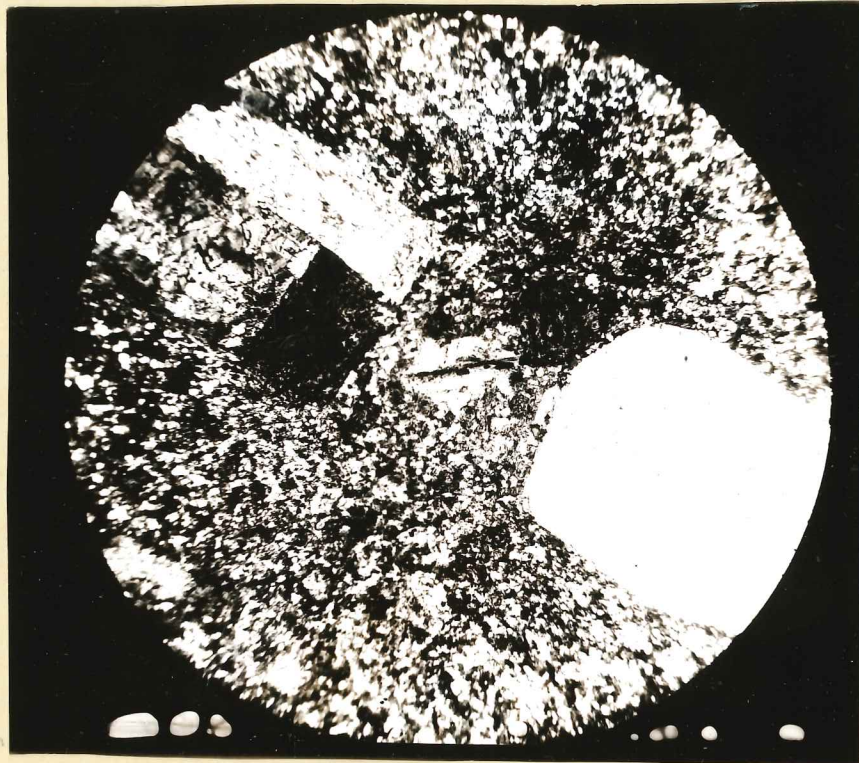
Plate 59.   Photomicrograph of the quartz
            monzonite porphyry. Note the large
            phenocrysts of quartz (white) and
            plagioclase (twinned) set in a very
            fine matrix of feldspar, quartz, and
            magnetite. No large phenocryst of
            orthoclase is visible in the photograph.
            x 15, Crossed nicols.

the hornblende remaining. Granules of magnetite are always associated with the epidote. The epidote grains average .3mm in their longest dimension.

The groundmass is a matte of uniformly fine-grained orthoclase and quartz with associated particles of magnetite, epidote, sericite, chlorite, and calcite. The average size of the quartz and orthoclase grains in the groundmass is .005mm. Plagioclase grains are not usually found in the matrix.

The average percentage of minerals in the quartz monzonite porphyry are as follows: orthoclase, 30; plagioclase, 25; quartz, 20; epidote, 8; magnetite, 7; sericite, 5; calcite, 3; chlorite, 2.

Summary of the Quartz Monzonite Porphyry

The significant points concerning the quartz monzonite stock are as follows:

1. The quartz monzonite porphyry body is intrusive into the Keechelus and it is, therefore, post-Keechelus in age.

2. The intrusion may have been contemporaneous with small intrusives of Miocene age that have been described by Buddington and Callaghan in Oregon. It may also have been contemporaneous with the diorite plugs described in the last chapter.

3. The quartz monzonite porphyry intrusive was probably responsible for mineralization in the Silver Creek area.

ECONOMIC GEOLOGY

General Statement

This portion of the Mt. Aix quadrangle is not a
highly mineralized province. Mining activity is practically
at a standstill. Two general divisions of the ore deposits
can be made--namely, those in the volcanic and sedimentary
rocks and those in the granitic rocks.

In the volcanic and sedimentary rocks, which comprise
a large portion of the area, metallization is weak and occurs
at widely scattered localities. Both vein and disseminated
type deposits occur but neither has been productive. The vein
deposits do not persist in length and probably not in depth,
although data on continuity at depth is lacking because
exploration seldom proceeded far below the surface.
Disseminated sulfide bodies, which are composed largely of
pyrite carrying slight amounts of gold, were too low grade to
encourage extensive exploration. Other sulfide ores that
occur in the volcanic and sedimentary sequences include the
following: chalcopyrite, chalcocite, sphalerite, galena,
bornite, and covellite. The usual gangue minerals are quartz

and calcite. Judging from the above mineral assemblage most of the deposits in volcanic and sedimentary rocks can be classed as mesothermal.

In the granitic rocks metallization is stronger than in the volcanic and sedimentary series. The deposits which are all of the vein type are fairly persistent in length and perhaps also in depth, although again there are no deep workings. Ore minerals identified in the veins in granitic rock include: chalcopyrite, arsenopyrite, scheelite, molybdenite, pyrrhotite, and pyrite. The gangue minerals are quartz, calcite, feldspar, and chlorite. Judging from the above mineral assemblage, which is quite different from that in the deposits in volcanic or sedimentary rocks, it is probable that the deposits in granitic rock were formed at relatively higher temperatures and belong to the hypothermal zone.

Descriptions of a few of the better known mining properties in this district will follow. None of them is being worked at the present time, nor is there any record of production in the past. The Black Jack prospect, which is located in sandy argillite, will be considered first.

The Black Jack Prospect

The Black Jack prospect, which is a few hundred yards north of Little Twin Sister Lake, was opened in the early days, the exact date is not known, by the sinking of a 50 foot incline

shaft down the dip of a six inch vein containing sphalerite,
bornite, chalcocite, and galena. The shaft is now full of
water. In a conversation with the son of the man who sank
the shaft, the writer learned that the vein had not increased
in width or tenor at the bottom of the shaft. Other workings
include a few small prospect pits that were dug at close
intervals along the strike of the vein. In none of the pits
was more than six inches of vein width exposed. The vein
outcrops for approximately 50 feet.

The strike of the vein is N 40° W and the dip, 40° NE.
Although the sulfide minerals are massive for a few inches
in the central portion, there is strong dilution by calcite
and wall rock gangue near the walls. The walls are well
defined by thin selvages of gouge. The country rock is a
highly indurated sandy argillite which was described in the
chapter on the Puget Group. Alteration of the argillite near
the vein is very weak or absent.

A photomicrograph of a polished section of the ore
from the Black Jack prospect (Plate 60), shows the mineral
relationships and provides a possible genetic interpretation
of the ore deposition. With reference to the photomicrograph
the earliest mineral appears to be calcite, which was largely
replaced by a solid solution of chalcocite and bornite.
Unmixing of the chalcocite and bornite produced the evident
mottled effect. The chalcocite and bornite were later

Plate 60. Photomicrograph of polished section
          of the ore from the Black Jack prospect.
          Dark gray is sphalerite, light gray is
          chalcocite, medium gray in the chalcocite
          is bornite. The black mineral in
          fractures is covellite, probably of
          supergene origin. The other black spots
          are calcite. White spots are galena.
          x 120, Reflected light.

partially replaced by galena which shows as white spots.
Sphalerite was probably the last primary sulfide mineral. It
partially replaces both the chalcocite-bornite portion and
the galena. Covellite, which appears as black stringers,
occurs only in fractures. It is probably supergene in origin.

Other than the vein on which the shaft was sunk there
are only scattered indications of sulfide mineralization in
the argillite. Sphalerite float which was found on the trail
north of the shaft could not be traced to its source, but
judging from the width of the sphalerite stringers in the float
boulders the vein is small.

The Black Jack prospect and surrounding 16 claims
have recently been the object of considerable interest due to
the promotion of the property by certain individuals. On the
strength of an independent report by H. P. Greenleay (14), the
Haile Mining Company dispatched an engineer and geologist to
inspect the property in the summer of 1951. After spending
three days in examination the Haile crew left the area and
submitted a negative report to their company. Latest news
from the district indicates that the meager showings are still
creating interest.

On the basis of the ore exposed in the shaft and
surface pits there is nothing to justify exploration at the
present time on the Black Jack prospect.

Other Prospects

Two other prospects in volcanic and sedimentary rocks, both of which have been abandoned for many years, are: (1) the Richmond prospect in Keechelus andesite located approximately three and one-half miles northeast of Mt. Aix on North Fork Creek. Exposure of the oxidized portion of the vein in the bottom of a gully shows two to three feet of iron oxide, carbonates, and quartz. The vein strikes N-S and dips 35° E. Ore on the dump near an old digging contained chalcopyrite and sphalerite in a calcite gangue. (2) The Gold Hill area in Keechelus andesite located north of U.S. Highway 410 on Morse Creek is riddled with prospect holes. The rock is impregnated with disseminated pyrite and veinlets of pyrite. Oxidation of the pyrite to limonite caused widespread reddish staining of the surface. Much of the pyrite carries traces of gold, but nowhere in sufficient quantity to make ore.

In the granitic rocks there are two mining properties. The Copper City Mine is the largest mine in the district on the basis of extent of mine workings. It has, however, produced no ore. The Keystone prospect consists of two short tunnels which have been caved for many years. The Copper City Mine will be considered first.

The Copper City Mine

The Copper City Mine, now laying idle, was opened in
1913 by the Copper Mining Company of Yakima, Washington. The
property consists of 42 claims, which are located along the
crest and on the east side of Miners Ridge in the Bumping Lake
mining district. The mine is approximately three and one-half
airline miles south of Bumping Lake. The property has been
operated intermittently for many years; the last major
development work was done in 1933.

The mine workings can no longer be reached by car,
because the two and one-half mile access road from the old mill
site on Deep Creek to the mine was washed out several years
ago. It is possible to reach the mill site by car from Bumping
Lake along a very poor dirt road that follows Deep Creek.

Total development work underground consists of
approximately 850 feet of drifts and cross cuts at the eastern
end of the mineralized zone as shown in Figure 3. A cross
cut at the western end of the vein system was started to
intersect that portion of the ore body at depth. Work on the
cross cut was halted far short of the goal. The tunnel is now
caved. Because there is no record of the length or bearing of
this opening, it is not shown in Figure 3.

In addition to the underground work approximately
twelve surface pits, which are plotted on the map, were dug
on the main vein. These pits expose the vein at intervals

along its strike and greatly facilitate tracing the outcrop.

There have been several geologic reports published previously on the Copper City Mine. A report on the property is given in Bulletin 34 of the State of Washington Department of Conservation and Development (1945) by Culver and Broughton (10). The mine was also examined by S. Warren Hobbs (18) of the U.S. Geological Survey in 1942. His report, originally listed as Confidential, is now on open file. Hobbs' map of the mine area is shown in Figure 3. Dubail (11) and Barry (2), former students at the School of Mines, University of Washington submitted theses for their Bachelors degrees on the Bird and Clara veins respectively.

The general geology of the mine area is not complex. The country rock is part of the Bumping Lake granite which was described previously. In the vicinity of the mineralized area the usual tan or buff color of the granite changes to grayish green due to the alteration of biotite to chlorite. The granite is intruded by numerous dikes of dacite porphyry and andesite porphyry. The width of the dikes varies from a few feet to 150 feet. These porphyry dikes are very probably related to the large dikes and sills of dacite porphyry that have been described previously. The dikes had no apparent relationship to ore deposition. This fact was stressed by Culver and Broughton and by Hobbs. The dikes usually cut across the veins at a wide angle, and because the dikes are

unmineralized they are almost certainly post-ore.

The mineralized zone consists of four, approximately parallel, closely spaced veins which strike N70°-80° W and dip 40° N. The width of the zone in which the four veins occur is seldom over 100 feet. Between the veins there is no mineralization and only weak alteration. From north to south the veins are named Red Bird, Bird, Clara, and King. The Bird vein is the strongest of the four and is the one on which most of the mining has been done. The Clara vein is fairly well-defined in the eastern part of the area, but it may merge with the Bird vein to the west. The map of the principal vein zone, Figure 3, very probably shows parts of both veins as they are frequently closely spaced and difficult to distinguish. The Red Bird and King veins are weak and cannot be traced the length of the zone. No development has been done on these two veins; consequently they are not shown in Figure 3.

The Bird vein can be traced for nearly 2,000 feet. It varies in width from one foot to seven feet. Where it is exposed in the surface cuts the vein consists of very hard quartz and jasperoid, locally brecciated, and always highly stained with a dark red iron oxide. Green, copper carbonate stains are commonly present. A fresh surface may show tiny stringers or blebs of arsenopyrite, chalcopyrite, and pyrite. At night under ultra violet light scattered grains of scheelite are readily visible. Some scheelite occurs in nearly every

exposure, but except for occasional pods or clusters it is usually widely disseminated and in very small grains. Principal ore minerals that were identified by Dubail and Barry in polished sections of specimens from the Bird and Clara veins include scheelite, chalcopyrite, molybdenite, arsenopyrite, pyrite, pyrrhotite, bornite, and malachite. The gangue minerals were principally quartz, orthoclase, plagioclase, calcite, and chlorite.

The lowest mine working, the lower Bird adit, intersects the Bird vein approximately 125 feet below the surface. At this depth there is no marked change in the width of the vein or in the tenor of the ore. An assay map prepared by the Copper Mining Company to show the tungsten values in the lower Bird adit indicated low grade ore along most of the vein. An average width of the samples taken was 3.5 feet and the average assay was approximately .20% WO3. The mine has allegedly produced some high grade tungsten ore from local pockets in the Bird vein, but apparently the pockets were widely spaced and exploration to find them was not worth the reward.

If exploration were to be started in the future, the writer would recommend the testing of the west end of the Bird vein at depth beneath the cluster of prospect pits which are shown in Figure 3. This portion of the vein appears to be the widest, strongest, and best mineralized and presents the best prospects for future search.

The Keystone Prospect

The Keystone prospect was opened on a small vein which reportedly contained molybdenite and "some arsenic mineral," probably arsenopyrite. The exploration headings which were driven many years ago consist of upper and lower tunnels on the vein. The adits, which are separated about 30 feet vertically, are now caved and almost obscured by broken rock and soil. Neither tunnel could be entered. One building, which was presumably built for a machine shop, is still standing. There is no record of production from the Keystone prospect.

The only means of reaching the property is by a trail that joins the Bumping Lake road at a group of old cabins about four miles west of the Bumping Lake dam. The trail ascends the west side of Nelson's Ridge for approximately a mile and one-half to the old workings which are about 1,000 feet above the valley floor of Deep Creek.

The country rock around the prospect is Granite Lake breccia which was described in detail in an earlier chapter. An andesite dike, 10-15 feet in width, intrudes the agmatitic breccia a few yards above the lower tunnel. The strike of the dike is N45°E. The dike has no visible relationship with the vein.

The vein is exposed for only a short distance on the slope of Nelson's Ridge because of a covering of soil and talus.

The vein strikes N 30° E and dips 75° SE. Its average width is three feet. The vein material is sericitized Granite Lake breccia, quartz, and iron oxide. There are no sulfide minerals visible in the oxidized portion. Alteration of the country rock extends several feet either side of the vein and consists principally of sericitization and kaolinization of the breccia. A distinctive yellow-green stain occurs in the vein and locally for short distances into the wall rock. The stain may be arsenious oxide which was derived by supergene alteration of arsenopyrite.

There is nothing to indicate that the Keystone prospect warrants any future development.

PHYSIOGRAPHY

General Statement

The relief of the area mapped in the Mt. Aix quadrangle is 5,100 feet. The lowest point, which is in the gorge of American River near its junction with the Naches River, is approximately 2,700 feet above sea level. The highest point is the summit of Mt. Aix at an elevation of 7,805 feet. Most of the area lies on the eastern slope of the Cascades, but a narrow zone in the westernmost part of the quadrangle falls on the western side of the crest. Principal eastward flowing streams are American River, Bumping River, and Deep Creek. The stage of regional erosion of the area as a whole is mature, relief at the present time being maximum. Almost every physiographic and topographic feature in the Mt. Aix quadrangle has been modified by glacial or peri-glacial processes. Consequently, little is preserved of landforms developed in pre-Pleistocene times. Because of wholesale disfiguration of the landscape by ice, any evidence in this vicinity to support or to refute the Willis (34)-Russell (24) concept of a high altitude peneplain in the Cascades has been destroyed. For that reason no discussion

of the subject is attempted in this work.

For a comprehensive review of physiographic investiga-
tions in the Cascades and central Washington, the reader is
referred to Coombs' "Geology of Mt. Rainier National Park"
in which the findings of early workers in this region are
summarized.

Glaciation and Its Effects

General Statement. Although there were probably
several periods of glaciation in this area during the
Pleistocene direct evidence of ice advances before the Wisconsin
glacial stage is lacking. Undoubtedly Wisconsin glaciation
destroyed or modified many of the features developed during
earlier stages. Search for pre-Wisconsin morainal gravels,
which might be distinguished from Wisconsin gravels on the
basis of degree of weathering or stratigraphic position,
revealed no clue of early Pleistocene glacial deposits. The
reasons for the lack of earlier glacial debris are: (1) that
due to the high relief in the area snow, ice, and running water
rapidly removed pre-Wisconsin glacial deposits before the
advance of Wisconsin ice; (2) that the earlier deposits are
completely obscured by the deposits of Wisconsin age.

During the Wisconsin period the western portion of the
area was nearly completely covered with glacial ice for several
miles east and west of the Cascade crest. The approximate

position of the ice during its maximum extent in the Wisconsin period is shown in Figure 8. Near the crest only small irregular bodies of rock projected above the surface of the ice. Farther to the east the ice masses occurred as tongues in the valleys now occupied by American River, Bumping River, and Deep Creek. Numerous smaller tributary glaciers contributed ice to the main tongues.

Cirque development. High altitude cirque walls and basins dominate the skyline and surpass all other topographic features in ruggedness and beauty. The exact number of cirques is not known but there are several score. The cirque level is approximately 5,500 feet. Below that elevation cirque cutting was not pronounced.

Topographically there are two distinct kinds of cirques depending upon the direction in which the basin opens. The northerly facing basins are extremely sharp. They are partially rimmed by nearly sheer cliffs, and within the basin there is no soil. Large scree slides form the lower slopes of the amphitheater. A north-facing cirque near the crest of Nelson's Ridge is a good example (Plate 61). The three most spectacular cirques of this variety include the Cougar Lake basin which is partially rimmed by a 1,200 foot wall, the Dewey Lake basin by a 1,400 foot wall, and Bismark Peak basin by a 1,600 foot wall.

The other type of cirques are those facing in a

Plate 61. Rugged north-facing cirque basin near crest of Nelson's Ridge. Rocks are Keechelus breccias.

southerly direction. These basins are less rugged and precipitous and usually broader than those facing north. The slopes of the amphitheater are mantled with soil. Loose talus occurs only locally. Downhill creep of the soil mantle which is brought about in part by solifluction has formed small terraces that follow the contour of the slope and resemble tiers of benches in an arena. Deer and elk follow these step-like terraces when crossing the basin and consequently make them even more pronounced. The soil is composed of wind blown sand and small fragments of rock derived from bed rock by frost wedging. Big Basin, shown in Plate 63, affords a good example of this type of cirque. On the topographic map Big Basin can be located by noting that the "A" of the words American Ridge lies within the basin.

The principal reason for the difference in cirque development of the northerly and southerly facing basins is that cirque cutting was more severe during the glacial periods, Wisconsin and earlier, on the north slopes where the rate of melting due to the sun's heat was slower. This difference in the melting rate allowed ice to accumulate to greater depths and also to erode for longer periods of time in the north-facing basins.

The same reason explains the effect of recent nivation processes which have maintained or perhaps increased the sharpness of the cirque basins facing north. Compare Plates 61
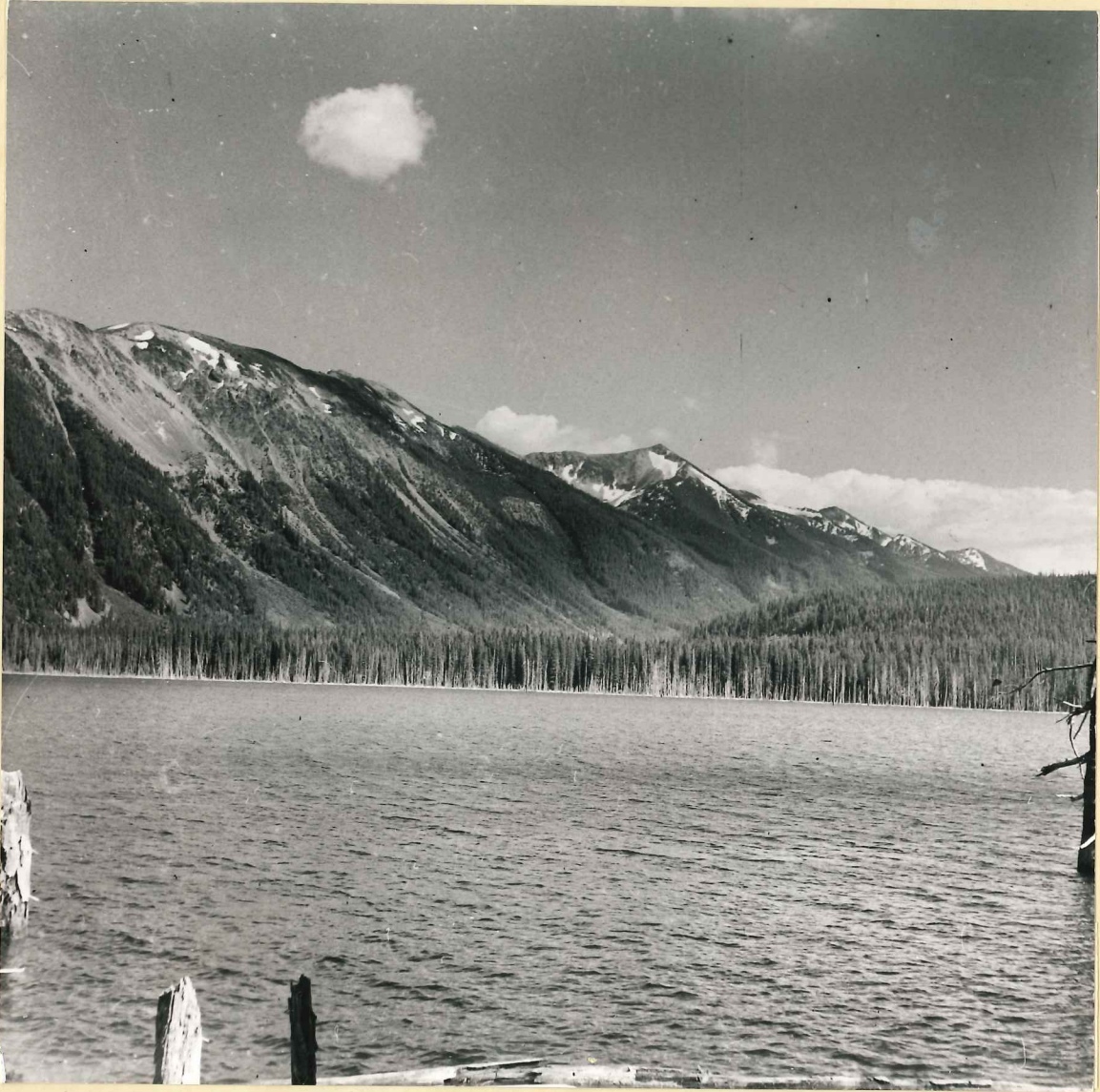
Plate 62.   Looking south across Bumping Lake. Photograph
taken to show the assymetrical topography of
Nelson's Ridge.

Plate 63. Big Basin, a large cirque basin that opens
toward the south. Solifluction processes
are evident in this type of country.

and 63 as to the amount of snow remaining in the basins. The photograph of the cirque on Nelson's Ridge (Plate 61) which shows a rather large patch of snow was taken on September 10th. The photograph of Big Basin (Plate 63) shows no snow. It was taken on August 29th.

Because rock disintegration by ice, snow, and frost proceeded more rapidly and for longer periods on the north and east slopes during and after the glacial stages, those slopes are notably more precipitous than the south or west flanks. This has resulted in an assymetrical topography in the higher elevations. Tuck (27) reported a similar assymetry of topography in Alaska. A photograph (Plate 62) taken toward the south of Nelson's Ridge shows the steep cirque walls of the high points on the north and east side of the crest and the relatively smoother slopes on the west side.

Large, high elevation ice sheets. During the Pleistocene glacial periods ice was contributed to the main valley glaciers not only from cirques but also from large, high elevation ice sheets. Ample evidence exists in this area that great sheets of ice moved over parts of the crest of the Cascades at an elevation of at least 6,000 feet. These ice masses may have been piedmont to higher peaks and coalesced to form broad, high elevation ice sheets. They may also have been formed by the fanning out from an ill-defined ice divide or center of accumulation on the high plateaus. Glacial
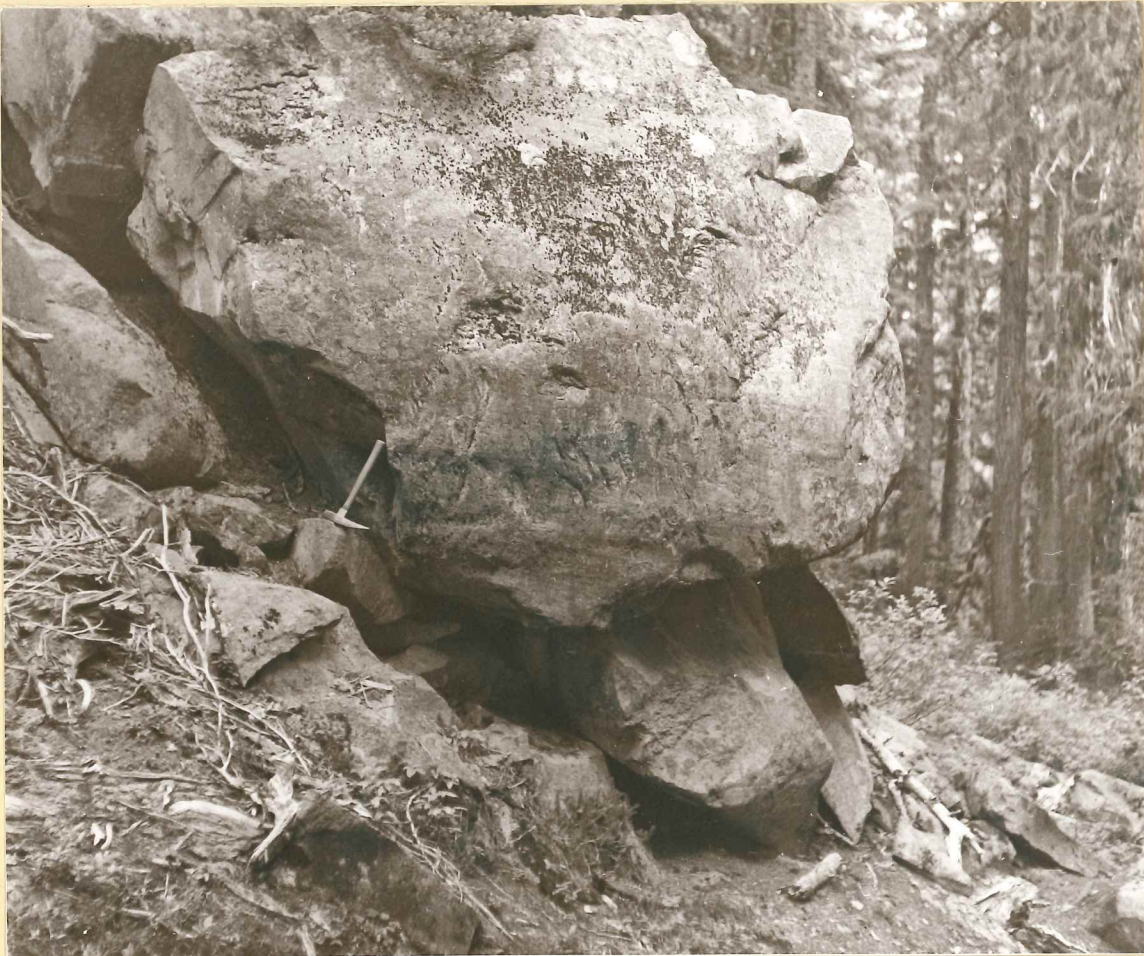
Plate 64. A large boulder of Deep Creek andesite on the crest of the Cascades, west of Swamp Lake. The glacial polishing and grooving was done by a high elevation ice sheet similar to or continuous with the ice mass that swept the Tumac plateau.

polishing and grooving by these ice sheets are well displayed
in the broad saddle one-quarter mile west of Swamp Lake and
also on the Tumac plateau south of Twin Sisters Lakes. Early
Pleistocene basalt in these two areas is deeply striated and
ridges in the basalt are smoothly rounded. The total original
extent of these high elevation ice sheets is not known, but
they were fairly extensive until toward the close of glacial
activity when headward working valley glaciers reduced the
area of the upland. Because the timber on parts of the Tumac
Plateau has been burned off, the effects of high elevation ice
sheets are well-exposed.

Effects of glaciation on the Tumac Plateau. Although
the most prominent feature on the Tumac Plateau is the Tumac
cinder cone, it is not directly involved in the discussion of
glacial features. Evidence presented here, however, may
strengthen the theory that the cone is post-Wisconsin in age.

Basalt ridges exposed on the Tumac Plateau show deep
grooves and scratches aligned east-west that were made by a
moving ice mass. The true direction of movement could not be
determined, but it is possible that the ice was spreading in
those directions from an ice divide somewhere in the central
part of the plateau. The approximate thickness of the ice cap
over the plateau can be estimated from the ice cut rock terraces
on the north slope of Big Peak which forms the southern boundary
of the Tumac Plateau. The higher of the two terraces is 600

Plate 65.   Valley flow basalt on Tumac Plateau.   Note
the effects of glaciation by high elevation
ice sheet.

Plate 66. Blakenship Meadow on Tumac Plateau. Elevation
approximately 5300 feet. The rock beneath the
meadow is Valley flow basalt.

feet above the general level of the plateau and at least 100
feet above the base of the Tumac cone. Therefore, it can be
assumed that the plateau was covered with an ice sheet that
averaged 300 feet in thickness. Valley glaciers around the
periphery of the high elevation ice sheet received some of
their ice from the ice cap. Inspection of the topographic
map shows these valleys radiate from the plateau region.
Beginning on the north side and viewing the plateau edge in a
clockwise fashion, the following streams and valleys may be
seen to encroach upon the plateau: Deep Creek, Indian Creek,
Clear Creek, Summit Creek, and an unnamed stream flowing north
to Carlton Pass. The Tumac Plateau ice cap may resemble to
some extent what has been termed a Norwegian ice cap.

       During the melting period of the ice cap, ice marginal
streams carried the melt waters from the plateau and contributed
it to the constantly advancing radiating valleys. Features
formed by an ice marginal stream are the broadly-curved basins
of Little Twin Sister and Big Twin Sister Lakes which occupy
depressions in meander sweeps of the former stream that flowed
along the northern edge of the ice cap (Plate 68).

       Most of the small lakes and ponds that dot the surface
of the plateau occupy depressions and plunge basins in channels
of former streams that carried melt water off the central part
of the plateau. Tumac Plateau is actually a miniature Channeled
Scablands, except that the Scablands were never covered by ice.

Plate 67.   Photograph taken from the summit of Tumac
             Mountain looking west across the Tumac Plateau.
             Note the monotonous surface of the plateau
             which is dotted with ponds and cut by many
             channels. Mt. Rainier looms in the background.

Plate 68. Looking north from the top of Tumac Mountain. Some ponds and old channels may be seen on the plateau in the foreground. Twin Sisters Lakes in the middle ground. Note rugged topography in middle distance north of the upper Bumping River valley.

Plate 69. Looking south from the top of Tumac Mountain.
Tumac Plateau in foreground. Note the many
ponds and large channels. Ice-cut terraces
on the north side of Big Peak, in the middle
ground, indicate thickness of ice sheet that
swept the plateau.

Wide and deep coulees in the basalt now carry only trickles
of water that seep through the marshy bottoms of the coulees.
This is in distinct contrast to the rushing torrents of water
that cut the coulees during the melting stage. At the base of
abandoned waterfalls in some coulees the plunge basins are now
the site of deep lakes. The whole surface of the plateau is
channeled in this fashion by coulees that radiate from the
central portion of the plateau and terminate at its edge.
This suggests that the center of the ice cap was located in
the central portion of the plateau. The edges of the plateau
are constantly retreating due to the headward advance of the
main streams that are sapping the basalt cap. Consequently,
the lakes and ponds near the edge are being drained. For
example, the head of Deep Creek is now only a few yards from
the north shore of Little Twin Sister Lake, and in the spring
and early summer when melting snow raises the level of the lake,
water spills over the north edge of the lake and flows down
Deep Creek.

Large glacial valleys. The three main valleys that
dissect the eastern slopes of the Cascade Range in this area
are those occupied by American River, Bumping River and Deep
Creek which joins Bumping River at Bumping Lake. Ice was
contributed to the glacial tongues in these valleys from high
altitude cirques and alpine glaciers and from the large ice
caps. The upper portions of the valleys are U-shaped glacial

Plate 70. Looking east from Chinook Pass down American River Valley. Note the broad U-shape. Goat Peak on American Ridge is the high point in the distance.
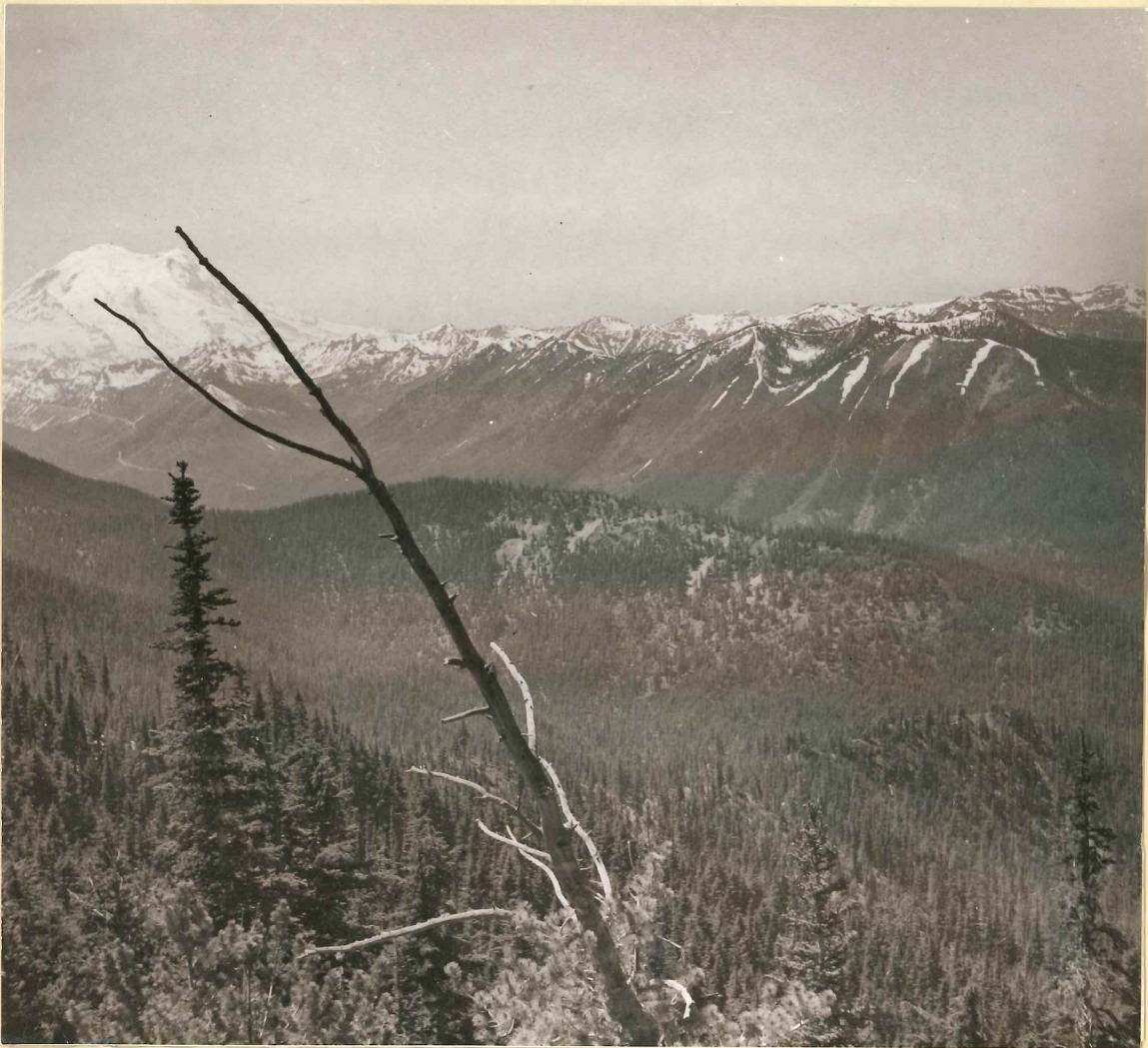
Plate 71. Looking west up American River from American
Ridge. Note faceted spurs on the north side
of American River valley. Mt. Rainier is in
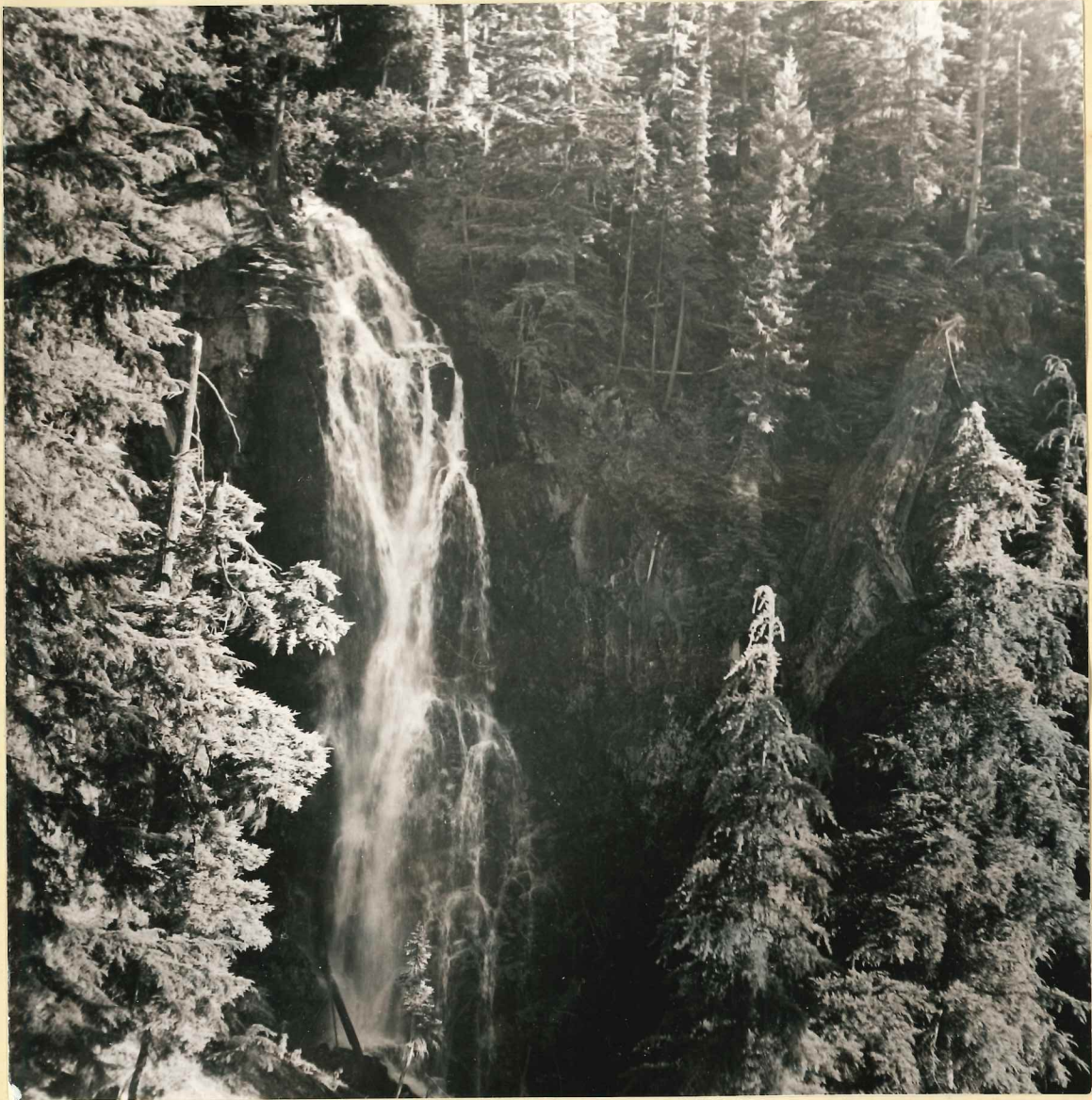the distance.

Plate 72.   The hanging valley of Mesatchee Creek on the
            south side of American River. The falls have
            retreated several hundred feet upstream since
            glacial times.

troughs. The U-shape of American River valley ends abruptly
at Hells Crossing downstream from which the gorge narrows
and assumes a V shape. The Bumping River valley changes from
U to V shape approximately where the word "Bumping" is printed
on the topographic sheet. It is assumed that the change in
cross section marks the terminus of the ice in these valleys.
The lowest elevation reached by the ice tongues in the two
valleys was approximately 3,000 feet as shown in Figure 8.

Contrasts in erosion between the upper portions of the
valleys, which were occupied by ice, and the lower portions,
which were not, is quite striking. This contrast is
particularly well shown in American River valley. Glacial
features in the U-shaped trough are faceted spurs (Plate 71),
hanging valleys (Plate 72), and striated bed rock. The upper
surface of the ice tongue in American River valley as
determined by the apex elevation of the faceted spurs in the
vicinity of Pleasant Valley was approximately 5,000 feet.
The estimated thickness of the ice in this locality was 1,500
feet. Evidence for determining the thickness of the ice in
Bumping River valley is not so clearly shown as in the American
River valley, however, the thickness of the two tongues was
probably nearly the same. The lower portions of the valleys,
where only features of normal downcutting by streams are
evident, lack all the features of glaciation mentioned above.

At the terminus of the two tongues in the main valleys

there is no vestige of terminal moraines; nor in any part of the upper portions of the valleys are there any recognizable recessional or lateral moraines. The reason for the lack of moraines is that river processes subsequent to the withdrawal of the ice have destroyed the morainal forms.

It is noteworthy that where two main glacial tongues converged large, poorly-drained flats now exist. A glance at the topographic map shows these flats in the valleys of American River and Bumping River. In the American River valley a broad swampy area, which was probably a lake sometime during the Quaternary, is quite similar to the lowland around Bumping Lake. Damming, which was caused by a choking of the valley with glacial debris, is probably responsible for the formation of these broad lowlands, and for the ponding of Bumping Lake.

Ancestral Bumping Lake. That a glacial Bumping Lake which was much larger than the present lake occupied the basin during glacial retreat is suggested by the extensive occurrence of fine-textured, bedded lake clays which are exposed along the banks of upper Bumping River one mile west of Bumping Lake. The stream has cut a channel twenty-five feet in depth through the yellowish clays. The stream bed is also composed of clay, consequently the total thickness of the lake deposit cannot be measured. It is probable that this large ancestral lake was formed by the damming of upper Bumping River by the Deep Creek

ice tongue, or by debris that accumulated at the junction of the Deep Creek and Bumping River tongues, or by both ice and debris. Lake sediments were not found at any other place surrounding Bumping Lake except in the above-mentioned upper Bumping River valley.

Thunder Creek moraine. A good example of a terminal moraine of an alpine glacier exists at the throat of Thunder Creek, a tributary of Bumping River, where it enters the main stream south of Goose Prairie. Looking south across Goose Prairie the lower valley of Thunder Creek is seen to be choked with a bulky mound (Plate 73). Close inspection of this mound reveals that it is composed of rounded boulders, cobbles, pebbles, and sand derived from the Thunder Creek valley. Particularly distinctive are the boulders of diorite whose only possible source was the Mt. Baldy diorite plug near the headwaters of Thunder Creek. Thunder Creek has cut a V-shaped gorge through the moraine, and Bumping River is currently removing large amounts of unconsolidated gravels from the face of the moraine.

Glacial pebbles in volcanic ash. In cuts along the tortuous road to Raven's Roost which is located north of Fifes Peaks about one-half mile outside the northern boundary of the Mt. Aix quadrangle, a peculiar phenomenon was encountered. Above 5,500 feet elevation the road passes through occasional cuts in unconsolidated, powdery, white to yellowish, moderately

Plate 73. Looking south across Goose Prairie up Thunder Creek valley. Large mound at mouth of valley is morainal material. Mt. Baldy on the right, Buffalo Hump on the left.

Plate 74.   Glacially facted pebbles from bed
of volcanic ash of the Fifes Peak
formation.   Pebbles were discovered
in road cuts north of Quartz Creek.

well-bedded volcanic ash. The presence of bedding is suggestive but not conclusive evidence that the ash was deposited in water. Many boulders and pebbles are scattered at random in the ash beds.   Three pebbles from the ash beds are shown in Plate 74. The pebbles are apparently glacial in origin judging from their shape which is typical of glacially faceted pebbles. The fact that these glacial pebbles, which are all composed of Fifes Peak andesite, are embedded in volcanic ash, and yet occur at a much higher elevation than the Wisconsin age valley ice was supposed to have reached in this area poses a problem.

A possible explanation is that the volcanic ash was laid down in a large high altitude lake either during the Wisconsin or an earlier glacial period. Melt waters from an ice sheet or ice cap, similar to the one that covered the Tumac Plateau, and ice rafting contributed faceted pebbles to the lake basin where they became incorporated in the volcanic sediment. Subsequent erosion destroyed the lake, but left isolated portions of the lacustrine ash beds and associated glacial pebbles perched high on ridges of Fifes Peak andesite.

Nivation of Tumac Mountain Cinder Cone

There is little question that the formation of the Tumac cone, which was described in an earlier chapter, occurred after the withdrawal of glacial ice from the Tumac Plateau. Because the cone is located directly on the crest of the Cascade Range

at an elevation of 6,300 feet in an area that receives an
enormous amount of snow in the winter, the cone has been rather
severely dissected by the action of recent snow and ice. The
result has been a north-south breaching of the cone as shown
in Plate 33. From reconstruction of the cone on the photograph
it can be seen that Tumac Mountain was originally nearly twice
its present height. Approximately one-half of the pyroclastic
material has been removed.

High in the breached portion of the cone, approximately
in the notch seen in Plate 33, there is a fairly large, north-
facing nivation basin. It measures approximately three hundred
feet across and roughly one hundred and fifty feet vertically.
In mid-September, when the cone was visited, snow still remained
in the basin.

The crater, which was previously described in the
chapter on Tumac Mountain, is assymetrically located on the
northwest side of the dissected cone (Plate 34). During the
winter a great thickness of snow undoubtedly accumulates by
drifting within the crater. In the past some of the melt water
from the crater has escaped by spilling over a low point on the
northwest side of the rim, and in doing so cut down the rim at
a rapid rate. In recent years there has been very little water
passing over the spillway, as evidenced by the growth of grass,
shrubs and trees in the spillway trough. Most of the melt water
at the present time seeps through the cinders and issues around

the base of the cone on the north side. A shallow lake, shown in Plate 34, occupies the bottom of the crater during the summer months.

Physiographic History of the Mt. Aix Region

From structural, lithologic, and stratigraphic evidence a possible physiographic history of the area is as follows:

Prior to the Eocene little can be surmized as to physiographic development. During the Eocene most of the area was coastal lowland, perhaps a large estuary, which was receiving arkosic sediments from highlands somewhere to the east. Near the close of the Eocene withdrawal of the water body was accompanied or caused by gentle uplift. Following closely, or perhaps, contemporaneously with uplift in late Eocene or early Oligocene time, floods of andesitic lavas concordantly, and possibly conformably, covered the Puget Group sediments. These lavas were the first of the great series of Keechelus volcanics that were deposited intermittently during most of Oligocene time. The vast amounts of volcanic tuff and breccia in the Keechelus series interbedded with flows suggests that periods of violent explosive vulcanism were interspersed with quieter volcanic activities.

During and after Keechelus deposition the volcanic rocks were locally weakly folded and faulted. In some localities the volcanics underwent relatively more severe deformation,

whereas other area were virtually undisturbed or only gently
tilted, usually to the northward. A long period of erosion
in late Oligocene or early Miocene time followed this weak
orogeny, and land forms were developed to a stage of late
maturity judging from the rough, but not precipitous, surface
upon which the later Fifes Peak andesites were laid down.

In about early middle Miocene time outpourings of
andesite lavas and showers of pyroclastic materials covered
vast areas in the eastern Cascades. These volcanic rocks
were deposited unconformably upon a hilly surface of truncated
Keechelus beds and dacite porphyry dikes, and comprise the
Fifes Peak series. The gentle regional eastward dip of Fifes
Peak lavas and pyroclastics was probably imparted by the uplift
of the Cascades in Pliocene and early Pleistocene times.

In later Miocene time flows of Yakima basalt reached
the Mt. Aix area and partially covered the Fifes Peak andesites
along the eastern boundary of the Mt. Aix quadrangle. It is
doubtful that the Yakima lavas extended appreciably farther
west than indicated by their present position. The Yakima
basalt rest concordantly upon a relatively even erosion surface
of Fifes Peak andesite. Local gentle warping of the Yakima
basalt and Fifes Peak andesite followed the spreading of the
basalt. In late Miocene time clastic sediments, known as the
Ellensburg formation, were deposited in structural basins in
the Yakima basalt. No Ellensburg sediments outcrop within the

area of this work, but they do appear several miles to the south along the valley of the Naches River.

In Pliocene and early Pleistocene time, during and after the uplift of the Cascades, the area was subject to an accelerated rate of downcutting which produced steep-walled valleys and a steep but rolling terrain. During this period the Deep Creek andesite flows filled some of the valleys with tongues of lava. Later, the Valley flows formed a high plateau, and flowed down valleys radiating from the plateau region.

During glaciation in late Pleistocene the present landscape was formed.

After withdrawal of glacial ice from this area a small volcanic cone composed largely of basaltic cinders grew to a height of over 700 feet in the central portion of the Tumac Plateau.

Recent and glacial alluvium now mantles the floors of the valleys and is being rapidly removed by swiftly flowing streams.

BIBLIOGRAPHY

1. Abbott, Agatin T., "Tumac Mountain, a post-glacial cinder cone in Washington state" (Abstract), <u>Geol. Soc. America Bull.</u>, 62:1495, 1951.

2. Barry, L. D., "The Clara vein of the Copper Mining Co., Inc.," unpublished Master's thesis, The University of Washington, School of Mines, Seattle, Washington, 1933.

3. Barth, T. F. W., "Petrography of the Pacific lavas," <u>Am. Jour. Sci.</u>, 221:378-405, 1931.

4. Becraft, George E., "Definition of the Tieton andesite on lithology and structure," unpublished Master's thesis, Washington State College, Pullman, Washington, 1950.

5. Burwash, Edward M. J., "Pleistocene vulcanism of Coast Range of British Columbia," <u>Jour. Geology</u>, 22:260-267, 1914.

6. Buddington, A. E., and Callaghan, Eugene, "Dioritic and intrusive rock and contact metamorphism in the Cascade Range in Oregon," <u>Am. Jour. Sci.</u>, 5th ser., XXXI:421-429, 1936.

7. Coombs, Howard A., "The geology of Mt. Rainier National Park," University of Washington Publications in Geology, no. 2, 3:131-212, 1936.

8. _____, Oral communication.

9. _____, "Extension of the Keechelus andesitic series" (Abstract), <u>Geol. Soc. America Proc.</u>, 33rd Ann. meet. Cordill. sect., 47:336, 1934.

10. Culver, H. E., and Broughton, W. A., "Tungsten resources of Washington," Dept. of Conserv. and Develop., State of Washington Bull. 34:79-84, 1945.

11. DuBail, G. R., "The Bird vein on the Copper Mining Company property," unpublished Master's thesis, University of Washington, School of Mines, Seattle, Washington, 1938.

12. Fuller, R. E., "Concerning basaltic glass," <u>Am. Mineralogist</u>, 17:104, 1932.

13. _____, and Peacock, M. A., "Chlorophaeite, sideromelane, palagonite, from the Columbia River plateau," <u>Am. Mineralogist</u>, 13:360-376, 1928.

14. Greenleay, H. P., Engineer's report on the sphalerite and apex group of mineral claims, Unpublished report, 3 p., 1950.

15. Goodspeed, G. E., "Xenoliths and skialiths," Am. Jour. Sci., 246:515-525, 1948.

16. _____, and Coombs, Howard A., "Replacement breccias of the lower Keechelus," Am. Jour. Sci., 5th ser., XXXIV:12-23, 1937.

17. Grant, Robert Y., "A John Day vertabrate fossil discovered in the Keechelus series of Washington," Am. Jour. Sci., 239:590-593, 1941.

18. Hobbs, S. Warren, Report on the Copper Mining Company property, Yakima County, Washington, U. S. Geol. Survey Confidential report, 1943. Now on open file at the Spokane, Washington office.

19. Hodge, E. T., "Geology of the lower Columbia River," Geol. Soc. America Bull., XLIX:846, 1938.

20. _____, and Bogue, Richard, "Cascades andesites of Oregon," Am. Mineralogist, 25:627-665, 1940.

21. Misch, P., Oral communication.

22. Pettijohn, F. J., Sedimentary rocks, Harper and Brothers, pp. 51-52, 1949.

23. _____, Ibid., p. 440.

24. Russell, I. C., "A geological reconnaissance in Central Washington," U. S. Geol. Survey Bull, 108:20-25, 1893.

25. Smith, G. O., U. S. Geol. Survey Geol., Atlas, Ellensburg folio, no. 86, 1903.

26. _____, and Calkins, F. C., U. S. Geol. Survey Geol., Atlas, Snoqualmie folio, no. 139, 1906.

27. Tuck, Ralph, "Assymetrical topography in high latitudes resulting from alpine glacial erosion," Jour. Geology, 43:530-538, 1935.

28. Warren, Walter, "The tertiaries of the Washington Cascades," Pan-Am. Geologist, 65:241, 1936.

29. _____, "Relation of Yakima basalt to the Keechelus,"
        Jour. Geology, 49:795-814, 1940.

30. Wegmann, C. E., "Geological investigations in southern
        Greenland," Medd. om Gronland, 113, no. 2, pp. 40-41,
        1938.

31. Wentworth, C. K., and Williams, Howel, "The classification
        and terminology of pyroclastic rocks," Nat. Research
        Council Bull. 89:19-53, 1932.

32. White, C. A., "On the Puget Group of Washington territory,"
        Am. Jour. Sci., 3d ser., no. 212, 36:443-450, 1888.

33. Willis, Clifford, Oral communication.

34. Willis, Bailey, "Contributions to the geology of Washington,"
        U. S. Geol. Survey Prof. Paper 19, pp. 47-95, 1903.

VITA

Agatin Townsend Abbott was born in Duluth, Minnesota, October 13, 1917. His parents are William Pitt Abbott, M.D. and Marie Lydia Agatin both of Duluth. His primary schooling was at the Normal School of the State Teachers College in Duluth. He took four years of preparatory training at Shattuck Military School, Faribault, Minnesota from 1931-1935. Undergraduate work in geology leading to a B.A. degree was accomplished at the University of Minnesota, Minneapolis from 1935-1939. He was engaged in professional work in mining geology from 1939-1949 except for two years in the U.S. Navy as Lt. (j.g.). Graduate work in geology toward a Ph.D. degree was at the University of Washington from 1949-1952. He is presently an assistant professor of geology at the University of Idaho, Moscow, Idaho.

THE GEOLOGY OF THE NORTHWEST PORTION OF THE
MT. AIX QUADRANGLE, WASHINGTON

ABSTRACT

The area mapped comprises approximately 300 square
miles along the crest and eastern slopes of the Cascade Range
of Washington. Except for a narrow section along the western
edge which is in Pierce and Lewis counties, most of the area
lies in Yakima county.

The principal contribution of this work is further
clarification of the sedimentary and volcanic sequences of
Tertiary age on the eastern side of the Cascades. Significant
information was also gained on the several types of intrusive
bodies that invade the sedimentary and volcanic series. A
basaltic cinder cone of post-Wisconsin age was the first to
be discovered in the Washington Cascades.

The oldest rocks are sediments consisting of arkosic
sandstones and banded, carbonaceous, argillite, which were
correlated on the basis of lithology and structural trend with
the Puget Group sediments of Eocene age that have been
described on the west side of the Cascades. Puget Group
sediments had not heretofore been reported east of the Cascade

crest. The exposed thickness in this area is in excess of 800 feet. The regional dip of the sandstone beds is about 15° north.

A series of moderately altered volcanic flows and indurated tuffs and breccias approximately 3500 feet in thickness and predominantly andesitic in composition overlie the Puget Group concordantly and possibly conformably. These volcanic rocks are part of the Keechelus andesite series that covers vast areas in the Washington Cascades. The terms, upper and lower Keechelus, applied by Smith and Calkins to this formation in the Snoqualmie quadrangle, are not used in this study because the upper Keechelus in this area belongs to a distinctly later volcanic sequence (cf. below). In this work the term, Keechelus, applies only to the former lower Keechelus. The name, upper Keechelus, is replaced by Warren's term, Fifes Peak andesite.

Folding and faulting followed Keechelus deposition. Locally the folding was intense, but large areas of the Keechelus underwent only moderate tilting which was usually northward. Keechelus volcanic activity probably started in very late Eocene or early Oligocene time and continued intermittently during the Oligocene.

The Fifes Peak andesite formation (formerly called upper Keechelus) lies with angular unconformity upon an erosion surface of Keechelus andesite. The Fifes Peak andesites consist

of at least 3000 feet of unaltered flows and pyroclastics.
The regional dip of the Fifes Peak formation is gently eastward.
The age of the formation is probably early to middle Miocene.

The Yakima basalt, which overlies Fifes Peak andesite
disconformably, occurs only along the eastern border of the
Mt. Aix quadrangle. The average thickness of the basalt is
250 feet. The Yakima flows probably did not extend westward
in this area much beyond their present limits. The Yakima
basalt is approximately middle Miocene in age.

Younger volcanic rocks that are not in contact with
either Fifes Peak andesite or Yakima basalt, and consequently
their ages cannot be determined definitely, include the Deep
Creek andesite, probably late Pliocene or early Pleistocene
in age, and Valley flow basalt, probably early Pleistocene in
age. Both formations rest unconformably on older rocks;
namely, Puget Group sandstone, or Keechelus andesite, or
Bumping Lake granite (cf. below), or dacite porphyry (cf. below).

The most recent volcanic eruption occurred in post-
glacial time. The eruption formed a cinder cone over 700 feet
in height on a high, glaciated plateau which is capped by
Valley flow basalt. The cone, called Tumac Mountain, shows no
effect of glaciation.

The intrusive rocks, mentioned in probable order of
their ages, include the buff-colored, quartz-rich Bumping Lake
granite which intruded the Puget Group sandstone and the lower

portions of the Keechelus formation; an agmatitic breccia,
which is closely associated with the Bumping Lake granite
genetically and spatially, contains dark-colored fragments of
Keechelus andesite embedded in a light-colored granite matrix.
Large dikes and sills of light gray dacite porphyry are
intrusive into the Keechelus and also into the granitic rocks.
The dacite porphyry was intruded after consolidation of the
granitic rocks but prior to the deposition of Fifes Peak
andesite.

Other intrusives which are relatively small in size
include two diorite plugs, an elongate body of quartz monzonite
porphyry, and Snoqualmie granodiorite, which outcrops in a
narrow zone and may be metasomatic in origin. All of these
bodies are post-Keechelus in age.

The ore deposits are small and of low grade. There has
been no production from any of the mines or prospects in the
area. There are two general types of deposits: those in
sedimentary or volcanic rocks, and those in granitic rocks.
Ore minerals identified from deposits in sedimentary and
volcanic rocks include: galena, sphalerite, chalcopyrite,
bornite, chalcocite, pyrite, covellite, and gold. The ores
are typical of those found in the mesothermal zone. Ore
deposits in the granitic rocks are more continuous in length
and probably in depth than those in sedimentary or volcanic
rocks, although no deep exploration has been attempted. Ore

minerals identified from deposits in the granitic rocks include: arsenopyrite, scheelite, molybdenite, pyrrhotite, and pyrite. Judging from the above assemblage it is probable that the deposits in granitic rock are largely of the hypothermal zone.

Glaciation has directly or indirectly shaped the present landforms. Prior to the glacial periods the topography was probably steeply rolling but not precipitous. The development of sheer cirque walls on the north slopes has resulted in a assymetrical topography. Three main ice tongues flowed eastward from the Cascade Range and imparted the distinctive U-shape to the upper portions of the valleys now occupied by American River, Bumping River, and Deep Creek.

Nivation has removed large amounts of loosely consolidated cinders from Tumac Mountain, and has caused breaching of the cone in a north-south direction.

Section Along Line A-A'

American River

American River

A
10000
5000
0

ok
blg
glb
blg
ok
dp
ok?
Mfp
my

A'
10000
5000
0

Scale: 1" = 10000'
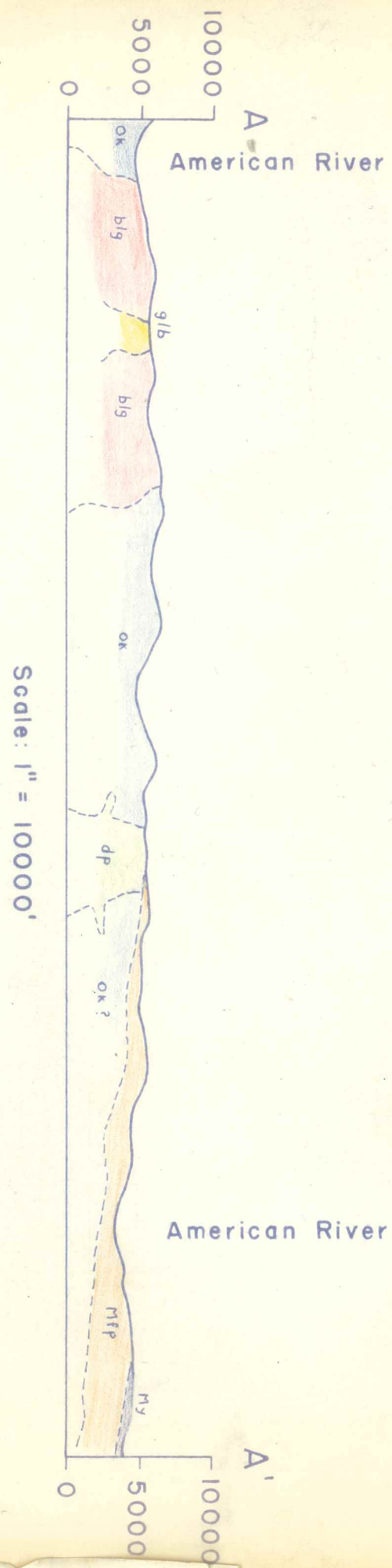
Fig. 5

Section Along Line C–C'

Fig. 7

Scale: 1" = 10,000'

C

10000
5000
0

Ok
?
?
?
Eps
Plv
blg   Bumping River
glb
Pdc
blg   Deep Creek
glb
dp   Nelson Ridge
Ok
?   North Fork
Ok?
Mfp

C'

10000
5000
0
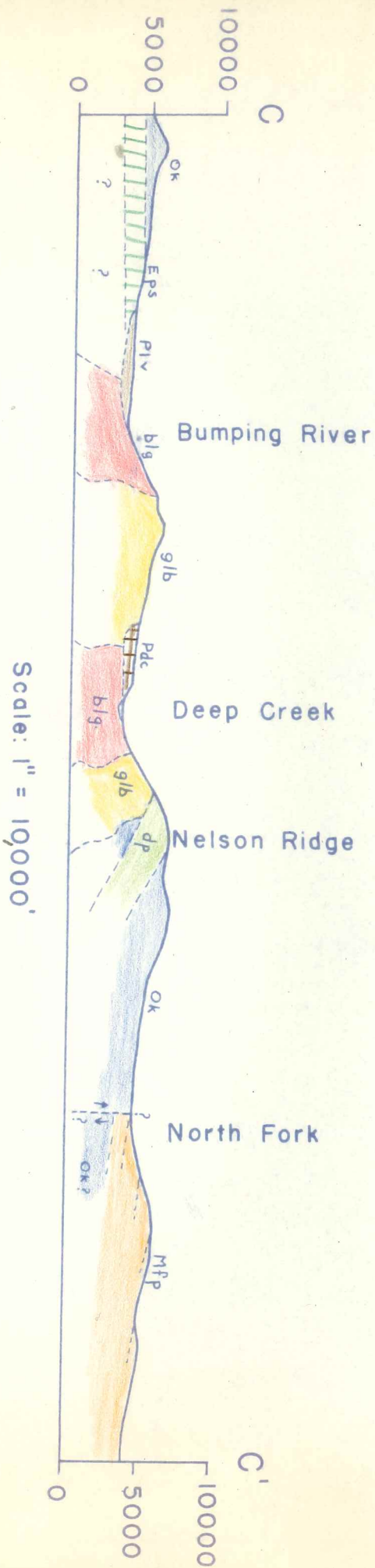
Section Along Line B-B'

Fig. 6

Scale: 1" = 10000'

Rainer Fork

American River

Bumping River

Tumac Mtn.

B

B'

MAP OF PRINCIPAL VEIN ZONE, COPPER MNG CO. PROPERTY

BUMPING LAKE MINING DIST?

YAKIMA COUNTY, WASHINGTON
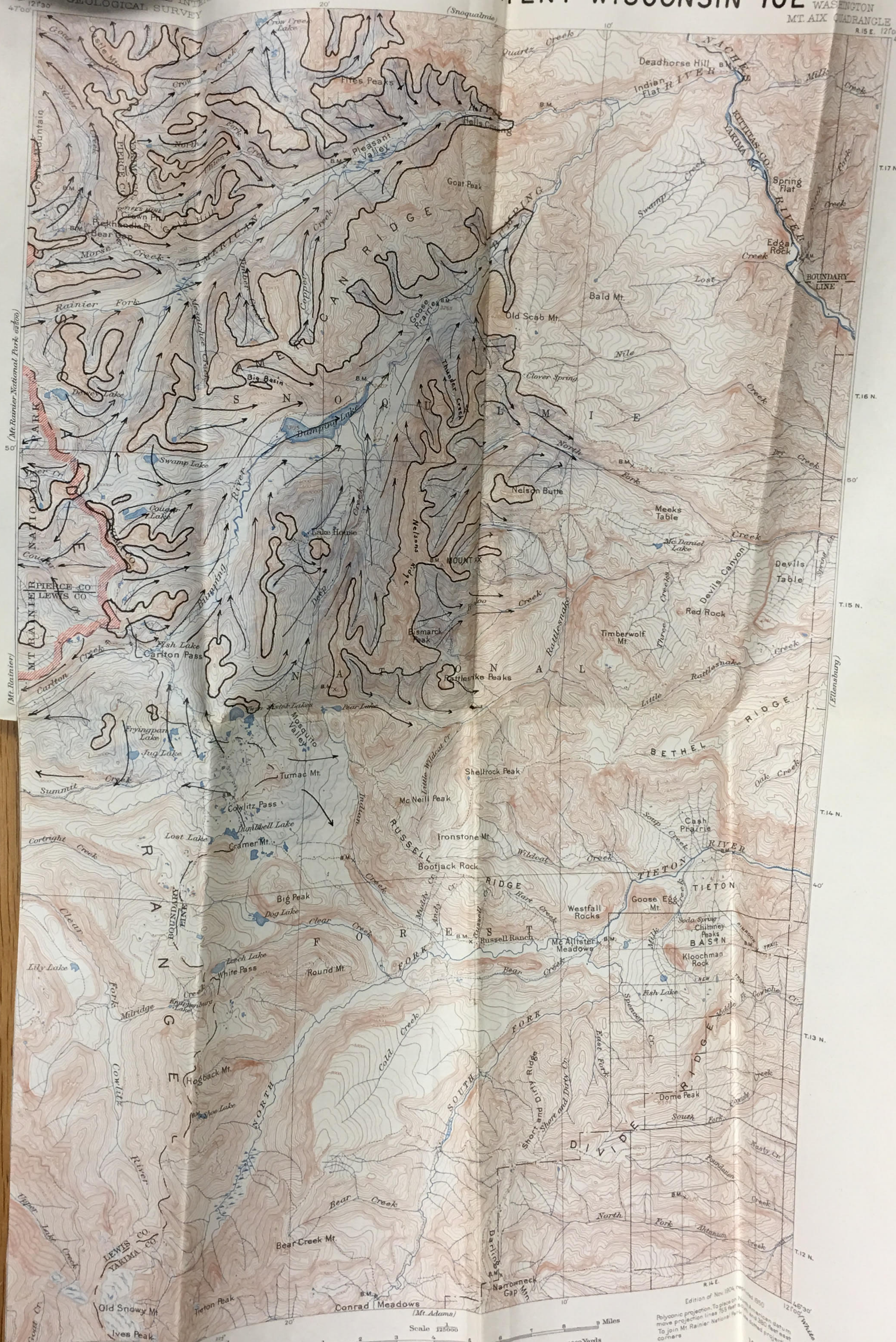
SCALE: 1 INCH = 100 FEET

CONTOUR INTERVAL: 50 FEET

AFTER S. WARREN HOBBS, U.S. GEOL. SURVEY
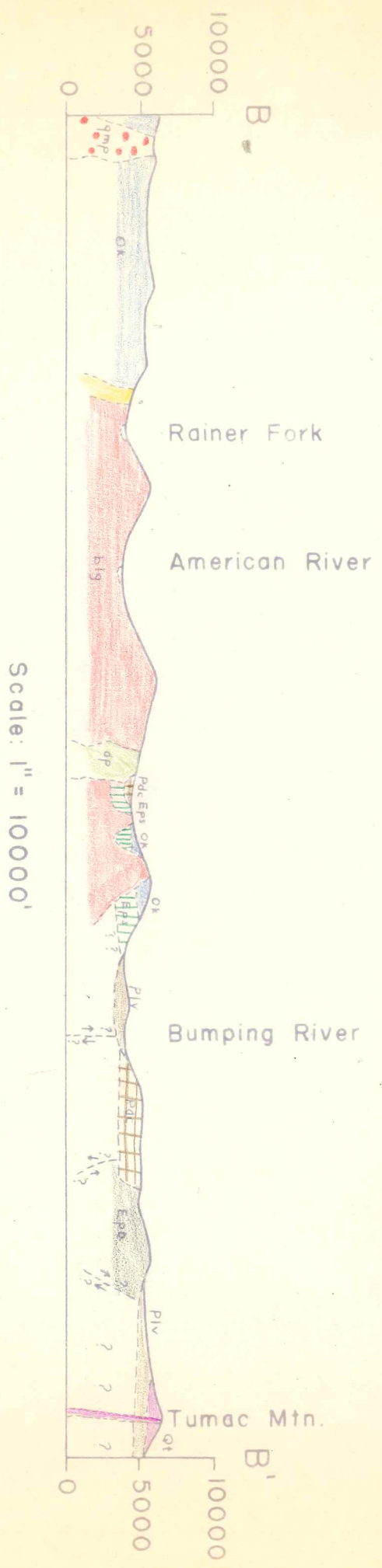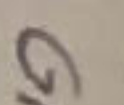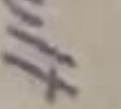
EXPLANATION:

Vein

Granite

Fault

MINERS RIDGE

MAP OF MAXIMUM EXTENT-WISCONSIN ICE
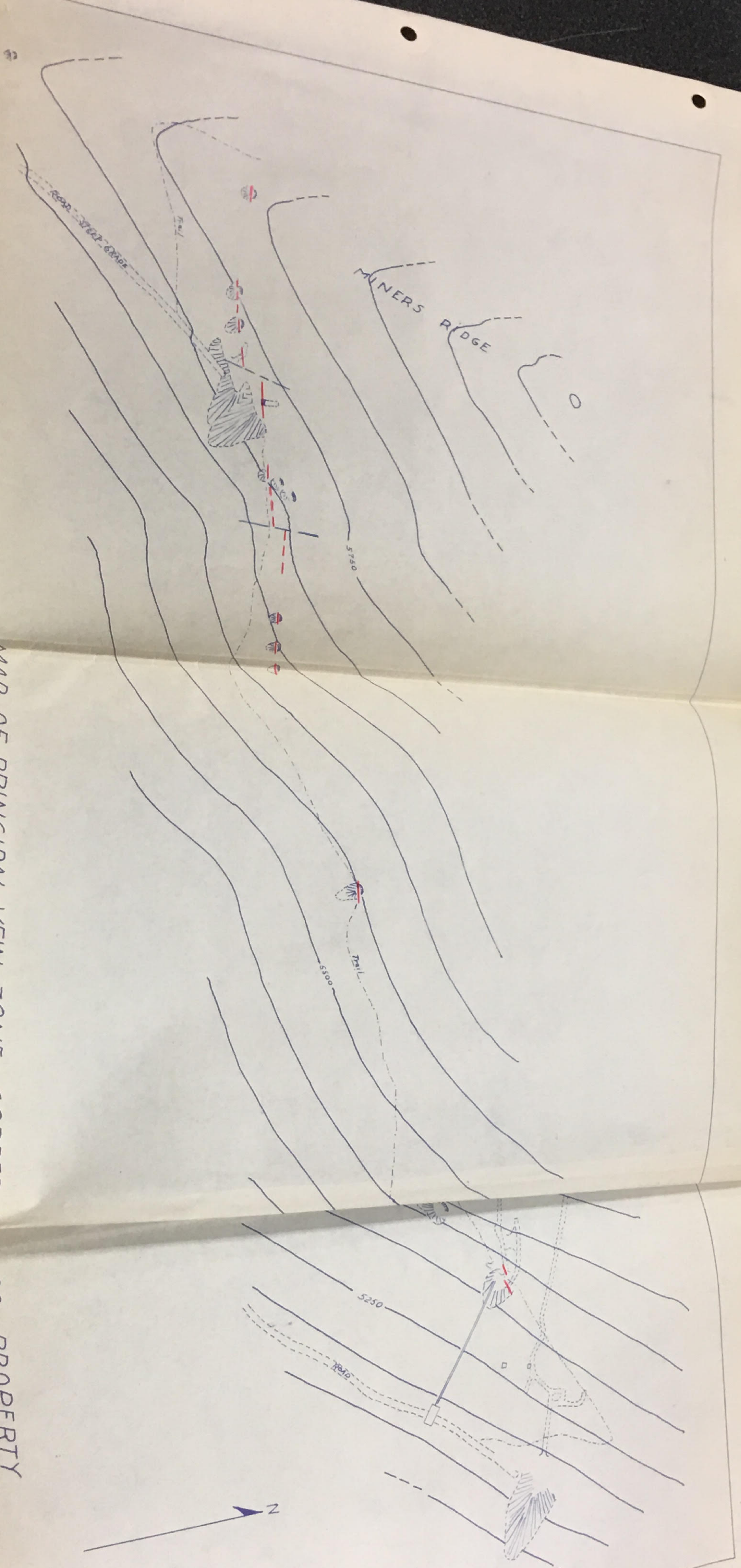
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WASHINGTON
MT. AIX QUADRANGLE

Scale 125000

Contour interval 100 feet
Datum is mean sea level

Fig. 8

Geol. J.J.Goode Geographer in charge.
Topography by A.H.Sylvester.
Triangulation by S.S.Gannett.
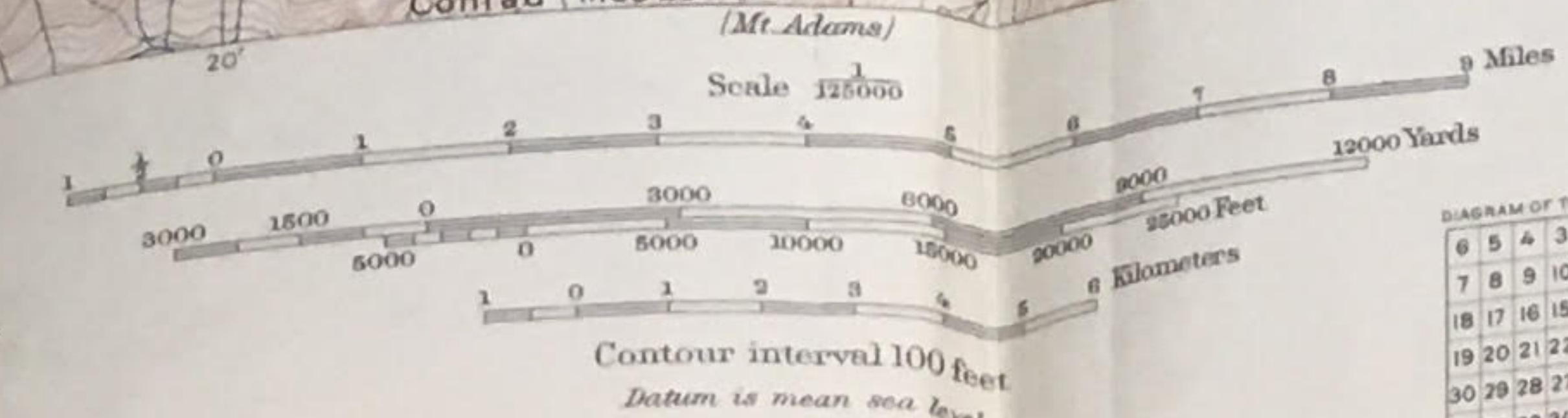Surveyed in 1900-1902.