GEOLOGY OF THE DECEPTION PASS AREA,

CHELAN, KING AND KITTITAS COUNTIES, WASHINGTON

By

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ABSTRACT

The area embracing the upper Icicle Creek and Deception Creek drainages in central Washington includes occurrences of the Chiwaukum schist, peridotite, Mount Stuart granodiorite, Swauk formation, and Keechelus volcanics.

The oldest formation in the area is the Chiwaukum schist. Next oldest is a mass of peridotite found in the southwest corner of the map area. The Mount Stuart granodiorite is intrusive into both the peridotite and schist in this area. The Tye Soda granite could not be distinguished from the Mount Stuart granodiorite. The youngest formations are the Swauk sediments and Keechelus volcanics, which are in fault contact with the older schist, peridotite, and granodiorite to the east. Complex relations such as interbedding indicate that the westward dipping Swauk sediments and Keechelus volcanics in this area may be closely related in age.

A large fault with a minimum of seven thousand feet of throw was found to separate the Mount Stuart granodiorite and peridotite on the east side from the sediments and volcanics on the west. The fault is here named the Deception Pass fault.

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INTRODUCTION

Purpose

During the summer of 1953 the writer made an investigation of the geology of parts of Chelan, King and Kittitas Counties in the Cascade Mountains of Western Washington. The area was selected because of its critical location with regard to the extent and structure of Cascade rocks. The problem of the contact of the western border of the Mount Stuart granodiorite with younger volcanics and sediments required the study of this previously unmapped portion of the Cascade crest.

A total of twenty-four days was spent in the field during August and September, 1953. Most of the work was done by making continuous traverses along the ridges and trails. A general field map was compiled, and about one hundred and fifty representative rock samples were collected for laboratory study.

Geographic Setting

The thesis area includes about one hundred square miles along the crest of the Cascade Mountains of Western Washington. The junction of King, Kittitas and Chelan Counties lies near the center of the region. The northern portion of the map area is accessible from the Stevens Pass highway, U. S. Route 2, and is about one hundred road miles from Seattle and ten miles east of Skykomish. The southern part of the area can best be reached from the Cle Elum River road, thirty miles north of Cle Elum on the Snoqualmie Pass highway, U. S. Route 10. From the west, access is made by the Icicle Creek road, twelve miles west of Leavenworth. The central part of the area is accessible only by National Forest trails.

Deception Creek, Surprise Creek and Foss River form the drainage west of the Cascade crest. They flow into the South Fork of the Skykomish River, along the Stevens Pass highway, and constitute a portion of the Puget Sound drainage area. Icicle Creek with its main tributaries, French Creek, Jack Creek and Leland Creek, flows eastward to join the Wenatchee River in the Columbia River Basin. The drainage to the south is to the Columbia by way of the Cle Elum and Yakima Rivers. Numerous picturesque lakes such as Square, Marmot, Klonaqua, Hyas and Leland Lakes occur in the area.

The area's highest elevation is Mount Daniel, 7,986 feet. The lowest elevation, 1,500 feet, is in the northwest on the South Fork of the Skykomish River.

Precipitation is typical of the Cascades, ranging up to 60 or 70 inches along the range crest. Variation in precipitation is markedly reflected by the vegetation. The thick, mossy forests of hemlock, fir and cedar on the west side of the Cascade crest are replaced by open forests of Ponderosa pine and even sagebrush a few miles to the east of the crest.

The main economic value of the region lies in the recreational facilities of the untouched wilderness. Lumbering is the principal industry in some of the adjacent valleys, but the thesis area has never been logged off except very locally along the marginal roads. Deer, bear, mountain goat and other animals are a valuable asset and attraction to hunters and trappers.

Geologic Setting

The Cascade Mountains of the West Coast can be divided into the Northern Cascades, the Central Cascades and various southern units. The Central Cascades consist of a complex series of massive volcanic rocks, such as Keechelus andesite-basalt series, and the high Cascade volcanoes. The Northern Cascades consist of older pre-Tertiary metamorphic and intrusive rocks. The area under consideration lies at the contact of these major geological rock provinces and includes rocks of both types.

The region occupies an important position in regard to physiographic concepts in the Cascades. Besides occupying the crest of the broad, overall north-south Cascade uplift, it occupies a position near the axis of the northwest-southeast Wenatchee uplift, which intersects the Cascade uplift. In connection with the Wenatchee uplift, it should be mentioned that the major north-south Cascade uplift is superimposed on the secondary Cascade structures which seem to trend northwest-southeast. Much of the area was covered by Alpine glaciation during the Pleistocene epoch.

Previous Work

The Cascade Mountains in Washington are one of the least known areas in the United States. During the latter part of the nineteenth century the Central Cascades were the scene of much prospecting, as was the Western Cordillera in general. Many areas, including the area under consideration, were far more densely populated then than now. In the late 1890's Israel C. Russell made a geological reconnaissance in Northern and Central Washington. He first described most of the major units in the vicinity of Mount Stuart, such as the Mount Stuart granodiorite, the Swauk sandstone and the Columbia River basalt.

Later George Otis Smith, Bailey Willis, F. C. Calkins and others were sent out by the U. S. Geological Survey. Their work resulted in the publication of the Snoqualmie, Mount Stuart and Ellensburg geologic folios and the publication of several papers. Considering the problems involved, this early work seems to be of excellent quality and gives the lithologic and physiographic background for understanding the geology of the region.

After the early survey work, very little was done. In 1912 Charles Weaver published on the Index Mining district, and in 1915 Warren Smith wrote on the Skykomish Basin. These papers deal primarily with economic deposits. In recent years the staff and students of the University of Washington have completed scattered studies in the area. Of special mention is the work of Keith Oles to the north of the worked area and the work of summer school field parties to the northeast. This work is unpublished.

Acknowledgments

The writer would like to acknowledge the assistance of the faculty of the Geology Department at the University of Washington in the preparation of this paper. Professor Howard A. Coombs immediately supervised the preparation of the thesis. Professor Clifford Willis suggested the problem and was of great help in planning the field work.

The writer is also indebted to the Forest Service for their help, especially to the staff at the Skykomish Ranger Station for their many helpful suggestions.

NOTES ON TOPOGRAPHY

While the primary intent in this thesis is an understanding of the bedrock relationships, certain physiographic factors cannot be overlooked. The investigation covers too small an area to work out the physiographic history of the region itself, but previous work and ideas can be applied to this limited area.

Stage of Regional Erosion

The most striking aspect of the mountains is the sharpness of their relief. Streams have cut narrow, V-shaped canyons through which they roar and tumble. In many places bedrock is exposed in the stream bed. The streams carry a heterogeneous assortment of boulders and gravel derived from abundant talus and glacial debris, all indicating a youthful stage of topographic development.

Upland Surfaces

One of the most interesting aspects of Cascade physiography is the question of upland surfaces. I. C. Russell in 1898 first drew attention to this problem. He recognized, in the concordance of summit levels in the Cascades, an erosional surface which he termed the Cascade peneplane. Bailey Willis also recognized in the concordance of summit levels a surface which he termed the Methow surface. He also recognized a younger surface which he called the Entiat surface. Three other erosion stages were recognized by Bailey Willis, the Twisp Canyon stage, Chelan glacial stage and Stuart glacial stage. In the writer's opinion, some of Willis' five erosional stages from the Chelan-Methow region can be correlated with observed erosional stages immediately east of the thesis area.

An attempt was made to recognize the Entiat surface in the thesis area. This surface is very evident east of the Cascade crest along the Wenatchee River. Here it is a rolling surface of considerable relief that breaks off abruptly into the precipitous canyons of the Twisp stage. From a height on the Cascade crest just south of Stevens Pass, one can look eastward over the Entiat surface above the Wenatchee River and above Icicle Creek. This upland surface, with its rolling topography, can be seen to extend westward to the Cascade crest in the vicinity of Stevens Pass. Here it merges into the rugged ridges west of the crest and is lost. The surface is well seen around Lake Josephen and can be recognized in the broad, rolling topography along Trappers Ridge.

Valley glaciers have modified the break between the Twisp valley stage and the Entiat surface in most of the high valleys.

South of Icicle Creek no evidence of an upland surface could be observed. The evidence is lost in the towering spires and cliffs of the mountains along the Wenatchee uplift. The great arching of the Wenatchee uplift strikes northwest through the heart of the mapped area.

Glaciation

Evidence of the work of glaciers can be seen everywhere in the mapped area. Small glaciers and neve fields are in existence on the highest mountains today. The valleys of Icicle Creek, Meadow Creek, Trappers Creek, Leland Creek and French Creek are all beautiful, U-shaped, glaciated valleys. At one time ice must have occupied all these valleys and coalesced to form the main Icicle Creek glacier which extended down to the Wenatchee River (Russell, 1898). The glaciated valley bottoms are remarkably broad and flat.

Glaciers also occupied Deception Creek, Surprise Creek, and Cle Elum River valleys. The Deception Creek glacier never reached the Tye River, nor did the Surprise Creek glacier. The Cle Elum River glacier reached the Yakima River where its terminal moraine forms Cle Elum Lake.

The great number of cirques, with their contained lakes full of fish, is one of the most inviting and enjoyable aspects of the region.

ROCK FORMATIONS

The rocks in the area include those of several lithologic provinces. The oldest units are the metamorphic rocks of Paleozoic age. They are included in the eugeosynclinal facies of the Cordilleran geosyncline. The Chiwaukum schist is the only representative mapped in the area, although numerous metamorphic formations have been described from adjacent areas.

The peridotite and the Mount Stuart granodiorite represent the intrusive rocks of the area. These intrusive rocks are also indicative of the later eugeosynclinal type of regional development.

Over the consolidated basement of metamorphic and intrusive rocks a great mantle of sediment and volcanic material was deposited in early Tertiary time. These units are represented in the thesis area by the Swauk sediments and Keechelus volcanic series.

Other rock units consist of dikes of several kinds and a dacite flow.

Chiwaukum Schist

Extent

The Chiwaukum schist was first described by Page (1939) from the exposures along Chiwaukum Creek northwest of Leavenworth, Washington. During the summer of 1953 the schist was traced southward by University of Washington students. The contact between the schist and the Mount Stuart granodiorite was partially mapped at this time.

Work during the present investigation involved mapping the westward extension of this schist. The formation was traced along Icicle Creek to a point above the confluence of Leland Creek with the upper Icicle. North of Icicle Creek the schist is in sharp contact with granitic rock. This body of schist is entirely separated from the body of schist to the north and east in the Chiwaukum Mountains by Mount Stuart granodiorite.

The schist composing the Chiwaukum Mountains was not actually mapped in detail. However, the dark brown, smooth slopes formed by the foliated rock are easily distinguished from the light, blocky talus slopes and ragged peaks of granodiorite. Thus, the Chiwaukum Mountain occurrence of schist can be traced across the ridges between Icicle Creek and the Chiwaukum Mountains.

The contact of the Icicle Creek occurrence of schist with the granodiorite crosses Leland Creek near its mouth and is well exposed across the top of French Ridge. Chiwaukum schist occupies much of the Jack Creek and Black Pine Creek drainage south of Icicle Creek, as can be seen on the writer's map. It is everywhere bounded by Mount Stuart granodiorite except for intervening peridotite in the Snowall Creek drainage area.

Petrographic Description

Megascopically the Chiwaukum schist is a dark reddish-brown, fine-grained schistose, well banded biotite-quartz schist. In most places the bands are well defined and consist of light-colored layers of fine-grained, sugary quartz alternating with dark, biotite-rich layers. The bands are a millimeter or so in width and seem to be very continuous and distinctive.

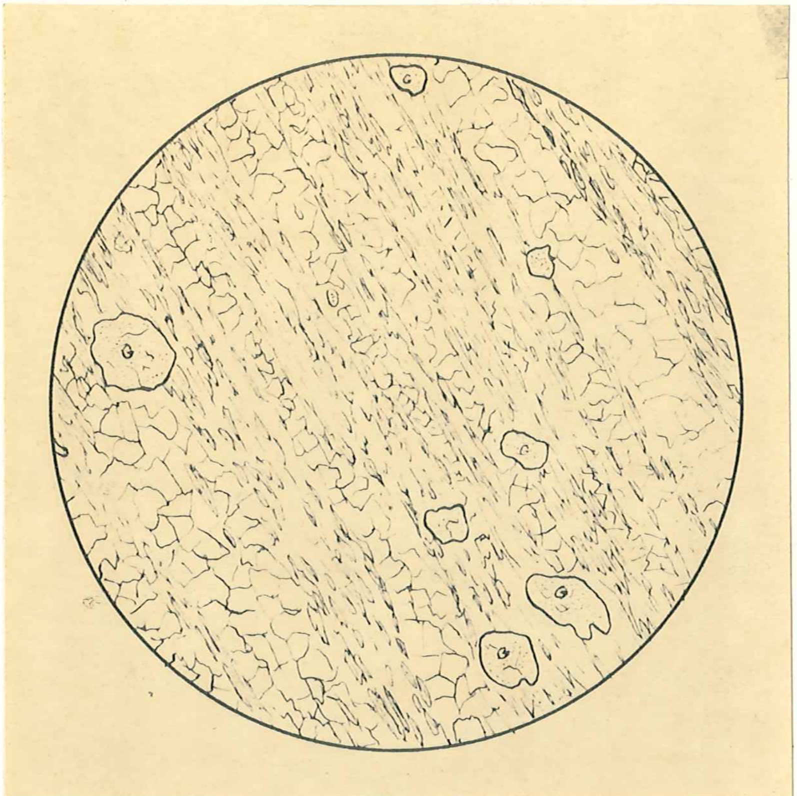

Fig. 2. Chiwaukum Schist

Quartz-biotite schist from Icicle Creek. The specimen is composed of 70 per cent quartz, 20 per cent biotite, 5 per cent kyanite, 2 per cent magnetite and graphite, and 3 per cent garnet (G). Quartz segregation bands and concentrations of biotite and graphite give the rock a banded appearance. The biotite shows synkinematic crystallization and good orientation. Garnet porphyroblasts are rather conspicuous.

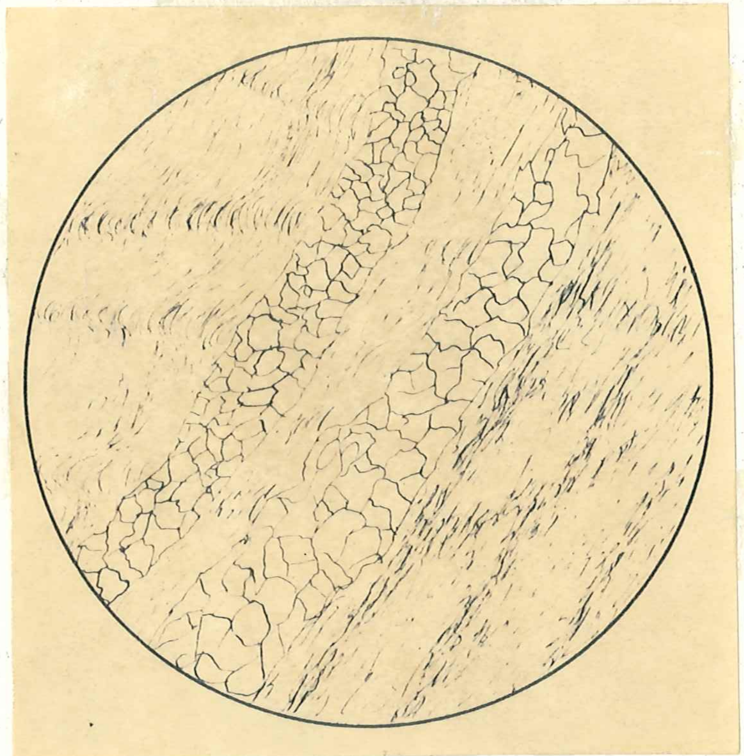

Fig. 3. Chiwaukum Schist

Specimen from the east side of Deception Creek. Minerals consist of over 90 per cent quartz with minor amounts of graphite, fibrolite, and biotite. Coarse-grained quartz bands and dark graphitic bands are distinctive. "B" as well as "S" structure is clearly shown.

In places, such as near French Ridge lookout, the schist is strongly folded. Associated with the ptygmatic folds are small lenses and stringers of coarse-grained quartz. The quartz lenses are up to an inch in width and stretch out along the planes of foliation, usually following the folding.

Microscopically the schist has several distinctive features. The rock as a whole usually contains 60 to 80 per cent quartz. When many coarse-grained quartz lenses are included, the percentage of quartz often runs as high as 90 per cent. The distinctive dark banding, which in hand specimens seems to be due to biotite, is in reality caused by concentrations of carbonaceous matter (graphite). The carbonaceous matter is fine-grained and definitely concentrated along foliation planes. The percentage of graphite often runs as high as ten per cent, but even one or two per cent gives distinctive bands.

Biotite occurs in several ways. The great majority of sections show biotite that is synkinematic, with but slight post-deformation growth. However, some specimens, especially those toward the Chiwaukum Mountains, show dynamically sheared and oriented biotite. Toward the southwest limits of the Icicle Creek schist body, static crystallization of the biotite seems to predominate.

There seems to be a gradual increase in the degree of metamorphism as the contact with the peridotite is approached. In several specimens taken along Icicle Creek, tremolite occupies up to 30 per cent of the rock and there is very little biotite. In one specimen several per cent of the rock was spessartite, and another specimen showed ten per cent late muscovite. In these specimens the biotite shows little late recrystallization. Further south, nearer the peridotite, the biotite shows progressive post-kinematic crystallization. On Black Jack Ridge, near the contact of the schist with the peridotite, the biotite has been completely replaced by hornblende. In one specimen the quartz formed an even-grained mosaic of tightly fitted crystals, and the hornblende formed minute inclusions and irregular bands within and between the quartz. These hornblende-rich rocks have a distinctive dark gray color and show less distinct foliation and no quartz segregation bands. The schist has been statically recrystallized and metasomatized in patches near the granodiorite. The resulting rock is a mesh of euhedral, zoned feldspar, recrystallized quartz, and biotite grains. A couple of these gray, even-grained, sugary-textured patches are well exposed along the upper Icicle Creek trail.

Correlation

Three large areas of Chiwaukum schist are indicated on the geologic map. The problem of correlating these three bodies with each other is an important one. In connection with the University of Washington summer field course, the writer collected several specimens of schist from the Chiwaukum Mountains and the type area along Chiwaukum Creek. An examination of these specimens reveals the same large percentage of quartz, up to 10 per cent graphite, and usually 20 to 30 per cent of synkinematic biotite, with some late static development. The schist along Chiwaukum Creek has up to 15 per cent staurolite, which is the only major mineralogical difference from the Icicle Creek schist. The texture and structure of the two bodies of schist are identical. They both show the same distinctive banding, the same coarse-grained quartz lenses, and the same distinctive ptygmatic folding. The attitude of foliation averages N 45 W in the Chiwaukum Mountains and north 40 to north 50 west along Icicle Creek. From the above evidence, it seems certain that the Icicle Creek schist body is the same lithologic unit as the Chiwaukum schist.

Another occurrence of schist was found on the west edge of the Mount Stuart granodiorite. This patch is bounded on the west by Swauk sediments, along the Deception Pass fault contact. It is exposed for about two miles along the Deception Creek trail, above its junction with the Tonga Ridge trail; however, its exact boundaries are well hidden in the dense, mossy forests. Lithologically the schist has up to 85 per cent quartz, ten per cent graphite and magnetite, and about five per cent late sillimanite, as well as a trace of staurolite. A distinctly banded structure is much in evidence, although the quartz lenses are less pronounced than in the schist further east along Icicle Creek. The strike of the foliation is consistently north 45 to north 50 west, the same as the Icicle Creek and Chiwaukum Mountain occurrences. It is on this evidence that these three separated occurrences of Chiwaukum schist are correlated.

Age

The age of the schist is a problem. Only the relative age of pre-Mount Stuart granodiorite and pre-peridotite can be determined from evidence in the area. However, there is a possible correlation of the Chiwaukum schist with other schists in the region. George Smith (1904) has described the Peshastin schist, the Easton schist, and the Hawkins formation from his work in the Mount Stuart Quadrangle. The Peshastin schist is described as a black slate (G. O. Smith) with associated marble and black schist and conglomerates (Weaver, 1911). The Hawkins formation is composed of metamorphosed volcanics and is generally considered to be more or less interbedded with the Peshastin. The Easton schist is described as a dark, foliated, mica schist with associated glaucophane schists, phyllites, and green schist (Smith, 1904). The age of these metamorphic rocks was tentatively placed as Carboniferous by Smith, who says, "They have a strong resemblance to the Carboniferous rocks of British Columbia (Cache Creek series) and to rocks of the same age in the Sierra Nevada (Calaveras formation)."

Warren Smith (1916 and 1915) has extended Easton schist, Peshastin schist, and Gun Peak (Weaver, 1911) metamorphics into the Skykomish Basin, just west of the thesis area. He describes the Easton schist, from the northwest section of the Skykomish Basin, as a quartz, biotite schist; and he mentions a very high percentage of quartz. This description sounds very much like that of the Chiwaukum schist; if the two described occurrences are in reality the same rock unit, this would make the Chiwaukum schist the same as the Easton schist insofar as W. Smith's correlation is valid. The present prevailing opinion is to consider all these metamorphic rocks as Paleozoic or older in age.

The Swakane gneiss is considered to be gradational with the Chiwaukum schist on the east because structures can be correlated across intervening Swauk sediments (C. Willis, 1953).

Peridotite

Occurrence

One of the most interesting formations in the Mount Stuart region is the peridotite. The peridotite was first described in the Mount Stuart Geologic Folio by George Otis Smith in 1904. He recognized a broad double belt of the rock south of Mount Stuart. This belt was extended into the Snoqualmie quadrangle (Smith, 1906) where its west end is cut by fault contact along the Cle Elum River (the Deception Pass fault). The only other work that concerns the peridotite body is that done by Weaver (1912) on the Blewett mining district.

In the present investigation the northwestern extension of the peridotite into the Skykomish and Chiwaukum quadrangles was studied and mapped. The northern contact of the peridotite with the Mount Stuart granodiorite, as seen just west of Mount Stuart in the Mount Stuart Folio (Smith, 1904), was found to extend in a northwest direction through the upper drainage basin of Jack Creek and then westward across French Creek and over the ridge east of the Cle Elum River valley. The peridotite is bounded on the west by the Deception Pass fault, which separates it from the Swauk sediments and Keechelus volcanics on the west side of the Cle Elum River valley.

North of the main body of peridotite, but entirely separated from it by a band of Mount Stuart granodiorite, is another occurrence of the formation. As can be seen on the writer's map, this occurrence forms part of a roof pendant of the granodiorite mass. In the roof pendant the peridotite grades into the Chiwaukum schist, as described under the schist.

Petrographic Description

The peridotite is a dark gray, fine-grained, hard ultrabasic. It breaks with an irregular concoidal fracture. Exposed surfaces weather to a soft orange-brown color. The principal mineral is dark, sugary olivine, which in a fresh sample may constitute 85 per cent of the rock. The large anhedral crystals of olivine are crisscrossed by many small fractures, along which antigorite has formed. Several sections show up to 10 per cent anthophyllite, which is also an alteration product.

The second major mineral of the unaltered peridotite is enstatite. This mineral forms large, stubby, anhedral crystals readily seen in a good hand specimen. Enstatite sometimes constitutes 40 per cent of the rock, but most specimens show a much smaller amount. The enstatite has largely altered to secondary minerals, mainly bastite, a form of serpentine.

From a relatively pure peridotite with as little as 5 per cent antigorite, all degrees of alteration to pure serpentine rock can be found. From a network of small cracks dissecting the olivine crystals, the antigorite gradually replaces the olivine until only small remnants of olivine are left. With the alteration to serpentine, magnetite is formed. The magnetite forms a blotchy mesh within the antigorite mass, although relatively large subhedral grains of magnetite are often apparent.

Extensive areas of serpentine rock are of the light green schistose variety, showing wide variations from the typical black, non-schistose rock. The green variety shows up to 80 per cent antigorite, although chrysotile has formed locally along fractures. Ten per cent of the rock is magnetite, distributed rather heterogeneously through the specimens. Considerable talc

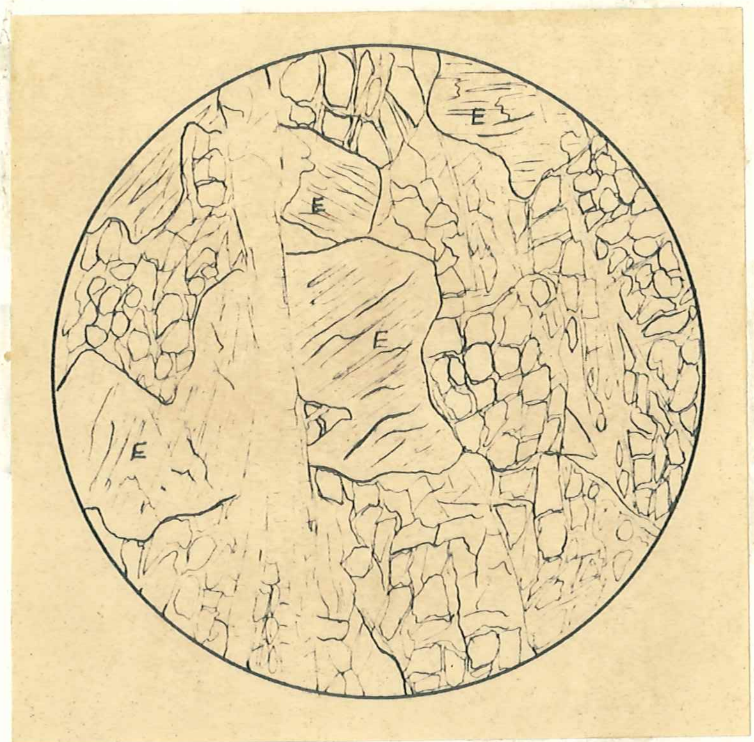

Fig. 4. Peridotite

A relatively unaltered specimen of peridotite from the head of French Creek. Large crystals of enstatite (E) show little alteration; however, the main mineral, olivine, is altering to antigorite along a network of typical fractures. A number of small shear zones transect the specimen.

is usually present, and in addition, carbonate and anthophyllite may be present. The schistose green serpentine shows no remnant of the original peridotite minerals. Most writers (Smith, 1904) assume that the rock is sheared due to the increased bulk resulting from hydration during serpentization, although regional metamorphism may also be involved.

Age

The age of the peridotite can only be determined relative to other formations. The formation is older than the Mount Stuart granodiorite because acidic dikes, derived from the granodiorite, are found intruded into the peridotite (Smith, 1904). Several large dikes of this sort can be seen at the top of Paddy Go Easy Pass. Conglomerates derived from the serpentine mass are found in the Paleocene Swauk formation.

The only contact with the older metamorphics, studied in the thesis investigation, was the contact with the Chiwaukum schist. The contact seems to be completely gradational. In the excellent exposures along the Cradle Lake trail, the rock grades from typical dark gray peridotite into a green gray hornblende-rich rock that is crisscrossed by a network of small quartz veinlets. The hornblende-rich rock gradually becomes more quartzose, banded and finally merges into the typical schistose, banded, quartz-biotite Chiwaukum schist. The contact zone is about 400 feet wide.

Patches similar to the gradational contact rock occur well within and intimately associated with the peridotite mass. These irregular areas are gray in color and crisscrossed by white quartz veinlets. Also associated with the peridotite are small patches of gabbroic rocks. Weaver (1911) recognized the same type of problem and says, "In a great many cases rocks resembling a basic diorite or gabbro porphyry occur intimately associated with the serpentine and are also partially serpentinized." He postulates a possible more acid phase of the ultrabasic or the possibility of partially assimilated xenoliths (Weaver, 1911).

Both Weaver (1911) and George Smith (1904 and 1906) indicate the age of the peridotite as younger than the metamorphic rocks in the region. Thus Smith says in the Snoqualmie Folio (1906), "In the northern part of the area the peridotite is plainly intrusive into the Peshastin and Hawkins formation but it is in turn intruded by the Mount Stuart granodiorite." So we must conclude that the best age available for the peridotite-serpentine mass is post-Peshastin (Carboniferous) and pre-Mount Stuart (Pre-Eocene).

Mount Stuart Granodiorite

By far the most extensive formation in the area, and the one that is the center of interest, is the Mount Stuart granodiorite. This formation was described from the type area at 9,470 foot Mount Stuart by George Smith (1904) in the Mount Stuart Geologic Folio. However, only the southernmost edge of this great mass of granodiorite is represented in the Mount Stuart Folio, and until the work of the present investigation the northern and western extent of the unit was completely unmapped.

Areal Extent

From the towering spire of Mount Stuart the granodiorite was traced northward into the Jack Creek drainage. Harding Mountain, which is represented on the Washington State geologic map (1936) as an isolated knob of granodiorite, was found to be continuous with the type section at Mount Stuart. From Harding Mountain, Mount Stuart can be traced northwest over the Cradle and directly into Granite Mountain, above Hyas Lake. Granite Mountain is represented on the State map (1936) as composed of Snoqualmie granodiorite, but the writer's work has shown this to be in error. The Mount Stuart granodiorite of Granite Mountain is bounded on the south by massive, red-brown peridotite, and the west side of the mountain is cut by the Deception Pass fault. From Granite Mountain the Mount Stuart granodiorite was traced north to the Stevens Pass highway, beyond which it apparently continues for an unknown distance. The west edge of the mass is bounded largely by the Deception Pass fault.

To the northeast the Mount Stuart granodiorite is bounded by the Chiwaukum schist. The northern reaches of the granodiorite are in part gradational into the schist (Oles, 1952). South in the Chiwaukum Mountains the schist-granodiorite contact is sharp and easily followed over the high ridge. Much of the eastern limits of Mount Stuart has been mapped by Clifford Willis (1950), Page (1939), Chappell (1936), and by members of University of Washington summer field courses (1951 and 1953).

The Mount Stuart granodiorite completely surrounds a large area (a roof pendant) of Chiwaukum schist and peridotite. This area has been mentioned in connection with the schist and peridotite. Its western end is very definitely surrounded by massive granodiorite, as seen on the writer's map. From work undertaken in the summer field courses, the writer is certain that the granodiorite extends in a continuous belt around the north and east ends of the roof pendant. The Mount Stuart Folio (Smith, 1904) indicates an unbroken expanse of granodiorite south of the roof pendant.

Petrographic Description

The Mount Stuart granodiorite is remarkably uniform in the map area. Megascopically the rock is a medium-grained granitic rock, light gray in color. Biotite, hornblende, quartz, and plagioclase are conspicuous in hand specimens. Chloritization is evident along fractures, but otherwise there is little evidence of chemical alteration. The rock disintegrates rapidly into its constituent grains. Upon examination, the bed of any stream shows no boulders of granite but a concentration of everything in the area except the granitic rock. Favorable locations along the stream will have sand deposits made almost exclusively of the disintegrated remains of the granitic rock.

Under the microscope the hornblende and biotite, together making up 15 to 20 per cent of the rock, are the only mafic minerals and usually occur in approximately equal quantities. The biotite usually occurs as large, green-brown subhedral crystals. However, in some specimens it appears as small, poorly formed grains. The hornblende is typically anhedral and in some slides is evidently altering to biotite, with the formation of magnetite. Apatite was observed in many specimens.

The feldspar is of two kinds: orthoclase and plagioclase. The orthoclase represents only a small part of the rock and in many specimens none was observed. George Smith (1904) considers 8 per cent of the rock as orthoclase, but from the writer's observations this figure seems a little high. Plagioclase is the dominant mineral, usually comprising 50 to 75 per cent of a specimen. The plagioclase crystals are usually well formed, subhedral grains 2 to 4 mm in length.

Fig. 5. Mount Stuart Granodiorite

Typical specimen from the top of Granite Mountain. Mineral composition is hornblende (H), biotite (B), plagioclase (P), and quartz (Q). Note high amount of quartz and absence of noticeable orthoclase. Megascopically the specimen is a light gray, medium-grained, granitic rock identical with that near Mount Stuart.

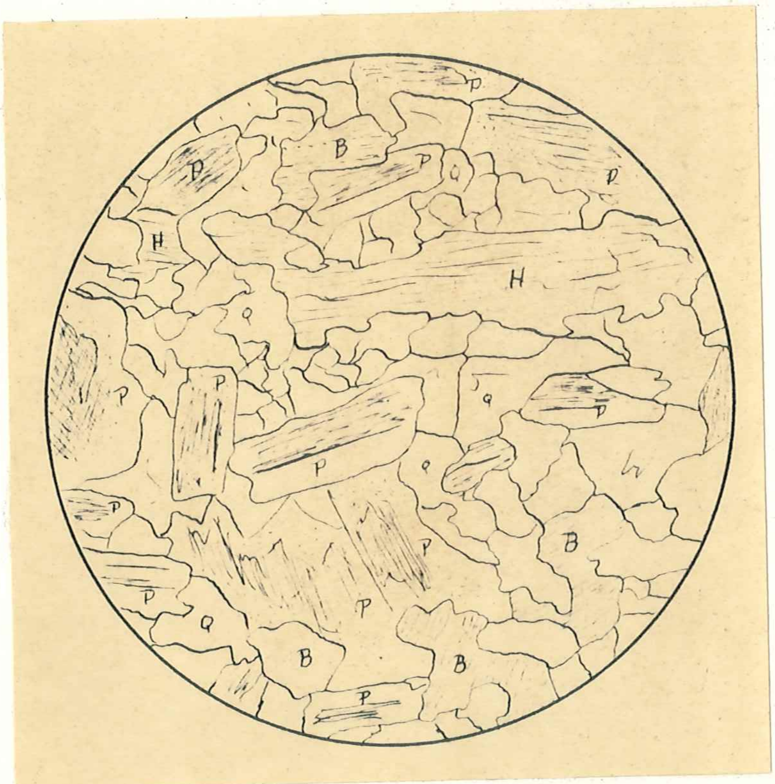

Fig. 6. Mount Stuart Granodiorite

A specimen collected from the east side of Upper Deception Creek. This phase of the Mount Stuart shows a relatively finer grain size, more anhedral crystals, and a generally darker, more heterogeneous appearance. Minerals consist of hornblende (H), cloudy zoned plagioclase (P), biotite (B), and quartz (Q).

The feldspar crystals are usually clouded with sericite. Sericite is more abundant in the center of the crystals than it is in the rims. Some crystals have become so cloudy that the twinning is completely obscured. The plagioclase varies from Ab_{60} An_{40} to Ab_{75} An_{25} and is therefore predominantly andesine with some oligoclase. The quartz usually constitutes 10 to 30 per cent of the rock as interstitial filling between the feldspar grains.

The above description is typical of 95 per cent of the Mount Stuart granodiorite. The minor portion of the granodiorite can be divided into several types: 1) inclusions (xenoliths) of altered schist which are particularly abundant in the northern portion of the map area; 2) a quartzose phase that occurs in large patches grading into the granodiorite; and 3) small pegmatite dikes.

The inclusions vary a good deal but are typically dark gray, rather fine-grained rocks with sharp, definite contacts with the granodiorite. Some inclusions show small porphyroblasts of feldspar and mafic material. Microscopically the inclusions have much quartz and small, usually zoned laths of andesine or oligoclase. Mafic material consists of hornblende and small laths of biotite. The texture of the inclusions shows extensive recrystallization and such metamorphic features as sutured crystal borders and inclusions within the crystals. Toward Granite Mountain and Mount Stuart, the inclusions are very small and scattered but show the same general composition as those further north.

Another type of variation in the Mount Stuart granodiorite is a fine-grained, very quartzose phase. This phase occurs in extensive patches in an area in the middle of the Leland Creek-Prospect Creek drainage. It forms red-brown talus slopes of highly fragmented rock. Individual fragments are very quartzose and hard and form a dominant part of the boulders in the streams. Microscopically the rock only has a few per cent of biotite and hornblende and is very high in quartz. The remainder of the rock is badly altered zoned feldspar. The quartzose phase shows every gradation with the typical Mount Stuart granodiorite and seems to be an acidic segregation from the main mass.

Pegmatite dikes are another phase of the Mount Stuart granodiorite. They occur rather extensively on Granite Mountain and French Ridge. A typical dike is only an inch in width and is composed of coarse-grained feldspars and quartz. The dikes terminate in lens fashion at each end and rarely extend over a hundred feet in length.

Structure

The Mount Stuart granodiorite mass, as seen by the writer, has all the aspects of a typical igneous intrusive body. Microscopically the granodiorite has textures typical of igneous granitic rock. Homogeneity of the formation is contributing evidence of an igneous origin.

The sharp contact of the granodiorite with the peridotite and the Chiwaukum schist, in the center of the area, is that of an igneous intrusion. Over the top of French Ridge, where the granitic rock cuts across the planes of foliation in the schist, the contact is very sharp, both megascopically and microscopically. Oriented biotite in the schist is seen to bend sharply at some contacts due to the "drag effect" of the intruding granitic rock.

The peridotite is also intruded by the granodiorite in the same manner as the schist. The contact between the granodiorite and peridotite

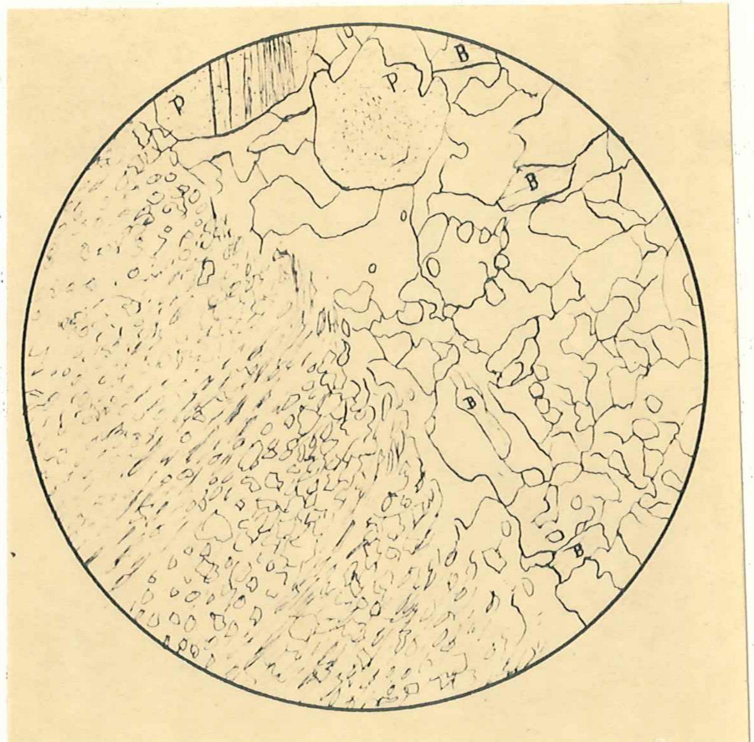

Fig. 7. <u>Chiwaukum Schist-Mount Stuart Granodiorite Contact</u>

A specimen from the top of French Ridge. Biotite, quartz schist, only slightly banded and high in quartz, is shown cut, across the trend of foliation, by intruding rock. The granodiorite is largely quartz with a few large, zoned plagioclase crystals (P) and small flakes of biotite (B). The high quartz content of the granodiorite is probably a reflection of incorporated schist. Note the bending of the foliation trends of the schist at the contact.

is smooth and regular because there is no controlling structure in the peridotite. Two types of granodiorite are in contact with the peridotite: 1) the typical Mount Stuart granodiorite, and 2) a fine-grained, chilled border phase. The fine-grained phase, intruding the peridotite, is usually intruded by apophysis of typical granodiorite. Acidic dikes and irregular bodies of fine-grained granitic rock, such as those in the peridotite on the ridge above Hyas Lake, are further manifestations of the intrusive nature of the Mount Stuart granodiorite. These acidic dikes were noted by G. Smith (1904) and are genetically related to the granodiorite.

Structurally the Mount Stuart granodiorite mass is a batholith that has been intruded into the older schist and peridotite. Erosion has exposed much of the batholith but has not yet removed the entire roof. Part of the roof lies in the form of a large roof pendant of schist and peridotite.

Tye Soda Granite

Warren Smith, in his work on the Skykomish Basin, has recognized a granitic mass which he termed the Tye Soda Granite. He describes the formation as follows:

> "The batholith, lying in the northeast corner of the quadrangle, consists of a massive, comparatively coarse-grained, granitoid, greenish-white, igneous rock composed of orthoclase, plagioclase, quartz, hornblende, and biotite, the latter in irregular lustrous brown flakes and the hornblende in recognizable green prisms. The feldspar weathers out to a lime-colored mass, leaving the anhedral quartz grains in relief, often giving the rock the appearance of a mosaic. The rock is typically fresh, but the feldspar is always slightly clouded. One large outcrop of this terrane occupies the northeast corner of the Skykomish Basin on Tye River, Martin Creek and Deception Creek. It is well shown along the Great Northern Railway between Scenic and the new village of Alpine."

(Smith, 1915, page 159)

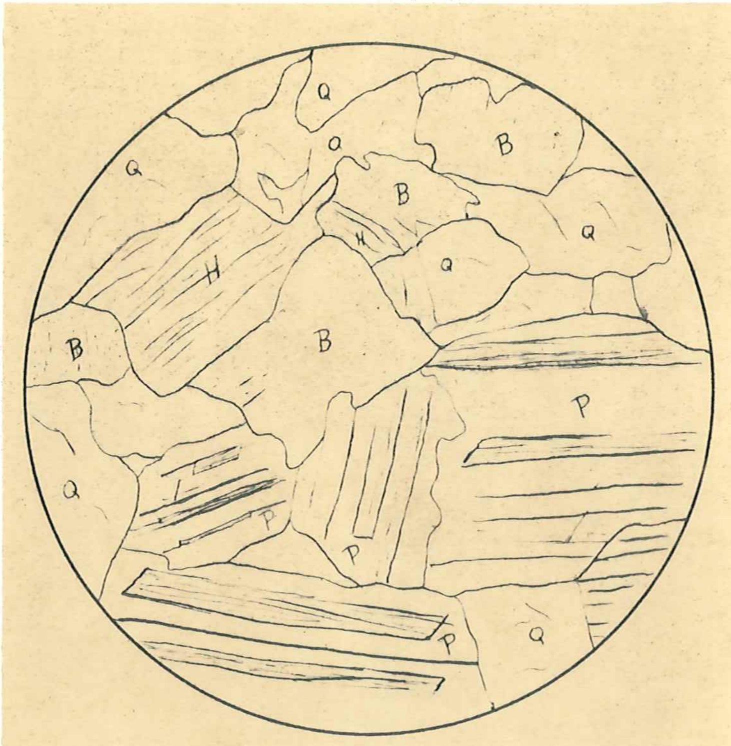

Fig. 8. Tye Soda Granite

Specimen from along the Great Northern Railway near Deception Creek. Composition is approximately 50 per cent plagioclase (P), 10 per cent biotite (B), 5 per cent hornblende (H), and 35 per cent quartz (Q). Note the similarity of Tye Soda Granite to the Mount Stuart granodiorite. Both of these rocks should technically be called diorite.

During the present investigation the author mapped the Deception Creek area and saw the outcrops along the Great Northern Railway, where Smith described the Tye. There is no discernible difference, either megascopically or microscopically, between the Mount Stuart granodiorite and the Tye soda granite. The Deception Pass fault runs through the region and nicely separates the Mount Stuart on the east side of the fault from the Tye on the west. The two granodiorite masses are probably one and the same unit. However, the writer believes the fault contact is a satisfactory although somewhat arbitrary dividing line. Until the surrounding areas to the north are mapped and regional petrographic and structural studies are made, the Tye-Mount Stuart problem cannot be definitely solved.

Along with the probable correlation of the Mount Stuart granodiorite with the Tye soda granite is the correlation of the Mount Stuart with the Index granodiorite and possibly even the Snoqualmie granodiorite. The Index granodiorite is described by Charles Weaver (1912) as a uniform light gray, holocrystalline, medium-grained, dense rock. The rock is composed of 40 per cent plagioclase (Ab_{60} An_{40}), 10 per cent orthoclase, 30 per cent hornblende and biotite, and 20 per cent quartz. This description is identical with the Mount Stuart granodiorite and was recognized as practically identical by Weaver, who says:

> "It resembles very closely the Mount Stuart granodiorite on the eastern side of the Cascade Mountains but in this report will be designated as the Index granodiorite."
>
> (Page 35)

Further in the same report, Weaver states:

> "This same formation is widely distributed through the Cascade Mountains, where it forms a prominent part of the surface outcrop in the vicinity of Mount Stuart, and from there northward to the British Columbia border."
>
> (Page 38)

The Snoqualmie granodiorite has not been seen by the author, but according to Warren Smith's map (1915) it should lie just west of the map area. However, from the detailed petrographic description of both George Smith, who named the formation (1906), and Warren Smith (1915), there seems little doubt that petrographically speaking the Snoqualmie and Mount Stuart granodiorites are the same. On the evidence that Snoqualmie intrudes post-Mount Stuart formations, they have always been separated. Thus George Smith, whose evidence later writers have all followed, states: "This relation excludes a correlation (of the Mount Stuart) with the Snoqualmie granodiorite which is Miocene or Post Miocene."

From the above discussion, it is clear that a great deal of work needs to be done on the granitic bodies in the Mount Stuart region.

Age

The Mount Stuart granodiorite cannot be dated directly. In the case of the Mount Stuart, even the indirect evidence is poor. The basic facts were summed up by George Smith (1906) as follows:

> "The granodiorite of the mass from which Mount Stuart is carved is intrusive in all the other pre Tertiary formations and is overlain by Eocene. ...clearly intrusive into the Hawkins greenstone and in the peridotite and overlain at the eastern base of Goat Mountain by the Swauk formation of Eocene age."

Assuming that the peridotite is the same age as the metamorphics, then the age of the Mount Stuart would be post-Carboniferous - pre-Swauk. However, the peridotite is generally considered to intrude the metamorphic formations and to postdate the metamorphism, although this relationship has been questioned. Thus the age of the Mount Stuart granodiorite can only be placed as post-peridotite pre-Swauk or post-Upper Paleozoic and pre-early Cenozoic.

One of the few workers since Smith to give any thought to the age relations of the Mount Stuart is Leupher, and he strongly doubted the pre-Swauk age relation, as follows:

> "Thus the evidence that the granodiorite constituted a part of the pre-iron (Cle Elum beds at the base of the Swauk-Eocene) terraine in the Mount Stuart region is indirect and unconvincing when based only upon direct contact relations, and as noted on a later page, the lithologic evidence furnished by the Cle Elum and Swauk sediments is also unsatisfactory."
>
> (Leupher, 1949)

Swauk Formation

Extent

The rocks in the investigated area include an occurrence of the massive arkosic sediments known as the Swauk formation. These massive continental deposits were first described by George Smith (1904) from the type area on Swauk Creek south of Mount Stuart. Later workers mapped the formation in the Snoqualmie quadrangle (Smith, 1906), northeastward into the Wenatchee quadrangle (Chappell, 1936), and into the Chiwaukum quadrangle (Willis, 1953).

In the area of this report the Swauk sediments were found to cover most of the region west of the Deception Pass fault. The massive Keechelus volcanic pile, constituting Mount Daniel, separates the Swauk into two separate occurrences — north and south of the mountain. The Swauk north of Mount Daniel is bordered on the east by the Deception Pass fault, separating it from the Mount Stuart granodiorite. On the north the Swauk is bounded by the Tye soda granite and older metamorphic rocks (W. Smith, 1915). The only other observed Swauk contact is on the north and south slopes of Mount Daniel where complex relations with the Keechelus volcanics were noted.

Structure

The structure of the sediments is rather simple in the thesis area. The beds are very massive with no distinctive marker beds. As a whole, the beds strike between north 15 west to north 40 west. The dip is consistently about 35 to 50 southwest. In the area under consideration there is no indication of folding or unconformities. At least 7,000 feet of section are exposed just north of Mount Daniel, and there is no indication of either a top or bottom to the sequence. There is also no observable difference between the structure north and south of Mount Daniel, and the indications are that the structure would be continuous if the Keechelus volcanics had not intervened.

Lithology

In the area west of Deception Pass fault, the sediments vary from almost pure sandstone to shale to conglomerate. The lower part of the section contains considerable conglomerate. The pebbles are well water-rounded and range up to three or four inches in length. The conglomerate is highly indurated and rather poorly sorted as to size. Black slate constitutes about 50 per cent of the pebbles with the remainder mostly quartz, chert, and schist fragments. South of Mount Daniel the composition includes a small percentage of granitic and felsitic pebbles. The conglomerate beds are thin but seem to be rather continuous.

Seventy per cent of the Swauk section is light gray, coarse-grained, massive, poorly bedded sandstone. The sandstone becomes more massive and homogeneous as one goes higher in the section. North of Marmot Lake several thousand feet of homogeneous sandstone are exposed with no distinctive breaks in lithology. A typical hand specimen is a light gray, hard, well indurated, equigranular, speckled, clastic rock. It is composed of quartz, feldspar, and dark specks of slate and mica. The mica and slate fragments lie in the plane of bedding and constitute the only feature on which an attitude can be taken.

Microscopically, the sandstone consists of 90 to 95 per cent angular, clastic, well sorted quartz grains. The quartz is held in a matrix of clay, carbonaceous matter, and iron oxide. All gradations from sandstone to arkose were noted. A specimen picked up near Marmot Lake consists of approximately 25 per cent angular quartz fragments, 5 per cent schist fragments, 10 per cent long phyllite fragments, 5 per cent biotite, and 55 per cent feldspar. The biotite fragments are coarse, elongated crystals that have been noticeably crushed between the irregular clastic quartz and feldspar grains. The feldspar is highly clouded with sericite.

A typical shale specimen will usually show a layering of clay and silt sizes, but often a sample will have a large per cent of fine-grained material with a heterogeneous admixture of sand grains.

On the north slope of Mount Sawyer, a 200-foot section consists of one or two inches clastic fragments of granitic rock. The fragments are irregular and angular and seem to be dispersed in a matrix of quartz, feldspar, and biotite grains of the same type as those found in the rock fragments. The rock fragments cannot be distinguished from the Mount Stuart

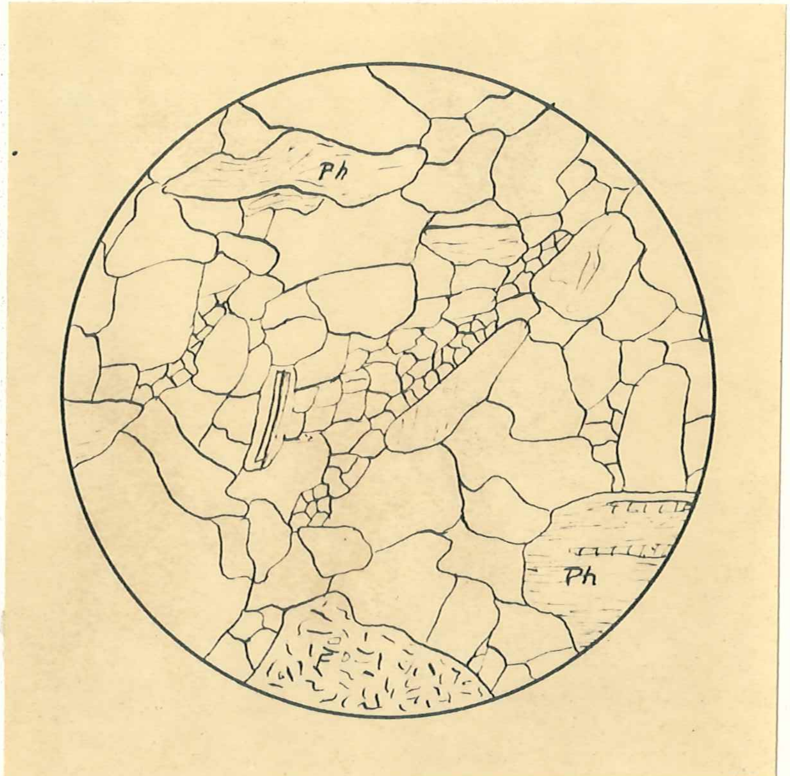

Fig. 9. Swauk Sandstone

A typical specimen of Swauk sediment showing small, rounded fragments of phyllite (Ph), felsite (F), and minor amounts of biotite, feldspar, and clay in a quartz sandstone. The high induration and poor sorting is shown. This specimen was collected near Deception Pass.

granodiorite and undoubtedly were derived from the Mount Stuart or Tye soda granite masses. The many granitic fragments indicate depositional conditions of rapid fill and a short transportation distance.

Age

The Swauk formation is the only unit in the area that can be dated with reasonable accuracy. The basis of dating is the fossil leaves which occur in local abundance in the shale layers. A collection of leaves found near Liberty, south of Mount Stuart, was studied by Knowland, who placed them in the Eocene (Paleocene) (George Smith, 1904). However, recent regional considerations indicate a probable correlation of the Swauk formation with the Chuckanut formation of northern Washington. Marine fossils indicate a late Cretaceous age for the Chuckanut. Thus there is the probability that the Swauk sediments may transgress considerable time — from Cretaceous through early Tertiary. They probably represent the continental equivalent of early Tertiary marine formations in the Puget trough.

Keechelus Volcanics

Extent

A great mass of volcanic material forms the vertical cliffs and towering spires in the vicinity of Mount Daniel. These volcanics are the western extension of the Keechelus andesite, first described by George Smith in the Snoqualmie Folio (1906).

On their east side the volcanics are bounded by the Mount Stuart granodiorite along the fault contact of the Deception Pass fault. The volcanics are bounded by the same fault from the head of Deception Creek, over

Deception Pass, to the south end of Hyas Lake — a distance of about five miles. The contact south of Mount Daniel is with Swauk sediments, in part gradational and in part apparently intrusive. It is well exposed in the cliffs near the outlet of Hyas Lake, and hence southwest over the Cle Elum River-Deep Creek ridge. North of Mount Daniel the volcanics are also bounded by Swauk sediments. The contact is indefinite, but in general it trends northwest from Deception Pass through Marmot Lake.

Warren Smith (1915) and the Washington State geologic map represent Mount Daniel as composed of Snoqualmie granodiorite, but on the eastern slopes the writer could find no indication of granodiorite.

Structure

In spite of the beautiful exposures of volcanics on Mount Daniel, practically no structure could be determined. Each specimen picked up seems to differ from every other one. In the field it is difficult to determine whether one is dealing with massive tuff, flows, or breccias. In places every gradation exists between the massive, structureless volcanics and massive bedded sediments.

From a distance, a fairly definite trend can be seen in tree lines, outcrop patterns, and color patterns which indicate that the over-all structure of the volcanics conforms with the attitude of the Swauk sediments to the north and south of Mount Daniel.

In the sandstone cliffs on the west side of Deception Pass, there is a 20-foot layer of greenish, fine-grained, massive porphyritic andesite, lensing out to the north and apparently intruded as a sill.

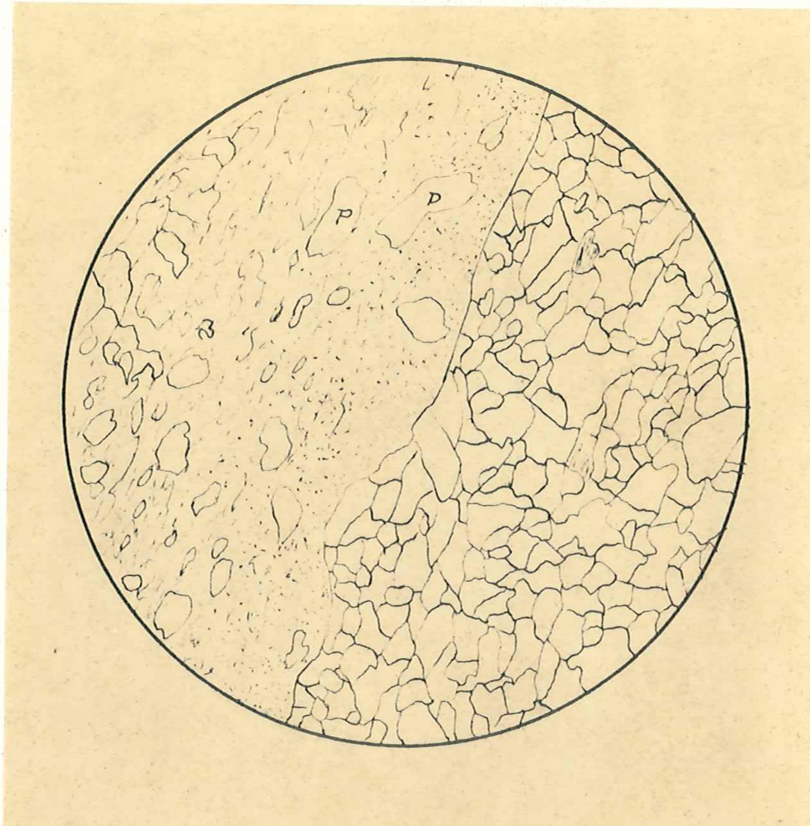

Fig. 10. <u>Contact of Swauk Sandstone with Keechelus Volcanics</u>

The sandstone is a light gray, well sorted, highly indurated, quartz sandstone with only a few feldspar and phyllite grains. The volcanic material represents a sill of andesite 20 feet thick. Irregular phenocrysts of andesine (P) in a fine-grained ground mass with a very fine-grained, cooled contact zone can be seen.

Cathedral rock is composed of massive dark, brown-gray, porphyritic basaltic rock with phenocrysts of white feldspar and a dark ground mass of fine-grained plagioclase and pyroxene crystals. On first glance, this pinnacle gives the impression of a volcanic neck. This resistant, homogeneous mass of volcanic rock might represent a conduct of some kind, but it is more probable that Cathedral rock is only a spectacular erosional remnant.

Petrography

The volcanics are a mass of altered tuffs, agglomerates, and intercalated flows. By far the greatest number of studied specimens consist of fragmental rock. The fragments are angular pieces of altered volcanic rock up to four or five inches across. Under a microscope it can be seen that much of the finer-grained material is also fragmental. Angular grains of very cloudy plagioclase, which is so turbid and altered to sericite and kaolinite that it can barely be determined, are numerous. Many angular quartz grains are present, especially near the contacts with Swauk sediments, and zircon also occurs. Chlorite, epidote, and angular calcite occur in most specimens as relatively large, irregular masses. These probably represent, along with the larger flakes of magnetite and hematite, the altered remnants of less stable fragments.

The ground mass and specimens with no fragments consist of a cloudy mass of magnetite, kaolin devitrified glass, and ash.

Several samples of porphyritic andesite were collected. The phenocrysts are glassy, striated feldspar with an albite twin extinction angle (measured perpendicular to 010) of 20° to 27°, making them andesine. Augite and hypersthene form the principal mafic minerals. Some chlorite and

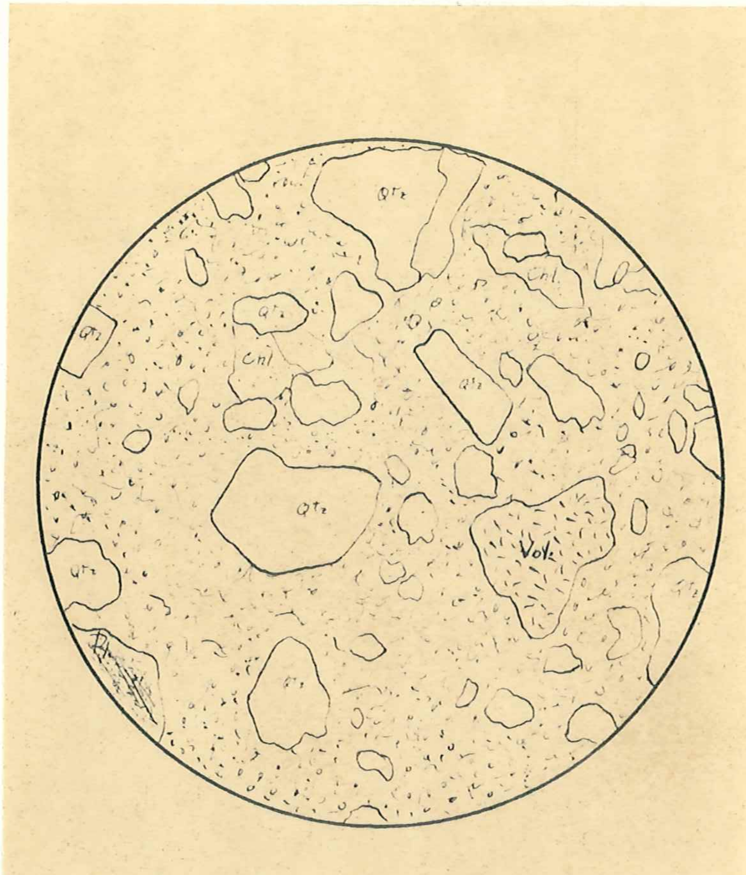

Fig. 11. Keechelus Pyroclastic Rock

A typical specimen of Keechelus type rock collected near Hyas Lake. Fragments of angular quartz (Qtz), volcanic material (Vol), cloudy feldspar (Pl), and chlorite (Chl) can be seen in a speckled, cloudy matrix of ash and glass. This probably represents the same rocks that Abbot (1953) called Richmond Breccia.

magnetite are also present. Sixty to 70 per cent of the rock is a matrix of small plagioclase laths and cloudy specks.

Relation to the Swauk

The relation of the Keechelus volcanics to the Swauk sediments is not clear. In the exposures along Marmot Lake there seems to be a complete gradation from sandstone into the volcanics. The north side of the lake is massive bedded arkosic sandstone. The south side is massive, apparently structureless volcanics. The rock is exposed along the shore and follows the strike of the sediments, and nowhere is there any observable demarcation between the two formations.

At the southern contact of the volcanic body with Swauk sediments, the relations are different. In tracing along the strike of a Swauk sedimentary bed, one suddenly comes to a place where it has been cut off by a sheared and baked intrusive contact. Areally the contact cuts up ridges and down valleys in a very irregular way, controlled largely by the bedding of the Swauk.

A different aspect of the problem is the occurrence of interbedded fragmental Keechelus tuffs and Swauk sediments in the vicinity of Deception Pass. A similar line of evidence is the wide occurrence of fragmental volcanic rocks near Hyas Lake and at the east base of Mount Daniel. The only logical way in which these fragmental rocks could be deposited is as surface layers before the great masses of Keechelus volcanics and Swauk sediments, which are higher in the section, were deposited.

In the area studied, much of the Keechelus volcanic sequence was apparently deposited as tuffs and flow breccias in the same depositional environment and contemporaneous with at least part of the Swauk sediments.

However, the volcanism lasted longer than the sediment deposition, and volcanic rock was intruded into both older Keechelus fragmental rocks and Swauk sediments. This is demonstrated in the intrusive contacts south of Mount Daniel and in such volcanic features as Cathedral rock.

Age

The Keechelus formation was first described by Smith and Calkins in the Snoqualmie Folio (Smith, 1906). The age was determined as Miocene because the volcanics unconformably overlie sediments determined as Eocene on paleobotanical evidence (Smith, 1906).

W. Smith extended the Keechelus north into parts of the Skykomish basin. Concerning the age of these rocks, he says: "It is only fair to say that as far as the Skykomish basin is concerned, the Keechelus series might have begun its formation in the Oligocene" (Smith, 1915).

Warren (1941) separated the Fifes Peak andesite as a distinct unit from the lower Keechelus. He dropped the lower Keechelus to a probable Oligocene age upon reexamining the paleobotanical evidence and on determining that it was older than the Yakima basalt. Recently a vertebrate fossil of Oligocene age has been found right in the Keechelus (Grant, 1941).

In his thesis, Abbot (1953) has divided the lower Keechelus into four units — the Cougar Creek, the Morse Creek andesite, the Richmond Breccia, and the Mount Aix andesite. The Richmond Breccia is described as the thickest member, composed of indurated fragmental rocks and flows, distinctive greenish tinge, cliff former, not a single structural feature except jointing, and again, a directionless pile of volcanic breccia and flows. The above comments fit the volcanics of Mount Daniel very well, and it may be well to denote them as Richmond Breccia, insofar as Abbot's division of the Keechelus is valid.

In the description of andesite flows interbedded in the sediments (Weaver, 1912), we see probable contemporaneous deposition with massive sediments. In this light G. Smith (1903) says: "In their larger exposures the tuffs and lavas display distinct bedding and some of the finer layers show the effect of water sorting and resemble ordinary shale or sandstone."

The Keechelus volcanics are a far more complex rock unit than the original description of Smith (1906) would imply. In the broad sense, the volcanics probably transgress considerable time. The writer believes that at least part of the Keechelus volcanics in the Mount Daniel region are contemporaneous with Swauk sediments and therefore Eocene (Paleocene) in age. However, this does not mean that the volcanics have not transgressed time and that the great mass of Keechelus overlies and is younger than the Swauk sediments.

Dikes

Numerous dikes were noted during the course of the field investigation. No special study was made of the dikes; however, some broad generalities should be noted. The dikes are of three distinct types: 1) intermediate dikes cutting the ultrabasic bodies and apparently directly connected with the Mount Stuart granodiorite; 2) a group of large basic dikes cutting the Mount Stuart granodiorite in the vicinity of Granite Mountain; and 3) small, scattered, dark-colored dikes cutting the Mount Stuart granodiorite.

Intermediate Dikes

On the crest of the ridge between the Cle Elum valley and French Creek, several three- to ten-foot wide intermediate dikes are well exposed for a length of several thousand feet. In the field they appear as light gray, fine-grained porphyritic bands that are in sharp contact with the dark greenish-black ultrabasic rock that surrounds them. Under the microscope a typical specimen was found to contain 40 per cent fine-grained laths of feldspar, 30 per cent fine-grained bundles of acicular actinolite crystals, and the remainder a fine-grained matrix of cloudy material containing small magnetite grains.

Andesite

The most spectacular set of dikes in the area is a swarm of large, dark, green-brown basic dikes cutting across the top of Granite Mountain. These dikes are distinctive in that their color contrasts very sharply with the light gray color of the country rock. The dikes weather out more rapidly than the granodiorite, and the result is that they are often found in trench-like depressions in the granodiorite. The dikes range up to 20 feet in width, strike north 45 to 55 west, and dip moderately southwest. They are distinctly finer-grained near their margins than in the middle.

A typical specimen shows 20 per cent cloudy and altered feldspar, 15 per cent chlorite, 5 per cent carbonate minerals, and 5 per cent iron ore. The remainder of the rock is fine-grained matrix that could not be determined. The feldspar occurs both as large phenocrysts and as small laths and is very much altered to kaolinite and sericite. The large amount of chlorite and other alteration products gives the rock a drab green, clouded appearance very similar to some of the altered Keechelus volcanics. In fact, it is not improbable that these dikes are associated with the nearby Keechelus volcanics.

Dolerite

The third type of dikes in the area is composed of dark gray dolerite. The dikes were found intruding the granodiorite and schist in widely separated occurrences. The maximum width of these steeply dipping dikes is about six inches. All the dikes seem to be offset a few inches along small shears in the granodiorite. Under the microscope the rock is seen to be a holocrystalline, fine-grained, porphyritic dike rock. The phenocrysts are oriented parallel to the contact. The rock is composed of about 80 per cent plagioclase (andesine) and 20 per cent hornblende. Phenocrysts form about 10 per cent of the rock with the remainder a mass of subhedral grains of feldspar and hornblende.

Dacite (Rhyolite)

A small flow of dacite was found in the timbered valley of Pablo Creek on Blackjack Ridge. The only reason this outcrop was found at all was because the writer was lost and blundered into it while looking for the trail.

The outcrop consists of light gray-brown, hard, porphyritic volcanic rock. The badly fractured nature of the outcrop made it difficult to obtain a good sample, and no well defined structure, except a crude, thin sheeting parallel to the surface, could be determined.

Under the microscope the rock is a holocrystalline, porphyritic dacite. The phenocrysts consist of subhedral, partly resorbed plagioclase laths up to 2 mm in length. Because of the high degree of sericitization, no good plagioclase determination was obtainable. Quartz occurs as irregular, anhedral grains of varying sizes. Small laths of altered hornblende constitute about 10 per cent of the rock. The ground mass consists of a cryptocrystalline aggregate of quartz and feldspar with scattered small dark spherulites.

George Smith (1904) has described several small rhyolite patches in the Mount Stuart Folio. He remarks that both compact lava and tuff were found, and he has assigned them to the Pliocene on very doubtful evidence. This patch may be similar in age and origin to those described by Smith.

STRUCTURE

Deception Pass Fault

Of major significance in the interpretation of the region is a great fault that forms the west boundary of the Mount Stuart granodiorite mass. On the crest of Deception Pass, between the valley of the Cle Elum River and Deception Creek, five hundred feet east of the main trail, there is a deep canyon. The canyon is perhaps a half mile in length. Its lower or northern end merges with the main valley of Deception Creek. Its upper end is a vertical wall of breccia and bands of gouge. A small stream coming down from Granite Mountain has eroded the canyon in a fault zone. The canyon floor is a heterogeneous mass of boulders, stones, and blocks, mostly of small size. The canyon walls, for the most part, are a reddish-brown, dirty-looking fault breccia. Much of the rock in the fault zone is sheared and has a dark gray, schistose appearance. Many boulders in the canyon bottom, however, are light red-brown, very quartzose and hard. All evidence on the crest of Deception Pass points to a great fault zone. The term Deception Pass Fault is proposed for this fault and has been used in this paper.

North of the canyon the fault passes down the bed of Deception Creek. The stream valley is several hundred feet broad and is filled with a heterogeneous assortment of rather small-sized, rounded boulders and stones. In two places massive cliffs of gray, medium-grained granitic rock (Mount Stuart) are exposed on the east side of the stream. On the west side of the stream a few poor outcrops of Swauk conglomerate and sandstone are exposed. These

Swauk outcrops show no discernible structure but instead display a broken and dirty appearance caused by faulting. Progressing downstream, the sharp break between granodiorite and schist, on the east side, and sediments, on the west, indicates the fault trace along Deception Creek. About a mile below the Deception Creek-Tonga Ridge trail junction the fault evidence disappears. The unfaulted condition of the stream bed can be seen where Deception Creek passes under the Stevens Pass highway bridge. The Swauk-granodiorite contact on the mountain sides west of Lower Deception Creek could not be found by the author because of the dense forests. However, W. Smith (1915) mapped an angular bend in the contact trace which suggests a contact other than high angled faulting.

Along the new power line road just south of Scenic and where the Great Northern Railway takes the bend to enter the Cascade Tunnel, several hundred feet of brecciated rock with minor, one- or two-inch bands of gouge can be seen. This fault zone dips steeply west (85° ±) and strikes roughly north 10 to 20 east. It heads directly into the ridge between Deception and Surprise Creeks, where a large gully marks the trace of the fault for several hundred feet.

Thus we have evidence of large-scale faulting on Deception Creek and the power line road. The two faults strike roughly the same, dip about the same, and look the same; and both were lost toward each other. Therefore, it seems logical to connect them across the Surprise Creek-Deception Creek ridge, a distance of approximately three miles.

South of Deception Pass no direct evidence of faulting, such as breccia and gouge zones, was found. The Cle Elum valley is glaciated and filled with Quaternary alluvium, as mapped by Smith (1906), and a fault was placed along the west side of the alluvium. The Deception Pass fault has been extended by the writer southward and across the valley, and connected with Smith's fault as mapped in the Snoqualmie quadrangle.

Several lines of evidence indicate faulting in the Cle Elum valley. The best evidence is lithologic. On the east side of the valley a massive, undissected ridge of Mount Stuart granodiorite and ultrabasic rock rises steeply with 3,000 feet of relief. Mount Daniel, composed of massive volcanics (Keechelus), and Goat Mountain, made of westward dipping sediments (Swauk), rise 4,000 feet above the west side of the valley. A fault contact is the only logical way to place these massive westward dipping volcanics and sediments against the massive plutonic rocks to the east. The steepness of the valley sides — especially at the base of Goat Mountain — may be partially due to fault control.

The kind and magnitude of the faulting is uncertain. Measurements taken on the dip of the fault gouge and the appearance of the breccia zone indicate a westward dip of 70 to 90 degrees. The very straight and regular surface trace of the fault over very rough terrain is also an indication of high angle displacement. It seems logical to interpret this dip as indicating a high angle normal fault separating the relatively older schists, granitics, and ultrabasics upthrown to the east, and the relatively younger volcanics and sediments downthrown to the west. In the Upper Deception Creek drainage area the massive sediments, dipping away from the fault, have a stratigraphic thickness of at least 7,000 feet. Extending the Swauk sediments over the granodiorite to the east and assuming an average fault dip of 80 degrees, a minimum throw of 6,860 feet is obtained. This figure is probably far short of the actual throw because no indication of the top or bottom of the sediments was found, and an undetermined amount of granodiorite has been eroded off. George Smith (1906) has no discussion of the fault where he mapped it in the Snoqualmie Folio. However, Leupher (1944) was probably referring to the same fault when he stated:

> "One major fault is located one and three fourths miles east of the Cle Elum River where the strata striking regularly eastward and dipping gently southward, end abruptly on the east against peridotite. The relations are very much obscured by dense timber and landslides, but the distribution of occasional peridotite and nickel ledge outcrops indicates that the continuation of the Cle Elum beds east of the fault has been offset 2,000 feet to the south. The relative values of horizontal and vertical components are unknown."

The time of faulting is probably late Tertiary (or post-Keechelus). It predates the latest phase of glaciation. The gouge and breccia zones are uncemented and seem fresh.

Minor Faults

Several other faults should be mentioned. Below Cathedral rock a zone of dirty red, oxidized and brecciated rock strikes north 5 east and dips northwest. A sizable gully, heading northeast toward Hyas Lake, has been gouged out along the fault. The fault could be due to the adjustment of rock to the Deception Pass faulting, but it seems to have no profound significance.

Another small fault zone was noticed crossing the first major tributary of Deception Creek as one goes upstream from the mouth.

ECONOMIC DEPOSITS

The area around Mount Stuart was the scene of a great influx of gold seekers during the latter part of the last century. Gold placers were discovered along Peshastin Creek, south of Mount Stuart, in 1860 and on Swauk Creek in 1868. Later vein deposits were opened up in the same area and west of the Cascade crest in the Skykomish basin (W. Smith, 1915) and the Index district (Weaver, 1911). In the days of the great gold rushes the region was much more densely populated than now, and many millions of dollars worth of values were taken from the earth (Smith, 1904).

The area of this investigation has only a few abandoned prospect tunnels reminiscent of past activity. Near the top of Paddy Go Easy Pass a few prospect holes are evidence of the bygone days of the gold seeker. One adit was found which was driven into solid black serpentine at the base of a vertical peak. The adit went in for several hundred feet and apparently the prospector was trying to intersect an acidic dike that can be seen high on the peak.

Several other prospect holes, now caved in, were also found nearby. On the crest of Paddy Go Easy Pass, an area of white quartz veinlets was noted. Several prospect holes and a small incline shaft were sunk to explore the veinlets, but everything is now caved. However, several six-inch chunks of nearly pure tetrahedrite had been set aside at one of the dumps to attest the presence of mineralization. The U. S. Geological Survey topographic map shows two mines in this area, and it seems reasonable to assume the mines were actively worked around 1902 when the survey was made.

At the head of French Creek three abandoned cabins are still standing. These cabins were part of a program to develop a small quartz vein on the western side of Paddy Go Easy Pass. The vein seems to follow a small fault zone in massive peridotite and fine-grained acidic rock. It strikes east-west and dips 65° north and is a foot wide. The vein is composed of coarse-grained comb quartz and seems to be a typical hydrothermal deposit. Other than a few specks of pyrite, no mineralization was observed.

SUMMARY

In conclusion, it must be realised that the investigation entailed no specific problem other than the general areal distribution of the formations in the area and their contact relations.

Two major contributions resulted from this investigation: 1) this previously unknown area was mapped geologically and the contact relations of the major units were investigated; 2) a major fault was found to border the west side of the Mount Stuart granodiorite mass. This fault, of at least 7,000 feet throw, was named the Deception Pass fault.

Several major problems were encountered. The relationship between the Keechelus volcanics and the Swauk sediments is apparently far more complex, at least in detail, than the simple stratigraphic sequence presented in the Snoqualmie Folio (G. Smith, 1906). In fact, the tremendous thicknesses and great lithologic variety in the Swauk and Keechelus, as individual units, indicates that years of work will be required to understand fully their complexities. Another problem, in which much fundamental work needs to be done, is the problem of the origin of the peridotite. It seems very doubtful that many of the observed facts concerning the peridotite in the area can be fitted into conventional magmatic theories of origin.

The ultimate goal of most areal geologic work is a reconstruction of the sequence of events which have produced the present geology of an area. A resume of the events in the area under consideration is as follows: 1) A great thickness of impure sandstone and similar sediments was laid down in a geosynclinal type of environment during Carboniferous(?) times. 2) These sediments were later regionally metamorphosed and changed into the schists and phyllites of the present metamorphic complex. At some time after the end of metamorphism, peridotite was inplaced into the older rocks. 3) The next major event was the inplacement of the Mount Stuart granodiorite mass, which is younger than the peridotite but older than the Tertiary volcanic and sedimentary rock units. 4) Derived from highland sources, a great sequence of arkosic and shaly sediments — the Swauk, Puget, and similar formations — was laid down during a period of continued tectonic activity, probably during late Cretaceous and early Eocene times.

5) At the time of sedimentation volcanic activity first occurred. Similar volcanic activity continued until late Tertiary time and has produced the massive Keechelus andesite and similar volcanic formations. 6) Continued deformation tilted and folded the Keechelus volcanics and Swauk sediments along northwest-bearing structural axes. 7) Extensive erosion followed during middle Tertiary times. 8) Recent general uplift of the Cascades superposed a north-south trend across the older northwest-southeast structural axes. This last phase of activity is probably still going on. 9) Alpine glaciation of the high regions, combined with normal stream erosion, produced the details of topographic expression so characteristic of the present Cascade Mountains.

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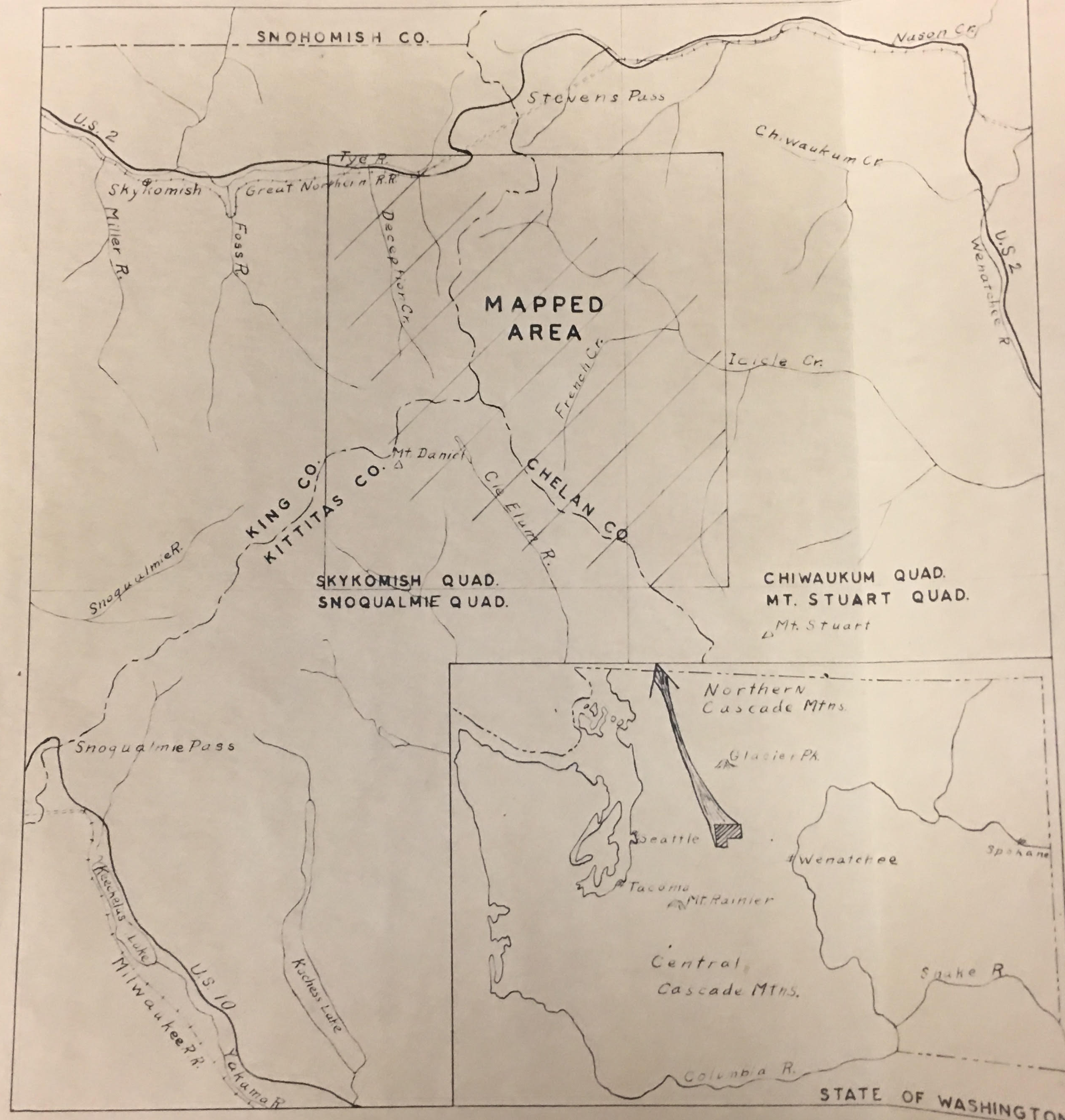

Fig. 1. INDEX MAP SHOWING THE LOCATION OF THE INVESTIGATION