GEOLOGY OF THE MILLER-FOSS RIVER AREA,

KING COUNTY, WASHINGTON

by

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EOLOGY OF THE MILLER-FOSS RIVER AREA, KING COUNTY, WASHINGTON
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The following conclusions present a brief summary of this report:

1. There is no evidence to indicate that the Chiwaukum schist is older than the Stilliguamish series. The two units are not in contact and are largely of different lithologies, thus the degree of metamorphism seems to be rather unsatisfactory basis for the determination of their relative age. The Chiwaukum schist is pre-Mt. Stuart in age.

2. The problem of the age of the Stillaguamish series is debatable. Smith (1916) suggests an Ordivician age. Danner suggests an Permian age. The only evidence available in the area mapped is that these rocks are pre-Tertiary inage.

ABSTRACT

The basement rocks of the Miller-Foss River area in the west-central Cascade Range of Washington include two widely separated and lithologically distinct metamorphic units; the Stillaguamish series of Permian age or older and the Chiwaukum schist of unknown age. In Mesozoic time the Mount Stuart granodiorite was intruded into the Chiwaukum schist. The lack of Mount Stuart dikes cutting the Swauk and the occurrence of Mount Stuart boulders in the basal Swauk conglomerate is given as evidence of the pre-Swauk age of the granodiorite.

At least 10,000 feet of late Cretaceous and/or earliest Tertiary arkoses, conglomerates and shales make up the Swauk formation in this area. Somewhat confusing relations in the vicinity of Maloney Creek appear to indicate that vulcanism to the west was contemporaneous with the closing stages of Swauk deposition. These early Tertiary sediments and volcanics rest with strong unconformity on the metamorphic and granitic basement.

About one-third of the mapped area is occupied by the Tertiary Snoqualmie granodiorite which post-dates all other rock units in this area.

TABLE OF CONTENTS

Page

ACKNOWLEDGEMENT

The writer is deeply indebted to Dr. Howard A. Coombs of the University of Washington Geology Department who suggested the problem, supervised the preparation of the thesis and critically read the manuscript. Acknowledgement is also rendered to Mr. Wilbert R. Danner of the University of British Columbia for his advice and suggestions during both field investigation and writing phases of this work. The writer wishes to thank the staff at the Skykomish Ranger Station for their many courtesies and suggestions during the time the writer was in the field. Grateful acknowledgement is also given to the writers' wife, Marilyn, without whose constant aid and encouragement this work would not have been realized.

GEOLOGY OF THE MILLER-FOSS RIVER AREA, KING COUNTY, WASHINGTON

INTRODUCTION

GENERAL STATEMENT

The region encompassing the watersheds of the Miller and Foss Rivers occupies a critical place on the geologic map of Washington. The rock units exposed in this area help to provide a geologic "link" between the pre-Cenezoic rocks of the northern Cascade Mountains and the Cenozoic rocks of the southern part of the range.

PURPOSE

Geologic study of the Cascade Range began during the late 1800's and has continued intermittently to the present time. More recent work has brought to light some interesting and sometimes conflicting relationships between rock units described by earlier workers. The Miller-Foss area, while not a geological unknown at the outset of this investigation, was never the less thought to deserve restudy due to its' critical location with respect to Cascade geology.

The purpose of this investigation was two-fold: First; to map the areal geology, and second; to study the relationships between the several formations.

The problem was therefore primarily one of field relations.

GEOGRAPHICAL SETTING

Location and access: The area mapped during this investigation lies only a few miles west of the Cascade divide near the geographical center of the State of Washington and the northeastern corner of King County(Plate I). It occupies slightly less than one-hundred square miles immediately south of the Skykomish (South Fork) and Tye rivers. The only settlement in the area is the small town of Skykomish which lies (by road) sixty-eight miles east of Seattle and seventy-six miles west of Wenatchee. A cross-state highway, U.S. Route #2, traverses the northern boundary of the area, providing direct access to it, and crosses the Cascade Divide through Stevens Pass fifteen miles east of Skykomish.

The main line of the Great Northern Railroad crosses the northern part of the area essentially following the south banks of the Skykomish and Tye rivers.

Access within the area includes a county road along the south bank of the Skykomish River, and the old Mine to Market roads built by the state many years ago up the Miller River and Money Creek. The U.S. Forest Service maintains the lower four miles of the Miller River road and the lower 0.7 mile of the

Money creek road, the upper parts of both being passable only on foot. The four mile long Foss River road was closed for rebuilding operations early in the field season and was not re-opened. A dry weather road follows the south bank of the Tye for about three miles from its' intersection with the Foss road. Logging access roads, in varying states of dilapidation, afford access on foot up the northern end of Maloney Ridge and to points on Temple Mountain.

Forest Service trails provide access to Tonga Ridge and the upper valleys of the Miller and Foss rivers.

Climate: The area receives one-hundred or more inches of precipitation annually, approximately sixty percent of it during the period November through February. Thus, at the higher elevations, over half of the annual precipitation is in the form of snow. About three inches of rain per month falls during July, August and September, mostly in the form of a slow continuous drizzle.

Temperatures are normally mild, ranging between 45 and 70 degrees during the spring, summer and fall, and in the high 20s and lower 30s during the winter months.

Vegetation: Because of heavy precipitation and mild temperatures the vegetation of the area may appropriately be described as a temperate jungle. The valleys are characterized by a dense profusion of vine maple, willow, dogwood, cottonwood, devil's club, alder and salal, to mention a few. Off trail travel in the valleys is therefore extremely difficult. Conifirs are sparse in the valley bottoms, but occur in increasingly larger numbers upward on slopes gentle enough to permit their growth. Most of the forested area is second growth timber, western hemlock and Douglas fir predominating, a thick non-descript undergrowth usually being present.

The heavy vegetative cover described above begins to thin out above the 4500 to 4800 foot elevations. Above 5000 feet are the alpine meadowlands characterized by heather, huckleberry, and many varieties of wild flowers and shrubs along with clumps of alpine fir, mountain hemlock and white bark pine. Only a small percentage of the area mapped during this investigation is meadowland. Economic aspects: Perhaps the greatest economic asset of the area is timber, most of which is being harvested for the second time. A small lumber mill is in operation a short distance west of Skykomish. The town itself, however, is largely supported by railroad activity.

On many a lonely slope are found the ruins of mining activity of a bygone day. At the time of W. S. Smith's work in the area, mining was evidently on the decline from which it never recovered. Historically, the Miller River-Money Creek area was known as the Berlin Mining district (from the now non-existent town of Berlin which was located near the mouth of the Miller River) and flourished during the closing years of the nineteenth century and the first decade of the twentieth. During this period small amounts of ore (mainly silver, lead, antimony and copper) were shipped from the several properties in the area.

Slides and vegetation have obliterated many of the workings, but occasional mine buildings and tailings may be seen along the Miller River and Money Creek and in Coney Basin. Descriptions of the several properties may be found in various publications by the state (Department of Conservation and Development, Division of Mines and Geology) or in the work of W. S. Smith(1915).

GEOLOGIC SETTING

Although the Cascade Range is a single topographic unit, it may be geologically divided into several units. The northern portion of the range consists largely of pre-Cenozoic metamorphic rocks and granitic masses. Coming southward to the central part of the range a gradual change is made into a terrain composed of Tertiary sediments and volcanics overlying a pre-Tertiary metamorphic basement complex. In the area immediately south of Snoqualmie Pass these sediments and volcanics disappear under a thick sequence of later volcanics that make up the southern part of the Cascade

Mountains in the State of Washington.

The Miller-Foss area lies in the northern part of the Central Cascades and, therefore, contains rock units common to both the northern and southern portions of the range. It also occupies a critical place with respect to the deformational history of the region. Although the topographic trend of the Cascade Mountains is north-south, this trend is superposed on an earlier series of broad, northwest-southeast trending folds. One of these broad arches has been termed the Wenatchee uplift (Russell 1899), the Wenatchee Mountains east of the divide being its' topographic expression. Weaver (1912) has given the name Skykomish uplift to the northwestward continuation of this broad arch. It is on the southwest flank of this uplift that the area mapped during this investigation is situated.

METHOD AND PROBLEMS OF INVESTIGATION

The work was initially approached by a reconnaissance mapping of the rock units and the compilation of a general field map at a scale of two inches to the mile. Several reasonably accessable locales were then selected for more detailed study of interformational relationships. The nature of the contacts, the dense vegetative cover, and the precepitous nature of much of the topography made this "selected locale" method desireable and practical.

A total of thirty-one days were spent in field investigation (summer 1954) during which operations were often impeded by bad weather. Over one-hundred specimens were collected for laboratory study and a representative number of thin sections were made and studied by the writer during the fall of 1954 and the spring and summer of 1955.

PREVIOUS INVESTIGATIONS

The miller-Foss area was included in an investigation of the Skykomish Basin conducted by W. S. Smith during the first decade of the twentieth century. This work resulted in the publishing of three papers. The first treated the petrology and economic geology (1915), the second, stratigraphy (1916), and the third, physiography (1917).

Workers in the immediate surrounding area include Weaver (1912), Bethel (1951), Oles (1951), and Pratt (1954). (Plate II).

N

1. SPURR (1900)
2. SMITH, G.O. (1904)
3. SMITH & CALKINS (1906)
4. WEAVER (1911)
5. WEAVER (1912)
6. SMITH, W.S. (1915)
7. WATERS (1930)
8. CHAPPELL (1936)
9. PAGE (1936)
10. LUPHER (1944)
11. WILLIS, C.L. (1950)
12. BETHEL (1951)
13. OLES (1951)
14. PRATT (1954)
15. FOSTER (1955)

MILLER-FOSS AREA

Index to Geologic Mapping in the Central Cascade Mountains Washington

SCALE

3 0 5 10 miles

CHELAN

USGS QUADRANGLES

PLATE II

RWG

PHYSIOGRAPHIC CONSIDERATIONS

GENERAL STATEMENT

Although the purpose of this investigation was a study of the relations between rock units, many observations were made during the course of the field work regarding the origin of the landscape. A discussion of the topography and certain aspects of the geomorphic history is therefore presented.

TOPOGRAPHY, RELIEF AND DRAINAGE

The area mapped during this investigation lies 15 to 20 miles inside the western Cascade mountain front where the ridges and peaks rise sharply several thousand feet above the glacially over-deepened valleys. (Figure I). This is typical of the topography encountered on the western slope of the northern and central Cascade Mountains. The lowest point in the area is the confluence of Money Creek and the Skykomish South Fork (elevation 850 feet) and the highest point is the summit of Bald Eagle (elevation 6200 feet). Thus the area has over a mile of total relief.

All drainage from the area is effected via the Skykomish South Fork. The Miller and Foss rivers, tributary to the Skykomish, are characterized by high but uneven gradients averaging 100 feet per mile in their lower reaches and increasing to 200

Figure I

Photograph looking south up the valley of the Foss West Fork, showing the extent to which this valley has been overdeepened by glaciation.

or more feet per mile, six miles upstream from their respective concordant confluences with the Skykomish and Tye rivers. Because of their high gradients the Miller and Foss rivers carry loads of considerable caliber. Boulders up to 2½ feet in diameter are seen in their beds during times of low water.

Secondary streams having their origin at or near the ridge crests often enter the main valleys with impressive waterfalls. Noteable of these are Malachite Falls dropping 700 feet just below the lake of the same name, and the falls dropping 200 feet or more on the main drainage from Goat Basin. A few of the secondary streams, however, have eliminated their falls by cutting vertical notches in the main valley walls. Examples of this may be seen along Maloney and Kimball Creeks.

One of the more scenic aspects of the area are the numerous lakes, for the most part occupying cirques or small rock basins at higher elevations. Typical of the cirque lakes are Copper, Malachite, and Fisher lakes. Characteristic tarns are the Jewel Lakes. Exceptions to these lakes lying in depressions of glacial origin are Trout and Alturas lakes which owe their origin to landslide damming.

GLACIATION

Evidence for recent glaciation is seen throughout the area. Even at the present time the Foss East Fork is fed largely by meltwaters from small glaciers in the Hingman area immediately to the southeast. The cross-sectional shape of the Skykomish, Miller, Foss, Tye and Beckler valleys and the common occurrence of erratic boulders in them indicate widespread alpine glaciation of a recent date. Cirques and shallow scoured basins are seen on all the ridges. Most of the cirques lie between elevations of 3000 to 4500 feet. Worthy of note however, is Coney Basin, perhaps the best developed of all the cirques in the area. The polished floor of this basin lies entirely below the 2500 foot contour line.

Several non-continuous deposits of verved clays and silts may be seen in the Money Creek, Foss and Miller valleys. These occur between elevations 1000 and 1200 feet and must post-date the maximum extent of the valley glaciers. The location of these deposits would virtually preclude their preservation during the maximum extent of valley glaciation. These deposits serve as further evidence for the existence of a glacial lake in the Skykomish valley during late Pleistocene time. As proposed by Cary and Carlston (1937), such a lake was caused by damming of the valley just inside the mountain front by Puget ice during Vashon time. They postulate further that the lake level reached an elevation of 1800 feet.

UPLAND SURFACES

Although the valley walls are steep and have considerable local relief the ridge crests themselves are relatively flat. When viewed from a good vantage point the ridge crests suggest a surface of rolling maturity. This surface, lying between elevations 4000 and 5500 may be traced in the field or on the topographic map (U.S.G.S. Skykomish quandrangle) from the high country just west of Fisher Lake, north to Tonga Ridge, westward across the valley of the Foss River to Sobieski Mountain and Maloney Ridge, thence across the Miller River valley to Cleveland and Lennox mountains.

This surface is interpreted by the writer as a westward extention of the Entiat surface as proposed by Bailey Willis (1903). To the writers' knowledge this is the first attempt to extend Willis' terminology west of the Cascade divide. Pratt (1954) has traced this surface from the type locality in the Wenatchee-Chelan area to the region immediately east of the Miller-Foss area.

Rising 500 to 1000 feet above this surface, especially in the southern part of the mapped area, are matterhorn-like peaks, and to the south all traces of a mature upland surface are lost. Pratt (1954) also noted this southward disappearance of the Entiat surface.

STAGE OF REGIONAL DEVELOPMENT

The development of the mature Entiat surface was followed by several thousand feet of uplift, resulting in canyon cutting and the disection of the mature surface. This youthful stage was interrupted by occupation and modification of the valleys by glaciers. Following the wasting of valley ice the youthful stage was resumed, resulting in the present composite landscape.

THE ROCK UNITS

GENERAL STATEMENT

The oldest rocks in the area are two widely separated, distinctive metamorphic units; the Stillaguamish series and the Chiwaukum schist. Unconformably overlying these rocks are the Tertiary sediments and volcanics of the Swauk formation, the Temple Mountain andesite and the Lookout breccias. Two of the most extensive of the Cascade granitic masses are represented in the area; the pre-Tertiary Mount Stuart granodiorite and the Tertiary, Snoqualmie granodiorite.

These units will be discussed in the above order.

STILLAGUAMISH SERIES

Occurrence: Perhaps the oldest unit represented in this area is also the least extensive. It occupies less than two square miles on and near the top of the ridge separating Goat Basin and Kimball Creek valley near the northwestern corner of the mapped area. These limited exposures represent only the southern tip of a narrow belt of rocks extending one-hundred or more miles northward. These rocks have recently been mapped by Danner (oral communication) who has suggested the name Stillaguamish series for the exposures in the valley by that name.

These metamorphic rocks are poorly exposed in the Miller

Foss area. The best outcrops are seen in a vertical cliff on the south side of Money Creek a short distance east of the entrance to Goat Basin. A few badly weathered outcrops may be found on the top of the ridge to the south. Limited exposures occur in the bed of Kimball Creek just upstream from its' confluence with Money Creek, and nearby in the bed of the latter.

Description: A variety of rock types are found in this unit, but the distribution and relations of each are masked in this area by vegetation. The series consists primarily of banded quartzites, actinolite and chlorite schists, several small lenses of limestone, breccias and basic igneous rocks.

The quartzites show irregular banding in hand specimen, but no banding is apparent in thin section. It is composed almost entirely of subhedral to anhedral quartz grains with anastomosing veinlets of larger quartz and epidote. (Figure 2). The rock usually has a light blue-gray tinge.

The schists are always extemely crumpled and commonly consist of tremolite-actinolite or a high percentage of chlorite. (Figure 3). A considerable amount of magnetite and ilmenite is found in all the schists. At one outcrop the writers' compass went completely erratic when an attempt was made to take the strike of the foliation. Other minerals usually occurring in the schists are quartz and orthoclase, both commonly showing undulating

Figure 2

Stillaguamish series- quartzite. Photomicrograph of specimen from the south wall of Money Creek valley, east of Goat Basin (Xnicols).

Figure 3

Stillaguamish series-actinolite-tremolite schist.
Photomicrograph of specimen from lower Kimball Creek (plane light).

and incomplete extinction.

The limestone might well be classed as a low grade marble. A typical specimen is light gray-blue in color, mottled, often containing cherty impurities which cause the rock to have a rough surface when weathered. Minute crystals of pyrite are common.

Associated with the above rocks along the west side of the outcrop belt is a gabbroic unit which Danner (oral communication) has termed the Crosby Mountain volcanics. A typical specimen is moderately coarse grained and somewhat porphyritic, the phenocrysts being clusters of plagioclase. In thin section the plagioclase is seen to lie around the andesine-labradorite border, occurring almost in equal amounts with hornblende. (Figure 4). A small percentage of magnetite is also present. The fresh appearance of this rock in thin section suggests that it may be much younger than the rest of the series.

<u>Relations</u>: The series is bordered on the east by the Temple Mountain andesite which overlies it unconformably. Here the strike of the volcanics is about north 80 degrees west with a steep north dip. In contrast the Stillaguamish series is striking roughly due north and standing vertical.

Along the cliffs south of Money Creek, immediately east of Goat Basin, the metamorphics are apparently in fault contact

Figure 4

Stillaguamish series- volcanics. Photomicrograph of specimen from the south wall of Money Creek valley immediately east of Goat Basin. (X nicols).

with the Snoqualmie granodiorite. The southward or northward tracing of this fault was prevented by the vegetative cover. In the high country south of the area of metamorphic outcrop no trace of it was found, thus its' extent, age, and relative displacement is not known.

Correlation and age: The Stillaguamish series includes a part of what was mapped by W. S. Smith (1915) as Peshastin series, assigned by him to the Carboniferous and correlated by him with the Peshastin series of G. O. Smith (1904). The basis for this correlation was presumably the occurrence of limestone and cherty (quartzitic) phases in both localities.

Subsequently, poorly preserved fossils obtained from a cherty phase of limestone in Lowe Gulch (north side of Crosby Mountain) were identified as *Rafinesquina deltoides* and *Illaenus americanus*, index fossils of Ordovician (Trenton) age. This was set forth by Smith in 1916, the name Maloney series suggested for these rocks, and their equivalency with the Gunn Peak formation of Weaver implied. On rather indirect evidence, the latter had been referred by Weaver (1912) to the Carboniferous.

Recently, Danner (oral communication) has obtained fusulinids from the Palmer Mountain limestone deposit (immediately northwest of Crosby Mountain) representing a northward continuation of the metamorphics outcropping on Crosby Mountain and south of Money Creek. These have been identified by Thompson, Wheeler and Danner (1950) as Neoschwagerina (large) sp. ind., and Schwagerina (large) sp. ind., both genera indicitive of the mid to upper Permian.

A diligent search by the writer in several small limestone lenses south of Money Creek failed to uncover any fossils.

From the evidence of Danner and W. S. Smith, the Stillaguamish series is therefore dated as Permian and older. Thompson, Wheeler, and Danner (1950) have identified over a score of species of mid to upper Permian fusulinids from the northward extention of the Stillaguamish series in Washington and from the Cache Creek series in British Columbia. Equivalency of these units is therefore suggested as has previously been done by Weaver (1912) and W. S. Smith (1915).

With respect to the locality of the Ordovician faunas W. S. Smith (in a personal communication to Mr. W. R. Danner dated 13 November 1954) said:

> ". . . the Ordovician limestone was high on the valley side and west of Lowe Creek. It was before the days of the cement plant and there was no nearby reference point such as a cabin. The rock was marmorized so that the fossiliferous characteristic was not easily noticeable."

Danner (oral communication) has not been able to find this locality due to subsequent quarrying, landslides and Smiths' rather inadequate description of it. The specimens obtained from this locality by Smith were identified by Caroline A. Duror at Columbia University. The report on these forms is included in Smiths' 1916 paper.

Regarding these fossils, Marshall Kay (Executive Officer, Department of Geology, Columbia University, in a personal communication to W. R. Danner dated November 29, 1954) said:

> I have been anxious about these forms, but have never been able to locate them. As the illustrations were drawings, I would be inclined to treat them with caution unless or until some confirmation is gained. Your (Danner's) evidence certainly is contradictory.

The problem of the age of these rocks has therefore reached a stalemate, it being impossible to check either the fossil locality or the identification of the specimens obtained by Smith. If the evidence presented by both Danner and Smith is taken together, however, it must be inferred that the rocks of the Stillaguamish series represent two widely spaced intervals of Paleozoic time.

The writer has seen only a portion of the rocks mapped by Weaver (1912) as the Gunn Peak formation. On a lithologic basis the Stillaguamish series may be correlated with considerable confidence with that portion of the Gunn Peak formation.

In the Snoqualmie Pass area to the south, Foster (1955) has designated a complex series of metamorphic limestones, limey hornfelses and basalts the Sunset formation which he considers to be of Paleozoic age. On the basis of the occurrence of limestone, the possibility exists that these rocks may be southern equivalents of the Stillaguamish series.

With regard to correlation between the Stillaguamish series and the Peshastin and Hawkins formations east of the Cascade Divide, the writer can only refer to the observations of G. O. Smith:

> . . . taken together they (the Peshastin and Hawkins) have a strong resemblance to the Carboniferous rocks of British Columbia (Cache Creek series) and to the rocks of the same age in the Sierra Nevada (Calaveras formation). . . but at present they can be described only as pre-Tertiary." (G. O. Smith, 1904 p. 4).

The paleontological correlations made by Thompson, Wheeler and Danner (1950) prove the mid to upper Permian age of both the Stillaguamish series (at least in part) and the Cache Creek series. Lithologically the Stillaguamish and Peshastin are not similar.

<u>CHIWAUKUM SCHIST</u>

<u>Extent</u>: While the Stillaguamish series is restricted to the northwestern part of the area the Chiwaukum schist is equally restricted to, but more extensive in the northeast. It is best exposed along the right of way of the Great Northern Railroad from the north end of Tonga Ridge eastward for over a mile. (Figure 5). It is also exposed along the railroad west of the

Figure 5

Photograph of an uncrumpled phase of the Chiwaukum schist outcropping along the Great Northern right of way on the north end of Tonga Ridge.

Foss River and for a limited distance along Burn Creek.

To the writers' knowledge these are the western-most exposures of this unit, but it has an extensive distribution east of the Cascade divide where it has been mapped by Page (1939), Pratt (1954) and others.

Most of Tonga Ridge is made of this unit. This is inferred from the rare outcrops on the east side of the ridge and the common occurrence of schist pebbles scattered on the ridge crest.

Description: With few exceptions the Chiwaukum schist in this area is of one lithology: a fine-grained carbonaceous-quartz-biotite schist. In outcrop this rock is dark-gray in color although often partly coated with iron oxide produced by weathering of the biotite. A characteristic sheen is usually seen produced by the mica and graphite content. The rock is usually rather crumpled and always strongly shistose with alternating light and dark bands up to three millimeters in width. (Figure 6).

In thin section it is seen to be composed of 70 to 80 percent quartz in grains of varying sizes, the remainder consisting of carbonaceous material, and biotite with some sericite. Garnet occasionally occurs as an accessory. Within a few inches of the contact between the schist and granodiorite or acid dikes andalusite porphroblasts are commonly developed.

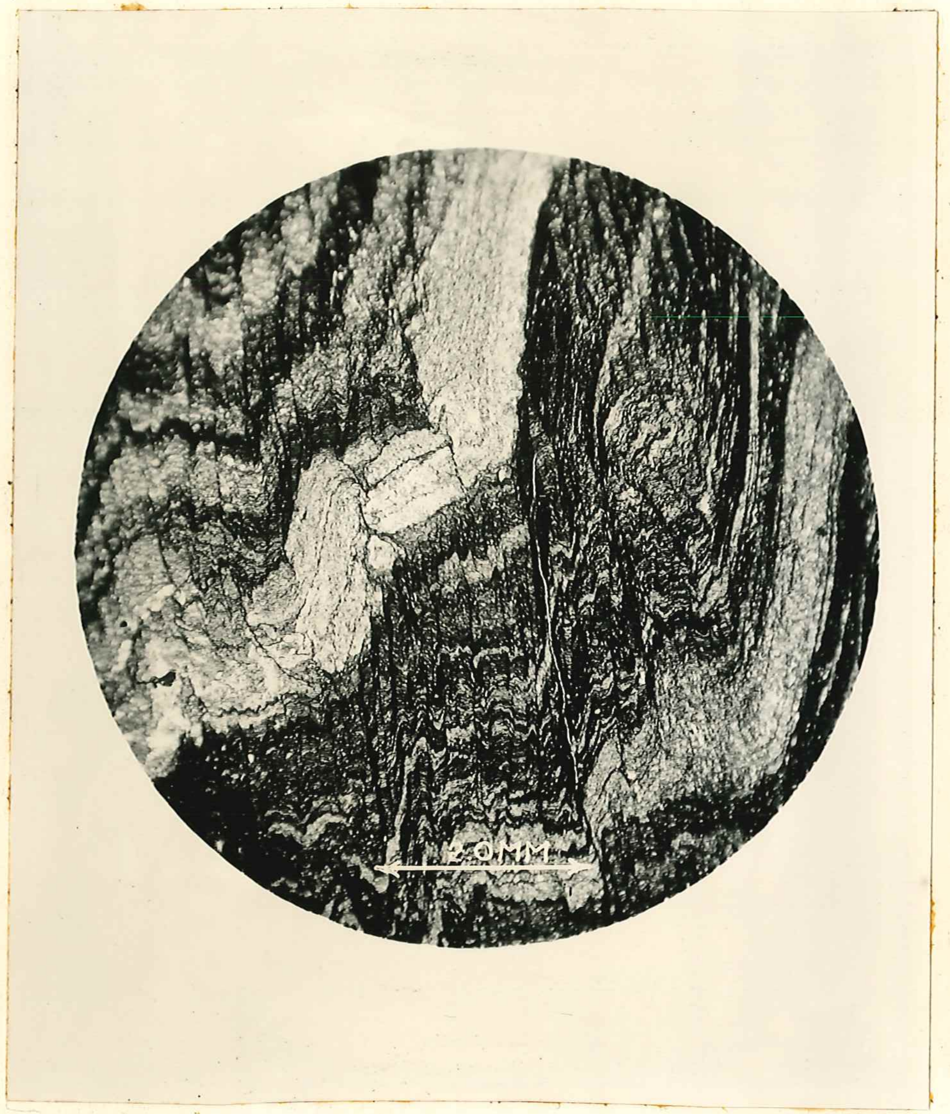


Figure 6

Chiwaukum schist- Carbonaceous quartz-biotite schist. Photomicrograph of specimen from the northwest side of Tonga Ridge (plane light).

Of the less dominant lithologies, perhaps the most important are the carbonaceous phyllites. This is a shiny, steel-gray rock consisting almost entirely of quartz and graphite, the latter making up perhaps as much as 20 per cent of the rock.

A third lithology is that of the bluish-green chlorite schists. This rock is rarely seen to be crumpled yet always displays good foliation. It consists largely of alternating bands of chlorite and quartz up to one millimeter in width. Diopside is also a primary constituent.

Two small outcrops of a metavolcanic rock (amphibolite) were encountered. This is a medium grained rock consisting almost entirely of tremolite-actinolite and small quantities of pyroxene. (Figure 7). These outcrops lie concordant with the foliation of the surrounding schist body and for purposes of this investigation are included in the Chiwaukum schist.

Relations: Along the Great Northern right of way the schist has clearly been intruded by the Mount Stuart granodiorite. Fingers and dome-shaped masses of the granodiorite poke up into the schist. Contacts are sharp and the schist is baked in a zone six inches to a foot in width. (Figure 8). The schist is cut by acid dikes from one to four feet in width which are apparently associated with the Mount Stuart granodiorite. (Figure 9).

The Chiwaukum lies unconformable beneath the sands and

Figure 7

Chiwaukum schist- tremolite-actionolite schist. Photomicrograph of specimen from along the Great Northern right of way near Carroll Creek (plane light).

Figure 8

Photograph showing the contact between the Mount Stuart granodiorite (left) and the Chiwaukum schist along the Great Northern right of way on the north end of Tonga Ridge.

Figure 9

Photograph of a dike (probably associated with the Mount Stuart granodiorite) cutting the Chiwaukum schist. Several such dikes are seen along the Great Northern right of way where it passes around the north end of Tonga Ridge.

conglomerates of the Swauk formation. This may be inferred from the outcrops along the railroad and is actually seen along Burn Creek.

In general the strike of the foliation trends north-south, but often departs as much as 40 degrees either way from this trend.

Correlation and age: The Chiwaukum schist was first described and named for the exposures along Chiwaukum Creek, a tributary of the Wenatchee River, by Page (1939). In 1953 the mapping of this unit was extended by members of the University of Washington, Geology Department field course, and later by Pratt (1954) westward to the area immediately east of the Miller-Foss area.

W. S. Smith (1915, 1916) identified the schist body in the Miller-Foss area with the Easton schist of G. O. Smith (1904). The writer, upon considering the areal distribution of the Chiwaukum as indicated by workers to the east, and after seeing the type area of the Chiwaukum, identifies the schist in the Miller-Foss area with the latter. Page (1939), himself, thought that this schist was the same as his Chiwaukum, and considering it older than the Peshastin formation on the basis of dynamic metamorphism, he indirectly dated it as pre-Ordovician (on the basis of W. S. Smiths work).

Through the courtesy of Dr. H. A. Coombs, the writer has seen specimens from the type locality of the Easton schist and cannot associate the schist in the Miller-Foss area with it on the basis of lithology.

There has been a trend ever since G. O. Smith's classic work in the Mount Stuart quadrangle to consider the metamorphic basement complex of the central Cascades as Carboniferous or older. Smith (1904) noted that the degree of dynamic metamorphism was much greater in the Easton schist than in either the Peshastin or Hawkins formations. On this primary criterion, therefore, he determined the relative ages of the former and latter two. He tentatively correlated the Peshastin and Hawkins with the Cache Creek (Carboniferous) series of British Columbia on the basis of similarity in lithology.

Following this example, W. S. Smith (1915,1916) inferred the relative ages of the Maloney (Stillaguamish) series and the Easton (Chiwaukum) schist in the Skykomish Basin entirely on the basis of dynamic metamorphism.

There is no field evidence in the Miller-Foss area to support the conclusion that the Chiwaukum schist pre-dates the Stillaguamish series. The two units are no where in contact. The Chiwaukum definitely pre-dates the Mount Stuart granodiorite, but there is no available evidence to indicate where in pre-Mount

Stuart time it belongs.

Furthermore, there are great lithologic differences between the two metamorphic units. The Chiwaukum is for the most part, the metamorphic equivalent of argillaceous sediments and carbonaceous rocks, whereas the Stillaguamish is primarily the equivalent of sands, limes and basic igneous rocks with much less argillaceous material. A difference in competency with respect to the effects of dynamic metamorphism may therefore be suggested. Moreover, in the argillaceous phases of the Stillaguamish series the writer has observed as high a degree of dynamic metamorphism as is to be found in the Chiwaukum schist.

Page (1939) and Willis (1950) have correlated the Swakane (gneissose) facies of the metamorphic complex with the Chiwaukum schist. This would suggest a northward and eastward increase in the degree of metamorphism. The time of the regional metamorphism and granitization which produced the Swakane gneiss is usually assigned to the Nevadian disturbance. (C. Willis, 1950, p. 68). This would obviously date the laying down of the sediments which now compose the Chiwaukum schist as pre-Nevadian.

The writer has observed that the black phyllitic rocks which were designated type Peshastin by G. O. Smith (1904) resemble very closely some portions of the Chiwaukum schist, the difference being only a slightly greater degree of recrystallization in the latter.

It is evident that much caution should be exercised in regard to the relative (to say nothing of the absolute) dating of units composing the Cascade metamorphic complex, especially where paleontological evidence is absent.

Until the structural complexities of the northern Cascades have been worked out more satisfactorily the age of the Chiwaukum schist cannot be definitely stated. It may range anywhere in time prior to the emplacement of the Mount Stuart granodiorite.

SWAUK FORMATION

Occurrence and Extent: The Swauk formation is perhaps the most extensive and important sedimentary unit in the central Cascade Mountains. It was initially named by George Otis Smith (1904) for the exposures along Swauk Creek in the Mount Stuart quadrangle. The importance and great extent of this unit was recognized by Smith in that area and subsequently it has been mapped and discussed by many workers.

In the Miller-Foss area the Swauk formation occupies a two to five mile wide belt trending northwest-southeast through the eastern and central parts of the area. The best exposures may be seen along the Foss East Fork (Figure 10) and in the high country to the north and east toward Mount Sawyer, but it is well

Figure 10

Photograph along the right bank of the Foss East Fork where an excess of 4300 feet of essentially flat-lying Swauk arkoses and shales are exposed.

exposed elsewhere on the northeast flank of Sobieski Mountain and in the canyon of Maloney Creek. Small scattered outcrops are seen along the Great Northern right of way 1½ to 2 miles east of Skykomish and a few hundred feet east of Carroll Creek.

The belt appears to continue northward across the Skykomish South Fork into the valley of the Beckler River and southeastward Pratt (1954).

<u>Structure and Thickness</u>: Lying on the southwest flank of the Wenatchee (Skykomish) uplift, these sediments strike between north 30 west and north 50 west, dipping homoclinally southwestward 30 to 55 degrees throughout the greater width of the belt in the northern part of the mapped area. Westward, the average homoclinal dip flattens out and in the valley of Maloney Creek the Swauk has, in part, been thrown into small open folds the limbs of which rarely dip more than 40 degrees, although attitudes of 70 degrees were occasionally measured by the writer. Some of these folds are well exposed along the Skykomish lookout road in the vicinity of the Swauk-Temple Mountain andesite contact.

The southwestward homoclinal dip of the Swauk is apparent in many places. Beginning with the most easterly (basal) beds at Carroll Creek, going west, no departure from this direction of dip is seen until one reaches the Maloney Creek drainage.

The strike of the beds precludes this homocline from being present in the southern part of the mapped area, but to the southeast, Pratt (1954) encountered only southwest dips right up to the Deception Pass fault. In the vicinity of Bald Eagle and east of the Foss East Fork, open folds of small magnitude are seen in the Swauk, their limbs dipping only a few degrees.

At several points along the east side of the Foss East Fork where the beds lie essentially horizontal, 4300 feet of Swauk is exposed in one scarp. On the basis of the structure in the northern part of the mapped area, however, the thickness of the Swauk may be inferred to be in excess of 10,000 feet in this area. A similar figure was estimated by C. L. Willis (1950, p. 95) in the Chiwaukum quadrangle east of the Cascade divide.

Description: In the Miller-Foss area the predominating Swauk lithology is a medium-grained, light grey, well-sorted micaceous arkose. The rock is usually moderately well indurated, massive or cross bedded. Bedding may commonly be discerned only from the orientation of muscovite flakes of from that of the less common biotite flakes. This rock can easily be mistaken for granodiorite in the field due to its' color, jointing, massive texture and mineral constituents. Often only upon close inspection is the detrital nature of the rock apparent.

The rock is primarily composed of angular to subrounded grains of plagioclase and quartz, with orthoclase, micas, mafics, and schist fragments occurring in small quantities. (Figure 11). The grains are rarely larger than one millimeter in diameter. This arkose is remarkably free of argillaceous material, the primary cement being silica. Some of the feldspars show slight weathering effects and near the contact with the Snoqualmie granodiorite have been partly or completely hydrothermally altered to sericite.

Pebbly arkoses are often intercalated with the medium-grained arkoses, the pebbles nearly always being angular to subangular schist or slate fragments up to one inch long. Biotite fragments up to 10 millimeters in length are also common in this lithology.

Pebble conglomerates were found by the writer at several horizons in the section, notably near the base and the middle of the section, although they may well be present elsewhere. The latter outcrops extensively on the west side of Tonga Ridge only a few hundred feet above the floor of the Foss River valley. It is composed of angular to subrounded pebbles of granodiorite, quartzite, schist and slate varying in maximum dimention from one-eighth of an inch to two inches. These lie in a sandy matrix of quartz and feldspar plus a rather high percentage of mafics.

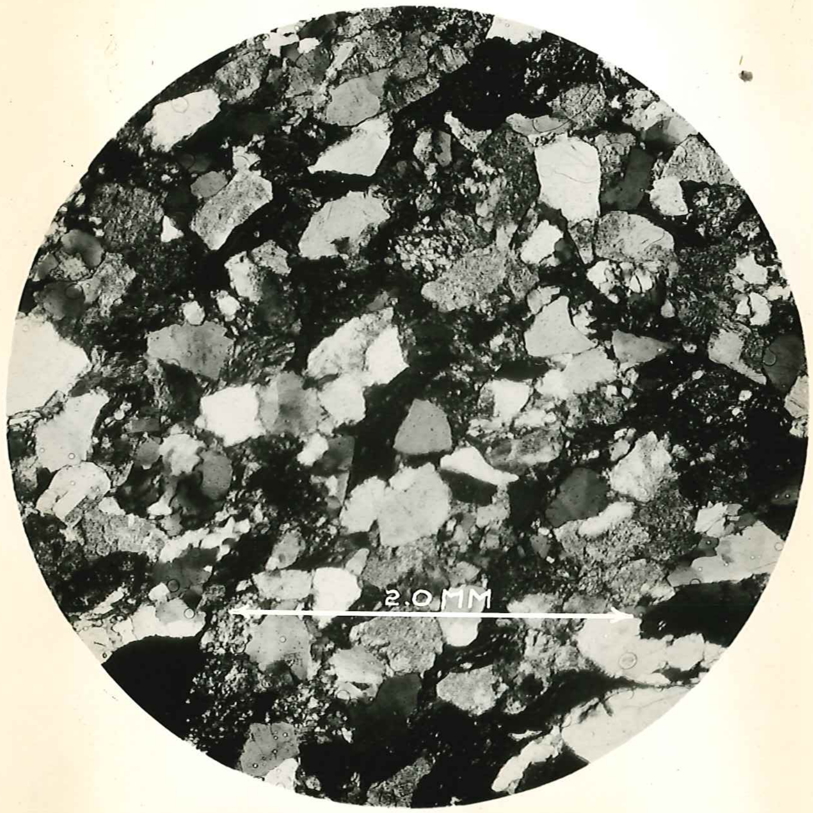


Figure 11

Swauk formation- arkose. Photomicrograph of specimen from west side of Tonga Ridge (X nicols).

A short distance east of Carroll Creek on the Great Northern right of way, the basal beds of the Swauk may be seen. They consist of 150 feet of dirty gray, coarse grained, often pebbly, feldspathic graywacke containing subangular to subrounded fragments of schist, phyllite, quartz and basic igneous material up to ten millimeters long. Individual beds vary from two inches to a foot or more in thickness. Certain beds, however, contain very few pebbles, consisting largely of angular to subangular feldspar and quartz grains between 1 and 2 millimeters in diameter. This rock is commonly orange in color, due to the iron oxide which cements the grains together. It is possible that this rock may be a local representative of Luphers' Cle Elum formation, but the writer did not feel it logical to separate it from the Swauk formation.

Above these coarse pebbly graywackes and conglomerates lies 70 feet of massive boulder conglomerate. These boulders are identical in lithology with outcrops of the Mount Stuart granodiorite one mile east. They are subangular to subrounded, have diameters up to 2½ feet and lie in a feldspathic graywacke matrix (Figure 12).

Similar boulders were observed at the base of the Swauk in Peshastin Valley (east of the Cascade divide) by G. O. Smith (1904, p. 5). They were thought by him to owe their

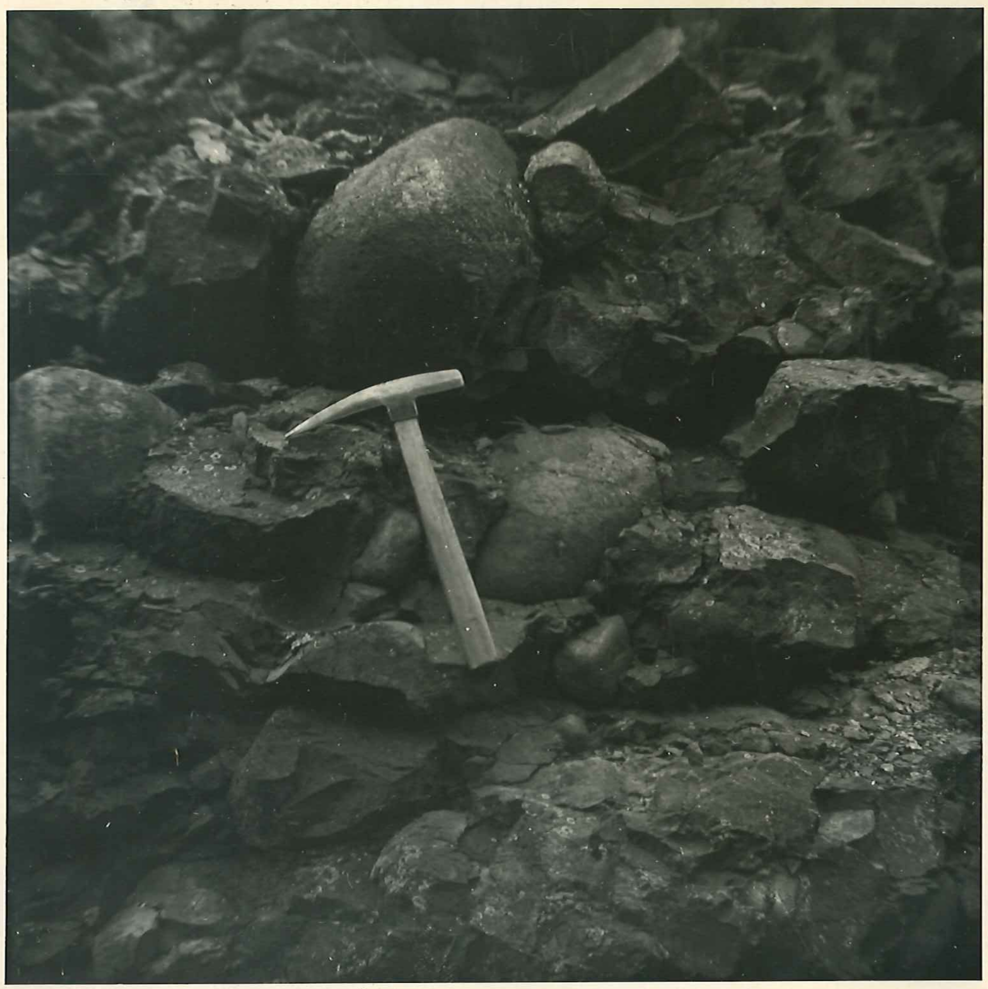


Figure 12

Swauk formation- boulder conglomerate. Photograph of part of outcrop along Great Northern right of way, just east of Carroll Creek. Boulders are of identical lithology as the Mount Stuart rocks outcropping immediately to the east.

shape to weathering and thus to have been residual boulders having undergone little or no transportation. The writer tenders the same explanation regarding the boulders in the conglomerate near Carroll Creek.

Apparently occurring only high in the section, outcropping only on the northeast flank of Sobieski Mountain and in the Maloney Creek drainage, massive to well-bedded shales are intercalated with the arkoses. The shales are commonly blue-black to dark blue-grey in color and occur in rather large lenses several tens to nearly 100 feet each in thickness. Under the microscope they are seen to be poorly sorted, often containing minute beds of quartzose sand. Some poorly preserved plant stems were found in these rocks in the vicinity of the Skykomish lookout road.

Relations: The Swauk formation is in contact with all other units in the mapped area except the Stillaguamish series. It is therefore the most important unit in the entire area.

The strong unconformity between the Swauk formation and the Chiwaukum schist may be inferred with complete confidence at several localities. At the Carroll Creek exposures the schist strikes roughly north-south and may be seen only a few feet from the overlying basal feldspathic graywackes and conglomerates of the Swauk striking north 45 degrees west and dipping 30 degrees southwest against the schist. The relationship of the boulder conglomerate to the base of the Swauk has previously been mentioned. Regarding similar relationships in the Mount Stuart quadrangle, R. L. Lupher observed:

> Conglometates are present in the lower part of the Swauk formation, but they lie mostly from 20 to 800 feet above the base. . . . The conglomerates appear to mark a well defined and widespread lithologic facies. . . . As a rule they do not constitute a definite bed, but appear as a series of beds including conglomerate, pebbly sandstone and coarse sandstone. The thickness ranges from 20 feet to more than 300 feet. (Lupher, 1944, p. 22)

The outcropping at Carroll Creek is the only good exposure of the base of the Swauk in the mapped area, for the country to the southeast is heavily timbered and affords little in the way of rock outcrops. Although the very base of the Swauk has a high iron oxide content, the Cle Elum (iron ore) beds as defined by Lupher (1944) are not present in this area. This may be due to the lack of ultra-basic rocks in the make up of the metamorphic complex in this area.

It is not, however, the base of the Swauk alone where the unconformity is seen. Along Burn Creek and on the east side of Tonga Ridge the sediments are again seen to dip in against the schist body. As is to be expected, the occurrence of schist fragments in the arkose is common near the contact. These horizons may be inferred to lie, in some cases, at least 2300 feet stratigraphically above the base of the Swauk, suggesting that the subsiding surface upon which the Swauk was deposited had considerable relief, perhaps over 2000 feet. In accounting for this relationship, however, the possibility of post-Swauk faulting cannot be disregarded, but the writer was unable to find any evidence in the field for such faulting.

The sands and conglomerates at Carroll Creek are only moderately indurated. There is no evidence to indicate that the Swauk has been affected in any way by the emplacement of the Mount Stuart granodiorite. On the other hand the origin of the boulders near the base of the Swauk can hardly be doubted. It is therefore inferred that the Swauk lies unconformably upon the Mount Stuart granodiorite. This contact was not actually seen due to vegetation and overburden, but the two units lie juxtaposition.

The relations of the Swauk formation with the Tertiary volcanics will be discussed more fully later in this report. It seems sufficient at this point to say that to the west, the Temple Mountain andesite apparently stratigraphically replaces, in part, the Swauk formation. In the vicinity of Maloney Creek, the volcanics and sediments are so intimately mixed that it is often difficult to apply a field name to any given specimen. Some beds of sandstone are actually seen to overlie andesitic flows and tuffaceous sedimentary beds. In other places the sandstone has been noticeably baked and disturbed, apparently by extrusive processes. In this vicinity these relationships are seen for a vertical stratigraphic distance of at least 800 feet.

Below the Skykomish lookout the top of the Swauk is rather well defined. Here the Lookout breccias appear to conformably overlie the shales and sandstones of the Swauk.

The Swauk is in gradational contact with the Snoqualmie granodiorite. Several traverses were made by the writer from one to the other and never was the contact well defined. This relationship is probably best exposed along Maloney Creek. Immediately behind the Skykomish ranger station a mafic rich phase of the Snoqualmie granodiorite outcrops. Tracing this lithology upstream, a point is reached where it is difficult to determine whether the rock is sandstone or granodiorite. Farther upstream, a somewhat recrystallized and well indurated sandstone may be seen. This is gradational with the moderately indurated arkose making up the bulk of the Swauk. Along U. S. highway #2, three quarters of a mile east of the Skykomish River bridge, the highly indurated and partly recrystallized arkose again outcrops, maintaining its' identity as a sediment, the beds striking north 30 west and dipping 45 degrees southwest. Several of the beds here possess a distinct greenish tinge, perhaps due to volcanic admixtures. On the southeast flank of Bald Eagle, a relationship is seen similar to that found along Maloney Creek, although the contact zone was much better defined.

In thin section the primary effect of the emplacement is the alteration of the feldspars to sericite. In some specimens this alteration is nearly complete, only relic rims of the feldspar grains remaining, the rock consisting almost entirely of quartz and sericite shreds.

The westward and northwestward disappearance of the Swauk may therefore be accounted for in two ways; it is apparently stratigraphically replaced, in part, by the Temple Mountain andesite or by the emplacement of the Snoqualmie granodiorite. Regarding the latter a problem arises as to the processes involved; i.e., whether the replacement is due to igneous instrusion and assimilation of the Swauk or by metasomatic replacement and granitization. This matter will be discussed more fully in connection with the Snoqualmie granodiorite, however, it should be stated that granitization of the type discussed by Coombs (1950) in the Wenatchee area apparently has not taken place in the Miller-Foss area as a result of the emplacement of the Snoqualmie granodiorite.

<u>Correlation and age</u>: From the collection of fossil leaves made by G. O. Smith in the vicinity of Liberty (Mount Stuart quadrangle), F. H. Knowlton (1904) indentified one species

common to the Denver and Laramie formations of the Rocky Mountains, and 25 new species bearing a close resemblance to forms found in the Denver, Laramie and Fort Union beds. On this rather insecure basis the Swauk was considered to be Eocene. It is not known whether Knowlton meant the term Eocene in the broad or restricted sense, but his reference to the Fort Union suggests that he used it in the broad sense, that is including the Paleocene. The Denver and Laramie beds have since been regarded by some workers to span the Cretaceous-Tertiary boundary.

W. S. Smith subsequently made a collection of fossil leaves from the shales of the Skykomish Basin. They were examined by Caroline A. Durer who considered them to be of Fort Union age (W. S. Smith, 1916).

R. S. La Motte (Chappell, 1936) identified collections of fossil leaves from the Swauk formation in the Wenatchee, Chiwaukum and Mount Stuart quadrangles and was strongly inclined to consider them Paleocene in age. He further compared these forms with those reported elsewhere in the State of Washington and found several species to be present in the rocks exposed along the north fork of the Nooksack River west of the Cascade Mountains near the international boundary. C. L. Willis (1950, p. 93) considered these rocks (along the Nooksack River) to be

". . . part of the Chuckanut formation which may be equivalent, in part, to the rocks of the Nanaimo group in the San Juan Islands of northwestern Washington."

With regard to the age of the Swauk formation Willis summarized:

> The identification and correlations of the fossil leaves of the Swauk formation. . . suggests that . . . (it) is, for the most part, Paleocene in age. However the limitations of paleobotanical correlations and the preliminary status of the work must be recognized. Parts of the Swauk formation may be uppermost Cretaceous early Eocene in age. (C. L. Willis, 1950, p. 92-93).

Five genera reported by Duror from the Swauk of the Skykomish Basin had been reported by Knowlton from a collection made by Bailey Willis (1899) from the lower Puget group (Carbonado formation) of western Washington. On this basis W. S. Smith (1916) correlated the Swauk with the lower Puget group.

With regard to the fossil locality in the Skykomish Basin, Smith (in a personal communication to Mr. W. R. Danner dated 13 November 1954) said:

> My recollection as to the source of the plant fossils is. . . vague. I have the impression that the locality was about 5 miles east of Skykomish and about 1½ miles south of the railroad, high above the valley (perhaps 3000 feet). . . . They were in black shales and their nature easily recognizable.

Accordingly, the locality would be on the east side of Tonga Ridge, now heavily timbered and affording almost no rock outcrops. However most of Tonga Ridge is shown on Smith's 1915 map as Easton shist. Smith reported these flora from two horizons "600 feet apart vertically, the lower being 1000 feet from the base of the Swauk. With the (lower horizon) is associated a coal bed some 14 inches thick on which stopes have been driven in the hope of finding mineable coal." (W. S. Smith, 1916, p. 565). G. M. Valentine (1949) mentions coal claims in the Foss River valley, but their accurate location is not given in his report. The Swauk outcrops extensively on the west side of Tonga Ridge however, but no shales were found by the writer in this area except for one small outcrop along the Foss River road.

Over and above the inadequacies of available descriptions of Smiths' fossil locality, the writer has reason to believe that it is stratigraphically higher in the Swauk than Smith realized. If this is so, and if Smith's correlation between the Swauk and the Carbonado is considered valid, on the basis of five genera common to both, it is only the upper part of the Swauk which can be correlated with the lower Puget beds.

The validity of this correlation has been openly questioned by Waters (1930) and Chappell (1936), and is also questioned by the writer. On paleontological evidence, Weaver (1916, 1937, 1944, 1945) has assigned the Puget group to the "Tejon" stage (middle to upper Eocene) which is considerably later than Fort Union (Paleocene) time. Moreover, the pre-Teanaway folding of the Swauk apparently has no counterpart that involves the Puget group in western Washington. Waters (1930) and Chappell (1936) were inclined to treat the Teanaway and Roslyn formations as equivalent to the Puget group. This inference is based on the extensive occurrence of coal in both the Puget group and the Roslyn formation, and the similarity of fossil leaf forms in the Carbonado formation (lower Puget) and in sedimentary phases of the Teanaway basalt. This appears to the writer to be a more valid correlation than that generally implied in the literature.

Immediately west of the Miller-Foss area, Bethel (1950) has designated a north-south trending belt of massive feldspathic graywackes the Calligan formation. He noted a similarity in lithology between these rocks and the Swauk formation of the Skykomish Basin as described by W. S. Smith. Concerning the age of the Calligan, Bethel said:

> On the basis of the worm tubes and the similarity of the lithology to Swauk type sedimentary rocks, the portion of the Calligan formation from Lake Calligan to the Snoqualmie Middle Fork. . . . (the portion free of andesitic fragments) is dated. . .as Cretaceous to Paleocene. (Bethel, 1951, p. 55).

Subsequently, Danner (oral communication) has noted rocks containing worm tubes similar to those of the Calligan formation occur over a wide area of the lower Skykomish valley in the vicinity of the town of Sultan, and at two localities contain fossils identified as <u>Aucella</u> of upper Jurassic and earliest lower Cretaceous age. This series of rocks is termed the Sultan series by Danner in the Sultan area, Nooksack series by Peter Misch in the northern Cascades and may also, on the basis of worm tubes, be equivalent to the Sol Duc formation of the Olympic Mountains. On this basis then a correlation between the Swauk and Calligan formations would be rendered invalid.

Twenty-five miles north of Skykomish, Spurr (1909) described an early Tertiary arkose which he lithologically identified with the Swauk formation. He observed boulders in this unit which he thought were equivalent to the Mount Stuart granodiorite.

In the Index area, immediately to the northwest, Weaver (1912) designated a thin (200 feet) sedimentary unit; the Howard arkose. This unit contains volcanic admixtures and interbeds and may be part of the Swauk formation.

Origin and environment of deposition: The environment in which the Swauk sediments were deposited was initially interpreted by G. O. Smith (1904) as lacusterine. Later workers have been inclined to label them as more purely continental, being deposited as alluvial fans and deltas.

After detailed petrographic and field study of the Swauk in the Chiwaukum quadrangle, however, Willis interpreted these sediments as flood plain and channel deposits ". . . deposited by large streams which built coalescent sheets and lenses of alluvial detritus by lateral shifting of their courses." (C. L. Willis, 1950, p. 107).

Many workers have noted that with the exception of the basal beds, the Swauk does not reflect the diverse character of the basement rocks upon which it lies. This coupled with the high content of feldspar, the index mineral of relief, suggests that the Swauk was derived from granitic massifs of strong relief. This reasoning is further supported by the evidence from the Miller-Foss area. On the basis of the character and composition of the sediments Willis (1950) inferred the source area to lie to the northeast, i.e., the Chelan-Okanogan highlands. In addition to the evidence presented by Willis, there is evidence in the Miller-Foss area to indicate volcanic activity to the west was contemporaneous, in part, with the deposition of the arkoses. This precludes the possibility of the source area lying to the west, for the bulk of the Swauk formation is completely free of volcanic material.

Willis supports the hypothesis first defined by Weaver (1937-1945) that central Washington was part of a broad, subsiding, northwest-southeast trending coastal plain during Swauk time. This hypothesis was apparently based, at least in part, on the assumption that the Swauk formation and the Puget group were contemporaneous. The validity of this correlation has been previously discussed.

However, of the earliest Tertiary geology of western Washington, Weaver (1916) said:

> No record is available of the geologic history of western Washington during the early Eocene epoch. The region was presecumably a land area not much elevated above sea level. (Weaver, 1916, p. 85).

Later, however, Weaver (1944,1945) recognized volcanics underlying (?) the Puget group. He associated these rocks with the Metchosin (?) volcanics and stratigraphically assigned them to the Paleocene and lower (Capay?) Eocene.

In the central Cascades, interbedded sediments and volcanics of earliest Tertiary age have been previously reported by Weaver (1912). In the Miller-Foss area this relationship is again found. This suggests that the western limits of the Swauk were and are defined by the presence of contemporaneous volcanism in western Washington during the latter part of Swauk time.

The above is further supported upon examination of the work of Smith and Calkins (1906) in the Snoqualmie quadrangle to the south. These workers designated a unit too often neglected in the literature; the Naches formation. On the basis of paleobotanical evidence, this unit was considered by Smith and Calkins to be contemporaneous with the Swauk and has apparently been considered by later workers as Swauk. As originally mapped, however, the Naches formation occupies a northwest-southeast trending belt lying parallel to and west of the Swauk formation in the Snoqualmie quadrangle.

Concerning the lithology of the Naches formation, Smith and Calkins said:

> The Naches formation is composed of interbedded sedimentary and volcanic rocks, the latter of basaltic character. Its' lower portion consists principally of sandstone, with which is intercalated a rather subordinate amount of basaltic material representing contemporaneous extrusions. The basalt, however, becomes increasingly important in the higher beds, and is dominant in the uppermost part of the formation. (Smith and Calkins, 1906. p. 5).

with regard to the contact relations:

> (The Naches formation). . . rests directly on highly metamorphosed pre-Tertiary rocks with marked unconformity. This contact is generally covered, however, by the Kachess rhyolite, a rock that bears a peculiar relation to the Naches and is in part contemporaneous with it, so that a heavy flow of Kachess rhyolite is interbedded with the Naches sandstone and basalt. The upper surface of the Naches formation, where it is not in contact with the Kachess, is overlain unconformably by the Keechelus volcanics. (Smith and Calkins, 1906, p. 4).

The combination of the Swauk-Chuckanut-Naches relations and contemporaneous volcanism to the west suggests that the scene during Swauk time was not one of a coastal plain, but that of a broad, subsiding basin, having as much as 2000 feet of relief. Such a basin would have been rather elongate, trending roughly northwest-southeast, and may have been open to the sea at its northwest end. It would represent a continental continuation of the northwest trending structural trough mentioned by Bradley (1950). It would have been bounded on the east by granitic massifs of strong relief (from whence the arkosic sediments were derived) and to the southwest by a region of volcanic activity, apparently strongest further south where considerable amounts of basic and acidic lavas are found interbedded with the earliest Tertiary arkoses.

THE TERTIARY VOLCANICS

Occurrence and extent. Occupying a position essentially between the Swauk formation and Snoqualmie granodiorite a belt of volcanic rocks outcrop trending northwest through the central part of the mapped area. These rocks were referred to the Keechelus andesitic series by W. S. Smith (1915,1916). During the course of the present investigation, however, field relations were seen to indicate that these rocks have a much different relationship to the early Tertiary sediments than do the rocks of the Keechelus series as defined by Smith and Calkins (1906). For the above reason, and so that no confusion might arise from a rather promiscuous use of the term Keechelus, the writer proposes names for the two more or less distinct Tertiary volcanic units outcropping within the boundaries of the mapped area; the Temple Mountain andesite and the Lookout beccias. This separation is effected primarily on the basis of lithologic differences.

The Temple Mountain andesite is named for the exposures on Temple Mountain where it outcrops rather extensively. Elsewhere it is seen on the slopes of Cleveland Mountain and in the valley of Kimball Creek. It is well exposed on the crest of Maloney Ridge as far south as Wernecke Lakes, making up the bulk of the northern portion of that ridge. It may also be seen along the walls of the valley of the Foss West Fork just below Trout Lake where its' outcrop belt crosses the valley. The outcrop belt of these rocks is apparently cut out somewhere on the west side of Bald Eagle, for they are not seen to continue north of the mapped area across the valley of Money Creek to the lower slopes of Crosby Mountain.

The Lookout breccias outcrop much less extensively, the only exposures being in the vicinity of the Skykomish fire lookout and on the northeast spur of Maloney Ridge.

Structure and thickness: The structure of the Temple Mountain andesite in the western part of the area is the counterpart of that of the Swauk formation to the east. Although the strike of these volcanics on Maloney Ridge is from north 25 to 50 west, it swings more westward as one goes west. Thus in the vicinity of Temple Mountain and Kimball Creek the strike is seen to be north 70-80 west. The dips in the eastern part of the outcrop belt are 40-45 degrees northeast. West of Kimball

Creek the dip varies from 30 to 70 degrees northward and the volcanics appear to be plastered against the north and east faces of the ridge which is largely composed of Stillaguamish metamorphics.

The structure is essentially a northwestward dipping homocline apparently representing the southwest limb of a broad regional downwarp. On this basis the Temple Mountain andesite is inferred to be in excess of 5000 feet thick.

On the north end of Maloney Ridge several open folds incorporate both volcanic and sedimentary rocks.

The structure of the Lookout breccias apparently conforms to that of the underlying Swauk formation and is seen to conform with that of the Temple Mountain andesite. Although the top of these breccias has been removed by erosion a thickness of at least 800 feet is exposed in the vicinity of the Skykomish fire lookout.

Description:

Temple Mountain andesite; This unit is largely composed of fine-grained, massive, gray to green, porphyritic andesites. Less abundant are local andesitic breccias and intercalated tuffs. All of these appear to thin eastward where they become intercalated with the arkoses of the Swauk formation at Maloney Creek.

In a typical hand specimen the massive andesites are green in color and usually porphyritic, having phenocrysts of feldspar up to ten millimeters in length. Under the microscope these rocks are seen to be composed of phenocrysts of calcic andesine or labradorite and augite with minor amounts of orthoclase, all lying in a fine matrix of quartz, feldspar and mafics. The phenocrysts are usually subhedral to anhedral and often largely altered to epidote and sericite. Twinning is usually obscured due to alteration. Diopside often forms a portion of the pyroxene content of the rock and small amounts of magnetite are present in all the sections studied by the writer. Flow structures are often observed in thin section but never in outcrop. (Figure 13).

Several specimens studied by the writer are composed of plagioclase and augite crystals in a matrix of devitrified glass. Other specimens appear to consist entirely of andesitic fragments in a tuffaceous matrix. (Figure 14).

Lookout breccias: This unit consists of tuffs and breccias which may be, in part, water laid, and thin, rather fresh looking andesite flows. In outcrop the breccias are reddish-brown to gray, the largest fragments being about ½ inch long and consisting of sandstone, shale and volcanic debris, or quartz and small plagioclase (oligoclase-andesine) laths in a

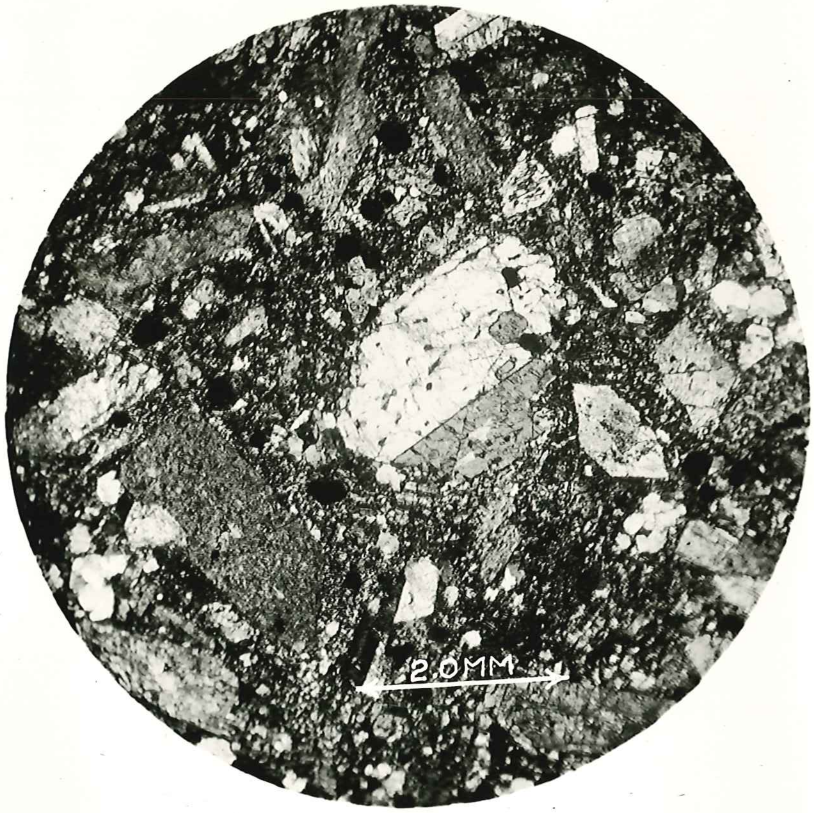


Figure 13

Temple Mountain andesite. Photomicrograph of specimen taken along a left bank tributary of Maloney Creek about 1½ miles south of Skykomish. (X nicols).

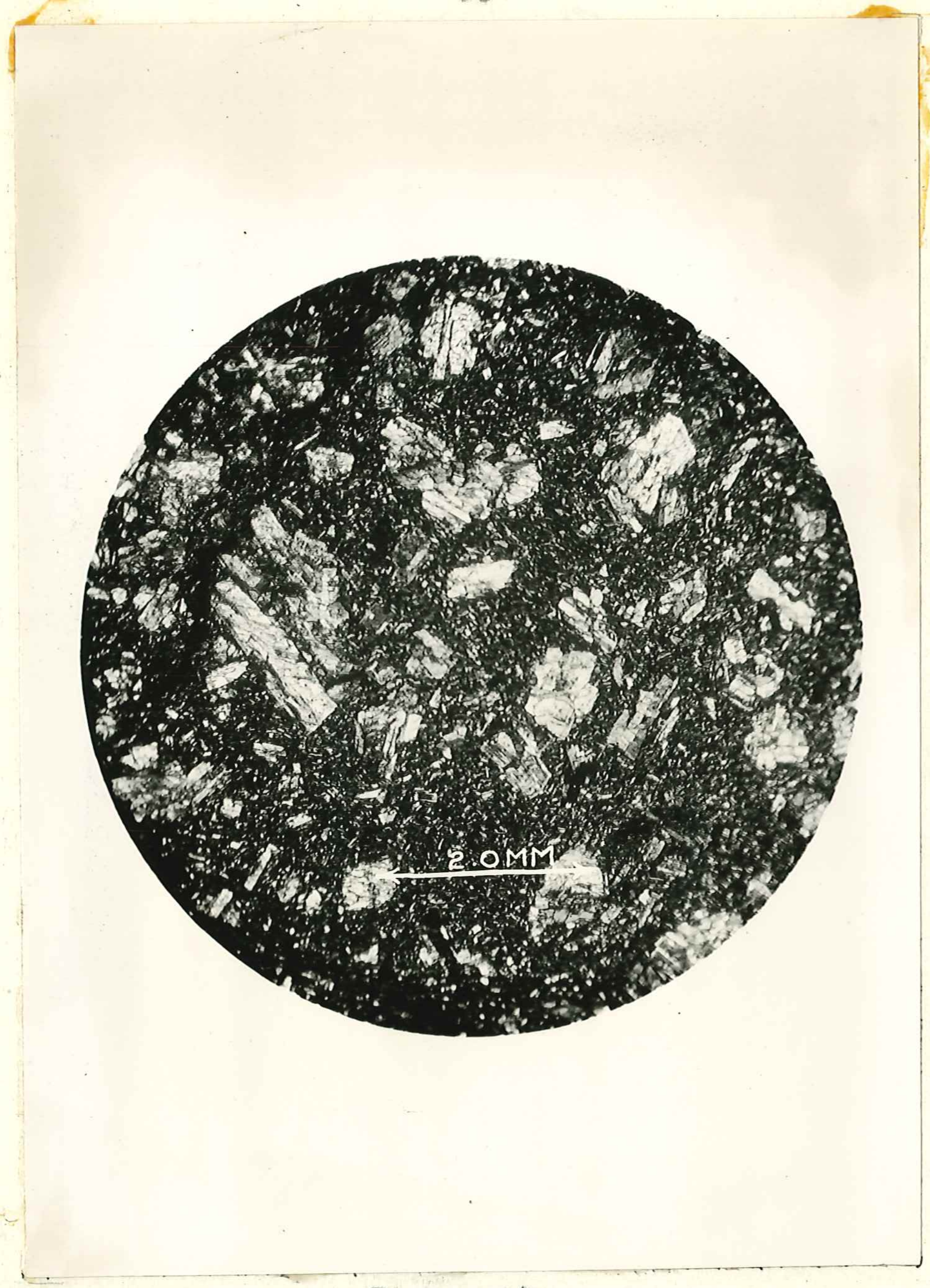


Figure 14

Temple Mountain andesite. Photomicrograph of specimen taken along the Miller River road at the east base of Temple Mountain. (X nicols).

tuffaceous or cryptocrystalline matrix. (Figure 15).

Intercalated with these breccias are several flows of greenish andesite not unlike the rocks described as Temple Mountain andesite consisting of plagioclase and augite with minor amounts of quartz and orthoclase. The flows are several tens of feet each in thickness and are vesicular at their tops. The vesicles are often filled with argillaceous material or secondary silica. Although these rocks are fresh looking in outcrop microscopic examination shows considerable alteration of the feldspars to sericite. The plagioclase and augite pheonocrysts lie in a very fine grained ground mass consisting of the above minerals, quartz and rather well-developed magnetite crystals.

Relations:

Temple Mountain andesite: The Temple Mountain andesite is inferred to lie unconformably on the Stillaguamish series. On the east and north slopes of the ridge separating Goat Basin and Kimball Creek the volcanics strike north 70-80 west and dip very steeply north so that they appear to be plastered against the side of the ridge. In contrast, the underlying metamorphic rocks strike north-south and stand vertical. A similar relationship is inferred from the outcrops in the beds of Money and Kimball creeks.

In the vicinity of Maloney Creek some interesting and

Figure 15

Lookout breccia. Photomicrograph of specimen taken from the northwest spur of Maloney Ridge. (X nicols).

somewhat confusing relationships are to be seen between the volcanics and the Swauk formation. These relations are fairly well exposed in the vicinity of the Skykomish lookout road and in the canyons of Maloney Creek and its' tributaries. (Figure 16). The structure in this vicinity consists of open folds of small magnitude which appear to die out as one goes down in the section. In some places shales and sandstones appear to be intercalated with thin andesite flows and tuffaceous sediments. The sediments immediately underlying a flow are seen to be disturbed and baked. In other localities a confusing mixture of sedimentary and volcanic debris may be observed in a single outcrop. (Figure 17). Often it is difficult to apply a field name to any of these rocks, they are so intimately mixed. Sedimentary and volcanic units are incorporated in the same folds in this area and are cut by later dikes which may be feeders of the andesites found in the Lookout breccias. On the geologic map, the Swauk-Temple Mountain contact is arbitrarily placed due to the scale of the mapping and the difficulties involved in tracing the contact which is concealed, for the most part, by soil cover and vegetation. This contact was not observed by the writer in the valley of the Foss West Fork for the latter reason.

The relations between the Temple Mountain andesite and the Snoqualmie granodiorite were observed along Money Creek, the

Figure 16

Photograph taken along Skykomish lookout road showing Swauk arkoses and shales (left), sill (?) of andesitic composition (center) and heterogeneous mixture of sedimentary and volcanic debris (right). Camera is pointing along strike of beds.

Figure 17

Swauk Temple Mountain andesite. Photomicrograph of specimen taken along a left bank tributary of Maloney Creek, 1½ miles south of Skykomish. Specimen contains admixtures of sedimentary and volcanic debris (plane light).

lower slopes of the north end of Maloney Ridge, on the crest of Maloney Ridge south of Wernecke Lakes and at the base of the cliffs northwest of Trout Lake. In most cases this contact is completely gradational. One may walk up the bed of Money Creek of southward along the crest of Maloney Ridge and pass from greenish-gray andesites through as series of hydrothermally altered andesites and into "typical" Snoqualmie granodiorite. The line of demarkation between them is purely arbitrary in these cases.

In specimens taken near the granodiorite-andesite contact in Money Creek the effect of the emplacement of the granodiorite has been an alteration of the feldspars to sericite, the appearance of epidote and chlorite as alteration products of the feldspars and mafics and the development of radial quartz porphroblasts. Some diopside has also been developed.

Along the Skykomish lookout road a short distance from its' lower end, a breccia consisting of angular fragments in a granitic matrix was observed by the writer in several outcrops. The complete relationship of this breccia to the volcanics and the granodiorite was not seen due to vegetation, but it definitely lies in the vicinity of the contact between the two units. A similar breccia was seen on the west side of Maloney Ridge in the vicinity of the same contact.

Lookout breccias: On the northwest spur of Maloney Ridge the Lookout breccias conformably overlie the Temple Mountain andesite and may actually be part (the top member) of it. To the east, however, these breccias overlie the shales and arkoses of the Swauk formation, and although this contact was not seen by the writer, the dip and strike of the flows and breccias compare favorably with those of the underlying sediments. The contact is therefore inferred to be essentially conformable. The sediments below the Lookout breccias on the northeast side of Sobieski Mountain are completely free of volcanic admixtures. This locality is about one mile east of the Maloney Creek valley where the sediments and volcanics (Temple Mountain) are seen intercalated.

Correlation and age: The evidence presented above, and that presented in the discussion of the Swauk formation, suggests that the deposition of these volcanics was, in part, contemporaneous with the deposition of the upper part of the Swauk and continued past the end of Swauk time. On the basis of the age determinations of the Swauk formation these volcanics are inferred to be of Paleocene and possibly of early Eocene age (the two terms are not used synonymously). They certainly represent a more or less continuous period of volcanic activity.

Northwest of the Miller-Foss area, Weaver (1912) has designated the West Index andesitic series which he describes thusly:

> The rocks composing this formation consist of a complex mass of intercalated layers of fine grained andesitic breccias, conglomerates and badly altered lavas. The total thickness. . . is between 2500 and 3000 feet. The rocks are gray, but often have a greenish tint. . . beds are found to contain fragments of quartzite and granite, indicating their partial sedimentary origin. . . . The members of this series grade into each other, but the larger part of the formation is composed of andesitic lava. (Weaver, 1912, p. 45)

From Weaver's description the west Index andesitic series sounds much like the volcanics in the Miller-Foss area. Moreover, the trend of the outcrop belt of the Temple Mountain andesite is toward the vicinity of the outcrop belt of the West Index series. For the above reasons, the writer tentatively correlates the two units. The West Index series dips to the southwest and is in contact with and bounded on the east by a narrow belt of metamorphics. These relationships are exactly the reverse for the Temple Mountain andesite suggesting that the two volcanic units outcrop in complimentary positions on the limbs of a positive northwest trending structure.

Four miles west of the Miller-Foss area in the latitude of Goat Basin, Bethel (1951) has mapped a group of andesitic to rhyolitic volcanics grading into water-laid tuffs which are interbedded with the Calligan formation. He considered these rocks to be of Cretaceous to Paleocene age. Later evidence

(Danner, 1955, oral communication) indicates that the Calligan belongs to the upper Jurassic or earliest Cretaceous, therefore the associated volcanics belong to a time considerably earlier than those in the Miller-Foss area.

The early Tertiary sedimentary-volcanic relations seen by Smith and Calkins (1906) in the Snoqualmie quadrangle have been partly reviewed in the discussion of the Swauk formation. The Kachess rhyolite and other volcanics associated with the Naches formation pass unconformably beneath the Keechelus series and the Yakima basalt. Regarding this episode of sedimentary deposition and volcanism, Smith and Calkins (1906) said:

> The episode of eruptions which the Kachess rhyolite represents began at some time near the middle of the epoch in which the Naches and Swauk formations were deposited. It continued during the latter half of the . . . epoch and for some time after its' close. . . . (p. 5)

On the basis of relations with the Swauk formation, the writer refers the volcanics in the Miller-Foss area to this same period of volcanic activity and not to Keechelus time as was formerly supposed.

These rocks may be equivalent to the early Tertiary volcanics of western Washington referred by Weaver (1944,1945) to the Metchosin (?) volcanics. It should be noted, however, that volcanic rocks are associated with sediments in western Washington thoughout much of Tertiary time, therefore any correlation between the volcanics of the Miller-Foss area and those further west cannot be made with confidence at this time.

Conditions of deposition: As there is evidence indicating that the Swauk arkoses were deposited on a surface of some relief, there is, as might be expected, similar evidence to support the same conclusion regarding the contemporaneous volcanic rocks. Considering the structural relations and the outcrop pattern of the Temple Mountain andesite and the Stillaguamish series in the northwestern part of the area, it is inferred that the relief at the time of the beginning of volcanic activity was somewhat in excess of 2000 feet. This estimate is of comparable magnitude with that made by the writer on the basis of Swauk-Chiwaukum schist relations in the eastern part of the mapped area.

MOUNT STUART GRANODIORITE

Occurence and extent: One of the most important of the Cascade granitic masses outcrops in a wedge-shaped belt in the northeastern corner of the mapped area. It outcrops alternately with the Chiwaukum schist along the Great Northern right of way from the north end of Tonga Ridge eastward to Sawyer Creek, east of which it forms the entire terrain. It may also be seen in several places along the Tye River notably at Alpine Falls near U. S. highway #2.

Although the Mount Stuart granodiorite cuts only a corner of the mapped area it is very extensive to the east and southeast in the Mount Stuart and Chiwaukum quadrangles.

Description: In this area the Mount Stuart granodiorite is a very coarse-grained rock, the mineral constituents are easily seen megascopically, the rock being composed of feldspar, quartz and biotite, the latter occurring in flakes up to ¼ inch in width. Under the microscope the rock is seen to be composed of well over 50 percent soda plagioclase (oligoclase) and 20 to 30 percent quartz, the remainder being made up of orthoclase, biotite plus small amounts of green hornblende. The feldspars are usually turbid and badly fractured across the twinning planes and the quartz grains show somewhat undulating extinction. (Figure 18).

The outcrops are generally light gray in color and present a rough weathering surface due to the weathering of the biotite and feldspar grains and the resulting protrusion of the quartz grains.

Relations: The relationship of the Mount Stuart granodiorite to the Chiwaukum schist is clearly seen along the Great Northern right of way from the north end of Tonga Ridge to Carroll Creek. Here discordant masses of granodiorite are in sharp, burned, intrusive contact with the schist. Acid dikes

Figure 18

Mount Stuart granodiorite. Photomicrograph of specimen taken along Great Northern right of way a few hundred feet east of Sawyer Creek. (X nicols).

associated with the Mount Stuart cut the Chiwaukum schist in this vicinity. The contact metamorphic effects have previously been discussed in connection with the schist.

No Mount Stuart dikes are seen to cut the Swauk formation although they are seen cutting the nearby schist. Moreover, the origin of the boulders occurring in the conglomerates at Carroll Creek (near the base of the Swauk) is confidently taken to be the granodiorite outcropping immediately to the east. The actual contact between the two units was not seen by the writer.

Lupher (1944) strongly doubted the pre-Swauk age of this granodiorite saying:

> . . . the Swauk sandstones. . . are metamorphosed, granitized and also cut by acidic dikes, thus showing a stronger suggestion of an intrusive contact than a depositional one. Certain acidic dikes of the type referred by (G. O.) Smith to the Mount Stuart episode are known to be intrusive in the Swauk formation. (R. L. Lupher, 1944, p. 6).

In the area in which Lupher discussed these relations the Swauk and Mount Stuart are separated by a 2 to 3 mile wide belt of ultr-basic rocks, and are not (as he noted) in contact. Moreover, there is reason to believe that the dikes referred by Smith (1904) to the Mount Stuart episode are associated with the later Snoqualmie granodiorite.

Although the evidence from the Miller-Foss area is not conclusive it strongly suggests that the contact between the

Mount Stuart granodiorite and Swauk formation is a depositional one as initially interpreted by G. O. Smith (1904).

Correlation and age: From the above discussion it is seen that the age of the Mount Stuart granodiorite is post-Chiwaukum schist and pre-Swauk. Even this is unsatisfactory because of the lack of evidence regarding the age of the Chiwaukum schist. Further evidence regarding the age of the granodiorite cannot be found in the Miller-Foss area.

To the east the granodiorite grades into the gneissose rocks described in the Stevens Pass area by Oles (1951) who noted that certain of these gneisses ". . . are identical with rocks occurring in the Entiat Mountains. . ." (p. 38). The regional metamorphism and granitization which produced the rocks in the Entiat Mountains were considered by C. L. Willis (1950) as probably occurring during the Nevadian distrubance. Upon this basis the Mount Stuart granodiorite is usually assigned to that time.

The rocks mapped as Mount Stuart during this investigation were mapped by W. S. Smith (1915), who suggested the name Tye soda granite. Subsequently Pratt (1954) traced the granodiorite from its' type area in the Mount Stuart quadrangle to the Deception Pass fault which, as mapped by Pratt, lies immediately east of the Miller-Foss area. The granodiorite west of the fault he (Pratt) termed Tye soda granite, but noted that the two cannot be separated either megascopically or microscopically.

The validity of this separation, although arbitrary, appears to be highly questionalbe. It is therefore suggested that the term Tye soda granite be discarded in favour of the older and more established term Mount Stuart granodiorite.

Correlation between the Mount Stuart and Index granodiorites, although made repeatedly in the literature, cannot be urged. As initially described by Weaver (1912) the Index granodiorite was thought to be pre-Tertiary in age, but recent conversations with people working with the field relations of this mass suggest that it may belong to the Tertiary.

Mode of emplacement: In the Miller-Foss area field relations indicate that the Mount Stuart granodiorite is intrusive. It should be realized, however, that this conclusion is based on only a few outcrops in a limited area and certainly does not necessarily hold true for the entire masss.

A few Miles to the east of the mapped area Oles (1951) has postulated a metasomatic origin for the granodioritic gneisses which are gradational with the granodiorite outcropping along the lower Tye River. Along U. S. highway #2, east of the area widespread migmititic zones are seen where all gradations between Chiwaukum schist and granodiorite may be found.

Future mapping of these rocks and more detailed petrographic studies may well show that the Mount Stuart granodiorite may owe its' great areal extent to both igneous and metasomatic processes.

SNOQUALMIE GRANODIORITE

Occurrence and extent: Occupying the southwestern third of the area mapped during this investigation the Snoqualmie granodiorite is one of the most extensive granitic masses in the Cascade Mountains. It has been mapped as far south as the Mount Rainier area (Coombs, 1936) and its' associated dikes have been recognized as far north as the Monte Cristo region (Spurr, 1900).

The best outcrops in the Miller-Foss area may be seen along the Miller West Fork, in Goat and Coney basins and in the vicinity of Trout, Malachite and Copper lakes. It forms the rugged terrains of Lennox Mountain, Cascade Mountain and the southern part of Maloney Ridge.

The granodiorite is seen to extend southward beyond the headwaters of the Foss and Miller rivers and northward across the Skykomish South Fork to the High country west of the Beckler River. It also continues westward into the Sultan quadrangle where it has been mapped by Bethel (1951).

Description: The Snoqualmie granodiorite forms impressive cliffs. Outcrops are generally gray in color and can easily be mistaken for Swauk arkose at a distance. Jointing is always well developed in several directions, the result being many overhanging cliffs and the production of great quantities of talus.

Perhaps the most striking feature of this granitic mass is its'apparent homogeneity in composition. With the exception of the border phases the lithology universally encountered in the Miller-Foss area is a medium-grained, black and white holocrystalline rock composed of 60 to 70 percent plagioclase (andesine) and 10 to 15 percent quartz, with orthoclase and biotite being the other primary constituents. (Figure 19). Traces of both hornblende and magnetite are usually found. The mafics often occur in small clusters although individual crystals are disseminated throughout the rock. The granodiorite is nearly always fresh looking and rarely is alteration seen in any of the mineral constituents.

Aplite dikes up to one foot in width often cut the granodiorite, but aplitic bodies of the type mapped by W. S. Smith (1915) were not seen by the writer.

Two important departures from this apparent homogeneity are seen near the borders of the mass. Along Money Creek, just

Figure 19

Snoqualmie granodiorite. Photomicrograph of specimen taken from Coney Basin. This is the typical lithology for this unit in the mapped area. (X nicols).

west of the entrance to Goat Basinthere outcrops a lithology identified by the writer as granite porphyry. (Figure 20). This rock is composed of orthoclase and plagioclase pheoncrysts in more or less equal numbers, lying in a ground mass of quartz and feldspar. Mafics make up less than 5 percent of the rock and a trace of magnetite is also seen.

A more common border phase is noticeably finer-grained and richer in mafic constituents, mainly hornblende, than the "typical" lithology. It also has a higher content of potash feldspar. This rock is greenish-gray in color and occasionally has orthoclase phenocrysts up to 5 millimeters long in it. The plagioclase is andesine, occurring in small euhedral laths. (Figure 21).

Although these variations were noted by the writer near the borders of the mass, the Snoqualmie granodiorite in this area is, for the most part, of the first lithology described.

Relations: The only sharp contact observed by the writer involving the granodiorite is apparently a fault contact between it and the Stillaguamish series. This is exposed along the south side of the Money Creek valley just east of the entrance to Goat Basin. Danner (oral communication) however, has observed this contact to be intrusive to the north.

The relationship of the granodiorite to the Tertiary

Figure 20

Snoqualmie granodiorite -- granite porphyry. Photomicrograph of specimen taken from the bed of Money Creek near the entrance to Goat Basin. (X nicols).

Figure 21

Snoqualmie granodiorite - fine-grained border phase. Photomicrograph of specimen taken from outcrop ¼ mile from bottom of Skykomish lookout road. (X nicols).

volcanics and Swauk formation is one of complete gradation. The primary effects of the emplacement of the granodiorite into these units has been a hydrothermal alteration of the feldspars and mafics to sericite, epidote and chlorite, and the recrystallization of quartz. One may pass from granodiorite into volcanics or sandstone without crossing any defined contact. It appears that no appreciable chemical change was fostered in the pre-existing rocks by the emplacement of the Snoqualmie mass. The effect is one of hydrothermal alteration.

About ½ mile south of the town of Skykomish and along the lookout access road a breccia was encountered by the writer in the vicinity of the granodiorite-volcanic contact. This breccia consists of angular bluish-green fragments of andesitic composition up to three inches across, lying in a granodioritic matrix. The contact between the fragments and the matrix is not sharp and projections of the matrix are found in some of the fragments. Porphroblasts of potash feldspar have also been developed within some of the fragments. (Figure 22).

A similar type of breccia was found in one outcrop on the west side of Maloney Ridge about a mile west of Wernecke Lakes. The origin of these breccias may be due to processes similar to those discussed by Goodspeed and Coombs (1937) with regard to the Keechelus series, but more outcrops would need be found and

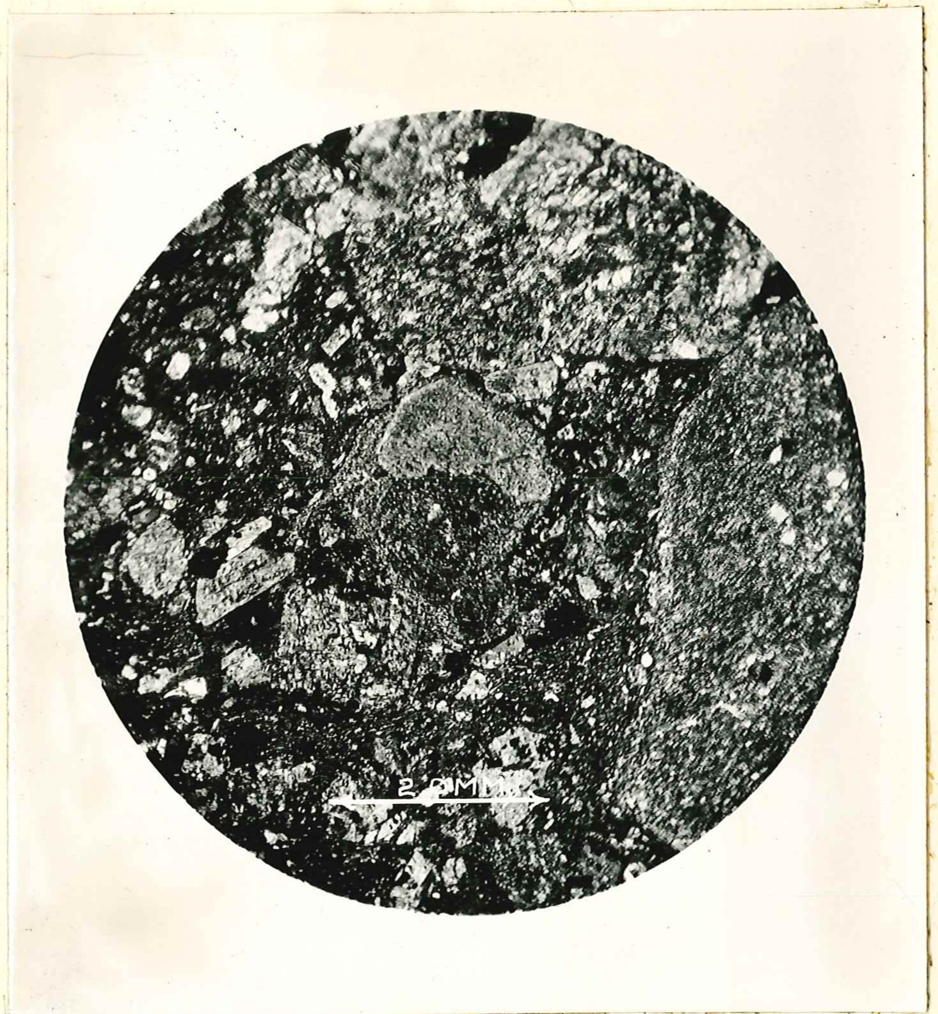


Figure 22

Snoqualmie granodiorite-breccia. Photomicrograph of specimen taken from Snoqualmie granodiorite-Temple Mountain andesite contact zone ½ mile south of Skykomish. (X nicols).

a great deal of petrographic work done before this explanation could be supported by conclusive evidence.

In the vicinity of Trout Lake several migmititic looking boulders are seen. A search conducted by the writer along the base of the cliffs above the lake to the west failed to produce any outcrops where these boulders may have originated. About ¾ mile above Trout Lake on the Copper Lake trail the writer encountered several outcrops of hornfelsic material in which pods and stringers of turbid orthoclase and quartz are seen. This rock may represent a migmititic border zone or a zone of contact metamorphism between the granodiorite and volcanics; but the writer is inclined to treat these exposures as boulder talus or landslide boulders. A search was also conducted along the base of the cliffs above and some similar talus was observed. In all probability these types came from the crags above which were impossible for the writer to scale alone.

On the southeast flank of Bald Eagle the contact between the Snoqualmie granodiorite and the Swauk formation, although better defined than any of those to the north is far from sharp. Here the Swauk is noticeably well indurated and somewhat recrystallized in a zone several hundred feet in width passing gradationally into the granodiorite.

<u>Correlation and age</u>: The Snoqualmie granodiorite was

initially named and described by Smith and Calkins (1906) in the Snoqualmie quadrangle to the south. On the basis of its' intrusive relations with the Guye formation and Keechelus series of Miocene age, its' age was considered as late Miocene or post-Miocene. The age determinations of the Guye and Keechelus have since been questioned by many workers. Recently, after a more detailed study of the relationships in the Snoqualmie Pass area, Foster (1955) has assigned an Eocene (probably upper Eocene) age to the Guye formation (restricted) on paleobotanical evidence, suggests that the base of the Keechelus may be as old as Eocene and that the Snoqualmie granodiorite is probably Eocene or Oligocene.

The Snoqualmie granodiorite is the youngest unit outcropping in the Miller-Foss area. The next youngest units are the early Tertiary volcanics. On this basis the emplacement of the granodiorite may be considered Eocene of later.

The writer has traced the Snoqualmie granodiorite from the Miller-Foss area southward to within two miles of the Skykomish-Snoqualmie quadrangle border. W. S. Smith (1915) mapped it to this boundary. According to the map of Smith and Calkins (1906) it is continuously exposed from this boundary to the type area near Snoqualmie Pass.

<u>Mode of emplacement</u>: The lack of evidence for magmatic

stoping and the presence of migmititic zones near the border of the Snoqualmie granodiorite lead Bethel (1951) to postulate a metasomatic origin for this granitic mass. On the other hand the writer has seen some of the definitely intrusive contacts mapped by Coombs (1936) in the Mount Rainier area. In the course of recent conversations with Mr. R. C. Ellis (who is working in the area immediately south of the Miller-Foss area) the writer has been informed that the Swauk-Snoqualmie contact a few miles to the south is intrusive in nature.

There is apparently in the Miller-Foss area the beginning of a change in contact relations, the contacts being wholly gradational in the northern part of the mapped area and less so on the southeast flank of Bald Eagle.

REGIONAL STRUCTURE

The area mapped during this investigation lies astride a northwest trending downwarp which apparently plunges northwest. The axis of this structure is located approximately through the center of the area, running through Alturas Lake in the valley of the Foss East Fork and crossing the Miller River at its' mouth. The Skykomish South Fork appears to follow this axis between the towns of Skykomish and Index.

In the central part of the area (i.e., in the trough of the downwarp) the Tertiary rocks have been thrown into a series of folds which die out downward. These folds are of too small a magnitude to be shown on the geologic map. Eastward the Tertiary rocks dip homoclinally southwest off the Wenatchee (Skykomish) uplift. Westward the early Tertiary volcanics dip northeast to northward off another uplift which is largely obscured by the Snoqualmie granodiorite. This broad regional warping, accompanied by local folding probably predates the emplacement of the Snoqualmie grandiorite.

Evidence for major faulting was not seen by the writer in this area, however, minor faults were seen involving both the Tertiary and metamorphic rocks. These faults may be seen only at scattered outcrops and are not traceable further. They have no common trend and cannot be assigned to any given period of time.

CONCLUSIONS AND GEOLOGIC HISTORY

The complete geologic history of the Cascade Range can obviously not be deciphered from an area as small as that mapped during this investigation. Considerable field study will be required to solve the many problems which have become apparent with regard to the geologic framework of these mountains. As a result of this investigation, however, the writer has reached the following conclusions:

1. There is no evidence to indicate that the Chiwaukum schist is older than the Stillaguamish series. The two units are not in contact and are largely of different lithologies, thus the degree of metamorphism seems to be a rather unsatisfactory basis for the determination of their relative ages. The Chiwaukum schist is pre-Mount Stuart is age.
2. The problem of the age of the Stillaguamish series is somewhat stalemated. The evidence presented by W. S. Smith (1916) for an Ordovician age of these rocks cannot be checked. The evidence presented by Danner (oral communication) indicates a Permian age. The bedrock relations in the Miller-Foss area only indicate these rocks to be pre-Tertiary.
3. The rocks mapped by W. S. Smith (1915, 1916) as Tye soda

granite are part of the Mount Stuart granodiorite mass. The term Tye soda granite should therefore be discarded in favour of the earlier and more established nomenclature.

4. The Mount Stuart granodiorite is post Chiwaukum schist and pre-Swauk in age, indicating its' age as pre-Tertiary as originally stated by George Otis Smith (1904).
5. The upper part of the Swauk formation is intercalated with volcanic rocks. Westward, the volcanics apparently replace stratigraphically the upper part of the Swauk formation. Some of these volcanics, however, lie essentially conformable on the Swauk, suggesting that volcanic activity to the west was, in part, contemporaneous with the closing stages of Swauk deposition and persisted after the end of Swauk time.
6. The Swauk formation is at least 10,000 feet thick in the Miller-Foss area, a figure considerably greater than that given by G. O. Smith (1904) for the type area or by W. S. Smith (1916) for the Skykomish Basin.
7. Swauk-volcanic relations indicate that the volcanic rocks outcropping in the Miller-Foss area are of an earlier age than previously thought, and are not correlatable with

with the Keechelus andesitic series of Smith and Calkins (1906).

8. The Snoqualmie granodiorite is definitely younger than the Swauk formation and the volcanic rocks in the Miller-Foss area. Judging from the thickness and attitude of the sediments and volcanics, they would have covered most of this area had it not been for the emplacement of the Snoqualmie granodiorite.

Deciphering the pre-Tertiary geologic history of the Miller-Foss area is somewhat confused by the lack of data indicating the relative ages of the Stillaguamish series and Chiwaukum schist. It is further complicated by the conflict of data regarding the position of the Stillaguamish series within Paleozoic time. However, the evidence indicates that during most part of the mid to late Permian, the region was characterized by a marine environment in which sands, limes and small amounts of argillaceous material were deposited. Whether the black shales, from whence came the Chiwaukum schist, were laid down previous to the sands and limes or later, is not known. The age of the metamorphism of these rocks is not known, but may well be Mesozoic.

The latter part of Mesozoic time was apparently characterized by regional metamorphism and the emplacement of the Mount

Stuart granodiorite and associated rocks. This was followed by a period of erosion exposing the granitic rocks and parts of the metamorphic complex.

Late in the Cretaceous period a continental basin of subsidence and accumulation developed trending north to northwest across the region now occupied by the central Cascade Mountains. This basin was apparently bounded on the east by a granitic highland and later on the west by a region of volcanic activity. Accumulation of Swauk sediments in this basin may have continued to early Eocene time. Later the sediments and volcanics deposited in this basin were uplifted and folded into a series of northwest-southeast trending broad warps which was accompanied by local folding of a smaller magnitude. Subsequent to this warping the Snoqualmie granodiorite was emplaced.

The only evidence in the Miller-Foss area regarding the events of the later Tertiary lies in the geomorphic history of the area. Prior to the uplift of the Cascade Range a mature surface of erosion was produced. The cycle of erosion was interrupted by the uplift of the Cascade Mountains along a north-south axis probably in late Tertiary time. The youthful topography resulting from this uplift was severely modified by glaciation during Pleistocene and recent time.

LIST OF PLATES AND FIGURES

REFERENCES CITED

Bradley, J. S. (1950), "Upper Cretaceous-Eocene Nanaimo group of the San Juan Islands," G. S. A. Bulletin, v. 61 #2, part 2, p. 1520. (Abstract).

Cary, A. S. & Carlston, S. W. (1937), "Notes on Vashon stage glaciation of the South Fork of the Skykomish River valley, Washington," Northwest Science, V. 11, #3 p. 61-62.

Chappell, W. M. (1936) "Geology of the Wenatchee quadrangle, Washington," University of Washington, Doctorate thesis.

Coombs, H. A. (1936), "Geology of Mount Rainier National Park," University of Washington, Doctorate thesis.

Coombs, H. A. (1950), "Granitization of the Swauk arkose near Wenatchee, Washington," American Journal of Science, V. 248, p. 369-377.

Foster, R. J. (1955), "A Study of the Guye formation," University of Washington, M. S. thesis.

Goodspeed, G. E. & Coombs, H. A. (1937), "Replacement breccias in the lower Keechelus," American Journal of Science, 5th ser. V. 34 #199, p. 12.

Lupher, R. L. (1944), "Stratigraphic aspects of the Blewett-Cle Elum iron ore zone, Chelan and Kittitas Counties, Wash." Washington State Dept. of Conserv. & Dev., Div. of Geology, Rept. of Invest. 11.

Oles, K. F. (1951), "The Petrology of the Stevens Pass-Nason Ridge area, Washington," University of Washington, M. S. thesis.

Page, B. M. (1939), "The Geology of the Southeastern quarter of Chiwaukum quadrangle., Stanford University, Doctorate thesis.

Pratt, R. M. (1954), "Geology of the Deception Pass area, Chelan, King and Kittitas Counties, Washington," University of Washington, M. S. thesis.

Russell, I. C. (1893), "A Geological Reconnaissance in Central Washington," U. S. G. S. Bulletin #108, p. 5-108.

Russell, I. C. (1899), "A Preliminary Paper on the Geology of the Cascade Mountains in Northern Washington," U. S. G. S. 20th annual report, V. 2, p. 85-210.

Smith, G. O. (1903), "Geology and Physiography of Central Washington," U. S. G. S. Professional Paper #19, p. 9-39.

Smith, G. O. (1904), "Description of the Mount Stuart quadrangle," U. S. L. G. S. Geologic Atlas, folio #106.

Smith, G. O. & Calkins, F. C. (1906), "Description of the Snoqualmie quadrangle," U. S. G. S. Geologic Atlas folio #139.

Smith, W. S. (1915), "Petrology and Economic Geology of the Skykomish Basin, Washington," (Columbia) School of Mines Quarterly, V. 36, p. 154-185.

Smith, W. S. (1915), "Stratigraphy of the Skykomish Basin, Washington", Journal of Geology, V. 24, p. 559-582.

Smith, W. S. (1917), "Physiography of the Skykomish Basin, Washington" U. S. G. S. 22nd annual report, part 2, p. 205-213.

Spurr, J. W. (1900), "Ore Deposits of Monte Cristo, Washington" U. S. G. S. 22nd annual report, part 2, p. 777-865.

Thompson, M. L., Wheeler, H. E., & Danner, W. R. (1950), "Middle and Upper Permian Fusulinids of Washington and British Columbia," Contributions from the Cushman Foundation for Foraminiferal Research, V. I, parts 3 & 4.

United States Weather Bureau (1945-1954), Climatological Data, Washington Section, V. 49-58.

Valentine, G. M. (1949), "Inventory of Washington Minerals, Part I - Non-metallic minerals", Wash. State Dept. of Conserv. & Development, Div. of Geology, Bulletin 37.

Waters, A. C. (1930), "The Geology of the Southern Half of the Chelan Quadrangle, Washington," Yale University, Doctorate thesis.

Waters, A. C., (1939), "Resurrected Erosion Surface in Central Washington" G. S. A. Bulletin, V. 50, p. 635-666.

Weaver, C. E. (1911), "The Blewett Mining District, Washington" Washington Geological Survey, Bulletin #6.

Weaver, C. E. (1912), "Geology and Ore Deposits of the Index Mining District," Washington Geological Survey, Bulletin #7.

Weaver, C. E., (1916), "The Tertiary Formations of Western Washington," Washington Geological Survey, Bulletin #13, p. 5-327.

Weaver, C. E. (1937), "Tertiary Stratigraphy of Western Washington and Northwestern Oregon," Univ. of Wash. Pub. in Geology V. 4.

Weaver, C. E. (1942), "Marine Tertiary of Western Washington and Western Oregon," University of Wash. Pub. in Geology, V. 5.

Weaver, (1945), "Geology of Oregon and Washington and its' relation to the occurrence of oil and gas," Bulletin A.A.P.G. V. 29, p. 1377-1415.

Weaver, et. al., (1944), "Correlation of Marine Cenozoic Formations of Western North America," Bulletin G.S.A., V. 55, #5.

Willis, B. (1903), "Physiography and Deformation of the Wenatchee-Chelan District, Cascade Range," U.S.G.S. Professional Paper #19, p. 43-101.

Willis, B., (1939), "Discussion of Resurrected Erosion Surface in Central Washington," Bulletin G.S.A., v. 50, p. 658-659.

Willis, B. & Smith, G. O. (1899), "Description of the Tacoma quardrangle," U.S.G.S. Geologic Atlas folio #54.

Willis, C. L. (1950), "Geology of the Northeastern Quarter of Chiwaukum Quadrangel, Washington", University of Washington, Doctorate thesis.

GEOLOGIC SECTIONS OF THE MILLER-FOSS RIVER AREA

KING COUNTY, WASHINGTON

1955

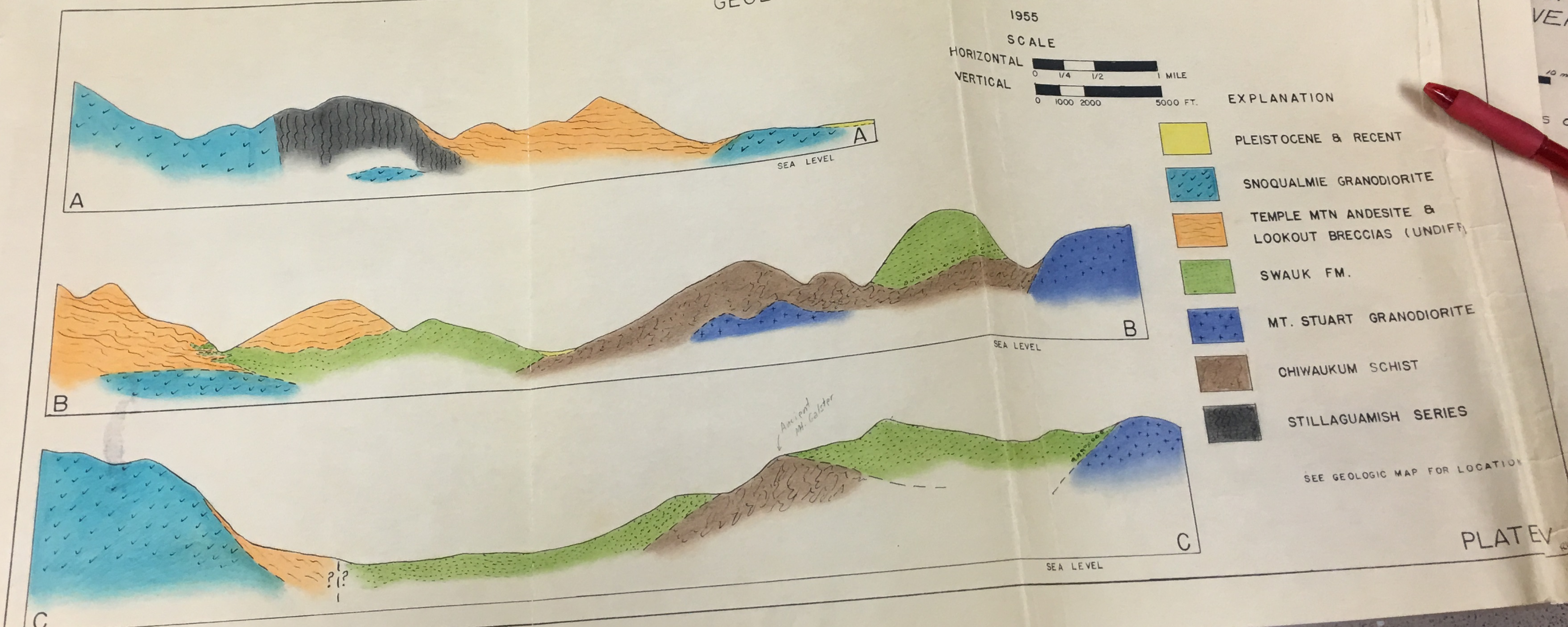
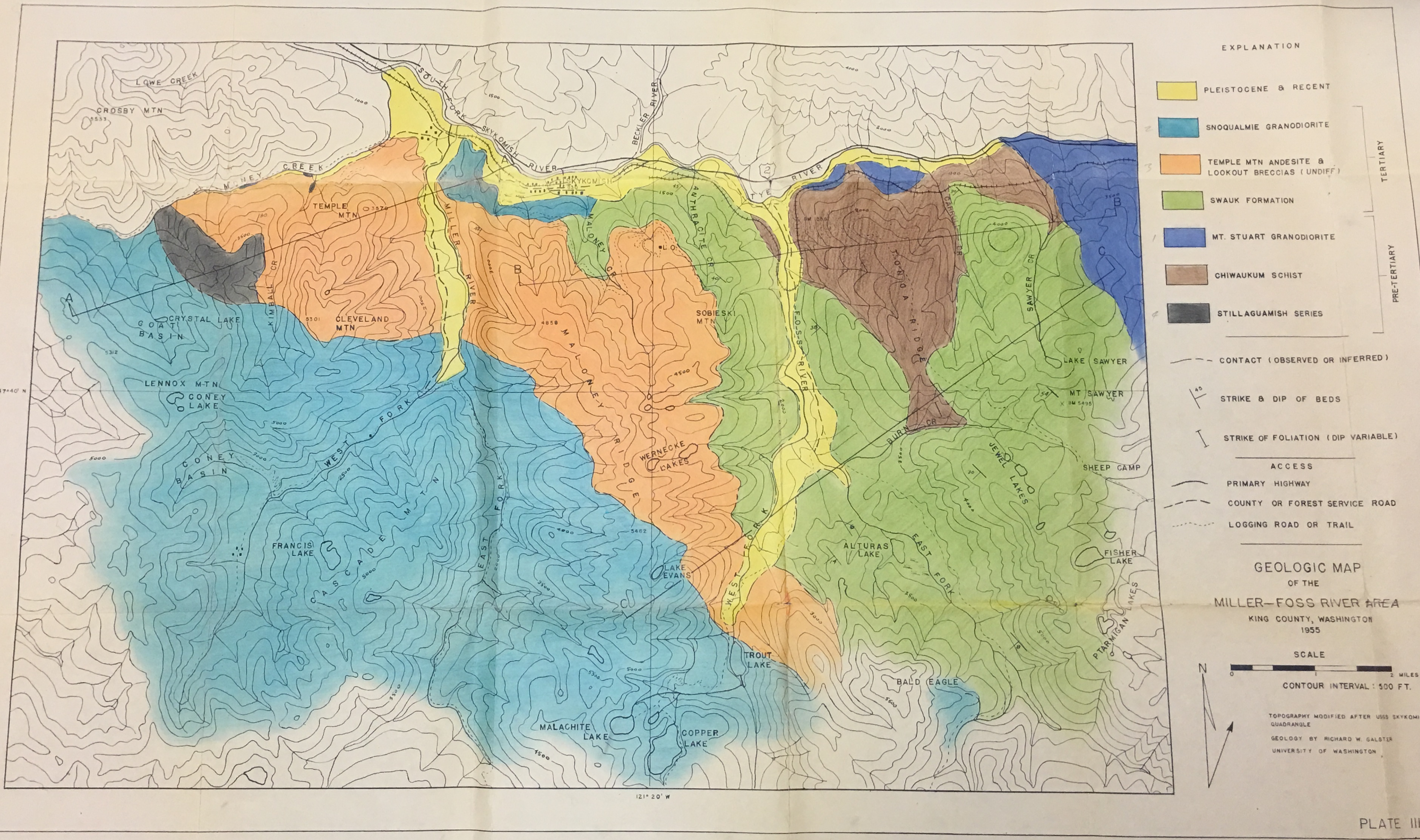
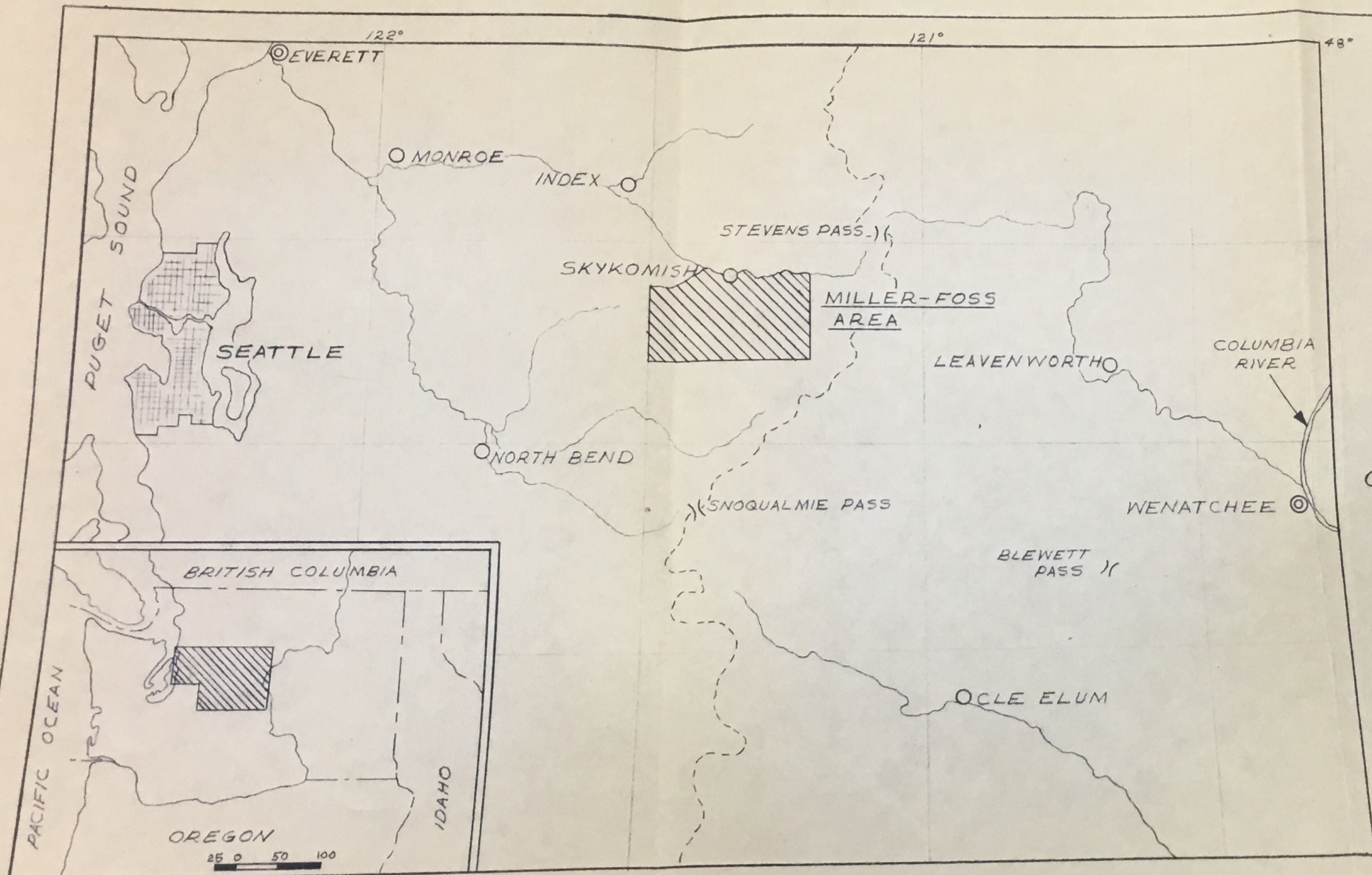


PLATE V


EXPLANATION
PLEISTOCENE & RECENT
SNOQUALMIE GRANODIORITE
TEMPLE MTN ANDESITE & LOOKOUT BRECCIAS (UNDIFF)
SWAUK FORMATION
TERTIARY
MT. STUART GRANODIORITE
CHIWAUKUM SCHIST
STILLAGUAMISH SERIES
PRE-TERTIARY
CONTACT (OBSERVED OR INFERRED)
STRIKE & DIP OF BEDS
STRIKE OF FOLIATION (DIP VARIABLE)
ACCESS
PRIMARY HIGHWAY
COUNTY OR FOREST SERVICE ROAD
LOGGING ROAD OR TRAIL
GEOLOGIC MAP
OF THE
MILLER—FOSS RIVER AREA
KING COUNTY, WASHINGTON
1955
SCALE
0 1 2 MILES
CONTOUR INTERVAL : 500 FT.
N
TOPOGRAPHY MODIFIED AFTER USGS SKYKOMISH QUADRANGLE
GEOLOGY BY RICHARD W. GALSTER
UNIVERSITY OF WASHINGTON
LOWE CREEK
CROSBY MTN
SOUTH FORK SKYKOMISH RIVER
BECKLER RIVER
TYE RIVER
SKYKOMISH
TEMPLE MTN
CLEVELAND MTN
CRYSTAL LAKE
GOAT BASIN
LENNOX MTN
CONEY LAKE
CONEY BASIN
WEST FORK
FRANCIS LAKE
CASCADE MTN
EAST FORK
MILLER RIVER
MALONEY CR
MALONEY RIDGE
SOBIESKI MTN
WERNECKE LAKES
LAKE EVANS
TROUT LAKE
MALACHITE LAKE
COPPER LAKE
ANTHRACITE CR
FOSS RIVER
TONGA RIDGE
BURN CR
ALTURAS LAKE
JEWEL LAKES
LAKE SAWYER
MT SAWYER
SAWYER CR
SHEEP CAMP
FISHER LAKE
PTARMIGAN LAKES
BALD EAGLE
47°40' N
121° 20' W
PLATE III



N

INDEX MAP
OF THE
STATE OF WASHINGTON
AND
CENTRAL CASCADE MOUNTAINS
SHOWING THE LOCATION OF THE
MILLER-FOSS RIVER AREA

SCALE
3 0 5 10 miles

DASHED LINE INDICATES CASCADE DIVIDE

PLATE I