A STUDY OF THE GUYE FORMATION, SNOQUALMIE PASS, KING AND KITTITAS COUNTIES, WASHINGTON

by

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INTRODUCTION

PURPOSE

The purpose of this work was to study the Guye formation, a complex stratigraphic unit designated by Smith and Calkins in the Snoqualmie Folio in 1906. At that time the Guye was dated as Miocene on paleobotanical evidence and this age was used to date the Keechelus series and the Snoqualmie granodiorite. In turn the widespread Keechelus series was used to date the stratigraphy of much of the middle Cascades. Recent work had indicated that some of these age determinations were not correct. Therefore, this study was undertaken in order to date accurately the Guye formation and to determine its relations with the Keechelus series and the Snoqualmie granodiorite.

LOCATION

The area covered in this report is in the northwest corner of the Snoqualmie Quadrangle, Washington, and lies on the boundary between King and Kittitas Counties. At approximately the center of this area, U.S. Highway 10 crosses the Cascades at Snoqualmie Pass. The crest of the main Cascade Range crosses this area in a southwest-northeast direction and divides the area roughly in half. Snoqualmie Pass is approximately fifty miles east of Seattle on U.S. Highway 10. The approaches to the Snoqualmie Pass region from other points in Washington are best shown on the index map.

Fig. 2. View north from Silver Peak toward Snoqualmie Pass. Snoqualmie Mountain is the high peak in the left background.

Fig. 3. View south from Snoqualmie Mountain. Snoqualmie Pass is in the foreground; Silver Peak in right background. Mt. Catherine is the ridge to the left of the center background. The low ridge in the middle ground is composed of Guye formation.

SUMMARY AND CONCLUSIONS

The Guye formation as originally designated by Smith and Calkins has been found by the writer to be of at least four rock types, probably of different ages. The oldest, a series of metamorphosed limestones, limy hornfelses, and basalts, is here designated the Sunset formation. The name, Guye formation, is restricted to the conglomerates and carbonaceous shales that contain upper Eocene plant fossils. The third part is the Kendall formation, a local clastic unit, which has been tentatively placed within the Keechelus series. The fourth rock type is the previously unreported rhyolite bodies which have been named the Mt. Catherine rhyolite. These rhyolites have been found to be extrusive at at least one locality, and are apparently related to the Snoqualmie granodiorite.

A brief study of the Snoqualmie granodiorite has shown it to be a complex of granitic rocks apparently intrusive into both the restricted Guye and the Lower Keechelus formations and thus is younger than upper Eocene.

METHODS

The mapping was done by Brunton and Pace using enlarged copies of the Snoqualmie quadrangle topographic sheet. Aerial photographs were available for study; however they could not be taken into the field so their main use was in correcting the map.

These investigations were carried out on weekends during the field seasons of 1953 and 1954. Petrographic study was done during the spring and summer of 1954 at the University of Washington.

ACKNOWLEDGEMENTS

This investigation was made possible by the cooperation of many people. Dr. Howard A. Coombs of the Geology Department of the University of Washington suggested the problem and advised the author during all phases of the investigation. The Washington State Highway Department provided maps of the road construction carried on in this area. The Chicago, Milwaukee, St. Paul and Pacific Railroad opened their files on the construction of the Snoqualmie Tunnel. The Seattle Headquarters of the Snoqualmie National Forest graciously allowed the author the use of aerial photographs of the region. Dr. Roland W. Brown of the United States Geological Survey National Museum studied the author's fossil leaf collections and dated them. This accurate date for the Guye formation is one of the major results of this study.

GEOGRAPHY

The features referred to in this section can be located on the geologic map.

The principal industry of the area is providing recreational facilities for sportsmen. It is the nearest ski area to the city of Seattle, and in the summers it is frequented by fishermen and hikers. Some lumbering also is carried on in this region. The only settlement is the town of Hyak at the eastern entrance of the railroad tunnel, where a few families

earn a living by maintaining the railroad facilities.

RELIEF AND ELEVATION

The elevation varies between about 2500 feet in the valley of the South Fork of the Snoqualmie River to 6270 feet at the summit of Snoqualmie Mountain. Most of the mountains in the vicinity are 5000 to 6000 feet in elevation and the valleys range between 2500 feet and 3000 feet. Thus the average relief is 2500 feet and the total relief is approximately 3800 feet.

TOPOGRAPHY

The most striking feature in this area is the immense amount of glaciation which must have occurred in the very recent past. All of the valleys are U-shaped with large cirques at their heads. The major valleys, such as Gold Creek, show these effects of recent glaciation, and the sides are cliffs approximately 2000 feet high with good rock exposures.

The higher peaks in the region occur to the north of Snoqualmie Pass and for the most part are carved from Snoqualmie granodiorite and the metamorphosed Sunset formation. South of Snoqualmie Pass, the Guye formation outcrops and its landforms are more subdued because it is less resistant to erosion. The ridge of Guye formation running south from Snoqualmie Pass is an example of this.

DRAINAGE

In the area under study, the main Cascade crest forms the divide between two major river systems; to the west is

the drainage of the South Fork of the Snoqualmie River, and to the east is the drainage of the Yakima River. A brief examination of the topography suggests that the present drainage is very young. The portion of the Snoqualmie River that suddenly swings back toward the northwest immediately northwest of Snoqualmie Pass lines up very strikingly with Coal Creek which flows southeasterly into Lake Keechelus.

The present drainage was probably formed by the diversion of the northwest portion of the Snoqualmie River and Commonwealth Creek to the South Fork of the Snoqualmie River. Commonwealth Creek above where it joins the South Fork of the Snoqualmie River is apparently a hanging valley as there is a steep gorge between the valley of the Snoqualmie River and the relatively flat glacial valley of Commonwealth Creek.

Denny Creek valley is a strikingly beautiful valley showing much of the history of the region. It is a U-shaped glacial valley which has recently been deeply incised by the present river as much as two hundred feet in some areas, and contains many spectacular waterfalls. This deep cutting has apparently been caused by the recent changes in base-level brought about by the above mentioned diversion and because Denny Creek flows in a hanging valley.

The upper reaches of Rockdale Creek show the effects of the glaciation in a much different manner. The creek heads in a small lake on the eastern side of the divide. After leaving this lake the creek runs north to another lake and

then south to a third lake and finally turns west, cuts through the ridge, and flows to the South Fork of the Snoqualmie River. This very circuitous route has apparently been caused by lateral moraines on the eastern side of the ridge.

ROCK EXPOSURES

This area receives a very heavy precipitation in the form of rain and snow. As a result of this, a luxuriant vegetation covers the area except on the ridge tops and the severely glaciated areas both of which occur, for the most part, above 5000 feet. Therefore good outcrops are to be found only in highway and railroad cuts and in exposed or glaciated areas.

PREVIOUS WORK

The first mapping in the Snoqualmie Pass region was probably done by the early railroad surveys. In 1883 the Northern Pacific Railroad built its main line over Stampede Pass, immediately south of Snoqualmie Pass. In 1889, Washington was admitted as a state, and the main mapping of the Cascades by the United States Geological Survey began. The three folios and numerous papers that were written in this

period are the classical studies of Cascade geology.[1] This work was culminated in 1906 with the publication of the Snoqualmie Folio.

The Snoqualmie Pass region was visited by parties of the United States Geological Survey during the summer of 1895. At that time Bailey Willis made the original fossil leaf collection from the Guye shales which were subsequently identified as Miocene by Frank Knowlton of the United States Geological Survey.[2] This date did not appear correct to Smith and Calkins nor to any of the later workers in the Cascades.

In 1900, Smith and Mendenhall in a preliminary paper discussed the relationships of the Snoqualmie granodiorite and the as yet unnamed Guye and Keechelus formations. They concluded that the granodiorite was of Tertiary age because it

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1. This list includes only papers on the central Cascades.

   Willis, B., 16th Annual Report, USGS, Pt. 1, p. 667, 1894-5

   Russell, I.C., Preliminary Paper on the Geology of the Cascade Mountains in Northern Washington, 20th Annual Report, USGS, Pt. 2, pp. 63-210, 1899-00.

   Smith, G.O. and Calkins, F.C., Gold Mining in Central Washington, USGS Bulletin 213, Contributions to Economic Geology, 1902

   Smith, G.O., Ellensburg Folio, Washington, Geologic Atlas of the United States, USGS, 1903

   Smith, G.O., Mt. Stuart Folio, Washington, Geologic Atlas of the United States, USGS, 1904.

   Smith, G.O. and Calkins, F.C., Snoqualmie Folio, Washington, Geologic Atlas of the United States, USGS, 1906

2. Smith, G.O. and Mendenhall, W.C., Tertiary Granite in the Northern Cascades, GSA, Vol. 11, pp. 224-226, 4-7-1900

intruded the Guye sediments that contained the Miocene leaves mentioned above.[3] Brief mention of Guye sediments was made in several reconnaissance reports at that time.[4] This work was brought to a conclusion in 1906 with the publication of the above mentioned Snoqualmie Folio. In this work, Smith and Calkins described the Guye formation as made up of detrital rocks with some chert and limestone and interbedded basalts and rhyolite with the Snoqualmie granodiorite intrusive into it and the Keechelus andesitic series overlying it.[5]

Since that time there has been little work done on the Guye formation itself. Beck, in 1934, described some of the leaves in the Guye formation as of Eocene age.[6] In 1941, Warren quoted Roland Brown of the United States Geological Survey as dating the Guye flora as Eocene on the basis of a restudy of the original leaf collection that had been made in 1895 by Bailey Willis.[7] In the meantime, there have been a

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3. Ibid., pp. 224-229.

4. Russell, I.C., op. cit., pp. 62-210.

   Willis, B., op. cit., p. 667.

5. Smith, G.O., and Calkins, F.C., Snoqualmie Folio, p. 7.

6. Beck, C.F., Tertiary Floras of Central Washington, Northwest Science, Vol. VIII, p. 3, September 1934 (abstract).

7. Warren, W.C., The Relation of the Yakima Basalt to the Keechelus Andesitic Series, Journal of Geology, Vol. 49, p. 810, 1941.

number of papers published on Cascade geology, many of which discussed the Guye formation, but no one has included any original work on the Guye formation.[8]

DESCRIPTION OF THE ROCK TYPES AND THEIR OCCURRENCE

In this section each of the rock units will be described and their field relations discussed. The distribution of outcrops is shown on the accompanying geologic map. On this map only the outcrops seen during this study are shown in color. The contacts are colored to aid in reading the map. It is hoped that this plan will separate the data from the interpretation and thereby aid future workers in this region.

THE SUNSET FORMATION

The name Sunset formation has been given to the oldest rocks of Smith and Calkins' Guye formation. Because of the excellent exposures uncovered by the recent highway construction on the Sunset Highway, U.S. 10, west of Snoqualmie Pass it has been possible to separate these rocks from Smith and Calkins' Guye formation. The name Guye has been restricted

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8. Coombs, H.A., The Geology of Mt. Rainier National Park, University of Washington Publications in Geology, No. 2, 1936.

Warren, W.C., The Tertiaries of the Washington Cascades, Pan-American Geologist, 1938.

Weaver, C.E., Geology of Oregon and Washington in Relation to Gas and Oil, Am. Assoc. of Pet. Geol., Vol. 29, pp. 1377-1415, 1945.

in this paper to the Eocene clastic rocks of Smith and Calkins' Guye formation.

Occurrence and Field Relations

The Sunset formation, as shown on the geologic map, extends from the region north of Silver Peak all the way to Denny Mountain. It also outcrops in the Guye Peak-Snoqualmie Mountain area, and from there probably extends to the Red Mountain-Lundin Peak area. Metamorphic rocks also appear in the northwestern part of the map and apparently extend along Chair Peak to Denny Mountain. These include Bethel's Wildcat metamorphics[9] which have been shown as Sunset on the map although the exact relationship is not known. The Sunset formation also outcrops in the area north of Kendall Mountain where Smith and Calkins reported altered basalts.

The extent of the Sunset is not known for its base has apparently been removed by the emplacement of the Snoqualmie granodiorite and it is overlain, probably unconformably, by the Guye formation. Included in the Sunset are several rock types, perhaps of different ages, that could not be conveniently differentiated because of the few outcrops, and because all of the rocks are thermally metamorphosed by the emplacement of the Snoqualmie granodiorite. Therefore all rocks older than the restricted Guye formation have been grouped together as the Sunset formation. The principal rock types in the Sunset

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9. Bethel, R.L., Geology of Southeast Sultan Quadrangle, University of Washington PhD thesis, pp 78-81, 1951.

are altered basalts, marble, and limy hornfels, although chert has been reported on Chair Peak and the Wildcat metamorphics to the north include banded schists and amphibolites. These rocks are believed to be pre-Tertiary because no limestone has ever been reported in the Tertiary rocks of the Cascades.

A typical section of the Sunset formation is displayed on the Sunset Highway from Ollalie Creek to just north of the snowshed. In the region between Ollalie Creek and Rockdale Creek the highway follows the contact with the granodiorite. As one goes north along the highway granodiorite is exposed at Ollalie Creek and just south of Rockdale Creek a dark purple grey hornfels with dikes of coarse granodiorite outcrops. These dikes contain large angular inclusions of the dark country rock. For the next half mile to the north of Rockdale Creek there are no outcrops; however for the next mile beyond this point there are continuous exposures of limy hornfels and porphyritic basalts. Good exposures of the basalts may be seen near Lodge Creek. Here the basalts are black or dark grey in color, in some places vesicular, and have many labradorite laths about three quarters of an inch long. In some of the rocks the vesicles are quartz filled. The hornfelses vary between light grey blue and dark purple in color and have radiating porphyroblasts of actinolite. The rocks in this region are traversed by small closely spaced garnet-diopside quartz veinlets of the type described by Goodspeed and

Coombs.[10] The replacement nature of these veinlets is quite evident from their intersecting patterns and their irregular contacts with the country rock. On the hillside just above Rockdale Creek there are pegmatite dikes which contain quartz, feldspar, and black tourmaline.

At the northern end of these exposures there is evidence of faulting. Several layers of fault gouge can be seen in this area dipping northwest at about 45°. The rocks change very abruptly from a dense dark hornfels to a broken, more weathered hornfels near these faults. It was on one of these fault surfaces that the fatal landslide occurred in 1955. North of the landslide, perhaps due to this faulting, there are no exposures for a half mile.

The next outcrops are north of the snowshed where for several hundred feet there is a dark purple hornfels which weathers to an orange color. This extremely dense aphanitic rock forming cliffs above the highway is the last exposure of the Sunset formation. After a break of a few hundred feet the Guye formation outcrops. At this point the Sunset Highway crosses the N 30° E trend of southeast dipping Guye rocks. The contact between the Sunset and Guye formations can be seen dipping steeply east on the hillside to the south. Higher on the same hillside the much less indurated Guye shales can be seen above the Sunset formation.

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10. Goodspeed, G.E., and Coombs, H.A., Quartz-Diopside-Garnet Veinlets, American Mineralogist, Vol. 17, No. 12, pp. 554-8, 1932.

North of the Sunset Highway in the Snoqualmie River canyon there are continuous exposures of both the Sunset and Guye formations. At Franklin Falls the water tumbles over altered hornfels. About a quarter of a mile above the Falls on the vertical canyon walls of the deeply entrenched stream the contact is exposed. The Guye is represented here by conglomerates and coarse sandstones and the Sunset is a gray hornfels. The intrusive Snoqualmie granodiorite, which outcrops nearby on the side of Denny Mountain, has greatly affected both of these formations so that they are difficult to separate in the field. The conglomerates are the first distinctive Guye sediments to appear. This metamorphism is a very local phenomenon, for nearby the Guye rocks are only slightly altered.

The southwestern shoulder of Denny Mountain is composed of limy hornfels and limestone of the Sunset formation. Limestone also outcrops for several hundred feet on the west side of the Guye-Snoqualmie saddle. In both of these regions the Snoqualmie granodiorite intrudes the limestones of the Sunset formation and small but spectacular mineral deposits have resulted. These are described later in this paper. Smith and Calkins also reported chert in the Chair Peak region, which is probably also part of the Sunset formation.

Petrography

The major rock types in the Sunset formation are basalts and limy hornfels. The contact effects in these rocks are so varied from place to place that petrographic description of the

various rock types encountered would be almost endless. These rocks will be described in only a general way because their metamorphism has little bearing on this study of the Guye formation.

The basalts in hand specimen are porphyritic with black to dark gray aphanitic groundmass and large plagioclase laths which tend to be glomeritic. These laths have all orientations, and are quite large, usually about three-quarters by three sixteenths of an inch. Many small inclusions in the laths are apparent even to the naked eye. Quarter inch vesicles filled with quartz are also present in some localities.

Under the microscope these basalts are seen to be composed of labradorite phenocrysts which are variously altered to sericite, chlorite, epidote, or kaolin, in a groundmass of much smaller labradorite laths and actinolite in both veins and radiating crystals. Less abundant minerals present include up to ten per cent magnetite, a little calcite, and some altered ferromagnesians including what are apparently small flecks of biotite which are present from one per cent to thirty per cent in some zones. The large number of inclusions in the plagioclase laths is a notable feature of this rock.

The limy hornfels are aphanitic rocks that vary from a light blue gray to a dark purple color. In a few places in these rocks there are radiating porphyroblasts of actinolite. Many of these rocks are traversed by the garnet-diopside-quartz veinlets mentioned above.

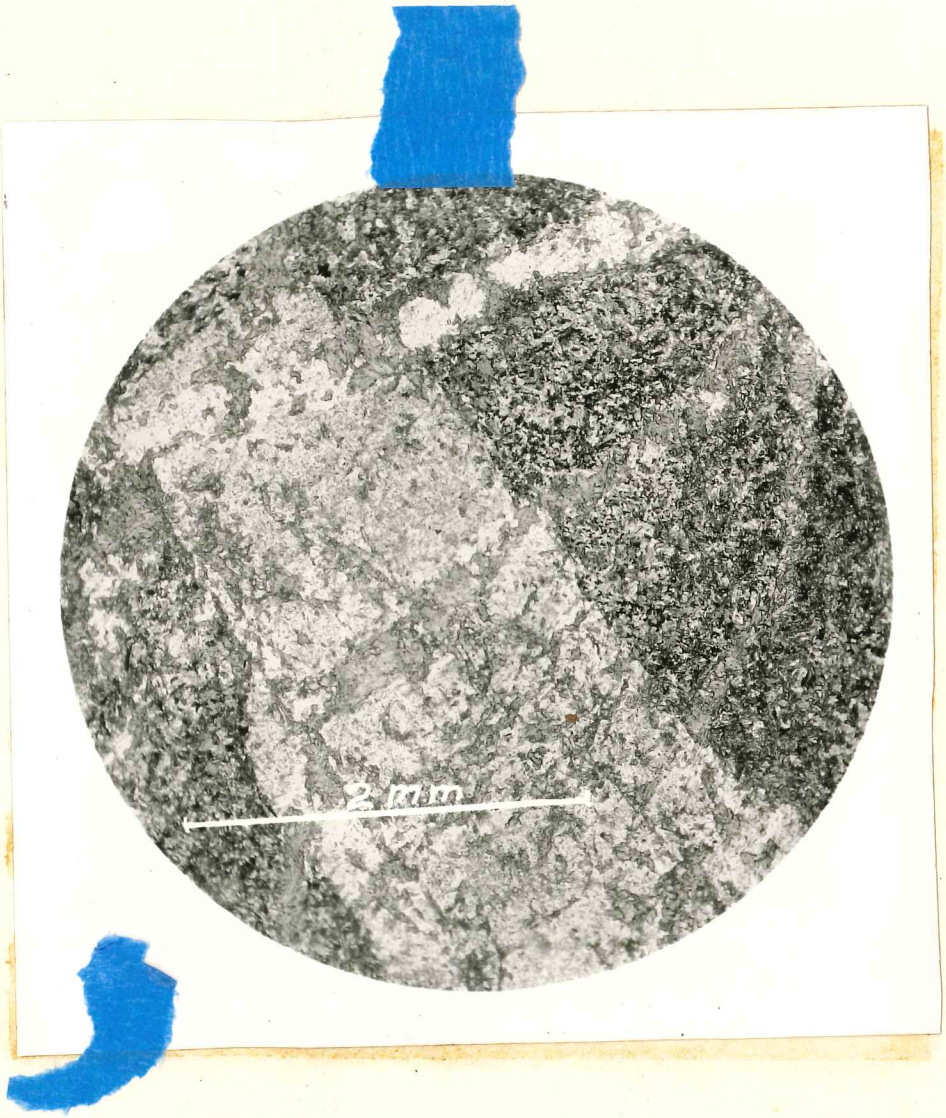

Fig. 4. Photomicrograph of Sunset basalt. Labradorite laths in a groundmass of smaller labradorite crystals, actinolite, and opaques. Veinlets are actinolite. Plain light.

Under the microscope the composition of these hornfelses is seen to be principally plagioclase, actinolite and chlorite together with some calcite, apatite, and magnetite. The percentages of these constituents are extremely variable, and in some zones the magnetite is as much as fifteen per cent.

The marbles in the Sunset formation are coarsely crystalline and white or gray in color.

Mineralization

The search for mineral deposits of commercial value in the Snoqualmie Pass region has resulted in considerable exploration, a little development work, and the publication of several papers. Although this search has gone on for over seventy years, nothing of commercial value has been found with the exception of a few small gold mines which have operated spasmodically during this entire period.

In 1883-4 nine claims were surveyed and patented on the Denny Mountain iron prospect on the western slopes of Denny Mountain, and in 1884 on the side of Guye Peak at the Guye iron prospect, J.W. Guye of Aberdeen, Washington filed nine claims.[11] In both areas the ore body was an irregular magnetite body along the contact of the Sunset formation and the Snoqualmie granodiorite, with a gangue of massive garnet,

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11. Shedd, S. et al, Iron Ores, Fuels, and Fluxes of Washington, State of Washington, Department of Conservation and Development, Division of Geology, Bull. 27, pp. 86-90, 1922.

calcite, hornblende, and quartz. Similar occurrences have been reported on Chair Peak but are unconfirmed. These deposits were well described by Smith and Calkins who reported that they originated from the intrusion of the Snoqualmie granodiorite into limestone.[12]

In the First Annual Report of the Washington Geological Survey in 1901, Landes reported adits at the Guye iron prospect and referred to the mountain as F.M. Guye's Peak.[13] The relationship between F.M. and J.W. Guye is unknown. In 1905 Landes further reported that a crystalline limestone occurs near Snoqualmie Pass.[14]

In 1922, Solon Shedd summarized most of the above information on the iron deposits near Snoqualmie Pass.[15]

In the 1949 inventory of Washington minerals a fair grade of limestone at least one hundred feet thick was reported to occur on Guye Peak and at Denny Mountain, 6,000,000 tons of high grade limestone was reported lying between granite and metamorphics. This same report also mentioned ten feet of

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12. Smith, G.O. and Calkins, F.C., Snoqualmie Folio, p. 14.

13. Landes, H., First Annual Report of the Washington Geological Survey, Wash. Geol. Survey, vol. 1, p. 120, 1901.

14. Landes, H., Cement Resources of Washington, USGS Bull. No. 285, p. 380, 1905. (non-military resources)

15. Shedd, S. et al, op cit, 1922.

massive garnet occuring at both of the prospects, probably grossularite. Also reported were quarts crystals in both of these regions.[16]

The mining activities of this region have been mentioned from time to time in the annual reports of the State of Washington. However these reports shed no important information on the geology of the Guye formation.

Age

Although a search for fossils was made, especially in the limestone section, nothing was discovered that would indicate age. The limestone is coarsely crystalline as a result of the intrusion of the Snoqualmie granodiorite and it is extremely doubtful that, had fossils existed in this formation, they could be recognised now.

The age of the Sunset formation can only be estimated beyond the obvious fact that it is pre-Guye and pre-Snoqualmie granodiorite. There has never been any limestone reported in the Tertiary rocks of the Cascades, so the Sunset is presumed to be pre-Tertiary. The nearest outcrops of limestone in this part of the Cascades occur in the Mount Index region where there is a small body of Permian limestone. Because of this, the Sunset formation has been called Paleozoic, although there are many known limestones in the Cretaceous section of the

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16. Valentine, G.M., Inventory of Washington Minerals, Pt. 1, Non-metallic Minerals, Washington Conservation and Development, Div. of Mines and Geology, Bull. 37, pp. 37-40, 1940.

northern Cascades and the Sunset may belong in this age.

The relationship of the basalts to the limestone could not be determined from the few available outcrops. They were included in the Sunset formation because of their metamorphism; however they are similar to certain rocks of Keechelus age described by Smith and Calkins. If they are of Keechelus age, their metamorphism would still be of Snoqualmie granodiorite age.

"A peculiar rock found in the Keechelus series at several localities is similar to the 'Labrador porphyrites' of Rosenbusch and the 'diabasic porphyrites' described by Turner for the Sierra Nevada and is probably allied to basalt in composition. Megascopically, it has a striking appearance. It is characterized by abundant phenocrysts of feldspar, tabular in form, with a length often exceeding half an inch, embedded in a black aphanitic groundmass. The phenocrysts are commonly assembled in groups, and in some places intersect so as to form peculiar aster-like figures.

"Microscopically, the phenocrysts are found to be labradorite. The groundmass has an intersertal texture, without flow structure, and consists of plagioclase laths with secondary ferromagnesium material ____ an olive micaceous mineral (iddingsite?) and a pale green amphibole. A similar but much fresher rock was found in association with the Naches sediments in Big Creek basin. This may be either a flow or a dike of the same age as the Keechelus series. In the groundmass of this rock, ...there is much augite as well as much iddingsite, some of which may have been derived from olivine." 18

THE RESTRICTED GUYE FORMATION

The Guye formation in this study is restricted to only the younger sediments of Smith and Calkins' Guye formation. Thus the Guye is here defined as the conglomerate, sandstone, and shale beds which contain Eocene plant fossils. The older rocks have been placed in the Sunset formation in this study.

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18. Smith, G.O. and Calkins, F.C., Snoqualmie Folio, p. 3

If the above restriction is made, then the structure of the Guye becomes very simple, not at all like the comment made by Smith and Calkins:

"The formation is much folded, and its structure cannot be worked out in detail, nor can any general section of it be compiled. Its base is nowhere exposed, and its top has been removed by erosion so that its limits and its thickness are unknown." 19

Occurrence and Field Relations

The Guye formation occurs only in the northwest portion of the Snoqualmie quadrangle where there are two main outcrop areas. The largest of these outcrop areas extends from the ridge running south from Snoqualmie Pass to the rhyolite in the vicinity of Kyak and is bounded on the south by the rhyolite mass of Mt. Catherine and on the north by the corridor of Snoqualmie granodiorite which extends from Denny Mountain to the Snoqualmie Mountain area. Throughout this area the Guye strikes approximately N 30° W and dips southeast steeply at 45° to 70° with top to the east. There are no large continuous exposures throughout this area so it is difficult to describe a type section. Although Guye Peak was shown as Guye formation on their map, Smith and Calkins described it in the text as made of silicious biotite granite, so it cannot be used as a type section.

The base of the Guye is exposed both along the highway cuts and along the South Fork of the Snoqualmie River, about three quarters of a mile southwest of Snoqualmie Pass. This

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19. Smith, G.O. and Calkins, F.C., Snoqualmie Folio, p. 7

contact was described in the last section. Here the Guye is made up of coarse conglomerates, shale and sandstones, all very indurated. These indurated rocks contain a few small veins of sulphides. Many good outcrops near the base of the Guye are found on the crest of the ridge running south from Snoqualmie Pass particularly in the first half mile. The outcrops above the ski area at the Pass contain the same three rock types plus a shale that contains one quarter inch sub-angular pieces of black chert of the same type that is present in the conglomerate. Also at these outcrops the sequence can be determined from poor cross-bedding and graded bedding. The latter is frequently displayed by the thin stringers of conglomerate that everywhere invade the sandstones and occasionally the shales. The main body of the Guye occurs to the east of Snoqualmie Pass where it is seen only occasionally because of the glacial cover in this area.

Along Coal Creek the Guye is represented by outcrops of black carbonaceous shales and a little coal. It is from these shales that the Eocene fossil leaves were collected.

At the mouth of Kyak Creek, the outcrops are shales with some sandstone. Going north from this vicinity, along the eastern or northbound portion of the Sunset Highway, the outcrops for several hundred feet are Guye shales veined with quartz and more indurated than at Kyak Creek. No more outcrops occur north of here for a distance of a mile until one reaches Snoqualmie Pass. South of the mouth of Kyak Creek, Coal Creek turns sharply east and good exposures of Guye shales,

conglomerates, and sandstones extend for a distance of one hundred feet east of the highway. The attitude of the beds can be measured here, and the order of succession can be determined from sedimentary features.

Along the eastern or southbound portion of the Sunset Highway a few hundred feet south of Ryak Creek, outcrops of conglomerate with interbedded shales and sandstones can be found on the eastern side of the highway. The sequence can also be determined here. At the mouth of the Snoqualmie tunnel, near the town of Ryak, some exposures of Guye shales, conglomerates, and sandstones can be seen. Exposures of Guye rocks may also be found in the old railroad cuts on the hillsides above the town of Ryak.

At Snoqualmie Pass good exposures of Guye formation can be found on the southeasterly slopes of Denny Mountain and in Commonwealth Creek. The rocks here are indurated by the Snoqualmie granodiorite which can be found quite close-by on the sides of Denny Mountain. Guye rocks are exposed along Mill Creek, the creek running just north of Mt. Catherine. They also outcrop on the northwest shoulder of Silver Peak. The rocks in this vicinity have been separated from the major outcrop area by the intrusion of the Mt. Catherine rhyolite. Outcrops also occur on the western side of the power line cut between Rockdale and Ryak. Here the Guye rocks are baked apparently by the intrusion of the dike of Mt. Catherine rhyolite that parallels the ridge. The power line cut has good

exposures of conglomerate and a purple sandstone that has excellent crossbedding showing tops to the east.

The other principal outcrop area of the Guye formation is along the northeastern slopes of Denny Mountain. The summit of Denny Mountain is made of Keechelus breccias. Just below the summit there is a bench along which the Guye rocks outcrop. Here the Guye is represented by somewhat indurated shales that contain leaf fossils similar to those from Coal Creek and identified by Dr. Brown. Well preserved leaf casts with much detail have weathered out on the surface of these rocks. Shale outcrops continue north along this ridge to the east spur above Source Lake where the bench ends. This spur consists of Guye conglomerates. From here northward the rocks are metamorphic and have been mapped as Sunset formation.

The summit of Denny Mountain is comprised of very coarse Keechelus breccias overlying the Guye sediments. The actual contact between these two formations could not be seen for it was covered with talus from the cliffs that make up the summit ridge. Smith and Calkins described this location as showing the unconformity between the steeply dipping Guye rocks and the less steeply dipping Keechelus rocks above. In the field these breccias appeared to lie on an irregular surface of Guye rocks; however no bedding could be discerned. West of here along Denny Creek and on the summit, these Keechelus rocks are intruded by the Snoqualmie granodiorite and so must be of Lower Keechelus

Fig. 5. Keechelus [illegible] breccia which lies above Guye formation [illegible]s near the summit of Denny Mountain.

age as defined by Warren.[20]

The contact relationships of the Guye formation are not easy to decipher. In the vicinity of Snoqualmie Pass it seems that the Guye formation directly overlies the older Sunset metamorphics. However in this region the lower part of the Guye formation, as here defined, has been indurated, apparently by the Snoqualmie granodiorite, and the relationships are not too clear. The major outcrop of the Guye formation is almost completely surrounded by the Mt. Catherine rhyolite whose intrusive nature is shown at two locations. One is on the northeastern shoulder of Silver Peak where the rhyolite interrupts exposures of the Guye formation, and the other is on the hillside south of the town of Kyak where in the old railroad cuts there is an exposure of Guye shale surrounded by the rhyolite.

Petrography

Lithologically the Guye is a very distinctive formation. The conglomerate is composed of black, gray, and white, very angular, poorly sorted fragments up to two inches in diameter, but usually less than one inch. The sandstones are usually of light to bluish gray color, and the shales vary from deep black to blue-gray color depending on the amount of carbon. Under the microscope the indurated conglomerates and sandstones are seen to consist of black to gray chert with minute quartz veins, and vein quartz, which together make up fifty per cent

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20. Warren, W.C. The Tertiaries of the Washington Cascades, 1936, p. 245.

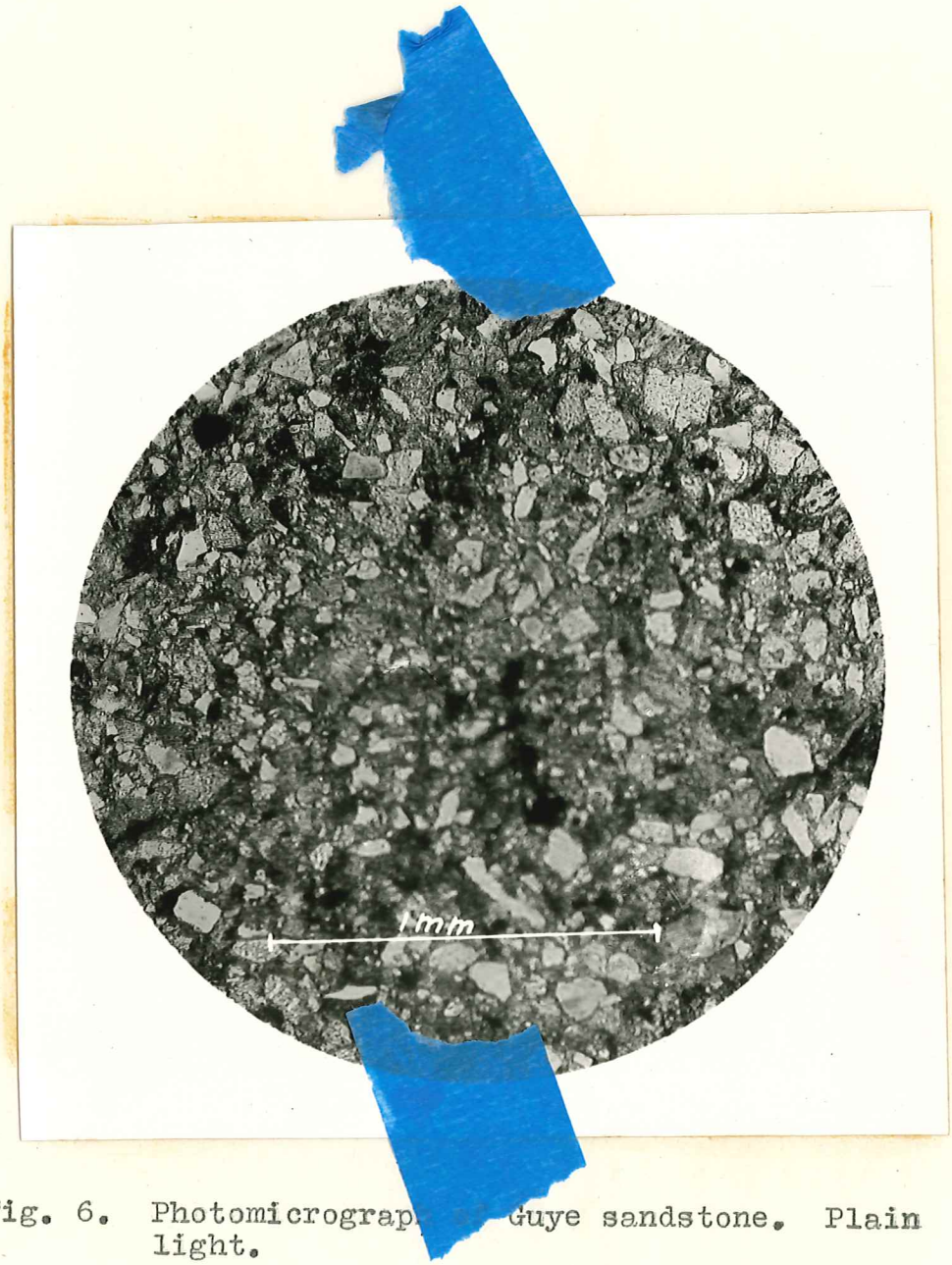

Fig. 6. Photomicrograp[illegible] Guye sandstone. Plain light.

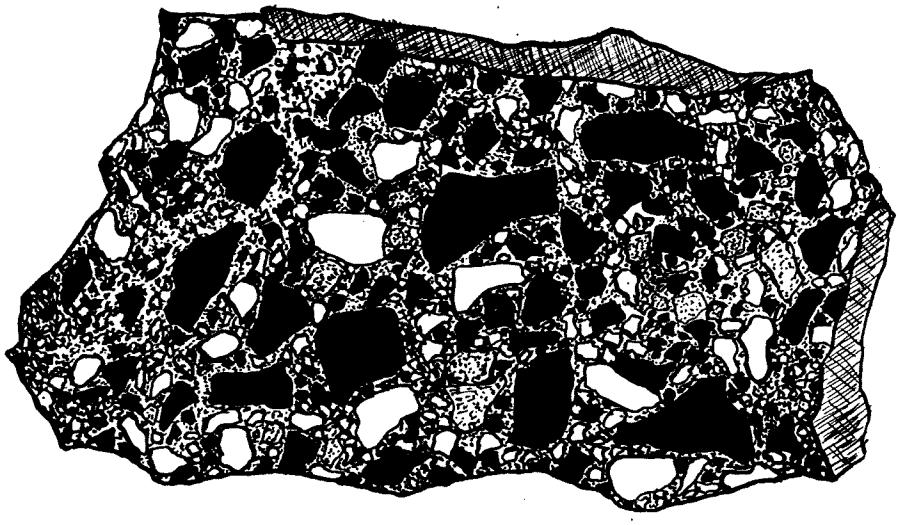

Fig. 7. Guye conglomerate composed principally of subangular, poorly sorted quartz and black chert fragments. Full size.

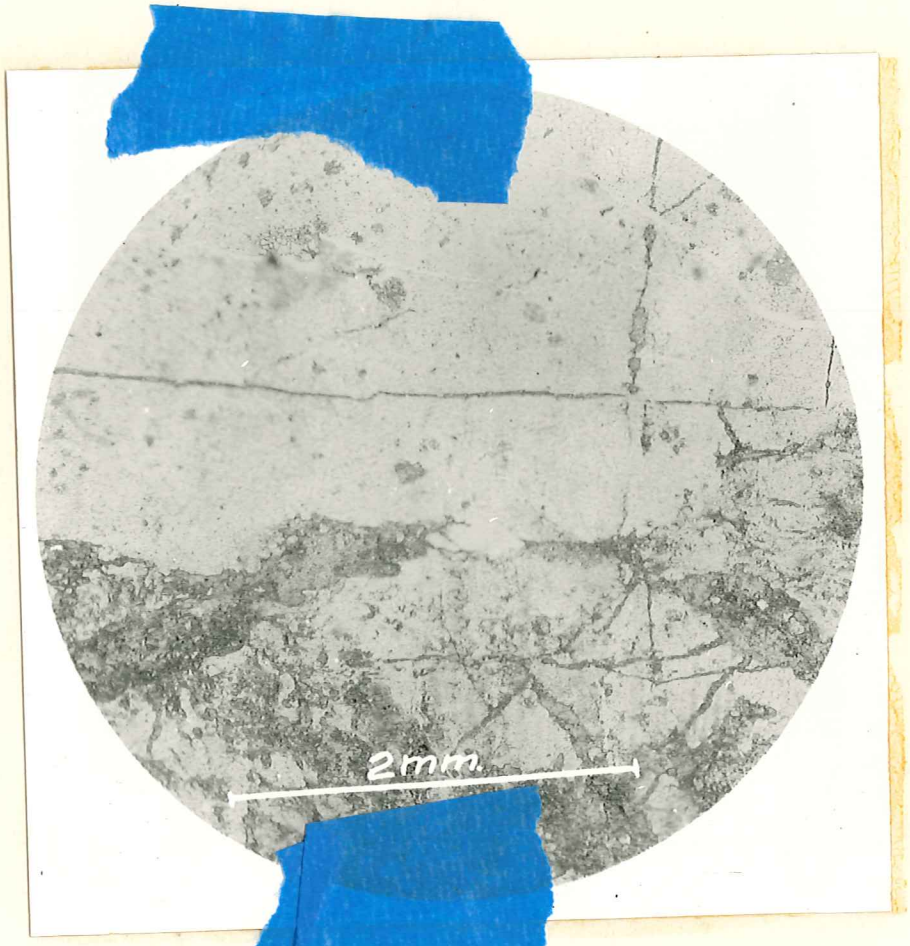

Fig. 8. Photomicrograph of indurated Guye conglomerate showing chert with small quartz veins. Specimen is from an outcrop near the Snoqualmie granodiorite. Plain light.

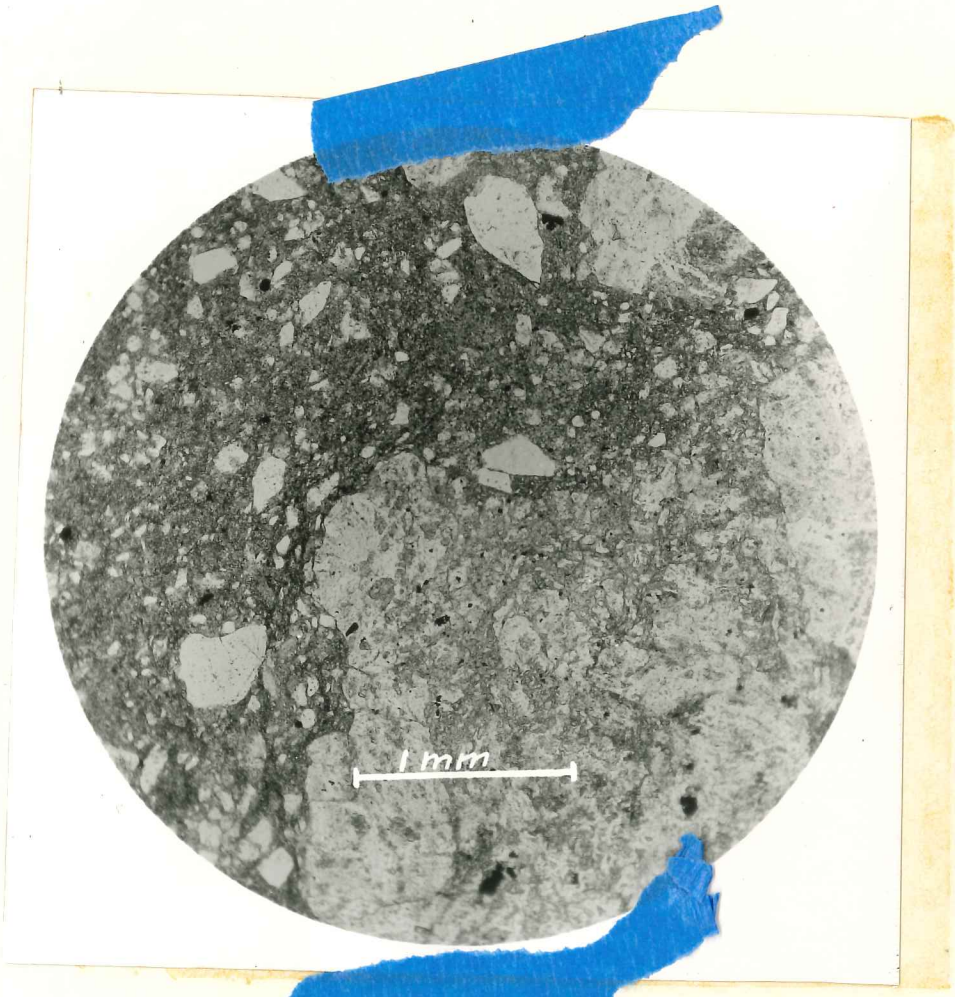

Fig. 9. Photomicrograph of contact between Guye conglomerates and sandy shale. Specimen is from an outcrop near the Snoqualmie granodiorite. Plain light.

of the rock. About forty per cent of the rock is cloudy feldspar, with a little clear plagioclase. The remainder of the rock is generally composed of chlorite, a little muscovite, a small amount of ferromagnesians and traces of other minerals. A typical indurated Guye conglomerate showed the following analysis: fifty-one per cent quartz or chert, five per cent fresh feldspar, thirty-five per cent turbid feldspar, three per cent chlorite, one per cent each, muscovite, augite, rutile, hornblende, garnet, and glauconite, with traces of other minerals. This same sample showed 78.2 per cent silica and 1.8 per cent ferric oxide.[21] A specimen of Guye sandstone taken from the vicinity of Coal Creek was much less indurated than the rock described above. This rock showed much more alteration, probably due to the fact that it is fairly porous in contrast to the indurated rocks. Under the microscope, it was seen to contain 25 per cent quartz, 15 per cent plagioclase, 10 per cent opaque, probably magnetite and carbon, 10 per cent ferromagnesians too altered to determine, and 40 per cent chlorite. Thus because of their high feldspar content, most of the Guye sandstones and conglomerates should be classed as arkoses.

The restricted Guye formation is composed of approximately three-quarters shale and the remaining one-quarter mostly conglomerate with some sandstone. Many of the shales, in spite of their black, carbonaceous appearance, are sandy and have

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21. Wilson, H. et al, Silica Sands of Washington, University of Washington Div. of Mines and Geology, Report 10, p. 37, 1940.

thin partings of fine sand.

The Guye sediments were apparently laid in a fluvial environment that had considerable relief. This is shown from the nature of the sediments. The coarse, angular conglomerates show that these fragments were not transported very far. The conglomerates and sandstones are composed principally of fragments of quartz, vein quartz, feldspar, and black chert veined with quartz. The high content of feldspar shows that these sediments were accumulated fairly rapidly. The black carbonaceous shales with their Eocene plant remains attest to the terrestrial conditions that must have obtained. These must have been deposited in rapidly filled swamps.

The origin of the pebbles that comprise the Guye formation is unknown. The only similar rocks referred to in the literature occur in the Peshastin formation in the Blewett mining area. The Peshastin is usually placed somewhere in the Paleozoic and is fairly widespread throughout the central Cascades. Conglomerates in the Peshastin are made of a black chert with tiny quartz veins.[22] Hence, if these are the same as those in the Guye formation, the origin of the pebbles that comprise the Guye formation must be of pre-Peshastin age or reworked Peshastin rocks.

Age

The age of the Guye formation was determined during this study as Eocene by Dr. Roland W. Brown of the United States

22. Weaver, C.E., Geology and Ore Deposits of the Blewett Mining District, Washington Geol. Survey, Bull. 6, 1911, p. 30

Geological Survey who studied a fossil leaf collection from the southwestern bank of Coal Creek, a few hundred feet below the mouth of Hyak Creek. He identified the following leaves: Allantodiopsis erosa (Lesq) Knowlton, Asplenium magnum Knowlton, Glyptostrobus dakotensis Brown, Ocotea eocernua Chaney and Sanborn. He commented, "This is an Eocene assemblage, and probably from the later part of the Eocene. Most of the specimens in the collection represented the one species Ocotea." Thus the date of the restricted Guye formation is set as Eocene rather than Miocene as stated by Smith and Calkins in the Folio. This permits the base of the Keechelus to be as old as Eocene, and not restricted to younger than Miocene.

Structure

The restricted Guye formation of this study was found to be homoclinal as outlined above. Its true thickness is difficult to estimate because of the unconformity at its top and the intrusion at its base. Computations assuming a 60° dip show a thickness of about 9000 feet for the remaining strata. This calculation is probably too high because of the plastic deformation of the shales within the Guye. Indeed many of the outcrops of the Guye formation showed some signs of plastic deformation. The ever present sandy lenses were often bent and the shales showed signs of having flowed, particularly near the intrusion of the granodiorite.

This great thickness could also be accounted for by either folding or faulting. If these rocks had been folded

the uniform dips would require recumbent folding; however, this possibility is ruled out because at every place where the sequence could be determined the strata were not overturned. Faulting probably accounts for some of this thickness. Although no evidence for faulting was found in the Cuye rocks, the cross sections show that some faulting is necessary to explain the regional structure. The evidence for this faulting may be covered by the glacial deposits or may be masked by the igneous intrusions.

IGNEOUS ROCKS

There are two major igneous rock masses in the Snoqualmie Pass region, the rhyolite which has been here named the Mt. Catherine rhyolite and the Snoqualmie granodiorite. This study has been directed primarily toward gaining an understanding of the Cuye sediments and these igneous rocks have been studied only in a general way in order to understand better the regional geology.

The Mount Catherine Rhyolite

Occurrence and Field Relations

The Mount Catherine rhyolite is a very distinctive rock. It is a light purple aphanitic rock with many quartz phenocrysts. It has been named for Mt. Catherine which is made of a thick body of this rhyolite dipping moderately to the south. The structure of Mt. Catherine is best seen from across Lake Keechelus on the Sunset Highway.

The Mt. Catherine rhyolite was originally mapped as a

member of the Guye formation by Smith and Calkins. On their map they showed this rhyolite passing from the Gold Creek exposures in a continuous band to a point north-west of Abiel Peak. The present field work has shown that no rhyolite outcrops occur on the Silver Peak-Abiel Peak saddle. However, west of this saddle, Snoqualmie granodiorite outcrops and may have a rhyolite phase which Smith and Calkins assumed to be connected with the Mt. Catherine occurrence.

The outcrop pattern of this rhyolite forms a roughly circular mass approximately three miles in diameter. However the ring is not complete, but is open to the north. At the northwest part of the ring the outcrop begins in the vicinity of Lodge Lake where the lake itself has been impounded behind a dam of the resistant rhyolite. Traveling south from here, occasional glimpses of rhyolite outcrops are seen in the heavily wooded steep hillside to the power line cuts on the slopes above the western entrance to the railroad tunnel, where there are good exposures. From these power line cuts, the rhyolite can be traced to the hill immediately to the south which connects with Mt. Catherine. Mt. Catherine forms the southern part of this arc. Northeast of Mt. Catherine the rhyolite can be followed to the hill above the town of Nyak and from there to north of the mouth of Gold Creek.

The eastern side of the rhyolite ring apparently has two parallel outcrops. They are the southwestern edge of Kendall Mountain and the summit ridge of Kendall Mountain. The relationship between these outcrops and Mt. Catherine has been

suggested on the accompanying map; however, no field evidence can be obtained because of the glacial cover in Gold Creek valley. The rhyolite on the southwest side of Kendall Mountain is probably connected with the rhyolite on Guye Peak. In spite of the fact that on their map Smith and Calkins showed Guye Peak as composed of Guye formation, they described it in their text as composed of siliceous biotite granite. The rhyolite continues to the southwestern side of the saddle between Guye Peak and Snoqualmie Mountain.

The Mt. Catherine rhyolite occurs in many ways. One of these is dikes of rhyolite which cut through the main body of rhyolite. This type of emplacement is suggested in the exposure just north of Gold Creek on the Sunset Highway, and is shown very clearly in the railroad cut about a mile south of Hyak. At this second location the rhyolite is cut by a rhyolite dike which is dipping steeply in its lower portion and flattens out in the upper part of the outcrop.

The rhyolite knob north of Gold Creek, which is well exposed in highway cuts, displays the breccia which is the chief type of occurrence of this rhyolite. In most hand specimens the brecciated nature of these rocks is not obvious; however in a few places the cementing rhyolite is stained a deeper red from a concentration of hematite and the structure of these rocks becomes obvious.

On the hillside to the south of Hyak the rhyolites are banded and vesicular. At at least one location the vesicles were filled with calcite.

Smith and Calkins also reported small quantities of rhyolite near Chair Peak and on the south ridge of Alta Mountain.[23] A small dike of rhyolite was found on the south slope of Denny Mountain.

Petrographic description

In the hand specimen this distinctive rhyolite is a light purple colored porphyry with clear quartz phenocrysts about one sixteenth of an inch in diameter. In a few areas however the phenocrysts are not present. At some locations it is a light orange rock with darker and lighter flow-bands which often swirl in intricate patterns. It is occasionally vesicular and the vesicles may be filled with calcite.

Under the microscope specimens from the west side of Lake Keechelus and from the creek on the southern side of Kendall Mountain both show flow lines which stream around the phenocrysts. The ground mass is a devitrified glass and shows uniform gray color in all orientations under crossed nichols. The phenocrysts are embayed, dipyrimidal quartz with an occasional piece of badly altered feldspar, presumably orthoclase, and the remains of some ferromagnesian mineral being replaced by magnetite.

The outcrop just north of the highway between Coal Creek and Gold Creek is typical of much of this rhyolite. The rhyolite here has rounded embayed quartz phenocrysts, as before, but the groundmass is made of angular glass pieces

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23. Smith, G.O. and Calkins, F.C., Snoqualmie Folio, p. 8.

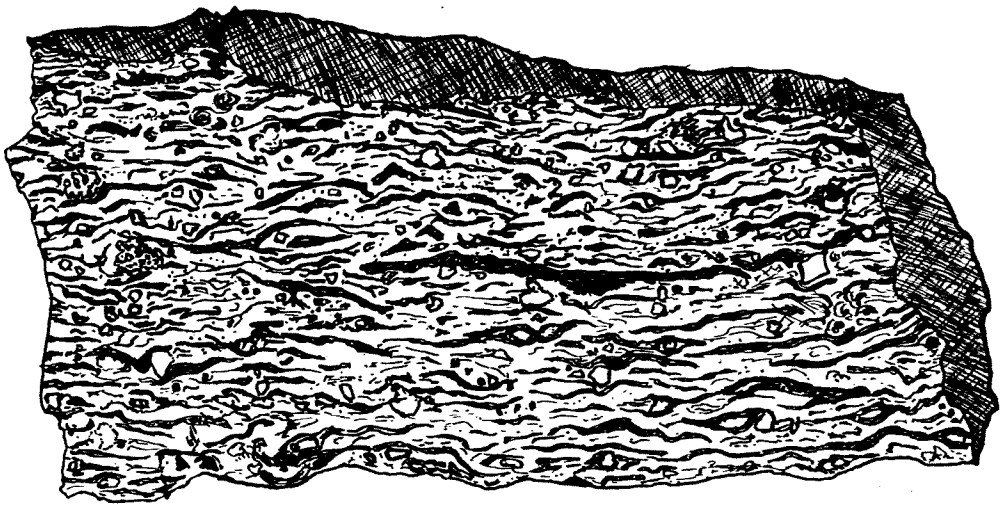

Fig. 10. Ignimbrite phase of Mt. Catherine rhyolite. Full size.

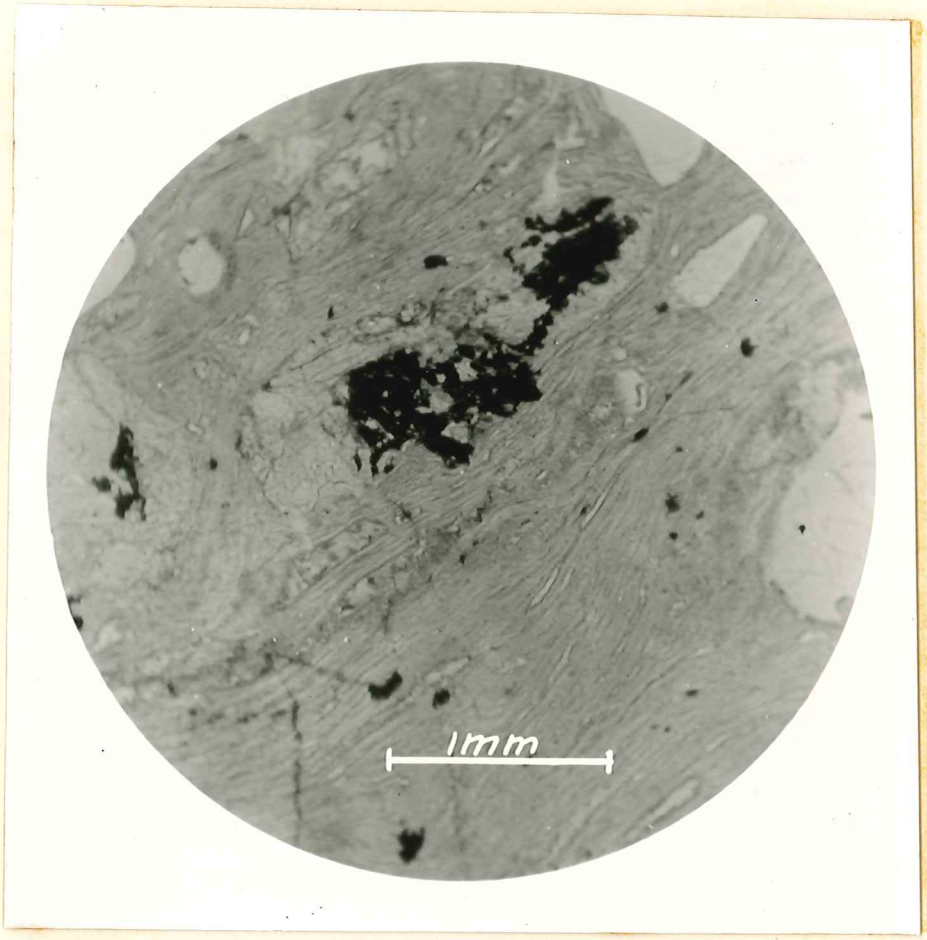

Fig. 11. Photomicrograph of Mt. Catherine rhyolite. Altered ferromagnesians and partially resorbed quartz phenocrysts in a glass matrix that shows flow lines. Plain light.

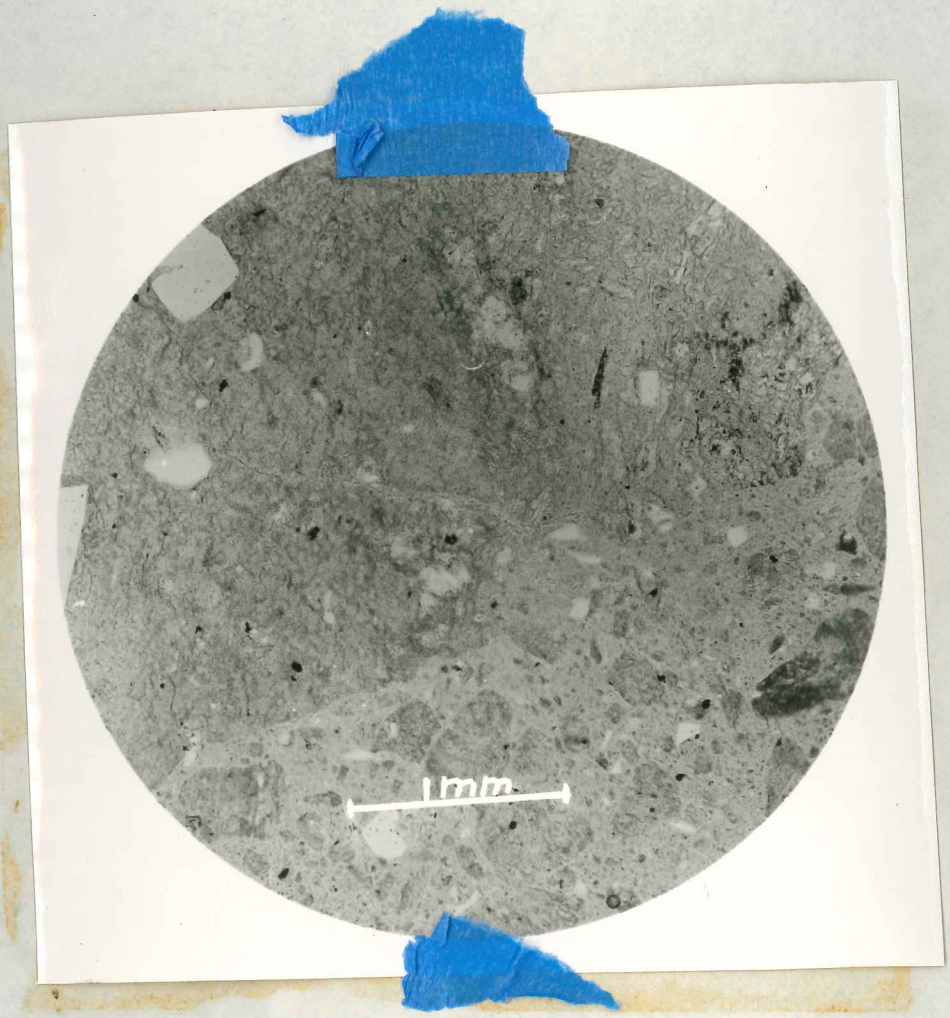

Fig. 12. Photomicrograph of ignimbrite phase of Mt. Catherine rhyolite. Embayed quartz and glass fragments in a matrix of glass. Plain light.

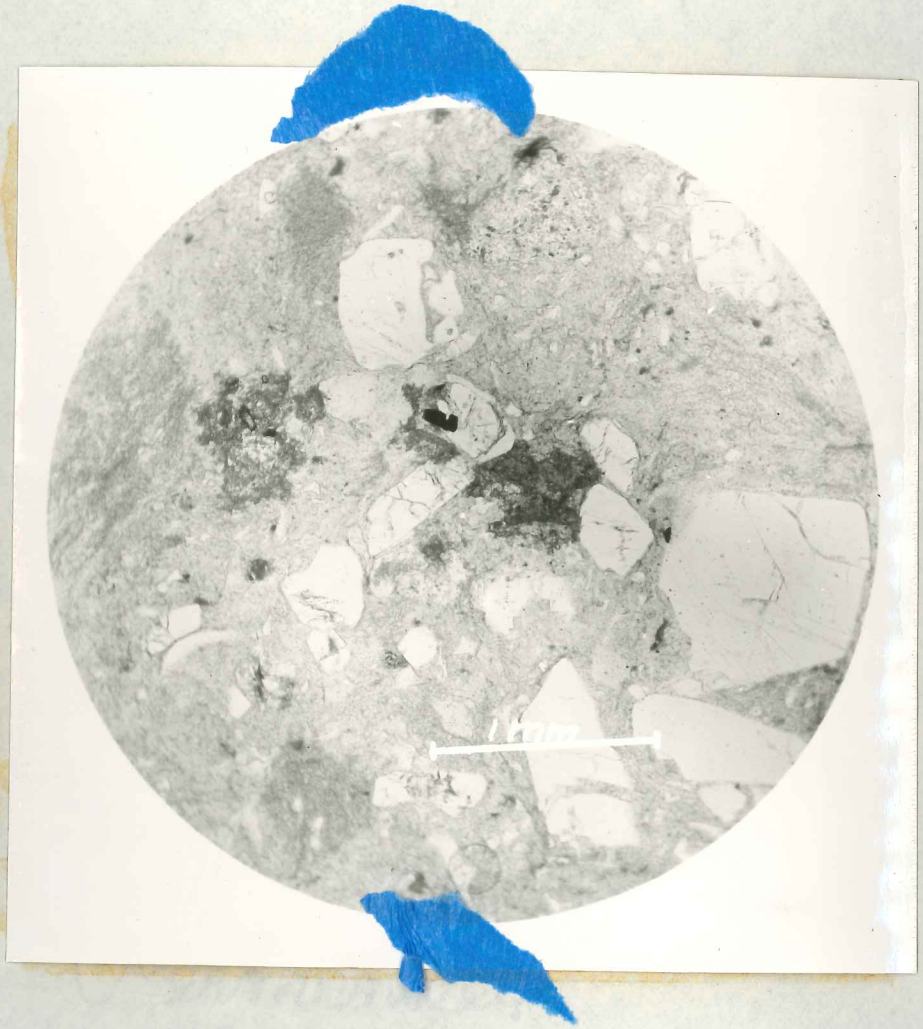

Fig. 13. Photomicrograph of rhyolite from the summit of Kendall Peak. Quartz, altered feldspars and altered ferromagnesians in a glassy matrix. Plain light.

cemented with apparently the same glass, all of which has been devitrified. A few pieces of altered feldspar occur in the rock along with about five per cent hematite. A thin-section cut from near the base of this flow shows the rhyolite to be devitrified, but the outlines of glass shards are still present. In one thin-section, just above this zone of glass shards, the breccia contains pieces of a dark trachytic lava. From the foregoing it appears that at least in this locality the Mt. Catherine rhyolite must have been extrusive. Portions of this extrusive rhyolite have the features of an ignimbrite. On the east side of Guye Peak the rhyolite is apparently interbedded with a burnt shale and appears extrusive. It is believed, however, that most of the Mt. Catherine rhyolite must be intrusive because it is found on the bottom, one side, and on the top of the Guye formation, and thus follows the contacts between the Guye formation and the Sunset, Keecholus, and Kendall formations.

On the east side of Gold Creek, the rhyolite takes on the aspect of a tuff. In the hand specimen it can clearly be seen to be made of angular pieces of felsitic rhyolite, three-sixteenths of an inch in diameter, which contain quartz phenocrysts. These fragments are bound together by a felsitic cement that has weathered to a somewhat clayey appearance. This outcrop occurs along the southern end of Rampart Ridge. The upper part of this ridge is composed of flat-lying volcanics (perhaps the Fife's Peak member of the upper Keecholus) and the lower part of the ridge is Smith and Calkins' type

Fig. 14. Looking northeast up Gold Creek valley toward Rampart Ridge. Flat lying upper Keechelus rocks cap the ridge.

section for the lower Keechelus series (see fig. 14).

The Snoqualmie Granodiorite and its Relationship to the Mt. Catherine Rhyolite

Among the peculiar relationships between the Snoqualmie granodiorite and certain dike rocks are those noted fifty years ago by George Otis Smith. He reported that on Denny Mountain there were what he termed granite porphyries with prominent dipyrimidal quartz phenocrysts in a felsic groundmass. This description is quite similar to the Mt. Catherine rhyolite in this study. He noted that in places the relationships between these dikes and the Snoqualmie granodiorite could not be found while in other places the Snoqualmie granodiorite was apparently continuous with this porphyry. However, he concluded that the relationship had not been completely defined because on Denny Mountain there are dikes of Snoqualmie granodiorite that are only a few thousand feet wide and are medium to coarse-grained. He described a dike as a few hundred yards in width for a mile or more, and swelling into two boss-like masses of granite over a mile in width, and another dike as extending up into the overlying andesitic lavas (apparently referring to the Keechelus rocks on the summit of Denny Mountain). He also described Guye Peak and the spur of Denny Mountain immediately west of it as made of siliceous biotite granite. He further noted that in some regions, "There are more basic phases of the Snoqualmie granodiorite intermingled in such a way as to make their separation as futile as it would be unnatural."[24]

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24. Smith, G.O. and Mendenhall, W.C., Tertiary Granite in the Northern Cascades, GSA Vol. 11, 4-7-1900, pp. 224-229.

In the field, Snoqualmie Mountain was noted to be made of at least three igneous rocks, but the relations among these were not determined. They were, first, a white granite composed of quartz, biotite, and altered feldspars; second, a white granophyre with quartz phenocrysts; and third, the Snoqualmie granodiorite. This heterogeniety of the Snoqualmie granodiorite has been long known. In 1915, Warren Smith recognized and mapped an aplite phase.[25] Bethell mapped the region northwest of Snoqualmie Pass, and separated the Snoqualmie granodiorite into several divisions.[26] Therefore much of what has been shown as Snoqualmie granodiorite, especially in the northern portion of this map area could be separated into several facies by detailed mapping. Thus it can be seen that the Snoqualmie granodiorite is a complex unit consisting of several phases and could be the source of the Mt. Catherine rhyolite.

Age of the Igneous Rocks

The Mt. Catherine rhyolite and the Snoqualmie granodiorite are probably of the same age as shown in the preceeding section. The only evidence as to their age that can be found in the area under study is that both intrude unfossiliferous Keechelus rocks. Therefore, one way to find their age is to date the Keechelus series. Another approach to dating these igneous

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25. Smith, Warren, Stratigraphy of the Skykomish Basin, Jour. of Geol., vol. 24, 1916, pp. 559-582.

26. Bethell, H.L., Geology of Southeast Sultan Quadrangle, University of Washington PhD thesis, 1951, p. 177.

rocks is to compare the Mt. Catherine rhyolite with another well-dated rhyolite that occurs in this region.

The relationship between the Snoqualmie granodiorite and the Keechelus series is apparently widespread. Warren observed that in the Mt. Aix quadrangle the Snoqualmie granodiorite apparently intruded only the lower portion of the Keechelus series. He thought that this might account for the massiveness and the metamorphism of the lower Keechelus rocks, and the apparent unconformity within the Keechelus series.[27] The condition of the lower Keechelus rocks made it difficult or impossible for him to work out the structural relations of the Keechelus series.

The age of the Keechelus series is not a simple problem and the present evidence suggests that it transgresses several epochs. The correlations for the most part are made on lithology so the possibility of more than one formation should be kept in mind. It has been reported to be interbedded with both the Swauk (Paleocene) and the Puget group (Eocene)[28], and may

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27. Warren, W.C., The Tertiaries of the Washington Cascades, Pan-Am. Geologist, vol. 65, 1936, p. 245.

28. Pratt, R.M., Geology of the Deception Pass Area, Skagit, King and Kittitas Counties, Washington, University of Washington Master's thesis, 1954, pp. 35 and 44.

Fisher, R.V., Partial Contemporaneity of the Keechelus Formation and the Puget Group in Southern Washington, Paper presented at the meeting of the Geological Society of America, March 26, 1954, Seattle, Washington.

Abbott, A.T., The Geology of the Northwest Portion of the Mt. Aix Quadrangle, Washington, University of Washington PhD thesis, 1953, pp. 29 and 46.

extend into the Oligocene as shown by the creodont jaw found by Grant.[29]

The age of the Mt. Catherine rhyolite may be similar to the nearby, well-dated Machess rhyolite. The Machess rhyolite was shown by Smith and Calkins to be interbedded with the Naches and Swauk formations (Paleocene), lying between the Naches formation and the Teanaway basalt (Eocene?) and interbedded with the Teanaway basalt. Similar relationships were noted by Warren in his study of the Keechelus series and he reports that a rhyolite similar to the Machess is in the lower portion of the Keechelus in the area he studied.[30]

Thus the age of the Snoqualmie granodiorite is probably Eocene or Oligocene.

THE KENDALL MEMBER OF THE KEECHELUS SERIES

Occurrence and Field Relations

The Kendall member is the third or upper division of Smith and Calkins' Guye formation that has been made in this study. It is apparently a local clastic unit made of sandstones and shales and found only on the southwestern side of Kendall Mountain. Its stratigraphic position is not clear for it is surrounded by igneous rocks, some of which are intrusive. This region has been rather poorly explored during this study.

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29. Grant, R.Y., A John Day Vertebrate Fossil Discovered in the Keechelus Series of Washington, Am. J. of Sci., Vol. 239, pp. 590-593, 1941

30. Warren, W.C., The Tertiaries of the Washington Cascades, Pan-Am Geologist, Vol. 65, 1936, pp. 241-247.

partly because of the terrain, and because these rocks were discovered by chance during the later stages of the field work. The problems encountered in studying the Kendall rocks and Kendall Peak are shown by the comments of Smith and Calkins.

"...Kendall Peak is carved from steeply inclined beds of Guye rocks, its sharp spurs and pinnacles being formed of the harder beds. In this vicinity the formation is represented chiefly by sandstones, with some shale, and interbedded with these are considerable basalt and a little rhyolite, both occurring in massive and in fragmental form. ....in the exposures on Kendall Peak (the sandstone) is closely cemented, taking on the character of tough quartzite, and breaks with conchoidal fracture. Some of the lighter arkose phases resemble fine-grained granite.

"A very peculiar apparently rhyolitic rock is found on the southwest shoulder of Kendall Peak. It consists mainly of a rather hard, aphanitic groundmass, dull coal black in color, which contains abundant small angular grains and crystals of quartz. Its texture and composition studied microscopically, indicate that it is tuffaceous. Its black color is due partly to an abundance of finely divided scaly material resembling green biotite and numerous black opaque particles of undetermined character.

"The basalt near Kendall Peak is mostly a greenish black, compact aphanitic rock, not very readily distinguished from the indurated black shale. Its true character was first recognised by the finding of amygdaloidal phases, with cavities full of quartz, hornblende and other secondary minerals. A little indurated tuff was also found."[31]

"Metamorphosed basalts have been collected on the north slope of Kendall Peak. ....The original basaltic texture is fairly well preserved. The lath-shaped feldspars are not much altered though always somewhat clouded. The most striking change produced in the rocks is the generally advanced and often complete utilization of the augite, a phenomenon rarely noticed in the basalts collected far from the granodiorite. In the more altered specimens the interstices between the feldspars are filled in with green amphiboles, and a finely divided greenish-brown mineral resembling biotite. The amphibole in some places forms ophitic plates and in others fine grained aggregates. Olivine is not present, nor is it represented by recognizable pseudomorphs. Epidote, zoisite, and pyrite are less common secondary constituents. The amygdules of the basalt near Kendall Peak contain quartz, amphibole, the micaceous mineral referred to, and granular apatite."[32]

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31. Smith, G.O. and Calkins, F.C., Snoqualmie Folio, p. 7.

32. Smith, G.O. and Calkins, F.C., Snoqualmie Folio, p. 10

The northern part of the outcrop area of the Kendall member is apparently mostly shale but in the southern portion, sandstone and shale alternate. Fairly extensive, poorly exposed outcrops of shale were found on the northernmost of the two ridges of Kendall Mountain. Here, soft, light grey shale forms steep high meadows for on this shale only coarse grass can grow. The shales in these outcrops were very fissile and broken so that only very small pieces could be obtained. Just a little above this shale a dark arkosic sandstone occurs. A quarter of a mile north of here on the Commonwealth Creek side of this ridge just below the summit ridge of Kendall many outcrops of a similar shale were found. Here the shale is a bit more massive and a little bit more indurated so that hand specimens could be obtained. Shales similar to this second location were also found on the east side of Guye Peak in a very few scattered outcrops.

The only other occurrences of the Kendall member that were seen occurred along the eastern side of the southernmost shoulder of Kendall Peak. Here in several small gullies shales and sandstones were found. Along the creek shown on the map these shales and sandstones were seen to alternate in eighteen inch to two foot beds for at least several hundred feet. The strike in this location was north 35 west with a forty degree dip toward the north.

Petrography

The shales are of a blue-gray color and the sandstones are

of a medium tan. The shales here contain an abundance of fossil wood and a few very poorly preserved leaves that are not sufficient to enable dating by paleobotanical methods. Under the microscope, the sandstone is seen to consist mostly of subangular quartz grains. In streaks between the quartz grains there is much carbonaceous material.

The most distinctive feature of these rocks is their muscovite content. Mica, apparently detrital, is scattered throughout the rocks; and, in the sandstone is concentrated in very thin bands usually less than an inch apart. This sandstone is very reminiscent of a sandstone found near the mouth of Gold Creek in a series of shales and tuffaceous sandstones where a small, undiagnostic leaf collection was made from a thin shale layer.

The thickness of the Kendall formation is approximately 2600 feet assuming that the 40° north dip holds throughout the area.

Stratigraphic Position

The field relations show that the Kendall rocks lie between rhyolite bodies apparently above the Guye formation. Lithologically it is different from both the Guye formation and the Keechelus rocks that outcrop nearby. It is, however, believed to be a part of the widespread Keechelus series for two reasons. First, lower Keechelus breccias (intruded by Snoqualmie granodiorite) usually overlie the Guye formation apparently unconformably. An example of this is the occurrence on the summit

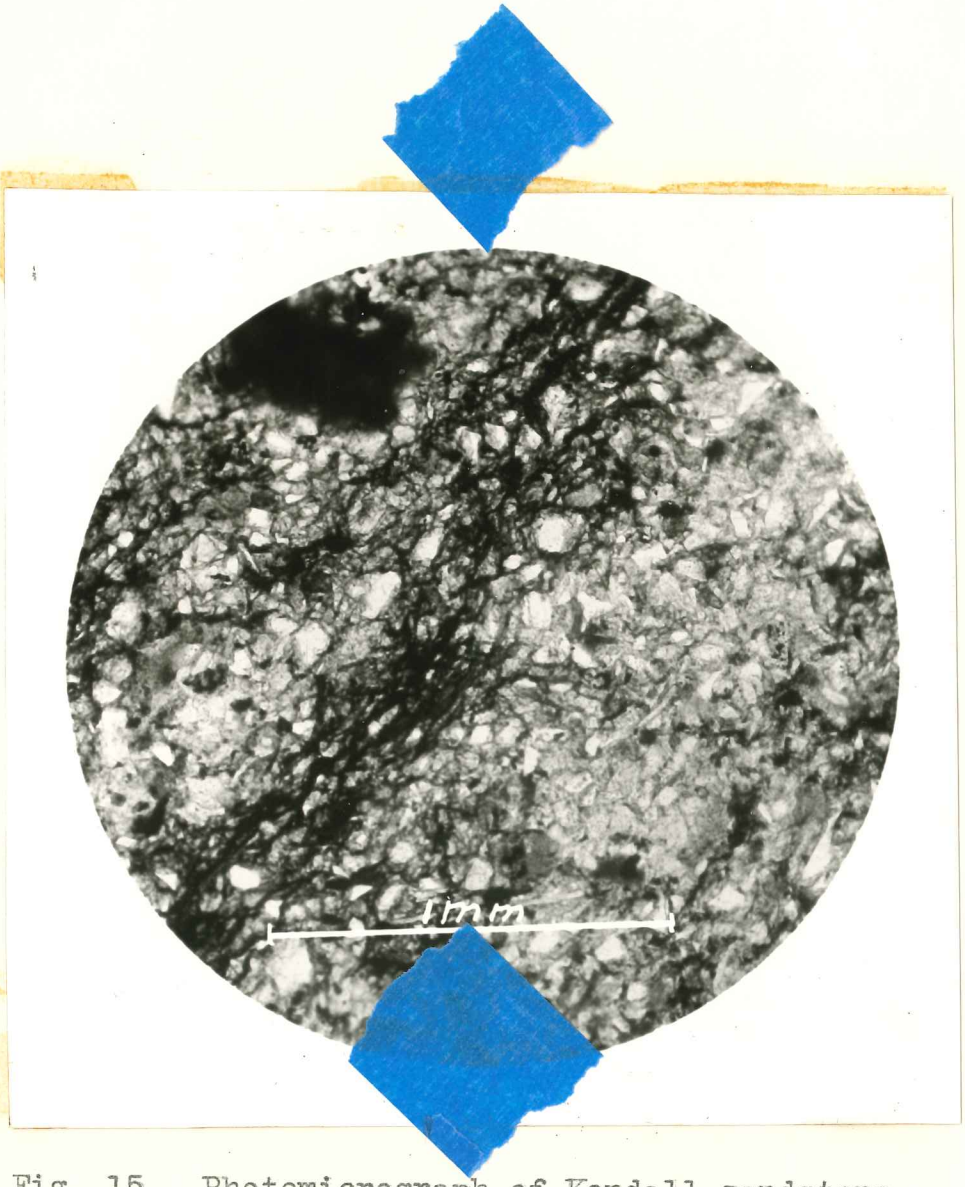

Fig. 15. Photomicrograph of Kendall sandstone showing micaceous and carbonaceous material parallel to the bedding. Plain light.

of Denny Mountain as described earlier. Sedimentary rocks have been described in the Keechelus series elsewhere in the Cascades. Smith and Calkins mentioned them,[33] and in the Mt. Aix quadrangle, Abbott found lowest Keechelus to be interbedded with the Puget group.[34] Fisher found this also in the region south of Mt. Rainier.[35] For these reasons, this small local unit has been referred to the Keechelus series although more field work is necessary to prove this relationship.

HISTORICAL GEOLOGY

The Snoqualmie Pass region is a dividing line in the lithology of the Cascades. To the north the older metamorphic rocks are exposed and to the south the younger Tertiary volcanics outcrop. Thus it is not surprising that in the small area under study rocks of both these ages appear. The oldest rocks encountered in this study belong to the Sunset formation. These rocks were previously referred to the Guye formation, but on the basis of this study the Guye formation has been divided. The Sunset formation is composed of limy hornfels, limestone, and basalt, all of which are metamorphosed to various degrees. It has been separated from the Guye formation

33. Smith, G.O. and Calkins, F.C., Snoqualmie Folio, p. 8
34. Abbott, A.F., op cit., pp. 29 and 46.
35. Fisher, R.V., op cit.

on the basis of this lithology. The outcrops of the Sunset formation trend in a general north-south direction. The age of the Sunset is not known beyond the fact that it is pre-Guye; however portions of it appear similar to the Permian rocks of the Cascades.

The restricted Guye formation lies above the Sunset formation. Lithologically the restricted Guye formation is very distinctive with carbonaceous shales and coarse angular conglomerates that grade rapidly to sandstones. The fossil leaves in these shales show that the Guye belongs in the upper half of the Eocene, and it is not of Miocene age as previously reported. The trend of the Guye sediments is N 30 E and they dip to the southeast at sixty degrees.

The thick, widespread Keechelus volcanic series lies above the restricted Guye formation. Because the Guye formation has now been accurately dated as Eocene there is no longer any reason to maintain a Miocene date for the Keechelus and its base at least in this region may be as old as Eocene.

The Kendall member of the Keechelus series, a local unit designated in this study, lies above a part of the Guye formation. It is a thin terrestrial unit, made up of thinly bedded shales and sandstones. The outcrop of the Kendall trends northwest and the strata dip to the northeast at approximately forty degrees.

The Mt. Catherine rhyolite occurs between the Guye formation and the Kendall member of the Keechelus. This remarkable

rhyolite whose outcrop forms a crude ring, is apparently an intrusive rock in several places along the contacts of the Guye formation and the Sunset, Keecholus and Kendall formations. It also occurs as an extrusive above the Guye formation. The relationship between the Guye formation and the Keecholus series has been obscured by this intrusion. The Mt. Catherine rhyolite is intrusive into both the Guye formation and the Keecholus series and thus is of the same general age as the Snoqualmie granodiorite which also intrudes both of these formations.

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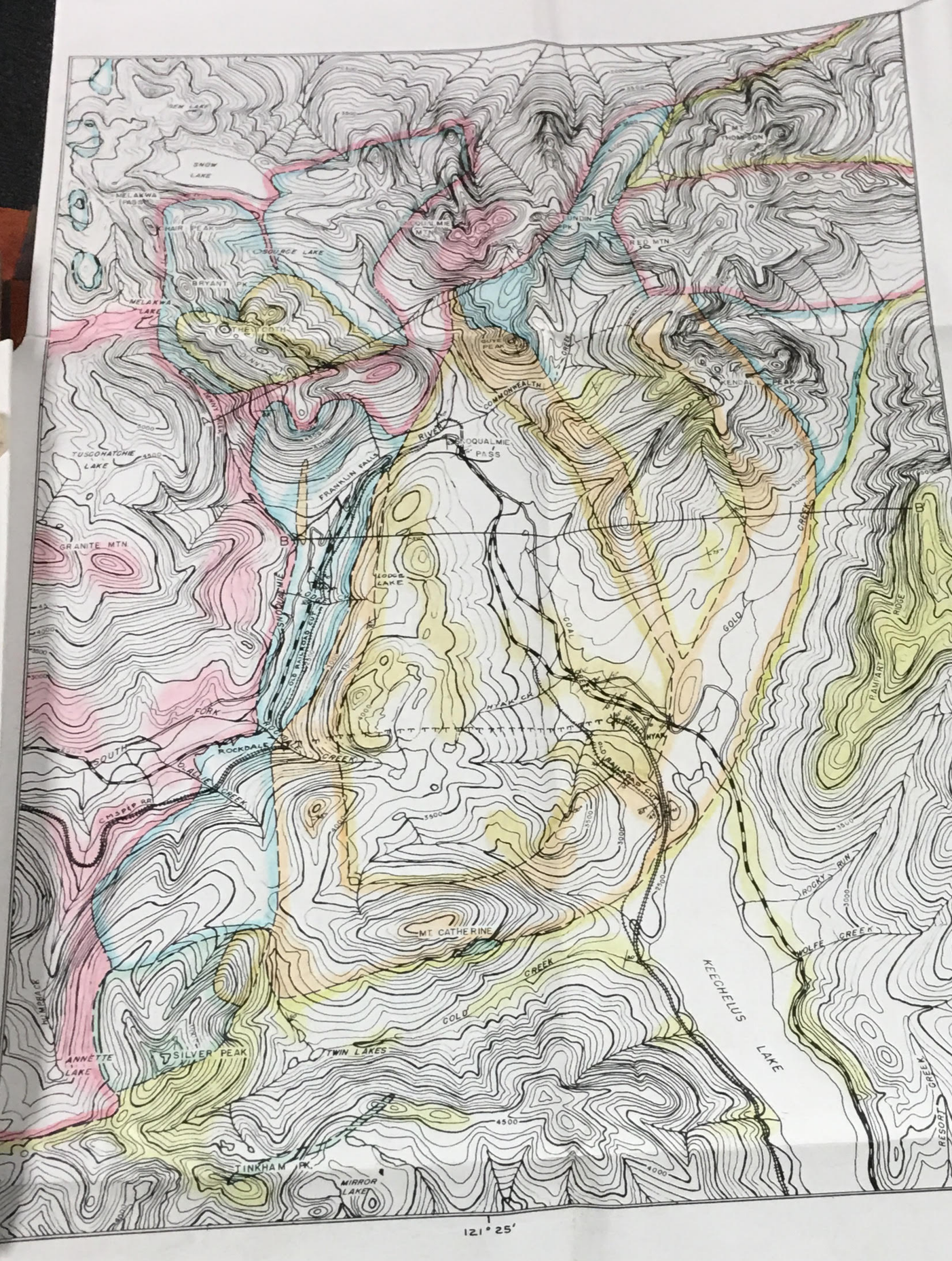

EXPLANATION

- SNOQUALMIE GRANODIORITE
- MT. CATHERINE RHYOLITE
- KEECHELUS PYROXENE DIORITE
- KEECHELUS FM.
- KENDALL MEMBER OF KEECHELUS
- GUYE FM.
- SUNSET FM.
- POWER LINE
- RAILROAD TUNNEL

SECTION A-A'

SECTION B-B'

GEOLOGIC MAP OF THE SNOQUALMIE PASS AREA

SCALE

ONE MILE

GEOLOGY IN PART FROM USGS FOLIO 139