A CONTRIBUTION TO THE GEOLOGY OF THE OLYMPIC MOUNTAINS WASHINGTON

by

WILBERT ROOSEVELT DANNER

A thesis submitted for the degree of

MASTER OF SCIENCE

UNIVERSITY OF WASHINGTON

1948

UNIVERSITY OF WASHINGTON

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION

BY WILBERT ROOSEVELT DANNER

ENTITLED A CONTRIBUTION TO THE GEOLOGY OF THE OLYMPIC MOUNTAINS WASHINGTON

COMPLIES WITH UNIVERSITY REGULATIONS AND IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

SIGNATURE *Peter Misch* *J H Mackin - Prof of Geology*

OFFICIAL TITLE *assistant professor of geology*

DATE *June 4* 19*48*

THIS THESIS COMPLIES WITH LIBRARY REQUIREMENTS.

J Ronald Todd *Thesis* LIBRARIAN

S. F. No. 3150—1936. 1M 6-44 1853-G.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF PLATES

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

A CONTRIBUTION TO THE GEOLOGY OF THE OLYMPIC MOUNTAINS WASHINGTON

INTRODUCTION

Location

The Olympic Mountains make up the major portion of the Olympic Peninsula which forms the northwestern portion of the State of Washington. The peninsula occupies an area of about 4000 square miles of which 2500 square miles is mountainous. It is bounded on the west by the Pacific Ocean, on the north by the Strait of Juan de Fuca, on the east by Hood Canal and Puget Sound, and on the south by the lowlands of the Chehalis River valley. A narrow coastal plain extends along the western and northern coasts. The mountains rise abruptly from this coastal plain to altitudes of nearly 8000 feet.

The central portion of the mountains form the Olympic National Park. Most of the surrounding area is included in

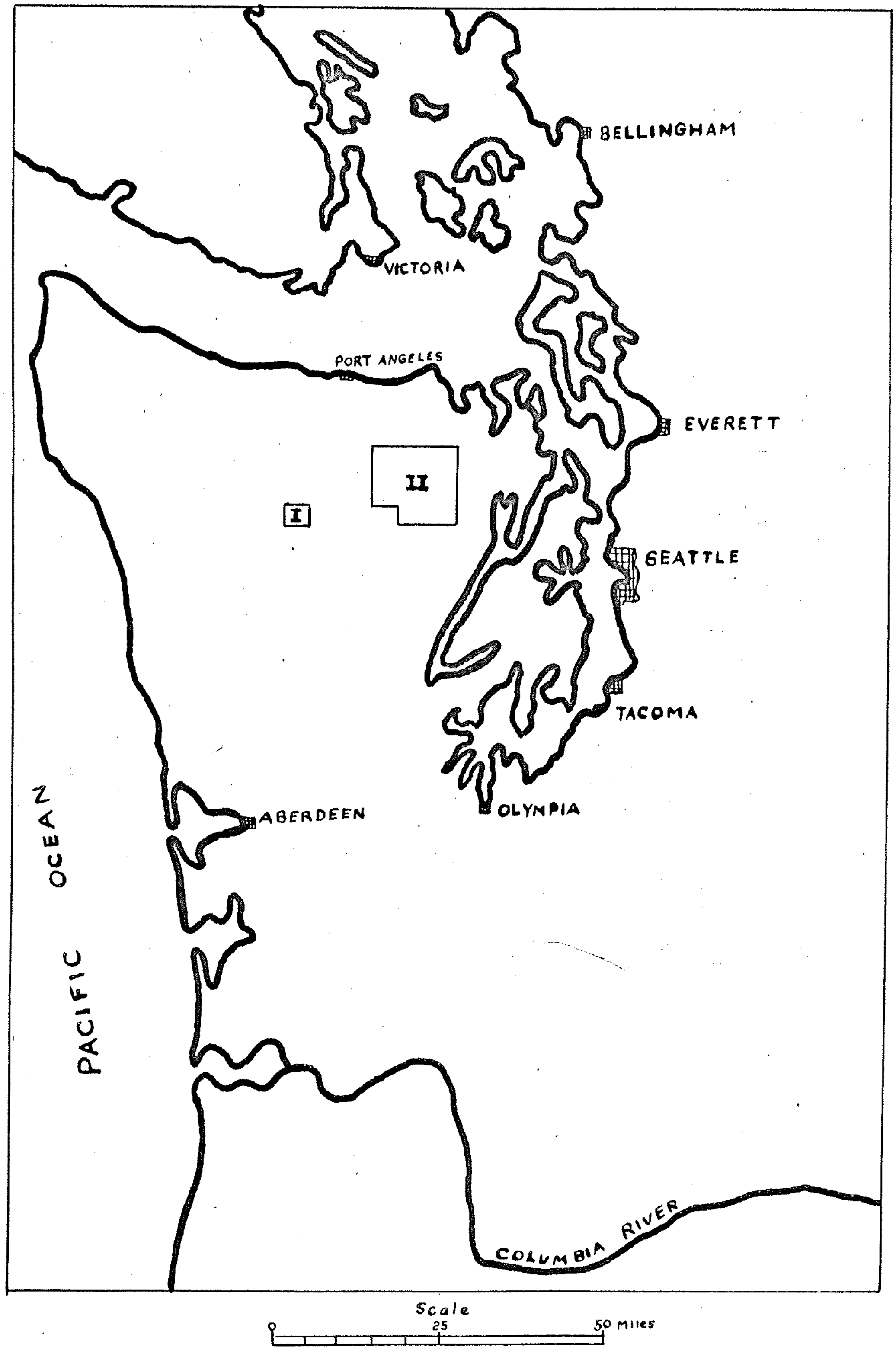


Figure 1. Index map of western Washington showing areas mapped on the Olympic Peninsula.

the Olympic National Forest. The peninsula consists of Clallam County, Jefferson County and portions of Mason and Grays Harbor Counties.

Purpose and Scope of Investigation

The Olympic Mountains are a conspicuous blank on the geologic map of the State of Washington. Conflicting reports have been given concerning their structure and stratigraphy. The structural relations of the Olympics to the rest of Western Washington have not been determined. While on hikes into the Olympic Mountains from 1938 to 1945 the writer became interested in the geology of the area. The eastern portion of the mountains seemed to be best suited for geological investigation. Field work was undertaken during the months of June, July, August and September of 1947. A reconnaissance geologic map was made of the Mount Constance area. A new formation was mapped in the vicinity of Mount Seattle. Base maps used were the topographic maps of the United States Geological Survey. Aerial photographs greatly aided in the field mapping.

Previous Work

There are only few published geological data on the Olympic Mountains. A geological map of the coastal region was made by Arnold (1906) and the stratigraphy of the rocks exposed on the beaches was described. The peninsula was completely inaccessible at this time and exposures in sea cliffs were the best obtainable. Reagan (1909) investigated the northwest coastal area and the valleys of the Soleduc and Hoh Rivers. He made a study of the structure and attempted to establish the age of the formations through faunal collections and on the base of their structural relations. Although the ages he assigned to the different formations have since been changed with the discovery of new faunas, his structural interpretations remain remarkably accurate. Weaver (1916) (1937) made a detailed investigation of the Tertiary formations of Western Washington and mapped several small areas on the peninsula. The stratigraphy of the Tertiary formations was described and evidence presented to show that these formations are unconformable upon an older series of highly folded sediments forming the interior of the mountains. McMichael (1946) mapped the northeastern Olympics and gave faunal and structural evidence that the more indurated sediments of the interior in that portion of the Olympics may also be of Tertiary age. Small but numerous manganese bearing sedimentary beds occurring as lenses in the Eocene basalts have been the subject of numerous investigations by the Geological Survey and the State of Washington Department of Conservation and Development. They were first described by Pardee (1921, 1927) and the occurrence of the rare manganese silicates Bementite and Neotocite was noted. A more thorough investigation was undertaken by Park (1942, 1946). Evidence was presented to show that the manganese minerals have formed by replacement. Green (1945) mentions the occurrence of manganese deposits and basalts in the interior where their presence had until then not been suspected. He believes they were downfaulted from an originally continuous blanket of Tertiary volcanics covering the Olympic Peninsula.

Topography and Drainage

The Olympic Mountains rise sharply from sea level to elevations of nearly 8000 feet. The highest peak, Mount Olympus (7923 feet), is located almost exactly in the geographical center of the peninsula. Streams radiate out in all directions from the central portion of the mountains. They descend steeply from their sources of glaciers and snow fields into narrow valleys which penetrate the heart of the peninsula.

The main valley bottoms are seldom more than 2000 feet above sea level; thus there is a local relief of nearly 6000 feet.

The Mount Constance area is a series of north-south trending ridges. They gradually decrease in elevation to the north. Mount Deception, Mount Constance and Mount Mystery, all rising above 7500 feet, are the highest points on these ridges. Deep valleys with northward flowing streams parallel the ridges. In the northern part of the area where the ridges become lower the streams cut across them and combine to form the Dungeness River and its major tributary the Greywolf River. In the extreme southern portion of the area mapped the Dosewallips River has cut a deep canyon across all of the ridges in an east-west direction.

Climate and Vegetation

The Olympic Mountains act as a barrier to the warm moisture-laden winds of the Pacific Ocean. As these winds rise over the mountains they become cooled and loose a considerable portion of their moisture in the form of rain and snow. As a result the western part of the peninsula has a yearly rainfall exceeding 160 inches. This decreases eastward to about 40 inches along Hood Canal. No measurements have been taken in

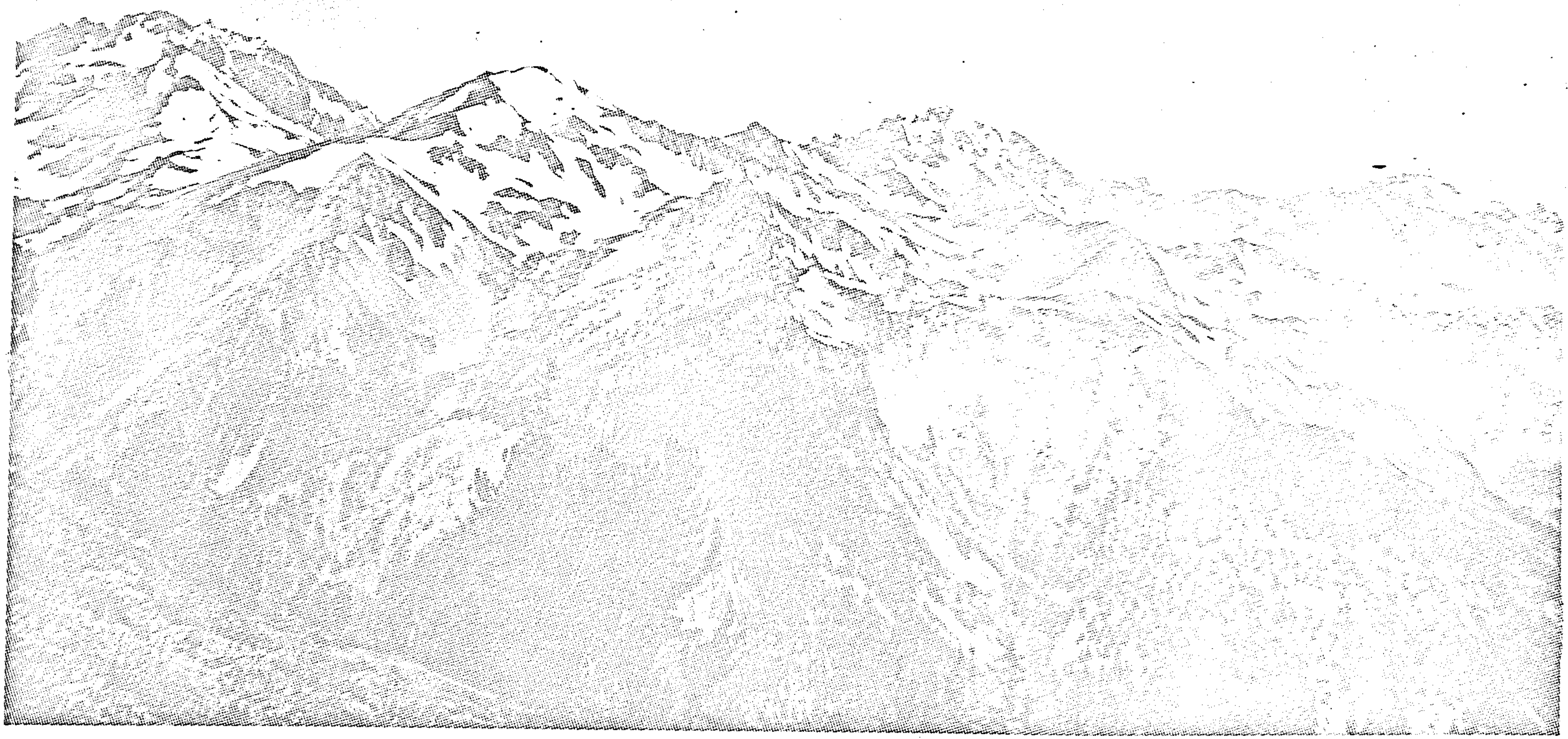


FIGURE 2. THE NORTHEASTERN PEAKS OF THE OLYMPIC MOUNTAINS. Looking westward across the upper Dungeness valley from the northern slopes of Mount Constance near Marmot Pass. The prominent ridge in the background rises to an elevation of 7772 feet in Mount Deception, second highest peak in the Olympics.

the interior. Snow falls in the higher country from September to July and permanent nevé fields are found above 6000 feet. July, August and September are driest and the only months suitable for geologic field work.

An exceedingly heavy growth of vegetation covers the lower elevations. This jungle-like cover renders a detailed study impossible. Above 5500 feet alpine meadows are common and the bare high peaks offer good exposures.

Acknowledgments

The writer wishes to thank for their interest and aid, Peter Misch and J. Hoover Mackin, faculty members of the Department of Geology of the University of Washington, who were his advisors. He also wishes to express his gratitude to Charles E. Weaver, G. E. Goodspeed, Howard Coombs and Julian Barksdale for their constant inspiration. Charles F. Park Jr., T. J. Etherington, Michael Rector and Walter Warren aided the author in contributing freely of their knowledge of the area. The rangers of the Olympic National Park and Olympic National Forest and the "Olympians" of Grays Harbor greatly facilitated the field work by their generous cooperation and hospitality. Thanks are also due to the Geological Survey for the use of unpublished topo-

graphic maps of the area. And lastly the writer must give his grateful thanks to his mother and father for their encouragement and financial help without which the study could not have been undertaken.

STRATIGRAPHIC GEOLOGY

General Statement

The formations of the Olympic Peninsula can be divided into two main groups, (1) the non-metamorphic and fossiliferous Tertiary sediments and volcanics forming the coastal plain, and some of the outer mountains, (2) the generally weakly metamorphosed and usually unfossiliferous sediments and volcanics forming the interior of the mountains. All of these formations apparently form a concordant sequence. A prominent band of volcanics along with some other stratigraphic members forms a more or less continuous outcrop in the northern, eastern and southern part of the mountains. This band has the shape of a large horse shoe open on the west. It is inside this horseshoe that the series (2) mentioned above occurs.

The formations in the area mapped seem to be all of Early Tertiary age and consist of both sediments and volcanics. Some of these have been altered to low grade phyllites and greenstones. No granites, schists or gneiss have been found in the Olympics by the writer.

Mount Seattle Formation

General Statement

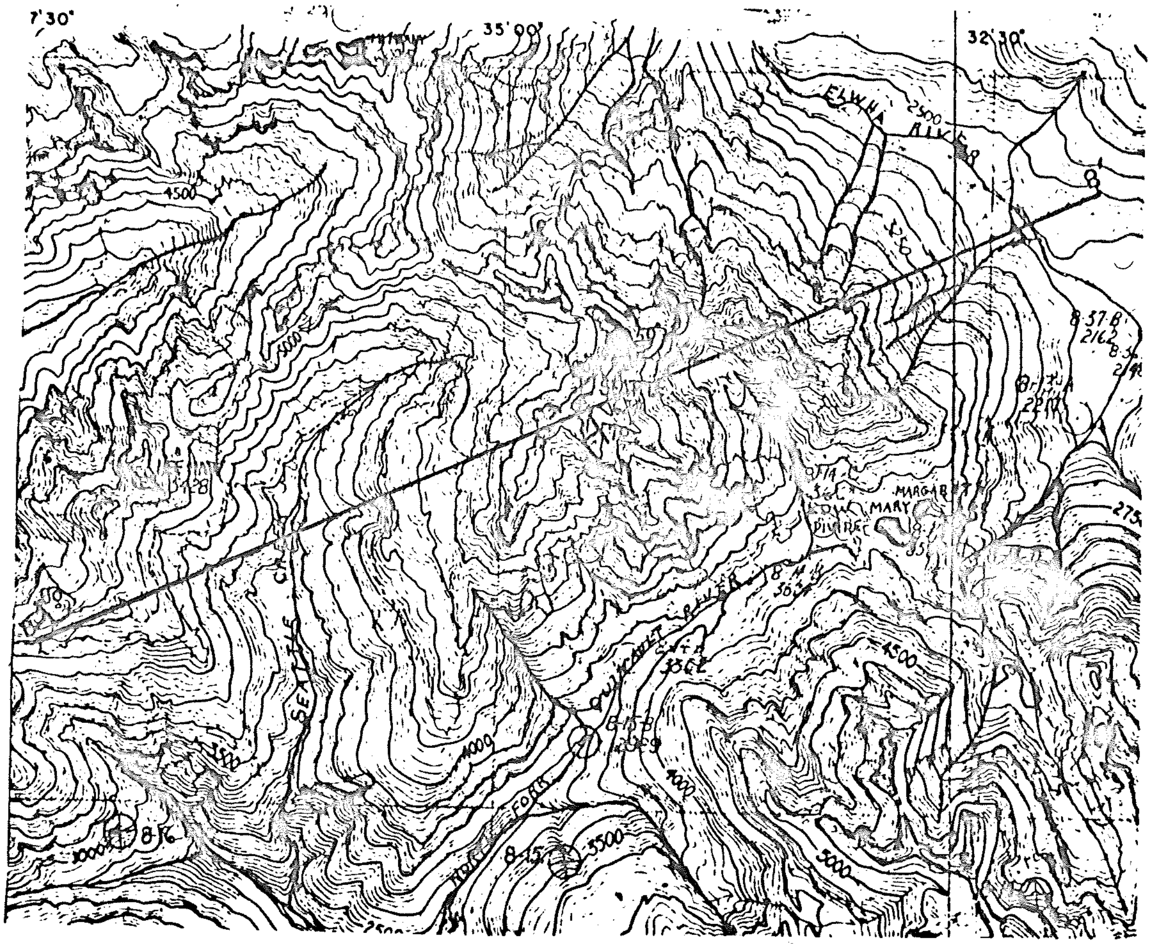
The name Mount Seattle Formation is given to a group of clastic rocks which occur in the center of the Olympics. Exposures of these rocks may be observed along the trail from Delabarre Creek south to Low Divide and along the Skyline trail in the vicinity of Kimta Basin. Mount Seattle and Mount Meany to the west and north of Low Divide are largely composed of these clastic sediments.

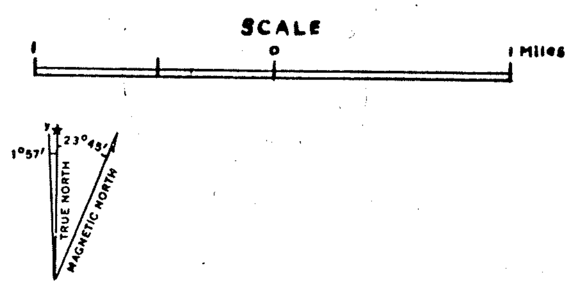
Lithology

The dominant rocks are arkosic sandstones, black slates and phyllites. The sandstones are light-grey in color, medium-grained and show little change in either grain size or color in any one bed. Thereis no gradation between sandstones and slates, the contacts between parallel beds being very sharp. Some of the sandstones contain lenticular masses of black slate over a foot in width and several feet long. The sandstones are fractured and the fractures filled with quartz. In many cases vugs and cavities in these fractures are lined with clear colorless quartz crystals. In rare instances green and also reddish crystals are found. Limonite has been deposited in some of the fractures and fills the spaces between the quartz crystals.

Quartz and quartzite fragments are the dominant

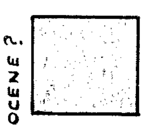
PLATE I

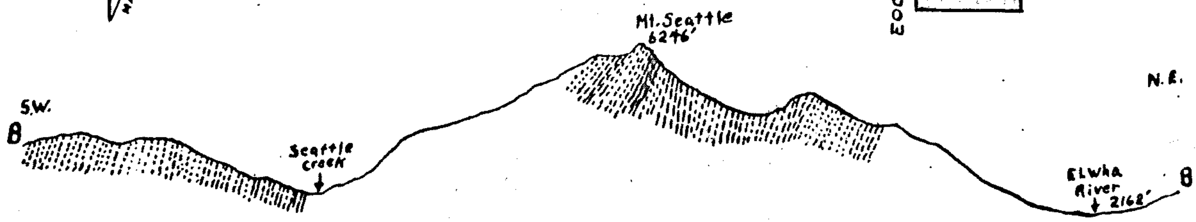




MT. SEATTLE AREA

CONTOUR INTERVAL 50 FEET

EOCENE ?  MOUNT SEATTLE FORMATION



GEOLOGY : W.R DANNER 1948

constituents of the sandstone. About 10 percent of the fragments are plagioclase and there are minor amounts of chlorite, sericite, muscovite, olivine, slate and volcanic rocks. The quartz grains are fractured and broken. An occasional altered muscovite is found bent around a quartz grain. Sericite is developed on the borders of the feldspar grains and is scattered throughout the rock in tiny flakes showing a crude alignment (Figures 4 and 5). All of the fragments are very sharp and angular.

The slate is predominently black in color and has strong slaty cleavage. It is evidently rich in iron and upon weathering is stained a bright yellow brown.

The slates and sandstones grade upward into a grey phyllite which outcrops near the top of Mount Seattle. Strong slaty cleavage is developed and a silky sheen is imparted to the rock by the development of sericite. In thin section the rock is seen to be composed predominately of tiny quartz grains and sericite. The quartz grains are long and angular and the sericite forms thin flakes around them. Limonitic material is common in bands which probably represent the bedding (Figure 7). The sericite is more conspicuous in the hand specimen than under the microscope.

Neither the top nor the bottom of the Mount Seattle formation was found. The thickness present on Mount Seattle is more than 5000 feet. Outcrops of similar clastic rocks are

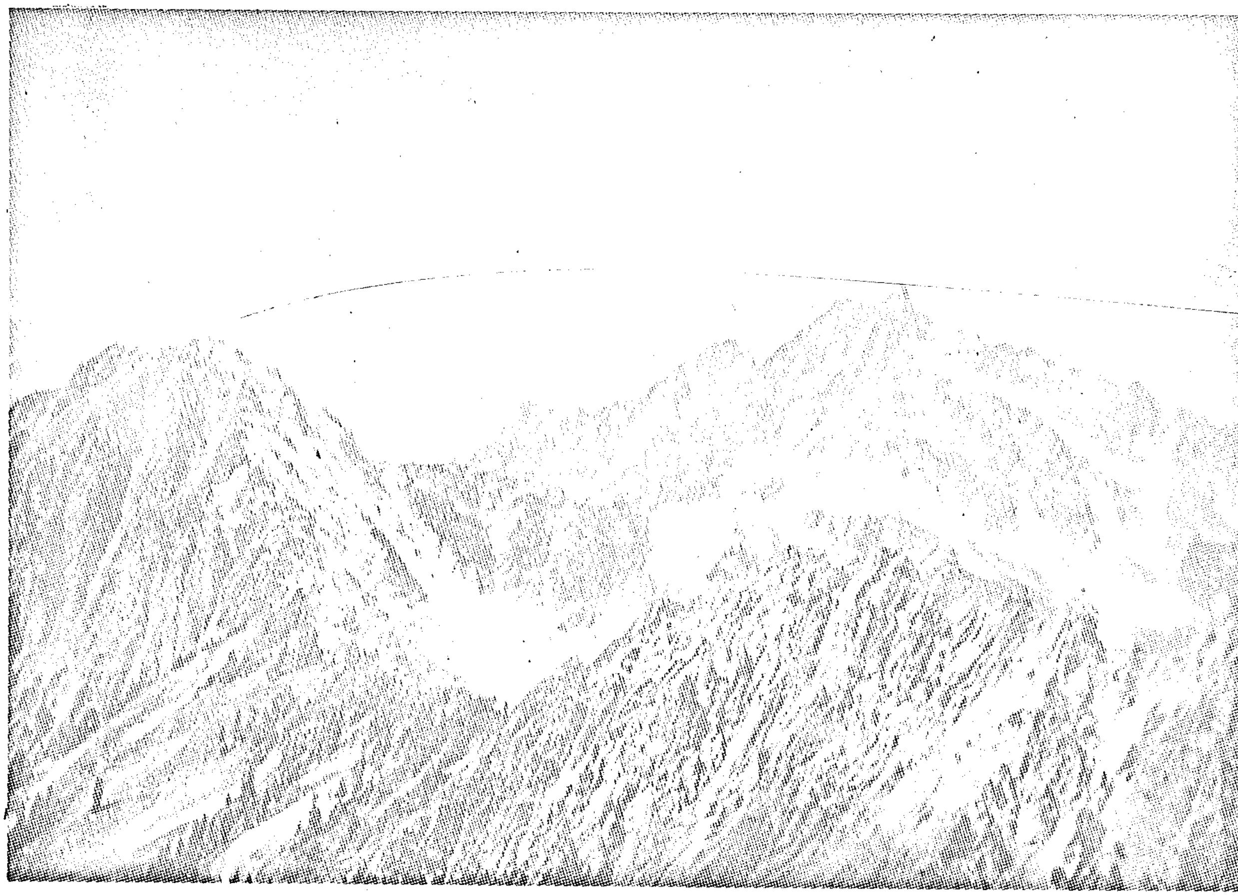


FIGURE 3. PHOTOGRAPH TAKEN LOOKING NORTHWEST FROM MOUNT SEATTLE. Mount Meany in the right background and Mount Olympus to the left. The steep barren ridges offer excellent exposures of the Olympic Formation.

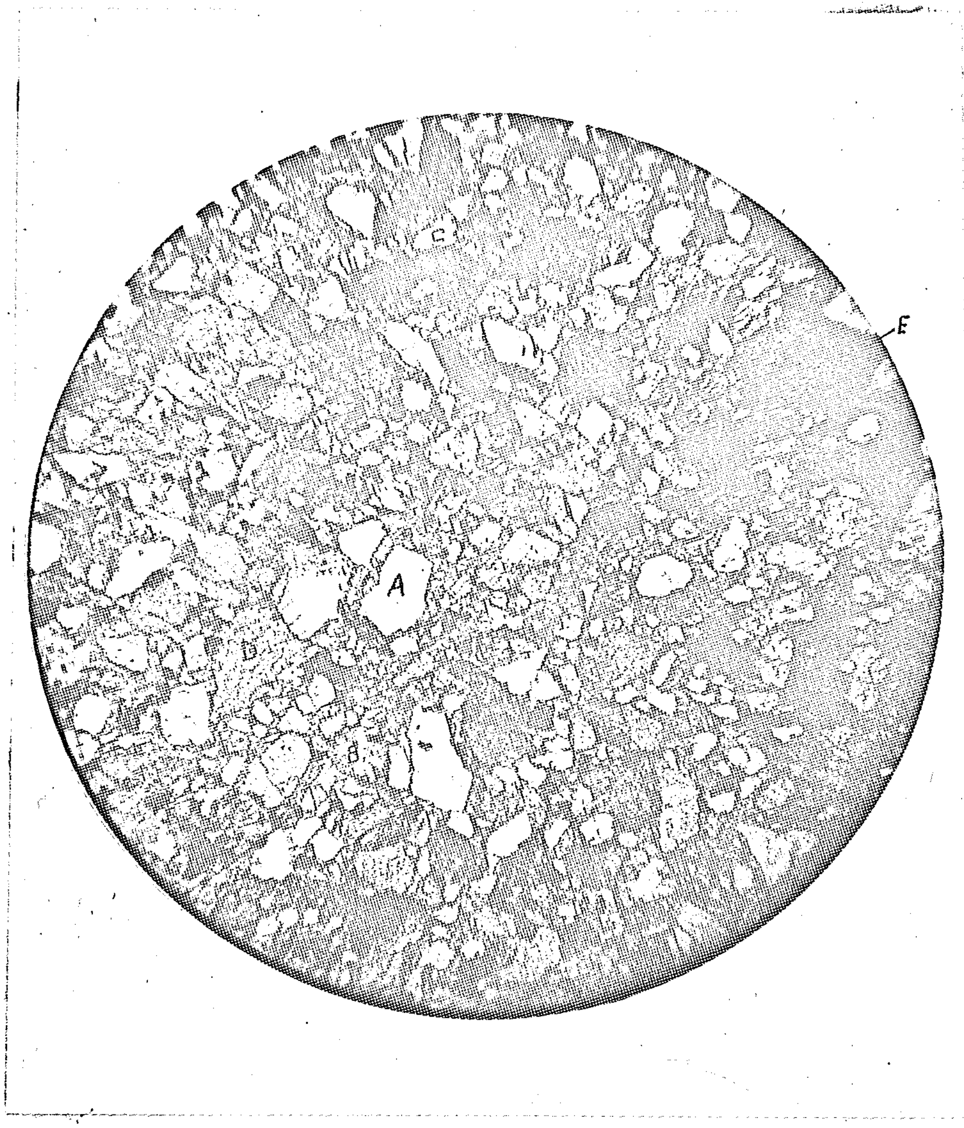


FIGURE 4. THIN SECTION OF SANDSTONE FROM THE TOP OF MOUNT SEATTLE. Plain light. X 20½. A Quartz, B Quartzite, C Plagioclase, D Volcanic rock fragment, E Slate fragment.

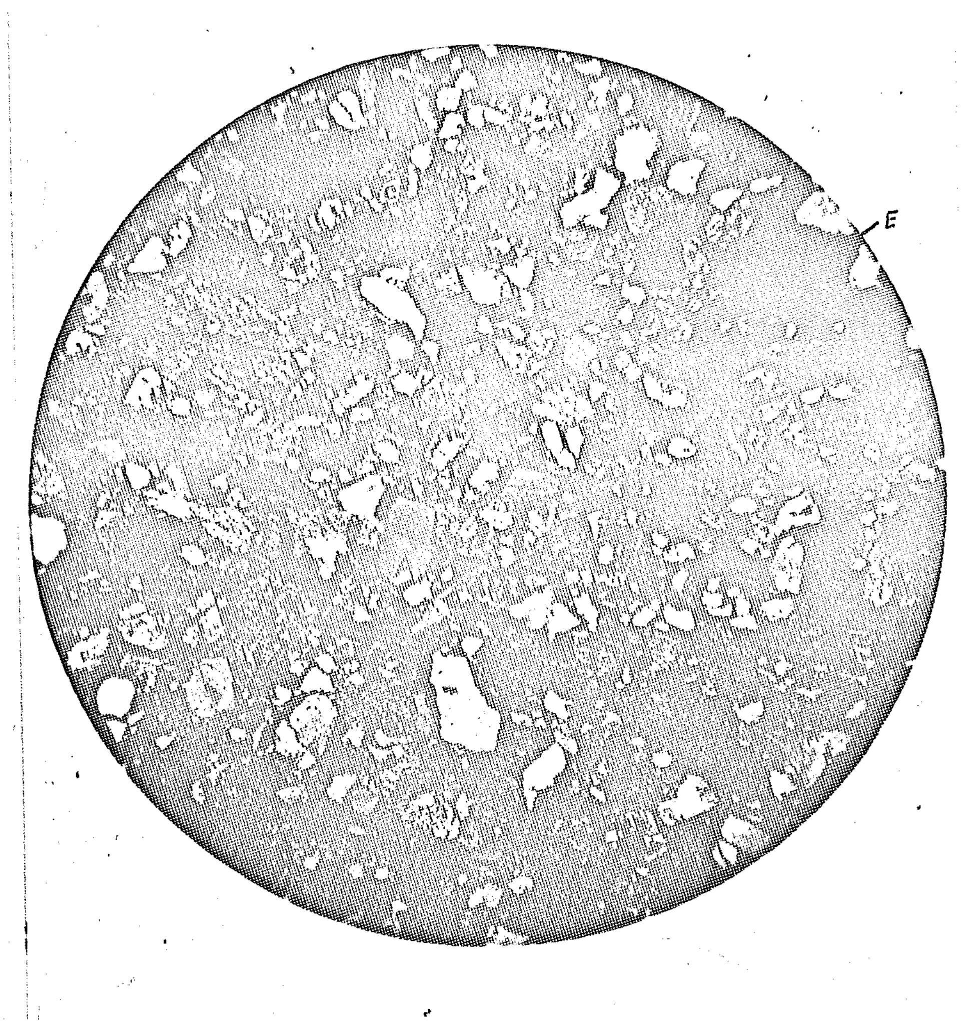


FIGURE 5. THIN SECTION OF SANDSTONE FROM THE TOP OF MOUNT SEATTLE. Crossed Nicols. X $20\frac{1}{2}$. A Quartz, B Quartzite, C Plagioclase, D Volcanic rock fragment, E Slate fragment.

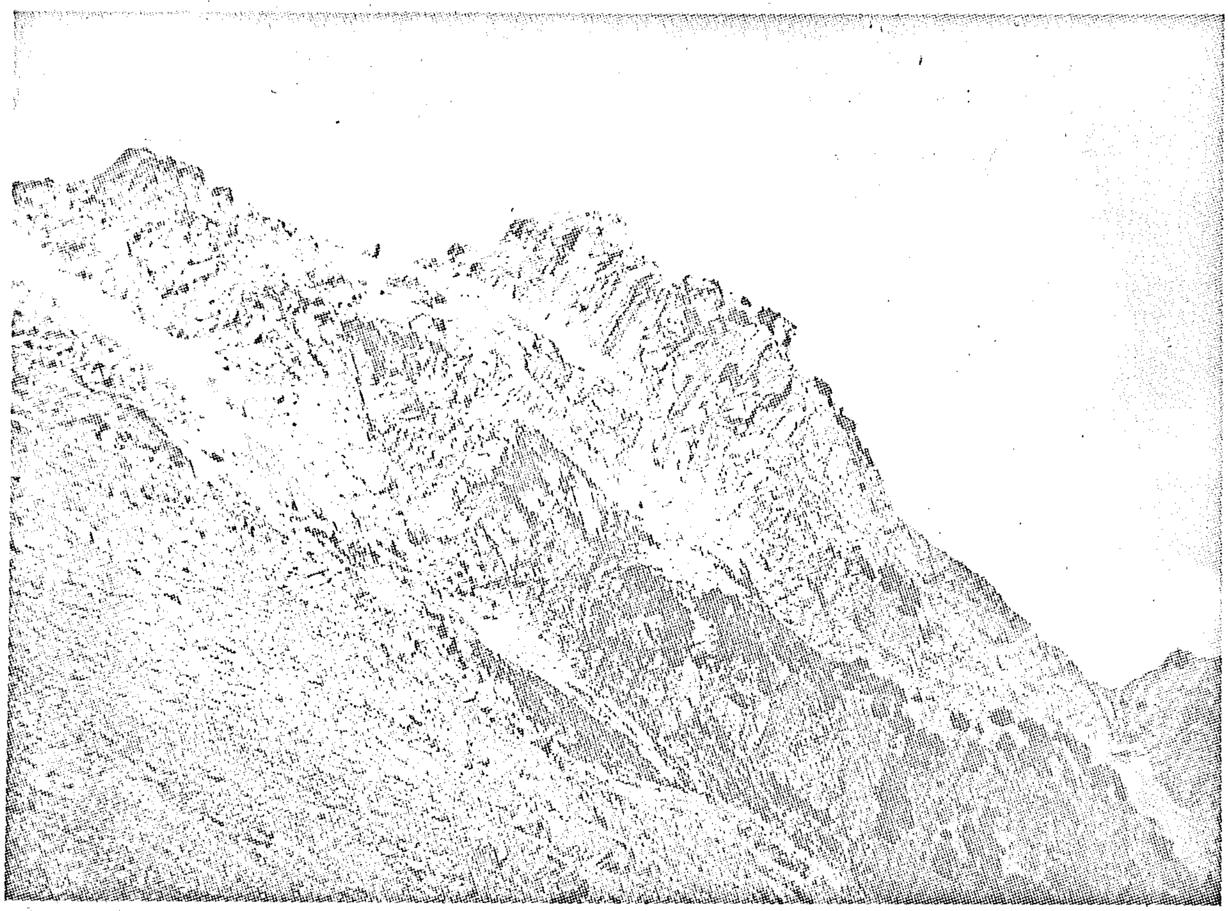


FIGURE 6. OUTCROP OF THE OLYMPIC FORMATION ON THE NORTH PEAK OF MOUNT SEATTLE. The dip here is about 50 degrees to the southwest. Photograph taken from near the top of the main peak looking in a northwesterly direction.

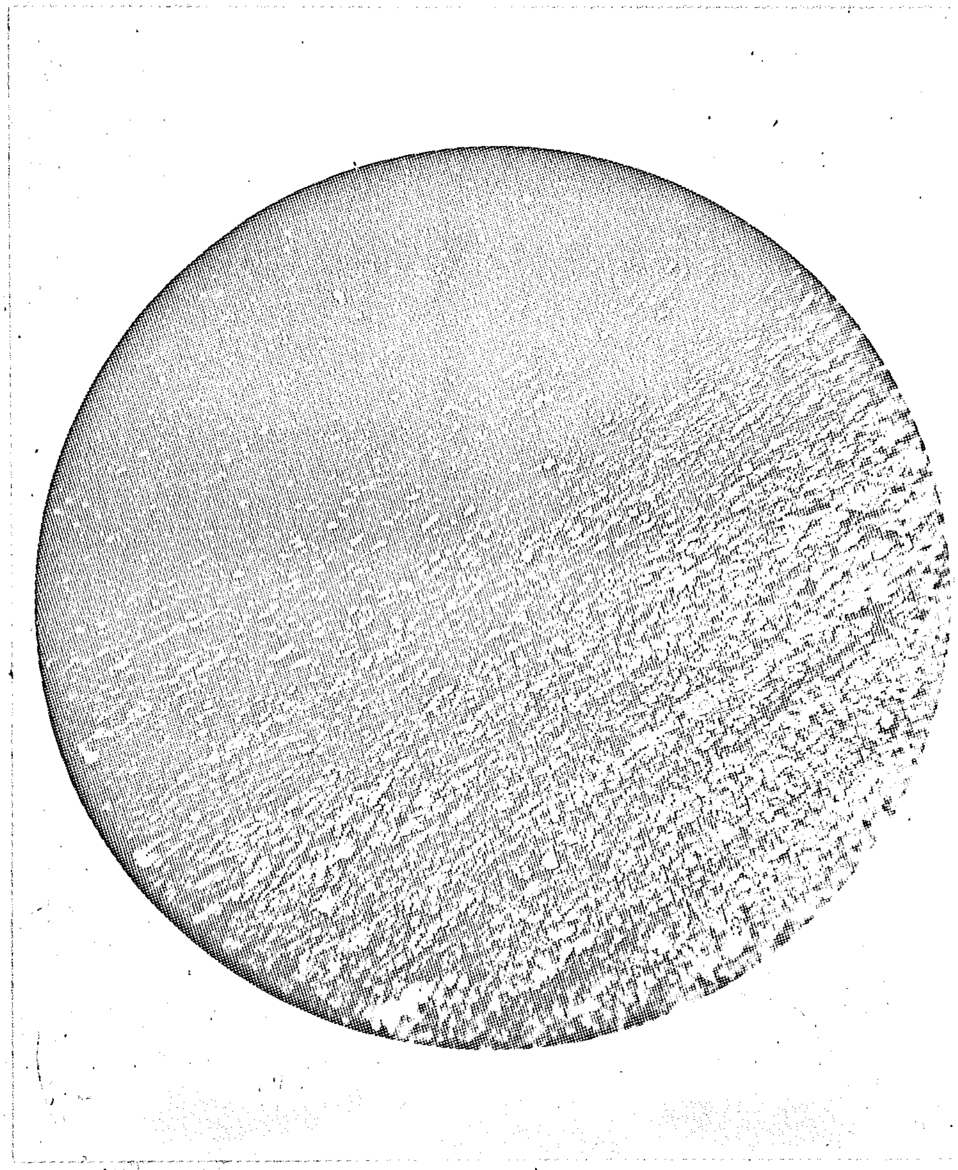


FIGURE 7. THIN SECTION OF PHYLLITE FROM THE EAST SIDE OF MOUNT SEATTLE. Plain light X 20½. Dark bands are limonitic material.

found to the south for a distance of 5 miles. The dip is steeply to the southwest, ranging from 45 to 85 degrees. No repetition of beds from Mount Seattle to the south could be recognized. An interfingering relationship would make a repetition of beds very difficult to find and this seems to be the case with this formation. In any case available evidence points to a great thickness. It may be as much as 20,000 to 30,000 feet.

Age and Correlation

No fossils have been found in rocks of the Olympic formation. It is distinguished from the Soleduc formation by its lack of detrital mica, light grey color of its sandstones and its stronger metamorphism. No specific age has been assigned to it but it may be contemporaneous with the very thick Puget Group (Lower Eocene) found in the Puget Sound region. It could also be older or younger. In all probability it is of Tertiary age.

Soleduc Formation

General Statement

The name Soleduc formation has been used by Reagan (1909) for a great thickness of clastic rocks in the northwestern part of the Olympic Peninsula. On stratigraphic evidence [Position below the Metchusin basalt] he placed the rocks in the Cretaceous. Palmer (1927) found Miocene fossils in these rocks and concluded that the entire sequence was of Miocene age. The fossils were found in formations that Weaver (1916) also believed were older than Miocene and had grouped under the general term Hoh formation. On reinvestigation Weaver (1937) found that the Hoh could be divided into a formation of less indurated sediments containing a Miocene fauna, and a more indurated series of sediments which did not contain fossils. The Miocene rocks were named the Hoh formation, and the unfossiliferous rocks were given the name Soleduc formation. The type sections of the Soleduc are at the southwestern shore of Lake Crescent, along the Soleduc River, and along the road from Lake Mills to Olympic Hot Springs. None of these are in the area mapped by the writer.

Lithology and Areal Distribution

The Soleduc formation consists of a great thickness of massive brownish-gray arkosic sandstones, graywackes, slates, breccias, and subordinate layers of altered volcanic rocks. The sandstones are fine- to coarse-grained. They are composed of sharply angular quartz, quartzite, plagioclase, biotite and muscovite grains. Sericite is commonly developed around the plagioclase and Muscovite. Many of the grains are broken and crushed, showing the effects of sheaving connected with folding. Quartz, quartzite and mica are the dominant constituents. Plagioclase is present in varying amounts up to 10 percent. It is predominately albite and oligoclase. Occasionally a fragment of slate or altered volcanic rock is found. The volcanic rock is too highly altered to be identified with accuracy but it closely resembles basalt.

An analysis of heavy minerals of several samples of the sandstone was attempted with negative results. No heavies were present.

The graywackes closely resemble the sandstones in composition but are darker in color and contain more detrital mica and slate fragments. The slate fragments may reach an inch in length and the rock is then more properly called a breccia. The large amount of detrital mica in the graywackes gives them the appearance of a schist.

The basal contact of the Soleduc has not been observed. It appears that in the upper part of the Soleduc the bedding is in many areas parallel to the overlying Metchosin basalt sequence. However, contact relations are obscure, and complex faulting has occurred along the contact in most areas. Fairly persistently a sequence of dark black argillite and slate occurs near the upper contact of the Soleduc. Muscovite in tiny flakes is common in these beds and gives them the appearance of phyllites. Fine grained, lighter-colored sandstones are found in thin layers in the slate. A few Echinoderm spines have been found in these slates near their contact with the Metchosin basalt at Pass Creek on the Dosewallips river and on the west side of Buckhorn Pass in the upper Dungeness drainage. No other fossils were found. Locally the slates and argillites become sandy and lighter in color.

The position of this member and its relation to the Metchosin basalt presents a difficult problem. From Constance Pass northward to Buckhorn Pass the slates and basalts show an angular relationship. There is good evidence that this contact is a fault. Mylonite is common very close to the contact and the sediments are much fractured and broken. The sediments dip consistently to the southwest and the basalts to the east and northeast. The black slate appears to be the lowest member in the SoleDuc section where the relationship is as described. On

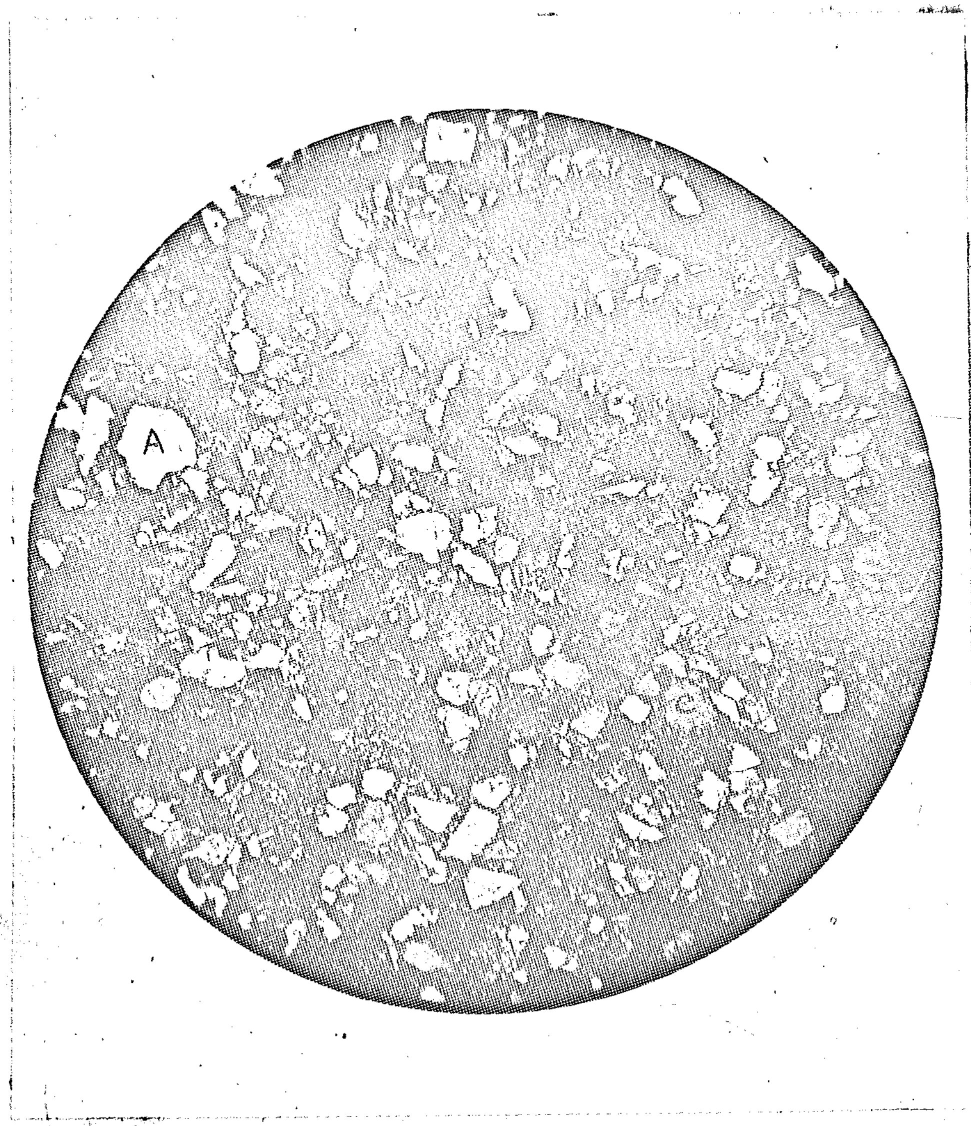


FIGURE 8. THIN SECTION OF ARKOSIC SANDSTONE FROM A TYPE SECTION OF THE SOLEDUC FORMATION ALONG THE OLYMPIC HOT SPRINGS ROAD. Crossed Nicols. X $20\frac{1}{2}$. A Quartz, B Oligoclase, C Quartzite, D Volcanic rock.

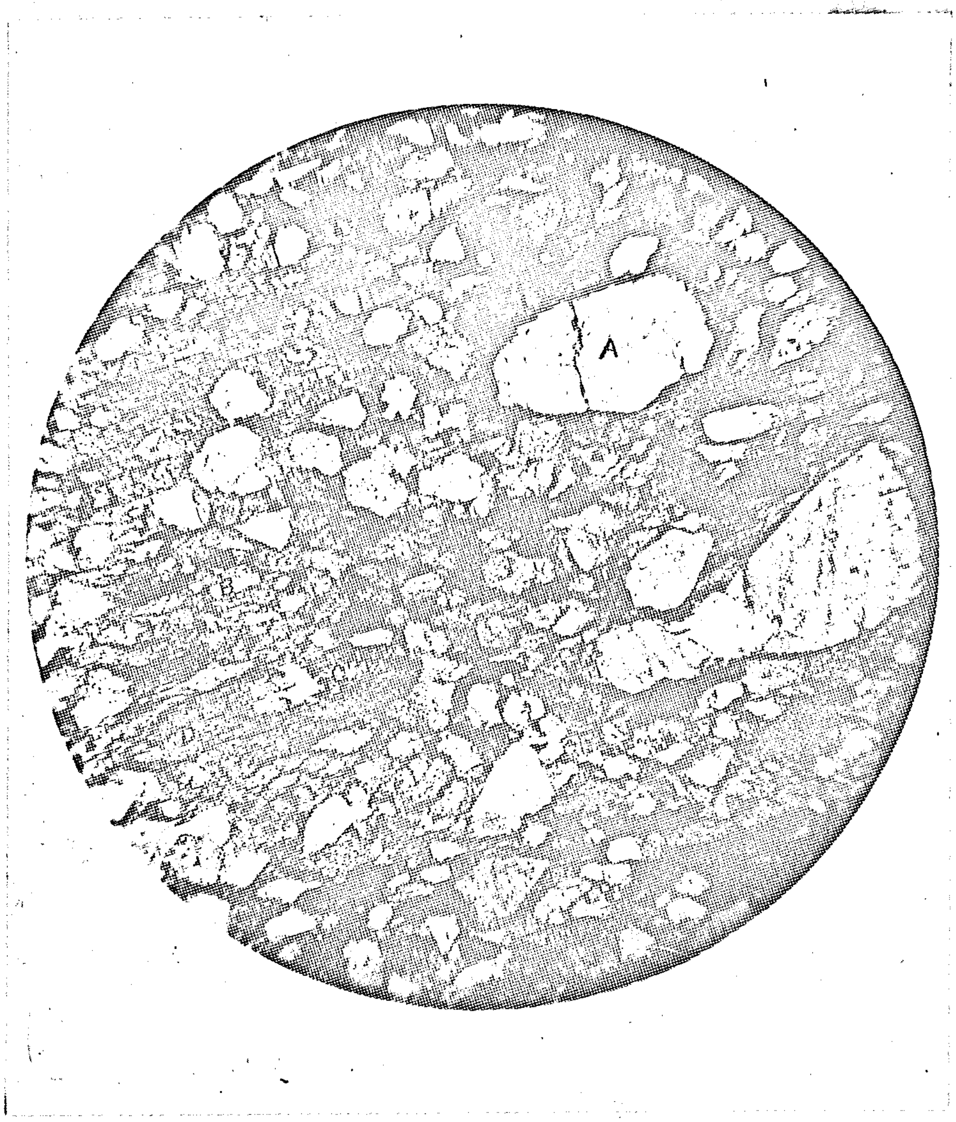


FIGURE 9. THIN SECTION OF SANDSTONE FROM NEAR THE TOP OF LOST PEAK AT THE HEAD OF DOSEWALLIPS VALLEY. Plain light. X 20.5. Note the fracturing of the large quartz fragment and the development of sericite. A Quartz, B Plagioclase, C Sericite, D Muscovite.

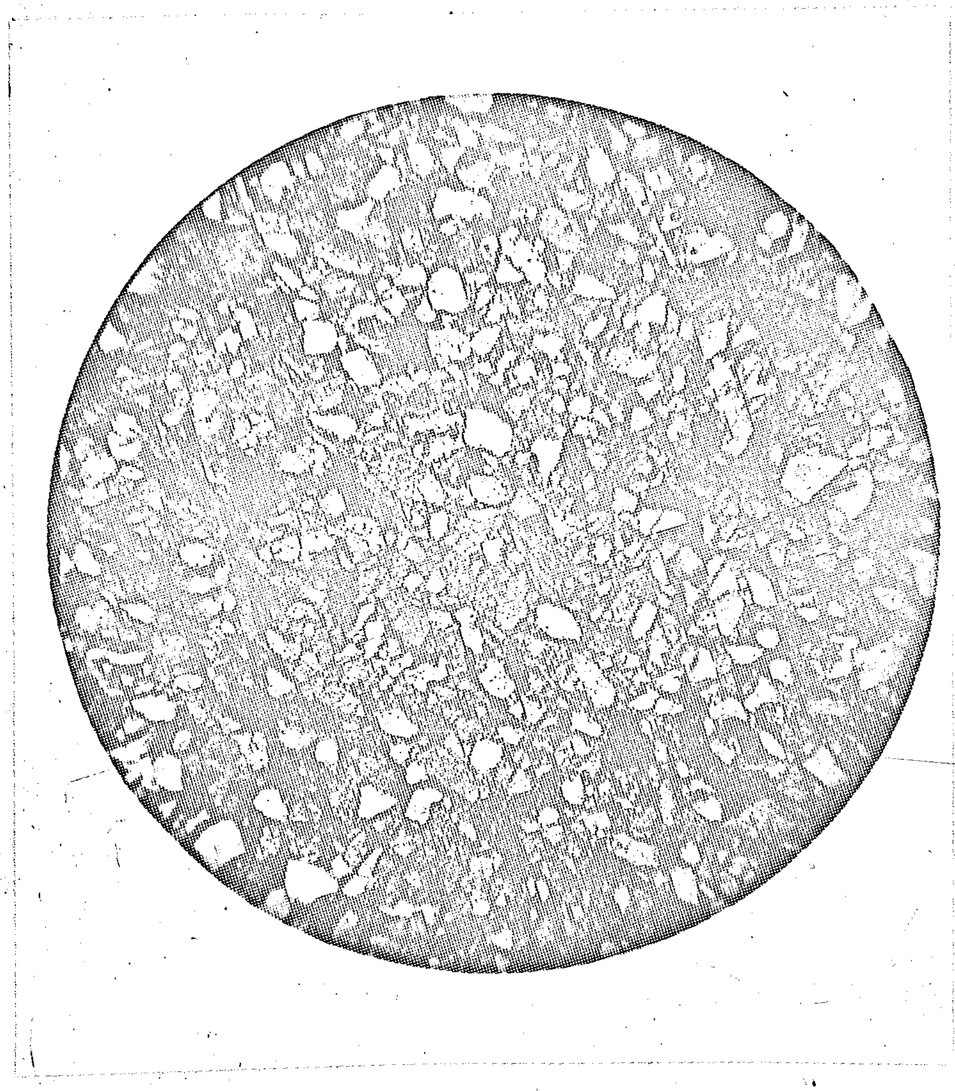


FIGURE 10. MICACEOUS SANDSTONE FROM ABOVE CAMP HANDY ON THE WEST SIDE OF THE UPPER DUNGENESS VALLEY. Plain Light. X 20½. The black grains are slate, the white grains mostly quartz. Muscovite is seen as long narrow flakes bent around the quartz grains.

FIGURE 11. THICK SEQUENCE OF SLATE AND SANDSTONE EXPOSED ON THE EASTERN SIDE OF ROYAL RIDGE ABOVE CAMP HANDY ON THE DUNGENESS RIVER. The beds dip to the southwest. The photograph is taken looking to the northwest from Lake Relief.

following the contact northward, the basalt also dips to the southwest and the black slate now appears to conformably overlie the basalt. Farther to the east, along the Olympic Hot Springs road type section, the slate member dips northward under the Metchosin which here also dips northward. This relationship suggests that the black slate is actually beneath the basalt and that where the slate appears to be above the basalt the sequence is overturned. There are indications that the basalt sequence along the Greywolf River is reversed. This and the fact that metamorphism increases towards the interior in the almost uniformly southwest dipping Soleduc formation, leads to the conclusion that the slate member may be on top or near the top of the Soleduc.

Stratigraphicly below the slate member is a great thickness of micaceous sandstones, graywackes and slate breccias. Several thick slate units also occur in this sequence. The section is well exposed on Royal Ridge on the west side of the upper Dungeness valley. Excellant exposures may also be seen along the ridge leading westward from Mount Constance. The sandstone and slate beds vary greatly in thickness and interfinger. Individual members are hard to trace, with the exception of a slate breccia occurring about the middle of the sequence. This breccia outcrops in the valley of Heather Creek, one of the sources of the Dungeness river, about a mile from its juncture with the Dungeness. It continues along the west side of the Dungeness valley, crossing the ridge above Camp Handy just below the timber line. It is observed on both limbs of the anticlinal structure forming Royal Basin on the east side of Mount Deception, and strikes from here to the northwest, crossing the Greywolf River at about the 13 mile marker (3000 foot contour line). This unit is probably not more than 100 feet thick, but is the only definite stratigraphic member that can be traced for any distance.

A total thickness of about 6000 feet of the micaceous sandstones and slates is exposed in this area. Although no definite faunal evidence is available, it is believed that deposition was in a shallow sea. The evidence as to marine origin are Echinoderm spines found in one of the slate beds and the occurrence of foraminifera (Globergerina ?) in limestone lenses in interbedded basalts. The basalts have good pillow structure and are therefore subaquacous.

The occurrence of the slate breccia indicates deposition in shallow water. The slate was originally mud, perhaps in a tidal flat. After drying, the mud curled up and was subsequently incorporated as fragments in newly deposited sandy layers. The slate fragments are sharp and angular and could not have come from a far distant source. Slate fragments of the Soleduc formation can be made into rounded pieces the size of quarters and nickels by agitating them for no more than two hours in a forminifera grinding jar. Such rounded fragments are also common near slate outcrops in all the streams.

Further evidence of deposition in shallow water are mud cracks and ripple marks observed in sandy black slates about a mile up Royal Creek and in Royal Basin respectively.

Similar slate breccias are found in the Quinault Valley glacial moraine between the towns of Humptulips and Lake Quinault in the extreme southwestern Olympics. This indicates a somewhat continuous outcrop of this member around the Olympic Mountains, paralleling the horse shoe outcrop of the Metchosin basalt.

Black micaceous sandstones outcrop along the upper Greywolf River from two miles east of Three Forks to its source. In these beds a uniform southwestern dip is observed. However, these beds are not a continuous sequence, but form several folds overturned to the northwest, as can be observed along the Graywolf River near the Olympic National Park boundary.

Sandstones are found along the Obstruction Point trail from Deer Park Lookout in the northern part of the map area. These sandstones and associated shales are only slightly metamorphosed and are brown in color. They were believed by McMichael (1946) to be of Crescent age. This was based on their similarity to known beds of Crescent age to the north.

Possibly these brown sandstones are identical with similar sandstones occurring in the Metchosin formation. Lithology and lack of metamorphism are strongly in favor of such a correlation. The contact of these unmetamorphosed sediments with the darker slates and sandstones of the Soleduc is obscure; the boundary has been mapped where the sediments become more dark-colored and somewhat metamorphosed. Indurated sandstones and black slates typical of the Soleduc are exposed in the vicinity of Obstruction Peak and farther south in Grand Valley and Lillian Valley. No section could be measured in this area due to very complex isoclinal folding. Some folds are vertical while others are overturned and broken by many small faults. Good exposures of these structures may be seen at the head of Grand Valley (Figure 12) and on the northern slopes of McCartney peak near Lillian Lake. This complexly folded area extends south to the Dosewallips River.

Slates and sandstones of probable Soleduc age occur in the upper Dosewallips River valley. They are somewhat more strongly metamorphosed than the Soleduc rocks farther down river. The dip is fairly persistant to southwest although a few folds can be observed. All the sediments are strongly contorted and wrinkled. Almost vertical beds are crumpled in a sinuous manner. Faulting has occurred along

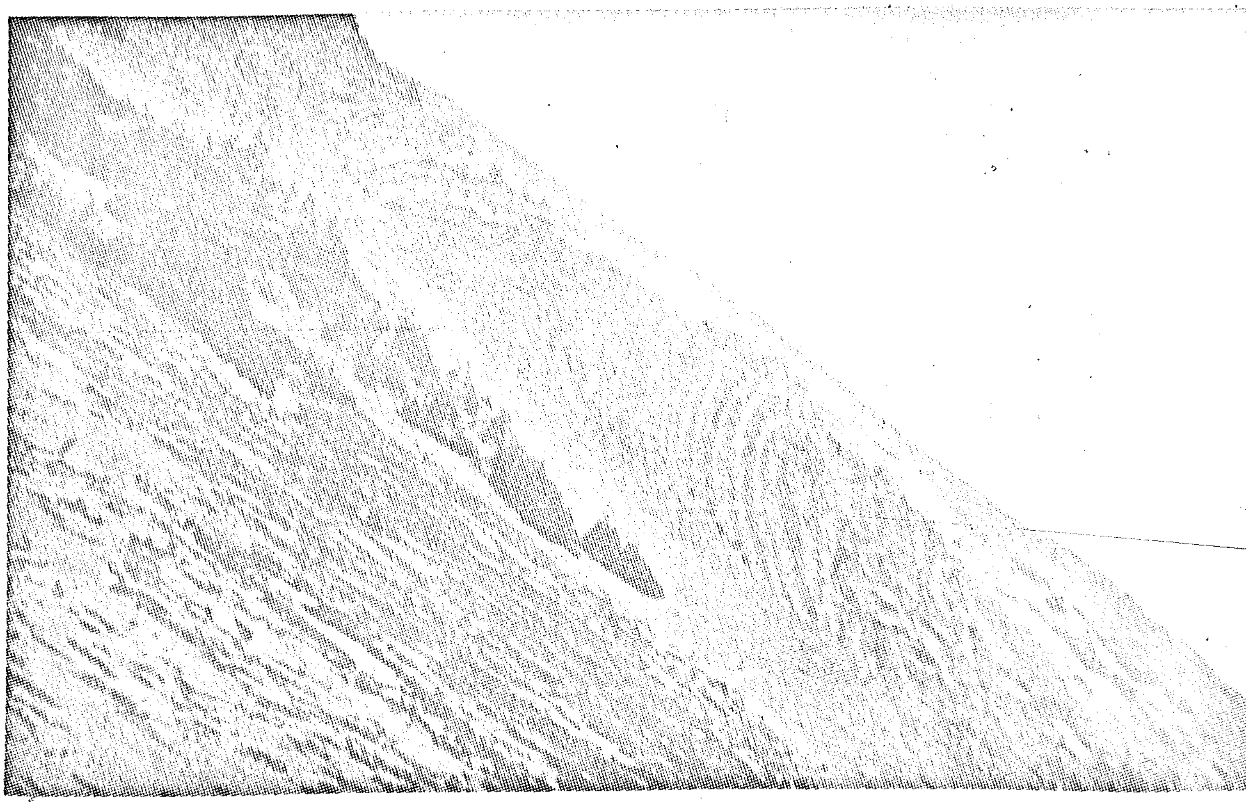


FIGURE 12. ISOCLINAL FOLD AT THE HEAD OF GRAND VALLEY. Photograph taken looking northwest from above Gladys Lake.

the bedding planes.........planes producing gauge areas which much resemble crumpled schist. No distinct lithologic units traceable over any distance were found. The predominate rocks are alternating massive sandstone and black slate beds. They thin and thicken along the strike. An excellant exposure may be seen on Mount Frome and Mount Claywood at the head of the Dosewallips. Conformably above this sequence is a series of grey quartzitic sandstones, green tuffaceous argillites and highly altered green pillow basalts and agglomerates. They outcrop on the top of Mount Frome and make up the great bulk of Mount Claywood. Associated with this series are a number of small limestone lenses containing quantities of the mineral hausmannite ($MnMn_2O_4$). Eleven lenses varying in thickness from three feet to but a few inches were observed on the northeast slopes of Mount Claywood. Associated with these limestones are beds of grey quartzite often containing disseminated grains of chalcopyrite which has altered to malachite where exposed. Quartz is also common and fills fractures in the quartzites and volcanic rocks. Clear crystals up to three inches in length occur in these veins.

The head of the Dosewallips river is a large glacial cirque. It is surrounded by five peaks: Lost Peak on the north, Mount Claywood and Frome on the west, Sentinel Peak on the south, and Wellesly peak in the southeast. Sentinel

Peak is composed almost entirely of black slate of which nearly 1000 feet is exposed on the steep north face. Just to the east of Sentinel in a low saddle a small outcrop of highly altered greenish pillow basalt is exposed. Surrounded by this basalt is a lens of grey sandstone and red limestone. It is highly fractured and solutions rich in manganese have penetrated the fractures gradually replacing the limestone, quartzite and basalt with hausmannite.

From Sentinel Peak southward to Mount Anderson similar slates and sandstones occur. The west peak of Mount Anderson clearly shows the regional structure, the hard and soft beds of slate and sandstone forming prominent serrated ridges along the mountain shoulder.

Good exposures of this formation may be seen at the headwaters of the Greywolf river. The slates and sandstones are strongly distorted and gouge is developed along the bedding planes where faulting has occurred. The dip is predominantly to the northwest, varying between 50 and 75 degrees. Such a northeastern strike does not coincide with the regional northwestern trend. It is due to the fact that the normally weakly inclined northwest-trending axes of minor folds are in this area almost vertical, in connection with some steep transverse deformation superimposed on the north-west trending regional folding structure.

FIGURE 13. STEEPLY TILTED SANDSTONES AND SLATES IN THE UPPER DOSEWALLIPS VALLEY. Photograph taken looking directly south. The dip is to the southwest.

FIGURE 14. LOOKING SOUTH TOWARDS MOUNT ANDERSON FROM HAYDEN PASS AT THE HEADWATERS OF THE DOSEWALLIPS RIVER. Eel glacier separates the West peak from the East peak. The regional strike and dip can be observed in the hills in the foreground and on the West peak of Mount Anderson.

The eastern side of the Greywolf valley is a ridge of altered pillow basalt. The slates and sandstones strike almost at right angles to this basalt but become parallel with it within a few hundred feet of the contact. The slates show strong slaty cleavage and where nearly vertical stand out as a series of knife edge slabs along the ridge tops.

Associated Igneous Rocks

Within the Soleduc Formation are several bodies of volcanic rocks. Thin and little extensive flows interbedded with the sediments are found near Obstruction Point, on Mount Claywood and Mount Frome, near the east side of Sentinel Peak, in Royal Basin and on the ridge between Cameron Creek and the Greywolf River. Thick and extensive flows form most of Mount Deception, Mount Mystery and Royal Ridge. The exact origin of some of the larger volcanic areas is obscure. Considerable faulting has taken place near the contacts. Field evidence tends to show that they are conformable with the Soleduc sediments.

The volcanics consist of highly altered pillow basalts and tuffs. They are grey brown to green in color with an aphanitic texture. They are often vesicular and in some areas are porphyritic. The farther the volcanics occur in the interior of the mountains, the more highly altered

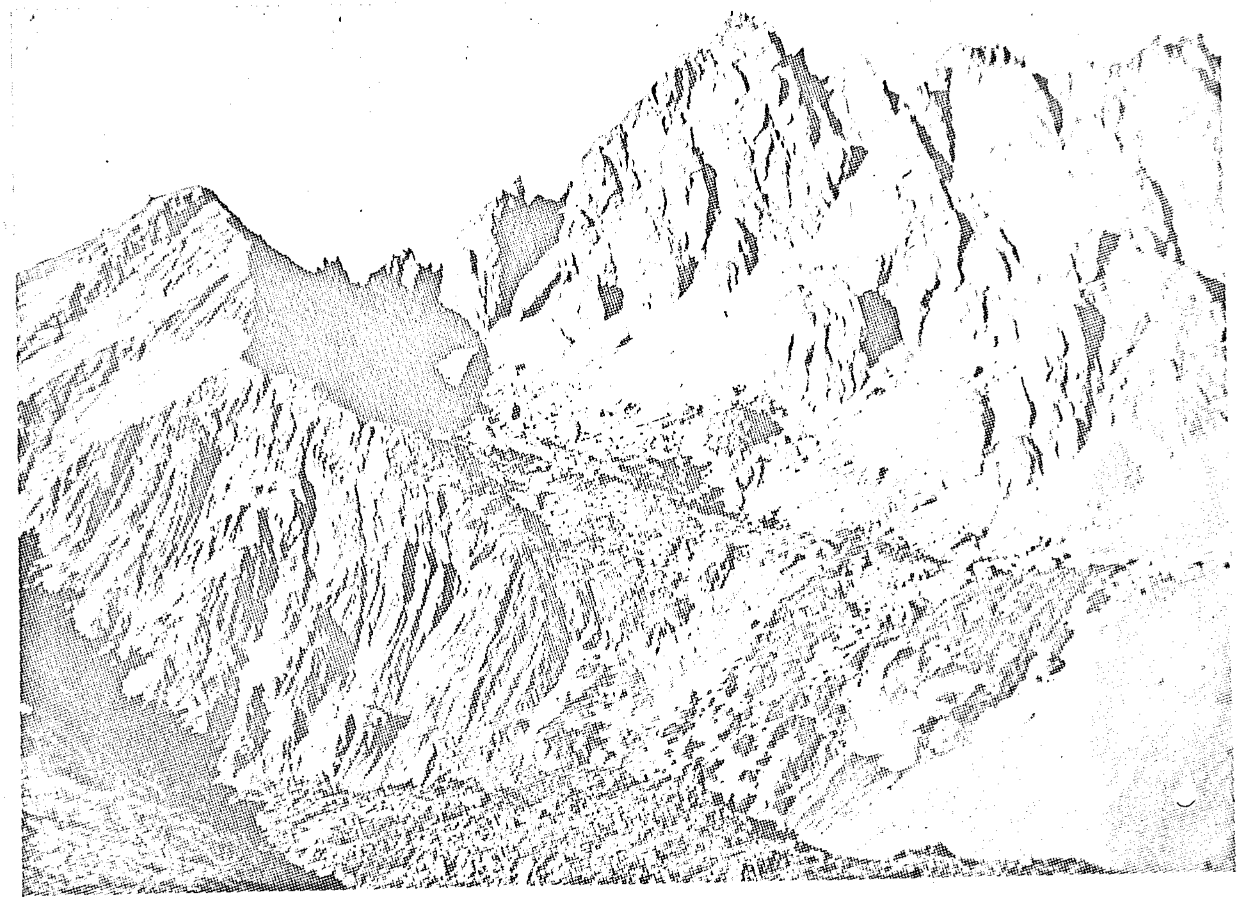


FIGURE 15. CONTACT OF BASALT AND SOLEDUC SEDIMENTS ON THE WEST SIDE OF THE NEEDLES. Photograph taken looking north along the contact on the east side of the Greywolf River valley. The contact is almost vertical and dips slightly to the west.

they become. The green color is due to the formation of epidote and chlorite. Small slender needles of epidote coat the surfaces of the individual pillows and fill fractures and cracks. Calcite and quartz are commonly associated with the epidote.

The volcanics are remarkably similar in composition and appearance. They have a microporphyritic texture. The phenocrysts are euhedral and were originally olivine and labradorite. The labradorite has since changed to albite. The olivine has been replaced by chlorite and in some cases calcite. Zeolites and epidote also fill cavities formerly occupied by olivine phenocrysts.

The ground-mass contains tiny radiating clusters of microlitic plagioclase. Augite and magnetite are abundant. Palagonite is common in some specimens and has a spheroidal structure.

The lavas can be termed spilites. Their alteration is similar to that found in spilites throughout the world. Park (1946) accepts the idea that albitization may result from a reaction between submarine basalt and sea water. This is favored by flows of large volume which accumulate rapidly and retain considerable heat. Such conditions existed during the formation of the basalts associated with the Soleduc formation.

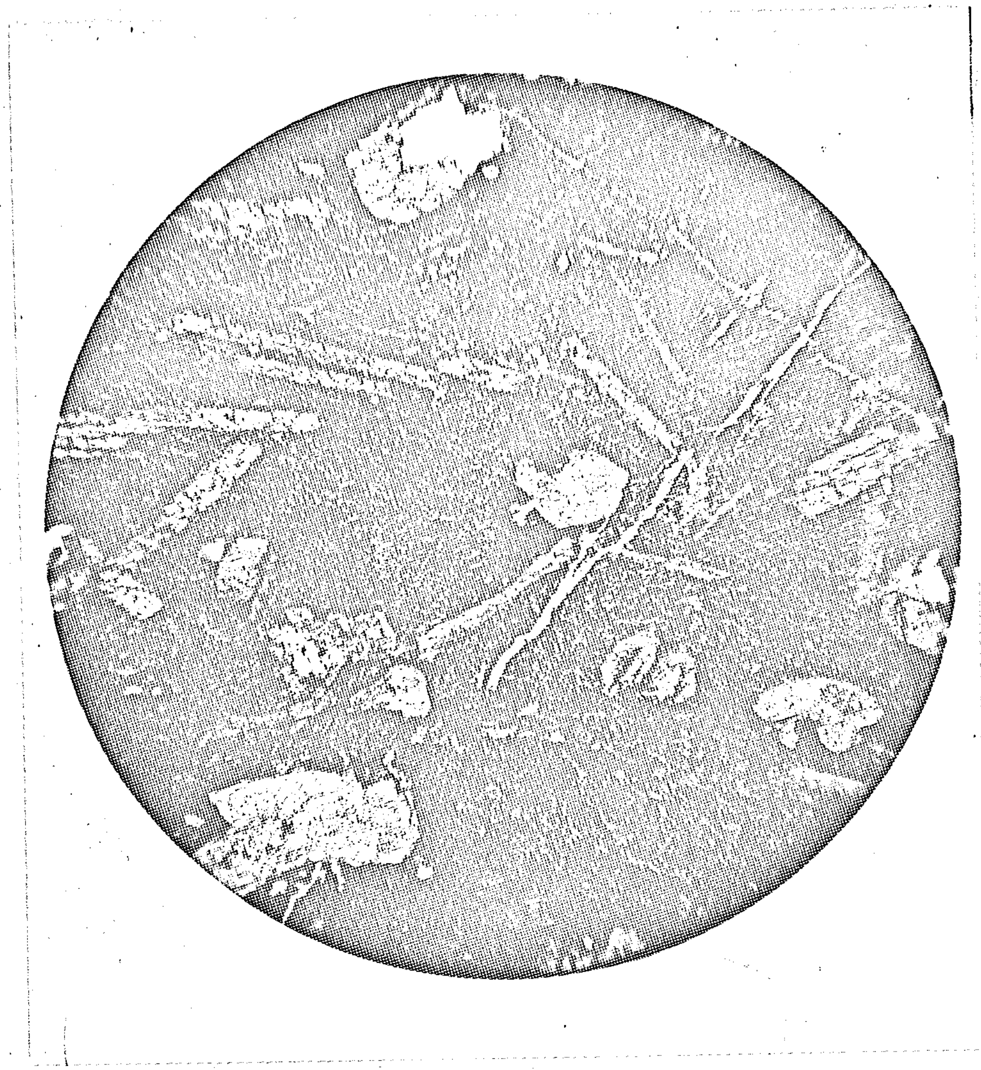


FIGURE 16. THIN SECTION OF BASALT FROM MOUNT DECEPTION. Plain light. X $20\frac{1}{2}$. The long needle-like crystals are albite. The euhedral areas are former olivine crystals, now largely replaced by chlorite.

No dikes were found in the map area though they are known to occur in areas of similar rocks to the south (Arnold 1909). The vast majority of the lavas possess pillow structure. They thicken and thin along their strike and tend to follow the regional trend of the Soleduc sediments. The largest area of basalt is exposed from Mount Mystery to the Needles, forming a belt nearly 5000 feet wide and 5 miles in length. Other basalt outcrops are only a few tens of feet in length, have a lenticular shape. Only on Mount Claywood where sediments are intercalated can individual basalt flows be distinguished. At least three flows are exposed on the northeast side of this peak.

Numerous small pods and lenses of red and green limestone occur between the pillows in the basalts. The red color is largely due to weathering of manganese impurities in the limestone. The limestone shows a blue-grey color on fresh surfaces. The weathering processes concentrate the manganese on the surface of the limestone where it forms a steel-blue coating of hausmannite. Loose weathered fragments of this manganese-bearing limestone found on the talus slopes give a false impression that there are large quantities of ore. On the northeast slopes of Mount Claywood 8 limestone lenses heavily stained with manganese are exposed. The exposed face is almost vertical and a great amount of talus material has accumulated below it.

FIGURE 17. THIN SECTION OF BASALT FROM WEST SIDE OF THE NEEDLES. Plain light, X 50. Groundmass composed of radiating microlites of plagioclase. White areas are chlorite, clacite and zeolites.

In other areas red limestones occur which seem to contain no manganese. They are more of an orange red and their color is probably due to hematite. Limonitic material covers the weathered surface of this limestone.

A subordinate amount of limestones are green and are siliceous.

The origin of these limestones and the associated manganese minerals has long been the subject of intensive study. Park (1946) believes that the limestones were formed in large part by precipitation from sea water, caused by chemical reactions due to the volcanic eruptions:

> Agitation of the sea water during submarine extrusion caused a precipitation of calcium carbonate. The resulting limestones mixed with fine grained volcanic debris, are the present-day "red rocks".
>
> .....during periods of rapid extrusion in deep water the sea water in the underlying sedimentary beds was trapped and heated. The fragmental volcanics chilled quickly and permitted rapid escape of the fluids, but the thicker flows tended to retain the heat, and were subjected to a continuous stream of escaping gases. The original constituents of the lavas were decomposed albite, and later zeolites were deposited in their place, and silica, lime, iron, magnesium, and manganese were carried upward. On reaching the limy accumulations near the top of the flows, the materials in the fluids were left as replacement deposits, or, where the conduits broke through to the sea floor, they were deposited as part of the accumulating sediments.

Absence of limestone in the thick sedimentary sequences above and below the basalts seems to confirm that the limestones associated with the basalts owe their origin to the volcanic activity.

The manganese-bearing limestones contain remains of Foraminifera (Globergerina ?). These are floating forms and when they die their tests sink to the sea bottom. The green limestones do not contain microfossils in any of the samples examined, and may have been entirely formed by precipitation due to the volcanic eruptions. The red limestones may be the combined result of such precipitation and of the accumulation of foraminifera tests. Undoubtedly the volcanic eruptions killed the foraminifera in large numbers which may account for their abundance in the inter-pillow limestones. No megafossils have been found in the limestones.

Associated with the red limestones on Mount Claywood and the east side of Sentinel Peak are thin layers of a bluish grey quartzose sandstone. It is very hard and compact and contains a small amount of disseminated chalcopyrite. The amount of chalcopyrite is so small that it would not be noticed if it were not for the malachite stain produced on the weathered rock surface.

A lustrous dark-brown coating rich in manganese and iron fills fractures in similar bluish-grey sandstones on Sentinel Peak and near Mount Deception, and probably represents deposition from solutions derived from the volcanic rocks.

Tiny flakes of graphite were found in some of the red

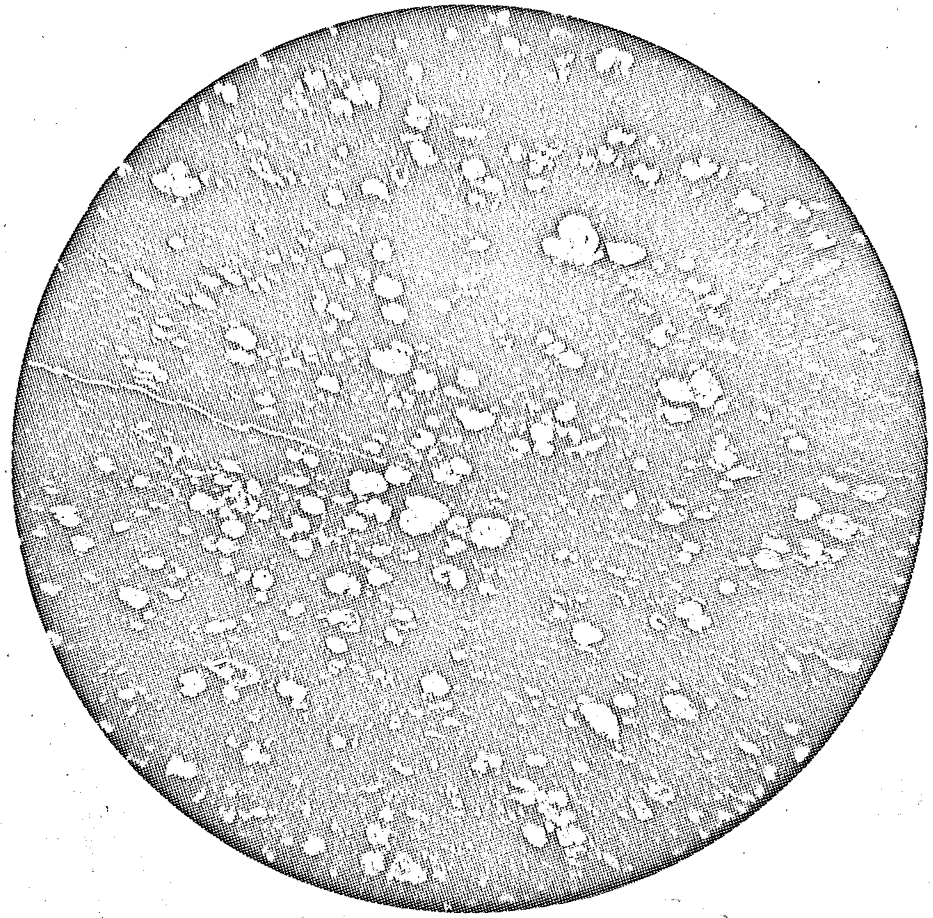


FIGURE 18. THIN SECTION OF RED LIMESTONE. Plain light, X 20½. From limestone lens on the northeast side of Mount Claywood. Micro-fossils are predominantly Globergerina ? and have been tectonically deformed. They are replaced by calcite.

limestones on Mount Claywood and are probably remnants of carbonaceous material that accumulated with the limestone.

Age and Correlation

The meager collection of fossils obtained from the Soleduc formation contains nothing of any stratigraphic value. The position of the Soleduc below beds of known Eocene age and its apparent angular relationship with these rocks in the few areas studied has led to the belief that it might be of Cretaceous age (Weaver 1937). Cretaceous formations occur on Vancouver Island to the north and on the San Juan Islands to the northeast, but they differ lithologically, are richly fossiliferous, and nowhere are they in contact with Tertiary rocks.

In 1940 Warren collected a few poorly preserved fossils from rocks generally included in the Soleduc near Mount Appleton.* They are considered to be most probably of Oligocene age.

The pillow basalts in the Soleduc Formation are mineralogically very similar to the basalts of the Metchosin formation. Both basalt formations contain manganese-bearing lenses and show the same kind of copper mineralization. The Soleduc volcanics trend parallel to the Metchosin volcanics.

---

* By Mr. Walter Warren, received 1948, personal communication.

FIGURE 19. PILLOW BASALT IN THE SOLEDUC FORMATION. A small body of basalt exposed in a stream bed in the upper portion of Royal Basin.

FIGURE 20. MANGANESE-BEARING LIMESTONE. Small lens of red limestone and grey sandstone in basalt on the east side of Sentinel Peak. Hausmannite fills fractures in the limestone and sandstone.

Since the Soleduc lithologically resembles formations of definite Tertiary age and there is no fossil evidence to the contrary, the writer places this formation in the Tertiary. Provided the succession Soleduc-Metchosin is normal, the writer would tentatively assign the Soleduc to the basal Eocene. If the fossiliferous rock of Mount Appleton stratigraphically belongs to the Soleduc, and if the fossils found there are really Oligocene, the Soleduc would, of course, be younger than the Metchosin, and the succession would not be normal. It is hoped that further field work will solve this question.

Metchosin Formation

General Statement

A broad belt composed of volcanic rocks surrounds the Olympic Mountains on the north, east and south. It was originally described as Crescent formation by Arnold (1906) and Weaver (1916). Clapp (1912) found a similar volcanic formation on southern Vancouver Island, to the north of the Olympic Peninsula. He called it the Metchosin formation. Weaver (1937) correlated the Olympic volcanics to the Vancouver Metchosin.

Areal Distribution and Lithology

In the area studied by the writer the Metchosin formation occurs in a broad band extending from the Dosewallips River north to the Dungeness River. From here it turns sharply to the northwest and then to the west, in the vicinity of Blue Mountain. In the vicinity of Mount Constance the belt of volcanics is over 8 miles wide. Farther northwest the width of this belt decreases to approximately 4 miles.

The rocks of the Metchosin formation are for the most part highly altered basalt flows, tuffs and breccias. They are resistant to erosion and form high jagged ridges with a steep drop along their contact with the less resistant Soleduc sediments. The most prominent of these ridges is that of Mount Constance.

In the western part of the belt, most basalts show pillow structure, whereas towards the east the flows become more massive and poorly developed columnar structure is locally present.

The basalt ranges in color from dark green to brown and black. It is predominantly aphanitic and locally porphyritic. Vesicular structure is common, and in many areas the vesicules are filled with calcite, zeolites and epidote.

The basalt is mirocrystalline and is composed of plagioclase, augite and olivine. In relatively unaltered basalt the plagioclase is labradorite. In altered rocks it is albite.

Individual flows of basalt are almost impossible to recognize, especially in pillow basalts like those composing Mount Constance. Where the Dosewallips River cuts through the basalt south of Mount Constance, the pillows appear to be nearly vertical; if the basalt sequence is considered vertical in this section, it is nearly 20,000 feet thick.

North of Mount Constance pillow layers are separated by beds of gray tuff and argillite. These intercalations are not continuous over a large area but may be followed for about 500 feet; their thickness ranges from a few inches to 100 feet.

A section of tuff and basalt is exposed between Marmot Pass and Buckhorn Pass (thickness approximate):

	Feet
Volcanic breccia and tuff	100±
Tuff with small individual flows of pillow basalt; individual pillows amygdaloidal and less than 2 feet in thickness	200±
Small pillow flows with minor amounts of brown tuff	50±
Pillow basalt; Pillows up to one foot in diameter	100±
	450±

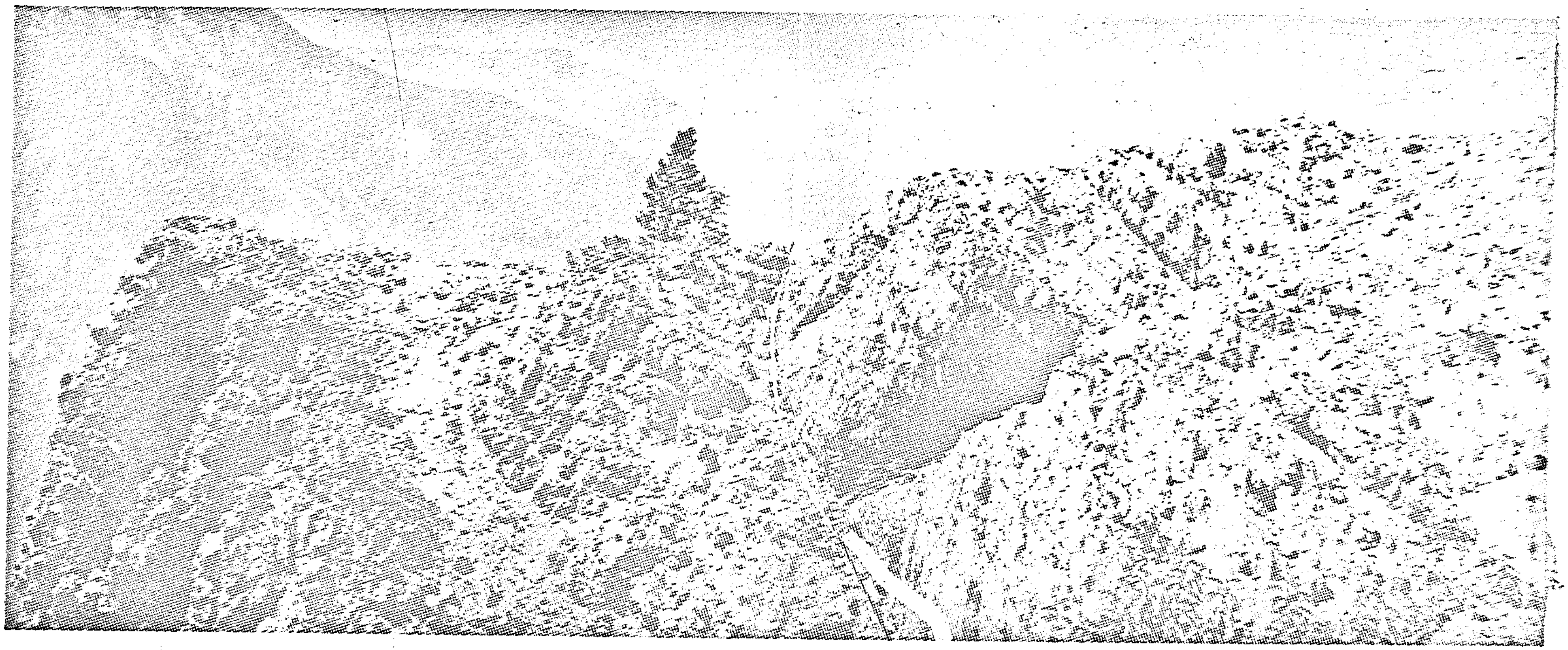


FIGURE 21. LOWER PORTION OF SECTION OF METCHOSIN VOLCANICS BETWEEN MARMOT PASS AND BUCKHORN PASS. Photograph taken looking north down the Dungeness River valley. The dip of the tuff is about 25 degrees to the northeast. Pillow basalts in the lower part of the section and tuffs with thin interbedded pillow flows above.

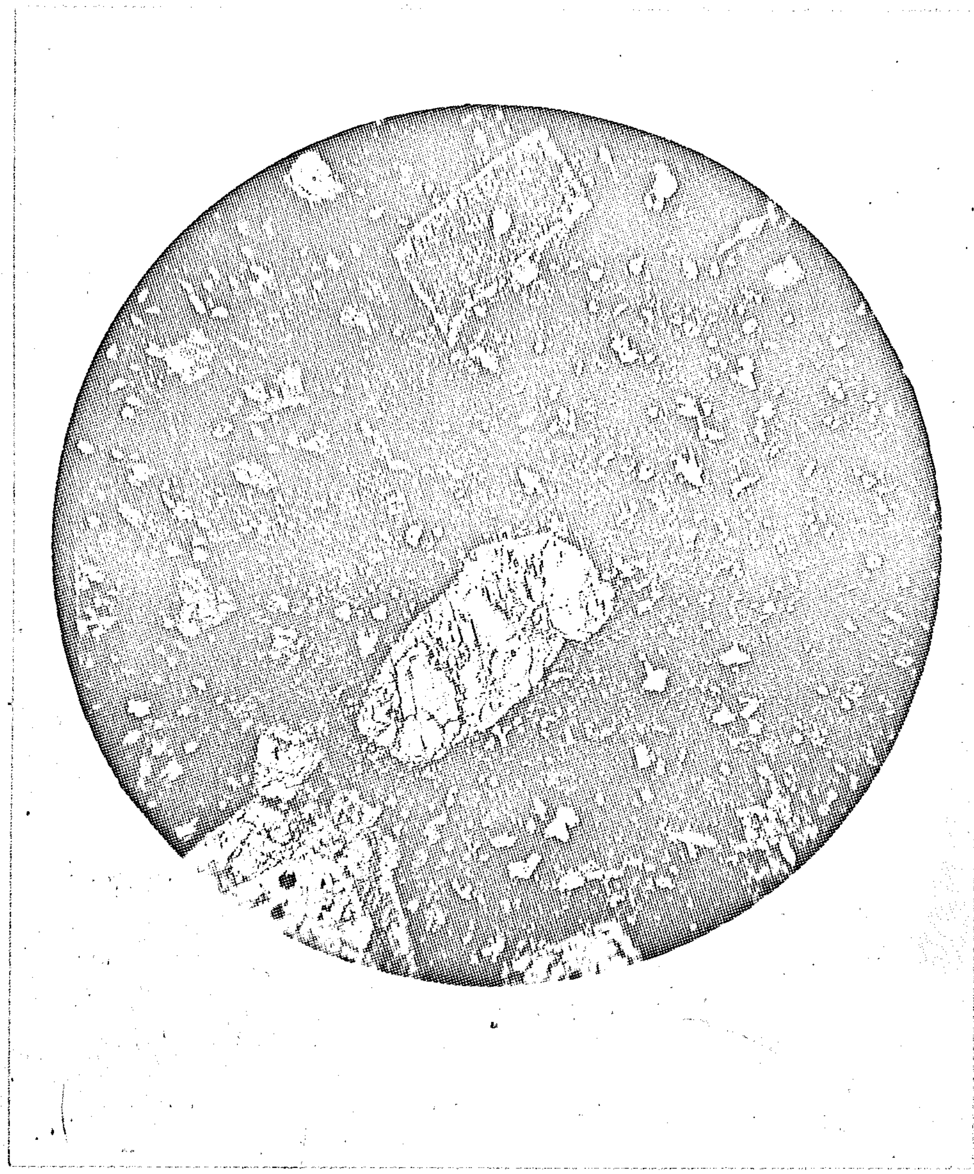


FIGURE 22. THIN SECTION OF BASALT FROM NEAR MARMOT PASS. Crossed Nicols X 20½. Large euhedral plagioclase crystal in the center of the section has been largely replaced by albite and calcite. Small white patches are amygdules filled with zeolite.

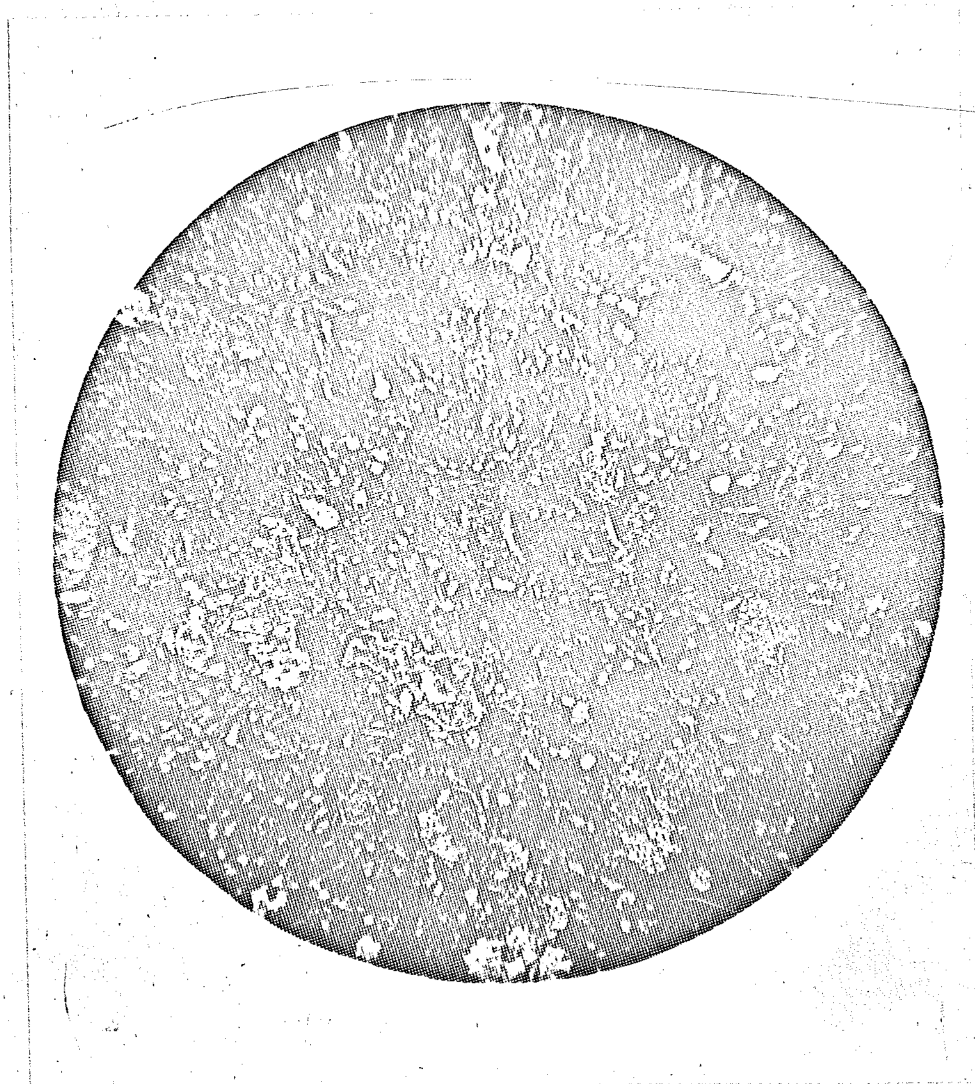


FIGURE 23. THIN SECTION OF PICRITE FROM 1 MILE NORTH OF MARMOT PASS. Plain light, X 20½. This flow is predominately composed of augite and olivine. The large irregular areas are amygdules containing chlorite, calcite and some zeolites.

Thin amygdaloidal pillow flows are found again on the Greywolf River 7 miles upstream from the end of the road. They closely resemble the flows between Marmot Pass and Buckhorn Pass. The amygdules are of a remarkably regular flat-elliptical shape. They are filled by zeolites and some calcite.

About a mile north of Marmot Pass a volcanic rock is exposed which resembles basalt but consists almost entirely of small crystals of augite and olivine (figure 23). Its composition is that of a picrite.

<u>Associated Sedimentary Rocks</u>

On the west side of Mount Constance lenses of brown limy shale and argillite occur in the Metchosin volcanics. Northward the number and also the individual size of such lenses increase. Just to the north of Marmot Pass several of these lenses are exposed. They are less resistant to erosion than the basalts, and on ridges they form low saddles. Such a saddle separates Buckhorn Mountain from Iron Mountain.

Farther north at Buckhorn Pass a massive conglomerate is intercalated in the basalt. The pebbles reach a diameter of 2 inches and are mostly quartzite. Basalt pebbles are surprisingly rare. No quartzites similar to those in the conglomerate are known to occur on the Olympic Peninsula. The conglomerate grades upward into a coarse gritty sandstone.

Small lenses of a very similar conglomerate are exposed near Camp Mystery 1 mile east of Marmot Pass and a few hundred feet west of the 7 mile post on the Greywolf River.

From Buckhorn Pass northwestward the amount of sedimentary rocks interbedded with the Metchosin flows increases until they exceed the basalt. The sediments are largely brown and dark-grey sandy shales. They are well-bedded and apparently unfossiliferous apart from some fragments of foraminifera closely resembling Globergerina, which were noticed in a thin-section of shale from the Greywolf River about 2 miles from its mouth.

Limestone lenses are also common in the Metchosin basalts. The limestone is generally deep chocolate-red and is often coated with black manganese oxide. Several bodies of the manganese silicates bementite and neotocite occur with these limestone lenses. Prospects have been opened at Elkhorn on the south side of Mount Constance and at the Tubal Cain mine on Copper Creek north of Iron Mountain. Varying amounts of manganese are found in these areas but the cost of mining and refining the material is at present prohibitive. Remains of Globergerina occur in these red limestones.

Small amounts of a bluish limestone are found near the red limestones; they generally form pockets only a few inches thick. A thin nodular bed of blue limestone occurs at Buckhorn Pass and has been altered into a fine-grained marble.

FIGURE 24, LENS OF ARGILLITE AND CONCRETIONARY SANDSTONE IN THE METCHOSIN VOLCANICS NORTH OF MARMOT PASS. View is to the north. The dip of the sediments is about 50 degrees to the north. The weak sediments form a saddle with the more resistant pillow basalts on either side.

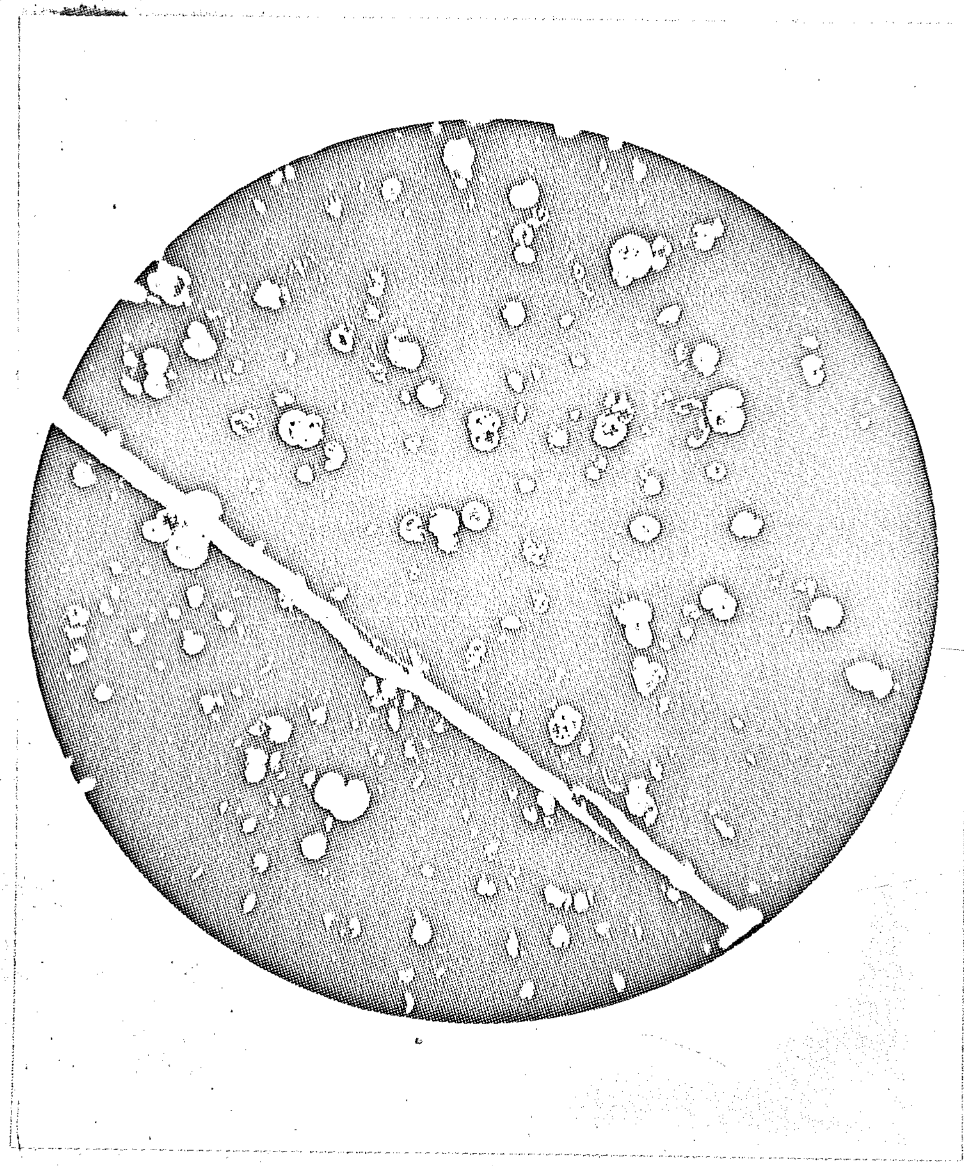


FIGURE 25. THIN SECTION OF RED LIMESTONE CONTAINING <u>GLOBERGERINA</u>. Plain light X 20½. Limestone lens in Metchosin basalt about 2 miles east of Marmot Pass on the north side of the Quilcene River valley.

Age and Correlation

On the Olympic Peninsula the Metchosin formation was placed in the Lower Eocene because of its stratigraphic position below the Middle Eocene Crescent formation (Weaver 1937). The discovery of specimens of *Turritella andersoni* in the upper part of the Metchosin on Vancouver Island indicates a Middle Eocene age for this portion (Weaver 1937).

Echinoid spines and shark teeth have been found in palagonitic material around pillows in the Metchosin basalt.* They do not help in determining the age of the basalt.

The scarce fossils found in the Metchosin on Vancouver Island and the Olympic Peninsula anyway seem to justify the assignment of a lower to middle Eocene age to this formation.

Crescent Formation

General Statement

Near the junction of the Dungeness and Greywolf Rivers there occurs a series of sedimentary rocks which are stratigraphically above the Metchosin volcanics. Similar sediments overlying the volcanics along the northern margin of the Olympic Mountains have been termed the Crescent

---

* Personnel Communication by Dr. Charles F. Park Jr., received 1948.

formation. The term "Crescent" originally included the Metchosin but the Crescent sediments and interbedded volcanic rocks are now considered as a distinct formation (Weaver 1937). It is confined to the northern border of the Olympic Peninsula. Its occurrence at the junction of the Dungeness and Greywolf Rivers has been reported by McMichael (1946).

Lithology

About 2500 feet of brown to bluish grey argillaceous shales and medium-grained sandstones are exposed along Dungeness River between Gold Creek and Greywolf River. The sediments are thin-bedded and poorly indurated. A few calcareous concretions are found. Near the contact with the Metchosin basalt, the Crescent formation is fractured, and in very few places can its dip be determined. Nowhere in this area has the actual contact been observed.

Age and Correlation

The type area of the Crescent formation is at Crescent Bay west of Port Angeles. Here, tuffaceous sandy shales rest on basalts of the Metchosin formation. Outside the type area the sediments vary in lithology. Foraminifera from Crescent Bay have by Berthiaume (1938) been correlated to those of the Middle Eocene Capay of California.

At the junction of the Dungeness and Greywolf Rivers shales and sandstones considered as Crescent by the writer, are succeeded by a higher basalt formation. In a limestone lens interbedded in this basalt Durham (1941) found *Turritella uvasana* subsp. *elequahensis* Weaver et Palmer. This suggests a correlation with the Upper Eocene Cowlitz formation for this basalt.

The fact that the sediments described as Crescent in the present report are underlain by the Metchosin and are succeeded by rocks of Cowlitz age, confirms the Crescent (Middle Eocene) age of these sediments.

At one locality on the Dungeness trail about one mile above its junction with the Snow Creek road, very fragile specimens of a gastropod resembling *Turritella* was found. No accurate determination of these fossils could be made.

STRUCTURAL GEOLOGY

The Inner Series

The outstanding structural features of the inner series of weakly metamorphosed rocks are their prevailing southwesterly dip and their isoclinal folding.

Wherever the rocks of the Mount Seattle formation have been observed they dip to the southwest at angles ranging from 50 to 85 degrees. There may be isoclinal folds though none were seen. In the high barren country of the central Olympics the more resistant sandstones stand out as ridges. From Mount Seattle north to Mount Meany these ridges are transected by deep narrow stream valleys and the southwesterly dip is easily observed on the steep valley sides.

The Soleduc formation also has a prevailing southwesterly dip in most areas, but the dip is not nearly as steep as that in the Mount Seattle formation. The Soleduc formation has been folded into several anticlines and synclines. A few of these folds are overturned to the northeast, both limbs of the folds dipping to southwest. A prominent anticline trends in a northwest-southeast direction across Grand Valley and extends southeastward to Royal Basin. In Royal Basin flows of the Soleduc volcanics are exposed in both limbs of this anticline. The core of a syncline overturned to the northeast is exposed one mile east of the junction of the three forks of the Greywolf River. A thickness of nearly 5000 feet of sediment is exposed in the northern limb of this syncline. Isoclinal folds may be observed at the head of Grand Valley, the west side of Lake Lillian and on the ridges to the west of Mount Deception.

Due to the scarcity of traceable lithologic units and fossils, the structure of the inner series is difficult to unravel. The enormous apparent thickness of sediments dipping uniformly to southwest is due to repetition in overturned isoclinal folds. Very detailed mapping and stratigraphic study are required to locate these folds and thus to get the true picture.

The Outer Series

In most of the area studied by the writer the dip of the Metchosin and Crescent formations is to northeast. The sediments interbedded with the Metchosin basalts dip at angles less than 50 degrees. A major anticline and syncline cross the Greywolf River in a northwest-southeast direction. Their continuation to the north and south is very difficult to trace, owing to the dense vegetation covering the area. An anticline is exposed farther south on the Dungeness River, but its continuation to the north could not be determined.

Minor faulting within the basalt is common, and slickensides are found in many areas. The amount of displacement could not be determined as no faults were found cutting the intercalated lenses of sediment.

The Metchosin-Soleduc Contact

One of the major unsolved problems in the Olympics is the nature of the Metchosin-Soleduc contact. In the immediate vicinity of Mount Constance the contact follows a northeasterly trend. Nowhere has the actual contact been seen, but exposures a few yards on either side show sediments dipping between 70 and 80 degrees to the southwest on the west side and bedded tuffs and limy shales dipping 25 to 50 degrees to the northeast on the east side. This relationship suggests either a fault or an unconformity. When traced from Constance Pass to the bottom of the Dosewallips Valley, over a vertical distance of 6000 feet, the contact is seen to be almost vertical. Farther to the north, none of the deep transverse canyons north of Mount Constance have penetrated Soleduc sediments beneath the Metchosin volcanics. This suggests that the contact remains vertical in this area.

South of Marmot pass a bright green and white quartzitic rock is exposed beneath the basalt a few feet from the contact. Under the microscope this rock shows strong mylonitic structure. It thus seems to be confirmed that the contact is a fault in this region.

Where the Soleduc-Metchosin contact crosses the Greywolf River, conditions are different. The basalt here appears to dip beneath the Soleduc. The actual contact is in the bottom of a narrow canyon and covered with talus, but the Metchosin and Soleduc formations have approximately the same southwesterly dip on the sides of the canyon. Either the Soleduc-Metchosin contact is normal and concordant here and has been overturned to the northeast, or the Soleduc formation has been thrust over the Metchosin. The lithologic succession within the Metchosin formation here is the reverse of what it is elsewhere; this suggests that the Metchosin is here overturned.

On Green Mountain brown sandy shales belonging to the Metchosin formation dip under the micaceous dark sandstones of the Soleduc. The actual contact was not found exposed.

Conclusions

A regional interpretation of Olympic structure depends on an understanding of the relationship, both stratigraphic and structural, between the inner and outer series of rocks comprising these mountains. Therefore the contact relations between Soleduc and Metchosin are of particular importance. In the area so far studied by the writer, different kinds of contact relations seem to be present in the major river valleys, and no exposure of the actual contact has been found; it is therefore difficult to come to any definite conclusion as to the Soleduc-Metchosin relationship.

Available field evidence indicates that at least in parts of the Mount Constance area the contact is a fault, whereas in other parts it is concordant and overturned, and probably normal.

Warren's discovery of probable Oligocene fossils on Mount Appleton in the inner series suggests the possibility of the Metchosin being thrust over a great thickness of Tertiary rocks. A detailed investigation of the lower contact of the Metchosin throughout the Olympic Peninsula and of the relations between the sediments constituting the inner series, and known Tertiary rocks, would be needed before it can be decided whether large scale thrusting is present or not.

REFERENCES CITED

Arnold, Ralph (1909). "Notes on some Rocks from the Sawtooth Range of the Olympic Mountains, Washington." American Journal of Science, 4th ser., 28: 9-14.

Arnold, Ralph (1906). "Geological Reconnaissance of the Coast of the Olympic Peninsula, Washington." Geol. Soc. Am. Bull. 17: 451-468.

Berthiaume, S. A. (1938). "Orbitoids from the Crescent Formation (Eocene) of Washington." Journal Paleont. 12: 494-497.

Clapp, C. H. (1912). "Preliminary Report on Southern Vancouver Island." Canada Dept. Mines, Geol. Surv. Mem. 36, pp. 1-143.

Durham, J. W. (1941). "Megafaunal Zones of the Oligocene of Northwestern Washington." Univ. of Calif. Press, Geol. Sciences. 27: 101-212.

Green, Stephen H. (1945). "Manganese Deposits of the Olympic Peninsula, Washington." State of Wash. Div. of Mines and Mining, Report of Invest. No. 7: 1-45.

McMichael, L. B. (1946). "Geology of the Northeastern Olympic Peninsula, Washington." Unpublished Thesis, Univ. of Wash. Library.

Palmer, R. H. (1927). "The Hoh Formation of Washington." Jour. Geol. 35: 276-78.

Pardee, J. T., Larsen, E. S. and Steiger, George (1921). "Bementite and Neotocite from Western Washington, with conclusions as to the identity of Bementite and Caryopolite." Wash. Acad. Sci. Jour. 11: 25-32.

Pardee, J. T. (1927). "Manganese-bearing deposits near Lake Crescent and Humptulips, Washington." U. S. Geol. Survey Bull. 795-A: 1-24.

REFERENCES CITED (continued)

Park, C. F. Jr. (1942). "Manganese Resources of the Olympic Peninsula, Washington, a preliminary Report." U. S. Geol. Surv. Bull. 931-R: 435-57.

Park, C. F. Jr. (1946). "The Spilite and Manganese Problems of the Olympic Peninsula, Washington." Amer. Jour. Sci. 244, No. 5: 305-23.

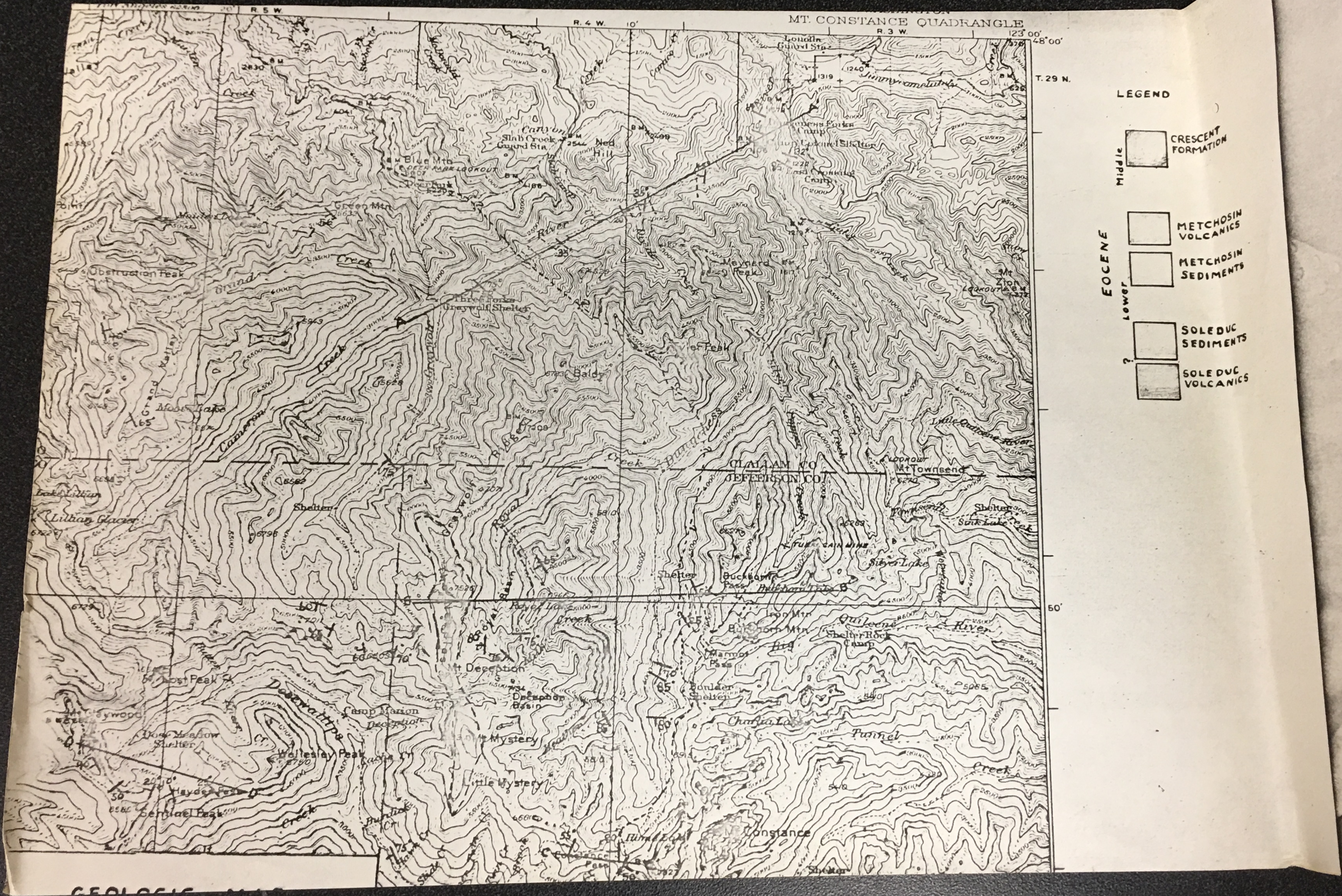
Reagan, A. B. (1909). "Some Notes on the Olympic Peninsula, Washington." Trans. Kans. Acad. Aci. 22: 131-238.

Weaver, C. E. (1916). "Tertiary Formations of Western Washington." Wash. Geol. Surv. Bull. No. 13: 1-327.

Weaver, C. E. (1930). "Eocene Lavas in Western Washington." Geol. Soc. Am. Bull. 41: 87.

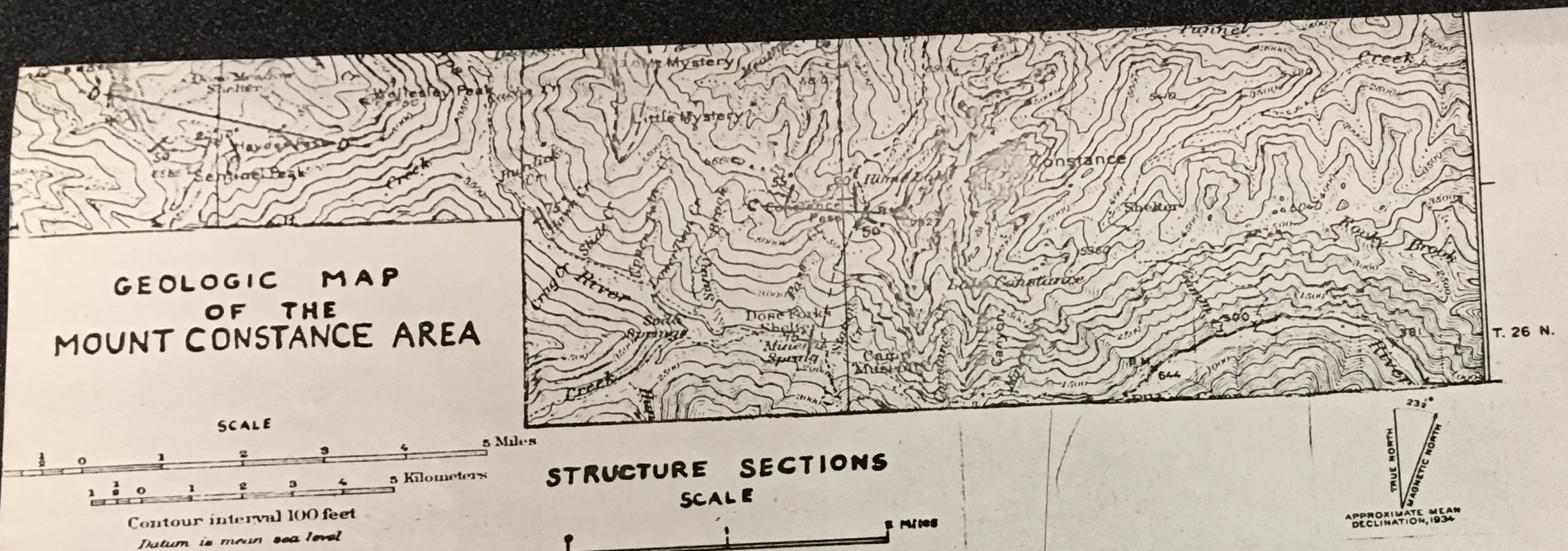
Weaver, C. E. (1937). "Tertiary Stratigraphy of Western Washington and Northwestern Oregon." Univ. of Wash. Pub. in Geol. 4: 1-265.

Weaver, C. E. et al (1944). "Correlation of the Marine Cenozoic Formations of Western North America." Geol. Soc. Am. Bull. 55: 569-98.



MT. CONSTANCE QUADRANGLE
R. 5 W.
R. 4 W.
R. 3 W.
123°00'
48°00'
T. 29 N.
50'
CLALLAM CO.
JEFFERSON CO.
Mt Townsend
Three Forks
Greywolf Shelter
Baldy
Maynard Peak
Obstruction Peak
Lake Lillian
Lillian Glacier
Mt Deception
Deception Basin
Camp Marion
Mystery
Little Mystery
Boulder Shelter
Marmot Pass
Buckhorn Mtn
Iron Mtn
Silver Lake
Constance
Wellesley Peak
Hayden Pass
Sentinel Peak
Lost Peak
Mt Zion
Green Mtn
Blue Mtn
Slab Creek Guard Sta
Ned Hill
LEGEND
CRESCENT FORMATION
Middle
EOCENE
METCHOSIN VOLCANICS
METCHOSIN SEDIMENTS
Lower
SOLEDUC SEDIMENTS
?
SOLEDUC VOLCANICS

GEOLOGIC MAP OF THE MOUNT CONSTANCE AREA



STRUCTURE SECTIONS