THE GENERAL GEOLOGY OF THE LAKE CUSHMAN AND HAMA HAMA RIVER AREA OF THE OLYMPIC MOUNTAINS

by

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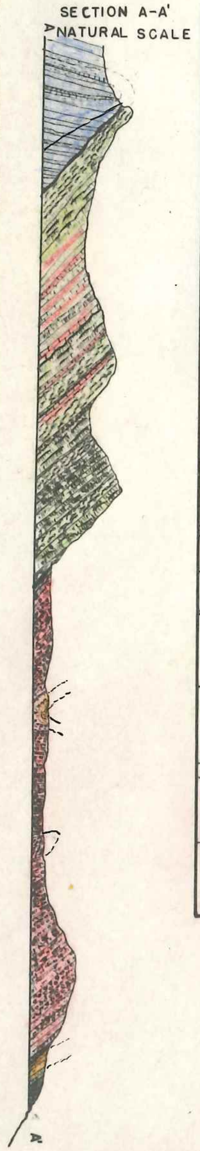

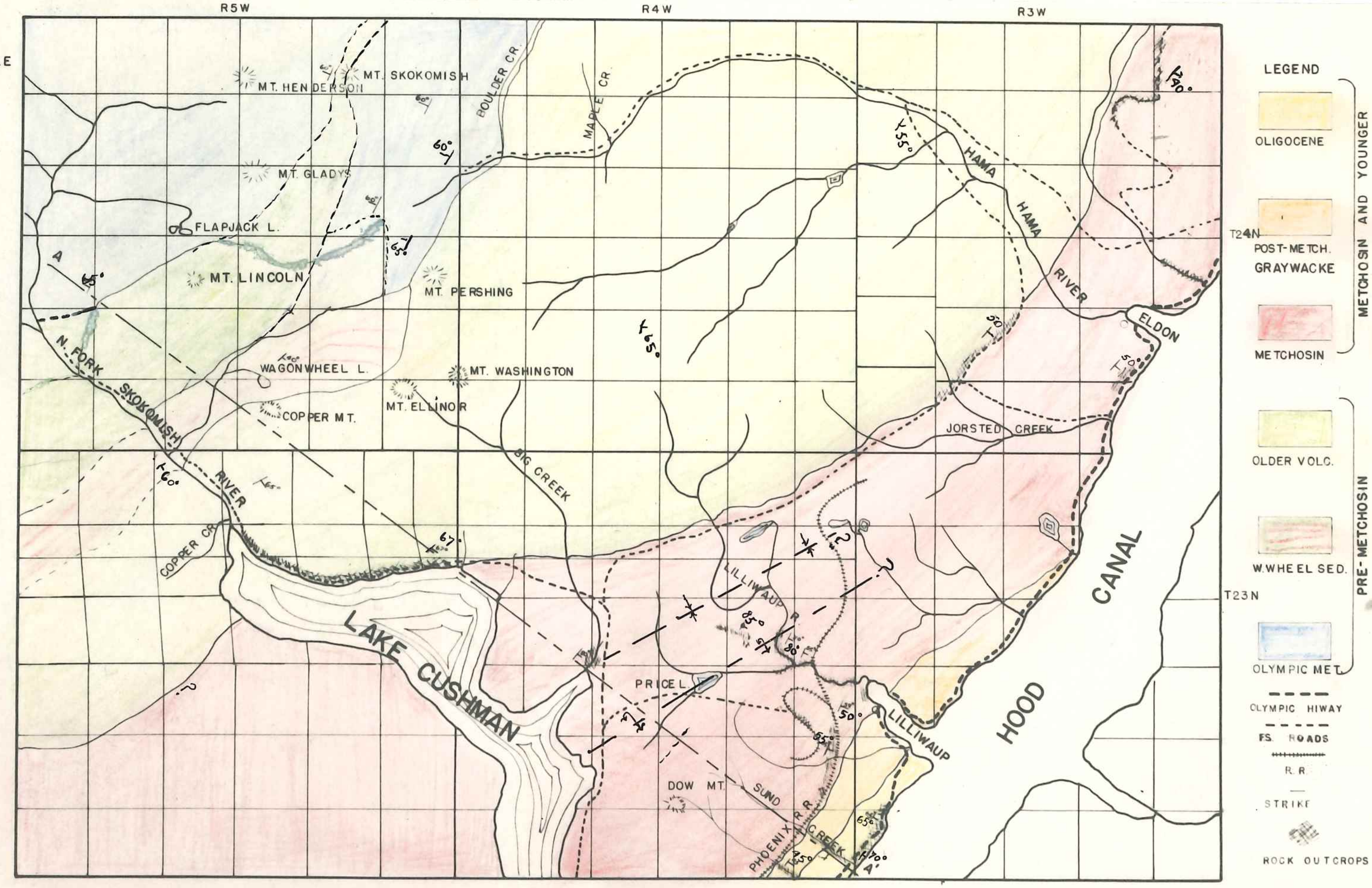

GEOLOGIC MAP
OF THE
LAKE CUSHMAN AND HAMA HAMA RIVER
AREA

SCALE

0 1 2 3 4 MILES

DRAWN BY JOHN ROBINSON

INTRODUCTION

Field Work

The writer first became acquainted with the field problems of the eastern flanks of the Olympic Mountains in 1935 when under the supervision of Dr. C. E. Weaver a reconnaissance trip was made into the region. Becoming interested in the structural relations of the supposedly Tertiary lavas and the underlying pre-Tertiary metamorphosed sedimentary formations, the writer under took the problem of tracing the contact of the two rock groups.

A six-day field trip during the summer of 1936 in the vicinity of the contact of the two rock groups, on the Hama Hama and North Fork of the Skokomish Rivers, disclosed that the supposedly Tertiary lavas were much thicker than anticipated. It was then decided to make a sufficiently detailed reconnaissance of the area between the Hama Hama and Skokomish Rivers to determine, if possible, the general lithology and structural relationships of all the formations outcropping in the district.

Approximately a week in the early summer and late fall of 1937 was spent in the field continuing the reconnaissance. Several trips were made to the north and northeastern sections of the Olympic Peninsula to compare outcrops and check field relationships to determine the validity of conclusions reached in the Lake Cushman and Hama Hama River area.

Acknowledgment

To the members of the Geology Department of the University of Washington, who have assisted me in the field and have critically read this manuscript and offered many helpful suggestions, I wish to extend my thanks at this time.

To my friends who have accompanied me on field trips into the Olympics and have made trips into rugged areas possible, I am grateful.

The analysis of manganese bearing rocks was done by Fergus Strathey, a graduate of the School of Mines, and who accompanied me on a field trip to the Lake Crescent area.

I appreciate the help that members of the National Park Service and Geological Survey have given me.

JWR

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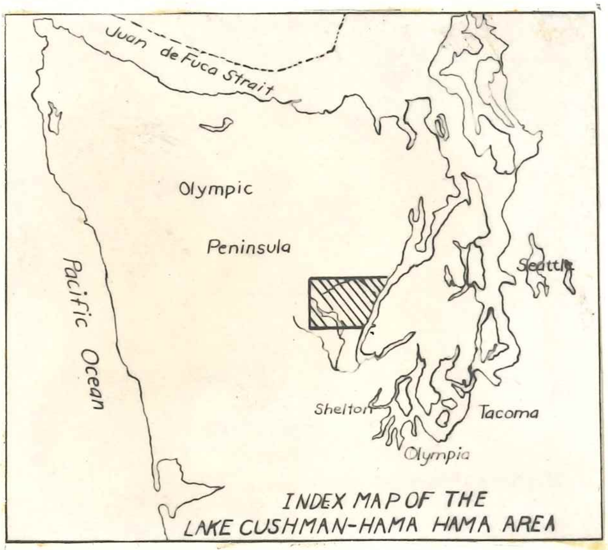
THE GENERAL GEOLOGY OF THE LAKE CUSHMAN AND HAMA HAMA RIVER AREA OF THE OLYMPIC MOUNTAINS

Location

The Olympic mountains are located in the extreme western part of the State of Washington on the Olympic Peninsula. The Lake Cushman and Hama Hama River area is that portion of the Olympic Mountains bounded by the Hama Hama River on the north and west, the North Fork of the Skokomish River on the south, and Hood Canal on the east.



INDEX MAP OF THE LAKE CUSHMAN-HAMA HAMA AREA

The area may be reached from Seattle by taking the ferry to Bremerton and then driving along the Navy Yard Highway to Hood Canal. The branch roads, leading into the heart of the area, leave the Olympic Highway, U. S. #101, at Hoodsport and two miles north of Eldon. The roads are well posted and section lines crossing these roads are marked with distinctive signs carrying their description.

The only available topographic map of the area is the Mt. Constance sheet of the U.S.G.S., which, unfortunately does not include that portion of the area lying south of Latitude 47 degrees 30 minutes north. The map is to the scale of 1/12500 with a contour interval of 100 feet. A Mason County map was used for that portion of the area not covered by the Mt. Constance Sheet.

Geography

An aerial view reveals two distinct breaks in topography; one, the banks of Hood Canal rising very steeply from sea level nearly five hundred feet, and two, the main mountain front which rises from eight hundred to a maximum of over 6000' above sea level in less than two miles. See Aerial Photo.

The mountain front trending northeastward is marked by Mt. Ellinor, elevation 5940 feet, and Mt. Washington, elevation 6250 feet, in the south, and slopes gently northward to ridges about 4000 feet high breached by the Hama Hama River. West of the mountain front are several irregular parallel ridges which control the trend of the drainage of the headwaters of the two main rivers.

Another parallel ridge, breached in the south by the North Fork of the Skokomish River and sloping gently to the north until it merges into the gravel plain at its intersection with the Lilliwaup River, lies three miles east of the mountain front. This ridge, called Dow Mountain, is surrounded on all sides by the gravel plain and is slightly less than 3000 feet high.

The Hama Hama and the North Fork of the Skokomish Rivers are the only streams which enter the mountain front and drain the interior of the Olympic Mountains. Lilliwaup River and Jorsted creek have their sources on the eastward flank of the mountain front and drain into Hood Canal. Other smaller streams drain the overflow from marshes and lakes on the gravel plain bordering Hood Canal. The drainage of the area has been greatly modified by glacial action during the Pleistocene and will be discussed under the heading of Glaciation.

Vegetation

The land surface, below the Alpine meadows, in its virgin state, was covered with heavy stands of Douglas Fir and Western Red Cedar, but logging has denuded nearly all the slopes bordering Hood Canal. The higher peaks are snow covered during most of the year and jut out in bold relief above the alpine meadows.

Because of the heavy rainfall, it is but a few years after the loggers strip the ground until a jungle of salaal, huckleberry, rhododendron, greasewood and young evergreens make travel tedious and sometimes almost impossible on the cut-over land.

GENERAL STRATIGRAPHY

The rock strata in the Lake Cushman and Hama Hama River area, for the purpose of this report, will be divided into two major groups based upon known age relationships; first, those of middle Eocene age and younger and, second, those whose definite place in the time scale is unknown at the present time, but which are older than the middle Eocene.

The pre-middle Eocene group may be divided structurally and lithologically into two major formations, which will be called Olympic formation and Older Volcanics and comprise those strata forming the mountainous part of the area.

The Olympic formation outcrops in the northwest corner of the area and consists of nearly isoclinally folded northeastwardly trending layers of highly indurated feldspathic sandstones and interbedded argillites and phyllites. These rocks are the oldest in the area and form the central part of the Olympic mountains. They have been previously called Hoh formation;[1] but the name Hoh formation is now delimited to include only the Miocene deposits of the western slopes of the Olympic Mountains. At the present time these strata are called Solduc formation in the vicinity just south of Lake Crescent.[2] As recently mapped by Dr. Weaver, the Solduc formation includes several widely differing units and does not include all of the oldest rocks of similar lithology. The oldest rocks have also been referred to as Pre-Tertiary Metamorphics[3] but as the dividing line between Tertiary and Pre-Tertiary rock is not known it is thought best not to use a name involving age implications.

The Older Volcanics outcrop in a northeasterly trending band forming the higher ridges and peaks east of the metamorphics and extending almost to the glacial debris covered plain. They consist of a series of submarine volcanic flows and associated sediments partly altered by regional stresses and broken by many faults. The name Older Volcanics is proposed not as a formational name but to distinguish them from the younger volcanic series resting upon their surface apparently conformably in this area. They have been previously grouped with those lavas of known middle Eocene age and called with them the Metchosin volcanics. But as

(1) Weaver, C. E. Tertiary formations of Western Washington: Wash. Geol. Survey Bulletin No. 13, pp. 1-327.

(2) Weaver, C. E. Tertiary Stratigraphy of Western Washington and Northwestern Oregon: p. 17.

(3) Weaver, C. E. Idem. Plate 3 p. 36.

the Older Volcanics form an easily mapped unit which may be traced around the north, east and south sides of the Olympic Mountains and is in places separated from the overlying volcanics by still another formation it is thought best to divide them in this area, although the dividing line is not as apparent as elsewhere.

The second major group of rock strata comprising those volcanics known to be at least as old as the middle Eocene and all younger overlying formations outcrop on the glacial debris covered plain and extend to and under Hood Canal.

The use of the term Metchosin in this paper is confined to those volcanic flows and included sedimentary rocks which can be traced into the volcanics on the north end of the Olympic Peninsula which have been correlated by Clapp[1] as equivalent to the Vancouver Metchosin formation. The volcanics on the north end of the Peninsula were originally named Crescent formation by Arnold[2] and later subdivided by Weaver[3] into the Crescent and Metchosin formations. Weaver calls the upper layers of the volcanics which are predominately marine and contain the fossils which Clapp used to date his Metchosin on Vancouver Island, the Crescent formation and calls the rest of the volcanics exposed, Metchosin. The Metchosin of the author includes the Crescent

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(1) Clapp, C. H. Sooke and Duncan map-areas, Vancouver Island: Canada Dept. Mines, Geol. Surv., Mem. 96 p. 291.

(2) Arnold, Ralph Geological reconnaissance of the coast of the Olympic Peninsula, Washington: Geol. Soc. Am., Bull., vol. 17, pp. 451-468.

(3) Weaver, C. E. Op. Cit. p. 4, 1937.

formation and that part of Weaver's Metchosin that lies above the sandstones and shales outcropping at the Forks of the Dungeness River. These sandstones and shales separate the Metchosin and Older Volcanics and are at least 1000 feet in thickness.

Overlying the Metchosin volcanics apparently conformably are a series of poorly bedded well indurated graywackes which are probably upper Eocene or lower Oligocene in age. They are tentatively assigned to either of these two periods because they overlie the Metchosin of middle Eocene age, and are in turn overlain by marine sandstones and shales which are similar to the Oligocene deposits elsewhere in Puget Sound, although, no fossils have been found in this area. These sandstones are exposed in the headwaters of Sunds's creek, two miles north of Hoodsport on the Olympic Highway.

Conformably overlying the graywacke sandstones in the same locality are a series of marine shales and interbedded feldspathic sandstones which because of lithologic similarity and stratigraphic position have been tentatively assigned to the Oligocene. Excellent exposures of these sandstones crop out along the Olympic Highway between Sund's creek and Lilliwaup.

LITHOLOGY OF THE FORMATIONS IN THE LAKE CUSHMAN AND HAMA HAMA RIVER AREA

The Olympic Formation

Field studies elsewhere in the Olympic Mountains indicate that neither the base nor the top of the Olympic formation is exposed in the area. A detailed field study would be required to build up a section as the rocks are complexly folded.

The best exposed and most continuous outcrops are along the Mt. Henderson trail starting at Boulder creek on the Hama Hama River. Along the trail is a series several thousand feet thick of indurated micaceous feldspathic sandstones, and inter-bedded black argillites. The layers of sandstone are from 6 to 15 feet thick and the argillites are from a few inches to 10 feet thick, and occasionally contain thin beds of sandstone within them. The gradation between sandstone and argillite is sometimes very sharp making it very hard to tell top and bottom of individual layers by gradational changes. Near the top of Mt. Skokomish the sandstones grade into fine grained sediments consisting of banded argillites and phyllites with an apparently conformable calcareous member invaded by a diabase sill. Strati-graphically below the calcareous layer outcrops a 100 foot bed of a low grade schist with irregular quartz segregations elongated parallel to schistosity. It is thought by the author that this schist represents the oldest rocks outcropping in the area as it is exposed in a known anticlinal fold and is picked up again in a similar fold in the pass between Mt. Gladys and Mt. Lincoln.

The Older Volcanics

The base of the Older Volcanics, adjacent to the Olympic formation is exposed just northeast of Flapjack Lakes R5W-T24N, in the pass between Mt. Gladys on the west and the Sawtooth Range on the east. The contact itself is covered with talus and it is impossible to tell whether it is a fault or a depositional contact. The basal member of the Older Volcanic group is composed of nearly 1000 feet of greenish pillow lava and agglomerates, sheared and altered to a greenstone in which it is impossible to discern detailed structure. The pillows are from one to three or four feet in diameter and are composed of slightly amygdaloidal fine grained meta-andesites with glassy borders. The amygdules are usually filled with calcite and the interpillow material consists of banded limy cherts and jaspers. (See Fig. 1, p. 10.) This basal member is called the Mt. Lincoln Pillow member from its excellent exposures on Mt. Lincoln.

The rocks directly overlying the basal Mt. Lincoln member in the southern part of the area, are called the Wagonwheel member for their excellent exposure in the ridge just north of Wagonwheel Lake. (See Fig. 2, p. 10.) These rocks are composed mainly of sandstones, phyllites, and impure red and green calcareous and cherty layers with occasional altered tuffs, diabase sills, and lava flows. It is in the red limestones of this member that most of the manganiferous deposits are found.

A typical section of the Wagonwheel member starting about 50 feet stratigraphically below those rocks making up the western rim of Wagonwheel Lake to the top of the member is as follows:

Top

50-100'--Impure red limestone.
30-60'--Brown massive arg. sandstone.
10-15'--Basalt flow into unconsolidated sediments.
100'--Dark brown arenac. argillite.
30'--Diabase sill, somewhat serpentinized.
150'--Red and green calcareous and cherty slate.
200'--Bluish black slightly aren. argillite.
100'--Light gray indurated calcareous feld. sandstone.
50'--Impure red limestone.

Overlying the Wagonwheel member is at least 5000 feet and possibly up to 10,000 feet of volcanics and occasional interbedded sediments. Immediately above the Wagonwheel group is a thick pillow flow and then still more red lime and chert layers.

Going up in the series are progressively few sediments and more pillow and massive lava flows until near the top, the series is preponderately massive pillow lavas with occasional altered tuffs which closely resemble flows. Most of the volcanics are altered and sheared, although, original structure has been retained in most layers. The pillow flows range from 50 to 100 feet in thickness; the massive tuffs from 25 to 200 feet, and the massive flows are usually less than 75 feet in thickness. Several diabase sills have been observed intercalated in the tuffs. Part of the thick massive flows and occasional interbedded sediments are well exposed along the north side of Lake Cushman.

The Metchosin Formation

The strata of the Metchosin formation vary greatly along the strike. In the south end of the area, a section obtained from the gorge of the Lilliwaup River gives the following succession:

Top

Poorly indurated tuffaceous basaltic agglomerates.
Massive basalt flows without columnar jointing.
Flow breccia with foreign fragments included within.
Amydaloidal basalt.
Basaltic agglomerate.
Fine grained black shales.
Basaltic agglomerate.
Rudely pillowed dark colored basalt flow.

Bottom?

The uppermost flows of the Metchosin formation are usually limited in areal extent and grade along the strike into agglomerates and tuffaceous sediments. In the northeast corner of the area, near the Webb Lookout on the Fulton Creek Branch of the

Fig. 1--Talus block of the Mt. Lincoln pillow basalt member near the base of Mt. Lincoln.

Fig. 2--View of the sediments making up ridge north of Wagonwheel lake. Hammer is on upper contact of diabase sill intruding the sediments.

Hama Hama road many of the flows show columnar jointing and appear to be surface flows. (See Fig. 1, p. 13.) There are also several flows which show a complex system of shrinkage joints that give them almost a brecciated appearance.

Most of the lavas of the Metchosin formation are fresh and unaltered, although locally in shear zones they are chloritized and serpentinized. No red or calcareous sediments are found associated with them in the area.

The Graywacke Formation

Conformably upon the surface of the Metchosin volcanics is approximately 1000 feet of coarse graywacke. These sandstones are poorly stratified but well indurated, gray to brown in color and are composed mainly of very fresh grains of volcanic rocks. The lithology is nearly uniform from bottom to top, and in weathered outcrops these sandstones are hard to distinguish from weathered basalts. They outcrop in the canyon of Sund's creek two miles north of Hoodsport. Although they apparently grade into the Oligocene strata, an arbitrary dividing line has been made at the bottom of a hundred foot bed of concretionary sandy shale, marking the first shale deposition in the post-Metchosin strata.

Oligocene Rocks

Overlying the graywackes apparently conformably are the Oligocene strata, the upper layers of which are covered by the waters of Hood Canal. The thickness of the exposed section is between 2500 and 3000 feet. The lowermost layers outcrop in the lower canyon of Sund's creek and the uppermost layers along the Olympic Highway just south of the mouth of the creek. (See

Fig. 2, p. 13.) A detailed traverse of this section was made with Dr. C. E. Weaver in the summer of 1935 and an excellent description of it is on page 145 of his publication, "Tertiary Stratigraphy of Western Washington and Western Oregon".

A generalized section is as follows:

Top

100'--Alternate beds of feldspathic sandstone and brown sandy shale with an increase in the amount of sandstone in the upper layers.
500'--Alternate beds of sandstone and shale.
1100'--Concretionary sandy shale.
100'--Massive feldspathic sandstone.
100'--Massive concretionary sandy shale.

Bottom

A few foraminifera occur in several of the upper sandstone members but no mega-fossils have been collected from any of the Oligocene outcrops in this area.

Fig. 1--Metchosin basalt outcrop on Webb Lookout road showing rude columnar jointing.

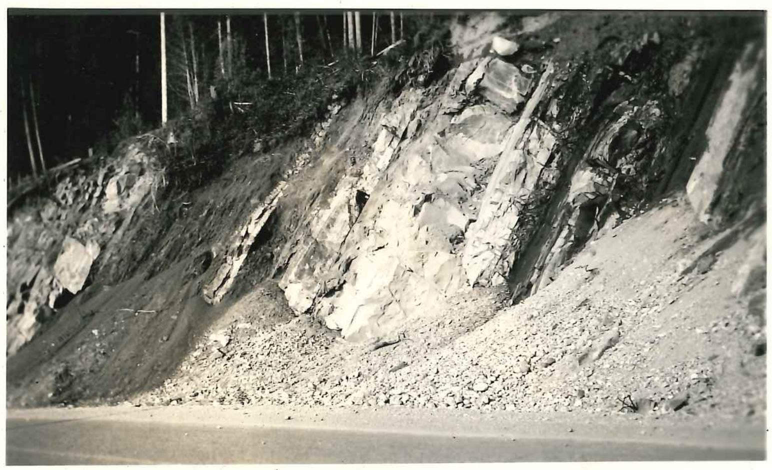

Fig. 2--Oligocene sandy shales and massive feldspathic sandstones outcropping on the Olympic Highway south of Lilliwaup.

STRUCTURAL GEOLOGY

The structure of the present Olympic Mountains may be described as a large irregular shaped dome, the top of which has been removed by erosion, and the western margin of which has been engulfed by the Pacific Ocean. The core of the dome is composed of a great thickness of tightly folded and differentially metamorphosed sediments, named in this report the Olympic formation. The encircling formations are composed of volcanics and sediments usually dipping away from the center of uplift.

The Lake Cushman and Hama Hama River area is located in the southeast sector of this complex dome and all of the strata, including the core, have a northeast trend. The strata of the Olympic formation are strongly compressed and as the Older Volcanics which overlie them have also been distorted and sheared, especially near the contact, the original juxtaposition of the two formation has been greatly disturbed. Without very detailed examination, in a small area such as this, it is difficult to prove conclusively the nature of the contact. When the contact between the two formations has been mapped for the entire Mt. Constance quadrangle it is likely that the areal distribution will clearly indicate the nature of the contact.

Nowhere in the area has an actual depositional contact between the two formations been seen by the author, as the contacts are usually covered by talus from the basalt cliffs above them, or else they are fault planes.

Along the section AA' on the Geologic Map the formations are apparently in normal sequence. The dip of the contact is much steeper than represented on the diagram, approaching the dip of the Olympic formation but as the structure of the Older Volcanics at that point is indeterminable it may be a high angle fault contact.

Northward in the vicinity of Mt. Skokomish a similar section would show the strata of the Mt. Lincoln Pillow member in contact with the Olympic formation on both sides. The strata of the Olympic formation continue eastward to Boulder creek where the main body of the volcanics overlie them disconformably. Here as elsewhere the actual contact is hidden but within a hundred yards of the contact the strata of the Olympic formation dip west 60-65° and from the outcrop pattern the contact dips eastward. A short distance east of the contact the flows of the Older Volcanics dip eastward. (See Fig. 1, p. 20.)

The outcrop pattern of the Mt. Lincoln member is difficult to explain in light of present lack of detailed field observation, but several hypotheses are offered and the present opinions of the author regarding the contact will be given.

1. The Mt. Lincoln member may be conformable with and infolded with the Olympic formation and older than the main group of the Older Volcanics to account for its apparent conformity and association. This seems unlikely as it apparently crosses structure in the Olympic formation when traced for miles along the strike, and is not found on both limbs of folds.

2. The Mt. Lincoln member may be unconformable and follow a pre-existing erosional depression in the Olympic formation, since deformed and infolded. This may be true in part as the Mt. Lincoln member usually outcrops along non-resistant members of the Olympic formation.

3. The Mt. Lincoln member may represent an infaulted block of lavas not yet eroded away, but its sinuous trend and apparent thinning and thickening along the strike point against its being one continuous fault. North of this area the outcrop is not continuous and is separated in some localities by several miles along the strike and is also shifted transversely and outcrops in two or three different bands instead of one, which indicates at least a part of it is fault controlled. Also actually vertical displacements of at least several hundred feet have been observed along the inner contact both north and south of this area.

The author at the present time believes that the Mt. Lincoln member represents approximately the basal member of the Older Volcanics and is unconformable with the Olympic formation, although the exact nature of the unconformity is unknown.

The Wagonwheel sedimentary member of the Older Volcanics is apparently conformable upon the Mt. Lincoln member, and everywhere north of the Skokomish River, dips to the east or is nearly vertical. It can be traced northward to the base of Mt. Pershing where the beds strike into the mountain and are lost beneath the talus. The beds do not appear again in this area and are either faulted out or are overlapped.

The contact of the main body of the Older Volcanics upon the Wagonwheel group is well exposed and is apparently conformable from the Skokomish River northeastward to slightly beyond the base of Copper Mountain. From there to the base of Mt. Pershing the contact is obscured by talus and forest growth and from its outcrop pattern is either unconformable or a fault. North of the base of Mt. Pershing the contact is between the Older Volcanics and beds of the Olympic formation. The actual contact is covered by talus, but may be located within a few hundred feet in the field. The contact cuts across beds of the Olympic formation and there is great angular discordance between the two groups with the volcanics dipping eastward and the sediments dipping to the west. The actual contact may be a fault, but the two formations are probably unconformable.

No folds have been discovered in the main body of the Older Volcanics. This may be due, however, to the lack of key beds to determine structure or to the fact that investigation has not been carried out in sufficient detail. The massive beds that make up the bulk of the series would not fold easily, and may have sheared and faulted to accomodate the stresses of deformation and never formed any major folds in this area. The limestone layers do show incompetent minor folds which thicken the outcrops two or three times. The widening of the outcrop in the northern part of the area is due in part to change in angle of dip and in part to the appearance of additional members which have been overlapped or eroded in the vicinity of Lake Cushman.

The Metchosin Formation

At no locality in the area has the actual contact between the Older Volcanics and the Metchosin formation been recognized. The contact between two series of somewhat similar lavas is very difficult to locate with absolute certainty and any slight angular discordance that might be present would not show on the contact due to the fluidity of the younger flows, which cause them to fill in irregularities. It is possible in the field to locate the contact within a 400-500 foot zone, because of the difference in general lithology of the two formations. The Older Volcanics contain occasional red calcareous layers, well developed pillow flows, are usually altered and are much more massive in outcrop than the younger lavas. The younger Metchosin formation contains, coarse agglomerates, poorly consolidated tuffs, occasional surface flows showing columnar jointing, only one or two pillow flows in which the pillows are poorly developed contain but small amount of interpillow material and are very dark in color. Nowhere in this area have red limy sediments been found interbedded with the Metchosin volcanics.

As nearly as can now be determined in the field, a moderately thick pillow basalt flow, which has but little interpillow material marks the base of the Metchosin in the northern part of the area. In the southern part there are very few exposures close to the base of the Metchosin. There is a marked difference in resistance to erosion in the two series of lavas and that is the principal reason for the sudden break in topography which follows very closely the contact as mapped.

The Metchosin volcanics vary in dip more than the Older Volcanics and are thought, by the author, to be folded into a syncline and anticline between the mountain front and Hood Canal.

A measurement across the strike of the Metchosin volcanics corrected for observed dip, indicates a section approximately 15,000 feet thick across the section AA' on the Geologic Map if there is no repetition of strata. In no place in the State of Washington or on Vancouver Island is Metchosin known to be over 7500 feet in thickness and it is usually much less. This does not mean that the volcanics cannot be much thicker locally but it does at least suggest a sudden change either by thickening, faulting or folding.

As the strata are everywhere dipping not less than forty degrees a high angle fault could not account for such thickening, and there is no evidence to support a low angle thrust of any magnitude. There is however evidence which tends to support the existence of folds. First, similar folds have been mapped elsewhere on the flanks of the Olympics although not as tightly compressed as the dips in this area demand. Second, in the channel of Big Creek where it empties into Lake Cushman, and very near the axis of the postulated syncline, outcrop poorly bedded graywackes indentical in appearance with those at the top of the section on the headwaters of Sund's creek on Hood Canal. Third, near the axis of the supposed anticline is a pillow basalt layer similar in appearance to one found near the base along the mountain front. The beds are all nearly vertical near the supposed anticlinal axis and the dip lessens on eastern limb. An attempt was made to determine top and bottom of the high angle beds but no conclusive determinations could be made in that particular locality.

The folds if present tend to die out to the north and merge into the Hood Canal Syncline and the Wild Cat Hills Anticline at their junction north of this area.

The Graywacke and Oligocene Rocks

The sediments conformably overlying the Metchosin volcanics dip 50-55° to the east at the contact and gradually steepen eastward to the canal until they are dipping up to 70°. Hood Canal at this point seems to follow the synclinal axis of non-resistant Oligocene rocks.

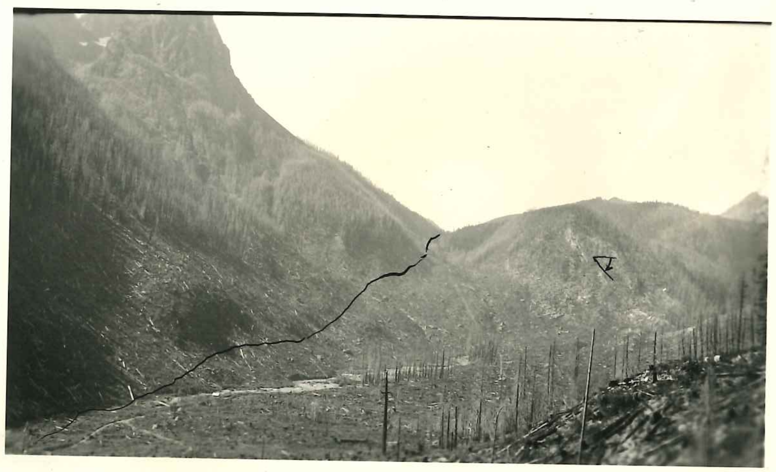

Fig. 1--Looking southward along the Older Volcanic-Olympic contact on the headwaters of the Hama Hama River. Note talus cover along contact; the westward dipping sediments in right background ; and the flat valley floor formed during high lake stage of Vashon Glaciation.

ECONOMIC GEOLOGY

Manganese Deposits

The manganese deposits of the Olympic Mountains are almost entirely confined to certain limestone layers in the Older Volcanics. Manganese has been found in the Lake Cushman and Hama Hama River area near the head of Lake Cushman and near Maple creek on the Hama Hama River.

The outcrops near Lake Cushman were studied by Pardee[1] and after a rather cursory field examination, handicapped by poor exposures, he attributed the present ore bodies to the result of concentration of manganese minerals due to regional metamorphism of manganiferous marine sediments. He also added the possibility of their being formed by concentration due to downward percolating waters at a time before the recent folding.

Pardee and Hewett[2] recently reached the conclusion that for all the regions in Washington, Oregon, and California, circulating hot waters related to igneous intrusion have either altered concentrated bodies of manganese carbonates or aided in the concentration of dispersed manganese carbonates. The resulting minerals are oxides, silicates, hydrous silicates, and carbonates of manganese. They describe the Olympic lodes as being made up of two distinct parts, one of which consists almost wholly of fine-grained quartz and hematite mixed in

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(1) Pardee, J. T.; Deposits of Manganese Ore In Montana, Utah, Oregon, and Washington, U.S.G.S. Bul. 725 p.

(2) Lindgren Memorial Volume; Ore Deposits of the Western States, Pardee and Hewitt p. 681.

different proportions, and the other is characterized by manganese silicates of which bementite, having the formula ($8MnO.5H_2O.7SiO_2$) is the most abundant. Locally the bementite is cut by veinlets that contain one or more of the minerals; quartz, calcite, manganocalcite, rhodonite, manganophylite, and native copper.

The manganiferous ore bodies in the Older Volcanics series are everywhere faulted, a fact which has hindered mining of the ore. The best ore bodies in this area have been found in a layer of red limestone which overlies a thick pillow lava containing a quantity of interpillow alteration products. Although other manganiferous horizone appear locally, this is the one which has the most persistant beds of ore. In some outcrops the ore bodies are two or three feet wide and continue for several hundred feet along the strike and down the dip as far as exposed. Sometimes the ore bodies are lenticular and are 50 to 100 feet long and up to ten feet thick.

The ore bodies were not formed by downward percolating waters at a time after uplift and folding as there is no apparent vertical gradation, but a gradation between top and bottom of sedimentary layers, suggesting formation at a time when the beds were horizontal or nearly so. This fact nearly obviates the theory that the beds were formed as the result of regional metamorphism. Also the displacement of the ore bodies suggest that they are at least older than the last deformation.

There is no clear cut evidence of hydrothermal alteration except possibly, alteration by hot solutions from contemporaneous flows. The flows might supply the heat energy to change low grade manganese containing limestones into ore bodies which contain some hydrothermal minerals. This is in part supported by field relations which show that in many deposits a lava flow is on top of the ore bodies, but there are other flows in direct contact with the red limestones that show no concentration of manganese as a result. Sometimes an orebody is overlain by unaltered limestone.

A study of the manganese deposits from a field relations aspect brings to light several new possibilities which suggest critical data to be looked for in future field studies. An interpretation of outcrops in the manganese area shows that during the time when the tremendous quantity of lava was being poured out over the area now occupied by the Olympic Mountains, part of the area was at times above sea level. These flows contained small but appreciable amounts of manganese (.2-.3%)* and a greater amount of carbonate and ferruginous material. Oxidation conditions existed upon the land and red soil was formed, which was slowly deposited in the surrounding waters along with calcium carbonate and innumerable tests of Globerigina. These red calcareous sediments contained from one to several per cent of manganese* in the form of oxides, carbonates and possibly silicates. Iron in the form of hematite was also intimately mixed in the ooze giving it a red color.

During deposition or rather during an interval of non-deposition, while the limestone was still unconsolidated, the finely divided minerals in the ooze, may have recombined to reach an equilibrium and made an enriched oxidized zone near

*Chemical Analysis

the surface of the deposits. Or, during the period of non-deposition, manganese still in solution in the overlying waters was precipitated and concentrated in the upper surface of the gel and permeated it to some extent. This explanation is offered because of the fact that iron is much easier to precipitate from solution than manganese. Possibly a supply of hot water derived from a nearby submarine flow would cause a reaction in the limy muds, or might carry manganese from the flow. The beds of limestone may also have been elevated slightly above sea level and surface oxidation may have concentrated the manganese distributed throughout the limestone, and left a richer oxidized zone on top.

After the period of concentration, by what ever method it was done, in some deposits still more limestone was laid down and buried the ore. Later flows covered the limestone to a depth of at least ten thousand feet and the deposits remained below the surface oxidation zone until recently. The present oxidation cycle has produced only a very thin film of oxides on weathered surfaces and along joint cracks.

Whatever process produced the enrichment of the manganese deposits it is very likely that the time of enrichment was very soon after deposition and perhaps before a very thick cover was laid down over them.

Fig. 1--Lake Cushman showing well developed terrace above present water level. Mt. Ellinor and Mt. Washington in background.

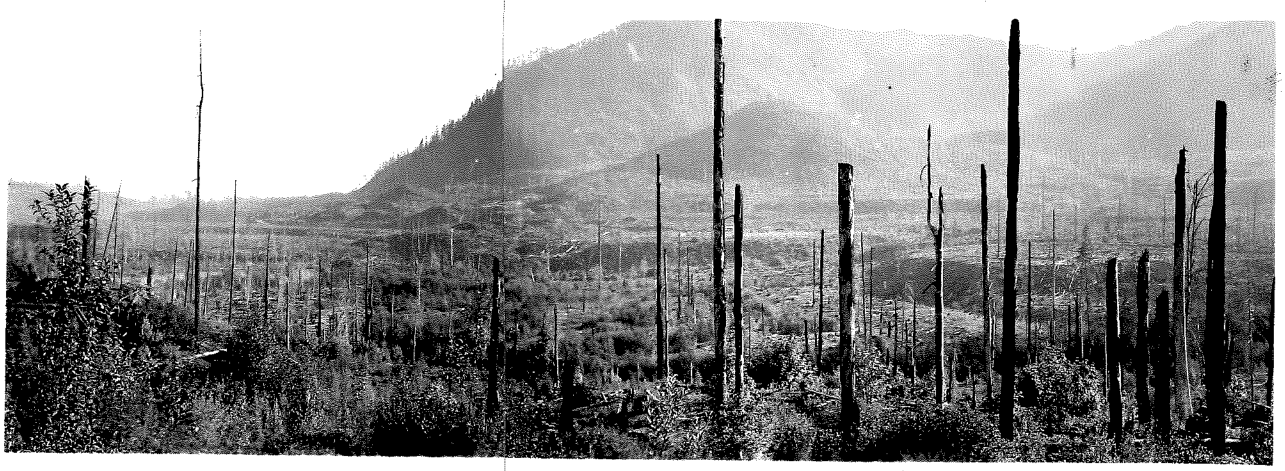

Fig. 2--Terraces cut in glacial drift in the valley of the Hama Hama River. These terraces are approximately 600 feet above present sea level. The river is now intrenched in a meandering course developed at the terrace level.

Glacial Geology

No detailed study of glacial deposits has ever been made in the Lake Cushman and Hama Hama River area. Bretz[1] recognized that Lake Cushman owed its origin to the damming of the valley of the North Fork of the Skokomish by lateral moraine of the Puget Sount ice sheet. He observed that the lake was then 150 to 200 feet lower than its original height as marked by shore line terraces. His observations were made before the city of Tacoma constructed the present dam which has re-elevated the waters of the lake to within 50 feet of its original level. (See Fig. 1, p. 25). Bretz also mentioned finding of what he considered to be Olympic till from a Skokomish valley glacier on the north side of the lake. The author has been unable to find outcrops of Olympic till in the vicinity but it is very possible that Bretz's outcrops were covered by the damming of Lake Cushman or that he mistook outcrops of poorly sorted residual basaltic fragments and soil for till. On the south side of Dow Mountain just north of Lake Cushman are many outcrops of this nature protected from Puget Sound ice by the higher slopes of Dow Mountain.

During the stage of Vashon glaciation, ice of the Puget Sound lobe coming southward from British Columbia stood at a level of at least 1500 feet on the eastern slopes of the mountains and dammed up the valleys of the Skokomish and Hama Hama Rivers. The lakes formed by the dam backed up the valleys and deltas were deposited wherever a stream entered. The

(1) Bretz, J. H. Glaciation of the Puget Sound Region: Wash. Geol. Surv., Bull. No. 8, pp. 9-244.

sediments left by the rivers in the high ice dammed lakes may be found above Big Log on the North Fork of the Skokomish River and at Boulder Creek on the Hama Hama River.

There are some scattered granitic boulders at an elevation of 2700 feet on the ridge by the Webb Lookout at the northernmost part of the area, which indicates a still higher ice level for the Puget Sound lobe but apparently this level persisted only for a very short time.

The forming of lake deposits in the Skokomish and Hama Hama River valleys to a level of 1500 feet with no associated till indicates that during this stage of Vashon glaciation the Olympic Glaciers were above that level. Field evidence suggests that the glaciers of the Olympics probably did not descend lower than 2000 feet at this stage. There is evidence of more extensive Olympic Glaciers at an earlier date but no morainic material has been recognized for certain beyond the mountain front. The valleys of the Skokomish and Hama Hama Rivers are U-shaped and apparently ice scoured below the upper end of the lakes formed by the Vashon ice, indicating at one time more severe mountain glaciation.

During the retreat of the Vashon ice, and after the high lakes were drained, the rivers found themselves ponded behind lateral moraines of the Puget Sound ice and were forced to find outlets at the lowest sag or where the retreating ice first uncovered a channel, usually on the southern side of the valley. The Hama Hama River was fortunate in finding but a narrow hard rock barrier in its new course and quickly cut down through the gravel and underlying basalt and graded itself to the level of glacial lake Hood from 150 to 200 feet above present Hood Canal. (See Fig. 2, p. 25.) The North Fork of the Skokomish turned southward along the eastern flanks of the mountains and emptied into the South Fork, or probably, during the Lake Hood stage, into Lake Hood. The bedrock was everywhere basalt and a deep, almost vertical, canyon resulted from the rapid erosion. But the barrier was never completely removed, thus Lake Cushman, although greatly reduced in size by lowering of outlet and silting up of its bottom, persisted until the present time.

Along the lower courses of all the streams flowing into Hood Canal, in the area under consideration are two very well developed terrace levels, one about fifty feet below the other. Because of lack of elevation control stations no projected profiles have been constructed to determine the height of water which caused the development of these terraces. Remnants of one or more shore line terraces are discernable along the shores of Hood Canal itself but no correlation between stream terraces and lake terraces has been attempted. These terraces are cut in glacial fill and owe their development to the easy erosion of the soft gravels and sands composing them, rather than to a long duration of the lake levels.

In road cuts along the Olympic Highway on the west side of Hood Canal are many well exposed section of lake deposits and associated glacial drift, which will yield much valuable information concerning the Vashon ice advance when properly studied. No pre-Vashon drift has been recognized in the are as yet, but will probably be found in future investigations.

CONCLUSION

The geology of the Olympic Mountains of Western Washington is little known as the ruggedness of the region coupled with lack of mineral deposits has forestalled investigation. The section drawn by the author represents the first attempt ever made to draw a geologic section across the eastern side of the Olympics. It is the first time that most of the outcrops have ever been visited for the purpose of geological investigation. The conclusions reached in this report should be considered on that basis.

The author has read all of the published literature on the Olympic Mountains and has visited every major area of the Olympics during his study of the problem, in order to make certain that the conclusions reached in the Lake Cushman and Hama Hama River area were valid for the Olympics as a whole.

The main conclusion of the author is, that there are two volcanic formations in the Olympics separated by a third formation in the Dungeness River area. These two volcanic formations are different in lithology and each are much thicker than the previous conceptions as published. The younger formation is to be compared with the Metchosin of Vancouver Island although the extent of the Metchosin formation downward in the time scale is not known. The older formation's age is unknown but probably extends back into the Mesozoic. The relationship between the Older Volcanics and the underlying rocks is still an unsolved problem but the author believes they are in the main, unconformable and separated by a time interval.

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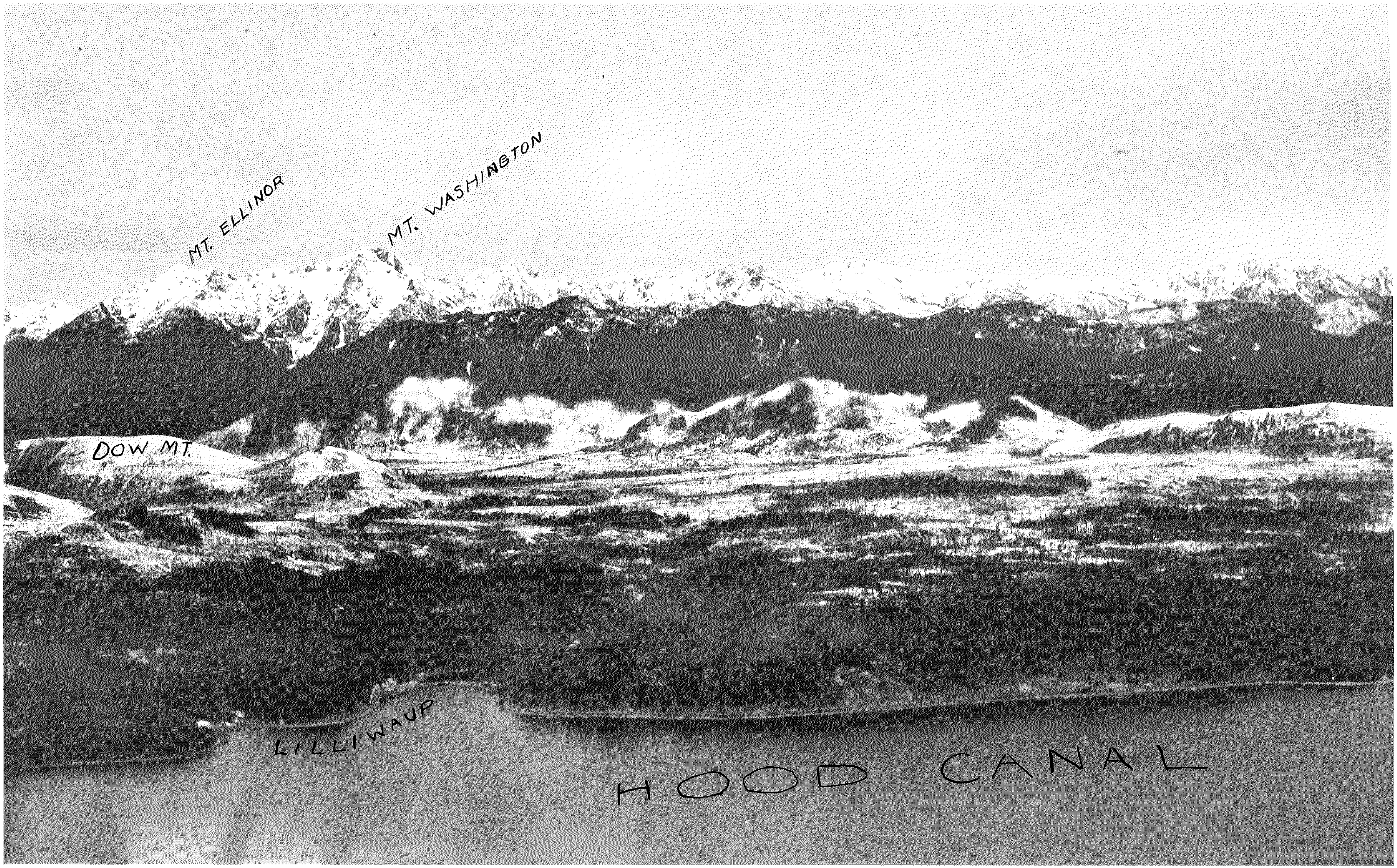

An Aerial View of Hood Canal and the Olympic Mountains in the vicinity of Lilliwaup. **The** striking topographic features of the Lake Cushman and Hama Hama River area are well shown in this view. Note how snow marks the logged-off areas.