GEOLOGY OF THE VEDDER MOUNTAIN - SILVER LAKE AREA

by

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ABSTRACT

The major rock units within the area investigated are: the Permian Chilliwack Group, the Upper Lower Jurassic - lower Middle Jurassic Cultus Formation, and the Upper Jurassic Lower Cretaceous Vedder Mountain Sediments. The Chilliwack rocks examined consist of four limestone units, a thick volcanic sequence, a conglomerate and argillites. The Cultus rocks consist of argillite, shale, graywacke and clastic limestone. The Vedder Mountain Sediments are graywackes, argillites and conglomerates. A tabular body of igneous rock and a schistose cherty rock are included in the sequence.

The regional strike is to the north-east. Most of the rocks in the area are strongly fractured. The Cultus Formation is folded into a series of overturned isoclinal folds with axial planes striking north east and dipping south east. The strongly folded Chilliwack rocks are thrust over the Cultus rocks from the south and south east. The relationship of the Vedder Mountain sediments to the other major rock units is unknown.

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Location

The area mapped is situated in southwestern British Columbia along the Canadian - United States Boundary approximately seventy miles east of the city of Vancouver. It extends eastward from the summit of the Vedder Mountain to the western slope of Church Mountain and southward from the Chilliwack River to the International Boundary and a few hundreds yards beyond. The approximate geographic limits are meridians 121° 52' and 122° 09' west longitude and parallels 49° 00' and 49° 05' north latitude.

Access

Cultus Lake, which is central to the major part of the area is easily reached from the Trans Canada Highway by paved road. A gravel road on the east side of Cultus Lake continues south through Columbia Valley to the boundary. Much of Vedder Mountain, parts of International Ridge, and the lower portion of Lihumitson Creek can be reached by logging roads, several of which are accessible to automobile. Church Mountain and the Lihumitson Lake Area are reached by a good trail. The area of the headwaters of Lihumitson Creek and Isar Mountain is devoid of roads or trails. The area on the American side is reached by the Mount Baker - Silver Lake road.

Topography, Vegetation and Drainage

Vedder Mountain is a long, north-easterly trending ridge, tapering in width from about three miles near the northern end to one and one half miles at the boundary. Its maximum elevation is 3060 feet. The topography is characterized by rounded rocky hummocks but bluffs and cliffs are common. The mountain has been almost entirely logged and is now covered chiefly by second growth timber and underbrush with large areas of burn, windfall, and logging slash.

The valley between Vedder Mountain and International Ridge is occupied by Cultus Lake in the north-east, at an elevation of 48 feet, and by Columbia Valley to the south-west, at an average elevation of approximately 800 feet. Columbia Valley is underlain by glacial till which has been cut into three terraces by stream erosion.

International Ridge, with a maximum elevation of 4858 feet on Mount Amadis, is a long, steep-sided, north-easterly trending ridge with five minor peaks. Its broader and higher southern extension across the boundary forms Black Mountain. This ridge has not been so extensively logged as Vedder and is largely covered by virgin and old second growth timber with very dense underbrush. Its major streams, Watt, Frost and Blue Creeks, all with deep canyons, flow in a westerly to north-westerly direction, draining into Cultus Lake.

The area between International Ridge and Church Mountain appears to have once been a plateau which has been dissected into its present rough topography by the down-cutting of Lihumitson Creek and its tributaries. The drainage pattern forms a rough triangle with the north-easterly trending International Ridge and north-westerly trending Church Mountain ridge as its sides and Isar Mountain as its base. A 4500 foot unnamed ridge juts into the centre of the triangle from the south between the two main branches of the creek. These ridges are very steep and are often covered by deadfall and very dense underbrush. Travel is extremely difficult.

Climate

No meteorologic stations are situated in the area, therefore no figures are available. However, the climate is definitely within the marine west coast regime. The precipitation, above 60 inches per year, is largely orographic in origin. In winter, more than twenty feet of snow accumulates above the 4500 foot elevation, making field work at these altitudes impractical until late July.

Previous Work

H. Bauerman, of the Geological Survey of Canada, who traversed from the Gulf Islands to the Rocky Mountains in 1859-60, produced the earliest geologic report concerning this area. He draws no distinction between what are now

called the Cultus Formation and the Chilliwack Group, assigning both to the Palaeozoic. He makes no attempt to solve the structure, other than on a very broad scale.

The most comprehensive report to date concerning the area was produced by R.A. Daly, who traversed from the Rocky Mountains to the Pacific along the 49th parallel during 1901-1906. He named the Cultus Formation, which he called Triassic, and the Chilliwack Group, which he assigned to the Carboniferous. He included the sediments of Vedder Mountain in the Lower Carboniferous. Daly's explanation of the structure of the area includes placing great normal faults at the eastern and western contacts of the Cultus with the Chilliwack, with a south-dipping thrust fault as the southern contact. He warns that his interpretation is very speculative.

C.H. Crickmay published a report on the Northern Cascades in 1930, in which he states, without citing supporting evidence, that the Vedder Mountain sediments are Triassic. He also concludes that the Cultus Formation consists of schuppen of Carboniferous and Lower Cretaceous rocks. He regards this structure as being part of a great thrust fault which continues north through Harrison Lake and forms the western boundary of the Chilliwack Group.

The latest published report referring to the area accompanies the Hope sheet of the Geological Survey of Canada

with notes by C.E. Cairnes (1942). This report includes the Vedder Mountain sediments in the Chilliwack Group. It places the Cultus in the Upper Triassic and accepts with reservations Crickmay's interpretation of the structure. It shows the eastern contact of the Cultus Formation with the Chilliwack Group exactly as does Daly's map, but shows a north-westerly striking contact between Chilliwack rocks and the south-west corner of the Cultus outcrop.

Present Investigation

Scope

The purpose of this investigation was to map the area geologically, attempting to establish the stratigraphic position of, and to solve the structural relationships between and within, the various rock units. Because of the large area covered, the short field season, the rough topography and dense forest cover, the information obtained is quite general in nature. The field season was shorter than originally anticipated owing to the abnormally high precipitation in June. The writer had other duties to fulfill during most of the other months. This work, therefore, must be regarded as a reconnaissance to be used as an aid to future, more detailed studies in the area. Among the more specific problems are to establish: the position and nature of the Cultus - Chilliwack contact; the stratigraphic position of, and structure within the Cultus Formation; the stratigraphic position of the various units within the Chilliwack

Group; the nature of the Vedder Mountain sediments, their structure and stratigraphic position.

Methods

Outcrop locations were plotted on topographic maps of a scale of 1:50,000, or on aerial photographs. Both were obtained from the British Columbia Department of Lands and Forests. Descriptions and attitudes of the outcrops were recorded and hand specimens collected for later study with the petrographic microscope. Creek beds and logging road cuts were paid particular attention but many cross-country traverses were made.

DESCRIPTIVE GEOLOGY

Regional Setting

The area mapped is within the western foothills of the Cascade Mountains. These mountains were formed during the Cascadian Revolution, which is thought to have originated in Miocene time and persisted until Pleistocene.

The regional trend of the rocks within the area is north-east with a south-east dip. The regional attitude over almost all of the rest of south-western British Columbia is, strike north-west, dip north-east.

The rocks mapped consist of Upper Palaeozoic clastic sediments, limestones and volcanics, and Mesozoic sediments. All rocks in the area have been strongly contorted. Just north of the area mapped, Tertiary rocks overlie the Mesozoic rocks with slight unconformity.

Rocks of the Jurasside Coast Range granitic province outcrop to the north-west, across the Fraser River. The glacial-fluviatile plain of the Fraser River Lowland lies to the west, beyond Sumas Mountain. Cretaceous and Paleocene rocks around the borders of the plain are relatively undisturbed.

ROCK UNITS

Chilliwack Group

Distribution

The type area of this Group was established by Daly along the Chilliwack River from approximately the confluence of Centre Creek to the confluence of Slesse Creek. Its limits of outcrop have not been established. Cairnes shows Chilliwack rocks, south of the Fraser River, extending from the vicinity of Lihumitson Creek to the summits of Slesse and Cheam Mountains, as well as in the vicinity of Cheam View. He also includes the Vedder Mountain sediments in the Chilliwack Group, a decision which available evidence seems to invalidate, as will be discussed later. Misch (1955) has mapped Chilliwack rocks south of the International Boundary as extending from the vicinity of the headwaters of Lihumitson and Tamilie Creeks to the North Fork of the Woodsack River. The writer has examined these rocks on the north and south sides of Chilliwack River, on Church Mountain, the headwaters of Lihumitson Creek, and on Isar, Black and Red Mountains. Chilliwack rocks have also been mapped extensively by the Geological Survey of Canada in the area between Harrison Lake and the Fraser River.

Lithology

Daly constructed a tentative section of the Chilliwack Group (P.514) with base and top concealed, in which he included quartzitic sandstone, argillite, several limestones, andesitic flows, tuffs, and agglomerates, shales, "grits", and conglomerate. Rocks of this group which the writer has examined include; a dolomitic limestone, a thick andesitic volcanic sequence, a crinoidal limestone, a thick boulder conglomerate and graywacke, a fusulinid-bearing dark limestone, reef limestone, argillites, conglomerate, and chert.

Bauerman estimated the thickness of the section exposed along the Chilliwack River to be 24,000 feet. He, however, neglected to take the complex structure into consideration.

Daly calculated a thickness of 6,780+ feet (page 514) in constructing his stratigraphic column for the group. The writer will not attempt to attach definite thickness to the formations within the group since nowhere were sections well enough exposed to permit accurate measurement. The complex and imperfectly understood structure of the area adds to the difficulty. For similar reasons, stratigraphic relationships within the group as reported in this paper must be regarded as tentative, pending further investigation. Only rock units of the western portion of the Chilliwack Group are discussed here.

Dolomitic Limestone

The apparent stratigraphically lowest unit of the Chilliwack Group to be examined by the writer, crops out on Frost Creek, about 200 yards south of the International Boundary and on the adjacent slope of Isar Mountain. It consists of: light grey, buff weathering, sandy textured dolomite; massive, medium grey, brecciated dolomite; and black medium to finely crystalline limestone. The limestone contains what appear to be poorly preserved fusulinids. The unit may correlate with the limestone in Daly's section II (P. 512) which crops out 1200 yards southwest of monument 45. This tentative correlation is based only on apparent stratigraphic position since both directly underlie the thick volcanic unit. Daly collected fossils (No. 1500) from section II, which were identified by Dr. G.H.Girty as:

Fusulina elongata Shumard

Rhombopora sp.

Productus (?) sp.

Isar Mountain Volcanic Sequence:

The writer traversed over Isar Mountain from Lihumitson Creek to Frost Creek almost along the International Boundary. From Lihumitson Creek, at an elevation of approximately 3000 feet to about the same elevation on the western slope, only volcanics and associated intrusives were seen. The one exception was one small outcrop of limestone

on the western slope at approximately the 3800 foot elevation.

The volcanic rocks apparently consist entirely of dark green, usually porphyritic andesites with phenocrysts of plagioclase and hornblende. These rocks are somewhat altered but are still easily identifiable. Volcanic breccias of the same material are common.

The apparently interbedded limestone is black, finely crystalline and massive. It is possible that this limestone indicates an infold of older or younger material.

A thick-bedded white chert, about 10 feet thick, with clear quartz fragments and stringers crops out in Lihumitson Creek, at the eastern limit of the volcanic outcrop.

Cairnes (1942) includes some rhyolite in his description of the Chilliwack Volcanic Member, of which the Isar Mountain volcanics are probably a part. The most acidic rocks encountered by the writer were fairly fresh, equigranular, medium grained rocks of granodioritic or quartz-dioritic composition, which the writer interpreted as being of intrusive origin. Medium grained, equigranular diorites within the sequence are also regarded as being of probable intrusive origin. The intrusions seem to be in the form of sills or dykes.

Daly's estimate of 2000+ feet as the thickness of this sequence seems to be of the right order of magnitude.

Because of the massive nature of the rocks, the abundance of jointing, and the dense cover, no definite attitudes could be read, but the rocks appear to dip gently in a south-easterly direction. Abundant slickensiding indicates that movement has occurred along many of the fractures.

Volcanic rocks of quite similar appearance crop out on Black Mountain and on the north side of the Chilliwack River opposite Tamilie Creek. The correlation of these rocks with the Isar Mountain volcanics can not be made at the present time because of the lack of sufficient evidence.

Crinoidal Limestone

Limestones containing abundant crinoidal debris are exposed on Red Mountain, Black Mountain and on the slope above Lihumitson Creek southwest of Church Mountain. If these various occurrences belong to the same rock unit, this unit appears to be stratigraphically higher than the Isar Mountain volcanics. They do not crop out in the vicinity of the volcanics. However the outcrops on Black and Church Mountains appear to be quite conformable with the overlying boulder conglomerate and fusulinid limestone which are exposed near the volcanics and appear to overlie them.

The crinoidal limestones are dark to light grey, often with a brownish tint. Due to the abundance of white calcite veinlets they frequently look white. They are medium crystalline and generally massive but are occasionally medium

bedded. The massive limestones weather grey while the bedded limestones usually weather a buff colour.

Approximately 150 yards below the Lihumitson Lake trail on the western slope of the 5659 foot peak, limestone of the above description forms a 75 foot cliff. The central fifteen feet of this otherwise massive, grey weathering limestone is medium bedded and weathers buff. Other than crinoid debris, the only fossils observed here were bryzoan fragments. The general attitude of the beds is somewhat obscured by jointing and folding, but the strike, in places appears to be slightly west of north. The dips are low both to the east and the west.

A similar limestone crops out on the northwest spur of Black Mountain. It exhibits the same massive structure, although three bedded layers are exposed. The strike is north east, the dip south east. The limestone crops out, over a small area of Karst topography and as an adjacent, almost vertical cliff. The total thickness exposed is of the order of 200 feet. Fossils collected include crinoid stems, cup corals, brachiopods and bryozoa. The limestone is overlain by a boulder conglomerate with apparent conformity. Underlying rocks were covered by snow at the time of the writer's visit to this locality.

Red Mountain was not geologically mapped by the

writer but three limestone occurrences situated on it were visited. The limestone exposed in the most northerly quarry on the east side of the mountain is medium grey to brownish grey, buff weathering, coarsely crystalline, entirely massive and very strongly jointed. White secondary calcite has crystallized along the joint planes, giving much of the rock a very coarsely crystalline and mottled appearance. Crinoid stems were the only fossils found here.

The quarries of the Olympic Cement Co. on the west side of Red Mountain contain the same general type of limestone with both massive and medium-bedded members. The limestone in the upper quarry contains a layer of greenish-gray shale interbedded with a chert pebble conglomerate of the order of 40 or 50 feet in thickness. The total exposure here exceeds 250 feet in thickness. The limestones are underlain by thin to medium bedded black argillites and shales with some interbedded black limestone.

Fossils collected from these limestones include brachiopods, bryozoa, crinoid stems and possible cup corals.

Boulder Conglomerate:

A very coarse conglomerate composed principally of volcanic boulders directly overlies the crinoidal limestone on Black Mountain with apparent conformity. It also overlies the crinoidal limestone on the Lihumitson Lake trail but a covered interval of about 100 yards separates the two

outcrops. The conglomerate is exposed also near the bottom of the ridge between the forks of the east branch of Lihumitson Creek.

The boulders are well rounded and up to more than a foot in diameter. They are composed of andesite porphyries, green aphanitic volcanics, chert, and some limestone. The conglomerate is interbedded with a fine-grained, greenish gray, medium bedded feldapathic graywacke.

On the Lihumitson Lake trail this unit is exposed through a stratigraphic thickness of at least 600 feet. The top was not seen. It strikes N 35° E and dips 30° S.E. Conglomerate is exposed for several hundred yards below the trail between the limestone and the Cultus argillites. It crops out about 100 yards north along the strike of the limestone and for an unknown distance below.

Fusulinid Limestone:

A dark gray to black, finely crystalline, thin to medium bedded limestone containing fusulinids is exposed on both sides of the ridge east of Isar Mountain. On the east side, about 400 yards north of the boundary it is exposed in Lihumitson Creek at an elevation of approximately 2700 feet. On the west side of the ridge it is exposed about 50 yards south of the boundary at an elevation of approximately 3800 feet. It cannot be stated absolutely that these are the same beds, since the fusulinids have not been specifically

identified, but they do possess the same type of bedding, texture and colour. On the ridge only argillites and shales, strongly resembling Cultus rocks, are found areally between the two limestones. On the western side a large argillite cliff crops out about 50 yards north of the limestone and topographically above it.

Limestone crops out above the coarse conglomerate on Black Mountain. The writer has not visited this occurrence but W.R. Danner (personal communication) reports that it contains abundant fusulinids. The writer has examined hand specimens from this locality.

Should these various exposures of fusulinid-bearing limestone prove to be from the same horizon, it is believed that this is the stratigraphically highest rock unit of the Chilliwack Group, examined by the writer, to be exposed in apparent contact with Cultus Rocks.

Doaks Creek Limestone:

Another limestone, resembling none of those discussed above, outcrops approximately 1½ miles south of the crinoidal limestone on the east side of Red Mountain. This limestone is dense to finely crystalline, dark grey, with fossiliferous beds containing thamnopora-like fossils which have not been definitely identified. A few rare cup corals were also found. The beds strike north-easterly and dip 20° to 30° south-east. No other rocks crop out in the immediate

vicinity. The stratigraphic position of this limestone cannot be determined at the present time although it is probably a unit of the Chilliwack Group, higher than any of those discussed previously.

A tentative general columnar section of the rock units of the Chilliwack Group so far discussed is shown in Table I.

TABLE I

Top	unknown
Doaks Creek Limestone	100' ±
Covered interval	unknown thickness
Fusulinid limestone	200' - 400' ±
Boulder Conglomerate	600' ±
Crinoidal limestone	200' +
Interval	unknown
Isar Mountain Volcanics	2000' ±
Dolomitic limestone	thickness unknown
Bottom	unknown

Other Rocks of the Chilliwack Group:

Rocks of the Chilliwack Group, including argillites, "cherty conglomerate", graywackes and green volcanics were examined on the north side of the Chilliwack River approximately opposite the confluence of Tamilie Creek. The argillites are thin to medium bedded, black to dark brownish

gray, and highly siliceous. The "cherty conglomerate" consists of chert pebbles or nodules in an argillaceous matrix. It is about 2 feet thick and exhibits no bedding. The greywacke is dark green and massive. It contains angular quartz fragments, rock particles, and a small amount of plagioclase and Chlorite in a dense matrix. The volcanics, further to the east, were not closely examined. They are dark green and massive. All these rocks are strongly folded and fractured. The general attitude at the western end of the outcrop is strike east-west, dip north. Towards the east the attitude changes to strike north-east, dip south-east.

At the confluence of Slesse Creek, a large outcrop of steeply dipping, dense, dark gray limestone with beds and nodules of black chert was found.

These rocks were not examined thoroughly enough to permit the determination of their stratigraphic position.

On the south side of the westerly trending ridge south of Lihumitson Lake, a medium grained, gray, hornblende diorite is exposed in a long, 60 foot cliff, at an elevation of approximately 4800 feet. No other rocks are exposed in the immediate vicinity. This intrusive-looking rock probably forms a sill within the Chilliwack Group. Float of the same type of rock abounds on the lower slopes of the next ridge to the south, indicating that the sill extends in that direction.

Age of the Rocks of the Chilliwack Group:

Daly made large collections of fossils from the Chilliwack limestones, but his localities are to the east and south-east of the area investigated by the writer.

His locality No. 1512, "on top of the ridge 1500 yards southwest of Monument 48" contains an assemblage of fossils which does not resemble any of those collected in the limestones visited by the writer. The fossils were determined by Dr. G.H. Girty and Dr. R.S. Bassler as:

Plant fragments

Clisiophyllum sp.

Crinoidal fragments

Fenestella sp.

Rhombopora sp.

Cystodictya sp.

Productus semireticulatus Martin

Productus aff. jakovlevi Tschern

Spirifer aff. cameratus Morton

Reticularia lineata Martin (?)

Spiriferina aff. campestris White

Martinia (?) sp.

Seminula (?) sp.

Terebratuloid (?)

Myalina aff. M. squamosa Sowerby

Aviculipecten sp.

Pleurophorus (?) sp.

Orthoceras (?) sp.

A similar assemblage was collected by Daly 1200 yards west of the summit of Church Mountain on top of the ridge, which would place it above the boulder conglomerate. This assemblage could be a faunal facies of one of the previously described limestones. The most similar fauna is that of the crinoidal limestone on Black Mountain. The most similar apparent stratigraphic position is occupied by the Fusulinid limestone on Black Mountain. It could not, however, be correlated with the fusulinid limestone on the strength of apparent stratigraphic position alone, owing to the high probability of faulting in this area. The north-west face of Church Mountain, as seen from the ridge to the west, shows extremely complicated structure involving faults and overturned folds. It is therefore impossible, without further examination, to say which, if any, of the limestones visited by the writer correlates with this outcrop.

"On the same ridge as 1512, 1000 yards farther north", Daly collected

Lonsdaleia sp.
Campophyllum sp.
Crinoidal fragments
Fistulipora sp.

This assemblage resembles much more closely that of the crinoidal limestone previously discussed.

Dr. Girty writes in his summary,

> "... The most natural geologic section with which to compare these fauna is that of northern California. ... There is nothing among your collections which suggest the Baird or McCloud. The most strongly characterized of your faunas (lots 1512, 1514 and 1500), however have much that is similar to the Nosoni. At present I am disposed to correlate the two horizons."

The California sequence was then regarded as being of Carboniferous age. It is now included in the Permian, the McCloud correlating with the Wolfcampian and Leonardian, the Nosoni with the Guadalupian.

The faunas of this area show distinct asiatic affinities. Several of the fossils collected by W.R.Danner and the writer have never been described from North American localities, according to Miss Helen Duncan of the United States Geological Survey. For this reason, fossil identifications and age determinations are very difficult.

Black Mountain Crinoidal Limestone:

Miss Helen Duncan writes concerning fossils collected on Black Mountain by W.R.Danner;

> "...The most conspicuous specimen exposed on the surface is a fragment of Iranophyllum aff. I spongifolium Smith. This is the first time I have seen this genus in an American collection. The genus was originally described from the "permo-Carboniferous" of Persia. ... Iranophyllum apparently has a considerable range in the Permian, so it is not possible to say whether the occurrence in Washington indicates Wolfcamp age or some later stage. ... Two of the specimens are an undetermined species of Lophyophyllidium, and the others are tentatively

> identified as Carruthersella sp. ... The type I am calling Carruthersella ? has a carcinophyllid axial column and a Lonsdaleoid dissepimentarium. Several other names - Kionophyllum .... have been proposed for corals with about the same characters; and some authors have referred similar forms to Lophophylloides and Lophophyllum. This group of corals is practically unknown in North America. Described species occur in the Lower Carboniferous of England and Asia and in the Middle and Upper Carboniferous of Russia, China, and the Carnic Alps. Some of the foreign Upper Carboniferous occurrences are probably temporal equivalents of North American early Permian (Wolfcamp).

The writer collected very large, poorly preserved brachiopods from the same outcrop. They strongly resemble Gigantoproductus, which is generally considered to be of Mississippian age in North America. However, since these lived in seas connected to Asia and not connected to other North American seas, it is highly possible that they could have persisted to the Permian.

Several smaller, poorly preserved brachiopods and some corals were also collected at this locality but have not yet been identified.

Fusulinid Limestone:

Miss Helen Duncan writes concerning bryozoans collected from the fusulinid limestone by W.R.Danner:

> ... I can recognize the following genera: Fenestella, 2 or more species; Polypora sp.; and Rhomboporella sp. ... The species represented in your sample are non-descript small-meshed forms that occur throughout the Carboniferous and Permian,

Of the fusulinids, Dr. J.W.Skinner of the Humble Oil and Refining Company writes to W.R.Danner

> "... There appears to be at least two species of Schwagerina and two of Pseudo fusulinella. One of the latter is very similar to P. occidentalis from the lower McCloud. I should feel little hesitation in correlating this bed with some part of the Coyote Butte of Oregon and the McCloud of California."

Doaks Creek Limestone:

This limestone is highly fossiliferous but none of the fossils have been positively identified yet. The internal structure of the peculiar Thamnopora-like fossil is unlike that of a coral. Miss Duncan has suggested that it may be a Triassic stromatoporoid. A cup coral was also examined but is as yet unidentified. It is most probable that these forms are Asiatic.

From the foregoing it is seen that the age of all of the limestones of the Chilliwack Group cannot be definitely established at present. It seems most probable that all the limestones discussed are of Permian Age. The lower three limestones are probably of Wolfcampian Age. However, it is possible that the age range may be from Mississippian to Triassic. Fossils which have been collected but not yet identified may help to solve the problem, although they represent a fauna almost unknown in North America.

Cultus Formation

Distribution

Daly (1912), named the Cultus Formation, which he called Triassic. The type section is described as being on "Cultus Ridge", which is now called International Ridge.

Rocks of the Cultus Formation crop out from the eastern side of Cultus Lake and Columbia Valley to the ridge east of Lihumitson Creek. The southern limit of outcrop lies very close to the International Boundary. The northern extent is not definitely known. It is shown by Cairnes (1942) as being in contact wit the Aluvial plain of the Fraser River. The writer, however, mapped only to the northern end of Cultus Lake.

An outcrop of Cultus rocks north of the Chilliwack River, on the Ryder Lake Road, reported to be fossiliferous, was also visited.

No Cultus rocks have been described north of the Fraser River. They appear to be confined strictly to the area outlined above.

Lithology

The Cultus Formation is composed dominantly of dark gray to black, medium bedded argillites interbedded with dark gray to black shales, siltstones, fine to medium grained

graywackes of various colours, volcanic breccias, probable tuffs, clastic limestones, shaly limestones and chert.

Besides the lack of fossils, the major difficulty encountered in working in the Cultus Formation is the lack of marker beds. The various sections resemble each other very closely in gross features. Minor variations observed in a particular section which might have helped in correlation were seldom observed elsewhere.

Argillite:

The major part of the Cultus Formation consists of thin to thick, regularly bedded, dark grey to black, brown weathering rocks, which in the field are termed argillites. It is apparent from examinations of thin sections, that all of the rocks with this appearance are not true argillites, that is, they are not all simply indurated rocks of argillaceous composition. Complete gradations occur from true argillites to graywackes. The majority of the rocks are silty argillites or argillaceous siltstones. When studied in thin section, they are seen to contain a dense matrix, which generally looks blue under crossed nicols and brown in plane polarized light. Small, very angular quartz and chert fragments, very small, angular plagioclase fragments, occasional fragments of aphanitic volcanic rocks, and usually a very small amount of calcite are also present. As the proportion of sand-sized particles increases, the rock grades toward a graywacke.

Clean, smooth surfaces, at right angles to the bedding, often exhibit fine colour banding from dark gray to light gray and brown. These bands are 1/16" to 1/2" wide. They are apparently due to slight textural variations. The bands are usually strongly contorted, quite obviously owing to soft sediment deformation, since the bedding planes are relatively smooth.

The beds are commonly 2" to 3" thick, but range up to several feet in thickness. They occasionally appear to be thin bedded due to very strong shearing which has broken the rock into thin slabs. South-east of the confluence of Lihumitson Creek, an outcrop appears to be thin bedded and dipping to the south. Close examination reveals that the rocks are actually thick bedded and dip south-east. A multitude of south dipping shear planes almost completely mask the bedding.

The argillites are usually silicified in various degrees. Some are so highly silicified that they resemble chert in hardness and breaking properties.

Thin shaly layers, from 1/4" to 1" in thickness, often are interbedded with the argillites. These are interpreted as being chiefly a result of slippage along the bedding planes, rather than original sedimentary features, since they are very common in highly contorted areas, but are rarely seen in relatively undisturbed outcrops. Further-

more, they are of a crumbly rather than a fissile nature.

Separate descriptions, regarding the argillites, of the numerous localities examined by the writer will not be included since there is so little variation between outcrops.

Thicknesses of sections are generally impossible to measure, owing to the strong contortion of the beds.

Graywacke:

The graywackes of the Cultus Formation were first described in the field by the writer as tuffs, since they present a very similar appearance in hand specimens. Upon examination of thin sections, however, it is seen that they are composed chiefly of elongate, angular shale or argillite fragments, ranging in length up to 1/2", volcanic rock fragments, quartz and plagioclase fragments, and calcite, set in a dense matrix. Several small, white discs with hollow centres were observed, but their origin is unknown. The elongate fragments are oriented in the plane of the bedding.

The beds range in thickness from 1" to 7 feet. The thinner beds exhibit very well defined graded bedding, the medium grained graywackes grading upward into argillite. The graywackes are interbedded with argillite.

The graywackes occur in various colours; bluish

gray, light greenish gray, brown, and dark gray. It is believed, however, that this variation in colour is often due to leaching, which appears to have affected these rocks to a depth of several inches. One specimen is dark gray in the centre, grading outward through light greenish gray to brown, 1½" from the central material. The dark rock is very calcareous. The rest of the material is non-calcareous. Leaching of the calcite and subsequent slight alteration of the remaining clastic material has apparently produced the colour variations.

A similar explanation may account for the appearance of a fine grained, dark brown, laminated, extremely porous, 18" thick bed which crops out on the road east of Cultus Lake at the south end of the camp ground. This extremely soft rock contains volcanic rock fragments and highly altered, unidentifiable material. The porosity exceeds 50%. It is probable that the present pore space was once filled with clastic calcite.

Many of the graywackes are highly silicified. It is believed that the silicification followed the decalcification, since little calcite is present in the siliceous rocks. This theory may account for the relatively fresh appearance of some of the hard blue, green, and brown graywackes. If samples could be obtained several feet under surface exposures, they would probably be of similar colour.

Graywackes occur throughout the Cultus Formation, therefore separate localities are not discussed. They are next in abundance to argillite, forming approximately 15% to 20% by volume, of the rocks of this Formation.

Calcareous Beds:

Calcareous beds occur as clastic limestones and calcareous shales or shaly limestones.

Clastic limestones are exposed in the lower canyons of Watt, Frost, and Blue Creeks. In outcrop, they closely resemble the graywackes in appearance. They occur in beds 2" to 6" thick, which are generally banded or laminated. They are dark bluish gray on a fresh surface and weather to light bluish gray, or brownish gray.

Upon examination of thin sections, it is seen that the rock is composed of 75% to 90% calcite, with very angular fragments of quartz, plagioclase, and rock fragments. Some of the calcite is in the form of semi-rounded, sand-sized rock particles, consisting of small crystals of calcite. Much of the calcite appears to have been dissolved and re-deposited, however masking somewhat the original clastic texture since it is finer grained than the crystals in the rock fragments. The rock fragments, which are chiefly elongate, angular argillite fragments, are oriented in the plane of the bedding and concentrated in thin bands. This produces the apparent lamination. The writer believes that detailed

examination would reveal that all gradations exist between graywacke, calcareous graywacke and clastic limestone.

The calcareous shales or shaly limestones crop out 500 yards south-west of Watt Creek at an elevation of 1800 feet. They are dark brown to black, soft and fissile. They are exposed through an apparent stratigraphic thickness of 60 feet and are overlain by medium-bedded, non-calcareous argillites.

Boulders of light yellowish brown travertine, up to 6 feet in diameter are found in Watt Creek from the Canyon to the mouth. The writer was unable to reach the source of the travertine. An outcrop above the second waterfall, which has been staked for its lime content by a prospector, proved upon examination to be argillite with a thin, white, calcareous coating.

Shale:

Shales of this Formation are brownish-black to black and very rarely fissile. They appear to grade into argillites and are probably a finer grained phase of the same material. There are very few true shales in the sequence.

Immediately above the fish hatchery on the east side of Cultus Lake, a hard, brittle, 1/8" to 1/2" bedded "shale" crops out. One hundred yards north, one of the rare occurrences of fissile shale is exposed through an apparent stratigraphic thickness of 50 feet.

Chert:

Very little true chert is found in this sequence, but cherty rocks, formed by the silicification of argillite and graywacke are common. A few beds of true chert were found on the east side of Cultus Lake. These were very light gray to black, in beds from 1" to 2" in thickness. They appear to have been formed by the replacement of other rocks by silica.

Volcanic Breccia:

Only two occurrences of volcanic breccia were found, one on top of the ridge west of Frost Creek Canyon, the other in Blue Creek Canyon, above the first waterfall. It occurs in both localities in a 2 foot thick bed. In hand specimen, it is mottled green and of medium to coarse pyroclastic texture. In thin section it is seen to contain chiefly aphanitic and porphyritic volcanic rock fragments, with some argillite and graywacke fragments and a small amount of quartz and secondary calcite.

The presence of volcanic breccia adds some support to the writer's belief that many of the graywackes in this sequence were once tuffaceous, but that the tuffaceous nature has been subsequently destroyed by induration.

Impure Chert:

A very dense, massive siliceous rock, which is usually light green but grades to dark green and gray, crops out at

the bottom of the two small hills on the east side of Columbia Valley between Blue Creek and the boundary. This type of rock also forms the nearly vertical cliff immediately to the south east of the small hills. Rocks of this type underlie the argillites with apparent conformity.

They are seen in thin section to be of extremely dense texture, dark under crossed nicols and brown in plane polarized light, with small scattered grains of quartz and rock fragments. Quartz veinlets form a mosaic pattern throughout the chert.

Age of the Cultus Formation

Daly (1912) found distorted ammonites "about 500 yards south of the Boundary and 900 yards west-south-west of Monument 47." Dr. T.W.Stanton of Washington identified these fossils as Arniotites vancouverensis Whiteaves? Daly concludes that, "little doubt need be entertained as to the Triassic age of the Cultus beds."

Dr. Hans Frebold of the Geological Survey of Canada has since re-identified these fossils, placing them in the Lower Jurassic (personal communication with Dr. Jack Armstrong of the G.S.C.).

Dr. Frebold writes to Dr. Armstrong, concerning fossils found by Dr. Armstrong in the Cultus rocks exposed on the Ryder Lake Road:

"Ammonites, probably Harpoceratids. The poor state of preservation does not permit any detailed determination.

Age: Probably Toarcian (upper part of Lower Jurassic) or Lower Bajocian (lower part of Middle Jurassic)"

A few more ammonites have reportedly been found in the Cultus Formation, but the writer was unable to find any.

The Lower or Middle Jurassic age of the Cultus Formation appears to be quite well established. It is possible, however, that this very thick formation may represent a considerable range in time.

Vedder Mountain Sediments

The name 'Vedder Mountain Sediments' is used by the writer to designate the sedimentary rocks which comprise approximately the eastern half of Vedder Mountain.

Distribution

The Vedder Mountain sediments crop out on Vedder Mountain from about 500 yards west of the summit, where they are in apparent fault contact with a metamorphic series called (Daly 1912) The Vedder Greenstone, to the western edge of Columbia Valley and Cultus Lake. They extend from 1/2 mile north of the lake southwestward to about 2 miles south of the boundary. These rocks may correlate lithologically with

part of the Nooksack Group of northwestern Washington (Dr. J.E. Armstrong, personal communication).

Lithology

Rocks comprising the Vedder Mountain Sediments include: a conglomerate, graywackes of various colours, argillite, schistose argillaceous chert, and altered rocks of igneous origin. The regional strike is north-east, the dip almost vertical.

Conglomerate:

A strongly cemented conglomerate, with components ranging from pebble to cobble size, crops out along the western shore of Cultus Lake, at an elevation of 48 feet, from the south end of the lake, northward for a distance of slightly over 1-1/2 miles. It extends westward up the steep slope of Vedder Mountain to an elevation of approximately 2000 feet.

The conglomerate contains cobbles and pebbles of granitic rocks, volcanic rocks and chert, which range up to 4" in diameter. It is interbedded with, and has a matrix of medium grained, dark greenish gray graywacke. The conglomerate is massive, but, judging from the interbedded graywacke, the regional strike is north-east and the dip is almost vertical. The cobble conglomerate grades into a pebble conglomerate of the same composition along strike toward the north-east corner of the outcrop.

Graywacke:

Massive graywacke crops out over a major part of Vedder Mountain. It is, however, noticeably scarce in the area between the north end of the lake and a point 2000 yards southwest. In this area, up to an elevation of 2500 feet, only three small outcrops of graywacke were seen. They are interbedded with argillite. To the south-west and west of the conglomerate outcrop, graywacke is the dominant rock type. On top of the ridge, graywacke is interbedded with argillite. Along the International Boundary from Monument 41 to 100 yards west of Monument 42, only graywacke is exposed.

The graywacke is dominantly dark green in colour and very closely resembles greenstone. It also occurs in brownish gray and blue-gray colours. It is fine to medium grained, containing rock fragments and quartz. Small angular shale fragments are noticeably common in the rock.

Argillite:

Very strongly contorted argillites crop out extensively from north of the conglomerate outcrop to the north end of Cultus Lake. They are interbedded with the graywacke on top of the ridge. Along the International Boundary, they are exposed from the base of the mountain to 100 yards west of Monument 42.

The argillite is dark gray to black, dense, and

quite brittle. It is so highly sheared throughout that the nature of the original bedding is usually impossible to determine. The shearing has broken the rock into thin, elongate splinters and slabs. However, a few beds were observed to possess fine banding similar to that of the Cultus argillites.

Argillaceous Chert:

From the north end of Cultus Lake, to a point 2000 yards south-west, and from the shore to an elevation approximately 100 feet above, a rock consisting of chert nodules in an argillaceous matrix is exposed. The nodules occur in layers separated by argillaceous or phyllitic material. They are light gray to white, ellipsoidal, about 2" long by 1" thick, and strongly fractured. The matrix is bluish black, often with a high lustre, and forms only thin layers around the chert nodules. The planes that are now visible are probably not original bedding planes. They would be more aptly called schistosity planes. Their general attitude is, strike N 65° E, dip S.E. 75°. These rocks are strongly folded and faulted. Relatively undisturbed, evenly bedded argillite crops out topographically above them 1700 yards southwest of the north end of the lake.

One 2 foot thick bed of dark gray banded chert crops out on the lake shore about 1500 yards southwest of the north end of the lake. It strikes east-west and dips 43° south. It is underlain by schistose argillaceous chert.

Altered Igneous Rock:

A highly altered rock of igneous origin forms a 20 to 40 foot cliff cropping out along the eastern edge of the top of the ridge on Vedder Mountain.

In hand specimen this rock is medium grained and black with brown and white spots. It is seen in thin section to contain amphibole, zoisite and a little highly altered plagioclase. The amphibole appears light green in plane polarized light and appears to be secondary after some original mafic mineral. The zoisite is secondary.

The outcrop is massive and very strongly fractured. The rock seems to be interbedded with the graywacke and argillite.

Relationships Within the Vedder Mountain Sediments

Because of the massive nature of most of the rocks, the high degree of folding and faulting, and the dense vegetation, the relationships between the various lithologic units of the Vedder Mountain Sediments are extremely difficult to solve. The sediments are divisible into the following lithologic units:

(a) The schistose argillaceous chert.

(b) The predominantly argillaceous sediments characteristic of the north-eastern part of the mountain.

(c) The predominantly graywacke section, characteristic of the south-eastern part of the mountain.

(d) The interbedded argillites and graywackes, characteristic of the top of the mountain.

(e) The interbedded conglomerate and graywacke, found in the lower, central part of the mountain.

Since the few dips that are obtainable, are almost vertical, it is impossible to say, without further evidence, what end of the outcrop is the top.

It is not known whether the lateral change from north to south, apparently along strike, from predominantly argillite to conglomerate to graywacke, is due to structure or to facies changes. It is conceivable that conglomerate and graywacke were deposited in a channel cut in older graywackes and argillites.

Age of the Vedder Mountain Sediments

No fossils have been found in the Vedder Mountain Sediments.

Daly (1912) included these sediments in the lower part of the Chilliwack Group, which he called Carboniferous.

Crickmay (1930) assigned the rocks to the Triassic Slollicum Series.

Misch and Armstrong (personal communication) believe that these rocks may correlate lithologically with a similar

appearing part of the Upper Jurassic-Lower Cretaceous ? Nooksack Group of north-western Washington.

The abundance of granitic-textured pebbles and cobbles in the conglomerate, presents strong evidence that this unit is no older than Upper Jurassic, since granitic rocks were not common in any potential source area until after the intrusion of the Coast Range Batholith supposed to have occurred during Upper Jurassic time.

STRUCTURES

The regional strike over the entire area mapped is to the north-east.

Chilliwack Group

The regional dip of the Chilliwack rocks is to the south-east. The internal structure of this group is not known, but folds overturned toward the north-west are exposed along the Chilliwack River, west of Slesse Creek, and on Church Mountain. The limestone units examined by the writer show evidence of gentle folding. All units examined are strongly fractured, with evidence of movement along many of the fractures.

Cultus Formation

Within the Cultus Formation, the regional dip is 30° - 60° to the south-east. Only a few, local occurrances of north west dips were observed. The dominant structures within this formation are overturned, isoclinal folds, whose axial planes have a similar attitude to the regional trend. These folds are not apparent except in sections cutting across the strike. They are very well exposed in all of the canyons of the creeks draining west from International Ridge. The axial region of only one syncline was seen, while the axial regions of at least ten anticlines were found.

The anticlines are exposed, approximately at right angles to their axial planes, over a length of 20 to 60 feet and a width of 10 to 50 feet. In Frost Creek Canyon, three such folds were seen to lie one directly above another. It is possible that low angle thrusting accompanied this type of folding, but only two well defined, low angle fault traces were seen, and both were exposed over a length of only 100 feet or less. Faults of small displacement are common throughout most of this Formation, but they cannot be traced along strike because of the dense vegetation. They occur in an innumerable variety of attitudes. Small faults are concentrated in sections which appear to be crumpled, that is, the rocks are involved in many small folds, of only a few feet in width. These folds have been offset in many directions by small faults.

Vedder Mountain Sediments

The regional dip of the Vedder Mountain sediments is almost vertical and varies from south-east to north west. The internal structures of these rocks are not understood. A considerable mount of faulting has occurred as evidenced by the abundant slickensiding throughout many of the rocks, especially the igneous rock and the argillites.

The only well defined structure involving these rocks, that was observed by the writer, is an overturned anticline,

which crops out 1-1/2 miles south-west of the south end of the lake at the bottom of Vedder Mountain. The outcrop is 200 feet long by 40 feet high and consists of the anticline, whose axial plane strikes north 55° west and dips north. The axis of the fold plunges to the north west.

Regional Structure

The rocks of the Chilliwack Group have apparently been thrust faulted over rocks of the Cultus Formation. From the nature of the contact, it seems most probable that two high angle thrusts are involved, one dipping to the south-east and one to the south. The south-easterly dipping fault would crop out on the ridge west of Church Mountain. The southerly dipping fault would crop out on Isar Mountain, just north of, and quite parallel to the International Boundary.

It is possible that only one south easterly dipping fault, thrusting strongly folded Chilliwack rocks over the Cultus is involved. The structural relationship of the Vedder Mountain Sediments to the other rock units is unknown.

GEOLOGICAL HISTORY OF THE AREA

This area has been highly unstable, at least since early Permian time until late Mesozoic time as evidenced by the geologic record contained in the rocks exposed. The alternation of limestones with conglomerates and volcanics in the Chilliwack Group indicates strong tectonic activity at the time of deposition of these rocks.

The graywackes, argillites and clastic limestones of the Cultus Formation indicate conditions of rapid deposition during early Jurassic time. The occurrence of these rocks through a great thickness without any noticeable change in lithology, indicates that a nearby, high-standing source area was constantly rising to compensate for the rapid erosion.

Similar, but more active conditions during late Jurassic-early-Cretaceous time are indicated by the nature of the Vedder Mountain Sediments.

All of the rocks exposed in the area were, therefore, deposited in a very active geosyncline.

The major deformation of the region occurred after Paleocene time.

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Plate I. Cultus Argillites exposed in Blue Creek Canyon.

Banded, medium bedded Cultus Argillites. View looking S.E. up Blue Creek Canyon.

Plate II. Contortion of Cultus Argillites

Highly contorted, thin bedded argillites, exposed in road cut 1 mile east of Lihumitson Creek. General strike north east.

Plate III. Chilliwack Conglomerate

Outcrop exposed on Lihumitson Lake trail. Thickness exposed is about 25 feet.

PLATE IV. Crinoidal Limestone on Lihumitson Lake Trail

Massive upper part of Crinoidal limestone. The cliff shown here is approximately 20 feet high.

PLATE V. Northwestern face of Church Mountain

Church Mountain as seen from south slope of first peak on Lihumitson Lake Trail.

Plate VI. Slope above Lihumitson Lake Cabin

A large limestone outcrop is visible in the background.

Plate VII. Thin section of Cultus Greywacke showing graded bedding.

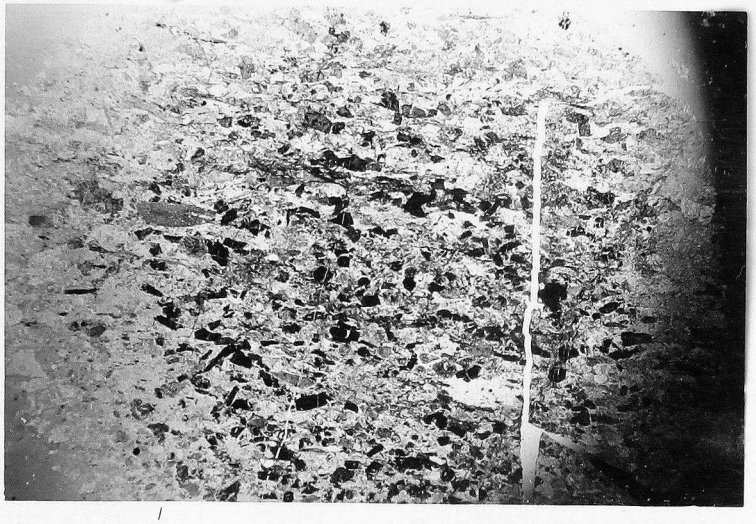


Plate VIII. Thin section of Cultus Graywacke showing orientation of elongate grains

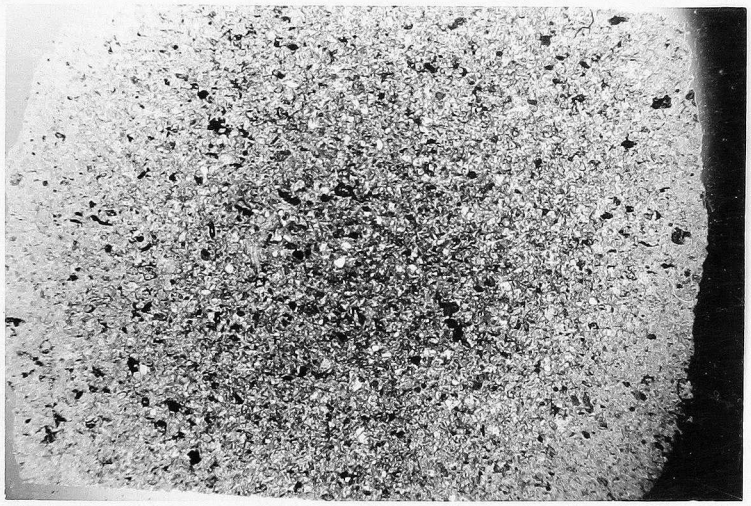


Plate IX. Thin section of impure Cultus clastic limestone.

VEDDER MOUNTAIN - SILVER LAKE AREA

Scale 1"=1/2 mile

GEOLOGY by NEIL HILLHOUSE

Topography from Nat. Topo. 92H/9, 92G/1,
and U.S.C.G.S. Van Zandt Quadrangle

LEGEND

	Conglomerate and graywacke	Vedder Mountain
	Schistose Argillaceous chert	Upper Jurassic - Lower Cretaceous?
	Graywacke and argillite	V
	Igneous	
	Argillite	Cultus Formation
	Limestone	Lower Jurassic
	Volcanic Breccia	Cu
	Limestone	Chilliwack Group
	Du - Dosks Creek	Permian
	Fu - Fusulinid	Ch
	Cr - Crinoidal	
	Dl - Dolomitic	
	Conglomerate	
	Volcanics	
	Diorite	

Assumed Fault — — — —

Schistosity

Assumed Contact — — — —

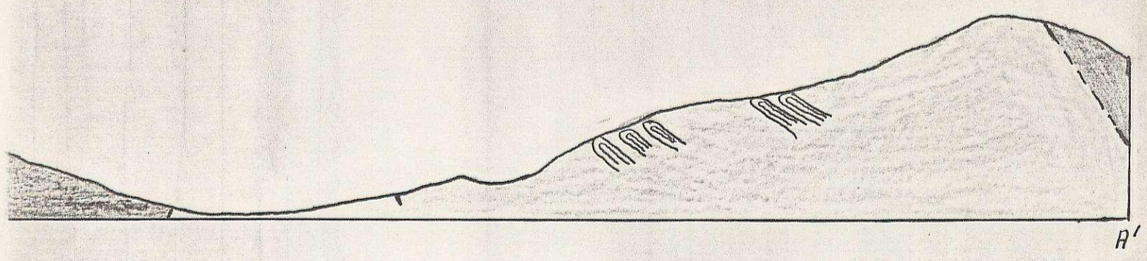
Contact ————

Fault

Overturned fold

CROSS SECTION A - A'

VERTICAL SCALE : 1" = 3000'



WESTMINSTER

BRITISH

ROYAL CANADIAN SCHOOL OF MILITARY ENGINEERING

No. 31

Cenotaph

Vedder Crossing

VEDDER RIVER

I.R. 13

I.R. 14

S.M.

Ryder L.

LOOKOUT RIDGE

CHILLIWACK RIVER

Sweltzer River

FISH HATCHERY

Cultus Lake

CULTUS LAKE

Cultus Lake

No. 39

RIBBON CR.

Creek

CHURCH MTN.

MT. AMADIS

HUMMITSON MTN.

PROVINCE OF BRITISH COLUMBIA

STATE OF WASHINGTON

Upper Sumas
Whatcom Road
Norton
Slough
Arnold
Saar
No. 33
No. 39
UNITED STATES
WASHINGTON
Sumas
Vedder Mountain
VALLEY
Anderson Lake
Cemetery
BM 548
Gravel Pit
Lone Tree Hill
Jacobs Spur
Nicolay
Creek
Columbia
Haystack Hill
Sugarloaf Hill
CHICAGO
Limestone Junction
COLUMBIA
Limestone Quarry
RED MOUNTAIN
BM 819
Silver Lake
MT. BAKER
South Pass
Paradise Valley
MILWAUKEE
Kendall
BM 441
Dodks Creek
Maple Falls
BM 668
Cem.
PACIFIC
RIVER
Boulder Creek
Maple Creek
Brackenridge Creek
Lost Lake
SUMAS 0.7 MI.
FROSST
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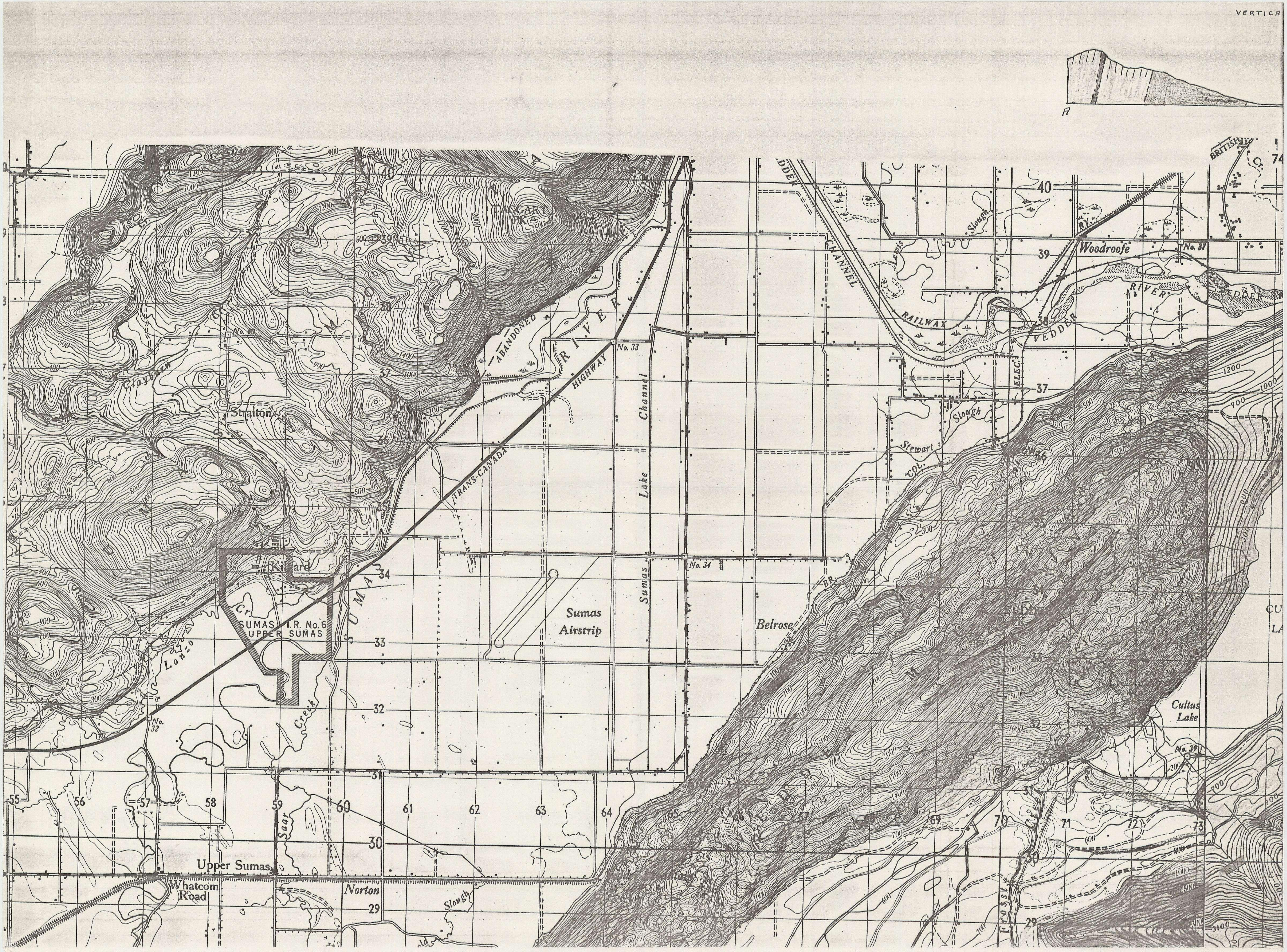
VERTICA
Taggart Pk.
Straiton
Kilgard
SUMAS I.R. No. 6 UPPER SUMAS
Sumas Airstrip
Sumas Lake Channel
Belrose
Trans-Canada Highway
Sumas River
Abandoned
Woodroofe
Vedder Channel
Railway
Vedder River
Stewart Slough
Cultus Lake
Upper Sumas
Whatcom Road
Norton
Saar Creek
Lonzo Cr.
Claybourn Cr.
Vedder Mountain
Slough
Frosst Cr.