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Geology and Mineral Deposits of the Shulaps Range

Southwestern British Columbia

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Geology and Mineral Deposits of the Shulaps Range, Southwestern British Columbia

CHAPTER I.—INTRODUCTION

GENERAL STATEMENT

The Shulaps Range is on the northeastern flank of the Coast Mountains, at the southwestern edge of the Interior Plateau. The range trends northwest and is 30 miles long and 10 miles wide. Shulaps Peak (latitude 50° 47′, longitude 122° 31′) is centrally located in it and is about 17 miles northeast of Bralorne and Pioneer Mine in the Bridge River district. Mineral claims have been recorded in this range on deposits bearing gold, mercury, manganese, chromium, and magnesite. Underground development has been performed on deposits of gold and mercury.

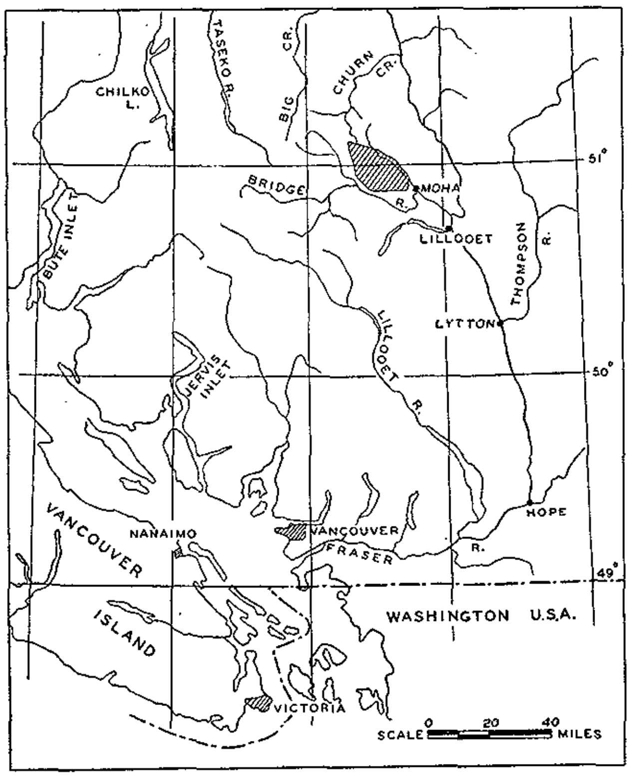

Figure 1. Key map of southwestern British Columbia.

ACCESS

Shulaps Range* is bounded on the east by the valley of Yalakom River,* and on the west by the valleys of Bridge River and its tributaries Marshall and Tyaughton Creeks. Each of these valleys contains a road or trail and most of the range is accessible from branch trails.

* The names " Shulaps " and " Yalakom " are derived from the Indian words for the ram and ewe of the mountain-sheep.

The eastern side is reached by road from Lillooet. The road is kept open as far as Moha, a settlement at the southeast corner of the range 23 miles from Lillooet, but travellers not familiar with the district should inquire at Lillooet before planning to use the part above Moha. This part follows the eastern foot of the range for 18 miles, and then, at Blue Creek, leaves the Yalakom Valley and ascends westward to timberline, terminating at the Elizabeth mine camp, which is 35 miles from Lillooet in a direct northwest line and 48 miles by road. The range is crossed by two trails that lead from this road. The southern trail leaves the road at Shulaps Creek, climbs westward over a 7,400-foot pass at the head of the creek, and descends Hog, Brett, and Marshall Creeks to the Bridge River road. The northern trail leads from the end of the Yalakom road on Blue Creek westward over a rugged 7,850-foot summit and descends Liza and Tyaughton Creeks to the Bridge River road. A trail follows the Yalakom River above Blue Creek and gives access to the northern tip of the range. All these trails are suitable for packhorses. A rough trail to timberline up the north side of the valley of Retasket Creek was used with horses by the writer in 1947. Horses can travel above timberline northward from Blue Creek. Access to the southern part of the range, south of the area mapped geologically, is by means of trails from Moha.

The western side of the range is reached from the Bridge River road that extends from Shalalth on the Pacific Great Eastern Railway to Pioneer Mine. The two trans-Shulaps trails described above are connected along the valley of Marshall and Liza Lakes. Timberline above Marshall Lake is reached by a trail up Jim Creek, and horses can travel from the top end of this trail southward above timberline to Brett Creek. Timberline above Liza Lake is accessible by a trail up Cromer Creek. The northwestern part of the range is served by a trail that branches from the Liza Lake–Blue Creek trail and passes via Noaxe Lake to Quartz Mountain. Quartz Mountain, at the northern tip of the range, can be reached from the south by this trail, from the west by a trail from the Tyaughton Creek road, and from the east by trails from Yalakom River and French Bar Creek. Flocks of sheep are herded from the Fraser River over the latter route to summer pasture at Quartz Mountain and vicinity.

PREVIOUS GEOLOGICAL INVESTIGATIONS

C. W. Drysdale made a reconnaissance survey of the Bridge River area, including the central part of the Shulaps Range, in 1915, and spent part of the following season in the area (Drysdale, 1916, 1917).* A geological map is included in the report published in 1916. W. S. McCann (McCann, 1922) continued Drysdale's work in 1919 and 1920 but with special emphasis on mineral deposits outside the Shulaps Range. His map (2 miles to the inch) included 130 square miles of the Shulaps Range, and the ultrabasic rocks there are classed as volcanic. The findings of Drysdale and McCann are discussed in the part of the present report that concerns the definition and previous descriptions of Shulaps ultrabasic rocks.

The geology of part of the southern portion of the range is shown on a sketch-map (6 miles to the inch) accompanying a report by J. F. Walker (1934).

C. E. Cairnes (1937) mapped in detail the geology of the Bridge River mining camp, 15 miles southwest of the Shulaps Range. He continued less detailed mapping northward to the Tyaughton Lake area (Cairnes, 1943), which adjoins the northwestern edge of the Shulaps Range, and revised part of the work of Drysdale and McCann. Some of the formations mapped by Cairnes occur also in the Shulaps Range.

In 1942 a party under A. F. Buckham, Geological Survey of Canada, prospected for chromite in the ultrabasic rocks of the range. No mapping was done.

SCOPE OF THE PRESENT INVESTIGATION

This report describes the geology of approximately 170 square miles of the northern two-thirds of the Shulaps Range. The area mapped extends northward from Shulaps

* Names and dates in parentheses refer to the bibliography at the end of this chapter.

Creek and Rex Peak. All the eastern flank of the range north of Shulaps Creek was investigated. On the western flank the mapping is continuous from Hog Creek to Liza Lake. North of Liza Lake only that part of the western flank at and above timberline was examined. The result is the mapping of an ultrabasic batholith and of a relatively narrow belt of the surrounding rocks.

The field work in 1947 and 1948 occupied a total of six months. No suitable base-map was available at that time. Control in 1947 was based on a plan of points plotted by photo-topographic resection from horizontal photographs on a scale of 1:40,000 by the British Columbia Department of Lands and Forests. Positions in the field were located with reference to these points by compass resection. The area drained by Burkholder, Retasket, Peridotite, and Blue Creeks was mapped by this method. Vertical aerial photographs taken in July, 1947, were used in the field in 1948. Geological data were recorded on transparent acetate overlays on the photographs and transferred by the three-ray intersection method to the accompanying map (*see* Fig. 2), prepared by the British Columbia Department of Lands and Forests. The area drained by Shulaps Creek and the western slope and northern tip of the range were mapped by this method.

In 1948 and 1949 the field work was supplemented by laboratory studies. These consisted of a detailed petrographic investigation of the ultrabasic* and gabbroid rocks and the chromite mineralization, the abridged results of which are included in the present bulletin. The complete findings and petrographic details are contained in a report entitled " Petrology of the Ultramafic and Gabbroid Intrusive Rocks of the Shulaps Range, British Columbia,"* copies of which are on file in the libraries of Princeton University and the British Columbia Department of Mines.

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PHYSICAL FEATURES

The southern part of the Shulaps Range exhibits the characteristic ruggedness of the Coast Mountains, whereas the northern end merges with the more subdued topography of the dissected Interior Plateau. Drainage is southwest to Bridge River and its tributary Tyaughton Creek, northeast to Yalakom River and, at the northern tip of the range, northward to Churn Creek. All these waters flow to the Fraser River.

Below timberline the slopes tend to be steep but rounded, although the western slopes, which are in general more abrupt than the eastern, are locally precipitous. Above timberline, on the other hand, much of the topography is jagged, except in the northern part of the range. The contrast is especially apparent on the east side of the range south of Blue Creek. There a series of closely spaced, precipitously walled cirques separated by sharp ridges gives way at timberline onto rounded slopes that lead to the Yalakom River. The crest of the range is mostly between 8,000 and 9,000 feet above sea-level, culminating in Shulaps Peak, 9,446 feet. There are no low passes. Local relief exceeds 6,500 feet in the southern part of the range.

* "Ultrabasic rocks"—a general term applied to igneous rocks containing little or no feldspar, but characterized essentially by one or more of the common mafic minerals, such as olivine, pyroxenes, amphiboles, etc. (Arthur Holmes, *The Nomenclature of Petrology,* 1928). The term " ultramafic " is synonymous, but " ultrabasic " is used in this report as having prior right and being in more general use.

Effects of glaciation are conspicuous in the map-area. The boundary valleys have, in general, U-shaped cross-sections, good examples of which are Yalakom Valley above Blue Creek and Marshall Valley near Brett Creek. Topographic details above timberline are chiefly the result of sculpturing by mountain glaciers, but the whole range was probably buried in ice one or more times. Erratic boulders occur above 8,700 feet on Rex Peak.

The contours of the northern third of the range were once relatively smooth, although the old surface was destroyed almost completely by cirque-erosion in the last stage of glaciation. This old surface resulted from the mantling of a still older, rougher surface by glacial debris. The debris is an unsorted agglomeration of boulders, pebbles, and mud, with a few small lenses of laminated silt (*see* Plate I). It has, however, a larger-scale rudely layered structure, in which the layers dip gently away from the crest of the range (*see* Plate II). The deposit is coherent enough to form stack-like erosion remnants at some localities. Its original thickness ranged up to some hundreds of feet, depending in part on the inequalities of the surface it mantled. No rocks foreign to the Shulaps Range have been recognized in it. Well-exposed sections of this deposit can be seen on Peridotite Creek and a mile west of Noaxe Lake.

The eastern flank of the range north of Shulaps Creek is subject to large-scale landslides. The upper boundaries of most individual landslide areas are crescent shaped. The upper portions, where blocks of ground have subsided as units, have step-like profiles, but the lower portions, which move more like gigantic mud-flows, are irregular. The displacements in many instances are combinations of downward and outward movements, and are thus somewhat rotational. The rotational effect is particularly well seen on the hillside half a mile southwest of the mouth of Blue Creek, where an originally flat gravel bench has been broken into a series of steps, of which some " flats " slope gently into the hillside. A landslide area north of the lower part of Burkholder Creek has a curved upper limit about three-quarters of a mile long and has some well-developed steps in its upper part; the lower part is a jumbled mass.

An unusual feature of the topography near Burkholder Creek is a group of deep gullies that are cut along, not down, the flank of the range. These cross parts of the slope that are convex toward the Yalakom Valley, and do not appear in embayments in the slope. Three gullies that cut across the low rounded spur northwest of Lake La Mare and two that cross the convexity between Burkholder and Retasket Creeks are particularly well defined, one being more than 250 feet deep for part of its course. Bedrock was observed in only two gullies; one of these, the gully nearest Lake La Mare, contains an outcrop of brecciated peridotite and may coincide with a fault-line, but a dyke crossing the other is not displaced, and the gullies in general are not believed to be related to bedrock structures. The gully containing brecciated peridotite slopes gently from north to south and has a gravel bench at its southern end, where the ridge through which it cuts gives way to the embayment containing Lake La Mare. The sinuous gullies north of Burkholder (Johnson) Lake also slope gently southward in all parts examined. The gullies do not resemble the headward expressions of landslips, and some are displaced by landslips. The gullies were probably eroded by streams flowing along the edge of a glacier that occupied Yalakom Valley.

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CHAPTER II.—GENERAL GEOLOGY

FOREWORD

The limits of the area mapped were influenced by the distribution of ultrabasic rocks, investigation of which was a major objective of the field work. Consequently, only a narrow belt of the surrounding rocks was mapped, the complexity of which hindered correlation within it. Hence in this report the geology is discussed on two bases: formation by formation where possible, and locality by locality where correlations are unknown.

STRUCTURAL SETTING

The Shulaps Range is on the eastern edge of the Coast Mountains, the site of a chain of composite granodioritic batholiths. It is about 10 miles outside the eastern margin of the main granodioritic batholith zone, and is on the northeastern flank of a large anticline that plunges gently northwestward.

The dominant structural trend in the range is northwesterly. An ultrabasic batholith, possibly Upper Triassic, underlies most of the part north of Rex Peak. The remainder consists of complexly folded and faulted sedimentary and volcanic strata of pre-Upper Triassic (late Palæozoic?), Upper Triassic, Jurassic, and possibly Cretaceous ages, cut by gabbro and late Mesozoic or Tertiary hypabyssal intrusives. The eastern base of the range is the site of the Yalakom fault zone, a major structure. The rocks east of this are Jura-Cretaceous strata younger than most of those in the range. The western base is, like the eastern, the site of faults that trend northward and northwestward.

Primary structures within the ultrabasic batholith strike northwestward and dip southwestward or vertically. The relationships of this batholith to adjoining rocks are described in a later section of this report. The pre-Upper Triassic strata of Cache Creek type that underlie the southern part of the area exemplify their position on the limb of the regional anticline, and strike northwestward and westward and dip northeastward and northward at moderate to steep angles. A subsidiary north-plunging anticline is transected by Shulaps Creek. Structures within the narrow belt of non-ultrabasic rocks mapped on the west flank are imperfectly known. The strata are diversely folded, but axes striking northwestward and northward are the most common. They are interrupted by numerous faults, generally steep, and most of these also trend northwestward and northward. Structural trends east of the Yalakom fault are on the whole more uniform than those farther west. Beds adjacent to Yalakom River strike northwest and dip northeast, though local reversals of dip occur. The uniformity of their strike does not, however, reflect complexities that have been introduced by strike faults. On the north flank of the range, still east of the Yalakom fault, the strata are involved in smaller folds, and dips are more varied than those farther south.

The Yalakom fault zone traverses the length of the map-area. Its northern limit is unknown but is certainly considerably northwest of Quartz Mountain. To the south it strikes into the Fraser fault system (Duffell and McTaggart, 1952). The width of the zone within the map-area ranges from a few hundred feet to a mile or more. Ultrabasic rocks occur in it for at least 5 miles northwest of the main Shulaps mass. It is a locus of carbonatization, especially of ultrabasic rocks. The trace of the southwestern side of the fault zone on Quartz Mountain, at the north end of the map-area, is slightly farther to the northeast in valleys than on ridges, indicating that the southwestern side dips steeply northeast. Eleven miles farther south, near the mouth of Blue Creek, the trace of the east side of the fault zone indicates a vertical or steep southwest dip. In the latter locality a fault plane is exposed at or near the east side of the zone, and slickensides on the fault plane indicate that the hangingwall was depressed relative to the footwall in the last movement. Ten miles still farther south, on the sharp ridge northwest of the mouth of

Shulaps Creek, a well-defined fault plane within the Yalakom zone dips 77 degrees to the southwest and is marked by slickensides which also suggest that the hangingwall was relatively depressed in the last movement. The trace of the southwestern boundary of the fault zone at Shulaps Creek, however, indicates a steep northeast dip, as at Quartz Mountain. The structure along the fault zone as a whole is such that older rocks lie to the west and younger rocks to the east.

The Yalakom fault zone strikes into the Fraser fault system, but the intervening ground is unmapped. Faults in that system may have been active as early as Lower Cretaceous time, and later movements have affected Eocene beds (K. C. McTaggart, personal communication).

SEDIMENTARY AND VOLCANIC ROCKS

Pre-Upper Triassic Rocks

Most of the drainage-basin of Shulaps Creek and much of the west flank of the range are underlain by pre-Upper Triassic rocks which are lithologically similar to parts of the Cache Creek group exposed east of the map-area, and to the comparable Fergusson group (Cairnes, 1937, p. 9; 1943, p. 2) west of the area. Argillite, chert, and greenstone predominate, and are accompanied by minor proportions of quartzite and limestone. The rocks have yielded no fossils, but are considered the oldest in the map-area on structural and lithological evidence. The term "Cache Creek type" used here refers to lithology only.

The argillite has two manners of occurrence: as beds and successions of beds measurable in feet or hundreds of feet, and as intimate interlaminations with chert measurable usually in fractions of an inch. The former is dark grey or black rock, not uncommonly rusty-weathering, in which bedding planes are hard to determine, partly because of the uniformity of the rock and partly because of the effects of deformation. It ranges from phyllitic or slaty to massive, and some of its closely jointed outcrops disintegrate readily into rubble. Argillaceous strata in the vicinity of Shulaps Creek have been converted into green phyllites similar in appearance to phyllites derived from the interbedded volcanic rocks.

Sequences of interlaminated chert and argillite are the most characteristic units in the rocks of Cache Creek type (*see* Fig. 3). Most of the chert layers are between a fraction of an inch and 4 inches thick, those in the 1- to 2-inch range being the most common. They are cut by closely spaced stringers of white quartz, many of which are approximately perpendicular to the layers. Almost all the intervening argillite layers are much thinner, most being mere films and few exceeding half an inch in thickness. The thicknesses of the chert and argillite layers vary considerably both across and along the strike. Some of the chert layers in an outcrop may maintain a uniform thickness for 10 feet or more, whereas adjacent chert may be markedly lenticular or even nodular. The chert-argillite sequences commonly are crumpled. Most of the chert weathers light grey or blue-grey and is grey on fresh surfaces, but some cherts are almost white, faintly greenish, or dark grey. Microscopic examination shows that the chert is an aggregate of interlocking cryptocrystalline quartz grains threaded by stringers of coarser quartz; where impure it contains greenish biotite, occasional garnets, and tiny apatite crystals. Most of the argillite is black, some of the thinnest sheared laminæ having a graphitic appearance, but brown, greenish, and cherty grey-black argillite laminæ can be found. Particularly good exposures of laminated chert-argillite occur 2 miles northeast of Rex Peak, between Brett Creek and the south end of Marshall Lake, a mile northeast of the south end of Liza Lake, 1½ miles northeast of the north end of that lake, and 2 miles north and northeast of Noaxe Lake.

The greenstones comprise volcanic and pyroclastic rocks and metamorphic rocks whose extrusive origin is less evident. Metamorphic rocks in the vicinity of Shulaps Creek are phyllitic grey-green to dark green, fine-grained rocks interbedded with phyllitic, argillaceous, and limy strata. Their original textures are destroyed, but their conformity with the sediments suggests an extrusive origin, although they may in part be sills. Microscopic examination shows them to be composed chiefly of actinolitic amphibole, albite-oligoclase, chlorite, carbonate, epidote, zoisite, clinozoisite, varied but as a rule small amounts of quartz, and titanite.

The less altered greenstones are dark brown or dark green on weathered surfaces and dark green on freshly broken ones. They are aphanitic or very fine grained, and when sheared may be distinguishable only with difficulty from adjoining argillaceous strata. They are traversed commonly by tiny calcite-filled fractures. The volcanic rocks are locally amygdular, the amygdules consisting as a rule of calcite, commonly rimmed by chlorite. Outcrops exhibiting pillow structure are not as numerous as those containing amygdules. The pillows generally are small and poorly formed. Fine-grained grey limestone is associated with many of the flows. Some limestone lenses are 30 feet long and 10 feet thick, but most are measurable in inches and many are mere lumps in the interstices of pillows. Chert lenses and nodules lie in the volcanic rocks in a few places. The volcanic rocks consisted originally of phenocrysts of plagioclase and less numerous ones of pyroxene or hornblende in a groundmass composed chiefly of the same minerals. They now consist essentially of albite, chlorite, and calcite, with or without clinozoisite, epidote, titanite, biotite, quartz, and magnetite. Because of the mineralogical alteration, the rocks are classified only as andesitic or basaltic.

Beds of limestone are a minor part of the sediments of Cache Creek type. The most important one seen by the writer outcrops in bluffs on the west side of Shulaps Creek 4½ miles from its mouth. This bed is 30 to 40 feet thick and can be traced at least 3,000 feet. The fine-grained grey-weathering limestone is foliated into alternate light-grey and dark-grey layers one-twentieth to one-tenth of an inch thick. The foliation is probably due to deformation because the planes curve round fragments torn from adjoining beds. A 4-foot bed of limestone is exposed along a tributary of Shulaps Creek 2 miles northeast of Rex Peak. The rock weathers light grey, is darker grey on fresh surfaces, and is cut by stringers and blebs of white calcite. Near the crest of the range, 2½ miles southeast of Shulaps Peak, a 4-foot bed of banded white and cream-coloured, finely crystalline limestone follows the contour of the mountain for a few hundred feet. Thinner beds were noted in argillaceous strata in the same vicinity and at a few points on the east side of the valley of Marshall Creek.

The strata of Cache Creek type are some thousands of feet thick, but deformation, the lack of marker horizons, and the difficulty of determining the tops of beds prevent accurate measurement. The prevailing strike is between west and northwest, approximately along the strike of the range, and northerly and northeasterly dips predominate. A large north-plunging anticline is transected by Shulaps Creek. Bedding is masked by secondary foliation in much of the southern part of the area. The relation of this foliation to bedding is seen in bluffs above Shulaps Creek. Bedding and foliation are concordant on a large scale but discordant in detail. The foliation is parallel to the contacts of the various units of the assemblage, but where the individual beds are contorted, as is commonly the case, foliation transects them. The outlines of major structures can be mapped by measuring foliation in instances where measuring only bedding in scattered small outcrops leads to confusion.

Hurley Group

Strata of the Hurley Group (Cairnes, 1943, p. 3; 1937, p. 18) are exposed extensively on the west flank of the Shulaps Range east and northeast of Liza Lake. The group consists mainly of fine-grained argillaceous and tuffaceous sediments, impure sandstones, and conglomerates, accompanied by lesser amounts of dark cherty strata and limestones of various degrees of purity. The sequence is distinctly limy, and carbonate is the usual cement in the medium- and coarse-grained rocks.

Much of the finer-grained portion of the Hurley group consists of black argillaceous material interlayered with grey fine-grained impure sandstone. The layers are generally a fraction of an inch thick, with distinct boundaries and little or no grain gradation. This banded rock is characteristic of the Hurley sequences.

The most distinctive parts of the Hurley group are the conglomerates and the limestones associated with them that contain foreign fragments.

The textures of the conglomerates range from fine-grained pebbly to bouldery. The components consist of sedimentary and volcanic rocks and, almost certainly, intrusive rocks. Chert, quartz, light-coloured felsites, green and black volcanic rocks, argillaceous fragments, and limestone are the common constituents, but pebbles of quartz porphyry and quartz-feldspar porphyry are present and, more rarely, fragments having a granitic aspect. Many of the detrital quartz grains are glassy and have a euhedral bipyramidal form that sugggests their origin in porphyries. Angular chunks of rock like the previously noted banded argillaceous-arenaceous rock occur sparingly in the conglomerates.

The lime content of the conglomerates, other than that provided by limestone fragments, ranges from amounts sufficient only to cement the smallest clastic particles to amounts sufficient to provide a visible matrix for sand grains and larger fragments. The lime-rich " end members " of this sequence are limestones that contain fragments of non-limy rocks and minerals. The limestone matrix in such beds is fine grained and is grey on both fresh and weathered surfaces. The latter are rough because the siliceous inclusions weather in relief.

The limestone fragments in the conglomerates are of two types. Type one are well rounded pebbles and cobbles of grey weathering fine- to medium-crystalline white or grey limestone identical with that in strata of Cache Creek type. Type two consist of fine-grained grey limestone that commonly holds particles or chunks of other rocks and minerals. Limestone fragments of type two are varied in shape but slabs are the most common, and range in size from chips to masses at least 6 feet broad. They are characteristically angular. The limestone in them is identical to the inclusion-bearing Hurley limestone already described, and is believed to be Hurley limestone that was brecciated and reworked soon after formation.

Strata east and northeast of Liza Lake strike fairly uniformly to the north but are highly folded and in places are overturned. Faults are numerous, especially east of the south end of Liza Lake. The Hurley group is some thousands of feet thick, but a complete succession is not exposed. The conglomeratic zones lie in the lower part but are not restricted to the base.

The Hurley group is intruded by gabbroic and ultrabasic rocks along its eastern and southeastern margins. On the west it is faulted against rocks of Cache Creek type and against Mesozoic (?) sediments and volcanics of unknown affinities, some of which may also belong to the Hurley group. On the south and southwest it is bounded by a greenstone-gabbro complex. The contact relations are complicated by faults, but part of the complex intrudes Hurley rocks, whereas greenstone and Hurley strata appear conformable in outcrops at timberline on East Liza Creek.

Equivalency of the strata near Liza Lake with those mapped as Hurley by Cairnes (1943, p. 3; 1937, p. 18) is based upon the distinctive lithology of the sequence. Drysdale (1917, p. 45) reported fossils in this part of the Shulaps Range, but they were too poor to identify (Cairnes, personal communication). The only identifiable ones found by the writer were in cobbles of crystalline limestone of Cache Creek type in Hurley conglomerate, and were poorly preserved corals, crinoid stems, bryozoans, brachiopods, and gastropods of late Palæozoic age. The Hurley group is believed by Cairnes to be Upper Triassic. In the Tyaughton Lake area the strata contain a coral identified as *Isastrea* cf. *vancouverensis* which, according to Shimer (1926), indicates the Lower Noric division of the Upper Triassic.

Taylor Group

Strata on Quartz Mountain and southward to Noaxe Creek are lithologically and stratigraphically similar to those of the Taylor Group (Cairnes, 1943, p. 6), of which they are believed to be a part.

The base of the sequence is missing, but the lower exposed part contains at least 1,000 feet of pebble and cobble conglomerate, the former predominating. The conglomerate is characterized by an abundance of chert pebbles, which make up 80 per cent or more of the total, the remainder consisting of quartz porphyry, limestone, white quartz, and andesitic rocks. The conglomerate is prevailingly massive, but its upper part contains interbeds of sandstone and black shale.

The upper exposed part of the sequence consists essentially of arkosic sandstone and grit, and of shale, with considerably lesser amounts of pebble conglomerate. The arkosic rocks are mostly green, but many are red, and glittering flakes of muscovite are a distinctive feature of them. Other constituents are chert, argillite, quartz, feldspar, and small soft chip-shaped, dark-brown and dark-green fragments composed of serpentine derived either from basic or ultrabasic rock. The shales are dark brown or black. They are soft and crumble readily. One thin, brown-weathering, amygdular andesitic flow was observed on the north wall of Noaxe Creek.

The group is not fully exposed, a fault forms the eastern and northeastern boundaries and the other boundaries lie outside the map-area, but the section within the area is at least 3,000 feet thick. The general strike is northwest and the dip southwest, but northerly and northeasterly strikes occur near Noaxe Creek, and the dip is reversed locally. Massive conglomerate is exposed in the southeastern and in the western parts of the area mapped as Taylor. The western conglomerate, 2½ miles northwest of Noaxe Lake, may be a faulted repetition of the eastern conglomerate because its eastern border is a gully containing angular slickensided fragments.

Fragmentary plant remains are common in the arkosic and shaly parts of the sequence, but the beds have yielded no diagnostic fossils.

The nearest Taylor strata mapped by Cairnes in the Tyaughton Lake map-area are separated from Quartz Mountain by 3 miles of unmapped ground. The Taylor sequence is characterized in the former area by thick massive chert-pebble conglomerate and by an abundance of mica in the finer-grained beds. The strata on Quartz Mountain are allocated to the Taylor group because they have identical characteristics. Plant remains and marine shells occur in the type area of Taylor rocks but do not serve to date the strata, which Cairnes (1943, p. 7) considers to be probably late Middle or early Upper Jurassic.

Unclassified Mesozoic(?) Rocks on the Western and Northern Flanks of the Shulaps Range

Introduction.—Parts of the western and northern flanks of the Shulaps Range are underlain by diversely oriented sedimentary and volcanic sequences whose ages and stratigraphic relationships are unknown. No diagnostic fossils have been found, but the lithology indicates a Mesozoic age for most or all of the strata. The descriptions that follow are on an areal basis, and it should be understood that rocks described in a given locality may represent more than one age and may be correlative with rocks described in other localities.

Marshall Lake.—The hill rising steeply from the northeast shore of Marshall Lake consists of basic volcanic rock at its northern end. The southern end, overlooking the mouth of Jim Creek, consists chiefly of argillite.

The volcanic rock is grey or grey-green and has a relatively fresh appearance. It is mostly aphanitic, but feldspar phenocrysts can be found in it, and, more rarely, hornblende. The rock contains numerous calcite amygdules. Pillow structures are abundant, most of them less than a foot long, and usually more amygdular at margins than at centres. The interstices of the pillows are filled with angular volcanic fragments, accompanied in some instances by fine-grained grey limestone. Calcite fills fractures and occurs also as irregularly shaped masses, mostly less than an inch across, that appear to replace volcanic rock. Judging from the shapes of the pillows, the volcanic rocks strike east or southeast and dip northward. Microscopic examination shows that the phenocrysts in the porphyritic rocks are plagioclase, pyroxene, and hornblende. Those of plagioclase are largest and most abundant, but their original composition is destroyed by albitization. The pyroxene and hornblende phenocrysts are relatively fresh, although altered somewhat to colourless acicular amphibole. The groundmass of the rocks consists of lathy plagioclase accompanied by lesser amounts of ferromagnesian minerals, especially acicular amphibole. Minerals of the epidote-clinozoisite group, chlorite, and titanite are present in all specimens. The volcanic rocks lack quartz.

The lavas and argillaceous rocks are bounded on the northeast by a fault roughly parallel to the northeast shore of Marshall Lake and about 1,800 feet from it. Northeast of the fault a belt of sedimentary rocks 1,000 to 1,500 feet wide is bounded in turn on the northeast by intensely serpentinized peridotite of the main Shulaps ultrabasic mass.

The sediments in the southern part of this belt are mainly black argillite and grey or bluish, fine- to medium-grained impure sandstone or greywacke with a subordinate amount of coarse greywacke characterized by tiny angular black fragments. In the canyon of Jim Creek, half a mile from the lake, water-worn outcrops display an alternation of black argillite and coarser grey sediment in layers that are mostly half an inch thick. The proportion of sandy material decreases northeasterly across the strike until the rock against serpentinite in the walls of Jim Creek is almost entirely black argillite, some of it cherty. These banded rocks are similar to part of the Hurley sequence 2 miles north, and to part of the Noel formation (Cairnes, 1937). The northern part of this sedimentary belt, faulted against volcanics on the southwest and in contact with ultrabasic rock on the northeast, contains few outcrops. The rocks exposed are grey ribbon-chert and black argillite. The chert is brecciated adjacent to serpentinized peridotite on the north bank of the first tributary of Jim Creek. The strata of the northern part of the sedimentary belt may be of Cache Creek type, in contrast to those of the southern part, which are probably Upper Triassic.

Sedimentary strata, with minor volcanic intercalations in the lower outcrops, are exposed a mile northeast of the north tip of Marshall Lake and extend for another mile up the slope. These rocks strike eastward and dip northward at moderate angles. The sequence is truncated on the east by ultrabasic rocks and bounded on the north by a greenstone-gabbro complex. This northern boundary is a fault at the only place it was seen. The sequence is separated on the south from the belt of sedimentary rocks already described by ultrabasic rock and by an area in which no outcrops were found.

The lower outcrops, at an altitude of about 5,600 feet, contain greywacke, grey and grey-blue thinly bedded chert, and thin grey and green amygdaloidal flows. The chert contains argillaceous partings, and is criss-crossed by black lines and by fractures containing calcite and (or) quartz. Chert and volcanic rock are associated in this sequence, but cherty layers occur also in the coarser sediments. The volcanics appear to be identical with those beside Marshall Lake. The dominant sediment in the higher outcrops has a medium sand-size grain and bluish colour. Coarser facies contain megascopic grains of quartz and feldspar, green chloritic material, and black fragments, mostly volcanic but some argillaceous. Similar, smaller black fragments occur in finer-grained beds. Argillaceous strata are considerably subordinate to arenaceous ones and usually have thin dark-grey cherty layers associated with them. The sequence contains limy beds and at least one 4-foot bed of grey-streaked white limestone.

Representative specimens of arenaceous beds were examined microscopically. Volcanic particles are major constituents in all of them. The strata are tuffaceous, and some are probably true tuffs. The microscope shows that these rocks are more altered and deformed than most Jura-Cretaceous strata in the district. They may be equivalent to the Noel formation or the Hurley group.

Cromer Creek and Southeastern Liza Creek.—Areas centred 1¼ miles and 2 miles respectively northeast of Liza Lake are underlain by strata in which no identifiable fossils were found but which are undoubtedly Mesozoic. They lie on either side of a belt of sedimentary and volcanic rocks of Cache Creek type.

Strata of the southern area are well exposed on the northwest bank of Cromer Creek. They are mostly greywackes or arkoses, some decidedly tuffaceous, accompanied by cherty and normal dark argillites, and greenish cherts. The arenaceous rocks are mostly greenish blue on fresh surfaces but some are black. They consist chiefly of particles of chert and volcanic material, plus feldspar and quartz, much of it glassy. The volcanic fragments are generally the largest detrital particles. Many of the strata, especially at the north end of the area, are pervaded with iron oxides, derived chiefly from pyrite, and weather rusty. The rocks are closely folded, with fold axes striking northward and northwestward. They are on the whole rather markedly fractured, though not sheared. The fractures are filled characteristically with quartz, and to a lesser extent with calcite. Quartz veins in the southeast bank of Cromer Creek, a mile northeast of Liza Lake, have been explored by an adit and trenches (*see* p. 51). The strata contain microscopic structures of apparent organic origin but yielded no identifiable fossils. They were observed in actual contact with rocks of Cache Creek type at only one locality. Here the latter rocks are thrust upon them by a fault that strikes westward and dips northward.

The rocks of the northern area are exposed best 2 miles northeast of Liza Lake, between altitudes of 6,500 and 6,900 feet. These outcrops are on a ridge-top separating two southern tributaries of Liza Creek. The rocks are well bedded grits, sandstones, shales, and limestones. The clastic beds are distinctly limy. The northwestern end of the ridge-top consists chiefly of brown-weathering bluish sandstone and grit interbedded with dark shale. The beds are clearly defined, the sandy ones generally 1½ to 3 inches thick, and the shales half an inch to an inch thick.

The southeastern part of the ridge contains limy sandstones with rough-weathering tan-coloured surfaces, black sandy limestone that weathers tan, limy shale, normal shale, and one or more beds of conglomerate. The limy strata bear evidence of deposition in currents in shallow water. Most pebbles in a 3-foot bed of conglomerate are well-rounded siliceous types, but a few are grey limestone. The rocks are contorted but strike in general north and northeast. Some are overturned to the east. Small dragfolds midway along the ridge strike northeast and pitch gently southwest. The strata contain what appear to be fossil worm castings. These curled cylindrical forms, about a twentieth of an inch in diameter and up to an inch or more in length, weather in relief above the black muddy limestone in which they occur. The strata may belong to the Hurley group, against which they are in fault contact to the east.

Volcanic rocks occur above timberline on both sides of the branch of Liza Creek followed by the Liza Lake-Blue Creek trail. They form a prominent ridge northwest of the stream and occur in smaller quantities to the southeast. They are partly conformable with, and partly faulted against, the strata just described. Their compositions are andesitic to basaltic. Fresh surfaces are dark bluish, greenish, or reddish, and weather to dark greens. Amygdular texture is common. Calcite amygdules are most numerous, but others consist of prehnite, chlorite, epidote, or quartz, and some contain mixtures of these minerals. Pillow structures are not hard to find. Most of the pillows are small, less than a foot across, and not markedly elongated. Their interstices contain jaspery material, which also fills fractures and occurs as lenses up to a foot thick and 2 feet long. Calcite fills fractures, but no pods of limestone were noted. The lavas are associated with considerably lesser amounts of pyroclastic materials. Microscopic study shows that the original finely porphyritic texture of the lavas is still present, but that the abundant plagioclase phenocrysts are now albitized. The lavas contain both orthorhombic and monoclinic pyroxenes, and some hornblende. Olivine may have been present in some of them, but if so it is now represented by chloritic minerals. Other lavas contain quartz. Chlorite replaces both ferromagnesian minerals and plagioclase. Some specimens are pervaded by finely crystalline calcite.

Vicinity of Pass on Liza Lake–Noaxe Lake Trail.—The pass through which the Liza Lake–Noaxe Lake trail crosses from the drainage of Liza Creek to that of Noaxe Creek, 2 miles south of Noaxe Lake, contains a varied assortment of rocks. Peridotite forms the eastern wall, and is in contact with sedimentary and volcanic rocks of Cache Creek type near the eastern edge of the pass proper. The latter rocks are intruded by peridotite, clinopyroxene-pyroxenite, and gabbro. They are succeeded to the west by Mesozoic rocks that underlie the western half of the pass and its southern approach. A fault marks the western edge of the pass. The adjacent slopes of Big Sheep Mountain, west of the fault, consist of Mesozoic strata intruded by porphyries of varied compositions (*see* p. 44).

At the southern foot of the pass, half a mile from its crest, the peridotite of the eastern mountain is bounded by rocks of Cache Creek type that outcrop over a width of 400 feet. These are overlain by rusty-weathering conglomerate which extends a further 1,000 feet westward and consists largely of chert pebbles, a considerable proportion of which are subangular. The conglomerate is succeeded on the west by black argillite, greenish-weathering basalt, tuff, and agglomerate. The latter is characterized by jaspery red fragments, though most of the fragments are green, as is the rock as a whole.

The scattered small outcrops on the crest and upper slopes of the western half of the pass contain conglomerate in which chert pebbles and grey limestone pebbles and boulders are conspicuous; another conglomerate, west of the first, that lacks limestone, weathers rusty black, and contains sandy lenses holding carbonized plant remains; amygdular volcanic rock; and a small amount of fine-grained grey limestone. These rocks are separated by the previously mentioned fault from thinly bedded strata of quite different appearance which underlie Big Sheep Mountain to the west. The fault, which strikes north and is approximately vertical, is a locus of ankeritization. Grey-green shale is a major component of the strata west of the fault and is accompanied by black shale, fine-grained dark limy sandstone, greenish sandstone and grit, and pebble conglomerate. These sedimentary rocks are cut by dykes of the porphyries that outcrop above them on the mountain. They are almost certainly Mesozoic in age and younger than the presumably Mesozoic rocks to the east, but no fossils were found.

Quartz Mountain Area.—The northeastern flank of Quartz Mountain and a smaller area east and south of Grizzly Bear Lake are underlain by varied sedimentary and volcanic rocks, the former dominant. The rocks may be of more than one age, but no fossils were found.

On Quartz Mountain they underlie the ridge between the stream that rises on the northern summit and the parallel stream a mile southeast, and extend across part of the southern headwaters of the latter stream.

The most abundant type is massive greywacke that is brownish-green on both weathered and freshly exposed surfaces. The greywacke, some of it tuffaceous, ranges from a fine-grained type, indistinguishable in the field from certain volcanic rocks, to a coarser type in which angular fragments are conspicuous. Despite the fact that much of this greywacke is so intensely fractured that fresh surfaces are difficult to secure, the microscopic texture indicates little deformation. The fragments are characteristically angular and do not have a squeezed appearance. They consist of abundant volcanic particles, together with chert, rock fragments of indeterminate origin, quartz, feldspar, aggregates of serpentine or chlorite, and, rarely but significantly, chromite. The volcanic fragments are porphyritic, and are fresh enough to retain twinning in some plagioclase phenocrysts. Plagioclase fragments likewise retain their twinned appearance. These greywackes are similar microscopically to Jura-Cretaceous greywackes east of Yalakom River, opposite and below Blue Creek. The volcanic rocks are massive, green and black, aphanitic, and sparingly amygdaloidal. They were not studied microscopically.

The ridge between the two creeks mentioned above contains small outcrops composed of contorted layers of grey ribbon-chert interlaminated with thinner layers of black or red argillite. This chert-argillite rock is identical with that characteristic of the Cache Creek type of assemblage elsewhere in the Shulaps and Bridge River districts. The ridge in question contains also small outcrops of a finely crystalline limestone, the grey weathered surfaces of which are rendered rough by resistant siliceous veinlets. The rocks are bounded on the northeast by the Yalakom fault, and on the southwest are faulted against the Taylor group. They are bounded on the northwest and southeast by rocks of Cache Creek type, but the nature of these contacts is unknown. Lenses of intensely serpentinized peridotite lie in shear zones in these rocks adjacent to the Yalakom fault.

The presence in adjacent small outcrops of greywacke similar to that known to be Jura-Cretaceous on the one hand and of chert-argillite and limestone of Cache Creek type on the other may indicate that lithology is not a reliable guide to age or that rocks of two ages are complexly infolded or infaulted. The latter explanation is probable.

East and south of Grizzly Bear Lake, which lies between Noaxe Lake and Quartz Mountain, are tuffs and greywackes associated with massive dark volcanic rocks. The tuffs and greywackes are thinly bedded in some outcrops. They weather green and brown and are green or blue on fresh surfaces. The coarser types contain angular black fragments of volcanic rock. Microscopic examination shows that the tuffs and tuffaceous greywackes are not deformed, and that a large proportion of the constituent particles are of volcanic origin. These strata are bounded by rocks lithologically similar to Cache Creek types.

The very summit of Quartz Mountain is aphanitic, greenish and reddish volcanic rock which rests on Taylor strata. The volcanic rock is bounded on the north by a small fault. Outcrops of rock that is similar though amygdaloidal occur 2,000 feet to the northeast.

Greenstone-Gabbro Complex

These rocks are fine-grained volcanics, medium-grained to very coarse-grained rocks of gabbroic aspect, and rocks intermediate between those types, intermingled on small and large scales. The complex is well exposed on the precipitous slopes at and above timberline 2¼ miles east of the south end of Liza Lake.

The volcanic rocks are aphanitic or very fine grained and are coloured grey-green to dark green, some in mottled pattern. They are typically massive, but vague pillow forms can be seen in a few outcrops. Amygdaloidal texture is more common, the fillings being composed of calcite. Microscopic examination shows that the volcanic rocks are finely porphyritic, many with trachytic texture. The phenocrysts are plagioclase, augite, and possibly hornblende. Sites of plagioclase phenocrysts are occupied now by albite and oligoclase, clinozoisite, zoisite, epidote, chlorite, and carbonate. The augite is altered partly or completely to fibrous amphibole and to chlorite. In some rocks it was originally as abundant as plagioclase, in others considerably subordinate to that mineral. Quartz is present in certain of these greenstones; much of it was introduced, but it also appears to be a primary constituent of some of the specimens examined. Titanium-bearing minerals are common. Exact classification of these greenstones is precluded by alteration of plagioclase, but the proportion of plagioclase relative to augite suggests that most are derived from andesite and basalt.

In the fine-grained portions of the complex, crystal outlines are only vaguely determinable with the naked eye, plagioclase and ferromagnesian minerals being represented by an obscure pattern of grey and dark greens. The mineralogy is essentially similar to that described above, and again alteration of plagioclase precludes exact classification.

Originally, coarser-grained parts of the complex consisted essentially of plagioclase and pyroxene in proportions usual in gabbro, but pyroxenitic facies can be found. Colour ranges from greyish green to dark green, depending on proportions and arrangements of minerals, grain size, and degree of alteration. Grain size is erratically varied, and small quantities of the rock have an almost pegmatitic texture. Outlines of grains are distinct, and the extensive alteration is indicated megascopically only by the dull grey-green colour of the plagioclase, which rarely shows distinct twin striations. Microscopic examination reveals that the plagioclase is saussuritized, and is represented by a confusing aggregate of albite or oligoclase, epidote, clinozoisite, tremolitic amphibole, chlorite, and carbonate. The augite is relatively unaltered but is replaced by amphibole and members of the epidote group. There is little or no primary amphibole. Sphene, ilmenite, and magnetite are accessory minerals.

The distribution of rocks of various grain sizes within the complex is erratic. Outcrops of greenstone contain gabbroic parts, and outcrops of gabbro contain areas of greenstone. Changes from one rock to another are gradational across distances ranging from inches to feet. Both gabbro and fine-grained greenstone can be traced gradationally into intermediate members of the complex. Instances can be found, however, of finer-grained types intruded by coarser-grained types without chilled contacts. The pattern in some outcrops is such as to suggest that a coarser-grained type has replaced a finer-grained type but, in the absence of distinct primary structures in the greenstones, corroboration is difficult. Determination of the origin of the complex requires more field work.

The volcanic part of the complex probably underlies the Hurley group conformably. Both are intruded by ultrabasic rock. It is probable that at least part of the gabbroic portion is related genetically to that gabbro at the heads of Liza and Jim Creeks which, just east of the main area of greenstone-gabbro complex, intrudes ultrabasic rocks. This gabbro is described in a succeeding section. The complex is similar in many respects to a complex of Pioneer greenstone with rock described as augite diorite in the Cadwallader Creek-Gun Lake region to the west. Although Cairnes (1937, p. 24) considered the greenstone and augite diorite there to be extrusive and intrusive representatives of the some magma, Stevenson (*Minister of Mines, B.C.,* Ann. Rept. 1948, p. 102) believes that augite diorite is a product of the replacement of greenstone.

Rocks within and East of the Yalakom Fault Zone

Introduction.—Rocks within and east of the Yalakom fault zone were examined along the lower slopes of Yalakom Valley and on the north flank of Shulaps Range. The formations are entirely sedimentary except near Shulaps Creek, where peridotite and massive and fragmental andesitic rocks occur within the fault zone. Strata on the eastern side of Yalakom Valley have a general northwesterly strike and northeasterly dip, but the apparent structural uniformity is complicated by faults and local folds. These formations were examined only where exposed adjoining the Yalakom fault or faults, and no continuous section that might correlate the strata of various localities was established. The rocks are described below in geographical groups in sequence from south to north.

Shulaps Creek to Burkholder Creek.—A traverse commenced on the west side of the fault zone and run eastward, roughly parallel to and a little north of Shulaps Creek, would show the following sequence: starting in ankeritized peridotite near the western fault it would pass across three-quarters of a mile of drift, then cross a fault (concealed here but exposed nearer the creek) into intensely disturbed sediments that extend half a mile to a well-exposed fault, from the eastern side of which a complex of andesitic flow, pyroclastic, and intrusive rocks extends to the river, 1¾ miles from the starting point of the traverse. Were the traverse to be continued up the eastern wall of Yalakom Valley it would cross pyroclastic rocks and lavas to an altitude of 3,800 feet and then pass on to sedimentary strata that extend to the crest of the mountain. The rocks in the foregoing section are described below.

The first-mentioned, intensely disturbed strata are exposed along half a mile of the sharp ridge separating the lower part of Shulaps Creek from Yalakom River. They consist chiefly of impure sandstone and siltstone, interbedded with which are one or more zones of conglomerate and a bed of limestone. The pebbles and cobbles in the conglomerate are well rounded. The most numerous are quartz-feldspar porphyry, quartz porphyry (both with aphanitic groundmass), grey chert, fine-grained greenstones, and bluish, grey, or green aphanitic and fine-grained rocks of unknown composition. Pebbles of white quartz and of limestone can be found in some outcrops.

The disturbed strata yielded no fossils. They are cut by lenses of serpentinized peridotite, some or all of which lie along faults. The eastern and western boundaries of this sedimentary belt are faults of the Yalakom system. The trace of the western fault is shown by brecciated and ankeritized sandstone on the north bank of Shulaps Creek 1 mile from its mouth. The fault on the eastern side of the belt crosses the sharp ridge three-quarters of a mile northwest of the mouth of the creek, and brings the sedimentary strata against andesitic rocks. It dips 77 degrees to the southwest.

The andesitic rocks are chiefly flows and pyroclastic deposits, but some are intrusive. They form bold outcrops on either side of Yalakom River at and above the mouth of Shulaps Creek. The flows consist of dark-green rocks that range from aphanitic to fine grained and are generally inequigranular. Glistening lath-shaped plagioclase crystals can be recognized in most specimens, and less-distinctly outlined masses of green augite, amphibole, and chlorite in many of them. Pyrite is sparingly but widely distributed. The intrusive (dioritic) facies, which cuts the flow near the Red Eagle prospect on the ridge west of the river, is fine to medium grained and contains the same minerals, but the plagioclase is dull grey-green and lacks crystal outlines. Microscopic examination shows that both facies originally consisted chiefly of plagioclase and augite. The composition of the plagioclase ranges from albite to andesine, but the original composition cannot be determined accurately. The plagioclase is albitized and is partly replaced by epidote, chlorite, colourless amphibole, carbonate, and prehnite. A considerable proportion of the augite remains. The rest is altered chiefly to chlorite and partly to amphibole. Hornblende phenocrysts exist in some specimens, and quartz is present in a few. Certain rocks containing abundant augite, some in diabasic relation to plagioclase, may be basalts.

Volcanic breccias and lapilli-tuffs occur on both sides of the river. The best exposures are along the eastern bank for 1½ miles above Shulaps Creek and west of the river three-quarters of a mile below Junction Creek. Weathered surfaces are mostly purple or green, though some are brown. The volcanic breccias and lapilli-tuffs consist essentially of aphanitic and fine-grained green and bluish andesitic fragments surrounded by varied amounts of green and blue tuffaceous, or red-brown jaspery, matrix. The most common size-range of fragments is from that of small peas to 4 inches long, but they range to about 1 foot in length. Most fragments are subangular, but rounded ones occur and certain rocks may be volcanic conglomerates. Some green pyroclastic breccias are difficult to distinguish from the flow-breccias in adjacent lavas. The pyroclastic breccias are associated with lava, tuff, chert, and jasper. Individual beds of chert and jasper are mostly between 4 and 10 inches thick. The beds occur singly and as aggregates which reach a thickness of 30 feet or more, in places containing interbeds of tuff. The common chert is dark grey-green, but some is blotched with red-brown and grades into jasper.

The over-all strike of the rather massive volcanic sequence, as indicated by associated chert and jasper beds, is west-northwest and the dip moderate to the northeast. Existing as they do in the Yalakom fault system, these rocks are cut by zones of close fractures and traversed by veinlets of carbonates and secondary silicates. Rusty-weathering ankeritized zones, some of which are the loci of faults, lie on both sides of the river with their long axes roughly parallel to it. The Red Eagle mercury prospect lies in an ankeritized zone west of the river, and rocks in the vicinity of the Golden Eagle prospect on the opposite bank are likewise ankeritized, as is part of the contact between the volcanic sequence and the sedimentary strata that lie to the east.

The contact east of the volcanic rocks is either a fault or a sheared unconformity. The writer prefers the former explanation, because the parts of the contact he saw are sheared, because it appears to involve different beds in different places, and because the beds are steeper along it than elsewhere. In addition, part of the contact is ankeritized, and this alteration characterizes faults in the Yalakom system, though it occurs also in fractured and permeable zones that are not faults. It is possible, however, that the conglomerates, at or just above the contact, mark an unconformity sheared by only local movement.

The sedimentary strata above the volcanic sequence consist chiefly of impure sandstone (greywacke) and shale, possibly both tuffaceous in part, accompanied by lesser but important amounts of conglomerate, and minor quantities of chert and limestone. They are intruded by a 200-foot prehnitized greenstone still east of the Golden Eagle prospect. The strata have a rather uniform general attitude, striking north 45 to 60 degrees west and dipping 65 to 70 degrees northeast, but local deviations are common. Conglomerates occur at two or more horizons, at and near the contact with the volcanic sequence. They are pebble and cobble types, but boulders 20 inches in diameter can be found. Most of the stones are rounded. Volcanic or hypabyssal rock types are the most common and include quartz-feldspar porphyry, feldspar-pyribole porphyry, quartz porphyry, feldspar porphyry, and aphanitic varieties. There are a few granite pebbles. Sedimentary fragments include chert and limestone. The limestone fragments in some places compose 10 to 15 per cent of the stones in the conglomerate. Fossiliferous ones containing fragments of crinoid stems and brachiopods are relatively easy to find. A brachiopod from a limestone boulder in this conglomerate was identified by Dr. B. F. Howell as *Spirifer* cf. *subrotundatus* Weller and stated by him to be almost certainly of Mississippian age. This would indicate that Mississippian limestone was eroded to form the conglomerate.

Fossils occur abundantly in sandy shale on the west side of Grouse Creek, which enters Yalakom River nearly opposite Shulaps Creek. A collection made at an altitude of 3,950 feet, from an outcrop 1 mile north of the mouth of Grouse Creek, was examined by Dr. J. A. Jeletzky of the Geological Survey of Canada, who reported as follows:—

"Despite insufficient preservation the following forms could be tentatively determined:—

"*Aucella* cf. *crassicolis* Keyserling var. *americana* Sokolow.
"*Aucella* sp. ex. gr. *crassicolis* Keyserling.
"*Aucella* sp. ex. aff. *crassicolis* Keyserling.
"*Aucella* sp. indet.

"This assemblage is typically Neocomian (Valanginian); therefore, despite the fact that not a single exact determination was possible, it suggests a Neocomian (Valanginian) age." Neocomian is earliest Lower Cretaceous time.

The belt of Lower Cretaceous strata reaches the Yalakom River two-thirds of a mile below Junction Creek. West of the river Lower Cretaceous strata outcrop near the mouth of Junction Creek, and on the east bank they are exposed as far as a prominent spur 1 mile north of Burkholder Creek.

The lower outcrops at this spur comprise grey-green sandstone and grit in beds as much as 10 feet thick, some separated by shale partings, and occasional thin beds of fine conglomerate characterized by numerous pebbles of grey limestone. Grains of limestone occur in the grit also. At river-level the beds strike north 55 degrees west and dip steeply northeast. About 300 feet above the river the sandstones and grits are succeeded by limy mudstones and shales. Seven hundred feet above the river the shales strike north 40 degrees west and dip northeast at moderate angles. The upper limit of the shaly strata was not seen. A carbonatized fracture zone in sandstone trends northwesterly up the southern side of the spur.

Burkholder Creek to Blue Creek.—Only limited investigations were made east of the Yalakom River and, as noted on page 19, the particulars of stratigraphic sequences and correlations are unknown. The rocks are shown on the map as an undifferentiated group (A), which probably includes strata equivalent to part of the Lower Cretaceous group (7) mapped farther south. North of the spur near Burkholder Creek, and on past Beaverdam Creek, the floor and lower slopes of the valley contain few outcrops. The river bed is underlain by soft sandstones and shales as far north as the sharp westward bend 5½ miles above Burkholder Creek. One mile below that bend the sandstone near the east bank contains a profusion of fragmentary plant remains, and a few non-diagnostic marine fossils were collected from beds that overlie them. A traverse up Beaverdam Creek showed that the sequence of sandstones and shales of the valley bottom is succeeded northeastward by a thick succession of massive greywackes that form bold cliffs along Beaverdam Creek. The greywacke is usually green on weathered surfaces but in places weathers rusty because of disseminated pyrite. It is blue-grey on fresh surfaces, and the naked eye can distinguish abundant angular fragments of feldspar, glassy quartz, and grains of grey and black rocks. Microscopic examination shows that the greywacke is composed essentially of particles of volcanic rocks, accompanied by grains of plagioclase and quartz, and a few fragments of chert or quartzite. The constituent particles are mostly angular to subangular. Part of the greywacke may be tuffaceous. The rock is very massive. It strikes northwestward and where investigated dips steeply northeast.

Part of the Yalakom fault system cuts across the bend in the river 5½ miles above Burkholder Creek and again swings west of the river just above Blue Creek. In the intervening distance the area east of the river and within the fault zone contains outcrops of serpentinized peridotite and altered sedimentary rocks. The fault forming the eastern boundary of this area can be traced in a number of outcrops. It is the locus of intense silica-carbonate (ankeritic) alteration which affects ultrabasic rock especially. The rocks east of the fault are sedimentary. They were examined along the steep banks of the Yalakom above Blue Creek.

Yalakom River above Blue Creek.—The strata adjacent to the river for 1½ miles above Blue Creek are chiefly greywackes, siltstones, and argillites, accompanied by large amounts of conglomerate and small amounts of chert and limestone. Most of the pebbles and cobbles in the conglomerates are fairly well rounded but subangular ones are not uncommon. They consist chiefly of aphanitic and aphanitic-porphyritic igneous rocks and of chert. No limestone-bearing conglomerates like those found farther south were seen here. The medium-grained strata are characterized by angular fragments of fresh-looking feldspar and by glassy quartz. These rocks are mostly greenish, usually dark green, and weather green. They are hard, and break across rather than around the constituent grains. Microscopic examination shows that the major components are rock fragments and fragments of albitic plagioclase and quartz. The rock fragments, most of which are subrounded, are chiefly volcanic and hypabyssal types of intermediate and basic compositions, with much smaller amounts of chert, quartzite, and argillaceous rocks. Plagioclase fragments are in general more abundant than quartz and comprise 15 to 20 per cent of certain beds; most of them are markedly angular. Grains of pyroxene or amphibole are present in some beds, and magnetite and ilmenite are minor constituents of all of them. The matrix consists essentially of fine-grained feldspar, quartz, and chlorite, generally accompanied by secondary epidote and carbonate. The heavy minerals in a specimen of typical greywacke, collected on the east side of the river 750 feet above a point 2,500 feet upstream from Blue Creek, were concentrated by magnetic and gravity separations and found to contain detrital chromite, some of it still exhibiting octahedral crystal form. The sedimentary sequence is of near-shore marine origin, as indicated by the lithology and by the presence of both marine fossils and woody plant remains.

A fault is presumed to trend north of west on the eastern valley wall, meet the river at a bend 2,500 feet upstream from Blue Creek, and then trend northwestward along the east bank. The actual trace was not observed, and the relative attitudes of strata on either side might be interpreted as an unconformity, instead of a fault, were it not for palæontological evidence described below. Beds west of the fault strike chiefly north 60 to 70 degrees west but range from north 45 to north 75 degrees west; dips are vertical and steeply southwest. Stratigraphic tops, as determined by grain gradation, face northeast in all localities where determinations were made; i.e., the beds are overturned. Strata east of the fault strike northwest, mostly north 45 to north 65 degrees west in the area investigated, and dip northeast at angles of 40 to 65 degrees. Their stratigraphic tops also face northeast.

Fossils collected on the east shore of the river, 300 yards upstream from Blue Creek and just south of a precipitous spur, were identified by Dr. F. H. McLearn of the Geological Survey of Canada as "*Lytoceras*"? sp., *Ostrea* sp., *Belmnites* sp., and *Pseudogrammoceras?* sp. An ammonite from the west bank half a mile above Blue Creek was identified as *Pseudolioceras?* sp. Dr. McLearn commented on this collection as follows:—

"The ammonoids of this collection are too poorly preserved for positive identification. There is some suggestion of an Upper Lias; i.e., later Lower Jurassic age."

An ammonite from the same locality, submitted for examination with a later shipment of fossils, was identified as *Tmetoceras?* sp. with the comment:—

"Age, probably late Lower Jurassic. The '*Lytoceras*' sp. recorded in the first report (January 13) may also be a *Tmetoceras* and of late Lower Jurassic age, but flattened specimens of ammonites which show neither the venter nor the suture line are difficult to identify."

The fossils named thus far are from strata west of the inferred fault. Fossils collected in beds east of the inferred fault, at a point 250 feet above the east side of the river half a mile north of Blue Creek, included *Tmetoceras* sp., *Lytoceras?* sp., *Pecten* sp., and "*Rhynchonella*" sp. The comment was: "The age is late Lower Jurassic (Aalenian)."

Dr. McLearn stated in later correspondence that the poor condition of the fossils renders all the above interpretations of age tentative rather than positive.

The relation of these strata to those which form the bulk of the mountain range east of the Yalakom, and which are probably in the main Cretaceous, is not known.

Horse Lake.—The rocks between the Yalakom fault and the river east and southeast of Horse Lake are all sedimentary. They consist chiefly of greywacke, but range from pea-size conglomerate to siltstone or shale and contain at least one bed of dark limestone. The greywacke is a dark dull green rock in which the unaided eye can detect abundant angular fragments of feldspar, fragments of both glassy and white quartz, chert, dark aphanitic igneous or sedimentary rocks, flakes of mica, and fragments of dark-green serpentinous rock. The latter may be ultrabasic, but their origin could not be identified with certainty. The beds strike eastward with dips ranging from gently south to vertical. They are bounded on the west by the Yalakom fault, which brings them against the main Shulaps ultrabasic mass and rocks of Cache Creek type. Plant remains are not uncommon in these beds. Pelecypods and gastropods collected 1 mile east of Horse Lake indicate a Jurassic or Cretaceous age.

Quartz Mountain.—The rocks on the northeast foot of Quartz Mountain between the Yalakom fault and Churn Creek are grey and green impure sandstones and darker siltstones, with lesser amounts of dark shale and a little dark limestone. The most conspicuous detrital grains are fragments of feldspar, quartz, much of it glassy, and dark aphanitic rock. The matrix is slightly limy. The folded beds strike westward and northwestward and are truncated by the Yalakom fault.

Volcanic Ash

Volcanic ash (pumice) is spread widely but thinly over the area. It overlies all but the most recent stream deposits and can be found even on sharp-topped ridges. The ash is rarely more than a few inches thick, except where redeposited by wind or water. The source of the ash is unknown but it is probably from the west.

The ash is greyish white to cream coloured. The bulk of the material is from sand to pea size, but the whole is an unsorted mixture of grains ranging in size from dust to fragments 1½ inches long. The particles consist of a cellular groundmass in which phenocrysts of white plagioclase and dark hornblende are visible to the naked eye. The groundmass, which is composed of glass and incipient crystals, makes up approximately 95 per cent of the material, plagioclase phenocrysts 4 per cent, and hornblende, augite, and biotite the remainder (Stevenson, L.S., 1947). Chemical analyses (Stevenson, L.S., 1947; Drysdale, 1917) indicate that the over-all composition is dacitic.

INTRUSIVE ROCKS

Shulaps Ultrabasic Rocks

Foreword.—The term "ultrabasic" signifies rocks with an especially large content of magnesium and iron. They consist essentially of olivine and pyroxene. Those containing more than 95 per cent olivine and little or no pyroxene are called dunite. The variety with more than 95 per cent pyroxene is designated pyroxenite. Intermediate types are classified according to the relative proportions of orthorhombic and monoclinic pyroxenes. Harzburgite consists of olivine and orthopyroxene. Distinctions can be made in the field between dunite, pyroxenite, and the intermediate group because weathered surfaces have characteristic colours and textures, but individual members of the intermediate group cannot be distinguished megascopically. The diagnostic colours and textures are especially valuable because they may persist in peridotite* that has been altered entirely to serpentine minerals, which are the usual alteration products. Peridotites altered so much that the original megascopic textural details are masked or destroyed will be described under headings such as "serpentinite" and "silica-carbonate" rock. (In this bulletin "serpentine" is used as a mineral name and "serpentinite" as a rock name.) Because chromite is a primary constituent of the ultrabasic rocks, its origin and alterations are discussed in this section. Descriptions of local concentrations of chromite are included in the chapter on economic geology.

Definition and Previous Descriptions.—Shulaps ultrabasic intrusive rocks are named after the Shulaps Range, of which they compose a major part. They consist of harzburgite, dunite, enstatite-pyroxenite, and serpentinized, steatitized (altered to soapstone), and carbonatized equivalents of those rocks. Diopside-pyroxenite is not included because its genetic relationship to the harzburgite, dunite, and enstatite-pyroxenite is not known.

Part of the area underlain by Shulaps ultrabasic intrusives was mapped by Drysdale (1916, 1917) and McCann (1922). Drysdale (1916, p. 79) introduced the name "Shulops volcanics" for certain

> red-weathering peridotites (dunite and wehrlite) . . . altered to serpentine in many places and associated with chromite.

He considered the Shulops volcanics part of a Jura-Triassic(?) Cadwallader series of sedimentary and volcanic rocks. His map (1916, facing p. 80) shows part of Shulaps Range underlain by serpentinite and gabbro of his Cadwallader series. A structure-section (1917, p. 46) illustrates peridotite, serpentinite, and gabbro occurring interbedded or sill-like in the Cadwallader series. Drysdale (1916, p. 78) introduced the term "Big Sheep volcanics(?)" for

> reddish weathering carbonate rocks containing chalcedony veinlets, fluidal and breccia structures, and associated with magnesite and cinnabar(?) closely related to Shulops volcanics and probably derived from them.

He mapped only one outcrop of this rock, on a tributary of Liza Creek on the western edge of the present map-area.

McCann (1922, p. 22) used the name "Shulaps volcanics" (new spelling based on a decision of the Geographic Board) for "red-weathering serpentine rocks (volcanic breccia, porphyry, and dense rocks)." He stated (1922, p. 27) that "Shulaps volcanics" included both the Shulops volcanics and big Sheep volcanics of Drysdale.

McCann described (1922, pp. 26–27) two phases of Shulaps volcanics:—

> The porphyritic phase appears to have been composed of such rocks as olivine-gabbro porphyrite, or the porphyritic equivalent of peridotite. These rocks, when weathered, have a greyish-brown appearance, and in the porphyry the more resistant pyroxene phenocrysts appear

* Peridotite is the general term used for olivine-bearing rocks, regardless of the amount of olivine in excess of 5 per cent. It includes dunite but not pyroxenite.

in relief, presenting a " warty " surface. . . . The dense serpentine rocks are more altered than the porphyritic rocks and were probably originally olivine basalts. Their weathered surfaces are usually red-brown to brown-yellow. . . . The dense serpentine rocks show flow structures and often form a volcanic breccia, the angular inclusions being principally of quartzite, but in some places, as in Taylor Creek, they are of limestone. . . . Evidence of the source of the volcanic flows may be found in the porphyritic serpentines of Shulaps mountains. These rocks, besides being porphyritic, have the somewhat crystalline appearance of some plutonic rocks. . . . It is believed that in this locality exists the volcanic pipe which emitted the outlying flow rocks. Dykes may also have contributed to the supply of flow rocks, as in the south-western corner of the map-area. From the above it is concluded that the serpentine rocks were extruded over the erosion surface of the Bridge River series of Pennsylvanian-Permian age, before the Cadwallader series of Upper Triassic age was laid down.

Cairnes (1937, pp. 28–31) described ultrabasic rocks which he named President intrusives in the Bridge River mining camp, roughly 15 miles southwest of the present map area:—

The President intrusives of this area were included by Drysdale and McCann with the *Shulaps volcanics and regarded as essentially of volcanic origin. Because all the bodies studied* by the writer present every evidence of being intrusive and because the so-called Shulaps volcanics are widely displayed elsewhere and may in places be truly volcanic, the name Shulaps has not been retained by the writer.

Cairnes later investigated the Tyaughton Lake map-area, which extends northeastward from the Bridge River mining camp and includes the serpentines of Taylor Creek, described by McCann as forming volcanic breccia containing limestone fragments. Cairnes states (1943, p. 8) that ultrabasic rocks of the Tyaughton Lake map-area " for the most part, if not entirely, represent peridotites and dunites, and as such may be correlated with the President intrusive rocks. . . ."

Shulaps ultrabasic intrusive rocks include those in the present map-area previously termed Shulaps volcanics by McCann. The change in name is based on evidence described later, which shows that in the present map-area these rocks are intrusive, and not volcanic.

Only four small outcrop areas mapped by McCann as Shulaps volcanics are not remapped by Cairnes or included in the present map-area. Three of these were investigated by the writer when he prospected in the district in 1942. All three contain disseminated chromite, which is not a normal constituent of volcanic rocks. There seems little ground for doubt that all rocks mapped previously as Shulaps volcanics are intrusive ultrabasic rocks.

The name " Shulaps " is retained because Shulaps Range is composed largely of ultrabasic rocks and is the type locality to which rocks of similar appearance were first referred. Use of the name " Shulaps " for these rocks is not invalidated by previous use of the name for the same rocks ascribed to a different origin.

The term " President " is not used because Shulaps has priority within the present map-area, and because ultrabasic rocks of the Shulaps Range have not been proved to be the same age as all similar rocks elsewhere in the district.

Distribution and External Structural Relations.—The main mass of Shulaps ultrabasic rocks is lenticular in plan. The major axis extends 20 miles northwesterly from the floor of the Yalakom Valley below Shulaps Creek to the divide between Grizzly Bear and Horse Lakes. The mass is 7 miles wide in the vicinity of Shulaps Peak.

Some of the contacts observed by the writer are definite faults. The others are bordered on the ultrabasic side by serpentinite which is (inherently?) so intersected by small slip-planes that the presence of a significant fault zone cannot be determined.

The southern contact, from Yalakom Valley to Jim Creek, is with rocks of Cache Creek type that strike westward and northwestward and, for the most part, dip north or vertically. The exposed parts of the contact appear conformable with these strata. The outline of this part of the mass might be termed smoothly irregular. There appears to be an intertonguing of ultrabasic and country rocks at the heads of Hog and Brett Creeks, but the positions of contacts here are mostly inferred.

An irregular protuberance from the ultrabasic mass intrudes Hurley strata on the ridge between Jim Creek and East Liza Creek.

The main mass is in contact with gabbro northeast of this last locality. The gabbro is part of a body 3½ miles long and from 500 to 2,800 feet in plan width, the southern half of which is within the ultrabasic mass. Much of the eastern contact of the gabbro dips eastward and is overlain (topographically) by ultrabasic rock. Ultrabasic rock lies topographically below the western side of the gabbro of Jim Creek, but the dip of the contact is unknown. The southern tip of the gabbro body, exposed on the headwall of Peridotite Basin, has ultrabasic rock topographically above and below it. Small bodies of similar gabbro are surrounded (in plan) by ultrabasic rock in the vicinity of Jim Creek. The relative ages of gabbro and ultrabasic rock are not conclusively proven by contact relations, but some gabbro is younger than ultrabasic rock. The gabbro is described more fully in a later section.

The rocks north of Jim Creek and west of the main ultrabasic mass are disrupted by numerous faults and have widely different attitudes. The dip of the ultrabasic contact on tributaries of Liza Creek ranges from vertical to gently eastward or northward. The contact is vertical in a cirque 1¼ miles southwest of the summit of the Liza Lake–Blue Creek trail, appears to dip gently eastward or northward three-quarters of a mile to the north, and is again vertical 3 miles farther northwest. Part or all of this outline may be governed by faults.

The main ultrabasic mass is bounded on the east and north by the Yalakom fault zone, on the other side of which lie Jurassic and Lower Cretaceous rocks that form the eastern wall of Yalakom Valley. No ultrabasic rocks were found east of the fault zone.

Many lenses and sill-like bodies of ultrabasic rock exist in pre-Jurassic rocks south and west of the main mass. Those along the foot of the range are altered to silica-carbonate rock. The valley of Marshall Creek and Liza Lake probably contains a major fault zone, and some of the northwesterly trending bodies of silica-carbonate rock on its eastern side are thought to lie along faults. Bodies exposed higher on the western slope of the range are not carbonatized, but all of them are intensely serpentinized and appear sheared. It is not unusual to find three or four lenses of serpentinite aligned, but most bodies are not in regular groupings. Lenses of serpentinite occur along contacts between different rock types and in shear zones and faults.

Two lenses of serpentinite are of special interest. The first lies 2¾ miles northeast of Liza Lake, on a sharp ridge composed of Hurley formation and gabbro, both of which are sheared. The locality is a quarter of a mile west of the main ultrabasic mass. Six serpentinite lenses outcrop in a distance of 300 yards along the ridge, and all six are parallel to the shearing which strikes northward across the ridge. Four are in sedimentary rocks, one in gabbro, and one in a shear-contact between sedimentary rocks and gabbro. The largest lens is 30 feet wide and the smallest is 5 feet wide. All have slickensided contacts, and the serpentinite in them is intensely sheared. The lens of special interest is 20 feet wide and lies in Hurley strata. It surrounds a fragment of fine-grained grey Hurley-type limestone similar to that in the adjacent beds. Stringers of serpentinite penetrate the limestone, but the limestone shows no contact-metamorphic effects.

The second lens of special interest is 1¼ miles southwest of the summit of the Liza Lake-Blue Creek trail and about a quarter of a mile west of the western contact of the main ultrabasic mass. Sediments of Hurley type are faulted against volcanic rocks, and the serpentinite lens lies in the fault. It surrounds a block of ribbon chert-argillite rock of Cache Creek type that is not known to outcrop within a mile of this point.

Carbonatized peridotite occurs along the Yalakom fault zone for at least 5 miles northwest of the main Shulaps mass. On the northeast flank of Quartz Mountain, 3 miles from the main mass, the main fault and a subsidiary transect greywacke that contains detritus of ultrabasic origin.

The main Shulaps ultrabasic mass is intruded by dykes, plugs, and irregular masses of diorite porphyry and quartz-diorite porphyry in and north of the drainage-basin of Blue Creek. The ultrabasic rocks are intensely serpentinized in this area. The Rexmount porphyry intrudes serpentinized peridotite near Shulaps Creek. These porphyritic rocks are late Mesozoic or early Tertiary in age. A basaltic dyke cuts peridotite 1 mile southeast of Burkholder (Johnson) Lake.

Internal Structural Relations.—Shulaps ultrabasic rocks originally consisted almost entirely of (*a*) dunite, with sensibly no pyroxenes, (*b*) peridotites containing 10 to 30 per cent of pyroxenes, and (*c*) pyroxenite, with practically no olivine. Enstatite (orthorhombic pyroxene) occurs in all rocks of group (*b*), and diopside (monoclinic pyroxene) in some of them. Because diopside, where present at all, is greatly subordinate to enstatite, all rocks of group (*b*) are classed as harzburgite.

Harzburgite is the dominant rock of the main Shulaps mass. Estimates made in areas where alteration did not prevent the determination of original rock types indicate that harzburgite originally constituted about 85 per cent of the mass. Dunite made up nearly all the remainder.

The varieties of ultrabasic rock in the main Shulaps mass lack the regularity of distribution characteristic of ultrabasic portions of gravity-stratified complexes of Bushveld and Stillwater type. The dominant harzburgite is prevailingly homogeneous, and the dunite and enstatite-pyroxenite occur in it either in layers or in sack-form and less regular masses. These are distributed at random throughout the harzburgite and do not appear especially concentrated at one end or one side. It must be borne in mind, however, that rock exposures suitable for study of internal structures are limited largely to the part of the mass above timberline, and that hidden concentrations could occur in the drift-covered area between Peridotite and Shulaps Creeks. Nothing in the structure of the large exposed area indicates that this possibility is important.

Compositionally layered ultrabasic rock, though spectacular in appearance, is limited in quantity. The major part of the rock is massive, and the areas containing compositional layering constitute less than 10 per cent of its total extent. These areas are not, moreover, layered throughout.

Layering is best seen in the basin of Peridotite Creek, especially at its northwestern corner and southern side, and in the basin above Noaxe Lake, especially at its southwestern floor and eastern rim. Smaller amounts of compositionally layered rock are to be found on Big Dog Mountain, on the north side of the trail at Liza Creek-Blue Creek summit, near the head of the south fork of Blue Creek, and in cirques at the heads of the northern and southern tributaries of Retasket Creek.

The layering results from parallel orientation of zones containing contrasting amounts of pyroxene crystals. Harzburgite of homogeneous character gives way to a layer of pyroxenite or of dunite merely by increase or decrease in the proportion of pyroxene. Contacts between layers are in general well defined, but never sharp. The gradation between layers is as a rule equally sharp on both sides of a given layer, but, where it is not, the difference is not systematic throughout the entire sequence. No interface can be seen between the material of a dunite layer and the matrix of adjoining harzburgite, and they appear identical. Boundaries between dunite and pyroxenite layers are readily seen, but in detail they are not plane surfaces because the pyroxene crystals project into the dunite.

The layering is repetitive. It is most apparent when pyroxenite and dunite are repeated, but, much more commonly, the repetition is of pyroxenite layers in harzburgite. Layers of dunite unaccompanied by pyroxenite are less common. Where paired layers of pyroxenite and dunite are separated by harzburgite, the succession is not necessarily orderly; i.e., the sequence may be harzburgite-dunite-pyroxenite-harzburgite-pyroxenite-dunite-harzburgite (-H-d-p-H-p-d-H-).

Layer thickness is varied but generally can be measured in inches. Most pyroxenite layers are between a quarter of an inch and 2 inches thick. Those thicker than 4 inches are rare. Many dunite layers are between 1 and 3 inches thick, but layers 1 or 2 feet thick are not uncommon. Thin layers are commonly repeated more often than thick ones, and may consist of alternations of pyroxenite and dunite without intervening harzburgite.

Compositional layers in Shulaps rocks do not extend for long distances on strike, and few can be traced for 100 feet. Most layers can be traced only 10 or 15 feet, beyond which, in the case of dunite or pyroxenite, they lose their identities in harzburgite. A layer similar to one that has ended may commence farther along the strike.

All compositional layering seen by the writer strikes into the northwest quadrant (i.e., in the direction of the long axis of the ultrabasic mass) and dips southwestward or vertically, but varied attitudes may occur even in small outcrops. Nearly all layers in the northern and northwestern parts of Peridotite Basin, where layering was studied especially, strike north 15 degrees to north 40 degrees west and dip from 65 degrees southwestward to vertical. Swerves are not unusual, and attitudes measured 100 feet apart may differ considerably. One outcrop, 150 by 150 feet in size, has, for example, attitudes which range through 40 degrees in strike and 20 degrees in dip. The outcrop is not disturbed by faults, and at least most of the variations in attitude are due to swirls in the layering. Layers on the southeastern side of Peridotite Basin strike more westerly than the others and have consistently lower dips.

The bulk of the dunite in the range is in sack-form or less regular bodies which have distinct boundaries against surrounding harzburgite. The boundaries of sack-form masses have over-all regularity but are commonly irregular in detail. All such boundaries examined are gradational across a few inches from pyroxene-free dunite to harzburgite, and are recognizable only through the change in pyroxene content. The olivine " matrix " surrounding the pyroxenes of harzburgite is indistinguishable from the olivine of dunite. Sack-form bodies are measurable in tens or hundreds of feet. The largest area of dunite seen lies near the head of the south fork of Blue Creek and was estimated to be 400 by 600 feet in maximum dimensions. It outcrops on a nearly vertical slope and is surrounded on all sides by harzburgite. Bodies 60 by 100 feet are more usual. Directions of elongation and dip are random. Small dunite bodies are characteristically elongate but commonly are irregular in outline.

Dunite bodies with definite dyke-form transect compositional layering. Close examination reveals no discontinuity where the dunite of a dyke meets the dunite of a layer in such occurrences. The two dunites appear identical, and the dyke could not be said to cut the layer if it did not also cut pyroxene-rich layers. Crossed dunite zones in almost unlayered harzburgite are shown in Plate VI. The contact relations of harzburgite toward crosscutting zones is similar to that described for larger bodies and compositional layers. No knife-edge or chilled contacts have been recognized. Dunite dykes in the northwest part of Peridotite Basin strike more commonly northwestward than in other directions but have no consistency of attitude.

Enstatite-pyroxenite is much less abundant than dunite. The bulk of the pyroxenite is contained in compositionally layered rocks, in contrast to the distribution of dunite, and only one body of massive enstatite-pyroxenite was seen. At an approximate altitude of 8,650 feet on the east wall of the uppermost cirque on the south fork of Blue Creek, a lens of pyroxenite 25 feet long and 10 feet wide lies at the base of a mass of dunite about 100 feet long and 75 feet wide. The country rock is harzburgite. Dykes of enstatite-pyroxenite transect compositionally layered rock in at least one locality.

Dunite.—All dunite bodies were originally almost identical in mineralogy and texture. Olivine, the only essential component, was accompanied by small quantities of accessory minerals, chiefly chromite, and, in some cases, by a few grains of pyroxene. Present variations are due to differences in intensity of alterations, chiefly of serpentinization, and alteration products may now compose as little as 2 per cent or as much as 100 per cent of the rock. Serpentine minerals and magnetite are the usual secondary products, and talc and carbonates are less common.

Dunite weathers to a tan or buckskin colour. This colour extends for a tenth to a quarter of an inch from the surface and then gives way sharply to darker hues. The surface is smooth and even grained, somewhat like that of brown-weathering sandstone. The fine-grained appearance is in most cases deceiving because the boundaries of the olivine crystals cannot be recognized, even though some of them may be nearly an inch long. Black chromite grains occur in small quantities in most dunite and are readily seen on weathered surfaces. Pyroxene crystals as a rule are lacking, but the few that occur weather in relief.

Freshly broken dunite is dark green, and the generally smooth conchoidal surfaces are texturally rather featureless. Relatively coarse-grained, unaltered dunite may contain areas of olivine which reflect light weakly. Intensely serpentinized dunite is in general darker and smoother on fresh surfaces than is less altered rock, but the degree of serpentinization cannot be determined readily by eye. Unaltered dunite is, of course, more resistant to the knife blade than is serpentinized material. Chromite grains are not nearly as apparent on fresh as on weathered surfaces.

Microscopic examination reveals that unaltered dunite is essentially a medium- to coarse-textured, inequigranular, allotriomorphic olivine-rock. There is considerable range in grain size within single specimens, but the distribution of sizes is seriate and porphyritic textures are lacking. Grain boundaries are generally smoothly interlocking. Euhedral crystals are rare, and subhedral grains, which are not abundant, are small. Nearly all olivine grains contain minute inclusions of colourless, dark, or opaque minerals, of which chromite is the only one definitely identified. This chromite occurs as octahedra and as plates.

Most grains, in fact almost all the medium and larger grains, exhibit undulatory extinction similar to that of strained quartz, or banded extinction, or both. The banded extinction is due to a structure parallel to the (100) crystal plane. This structure has a misleading resemblance to twinning but is a product of translation gliding. Olivine grains with banded extinction occur in dunites that show no evidence of cataclasis. The gliding apparently took place under relatively little stress.

The compositions of olivines from all dunite masses are relatively uniform. The range is between 96 and 87 per cent of the theoretical forsterite molecule, as indicated by measurements of indices of refraction and optic axial angles. Nearly all the olivine is between Fo_{92} and Fo_{87} however, and material more magnesian than Fo_{92} is not abundant. Coarse-grained olivine from a dunite stringer transecting compositional layering contained 88 per cent of the theoretical forsterite molecule.

Chromite is the only accessory mineral (other than the aforementioned minute inclusions and occasional grains of pyroxene similar to those described under harzburgite). Euhedral chromite occurs included in olivine and, rarely, interstitially. It is probably exceeded in quantity, though not in numbers of grains, by anhedral chromite interstitial to olivine.

Serpentinization and other alterations of dunite are discussed in a later section.

Harzburgite.—Olivine and enstatite are the essential primary minerals in harzburgite. Diopsidic pyroxene is commonly present in the Shulaps rocks, but because it is usually considerably subordinate in amount to enstatite, and probably never exceeds it, the term " lherzolite " is not used. Olivine is generally four to nine times as abundant as pyroxene. Chromite is the only significant accessory mineral. It exists as small euhedra included in primary silicates and as larger interstitial anhedra.

Harzburgite weathers in shades of red-brown and orange. The colour is redder than that of dunite, and the two rocks can be differentiated at a distance, especially when " buckskin " dunite lies in or against red-orange harzburgite. Harzburgite is distinguishable even more readily by its characteristically warty surface (*see* Plate VI), which results from differential weathering of resistant pyroxene grains above less durable olivine and serpentine which surround them. Chromite, the only visible accessory mineral, is sparse but widespread and is best observed on weathered surfaces.

Harzburgite can generally be distinguished from dunite on freshly broken surfaces, which are usually a slightly duller green than those of dunite. Pyroxene grains provide glistening cleavage planes which can be seen without difficulty, in contrast to the vague, less regular reflecting areas sometimes visible in coarse unaltered dunite. The glistening surfaces remain when the pyroxenes have been replaced pseudomorphously by serpentine, then called "bastite." This inheritance of texture is valuable because it permits recognition of original rock type even after all olivine and pyroxenes are serpentinized.

Microscopic examination of fresh harzburgite shows that it is medium to coarse grained, inequigranular, and allotriomorphic. Most olivine grains are between 0.5 millimetre and 3 millimetres long, but individuals as large as 1.3 centimetres are not rare. Most enstatite grains are between 0.7 and 3 millimetres long. Both are usually embayed or irregular, and few subhedra and almost no euhedra are present. Enstatite bears no constant spatial relation to olivine and rarely includes it. All diopsidic pyroxene is markedly anhedral, and most appears interstitial to olivine and enstatite. The grains are considerably smaller than those of olivine and enstatite.

The olivine in harzburgite is similar to that already described in dunite. The molecular composition (as determined from optical constants) ranges approximately between Fo_{93} and Fo_{87}, with representatives of the latter end most common.

Enstatite is colourless in thin section. The composition ranges from 92.5 to 89.5 molecular per cent of magnesium silicate ($MgSiO_3$), with a composition near 91 per cent represented most abundantly. (Compositions are based on measurements of refractive indices and optic axial angles.)

Enstatite in most specimens of harzburgite contains diopsidic lamellæ that lie parallel to the optic plane of the host. They are best visible in enstatite sections containing the Y and Z optical directions. Lamellæ 0.0015 millimetre across are relatively wide, and many are of the order of 0.0001 millimetre in width. They commonly pinch out before reaching the periphery of the grain. Blebs and less regular masses of the diopsidic pyroxene accompany the lamellæ in many enstatite grains and extinguish simultaneously with the lamellæ. Lamellæ are fewer and thinner adjacent to many, but not all, of the blebs and patches. The impoverishment is more pronounced " fore and aft " of elongate blebs than along their sides. The lamellæ are more resistant to serpentinization than are their enstatite hosts, and project as spines into serpentine during the initial stages of serpentinization of enstatite (*see* Plates X and XI). A sample of enstatite holding abundant diopsidic lamellæ contains 1.96 weight per cent calcium oxide (CaO), whereas enstatite (from enstatite-pyroxenite) bearing fewer lamellæ contains only 0.79 weight per cent CaO (analyst, L. C. Peck, Laboratory for Rock Analysis, University of Minnesota). The diopsidic material is believed to have exsolved during slow cooling of enstatite.

The discrete grains of diopside that are a minor constituent of harzburgite are colourless in thin section. The diallage parting is general. Their composition can be represented by the following atomic ratio: $Ca_{47}Mg_{47}Fe_6$ (based on intermediate refractive index 1.86±, optic axial angle 55 to 57 degrees, extinction angle 38 to 39 degrees).

Accessory chromite is slightly less abundant in average harzburgite than in average dunite. Euhedral and subhedral grains occur characteristically as inclusions in olivine and pyroxenes and anhedral grains occur interstitially. The amounts of chromite included in olivine and in enstatite seem approximately proportional to the amounts of those minerals, but chromite may possibly be less abundant proportionally in diopside. Although the euhedra and subhedra may equal the anhedra in number, they are far inferior to them in combined quantity. Most of the megascopically visible chromite is anhedral and interstitial.

Minute fibres of an amphibole-like mineral replace or grow upon enstatite in some harzburgite. Serpentine minerals occur in all harzburgite examined. The original character of the rock can sometimes be inferred even in completely serpentinized harzburgite because enstatite is replaced pseudomorphously by bastite (a form of serpentine). This phenomenon will be referred to again in the section on serpentinization.

Enstatite-pyroxenite.—Enstatite-pyroxenite consists almost entirely of enstatite, with accessory diopside, olivine, and chromite. The surface is rough, but individual grains do not stand markedly higher than their neighbours. Much of the roughness is due to differential weathering of parts of single crystals and may obscure details of grain shape. Enstatite-pyroxenite weathers to shades of brown, but the surface discoloration extends less deeply into the rock than it does with dunite and passes abruptly into olive-green unweathered material. Such material is " live-looking " and has many reflecting planes of medium- to coarse-grained vitreous crystals.

Microscopic examination shows that the enstatite contains diopsidic lamellæ that are thinner and less numerous than those in enstatite from harzburgite. No diopsidic blebs were noted. Many of the larger enstatite grains exhibit what may be glide twinning.

Purified enstatite from enstatite-pyroxenite in the mass at the head of the south fork of Blue Creek contains the following weight percentages:—

	Per Cent		Per Cent
SiO_2	56.98	H_2O-	0.11
Al_2O_3	1.26	TiO_2	0.03
Fe_2O_3	0.41	Cr_2O_3	0.50
FeO	4.86	NiO	0.10
MgO	34.78		
CaO	0.79		99.82

—Analyst, Lee C. Peck, Laboratory for Rock Analysis, University of Minnesota.

Recast in terms of atomic ratios this is $Ca_{1.48}Mg_{90.88}Fe_{7.64}$. The greatest refractive index of this enstatite is 1.6725. Dispersion of the optic axis is $r>v$, as follows:—

79.05°±0.10° in light of 4860A° (blue).
79.25°±0.10° in light of 5280A° (green).
79.95°±0.10° in light of 5890A° (yellow).
80.40°±0.10° in light of 6510A° (red).

Enstatite-pyroxenite resists serpentinization better than any other ultrabasic rock in the Shulaps Range. The alteration advances unevenly into the grains from boundaries, cleavages, and fractures.

Serpentinite.—Serpentinite, as used here, is a field term including all serpentinous ultrabasic rocks in which serpentinization and rock movements have masked or destroyed the megascopic evidence of original composition and texture.

Weathered surfaces are usually grey, brown, or apple-green to dark bluish-green. The green outcrops in general are cut by myriads of slip-surfaces and exfoliate into chip-shaped fragments. Dark-green fragments are homogeneous, but light-coloured ones commonly are coated with enamel-like or splintery serpentine structurally different from the darker, dense, even-textured material within. Many serpentinites and rocks approaching serpentinite have an apparent flow structure, with " inclusions " set in a matrix containing planes that bend around them. The " inclusions " are serpentinite or partially serpentinized peridotite, and have remained massive while the rest of the rock was cut by slip-planes. The microscopic features of common serpentinite are described below.

Serpentinization.—Serpentinization of ultrabasic rocks has long been a subject of controversy, and there are at present two chief theories concerning its origin. The first (deuteric) is that the serpentinizing solutions emanate from the cooling ultrabasic mass itself. The second (hydrothermal) is that serpentinization is brought about by solutions emanating from outside the ultrabasic body, perhaps chiefly from younger intrusive rocks. Favouring the first theory is the occurrence of large bodies of uniformly serpentinized rock in which the intensity of alteration bears no relation to younger intrusions or to structural features. Supporting the second are examples of especially intense serpentinization around younger intrusions and along zones which could have acted as passageways for hydrothermal solutions. Both processes of serpentinization might affect the same ultrabasic rock.

In the Shulaps Range the degree of serpentinization is relatively uniform over considerable areas in which the same minerals are altered to about the same degree. Such uniformity suggests that serpentinization resulted from a residual liquid uniformly distributed among the olivine and pyroxene crystals. The intensity of serpentinization generally changes gradually from place to place, but it follows no apparent pattern and is not related to the borders or to directions within the mass, as might be the case if it were produced by solutions emanating from wallrocks or guided by a system of fractures. For these reasons the writer believes that most serpentinization in the Shulaps Range is of the deuteric type.

On the other hand, the parts of the ultrabasic mass intruded by Blue Creek and Rexmount porphyries are intensely serpentinized. This association is thought to be fortuitous, however, because the intensity of serpentinization has not been proved to be governed by proximity of porphyry and because other equally intensely serpentinized areas show no evidence of porphyry, but the possibility of large-scale hydrothermal serpentinization cannot be discounted entirely. The evidence of local hydrothermal serpentinization is more positive. Small gabbroid dykes and lenses of unknown origin, most of which are only about 2 feet wide and a few yards long, cut the Shulaps mass. Nearly all are in regions of complete serpentinization, but a few occur in moderately serpentinized areas where gradations in intensity can be noted, and there the intensity of alteration is greatest next to the dykes. This relation is illustrated on the southwest side of the valley at the head of Noaxe Lake, where two gabbroid dykes coincide in position with lenticular zones of intense serpentinization that grade outward in a few feet to the lower intensity characteristic of that area. Comparable exposures exist near the outlet of Peridotite Basin. These appear to be examples of hydrothermal serpentinization. The solutions responsible may have accompanied emplacement of the dykes, or may be younger and merely guided by the same structures.

There is at present no uniformly accepted classification of serpentine minerals, but they are generally divided into two groups, one of which is fibrous and the other platy. The term " chrysotile " is commonly applied to part or all of the fibrous group, and the term " antigorite " to the platy group. The name serpophite has been given to serpentine that forms rounded, nearly isotropic bodies that occur with the more definitely crystalline types. Serpophite may be a form of chrysotile. The ranges of optical properties of various serpentine minerals overlap, and positive identification is dependent upon X-ray investigation.

The terms " fibrous serpentine," " antigorite," " serpophite," and " bastite " are used in the microscopic descriptions that follow. Fibrous serpentine, as used here, occurs characteristically in veinlets or lenses. The fibres, which have either positive or negative elongation, are almost always oriented perpendicularly to the walls of the veinlet or lens. Thus the sign of elongation of the veinlet or lens as a whole is opposite to that of its constituent fibres. Antigorite occurs generally in bladed, fan-like, or platy forms which have positive elongation and commonly present a reticulated pattern in thin section. The association in which cores of serpophite are set in a network of veinlets of fibrous serpentine is referred to as mesh serpentine. Bastite is the product of pseudomorphous replacement of pyroxene by a serpentine mineral that is almost certainly a form of antigorite. Many of the properties of brucite are similar to those of serpentines, and it is probable that brucite occurs in some of the serpentine veinlets.

The most common type of serpentinization in Shulaps rocks yields fibrous serpentine and serpophite, combined in mesh textures, and bastite. These products are characteristic in most of the main ultrabasic mass. Antigorite, on the other hand, is the characteristic serpentine in stressed satellitic bodies and in that part of the main mass that contains secondary foliation (as distinct from mere slip-planes). Antigorite replaces mesh serpentine.

Olivine is more readily serpentinized than pyroxenes. In replacement of olivine by fibrous serpentine and serpophite (mesh texture) the alteration advances evenly from grain boundaries and fractures. When the alteration is complete, there is little evidence of original texture, except that irregular grains and feathery aggregates of magnetite (maghemite?), containing iron released from olivine, tend to be concentrated in sites of original grain boundaries and fractures. Enstatite, on the other hand, is typically replaced pseudomorphously by bastite, and this partial retention of texture may allow recognition of what was originally harzburgite, even of its pyroxene:olivine ratio, in completely serpentinized rock. Enstatite grains bearing diopsidic exsolution lamellæ are serpentinized unevenly (*see* Plates X and XI) because the lamellæ are more resistant than their host. Diopside grains, relatively resistant to serpentinization, are eventually replaced pseudomorphously by bastite that is distinguishable with difficulty, if at all, from that formed from enstatite.

In mesh serpentine, veinlets that form the network surrounding bodies of serpophite consist of three zones: two marginal ones, composed of fibres oriented perpendicular to the walls; and a medial zone, which generally appears isotropic and in which magnetite grains are concentrated. The fibres of the marginal zones have, almost without exception, negative elongation, and all those in which an optic sign is recognizable are biaxial negative. Mesh serpentine is cut by other veinlets that appear laminated. The " laminæ " have negative elongation. Some extinguish in a way that suggests that they consist of cross-fibres with positive elongation, but others show no indication of fibrous components.

Antigorite is the characteristic mineral of intensely sheared serpentinized Shulaps rocks and has, in nearly all instances, developed at the expense of the mesh serpentine-bastite assemblage. No evidence of replacement of antigorite by mesh serpentine was found. Bastite resists the change to bladed antigorite better than mesh serpentine. This may be evidence that bastite is really a form of antigorite, a form stable under part of the range of conditions under which antigorite replaces mesh serpentine (which is largely chrysotile).

Antigorite has formed directly from primary olivine, and perhaps from pyroxene, in sheared peridotite near the southern border of the main Shulaps mass. Talc and carbonate, both of which replace antigorite, are constituents of the same rocks. The antigorite may be the product of hydrothermal serpentinization (in contrast to the general deuteric serpentinization).

Stress (directed pressure) is a dominant factor in the genesis of antigorite, whether by replacement of other serpentine minerals or by direct alteration of primary silicates. The field evidence given here is supported by the laboratory evidence of Bowen and Tuttle (1949), who state that chrysotile, not antigorite, develops even under 40,000 pounds per square inch of uniform pressure. The role of temperature is not fully understood, but high temperature alone will not cause formation of antigorite. Mesh serpentine in xenoliths of serpentinized peridotite engulfed in the basaltic dyke near Burkholder (Johnson) Lake is recrystallized directly to olivine without intermediate formation of antigorite. This phenomenon is described more fully in the following section.

Regeneration of Olivine from Serpentine. — Olivine has been regenerated from serpentine in two distinct types of occurrence, one the result solely of thermal action and the other apparently dynamo-thermal.

The first occurrence is in ultrabasic xenoliths in a 60-foot basaltic dyke that cuts serpentinized peridotite 1 mile southeast of Burkholder (Johnson) Lake. The xenoliths have rough orange-coloured weathered surfaces on which grains of chromite are visible. Their fracture is conchoidal, and fresh surfaces are dull brownish-green, with a sub-porcellainous aspect. They are aphanitic, except for the chromite grains. Microscopic examination reveals that the xenoliths consist almost entirely of extremely fine-grained olivine. The grains range in size from those at or below the resolving power of a microscope to those about 0.06 millimetre in greatest dimension. Their identity was confirmed with an X-ray spectrometer.

No rocks texturally similar to the xenoliths occur in the Shulaps area. No xenoliths of normal serpentinized peridotite were found in the dyke. The writer considers, therefore, that the xenoliths represent fragments of serpentinized peridotite in which the serpentine minerals are reconstituted to olivine.

An intermediate stage in the process is illustrated in the wallrocks of the dyke. The ultrabasic rocks within 8 feet of a well-exposed dyke contact are altered to aphanitic material that has a conchoidal fracture, a density near 2.328, a hardness of 3 on the Mohs' scale, and an appearance like brown sealing wax. The brown rock grades outward patchily into material which is of similar form but is green and recognizably serpentinous, and which in turn grades outward into normal serpentinized peridotite.

Microscopic examination of the brown rock shows that it contains colourless, apparently isotropic material with a refractive index near 1.56, a red-brown iron oxide, and chromite. The iron oxide is concentrated in zones that form a network around areas of the isotropic material. The rock yields a diffuse pattern of chrysotile when investigated with an X-ray spectrometer. Study of rocks transitional between the brown type and normal serpentinized peridotite (which contains chrysotile and serpophite in mesh texture) shows that the apparently isotropic material is derived from serpentine, the iron oxide from magnetite, and that the net pattern is inherited from the pattern of magnetite in mesh serpentine.

The other occurrences of olivine regenerated from serpentine are in integral parts of the main ultrabasic mass.

Olivine of this type forms porphyroblasts in rock with a misleadingly porphyritic aspect, occurring on the eastern end of the sharp ridge between the north and middle forks of Retasket Creek and in one or more localities on near-by Shulaps Peak. The country rock in this general area is serpentinite, cut here and there by lenses of gabbroid and " white " rocks that are described in a later section. Weathered surfaces of the olivine-bearing rock are spotted with tan-coloured olivine bodies, mostly between 0.03 inch and 0.4 inch long, set in a green to black serpentine matrix (*see* Plate VIII). The pattern is less apparent on fresh surfaces. The olivine bodies are randomly arranged in much of the rock, but in some outcrops they have a planar orientation that strikes northward and is vertical or dips eastward. Olivine grains enclose coarse chromite grains that are parts of uninterrupted chromite-rich layers in a specimen from the southwest flank of Shulaps Peak.

Microscopic examination shows that the spotted rocks contain olivine, antigorite, chromite, magnetite, carbonate, and a vein-forming serpentine. The olivine bodies consist of single olivine grains or, more commonly, clusters. The olivine has a dusty brown appearance due to myriads of tiny inclusions. Larger identifiable inclusions are chromite and magnetite (*see* Plate XII). The chromite grains have opaque rims and irregular protuberances of a type found only on chromite altered during serpentinization (*see* section on chromite and its alteration). The olivine extinguishes evenly, in contrast to that in dunite and harzburgite which characteristically has undulatory extinction. Its optical properties indicate a content of approximately 87 molecular per cent of forsterite. Antigorite forms the groundmass in which the olivine grains and clusters lie. Blades of antigorite jut into olivine, but contacts of olvine grains with one another and with inclusions are not loci of serpentinization, a relationship in marked contrast with that in other olivine-bearing rocks.

Another example of regenerated olivine, not recognizable megascopically, occurs in foliated rocks at the head of Burkholder Creek and of the south fork of Retasket Creek. Weathered surfaces of these rocks are brown and have a pattern of narrow parallel green lines and dark-green lenticular mottles whose long axes are parallel to the lines. In distribution and size the mottles are similar to pyroxenes in harzburgite, but they do not weather in relief. On fresh surfaces the rock is dark green and the structure is indistinct.

Microscopic examination reveals that the foliation is the combined result of parallelism of lenticular aggregates of olivine grains, planar concentrations of opaque minerals, and rude layering in antigorite. The rock is composed chiefly of olivine and antigorite, together with some talc and carbonate which are younger than the other minerals. The olivine is the dusty type described above but is extremely fine grained. It occurs in tightly packed clusters and also as chains and networks that extend from chromite nuclei (*see* Plate XIII) and lie in the plane of foliation. The olivine in this rock is believed to have been regenerated from serpentine during dynamo-thermal metamorphism, the lenticular aggregates resulting in part from replacement of bastite. The following sequence of events is postulated. Peridotite was first serpentinized to mesh serpentine and bastite (no mesh serpentine survives, but ghost pyroxene structures remain). The mesh serpentine, and probably some bastite, was then replaced by bladed antigorite. This in turn broke down to form olivine. The formation of olivine probably commenced before all the bastite had been replaced by the bladed form of antigorite. (The ghost pattern of pyroxene would have been destroyed if all the bastite pseudomorphs had given way to bladed antigorite.) Finally, the regenerated olivine was partially serpentinized when metamorphic conditions became less intense, and the new serpentine was in turn partially replaced by carbonate and talc.

The regional extent of the development of regenerated olivine is unknown. Although the rocks in which it occurs were recognized as having an unusual appearance in the field, the presence of regenerated olivine was unknown at the time of the field work, and the rocks were not systematically sampled.

Carbonatization and Steatitization.—Bodies of silica-carbonate rock derived from peridotite occur chiefly along the Yalakom Valley and the valley of Marshall Creek and Liza Lake; namely, in northwest-trending zones on either side of the main ultrabasic mass. All such rock in the Yalakom Valley lies along the Yalakom fault zone. Some of the bodies in the western belt are related to definite faults or to sheared zones, but other bodies, with irregular rather than rectilinear outlines, are not obviously related to such structures.

The rocks are composed essentially of silica (chalcedony and quartz) and magnesitic carbonate, in varied proportions. Many contain partly altered remnants of serpentinized peridotite. The silica minerals occur in anastomosing veinlets and irregular masses in a matrix of carbonate. Weathered surfaces are buff or rusty coloured, and are rough because networks and knobs of silica stand in relief above the softer and more soluble carbonate. Fresh surfaces are grey, reddish, or grey flecked with red and green.

The carbonate generally is iron-bearing, hence the rusty weathered surfaces. Late veinlets of almost pure magnesite are present in most outcrops, and there are some veins large enough to have attracted the attention of prospectors, especially along the Yalakom fault zone north of Blue Creek, and near Liza Lake.

Rock types transitional between serpentinized peridotite and silica-carbonate illustrate the progress of the alteration, but the origin of the rock in outcrops consisting entirely of silica-carbonate is sometimes difficult to determine in the field. The criterion of origin used by the writer is the presence of chromite, which is little or not at all affected by the alteration.

Microscopic examination shows that the alteration commences through introduction of ramifying carbonate stringers into serpentinized peridotite. (No evidence of direct formation of silica-carbonate rock from unserpentinized peridotite was seen.) The zones of magnetite formed during serpentinization are commonly loci of early carbonate. Silica is not generally visible until carbonate is present in considerable amount. These minerals eventually replace all the serpentine. The rock then has a groundmass composed of an intricate fine-grained intergrowth of quartz and occasionally other forms of silica with feathery carbonate, cut by veinlets of the same minerals. Carbonate considerably exceeds silica in typical silica-carbonate rock. Many late veinlets consist of magnesitic carbonate in comb texture. Quartz or chalcedony is present in the medial openings of some of these veinlets, or along one or both walls, but repeated crustification of carbonate and quartz is not usual. Chromite grains show no sign of replacement by these minerals.

Steatitized ultrabasic rock is less abundant than carbonatized material. The zones of alteration are elongate in plan and appear related to fault zones. They occur chiefly in the vicinity of Greasy Peak. The rocks in the steatitized zones are talcose but by no means consist of pure talc. They are coloured in shades of grey, brown, and green, depending on their mineral content, and mostly weather brownish or yellowish, some with a pinkish cast. The specimens examined microscopically consist essentially of talc, carbonate, and serpentine minerals, with little or no olivine or enstatite. Steatitization took place after serpentinization, the talc and associated carbonate replacing serpentine minerals.

Chromite and Its Alteration.—Chromite is an accessory mineral in all Shulaps ultrabasic rocks and forms local concentrations in a few localities. The genesis and alteration of chromite are described in this section, but descriptions of particular deposits are included in the chapter on economic geology.

Chromite grains large enough to be visible to the naked eye are disseminated in almost all the rocks. They are easily visible on the " buckskin " and red-brown weathered surfaces of dunite and harzburgite but are less conspicuous on fresh surfaces and in serpentinite. Dunite contains proportionally more chromite than do harzburgite and pyroxenite. In layered rock chromite is concentrated especially in the central parts of dunite layers.

Microscopic examination of chromite in relatively unserpentinized peridotite shows that both euhedral and anhedral grains occur. Although euhedra may equal anhedra in number, they are smaller and consequently constitute only a relatively small amount of the chromite in the rock. Most disseminated grains large enough to be visible megascopically are anhedral. Euhedra and subhedra occur characteristically as inclusions in olivine and pyroxenes, whereas the anhedra are mostly interstitial to the silicate grains. The interstitial chromite does not enter cleavages or fractures in the silicates.

The disseminated chromite crystallized partly contemporaneously with olivine and pyroxenes (a small proportion may be older) and partly immediately after them; it is therefore all magmatic, partly late magmatic. The chromite in deposits consisting of lenticular, gradationally bordered concentrations has similar relations to silicates and is likewise considered magmatic. Much of the chromite in the deposit at the head of the south fork of Blue Creek (*see* Chapter III), on the other hand, forms veins, lenses, and irregular bodies with sharply defined walls. The constituents of the chromite in this deposit were mobile after the host rock was sufficiently consolidated to fracture, but the lack of alteration in the wallrocks suggests a lack of hydrothermal solutions. This chromite also is probably late magmatic.

Chromite in unserpentinized or relatively unserpentinized peridotite comprises, as already noted, a considerable proportion of euhedral and subhedral grains. The chromite (as seen in thin section) is uniformly translucent and red-brown from margin to centre. Microscopic examination of a series of successively more serpentinized peridotites reveals, in general, a progressive decrease in the proportion of chromite grains with euhedral outlines and an increase in the number that are partly or entirely opaque. (This generalization does not hold true in all cases. The chromite deposit above Marshall Creek lies in serpentinite, but the grains, as seen in thin section, are homogeneously red-brown; the original texture is destroyed by crushing, but some grains appear euhedral.) Many subhedral chromite grains in partially serpentinized peridotite were originally euhedral but have lost their former outlines through replacement by and accretion of opaque material. The opaque material is metallic-looking in reflected light and is more magnetic than chromite. Some is continuous with the magnetite (maghemite?) formed from silicates during serpentinization and appears identical with it.

Chromite grains disseminated in some of the partially serpentinized rocks are sheathed with chlorite. The sheaths are especially common about chromite grains in layers and lenses of dunite, whereas they are lacking in the essentially unserpentinized pyroxenites. They have no constant thickness, but many are about equal in width to the diameter of the grain they enclose. The sheaths about closely spaced grains tend to coalesce to form a zone with the appearance of a vein (*see* Plate IX). Weathered surfaces of the chlorite are dull dark green, and fresh surfaces are dark bluish grey. The chlorite and chromite weather in relief above the host rock (*see* Plate VII). A large proportion of the projecting masses are cup-shaped because the chromite they contained has disappeared. The disappearance is more likely due to mechanical than to chemical disintegration. The manner in which dark-weathering chlorite stands in relief above brown-weathering surfaces of the rest of the rock causes rapidly made estimates of the chromite content of the rock to be unreliable because less than half the material in relief may be chromite.

Microscopic examination shows that chromite grains surrounded by chlorite have either opaque borders and opaque material along fractures (*see* Plate XIV) or are entirely opaque. Few are euhedral, and the rim of chlorite around most of these is comparatively narrow (*see* square cross-section near top of specimen in Plate IX). The opaque material at least in part replaces translucent chromite. The replacement is irregular in many grains but in others it advances evenly from margins and fractures. The proportion of opaque material varies roughly with the width of the chlorite sheath. Grains surrounded by relatively wide sheaths or by coalesced sheaths have embayed and cuspate outlines and are split apart (*see* Plate XV); such grains are largely or entirely opaque.

The opaque material that rims and replaces the chromite that is sheathed by chromite is soft, has a red-brown streak, and is more magnetic than unaltered chromite. It has an earthy brown appearance in reflected light and does not take a polish. Powdered samples examined in transmitted light are seen to consist at least in part of granular aggregates of highly refringent yellow-brown or orange material. The material is probably in part an oxide of iron other than magnetite.

The chlorite has optical properties similar to those of the variety clinochlore. It contains myriads of tiny dark inclusions. The smoothly curving boundaries of chlorite sheathing chromite transect the structures of the surrounding mesh serpentine.

An association of chromite and chlorite has been noted in various parts of the world. Occurrences like that in Plate IX have been interpreted by some investigators (e.g., Fisher, 1929, p. 694) to mean that the chromite is hydrothermal. The present evidence shows that the chlorite occurs only with chromite. It has been observed that there is a relation between increased amount of red-brown opaque material in chromite grains (and concurrent destruction of crystal outlines) and increased amount of surrounding chlorite. Vein-like forms of chlorite are explained by coalescence of chlorite rims about adjacent chromite grains. This coalescence forms a " veinlet " which contains a more or less continuous succession of chromite grains and which commonly bulges outward around these grains. Chlorite is definitely later than chromite because it cuts through chromite grains and wedges them apart (*see* Plates IX and XV). Contrary to the conclusions of Fisher (1929) therefore, it seems that the chlorite is localized by the chromite and is formed by chemical reactions involving the chromite. In other words, the chromite in occurrences like that shown in Plate IX is, like the rest of the disseminated chromite in the rocks, believed to be magmatic, not hydrothermal.

During metamorphism in which mesh serpentine is replaced by antigorite, as described on page 33, the chlorite is likewise replaced by antigorite. The earthy brown opaque material meanwhile is apparently replaced by a mineral similar or identical to the secondary magnetite (maghemite?) in the rest of the rock, but intermediate stages in that process have not been observed.

Origin and Age.—Ultrabasic rocks occur, in general, in one of two ways. Some are parts of stratiform igneous complexes which consist largely of feldspathic rocks and which are believed to have formed by gravity-stratification during the crystallization of a gabbroic magma. Others lack uniform association with, or obvious genetic relation to, feldspathic rocks and commonly occur as separate bodies.

The Shulaps rocks belong to the second group because they are not, in their present state at least, part of a gravity-stratified complex. Gabbro and diopside-pyroxenite occur in and along the western edge of the main ultrabasic mass which contains westward-dipping compositional layers, and are thus "stratigraphically" in the position to be expected in a gravity-stratified complex, but nearly all layers within the gabbro, and much of the eastern contact of its main body, dip eastward in an opposed direction. Furthermore, the exposed gabbro is quantitatively greatly inadequate to complement the ultrabasic rocks. In general, individual bodies of gabbro and diopside-pyroxenite bear no simple structural relation to the Shulaps rocks. No gradations between the ultrabasic rocks and gabbro or diopside-pyroxenite have been found, but a genetic connection is neither proved nor disproved. Part of the gabbro is younger than the Shulaps rocks, though it is not necessarily appreciably different in age.

Petrologists disagree on the mode of emplacement of ultrabasic rocks of the second group, and there are two main schools of thought.

One school, led by N. L. Bowen (Bowen and Tuttle, 1949), denies the existence of ultrabasic magmas, and believes that intrusion is by solid flow of hot or cold ultrabasic rocks that formed previously as crystal accumulates or were derived directly from a peridotite substratum in the earth.

The other school, of which H. H. Hess (1948, p. 432) is a proponent, believes that these ultrabasic rocks were emplaced as fluid masses (possibly containing some olivine crystals) derived in some manner from the peridotite substratum. Hess believes, in addition, that emplacement can occur only once in a given zone. This school does not deny that some ultrabasic rocks, particularly those that are intensely serpentinized, may later move by solid flow during intense deformation.

The schools differ also as to the source of the volatiles responsible for serpentinization. The first believes them derived outside the ultrabasic mass. The second considers that they were largely contained within the fluid mass at the time of emplacement but that a lesser amount may be derived from wallrocks or other sources (Hess, 1933).

Although the evidence recognized in the Shulaps Range does not warrant a conclusion as to whether the ultrabasic rocks consolidated in their present positions or were consolidated elsewhere and reached their sites by solid flow, the following data bear on the problem.

Almost all the ultrabasic rocks have microscopic stress features. The olivine in particular shows strain and translation gliding, but this is not proof of intense deformation (Turner, 1942). The rocks were deformed before serpentinization, as is shown by the fact that mortar structure, ruptures in bent pyroxenes, and close-set parallel microfractures are loci of the earliest serpentinization, but the evidence does not indicate whether deformation took place during emplacement or later. The major zones of cataclasis that should occur if large crystalline ultrabasic masses were forced into new positions are lacking.

The main Shulaps mass has a certain structural uniformity, in that the compositional layers in all the rather widely separated areas in which layering is found strike in the northwest quadrant and dip southwestward or vertically. Rhythmic layers of this type are commonly considered to form by some mechanism involving crystal sorting and (or) fluid flow. If it is correctly presumed that the layers were at least as uniformly oriented when first formed as at present, and if the layers were formed elsewhere in the earth's crust, then they and their immediate surroundings were transported as a unit. This means that if emplacement was by solid flow, a mass about 7 by 2 miles in cross-section moved as a unit. An alternative explanation is that the various layered parts were emplaced separately and that their present parallelism is due to fortuitous rotation during emplacement. It is evident that considerable difficulties are encountered in attempting to explain the emplacement of the main Shulaps mass by solid flow.

Features of some of the satellitic bodies, however, could be explained by this mechanism. These bodies occur characteristically along formational contacts in sheared zones and in proven faults. They consist of serpentinite with innumerable slip-planes or of silica-carbonate rock formed from it. Serpentinite may originally have localized the sheared zones and faults in some instances, but in general it exists as isolated lenses which are seemingly inadequate to govern the fault positions, and it was more probably emplaced in pre-existing loci of active shearing. Emplacement might have been by solid or by fluid flow, but the presence of unmetamorphosed limestone in serpentinite (*see* p. 26) indicates low temperature and inactivity of hydrothermal solutions, conditions more likely to obtain during encirclement by plastically flowing serpentinite than during engulfment by ultrabasic fluid.

The following is a summary of facts bearing on the age of the Shulaps ultrabasic rocks. The main mass cuts Hurley strata (Upper Triassic). Chromite occurs in beds containing fossils suggestive of late Lower Jurassic age, so ultrabasic rock was probably unroofed by that time. The euhedral character of this chromite indicates a near-by source and, as the chromite-bearing beds are adjacent only to the main Shulaps ultrabasic mass, it is probable that this mass was the one unroofed. Euhedral chromite occurs also in strata of unknown age on the north flank of the Shulaps mass, and it is likewise probable that this mass was the source. These northern chromite-bearing strata are intruded by ultrabasic rock lying along the Yalakom fault, which also cuts the late Lower(?) Jurassic beds and bounds the Shulaps mass for 17 miles.

These relations may be explained by either of two hypotheses:—

(1) Ultrabasic rocks reached the Shulaps area at two or more times.

(2) All the ultrabasic rocks reached the Shulaps area at the same time but certain parts were later redistributed by solid flow.

Hypothesis (1) entails both pre- and post-late Lower(?) Jurassic intrusions, the younger of which would post-date at least some movement on the Yalakom fault.

Hypothesis (2) is based on the possibility of limited plastic flow of stressed ultrabasic rock. According to this hypothesis the Shulaps mass was intruded after Hurley strata were deposited and early enough to be unroofed in time to supply chromite to late Lower(?) Jurassic sediments. The altered ultrabasic rock in fault zones was originally part of the main mass but was squeezed from it at some later time or times. The writer favours this hypothesis. Consideration of the regional geology shows that Upper Triassic orogeny, younger than Hurley but older than Tyaughton strata, is probable.

Gabbro and Diopside-pyroxenite

Foreword.—Diopside-pyroxenite is related spatially to gabbro that contains a facies of like composition. For this reason its description is linked with that of gabbro, although no genetic relation can be proved.

Distribution.—Gabbro outcrops at the heads of creeks northeast and east of Liza Lake, on Jim Creek, and in the headwall of Peridotite Basin. It forms precipitous outcrops that stand out from adjacent slopes underlain by serpentinite. Massive diopside-pyroxenite adjoins part of the gabbro body on Jim Creek and outcrops with gabbro 6 miles to the northwest on a ridge separating the drainage areas of Liza and Noaxe Creeks.

Lithology.—The gabbro is typically a light to dark grey-green medium-grained rock, but grain size ranges from fine to pegmatitic. The outlines of the green ferromagnesian minerals (diopside or its alteration products) are distinct. The plagioclase is altered to cream-coloured or greenish material, and the outlines of the original grains are indistinguishable. Light-coloured minerals exceed dark minerals in average gabbro, with the most common ratio being 60 light to 40 dark, but the proportions are by no means constant and the range extends from a facies consisting entirely of pyroxene to one consisting (originally) of plagioclase.

Distribution of the various facies of gabbro is erratic. In some localities fine-grained facies are cut by coarser ones, and in other localities such types are gradational. Some outcrops are best described as composite gabbro.

Compositional layering, a significant exception to the usually erratic distribution of facies, occurs in five areas, each less than 30 feet in maximum dimension. All are on the headwaters of Jim Creek, and the northern one is about 1,000 yards from the southern. The layering, which is on inch scale, results from repetitive changes in mineral proportions. In three of the areas the layers consist of pyroxenite and feldspathic gabbro, and in the other two of gabbro and feldspathic gabbro. The layers are distinct but are gradational in detail. They strike parallel to the long axes of the individual areas in which they occur and fade into massive gabbro. Strikes are varied, but the dip is easterly in four areas and vertical in the fifth.

Microscopic examination of gabbro reveals that the diopside in it contains proportional ranges of elements expressed by $Ca_{46-47}Mg_{44-47}Fe_{7-9}$ (as indicated by optical properties). It is altered partly or entirely to hornblende, actinolite, and chlorite. Some hornblende in the rock may be primary. All the plagioclase is altered to combinations of oligoclase or albite and zoisite, clinozoisite, epidote, actinolite, and chlorite. Accessory minerals in the gabbro include sphene (partly altered to leucoxene), apatite, and ilmenite or magnetite. The classification of these rocks as gabbro depends, in the absence of unaltered plagioclase, on the proportion of original plagioclase to diopside and on the lack of significant amounts of primary hornblende.

Massive diopside-pyroxenite is medium to coarse grained, brown on weathered surfaces and dark green on fresh ones. It is darker than the pyroxenite facies of the gabbro, the difference being due chiefly to differences in alteration products. Serpentinization is the dominant alteration in massive pyroxenite, but most pyroxenite is less than 20 per cent serpentinized. Actinolite has developed in many specimens. The microscopic optical properties of the diopside indicate proportions of elements in the ranges $Ca_{45-47}Mg_{44-47}Fe_{6-9}$. Some diopside-pyroxenite contains very small amounts of olivine.

Structural Relations.—The main body of gabbro is exposed for 3½ miles with a plan width of 500 to 2,800 feet. The northern half is bounded by sedimentary rocks on the west and Shulaps serpentinite on the east. The southern half is bounded by serpentinite and diopside-pyroxenite. Much of the eastern (upper, topographically) contact dips northeastward and is overlain by serpentinite. The dip of the western (lower, topographically) contact is unknown but the southern tip is surrounded by serpentinite, and the body as a whole may be tabular.

The gabbro contains inclusions of Hurley strata 2½ miles east of Liza Lake and is thus younger than those strata.

Contact relations with Shulaps ultrabasic rocks are difficult to evaluate because most serpentinite looks sheared whether it is faulted or not. In some instances gabbro is finer grained against serpentinite than away from it, but in other instances no grain gradation is apparent. The evidence is conflicting, and interpretation is hampered by the inconstancy of grain size even within the main gabbro mass and by the possibility of the existence of unrecognized faults. Gabbro similar to that of the main body intrudes Shulaps rocks in the vicinity of Jim Creek. This fact, together with the position of the main body, which partly follows the ultrabasic-sedimentary contact and partly projects into the ultrabasic mass, suggests that the main gabbro body is younger than the Shulaps rocks, although it is not necessarily appreciably different in age.

Most of the diopside-pyroxenite occurs along the southwest (lower, topographically) and south contacts of the main gabbro body, but it is not a border phase of the gabbro. Small lenses were observed farther north along the western contact and one on the eastern contact. It outcrops also on Jim Creek, separated from the main gabbro by about 250 feet of sheared serpentinite.

Massive diopside-pyroxenite was not seen to grade into gabbro, although the gabbro does have internal pyroxenite facies. Contacts of massive pyroxenite against gabbro are sharp but provide conflicting evidence as to age. For example, gabbro increases in grain-size away from one part of a well-exposed contact but shows no change at another part of the same contact. Dykes or lenses of gabbro occur in pyroxenite near the main gabbro contact, and some gabbro therefore appears to be younger than pyroxenite, but similar dykes cut parts of the gabbro body itself.

Diopside-pyroxenite is in contact with Shulaps rock (serpentinite) in the vicinity of gabbro only. The contacts have a sheared appearance, and no chilled borders, apophyses, or gradational contacts were recognized. Adjacent serpentinite does not appear to have been derived from pyroxenite, and, in fact, pyroxenite adjacent to intensely serpentinized Shulaps rock is notably little altered.

Gabbroid Dykes and " White Rock " in Shulaps Ultrabasic Rocks

Small dykes and lenses of gabbroid rock and rock of apparently gabbroid origin cut Shulaps rocks. Some are similar to dykes that cut the composite gabbro, but most are modified by the ultrabasic wallrocks. Constituent minerals, where discernible at all, are visible only in the central parts of the bodies. The megascopically grained portions grade outward, by reason of decreasing clarity of grain boundaries, into dense light-coloured aphanitic rock, which in turn is in contact with ultrabasic rock. Small elongate or rounded bodies composed entirely of similar aphanitic rock are common in serpentinite, though not all can be proved to have gabbroid origins. Many are completely surrounded by the ultrabasic rock and have no physical connection with near-by masses. Some form zones of lenses (*see* Plate V), but most appear to have random distribution. The " white rock " was found in serpentinized Shulaps rocks only.

Microscopic examination shows that the dykes and lenses were originally composed essentially of plagioclase and augite or hornblende, or both, with abundant sphene and less ilmenite. The original plagioclase is now completely altered, and the rock consists of remnants of the other primary minerals accompanied by secondary plagioclase and hornblende, actinolite, chlorite, zoisite, clinozoisite, leucoxene, and colourless grossularitic garnet. Thompsonite and vesuvianite occur in some of the rocks. The garnet is a secondary mineral, derived in large part from the constituents of plagioclase. It is developed typically in the borders of dykes and in " white rocks," some of the latter consisting 40 per cent of garnet, but smaller amounts occur in the central portions of dykes.

Similar garnetiferous " white rock " is associated with ultrabasic rock in many parts of the world and has been called " rodingite " (Grange, 1927). The garnet grew in gabbroid rock altered by solutions, but the chemical reactions must also have involved the wallrock because the reaction products are peculiar to gabbroid rocks in ultrabasic surroundings. It has been observed that " white rocks " occur only in serpentinized portions of the Shulaps mass and that serpentinization is especially intense adjacent to gabbroid and " white " dykes. It is possible that solutions accompanying emplacement of gabbroid rock were responsible for the development of garnet and were also responsible for some serpentinization. These alterations might also be due to later solutions which followed structures that had previously guided the gabbroid intrusives. (It was pointed out in the section on serpentinization that neither process is believed accountable for most of the serpentinization in the Shulaps Range.)

Blue Creek Porphyries

Feldspar-hornblende porphyries, mostly quartz diorite, intrude ultrabasic rocks underlying the drainage area of Blue Creek and the adjoining slope of Yalakom Valley. They are especially abundant north of the middle part of Blue Creek. A large amount of this area is mantled with loose rock that obscures the outlines of the porphyry bodies.

The porphyries are sufficiently alike to allow description in a group, although textures range from almost equigranular and medium grained to markedly porphyritic with coarse phenocrysts in an aphanitic matrix; compositions range from quartz diorite to diorite. The rocks are believed to be related in origin, the textural differences being dependent on variations in conditions of intrusion.

Weathered surfaces are brown, buff, or grey, commonly so uniformly coloured that the rock appears at first sight to be even textured. Fresh surfaces show a pattern dominated by white or grey plagioclase phenocrysts in a medium-grained to aphanitic groundmass. Most of the plagioclase phenocrysts are between a tenth and a quarter of an inch long. Hornblende phenocrysts are conspicuous in most bodies. The colour of the groundmass ranges from " pepper and salt " and light grey through grey green to dark grey, depending upon grain-size and mineralogical freshness. Feldspar and hornblende are recognizable in the groundmass of the coarser and least-altered rocks. Quartz is not visible as a rule, but is seen readily in medium-grained rocks in the valley of the north fork of Blue Creek. Biotite occurs in quartz-diorite porphyry on the Elizabeth claims. Grain boundaries are poorly defined in many altered rocks in which the groundmass has a featureless dull-greenish appearance even when not truly aphanitic.

Microscopic examination of thin sections shows that even fresh-looking porphyries are so altered that their original compositions cannot be determined accurately. In certain rocks that megascopically retain a porphyritic appearance, the plagioclase is replaced completely by secondary minerals. The plagioclase phenocrysts were originally andesine and oligoclase-andesine and now consist chiefly of albite or albite-oligoclase, sericite, clinozoisite, epidote, chlorite, carbonate, and a brownish clay mineral. Original plagioclase zoning is reflected by concentrations of secondary minerals at the centres of phenocrysts and their disposition in concentric rings. The hornblende phenocrysts in the fresher rocks are altered partly to actinolitic amphibole and to chlorite, but in the more altered rocks are replaced entirely by chlorite, chiefly the variety penninite. The biotite present in a few samples is partly primary and partly formed from hornblende. The microscope shows that the groundmass of the porphyries consists essentially of feldspar, chiefly or entirely plagioclase, and hornblende, and their derivatives. Quartz was identified in more than half the specimens examined, sometimes in considerable quantity, and may be hidden in the extremely fine-grained groundmass of others. It is intergrown with feldspar in a few specimens. Much of it is primary, but some, and especially that associated with carbonate, is introduced and replaces minerals of the groundmass. Apatite is a characteristic accessory; sphene, magnetite, and ilmenite are common; and zircon is present sparingly. Pyrite occurs in most specimens and carbonate in all, replacing the groundmass and plagioclase phenocrysts. Carbonate is especially abundant near contacts with peridotite.

The bodies of porphyry range in size from lenses a few feet long to a stock that may be three-quarters of a mile across. They are varied in form. Flat-lying dykes, for example, can be found 1½ miles northwest of the mouth of Blue Creek, whereas a vertical plug 55 feet in diameter occurs on the ridge between the middle and south forks of the creek. Other bodies, such as those in a small canyon on the north fork, have decidedly irregular outlines. The porphyry that forms prominent bluffs on the north side of the creek 2 miles from its mouth has an exposed vertical dimension of 150 feet. The outcrop pattern indicates that the body is tabular and is floored and roofed by peridotite, but the possibility of its being the apex of a stock is not disproved.

Rexmount Porphyry

Rexmount porphyry derives its name from the settlement of Rexmount at the western foot of the Shulaps Range (Drysdale, 1916, p. 78). It comprises the summits from Windy Pass (between Hog and Shulaps Creeks) southward beyond the limits of the mapped area. A stock outcrops below timberline on Brett and Hog Creeks, and small masses occur on the eastern flank of the range adjacent to Shulaps Creek.

Lithology.—The porphyry is relatively uniform in all outcrops. It is light grey on both weathered and new surfaces and has an unaltered appearance. Typical porphyry contains megascopic phenocrysts in an aphanitic groundmass. Plagioclase, the most abundant phenocryst, is accompanied by aggregates of chlorite pseudomorphous after biotite, hornblende, and smaller hexagonal bipyramids of glassy quartz. Most plagioclase phenocrysts are less than a tenth of an inch long, but some attain a quarter of an inch. Porphyry in the stock on Brett Creek differs from that just described inasmuch as the groundmass is not aphanitic and quartz phenocrysts are scarce or absent; it may be more potassic.

Microscopic examination shows that almost all feldspar phenocrysts are altered, being riddled with minute flakes of sericite and a clay mineral, and lesser amounts of carbonate and chlorite. The most common feldspar is andesine, but many crystals are compositionally zoned, those in the Brett Creek stock ranging from calcic andesine to albite. The quartz phenocrysts, originally euhedral, are rounded and embayed. Hornblende, with an extinction angle of 20 degrees, is altered to biotite and, to a lesser extent, to chlorite. Primary biotite occurs also, but is mostly altered to chlorite (penninite), which is accompanied by epidote, clinozoisite, carbonate, and magnetite. The groundmass of the porphyry consists chiefly of quartz and feldspar. Most feldspar grains are too small for determination of composition, but all those identified were plagioclase. Apatite is the most abundant accessory mineral, and is accompanied sparingly by sphene, magnetite, and zircon.

Contact facies of porphyry show flow structures, with phenocrysts aligned parallel to the walls. The extreme chilled phase is marked by a dark glassy-looking zone an eighth to a quarter of an inch wide in which there are distinct phenocrysts of quartz and biotite and less distinct plagioclase. This chilled zone contains spherulites, all but a few of which are microscopic.

Structural Relations.—The porphyry on Rex Peak and the peak 1 mile to the northwest is part of a warped wedge-shaped mass that dips and thins to the northeast. The trace of the lower contact is exposed conspicuously on the western flank or the range, where the blocky grey porphyry rests on and sharply truncates dark strata of Cache Creek type. At Rex Peak the lower contact strikes north 70 degrees west and dips 35 degrees northward. The underlying strata dip at angles of 60 to 80 degrees, and are cut also by porphyry dykes that are parallel to and within 500 feet of the floor of the overlying mass. A 1,000-foot section of porphyry is exposed here, and the presence of several large inclusions near the top of the peak suggests that the roof was not far above the present summit. Both floor and roof are exposed in Windy Pass, where the body is only a few tens of feet thick and almost flat-lying. Shulaps Creek flows eastward along the northerly dipping roof contact, falling 1,900 feet in 3 miles. The lower contact is arched gently and is breached by erosion in the saddle and cirque between Rex Peak and the peak 1 mile to the northwest. The contacts lose their smoothness 1½ miles east of Rex Peak, and intrusion is irregular at and beyond the southern edge of the map-area.

The porphyry is closely jointed by three sets of joints. Two steep sets are approximately perpendicular to the floor of the wedge-shaped porphyry mass, and the third, less well developed, is parallel to it. The same relations obtain at the upper contacts. The flat-lying dykes below the main mass have columnar jointing perpendicular to their walls and closely spaced joints parallel to them.

The Brett Creek-Hog Creek stock is 1½ miles in diameter. The northwest border is vertical where crossed by Brett Creek, and contacts elsewhere are steep. The stock is closely set with steeply dipping joints.

Drysdale (1916, p. 78) and McCann (1922, p. 40) believed the age of the Rexmount porphyry to be Tertiary, possibly Eocene or Oligocene. McCann stated that at Jones Bluff, 3 miles southerly from Rex Peak, post-Lower Cretaceous (possibly Oligocene) sediments are overlain by andesitic tuffs, breccias, and agglomerates, which in turn are overlain by some Rexmount porphyry that he regarded as extrusive (1922, p. 39). The writer has not seen these exposures. In the present map-area the porphyry is all intrusive. It is in contact only with rocks of Cache Creek type and altered ultrabasic rocks, and is younger than both. It is older, however, than the basalt dyke near Burkholder (Johnson) Lake (*see* next section).

Minor Intrusions

Porphyries of various compositions, possibly not all instrusive, occur on Big Sheep Mountain 2 miles southwest of Noaxe Lake. They range in colour from light to dark, and in composition from types containing abundant quartz to those with little or none. Breccia occurs but was not seen in place. The porphyries are of two main types. That on the eastern end of the mountain is dominantly light coloured and contains phenocrysts of dull feldspar, quartz, and chloritized biotite, in an aphanitic matrix. The bold columnar-jointed cliffs at the head of the cirque on the north flank consist of dacitic porphyry with phenocrysts of plagioclase, altered hornblende, quartz, and magnetite, in a fine-grained or aphanitic groundmass. This rock contains inclusions of darker, more hornblendic porphyry. A mile southeast of the peak, across a tributary of Liza Creek, brown-weathering outcrops of andesitic porphyry contain phenocrysts of extremely glassy plagioclase, altered hornblende, and magnetite, in an aphanitic groundmass.

A small granodiorite intrusion is exposed a mile above the mouth of Brett Creek. It may be related to Rexmount porphyry.

Andesitic or basaltic porphyry, consisting of lustrous dark hornblende phenocrysts and a few much smaller plagioclase crystals in an aphanitic groundmass composed essentially of the same minerals, intrudes Rexmount porphyry a mile north of Rex Peak.

A basalt dyke cuts serpentinized peridotite a mile southeast of Burkholder (Johnson) Lake. It is 60 feet wide, vertical, and strikes west. There are numerous xenoliths of ultrabasic rock and Rexmount porphyry in it. The ultrabasic ones contain olivine regenerated from serpentine (described on p. 33). The basalt is brown on weathered surfaces, and pits mark the sites of olivine phenocrysts. The aphanitic groundmass has a trachytic texture and consists essentially of plagioclase and augite. The rock contains scattered zeolite amygdules.

Basalt outcrops, probably parts of a single dyke, occur on both sides of the ridge-top three-quarters of a mile northeast of the north end of Liza Lake. The rock has columnar jointing approximately perpendicular to the walls and contains numerous zeolite amygdules. Augite phenocrysts lie in an aphanitic groundmass that has a pronounced trachytic texture. The basalt is not ankeritized, though it occurs in an intensely ankeritized zone, and appears to have been injected after the ankeritization.

CHAPTER III.—ECONOMIC GEOLOGY

CHROMIUM

The largest concentration of chromite known in the Shulaps Range is northeast of Marshall Creek midway between Brett Creek and Marshall Lake, at an altitude of about 5,500 feet. The exposure is on a 35-degree slope in the lower part of a belt of serpentinite 900 feet wide. The serpentinite is highly sheared. Some of the planes are faults, but many are merely the anastomosing slip-planes characteristic of serpentinite. The rock in immediate contact with chromite is light coloured and talcose.

The chromite-rich zone is exposed for 20 feet along the hillside and for about 12 feet up-slope. The eastern end is partly truncated by small faults and the southeast corner is hidden by talus. No extension of the zone is visible in adjoining outcrops to the east. The western end is 12 feet wide where it disappears under talus, but the serpentinite 20 feet distant on strike is barren. Most of the chromite is contained in eight or more bands and lenses whose aggregate area is about 50 square feet. Most of them dip into the hill, but their shapes are determined largely by shearing. Another 30 square feet is covered with a succession of thin shear-slices of chromite and serpentinite that lie parallel to the slickensided outcrop-surface and may not extend into the hillside. In the deposit as a whole, shearing has smeared one type of material over another, so what looke like solid chromite may be only a thin veneer on a slip-surface, or, conversely, what appears on the surface to be barren silicates may be massive chromite only thinly covered. The chromite-rich material consists of closely spaced grains with interstitial silicates, but silicate-free aggregates of hand-specimen size are present. Talc and serpentine minerals are accompanied by smaller amounts of white carbonate and mauve kaemmererite.

A sample of purified chromite from this deposit contained the following weight percentages:—

	Per Cent		Per Cent
Cr_2O_3	57.43	CaO	Trace
Al_2O_3	7.44	H_2O+	0.40
Fe_2O_3	5.08	TiO_2	0.08
FeO	12.09	SiO_2	3.58
MgO	13.57		
MnO	0.43		100.10

—Analyst, S. W. Metcalfe, British Columbia Department of Mines.

The percentage of SiO_2 is an indication of the amount of impurities in the sample, chiefly thin coatings of talc and serpentine minerals on the chromite particles.

Eight hundred feet west of this deposit there is a chromite lens 3.5 feet long and 1.5 feet wide. A smaller lens lies 80 feet still farther west. A third of a mile northwesterly from the deposit just described, and separated from it by a tributary of Marshall Creek, seven closely spaced small lenses of chromite outcrop in intensely serpentinized peridotite. They are of the order of 1 to 2 feet long and less than a foot wide, and do not occur in any regular pattern.

The second largest concentration of chromite known to the writer is at an approximate altitude of 8,650 feet on the east wall of the southernmost compound cirque drained by the south fork of Blue Creek. The deposit is of genetic rather than economic interest. The harzburgite country rock contains irregular bodies of dunite and enstatite-pyroxenite. The rocks are relatively unserpentinized. Chromite occurs in all three types.

The chromite in this deposit differs from that elsewhere in the range in that a large proportion is massive and has sharply defined unsheared contacts with adjoining silicates. The bodies of massive chromite are small. None seen by the writer is longer than 7 feet or wider than 8 inches, and most are of the order of 6 inches long and 1½ inches wide.

They are in random orientation with respect to one another and to the margins of the enclosing rocks. Some are smoothly lenticular, some crescent shaped and cuspate, and others are markedly irregular. Most have sharp boundaries, but a few are gradational, especially those in dunite. No chlorite is present. Considerably less than a ton of chromite was estimated to be visible in the area 60 feet square which contains nearly all the massive material. The surrounding rocks contain small amounts of disseminated chromite.

A purified sample of chromite from this deposit contained the following weight percentages:—

	Per Cent		Per Cent
Cr_2O_3	59.33	MnO	0.16
Al_2O_3	10.78	CaO	0.23
Fe_2O_3	0.78	TiO_2	0.14
FeO	14.91	SiO_2	0.63
MgO	13.32		
			100.28

—Analyst, S. W. Metcalfe, British Columbia Department of Mines.

Recalculated to eliminate the small amount of silicate gangue (enstatite and diopside), the composition of the chromite in molecular percentages of R_2O_3 and RO, after the method of Thayer (1946), is $Cr_{77.9}Al_{21.1}Fe_1(Mg_{60.9}Fe_{39.1})$. Expressed in normative form (Thayer, 1946, p. 205), this is:—

	Per Cent
Chromite (Mg,Fe) Cr_2O_4	77.9
Spinel (Mg,Fe) Al_2O_4	21.1
Magnetite $FeFe_2O_4$	1.0

The ratio Cr:Fe is 3.37:1.

GOLD

Blue Creek

Elizabeth Group (Bralorne Mines Limited).—[References: *Minister of Mines, B.C.,* Ann. Rept., 1941, p. 58; 1946, pp. 98–101; 1947, pp. 132–133; 1948, pp. 95–96; 1949, p. 104.]

Introduction.—Bralorne Mines Limited owned or controlled in 1949 forty-one surveyed Crown-granted mineral claims and fractional claims in the northern half of the drainage area of Blue Creek. The claims are about 35 miles from Lillooet in a direct northwest line or 48 miles by a fair road via Moha. Nearly all are above timberline.

The company's activity at Blue Creek began in 1941 with the optioning of recently located claims and locating of additional claims. Late in the field season of that year four quartz veins were explored by stripping and short diamond-drill holes. Exploration was continued in 1942 but was suspended for the duration of the war. In 1947 the road from Lillooet via Moha was extended to the property, frame buildings were constructed at an altitude of 6,630 feet, and underground work commenced. Underground exploration continued till May, 1948, when the road was destroyed by floods of the Yalakom River. By that time the crosscut was 2,204 feet long, and 1,230 feet of drifts had been driven on two veins intersected by the crosscut. In 1949 a raise was driven on each vein and newly discovered vein outcrops were stripped.

General Geology. — The claims are underlain by peridotite intruded by dioritic porphyries, chiefly quartz diorite. The veins explored are in porphyry, on Elizabeth Nos. 1 and 2 claims where work was concentrated, and on Yalakom No. 2 claim.

The crest of the ridge straddled by the Elizabeth group consists of glacial deposits, partly arranged in rude layers that dip gently eastward. Bedrock is at or close to the surface on the upper flanks of the ridge but is obscured by loose rock. Outcrops are scarce on the rubble-covered lower slopes.

The peridotite is typical of that in the rest of the Shulaps ultrabasic mass. Most of it is intensely serpentinized.

A zone of silica-carbonate alteration of serpentinized peridotite is exposed at intervals for 3,000 feet from the northwest corner of Yalakom No. 1 claim to the northern part of Plateau No. 2 claim. The silica-carbonate rock resists erosion and stands as a rusty uneven rib on the hillside. This is referred to locally as "the Bralorne dyke." The exposed parts range from 30 to 70 feet in width and the zone appears to be vertical. It lies between serpentinized peridotite on the west and quartz-diorite porphyry on the east. The porphyry along parts of the zone, especially at its northern end, is affected by the same alteration. It weathers rusty, has a yellowish cast on fresher surfaces, and grain outlines are indistinct. It is cut by irregular stringers and veinlets of quartz. Pyrite occurs in and adjacent to the quartz. The "Bralorne dyke" zone is due to action of hydrothermal solutions guided by what may be a fault or merely the intrusive contact of porphyry against peridotite.

The two largest outcrop areas of quartz-diorite porphyry, on Elizabeth Nos. 1, 2, and 3 claims and on Yalakom No. 2 claim, are, respectively, on the southeast and north slopes of the ridge containing the mine workings. The intervening crest is covered by glacial deposits that would hide a connection, if any exists, between the two masses. Their outlines are complicated by the presence of irregular offshoots and satellitic bodies of similar rock, and by faults.

Typical porphyry in the main outcrop area is grey on both fresh and weathered surfaces. Crystals of plagioclase and generally of hornblende, the most conspicuous constituents, are surrounded by slightly smaller or much smaller (medium to fine) grains of the same minerals. Quartz occurs in considerably lesser amounts and is not everywhere visible. Biotite is present in some of the rocks, which differ in this respect from the rest of the Blue Creek porphyries. Contact facies are more markedly porphyritic in appearance because the groundmass is finer and darker.

The rocks in the smaller outcrops, some of which may be continuous with the main masses, range in appearance from distinctly porphyritic to equigranular, and in composition from quartz-rich quartz diorite to diorite. Some contain introduced quartz.

Zones containing rock of aplitic appearance cut the quartz diorite adjacent to quartz veins on the western part of Elizabeth No. 1 claim. This rock was not studied microscopically, but rock of somewhat similar appearance exposed in the crosscut is intensely altered porphyry, not aplite.

Specimens collected from drill core and underground workings on Elizabeth No. 1 claim prove, on microscopic examination, to have been initially quartz-diorite porphyry, although the original character of some is masked by alteration. The plagioclase phenocrysts were originally andesine or oligoclase-andesine but now contain albite-oligoclase, sericite, epidote, clinozoisite, and clay-like material. The hornblende is partly altered to biotite in a few specimens and to chlorite in all of them. Primary biotite occurs also. Quartz is present in the groundmass of all specimens examined. Part is an initial constituent, but some is introduced, replacing minerals of the groundmass. Quartz does not form phenocrysts, and what appear at first sight to be phenocrysts are actually rounded aggregates of interlocking quartz grains.

Surface Workings.—At least four quartz veins in quartz-diorite porphyry are exposed in outcrops and trenches in the southwest half of Elizabeth No. 1 claim and the northeast half of Elizabeth No. 2 claim. The exposures are between 7,150 and 7,600 feet in altitude, and the hillside above and below them is covered by drift and mantle rock. With one exception they strike northeastward, roughly contouring the slope. A faulted vein in Elizabeth No. 2 claim strikes northwestward.

The exposures were examined by J. W. McCammon in 1946 (*Minister of Mines, B.C.*, Ann. Rept., 1946, pp. 98–101), at which time the trenches were mostly caved and part of one vein was covered by snow. The same conditions prevailed at the writer's visit.

McCammon described the veins as follows:—

> The one designated herein as No. 1 vein, which has been called the "High Grade" vein, occurs highest on the hill. The exposure follows the contour from east to west for some 600 feet, and at the northeast end the vein was still covered by snow late in August. At one place near this end considerable free gold was seen in the quartz. Sulphides are very scarce. The vein appears to be of the fissure type. Late movement has sheared and fractured the quartz, giving it a ribboned appearance. Wall-rock alteration is slight. At present the vein can be seen only in the quartz-diorite. The width of the vein seen varies from a few inches up to 46 inches at the extreme south-west end. It strikes from 20 degrees to 40 degrees west of south and stands vertical.
>
> The second vein occurs some 200 feet lower, down the slope from No. 1 vein. Going from east to west, the first exposure consists of a sheared mass of vein-quartz and wall-rock approximately 6 feet wide. This strikes south 8 degrees west and dips 68 degrees to the west. No mineralization was visible. The next exposure on what is presumably the same vein occurs 110 feet to the south-west. The vein is exposed for about 100 feet along the strike south-westerly from this point. It averages 24 inches wide and consists of ribboned, fractured, and slightly rusty quartz. Wall-rock alteration is slight. The average strike here is south 38 degrees west, dip 70 degrees to the north-west. The two exposures of vein, separated by an area of heavy talus, are assumed to be segments of one vein offset by faulting, which would also explain the change of strike. . . .
>
> Vein No. 3 is exposed by four small cuts over a total length of 100 feet on a small bench below No. 2 vein. The exposures are in grassy talus, but the vein appears to be in-place in much-fractured quartz-diorite. The vein as exposed averages 37 to 42 inches wide. It strikes south 70 degrees west and dips 79 degrees to the south. The quartz is fractured but not so ribboned as in veins No. 1 and No. 2. Very little mineralization is visible.
>
> The No. 4 vein, exposed in a dry wash about 900 feet west of No. 3 vein, has been found only in quartz-diorite. There is much small cross-faulting but not much shearing parallel to the vein. The vein varies from 25 inches wide at the lowest part of the exposure to 3 inches wide at the highest part. Little mineralization is visible in hand specimens. The vein strikes north 60 degrees west and dips 65 degrees to the north-east.

There are indications of another vein between those designated No. 1 and No. 2 by McCammon. There are indications also that a separate vein, or a branch vein, occurs immediately southeast of the western exposure of the group designated No. 2. Sheared serpentinite occurs near the eastern exposure of that group.

Samples were taken from each vein by McCammon. One taken near the north-eastern end of the exposure of No. 1 vein across a width of 29 inches assayed: Gold, 0.08 ounce per ton; silver, *nil*. The others assayed: Gold, *nil*. The values in samples taken by Bralorne Mines Limited were erratic but more encouraging.

Boulders of gold-bearing quartz occur on Yalakom No. 2 claim. Their discovery in 1949 led to stripping that uncovered a vein in porphyry on that claim.* These workings exposed a vein, strike northerly, dip 70 degrees westward, that is 2 to 3 feet wide and traceable for 200 feet. This vein has been named No. 9. Although No. 9 vein in the cuts contained encouraging amounts of gold, it did not contain the spectacular free gold found in the float, and there is some doubt about its being the source of that float.

Underground Workings (1949).—The main underground workings in 1949 consisted of a crosscut 2,204 feet long, 1,230 feet of drifts on two veins, and two raises totalling about 340 feet in length (*see* Fig. 3). Besides these workings there are four adits, each driven a few sets only, two in overburden about 500 feet southwest of the camp and two, now caved, in serpentinized peridotite west and north of the camp.

The crosscut is driven north 87 degrees west from a point in the southern part of Churn No. 1 claim to a position in the southwest corner of the adjoining Elizabeth No. 1 claim. The eastern (outer) third of the crosscut exposes serpentinized peridotite cut by small dioritic bodies. Peridotite is subordinate to quartz-diorite porphyry in the middle third. The western (inner) third, from which drifts follow the two quartz veins, is entirely in porphyry. A hole drilled ahead from the face of the crosscut is reported to cut porphyry along its entire length of 580 feet. Another drill-hole, collared on the north wall of the crosscut, 35 feet from the face, and striking approximately north 60 degrees west, shows porphyry to extend in that direction for at least 200 feet.

* *Minister of Mines, B.C.,* Ann. Rept., 1949, p. 104.

The quartz veins and stringers exposed underground are in porphyry and occur in fractures that strike northeastward and dip 55 to 80 degrees northwestward. Their disposition is governed by a combination of fracture pattern and rock type.

The dominant structure is a system of moderately to steeply dipping fractures and slips striking northeastward and dipping, in the main, northwestward. Porphyry and serpentinized peridotite reacted differently to stresses. The brittle porphyry failed along " clean " fractures and by brecciation. The serpentinized peridotite failed along a multitude of small tight slip-surfaces, rather than by brecciation. In addition, the more extensive faults in serpentinized peridotite are mostly filled with gouge.

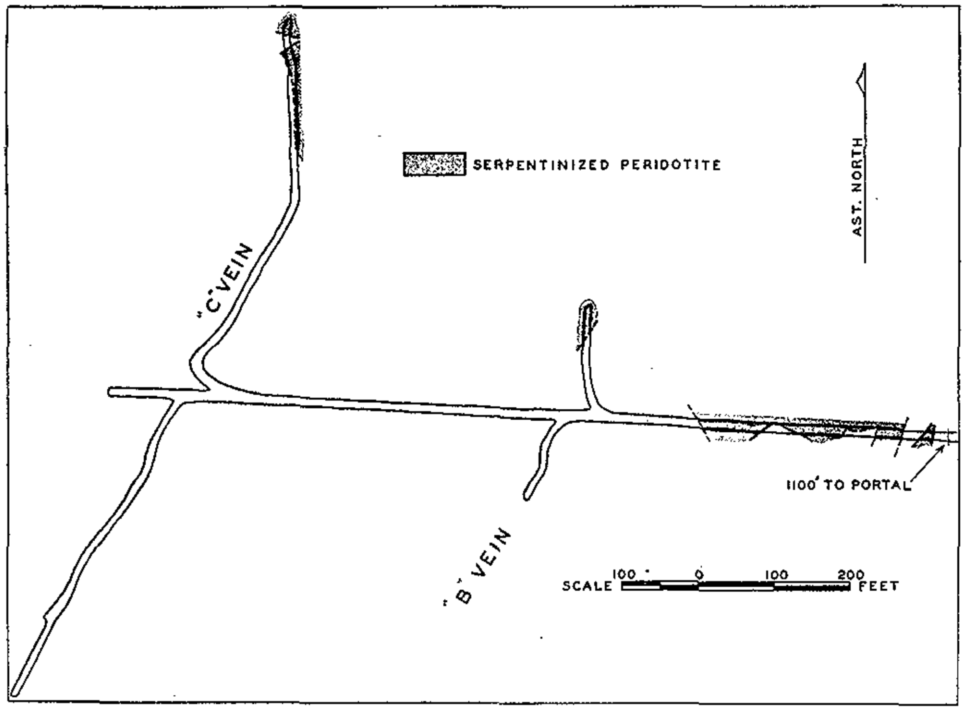

Figure 3. Plan of Elizabeth adit.

Quartz stringers are numerous in the body of fractured porphyry bounded on the east and west by peridotite and exposed in the middle third of the crosscut, but the important veins lie in the main stock of porphyry.

The two veins drifted on in 1948 were intersected at 1,611 feet and 2,103 feet, respectively, from the portal of the crosscut. Their relationship to veins at the surface has not been determined. They are described below. Another vein, intersected at 2,164 feet, is 9 inches wide. The hole drilled on the line of the crosscut from its face is reported to have cut additional quartz veins 2 feet and 7 feet thick, at 218 and 436 feet respectively.

The eastern or " B " vein is continuous for 150 feet. The average strike is north 24 degrees east, and the dip ranges from 65 to 80 degrees northwest. The vein is 5.8 feet wide in the crosscut, and in the drift that extends 113 feet southward it maintains its width for 40 feet. Beyond this point the drift reveals only disconnected quartz veins, lenses, and stringers in fractured porphyry, the largest now visible in the back being 20 feet long and 1.5 feet in maximum width. About 60 feet south of the crosscut a raise extends to a point 271 feet from the level. The vein is intersected near the top of the raise and is there 4 feet wide.

The northern part of " B " vein is followed by a drift that intersects it 65 feet from the crosscut. The vein at this point is 3 feet wide, the footwall is a slip-surface, and the fractured porphyry of the hangingwall contains quartz stringers. The vein narrows northeastward and in 27 feet thins to 1.5 feet, but is by then accompanied on the hangingwall by a 2-foot zone of stringers. The vein fracture then swings north, retaining the westward dip, and in another 20 feet enters serpentinized peridotite, where it contains only 1 to 2 inches of quartz. The drift terminates in peridotite, 81 feet north of the point where it intersected " B " vein.

The western or " C " vein occupies a shear zone that strikes north 30 degrees east (except at its northern end which strikes north) and dips 50 to 70 degrees westward. The shear zone has been traced for 920 feet, the southern 810 feet entirely in porphyry and the northern 110 feet along a contact of porphyry and peridotite. It is strong at the southernmost end of the workings, in porphyry, but is not well defined in the northernmost end, in and on the contact of serpentinized peridotite. The exposed width of the shear zone ranges from 2 to 10 feet. Along most of the zone the walls are marked by pronounced slip-planes, and the intervening space is laced with subsidiary shears or, less commonly, merely brecciated. Quartz occurs along nearly all of the zone in porphyry, but no single vein extends the whole distance.

The greatest thicknesses of solid quartz are in the section extending 80 feet south and 300 feet north of the crosscut. Quartz is continuous over this distance, partly as a vein as much as 8 feet wide and partly as a series of veins or long lenses 1 to 3 feet wide connected along the strike of the zone by groups of stringers.

North of this section 70 feet of the shear zone contains a fairly continuous vein averaging 6 to 8 inches wide. Still farther north the zone contracts to a single shear on the contact between porphyry and peridotite, and contains only a few small lenses of quartz.

Southward from the greatest thickness of quartz the strongly developed shear zone is 2 to 7 feet wide. It contains a series of lensing and overlapping quartz veins and stringers whose composite width ranges from nothing to 3.5 feet. Quartz is exposed continuously along the southernmost 225 feet of the drift, the veins containing abundant fragments of porphyry.

Ribbon structure occurs in the veins, especially in the southern part of " C " vein, and inclusions of wallrock are common. The opaque white vein quartz has been fractured more than once. Early fractures are filled with clearer, darker quartz that is cut in turn by fractures containing dolomitic carbonate. Sulphide mineralization is sparse. Pyrite is disseminated in quartz and along fractures. Small grains of an unidentified dark-grey sulphide have been noted, and limited amounts of green stain indicate the presence of a copper mineral. Miscroscopic examination shows that the quartz contains myriads of cavities, each containing liquid and a bubble, which impart a " dusty " appearence except under high magnification.

Alteration of wallrock along veins is not intense, but some porphyry, especially fragments included in veins, is rendered uniformly dull grey and the porphyritic texture is obliterated. Microscopic examination shows that the plagioclase is intensely sericitized and albitized and that pyrite and considerable quantities of quartz have been introduced. Introduced quartz is characterized by abundant liquid-gas inclusions. Adularia is associated with inclusion-filled fine-grained carbonate along the walls of fractures whose centres contain clearer, coarser carbonate.

The gold content of the veins found underground has not been sufficient to sustain undiminished the optimism aroused by original surface discoveries.

Other Properties on Blue Creek

In 1949 some seventy claims were held by location surrounding and east of the Elizabeth group of Crown-granted claims. Twenty-four were owned by Harry Reynolds, nineteen by Francis Billings, twelve by R. Boud, six by Egil Willman, six by L. Hansen, and three by Sophia Hansen. Twenty of Reynolds' claims were on the ridge between the south and middle forks of Blue Creek, south of the Elizabeth group. This ground is underlain by intensely serpentinized peridotite cut by scattered small dykes, lenses, and plugs of dioritic porphyries. Surface work exposed quartz stringers in a few of the porphyry bodies and a 17-foot adit was driven in serpentinite near the middle fork of Blue Creek. Four other claims were east and north of the Elizabeth group. Ten of Billings' claims extended eastward from the southeast corner of the Elizabeth group, four were north of it, and four southwest of Reynolds' main group. Trenches and pits were dug in the vicinity of small bodies of porphyry. Willman's claims adjoined the southwest part of the Elizabeth group and Reynolds' claims, in a peridotite area with few outcrops. Boud's claims were along the north fork of Blue Creek and extended eastward from the northeast part of the Elizabeth group. The serpentinized peridotite here contains numerous intrusions of porphyry. Some of these are fractured and contain disseminated pyrite and quartz stringers, but assays are stated to have indicated negligible gold values. The claims of S. Hansen and two of L. Hansen's were adjacent to Boud's, where the geology is similar. Four other claims of L. Hansen are farther east, along the silica-carbonate zone of the Yalakom fault. They contain magnesite veins that are described in a succeeding section.

Cromer Creek

A quartz vein in sedimentary rocks on the south bank of Cromer Creek 1 mile northeast of Liza Lake is explored by an adit. The wallrocks at the portal strike south 10 degrees east and dip 75 degrees east. The vein and its offshoots are controlled by a shear zone that strikes south 50 degrees east and dips 50 degrees northeast at the portal, but which thereafter curves gently eastward and sends successive branches into the hangingwall. The zone is cut by a cross-shear. The workings consist of a 77-foot drift, from which two stub drifts turn into the hangingwall. The vein is 2 feet wide at the portal and widens just inside, but it splits; and the branches narrow downward and along the strike. The quartz is white and vitreous and contains a few small vugs. No sulphides were seen, but their presence is indicated by small limonite-filled pits. Three chip samples of quartz taken in different parts of the workings assayed *nil* in gold and silver.

Two hundred feet south of the adit a 1.5-foot vein, striking north 85 degrees west and dipping 30 degrees north, is exposed for 50 feet along the hillside. Two hundred and fifty feet farther south a trench exposes a 1-foot vein that strikes north 20 degrees west and dips 65 degrees northeast.

Jim Creek

Placer-mining has been carried on to a limited extent in the canyon of Jim Creek, but the production is not recorded.

MANGANESE

Manganiferous rocks are exposed on the north face of a steep-sided knob 1 mile southwest of Rex Peak. The knob consists of strata that differ from rocks of Cache Creek type exposed farther east and are probably separated from them by a fault. The exposed manganiferous zone is about 300 feet long and about 80 feet wide. The eastern end is covered by talus. Part of the upper border is a fault containing breccia. Quartz stringers, and disseminations and stringers of pyrite occur in a rusty-weathering area near the west end of the upper part of the manganiferous zone. Most of the manganiferous rock is black and dense, somewhat cherty looking, with a purplish sheen on weathered surfaces, but some is red-brown. Joints and fractures are coated with manganese oxides, and in consequence the apparent manganese content of outcrops and talus blocks is deceptively high. Microscopic examination shows that the black manganiferous rock consists of small opaque grains disseminated in a matrix of silicate minerals. Magnetite is a major constituent. A sample of selected black manganiferous rock assayed 6.27 per cent manganese. A selected sample of red-brown manganiferous rock assayed 8.49 per cent manganese.

The manganese showings have been located more than once, but little or no work has been done on them.

MERCURY

Red Eagle

[References: *Dept. of Mines, B.C.,* Bull. No. 5, 1940, pp. 68–70; *Minister of Mines, B.C.,* Ann. Rept., 1941, p. 80; 1942, p. 77; *Canada, Dept. of Mines and Resources,* Bureau of Mines Pub. No. 797, pp. 55–57.] This cinnabar deposit is on a steep ridge above the west side of Yalakom River immediately northwest of the mouth of Shulaps Creek. Claims were located in 1937 and explored until 1942. About half a dozen 76-pound flasks of mercury were produced in 1941–42. The workings consist of two adits and some eighteen open-cuts and strippings.

The most complete description of the deposit, in Bulletin No. 5, appears to be based on an examination carried out in 1938, before many of the excavations were made. By 1948, when the writer visited the deposit, one adit had caved, the other was in bad condition, and most of the surface workings had slumped; in consequence the study of the mineralization was confined chiefly to chunks of ore piled near excavations, and proper estimation of quantity or distribution was impossible.

The workings follow the contours of the slope at an altitude of 2,975 feet and are reached by a trail that branches from the Yalakom road 600 yards north of Shulaps Creek. They are at the top of a series of bluff outcrops and steep slopes that rise 400 feet above the river. The almost equally steep hillside above the workings is practically devoid of outcrops except near its crest, 800 feet higher.

The country rocks are green andesitic lavas interbedded with purple and green volcanic breccias and cut by small quantities of apparently related dioritic rock. They lie in the Yalakom fault zone, are considerably fractured, and are locally ankeritized. The strike is northwesterly and the dip probably northeasterly, but bedding is obscure. At the workings, lava is apparently overlain by volcanic breccia, but only a little breccia is exposed, and there is no indication of its extent under the detritus mantling the slope above the workings. The long axis of a zone of ankeritization about 20 feet thick coincides roughly with the lower contact of the breccia. This zone, or perhaps a series of zones, can be traced 700 feet along the hillside. The principal workings are at the southeast end of this belt. The pattern is complicated by the presence of masses of relatively unaltered rock within the zone of ankeritization and by irregular areas of ankeritization in the adjacent country rocks, especially in volcanic breccia. The ankeritized rock weathers buff or rusty-brown. Fresh surfaces are mottled in shades of cream, buff, brown, purple, and green, the proportions depending upon the relative amounts of carbonates, silica, and unreplaced volcanic fragments in the rock. It is laced by stringers containing dolomitic carbonate and varied amounts of quartz. Veins of similar composition reach 1 foot or more in thickness, and smaller ones occur in relatively unankeritized volcanic breccia near by.

Cinnibar occurs in part of the intensely ankeritized zone and also in adjacent crushed volcanic breccia. It forms short narrow stringers, blebs, disseminated grains, and films on fracture planes. Some occurs in dolomite veinlets, but most appears to exist haphazardly in all constituents of the partly or completely ankeritized rock, and in purple fragments within adjacent sheared volcanic breccia. Pyrite occurs sparsely.

The accessible adit, about 100 feet long, passes through rotten, sheared, partly ankeritized breccia. At the face there is a film of cinnabar on a slip-plane, and a few blebs were seen on one wall.

Golden Eagle

[Reference: *Dept. of Mines, B.C.,* Bull. No. 5, 1940, pp. 64–68.] This cinnabar deposit is on the eastern bank of Yalakom River 1 mile above Shulaps Creek, almost directly across the valley from the Red Eagle property. It was located in 1938 and prospected until 1941. A small crude retort was built at the water's edge below the showings, but there is no record of production.

The showings are on a steep slope that rises 1,800 feet above the river and consists of bare rocky ridges separated by broad talus slides. The main showings are 250 to 300 feet above the river. The hillside below is almost entirely talus covered, but outcrops are extensive at and above the showings.

Two series of rocks underlie the slope. The lower, which extends from the river at an approximate altitude of 2,625 feet to 3,800 feet, is principally volcanic. The upper, which extends another 500 feet to the summit, consists of Lower Cretaceous sediments. The bottom 400 feet of the hillside is underlain by andesitic volcanic breccias, chiefly purple but some green, with which are interbedded smaller quantities of bluish tuff and grey-green and jaspery chert. The average strike is north 70 degrees west, and the average dip is 55 degrees northeasterly into the slope, but there is much local crumpling, crushing, and faulting. Parts of this succession are ankeritized. The chief cinnabar occurrences are in purple volcanic breccia and its ankeritized equivalents. At 2,850 feet, about 100 feet above these showings, the prevailing fragmental succession gives way to one composed dominantly of massive green andesitic lavas. This succession, which contains some volcanic breccia and chert, composes the remainder of the volcanic series. Both this series and the overlying Lower Cretaceous sedimentary series are described more fully in the section entitled "Rocks within and East of the Yalakom Fault Zone."

Cinnabar exists in at least four localities on the hillside. The most important occurrence, referred to here as the main showing, was prospected with open-cuts and strippings, perhaps a dozen in all. A second cinnabar occurrence is about 700 feet northwest of the main deposit, at the same elevation. Here a few grains and blebs of cinnabar were noted in a shear zone in volcanic breccia. A third occurrence is near river level below the second, where an open-cut in an ankeritized shear zone is reported (R. Land, personal communication, 1948) to have exposed a little cinnabar. A fourth occurrence is at an altitude of 3,800 feet, almost directly above the main showings. Here a few grains of cinnabar were reported (Bull. No. 5, p. 67) in dolomitic veinlets in the lower part of an ankeritized zone along the contact of the volcanic series and the Lower Cretaceous sedimentary series. The cinnabar is younger than at least most of the ankeritization, which in turn is post-Lower Cretaceous.

At the main showings the cinnabar is in and near remnants of purple volcanic breccia in an ankeritized zone. The zone trends northwestward along the hillside, roughly parallel to the rock structure, and the exposed width is as great as 350 feet at the showings. The upper side is about 150 feet above the middle of the cinnabar showings, in a group of cherts, jaspers, and tuffs that underlie the lava sequence. The zone consists of dense ankeritic carbonates, unreplaced remnants of breccia, and a considerable though inconspicuous amount of silica. There are representatives of all stages of alteration, from purple and green breccia to brownish carbonate-silica rock. The zone is laced by white veins containing crystalline dolomite and varied amounts of quartz and, in some instances, calcite. Most are mere stringers, but a 4-inch vein was traced 25 feet. They vary erratically in size and attitude and form no obvious pattern, though possibly a strike of north 70 degrees east is most common.

At these main showings the area in which cinnabar is exposed extends 200 feet along the hillside, with both ends bounded by talus, and ranges from nothing to 35 feet wide. It is crossed by a fault with 5 or 10 feet of apparent displacement, along which a gully is eroded. Cinnabar and sparse pyrite are the only sulphides noted. The cinnabar occurs as small veinlets, blebs, and disseminated grains, and as films on fracture planes. Most of it is close to carbonate veinlets, and cinnabar occurs on one or both walls of some veinlets. Assays of typical mineralized zones are reported in Department of Mines Bulletin No. 5, pages 67 and 68.

[Reference: *Minister of Mines, B.C.*, Ann. Rept., 1942, p. 77.]

Christie This working is on the eastern side of Yalakom River 2 miles upstream from Shulaps Creek. An adit extends north 75 degrees east for about 70 feet in purple volcanic breccia, 500 feet above the river. The adit is near the southern tip of an ankeritic zone that extends northwestward along the hillside, but the rock it cuts is not ankeritized. The adit intersects groups of white carbonate veinlets at distances of 23, 30, and 52 feet from the portal. Each group strikes north 15 degrees east. The first is 2 inches wide and dips 75 degrees west, the second is 6 inches wide and vertical, and the third 1 foot wide and dips 60 degrees east. No cinnabar was noted in them in 1948.

[Reference: *Minister of Mines, B.C.*, Ann. Rept., 1946, p. 97.]

Quartz Mountain Scattered grains and small veinlets of cinnabar have been found in tan-weathering ankeritized peridotite (silica-carbonate rock) in the Yalakom fault zone on the northeast flank of Quartz Mountain. The same rock occurs elsewhere along the fault zone and extends for an unknown distance northwest of Quartz Mountain.

Cinnabar is reported to occur also in chert cobbles in conglomerate, 150 feet south of the summit of Quartz Mountain.

INDUSTRIAL MINERALS

Asbestos

Asbestiform serpentine is not rare in intensely serpentinized rocks, but nearly all of it is of types intermediate between picrolite and truly flexible chrysotile. Material in this category was noted particularly on Blue Creek, south of Retasket Creek, and at the heads of Brett and Hog Creeks. Silky slip-fibre 6 inches long was found above the small lake at timberline on the south fork of Retasket Creek, but this asbestos occurrence is of interest more for its uniqueness than for its extent.

Magnesite

Impure magnesitic carbonate is a common product of the alteration of ultrabasic rock, especially along faults (*see* p. 35). The silica-carbonate rocks contain veins and stringers of purer magnesite. Some of the larger veins, especially in the Yalakom fault zone north of Blue Creek, and near Liza Lake, have attracted the attention of prospectors.

The largest magnesite veins seen by the writer are on the sharp ridge between Yalakom River and lower Blue Creek, on the Sunny Nos. 1 to 4 mineral claims held in 1949 by L. Hansen, of Vancouver. Intermittent outcrops are limited to the narrow ridge-top for about 3,000 feet along the trend of the Yalakom fault zone. The silica-carbonate rock contains magnesite veins ranging from a fraction of an inch to, in one instance, 12 feet in width. Most are measurable in inches. The smaller veins are anastomosing and are variable in width, but the larger ones tend to strike northwestward, roughly parallel to the strike of the silica-carbonate zone, and are nearly vertical. The larger magnesite veins are composite and also have banded internal structure. Samples from them have assayed from 32 to 42.8 per cent magnesium oxide. Outcrops are insufficient to indicate the full length of the widest veins, but the nature of the deposit is such that individual veins of pure magnesite cannot be projected far on strike.

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Plate I. View southward across Noaxe Lake and meadows, Shulaps Range.

Plate II. Glacial debris, north side of Peridotite Creek (compare Plate III); the pick is 13 inches long.

Plate III. Glacial deposit, north side of Peridotite Creek, a more distant view of the material in Plate II.

Plate IV. Ribbon chert with interlaminated argillite, an association characteristic of pre-Upper Triassic rocks of Cache Creek type. The pick is 13 inches long.

Plate V. " White rock " (rodingite) in serpentinite on the southwest face of Shulaps Peak.

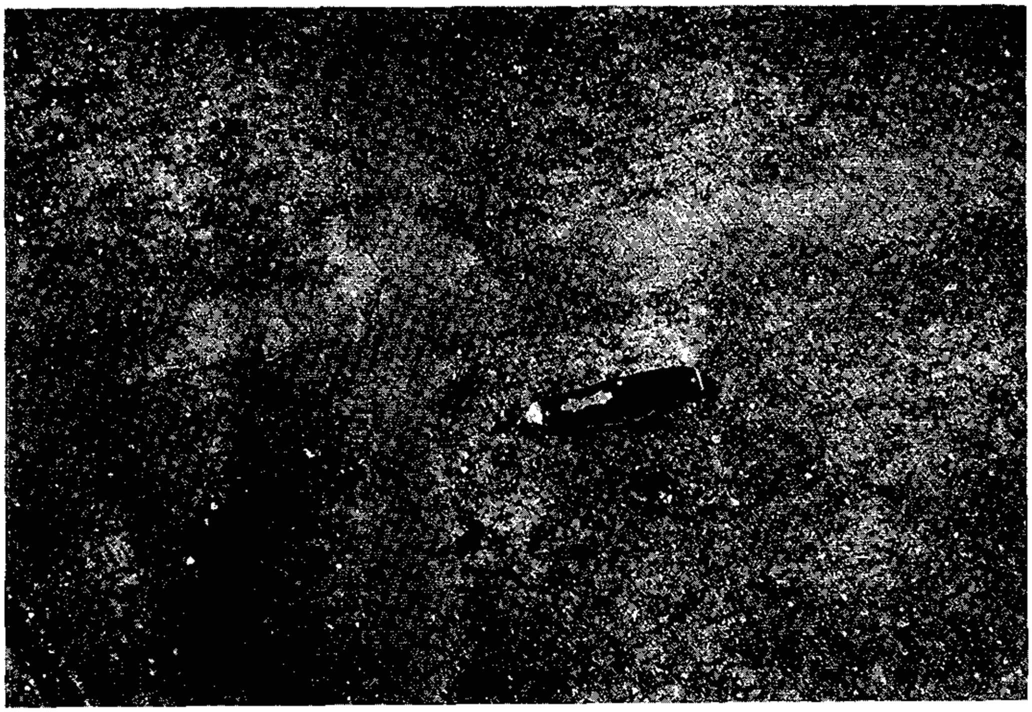


Plate VI. Dunite dyke transecting incipient compositional layering (parallel to the pocket-knife) in harzburgite, Peridotite Basin. The rock is relatively unserpentinized; enstatite grains stand in relief on the weathered surface of harzburgite.

Plate VII. Nodules composed of chromite and chlorite weathered in relief above dunite; 0.64 natural size.

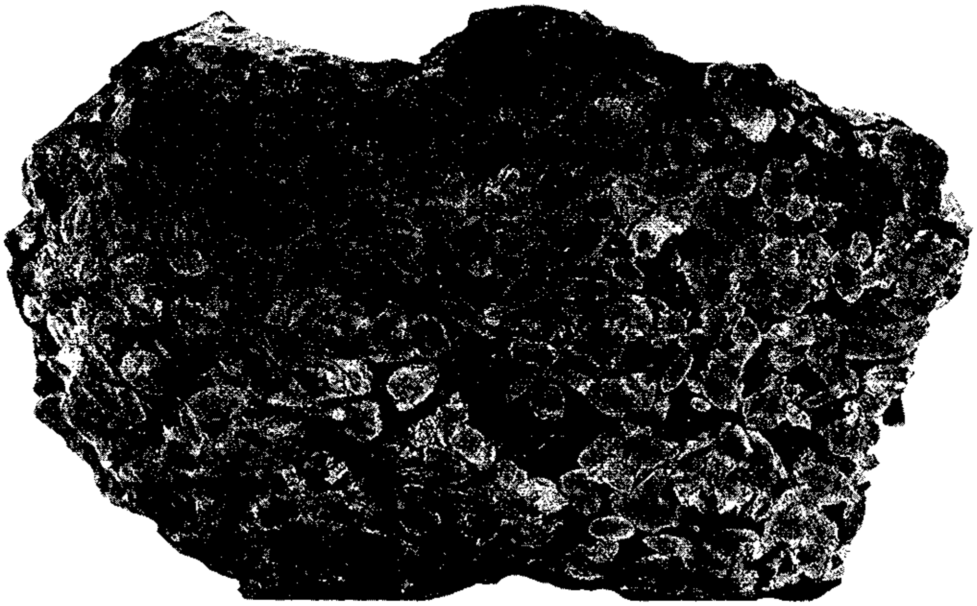


Plate VIII. Porphyroblasts of olivine regenerated from serpentine, Retasket Creek. the dark groundmass is serpentine; natural size.

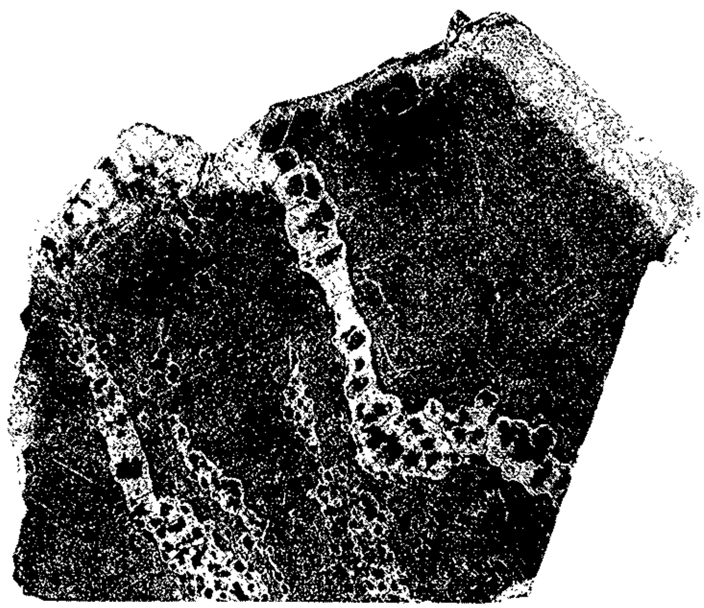


Plate IX. Chromite (black) and chlorite (light grey) in dunite. "Veins" of chlorite result from coalescence of the chlorite sheaths about closely spaced chromite grains; the chromite grains are altered and disrupted during the process (*see also* Plate XV); light-coloured material at the top of the specimen is weathered dunite; 1.2 natural size.

Plate X. Uneven advance of serpentinization from a fracture in a large enstatite grain that contains diopsidic lamellæ (*see* Plate XI). The lamellæ are relatively resistant to serpentinization and project into the serpentinized part; the material above the enstatite is partly serpentinized olivine; magnification, ×78.

Plate XI. The enstatite grain of Plate X photographed under crossed nicols to show the exsolved diopsidic lamellæ and blebs (bright); magnification, ×76.

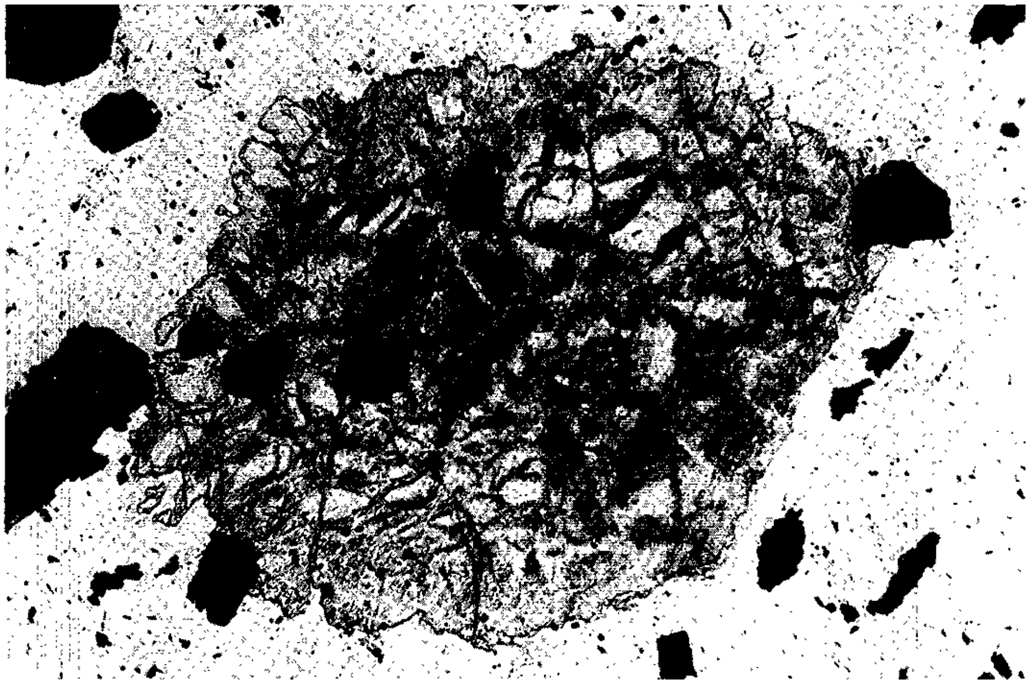


Plate XII. Olivine regenerated from serpentine, a porphyroblast from a rock similar to that shown in Plate VIII. Note dusty character of the olivine; the larger black bodies are chromite grains that have translucent centres and opaque irregular borders; the olivine is surrounded by antigorite (featureless in this photo); magnification, ×80.

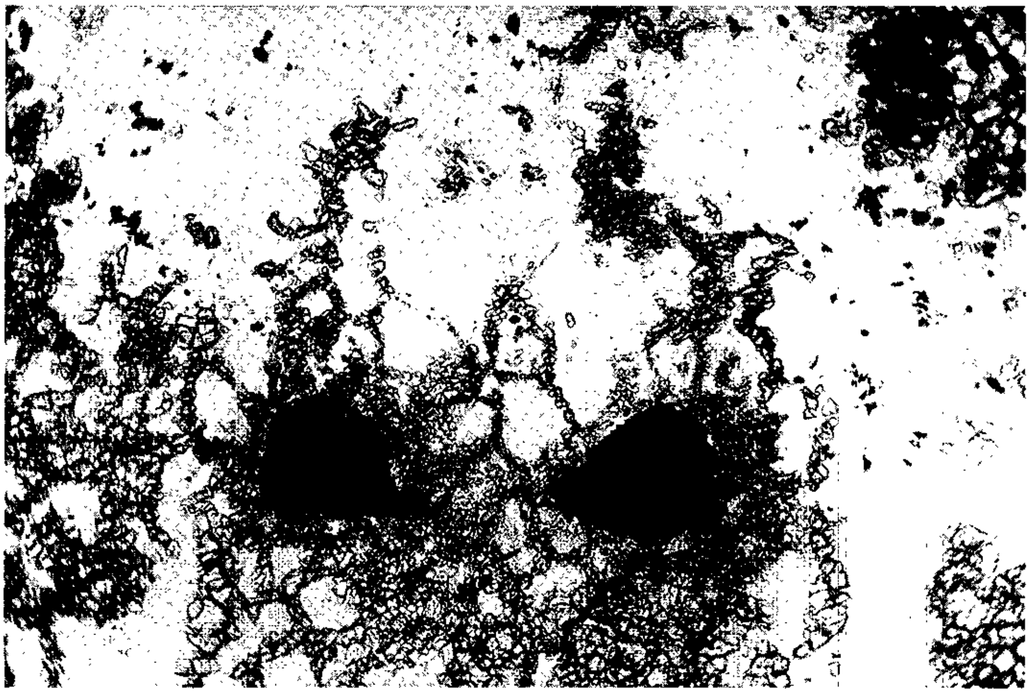


Plate XIII. Clusters and chains of olivine grains regenerated from serpentine. The large black grains are chromite and the featureless groundmass is antigorite; magnification, ×75.

Plate XIV. Translucent picotitic chromite (grey) bordered and replaced by opaque oxides (black), surrounded by chlorite (white); magnification, ×120.

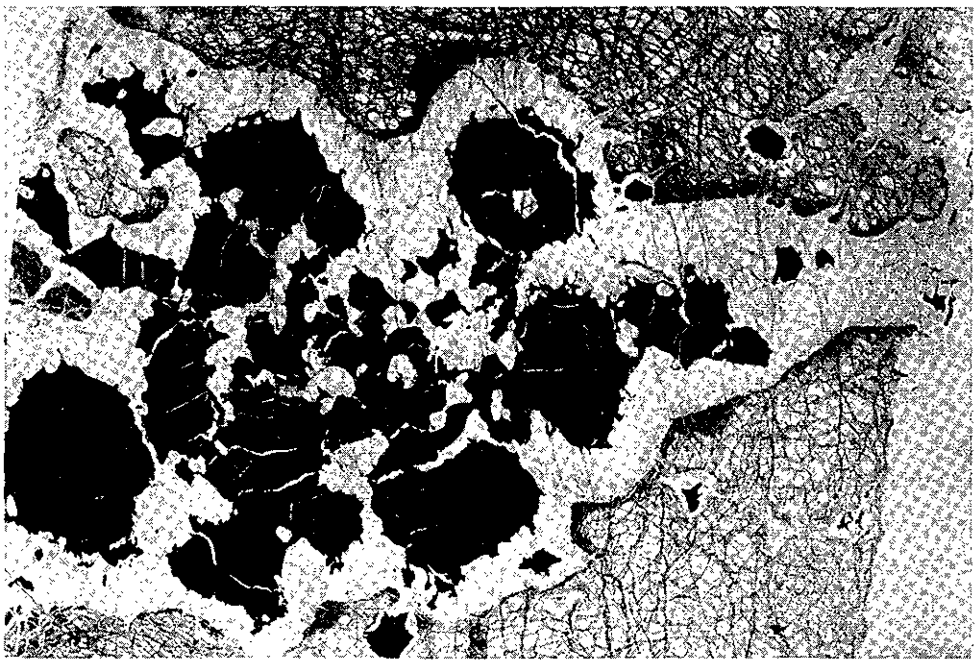
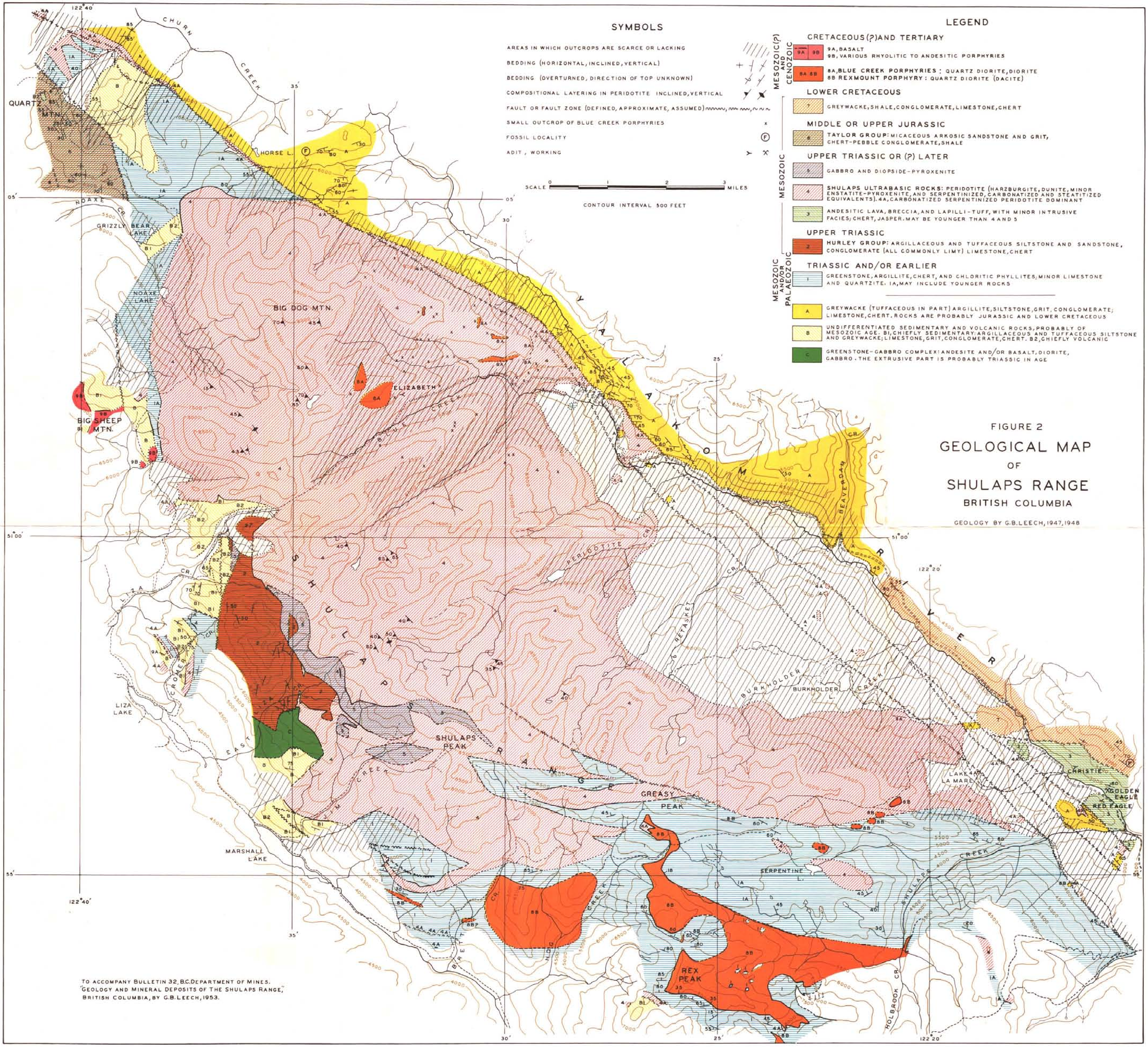


Plate XV. Chromite in a "vein" of chlorite, from a specimen similar to that in Plate IX. The chromite grains have translucent centres and opaque rims. Note how the walls of the "vein" bend outward around chromite grains, especially the small one at the bottom, and the manner in which chromite grains are wedged apart by chlorite. Magnification, ×7.7.



SYMBOLS
AREAS IN WHICH OUTCROPS ARE SCARCE OR LACKING
BEDDING (HORIZONTAL, INCLINED, VERTICAL)
BEDDING (OVERTURNED, DIRECTION OF TOP UNKNOWN)
COMPOSITIONAL LAYERING IN PERIDOTITE INCLINED, VERTICAL
FAULT OR FAULT ZONE (DEFINED, APPROXIMATE, ASSUMED)
SMALL OUTCROP OF BLUE CREEK PORPHYRIES
FOSSIL LOCALITY
ADIT, WORKING
SCALE 0 1 2 3 MILES
CONTOUR INTERVAL 500 FEET
LEGEND
MESOZOIC(?) AND CENOZOIC
CRETACEOUS(?) AND TERTIARY
9A, BASALT
9B, VARIOUS RHYOLITIC TO ANDESITIC PORPHYRIES
8A, BLUE CREEK PORPHYRIES: QUARTZ DIORITE, DIORITE
8B REXMOUNT PORPHYRY: QUARTZ DIORITE (DACITE)
MESOZOIC
LOWER CRETACEOUS
GREYWACKE, SHALE, CONGLOMERATE, LIMESTONE, CHERT
MIDDLE OR UPPER JURASSIC
TAYLOR GROUP: MICACEOUS ARKOSIC SANDSTONE AND GRIT, CHERT-PEBBLE CONGLOMERATE, SHALE
UPPER TRIASSIC OR (?) LATER
GABBRO AND DIOPSIDE-PYROXENITE
SHULAPS ULTRABASIC ROCKS: PERIDOTITE (HARZBURGITE, DUNITE, MINOR ENSTATITE-PYROXENITE, AND SERPENTINIZED, CARBONATIZED AND STEATITIZED EQUIVALENTS). 4A, CARBONATIZED SERPENTINIZED PERIDOTITE DOMINANT
ANDESITIC LAVA, BRECCIA, AND LAPILLI-TUFF, WITH MINOR INTRUSIVE FACIES; CHERT, JASPER. MAY BE YOUNGER THAN 4 AND 5
UPPER TRIASSIC
HURLEY GROUP: ARGILLACEOUS AND TUFFACEOUS SILTSTONE AND SANDSTONE, CONGLOMERATE (ALL COMMONLY LIMY) LIMESTONE, CHERT
MESOZOIC AND/OR PALAEOZOIC
TRIASSIC AND/OR EARLIER
GREENSTONE, ARGILLITE, CHERT, AND CHLORITIC PHYLLITES, MINOR LIMESTONE AND QUARTZITE. 1A, MAY INCLUDE YOUNGER ROCKS
GREYWACKE (TUFFACEOUS IN PART) ARGILLITE, SILTSTONE, GRIT, CONGLOMERATE; LIMESTONE, CHERT. ROCKS ARE PROBABLY JURASSIC AND LOWER CRETACEOUS
UNDIFFERENTIATED SEDIMENTARY AND VOLCANIC ROCKS, PROBABLY OF MESOZOIC AGE. B1, CHIEFLY SEDIMENTARY: ARGILLACEOUS AND TUFFACEOUS SILTSTONE AND GREYWACKE; LIMESTONE, GRIT, CONGLOMERATE, CHERT. B2, CHIEFLY VOLCANIC
GREENSTONE-GABBRO COMPLEX: ANDESITE AND/OR BASALT, DIORITE, GABBRO. THE EXTRUSIVE PART IS PROBABLY TRIASSIC IN AGE
FIGURE 2
GEOLOGICAL MAP
OF
SHULAPS RANGE
BRITISH COLUMBIA
GEOLOGY BY G.B.LEECH, 1947, 1948
QUARTZ MTN.
BIG DOG MTN.
ELIZABETH
BIG SHEEP MTN.
GRIZZLY BEAR LAKE
NOAXE LAKE
HORSE L.
CHURN CREEK
YALAKOM RIVER
SHULAPS RANGE
SHULAPS PEAK
GREASY PEAK
REX PEAK
LIZA LAKE
MARSHALL LAKE
SERPENTINE L.
BURKHOLDER L.
BURKHOLDER CREEK
PERIDOTITE CR.
BEAVERDAM CR.
CHRISTIE
GOLDEN EAGLE
RED EAGLE
LAKE LA MARE
HOLBROOK CR.
SHULAPS CREEK
BLUE CREEK
122°40'
122°20'
51°00'
TO ACCOMPANY BULLETIN 32, B.C. DEPARTMENT OF MINES. "GEOLOGY AND MINERAL DEPOSITS OF THE SHULAPS RANGE," BRITISH COLUMBIA, BY G.B. LEECH, 1953.