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GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

PAPER 64-32

BIG BEND MAP-AREA, BRITISH COLUMBIA

82 M (East half)

(Report and Map 12-1964)

J. O. Wheeler

Price 75 cents

1965

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OF CANADA

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ROGER DUHAMEL, F.R.S.C.
Queen's Printer and Controller of Stationery
Ottawa, Canada

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ABSTRACT

Monashee Mountains in the western half of the map-area are underlain by the Shuswap Metamorphic Complex. Selkirk Mountains, in the eastern half of the area, comprise Proterozoic clastic rocks and minor limestone of the Horsethief Creek Group, Lower Cambrian quartzite and greenstone of the Hamill Group and limestone of the Badshot Formation, Lower Cambrian and later clastic rocks of the Lardeau Group, and several granitic stocks. Cambrian sediments of the Rocky Mountains occur in the northeasternmost corner of the map-area.

The Shuswap Complex is featured by a gneiss dome centred near Frenchman Cap. Granitic gneisses in the core of the dome are surrounded by successive envelopes: an inner zone of paragneiss, schist, and quartzite; a central zone of paragneiss and abundant pegmatite; and an outer zone of granitic gneiss and pegmatite. The dome is characterized by northwest-trending folds of variable plunge that have increasingly flatter west-dipping axial planes towards the eastern margin of the dome. Such folds were superimposed upon apparently earlier westerly trending, attenuated, recumbent folds.

In the western Selkirks, opposite the gneiss dome, northwesterly trending structures are overturned to the southwest with increasing intensity of deformation towards the dome. Such structures were superimposed upon apparently earlier attenuated, recumbent folds with northeasterly and easterly trending axes. Structures in the northeastern Selkirks, developed in Proterozoic rocks metamorphosed to almandine-amphibolite facies, are overturned northeastward.

Lead-zinc sulphides are commonly associated with limestones of the Badshot Formation and in the lower part of the Lardeau Group and with the impure marbles of the inner zone surrounding the core of the gneiss dome.

Note

On the sections accompanying Map 12-1964 Unit 10 was inadvertently treated as a bedrock formation instead of as a thin layer of drift covering bedrock.

BIG BEND MAP-AREA, BRITISH COLUMBIA

INTRODUCTION

Big Bend map-area is a region of rugged glacier-hung mountains, dissected by deep steep-walled valleys. Below an elevation of about 7,000 feet the valleys are heavily timbered and thickly matted with underbrush. There are few roads and trails away from the main highways. Okanagan Helicopters Ltd. has a helicopter available for charter from Revelstoke. Above timber-line rock exposures are good, especially in freshly deglaciated areas. Travel above timber-line commonly requires the negotiation of serrated ridges, cliffs, and crevassed snowfields and glaciers, and locally ropes and mountaineering techniques are needed.

Previous geological work in the map-area consisted of studies along the line of the Canadian Pacific Railway by Dawson (1891) and by Daly (1915); mapping around Shuswap Lake by Dawson (1898); and reconnaissances between Revelstoke and Albert Canyon by Bancroft (Walker and Bancroft, 1929), of the western Selkirk Mountains north of the Canadian Pacific Railway by Gunning (1929), and of the northern Selkirks and adjacent Rocky Mountain Trench by Fyles (1960a).

This preliminary report is based on earlier studies (including some unpublished information by J.T. Fyles), and field work during the summers of 1962 and 1963. Travel away from the roads was accomplished partly by long back-packing trips supplied in advance by helicopter, and by helicopter operated from bases at Birch Creek, Downie Creek, Seymour Arm, and Revelstoke. Efficient and cheerful assistance was given in 1962 by D.B. Craig, N. Close, R.S. Harrison, T.P.T. McCullough, and K.R. MacKenzie and in 1963 by B.E. Lowes, J.J. Hylands, G.S. Headley, G. Bird, and K. MacKenzie. P.E. Fox carried out an independent study of the western tail of the Adamant batholith for the Geological Survey of Canada in 1962. Efficient and willing service was given by pilots, E. Pruss and H. Trace, and engineers, W. Bouton, R. Hawkins, and E. Rovere of Associated Helicopters, Ltd. The writer acknowledges many courtesies extended by residents of the area; particularly helpful were Ed and Mrs. Wallis, Mr. and Mrs. Don MacKinnon, E. Dodson of Falconbridge Nickel Mines, Ltd., and B.R. Styles, Superintendent of Mount Revelstoke National Park, and his staff.

GENERAL GEOLOGY

Big Bend map-area embraces three geological provinces. These are from west to east: the Shuswap Metamorphic Complex (Reesor in Leech, et al., 1963, p. 26) underlying Monashee Mountains and the region northeast of Revelstoke and south of La Forme Creek, the Selkirk Mountains part underlain by Proterozoic and lower Palaeozoic rocks, and the Rocky Mountains part underlain by Cambrian rocks.

SHUSWAP METAMORPHIC COMPLEX

The Shuswap Metamorphic Complex in the map-area is featured by a gneiss dome having culminations near Frenchman Cap and upper Ratchford Creek. The core of the dome is composed mainly of mixed gneisses and subordinately of more or less homogeneous, discontinuously layered granitic gneiss and swirled gneissic granite. The core is surrounded by successive envelopes, an inner zone of paragneiss with quartzite and marble and relatively little associated pegmatite, a central zone of paragneiss with abundant pegmatite, and an outermost zone of granitic gneisses with abundant pegmatite and minor paragneiss. The outermost zone contains areas of schists possibly belonging to the Mount Ida Group.

Mixed Gneisses (Map-unit A)

The mixed gneisses comprise an assemblage of various types of gneisses and transitional rocks whose salient features are described as follows. Banded gneiss is characterized by well-defined, alternating layers, ranging from a fraction of an inch to several inches in thickness. The darker layers commonly contain hornblende and biotite as mafic minerals whereas the lighter layers comprise quartzo-feldspathic material commonly accompanied by biotite. Garnets may occur in either layer. Banded gneiss grades into discontinuously banded gneiss in which quartzo-feldspathic layers pinch and swell and locally cut across adjacent layers. The banded gneiss grades further into veined gneiss featured by irregular quartzo-feldspathic veins up to 6 inches in thickness, locally pegmatitic, generally parallel with the banding but locally crosscutting. The quartzo-feldspathic layers are commonly bordered by a layer rich in biotite, a few millimetres or less in thickness. Other prominent rock types are feldspar augen-gneiss and more or less homogeneous granite-gneiss. In the latter rock mafic minerals, chiefly biotite, are arranged in more or less parallel streaks up to several inches in length as well as being scattered throughout the rock as subparallel

flakes. This rock grades into gneissic granite in which the mafic streaks are absent. Locally such gneiss contains schlieren of more mafic-rich material. When such schlieren are abundant the rock is termed streaky gneiss. In some places, such as south of the headwaters of Jordan River and north of Frisby Glacier, gneissic granites grade through fuzzy transitional zones into less-foliated mixed rock types forming nebulitic rocks.

Folds ranging from several hundred feet to a few inches in amplitude are displayed in the mixed gneisses throughout most of the gneiss dome. On the northern and southern flanks of the dome, folds involve both light and dark gneisses. Small folds, a few inches in amplitude, in these areas, however, are more commonly developed in the lighter-coloured gneisses than in the darker amphibolitic rocks which may not be folded but just gently warped. The central and eastern part of the dome is the most irregularly and severely folded. There the gneisses are more heterogeneous. The darker layers have been stretched, fractured, and invaded by leucocratic material and in some places have been subjected to further movement. Thin quartzo-feldspathic layers amidst darker gneisses have been broken and disrupted to form tectonic breccia. A common feature is plastic shears, whose attitude is about parallel with the axial planes of generally northerly trending folds. These shears cut the gneisses so that the individual layers are bent but not broken, producing a wavy pattern in the gneisses. In some places the leucocratic quartzo-feldspathic fraction appears to have been mobilized. This is suggested by its intricately folded and twisted internal structure, suggestive of a high degree of flowage, and its apparent invasion of adjacent gneisses.

The mixed gneisses contain several rusty zones south of Bourne Creek and east of the east fork of Perry River. These rusty zones are composed of highly micaceous schists and speckled granoblastic quartzo-feldspathic rocks characteristic of the paragneiss units, and probably represent undigested remnants of them.

Homogeneous Granite-Gneiss (Map-unit B)

Map-unit B is a more or less homogeneous granite-gneiss characterized by discontinuous layers and streaks of mafic minerals, chiefly biotite and, less commonly, both biotite and hornblende. The gneiss also contains various combinations of quartz, perthite, antiperthite, microcline, plagioclase, myrmekite, and locally garnet. The granite-gneiss commonly is veined with quartzo-feldspathic material in layers ranging from a fraction of an inch to

3 inches in thickness, spaced every few inches. The characteristic feature of the granite-gneiss is its rather uniform appearance in outcrop in contrast to the heterogeneous look of the mixed gneisses. The granite-gneiss contains layers of augen-gneiss which are particularly well exposed south of Bews Creek, north and south of Bourne Creek, and at the heads of Fissure and Ratchford Creeks. The granite-gneiss locally reveals boudins, attenuated folds, and schlieren, abundant enough to call the rock "streaky gneiss".

The homogeneous granite-gneiss appears to be most abundant in the western part of the dome. Contact relations with the mixed gneiss unit are not known and the boundaries of the granite-gneiss have been indicated in only a general way. It is possible that some of the layers of discontinuously layered granite-gneiss within the mixed gneisses may represent fingers of the granite-gneiss unit extending eastward.

Swirled Gneissic Granite (Map-unit C)

Swirled gneissic granite is characterized by extremely irregular foliation outlined mainly by biotite and to a lesser degree by hornblende. Potash feldspar generally greatly predominates over plagioclase, and about a third of the rock is quartz. Locally other distinctive constituents are garnet and rutile. The foliation is so irregular that even in a single outcrop it is difficult to arrive at an average attitude. The mafic minerals locally form streaks and clots but are generally scattered throughout the rock. The gneissic granite is restricted to an area in the central part of the southern flank of the dome. Its contact relations with the other gneisses are not known.

Amphibolite

All three gneiss units described above contain bodies of amphibolite. The mixed gneisses contain layers of amphibolite parallel with the foliation which have been involved in attenuated folds developed about westerly trending axes. Some highly boudinaged, beaded layers of biotite amphibolite such as those south of upper Jordan River appear to be sills. Other amphibolite bodies are clearly dykes. They intrude all three gneiss units and also the beaded sills. Subsequent to their intrusion the dykes were folded and metamorphosed.

Schists and Paragneiss (Map-unit D)

The schist and paragneiss envelope immediately surrounding the core of the gneiss dome contains little pegmatite. The more highly aluminous schists and gneisses contain biotite and some muscovite and varying amounts of garnet, kyanite, and sillimanite. Kyanite is well developed south of Ratchford Creek west of the headwaters of Perry River, around the big westerly trending fold between Seymour River and Kirbyville Creek, and south of Big Eddy Creek. Sillimanite was noted in the envelope around Liberty Creek, at the head of Blais Creek, southwest of the Cottonbelt Mine, in the re-entrant east of the head of Perry River and at various localities on the south and southwest sides of the dome.

The paragneisses also include speckled, granoblastic, biotitic quartzo-feldspathic layers a few inches to several feet in thickness. Some granitic gneiss sheets several hundred feet in thickness are particularly prominent between Bews Creek and Columbia River north of Revelstoke.

Quartzite and marble beds are the best markers within the paragneiss envelope. Without these beds most of the folds would not have been recognized. Where the paragneisses are least deformed and appear to wrap conformably about the granitic gneisses in the core of the dome, marble and calc-silicate beds occur both with the lower quartzite and slightly higher in the succession beneath higher quartzites. Some of the higher limy beds are host rocks for lead-zinc minerals at the Cottonbelt and River Jordan properties.

The quartzite consists essentially of quartz but commonly contains appreciable amounts of potash feldspar, biotite, muscovite, and tourmaline. In the area near the big fold between Kirbyville Creek and Seymour River, considerable areas of amphibolite and amphibolite gneiss are intimately associated with the quartzite. Elsewhere, where quartzites occur around the dome, such amphibolite is absent.

The lowest quartzite beds are separated in many places from the underlying mixed gneisses by perhaps 50 to 100 feet of micaceous quartzo-feldspathic schist and feldspar augen-gneiss. Locally, as north of Copeland Creek, the beds just below the quartzite are pseudo-conglomerate characterized by numerous sheared quartz augen. Nowhere could it be demonstrated that the paragneisses had conglomerate at their base or that the paragneiss envelope lay unconformably upon an old basement.

Paragneiss and Pegmatite (Map-unit E)

Paragneiss, similar to that in the innermost envelope, together with abundant interlacing sheets and lenses of pegmatite, forms the next enveloping map-unit. Pegmatite bodies are so numerous that they obscure the structure and continuity of the gneisses and only the most obvious strata such as marble beds and broad calc-silicate zones can be readily mapped. Micaceous quartzites occur north and south of Ruddock Creek but their relationship to the quartzites of map-unit Db is not known.

Pegmatites are generally simple mineralogically, comprising quartz, feldspar in which potash feldspar greatly predominates over plagioclase, minor muscovite and biotite, and rare hornblende, garnet, and tourmaline. Many pegmatites are crudely banded. This layering is expressed by extremely coarsely crystalline zones alternating with zones that are merely coarse grained or by relict layers of gneiss within the pegmatite.

The pegmatites show various relationships to the adjacent gneisses. In some places they lie more or less parallel with the foliation of the gneisses and in others they transect the foliation at varying angles. Some pegmatites split into branching bodies and others send fingers a distance of a few feet to a few inches across the foliation of the surrounding rock. The pegmatites commonly show boudinage structure in which the boudins range from greatly elongated lenses several feet in length to closely spaced beads a few inches across. Some pegmatites follow the foliation part way around a fold and then cut sharply across its crest, whereas others will faithfully follow the gneisses around the fold. The borders of the pegmatites in some cases are sharp on both sides, or sharp on one side and gradational on the other, or gradational on both sides. Transitions from feldspar augen-gneiss in the gneisses to pegmatite are apparent in many places. Minerals such as the micas and quartz commonly have a preferred orientation such that some pegmatites have had a foliation or lineation developed in them parallel with the adjacent gneisses. Some crosscutting pegmatites, however, show a relict foliation. In such cases the foliation passes undisturbed from the adjacent folded gneisses into the pegmatite and across it in such a way that the forms of the folds are perfectly preserved.

It is clear that the pegmatites were introduced over a considerable period during which the gneisses were being deformed. Most pegmatites appear to have been folded to some degree. Some others, in particular the southwest-dipping pegmatites west of Seymour River and east-northeast-trending pegmatites south of the head of Sibley Creek, are virtually undeformed. The latter pegmatites, which locally pinch out downwards, transect folds but in such a manner that the outline of the fold can be traced through the pegmatite, and the pegmatite is lineated parallel with the adjacent gneisses.

Granitic Gneiss, Foliated Granitic Rocks, and Pegmatite (Map-unit F)

The outermost enveloping map-unit differs from map-unit E in that abundant pegmatite is intimately associated with granitic gneisses and foliated granitic rocks rather than paragneisses. Some paragneiss with marble and calc-silicate rocks outcrops on Anstey Arm. Except on the mountains north of Kitson Creek the map-unit underlies a heavily timbered region and consequently the assemblage is not well understood.

Migmatite Complex in Clachnacudainn Salient (Map-unit Fb)

A great variety of metamorphic and granitic rocks constitutes what may be broadly termed a "migmatite complex" in the Clachnacudainn Salient northeast of Revelstoke. The southwestern part of the salient around Mount Revelstoke is composed principally of a mixture of hornblende granodiorite-gneiss and leucogranite. The latter occurs as dykes within the granodiorite-gneiss and as masses so extensive that the granodiorite-gneiss appears only as inclusions. The granodiorite-gneiss, leucogranite, and some pegmatite bodies are strongly lineated. The leucogranite dykes were apparently emplaced after folding and faulting of the granodiorite-gneiss. This is evidenced by faults and folds which affected thin quartzo-feldspathic layers in the granodiorite-gneiss but not the dykes. Some of the dykes even follow the faults.

Paragneiss, sillimanite schists, and limy beds abundantly laced with pegmatite underlie the region between Mount Revelstoke and Clachnacudainn Creek.

Irregularly banded hornblende-biotite granodiorite-gneiss, grading into foliated granodiorite and locally containing mappable bodies of hornblende diorite and hornblendite form most of the mountains immediately west of the granite body at the head of West

Woolsey Creek. Some of the gneiss contains a form of agmatite in which undisturbed subrounded inclusions of granodiorite-gneiss are surrounded by fine-grained granodiorite in which foliation is roughly parallel with the borders of the inclusions. Pegmatite veinlets and dykes are common.

North and northeast of this granite body the salient is underlain by discontinuously layered granite-gneiss and paragneiss. Attenuated folds and boudinage structures are developed here and there.

Schists West of Seymour River (Map-unit G)

Wrinkled schists and micaceous quartzites, some carrying large crystals of andalusite and others that are graphitic, may belong to the Mount Ida Group exposed in Adams Lake (R.B. Campbell, personal communication, 1963) and Vernon map-areas (Jones, 1959). The schists are cut by numerous leucogranite and pegmatite dykes.

Age of Rocks Within Shuswap Metamorphic Complex

The rocks constituting the Shuswap Metamorphic Complex probably range broadly in age. Dawson (1898), Daly (1915), and Jones (1959) considered the rocks like those in map-units A to F to be Archaean in age. Cairnes (1939) and Reesor (personal communication, 1963) inferred that the Shuswap Terrane may contain rocks as young as upper Palaeozoic or Mesozoic.

The quartzites within the paragneiss envelope are the only beds that offer hope of correlation with unmetamorphosed rocks elsewhere in the region. Relatively pure quartzites in southeastern British Columbia occur with magnesian limestones and slates in the Purcell Mount Nelson Formation of the Windermere area (Walker, 1926), in the Lower Cambrian Hamill Group of the Selkirks sandwiched between the limestone-rich part of the Horsethief Creek Group, and the Lower Cambrian Badshot Formation, and in the Ajax Formation (Fyles and Eastwood, 1962) amid carbonaceous clastic sediments of the Lardeau Group. The association of quartzite in the enveloping paragneiss with marble and calc-silicate rocks suggests a correlation with either the Mount Nelson Formation or the Hamill Group. A correlation with the latter is favoured because it is probably more than coincidental that the development of hornblendic gneiss and amphibolite in intimate association with quartzite is restricted to the northern outcrops of the latter at about

the same latitude in the mountains south of Goldstream River which contain the greatest development of greenstone in the Hamill Group.

At least part of map-unit E within the drainage of Pat Creek probably belongs to the Horsethief Creek Group. This is suggested by the fact that Horsethief Creek strata can be traced from unmetamorphosed strata northwestward, particularly the limy beds (map-unit 1c) adjacent to the Hamill Group. The limy beds are inferred to extend down Birch Creek and up Pat Creek, leaving the map-area at 118°45'W.

In conclusion, the Shuswap Metamorphic Complex, exclusive of map-unit G, in Big Bend map-area probably includes strata of the Horsethief Creek and Hamill Groups and very likely also those of the Badshot Formation and Lardeau Group.

Ultramafic Rocks (Map-unit H)

Two small bodies of dunite were noted within calc-silicates of map-unit E north of Scrip Creek. Several small bodies of biotite-hornblende pyroxenite occur in the gneisses of map-unit E at the head of Hoskins Creek. Only the largest one is shown on the map.

SELKIRK MOUNTAINS

Windermere

Horsethief Creek Group (Map-unit 1)

Although it has not been possible to establish the stratigraphic succession within the group or to estimate its thickness, some gross relationships are apparent. The group is composed predominantly of clastic sediments. The uppermost part of the group is particularly limy as evidenced by the common occurrence of limestone and calc-silicate rocks (1c) near the quartzites of the overlying Hamill Group, especially north of Goldstream River. Arenaceous rocks, especially feldspathic grits, appear to be less common than in the adjoining Rogers Pass map-area (Wheeler, 1963) to the east.

White quartzite overlies marble in the synform in the lowermost part of Trident Creek and is exposed at intervals east of Windy Creek just north of the Adamant batholith. Such pure quartzite is rare in the Horsethief Creek Group and hence may belong to the Hamill Group.

Much of the terrain underlain by the Horsethief Creek Group is highly metamorphosed (1a). As shown by the approximate isograds on the accompanying map the metamorphic grade increases from garnet-bearing schists at the Rocky Mountain Trench, through kyanite schists and gneisses to sillimanite-bearing rocks in a zone extending northwest from Adamant batholith. The sillimanite zone apparently grades rapidly into a garnet zone to the southwest. Some staurolite was found just east of Goldstream Mountain but otherwise no other minerals of grade intermediate between garnet and sillimanite were noted. The terrain south of the garnet isograd all belongs within the greenschist facies.

Crosscutting pegmatite bodies, up to several tens of feet thick, are scattered through the rocks between the Adamant batholith and the lower part of Argonaut Creek. Many of these bodies carry numerous tourmaline crystals up to 2 inches in length, and some garnet. Pegmatite is particularly abundant northeast of the belt of Hamill Group rocks. Most commonly the pegmatite bodies are parallel or subparallel with the foliation in the metamorphic rocks.

An important belt of amphibolite (1d) extends across the ridges south of the head of Mica Creek. Numerous small bodies of amphibolite occur along strike to the southeast on the northwest ridge of Mount Chapman.

Cambrian

Hamill Group (Map-unit 2)

The group is composed predominantly of pure quartzite as in the adjoining Rogers Pass map-area to the east. Some rusty-weathering dark grey phyllite south of Sorcerer Creek has been mapped with the Hamill Group but may in part belong to the Horsethief Creek Group.

The greatest development of greenstone in the Hamill Group occurs between Goldstream River and Sorcerer Creek. There, the greenstone is virtually all a homogeneous, sheared rock with megacrysts of chlorite. Bedded tuff and breccia occur in both belts of greenstone at the eastern edge of the map-area.

Hamill rocks are difficult to map in the highly deformed imbricate zone around the headwaters of Carnes Creek and the east fork of La Forme Creek. Some large pods and lenses of sheared quartzite have been mapped separately as Hamill Group. In some other areas, particularly between Mount La Forme and the Mastodon

mine it is uncertain whether interbedded brown quartzite and phyllite with rare rusty-brown carbonate beds belong to the Hamill Group or whether this assemblage is the equivalent of part of the Broadview Formation of the Lardeau Group.

Quartzites of the Hamill Group thin gradually northwestward and disappear near the head of Birch Creek. Some of the thinning and termination of belts of quartzite can be accounted for by the deformation of the beds into extremely attenuated folds developed about east- and northeast-trending axes. But perhaps the main reason for the disappearance of quartzite northwestward is that it may change facies in that direction into argillaceous rocks. This is suggested by the stratigraphy in the Cariboo Mountains where quartzite is absent below the correlative of the Badshot Formation — the Lower Cambrian Cunningham limestone (Campbell, 1963; Sutherland Brown, 1963). Instead the limestone grades downward through 1,000 to 2,500 feet of phyllite and limestone of the Isaac Formation into impure arenaceous sediments of the Kaza Group.

The Hamill Group is highly metamorphosed (2a) near the head of Norman Wood Creek and northwestward to Birch Creek. Quartzite is highly recrystallized and in addition to quartz contains muscovite, biotite, plagioclase, and potash feldspar. Greenstone has been metamorphosed to amphibolite.

Badshot Formation (Map-unit 4)

Incomplete stratigraphic successions only are preserved in the highly deformed "imbricate zone" southwest of Downie Creek. In that region unfossiliferous carbonate bodies, principally light grey and dark grey limestone and locally buff dolomite and phyllite, have been mapped as Badshot Formation because of their similarity to carbonate rocks containing Lower Cambrian Archaeocyathids which occur about 1 mile east of the map-area near the head of Downie Creek and for their association with dark grey carbonaceous phyllites characteristic of the lower part of the Lardeau Group.

Near the head of the east fork of Carnes Creek, carbonate beds grade along strike into quartzite that was probably originally chert. Such quartzite is mapped with the Badshot Formation.

Marble, amphibolite, and skarn, probably belonging to the Badshot Formation, outcrop near the head of Norman Wood Creek. There this assemblage, which occurs in the core of an almost vertically plunging fold closing to the north, must overlie the

Hamill Group since the latter is in contact both to the east and the west with rocks of the Horsethief Creek Group. This structure is more fully described in the section on Structural Geology (Selkirk Mountains, "Westerly Trending Structures").

A discontinuous bed of limestone between the bend of Sorcerer Creek and Goldstream River may also belong to the Badshot Formation. It is associated with phyllite and slate on trend with Lardeau and Badshot rocks exposed at the head of Sorcerer Creek just east of the map-area.

Cambrian and Later

Lardeau Group (Map-unit 5)

It has not been possible to subdivide the Lardeau Group as was done in the adjoining Rogers Pass map-area. South of the head of Downie Creek the terrain is underlain by elements of the Broadview Formation. Elsewhere the stratigraphy is confused. Both buff slates and dark grey carbonaceous slate and phyllite characteristic of the lower part of the Lardeau Group in Rogers Pass map-area are associated with marbles mapped as Badshot Formation. Dark phyllites are also common west of the granite on Belcher Creek. Greenstone sills and chlorite schist are prominent around Standard Peak. Strongly sheared phyllonites were noted on the ridges around Mars and Holdich Creeks.

The Lardeau Group is highly metamorphosed to crystalline schists and gneisses around the west end of the granite body south of Goldstream River. Bedrock in this area is poorly exposed, but scattered outcrops give the impression that fingers of granite are intermixed with the crystalline metamorphic rocks. The Lardeau rocks have been contact-metamorphosed to hornfels and skarn around the southeastern end of the granite south of Goldstream River and near the contacts of the neighbouring granites.

ROCKY MOUNTAINS

Cambrian

Map-unit 3

This map-unit corresponds to the "Sullivan quartzites" of Fyles (1960a) and is the northwestward continuation of map-unit 3 in Rogers Pass map-area.

An approximate section by Fyles is as follows:

	Estimated Thickness (feet)
Crossbedded limy quartzite	
Grey limestone	50 - 100
Quartzite and green phyllite	100
Buff-weathering limestone, argillaceous limestone, and dolomite	100 - 200
Rusty-weathering grey to brown argillaceous quartzite. Beds range from a few inches to a few feet thick. Pinkish, whitish, and locally greenish beds near the top	several hundred feet
Blocky fine-grained white quartzite	200
Massive light grey grits	
Base not exposed	

Canyon Creek Formation (Map-unit 6)

Light grey and dark grey argillite and slate overlying quartzites of map-unit 3 on Kinbasket Mountain were named by Fyles the "Tsar Creek argillite". This map-unit is the northwestward continuation of beds assigned to the Canyon Creek Formation in Rogers Pass map-area. There, about 8 miles east of the south end of Kinbasket Lake, the Canyon Creek beds overlie conformably strata containing Olenellus.

Chancellor Formation (Map-unit 7)

Map-unit 7 consists mainly of thin-bedded micaceous marble and argillaceous limestone, lying apparently conformably upon map-unit 6. The rocks are tightly folded so that the thickness of the unit is unknown. These beds were called the "Kinbasket limestone" by Fyles and are probably correlatives of map-unit 8 in Rogers Pass map-area, i.e. the lowest member of the Chancellor Formation.

NEPHELINE SYENITE-GNEISS (Map-unit 8)

Grey, crumbly nepheline syenite-gneiss occurs in the core of an undulating, recumbent nappe southwest of Kinbasket Lake (Section ABC). There it appears to form a lenticular body, which diminishes in thickness to the northwest and to the southeast away from its thickest part near Trident Mountain. In addition to nepheline the gneiss contains potash feldspar, sodic plagioclase, biotite, and some brown hornblende. The gneiss contains a strip of rusty schist and micaceous gneiss.

Grey, somewhat crumbly gneiss is exposed on the southwestern slopes of Mount Copeland. In the field the rock was considered a granitic gneiss but in thin section it was discovered that the rock contains no quartz but nepheline instead. Other minerals in the rock include biotite, potash feldspar, sodic plagioclase, carbonate, and opaque minerals.

No intrusive relationships into the adjacent rocks were observed with the two bodies described above.

INTRUSIVE ROCKS (Map-unit 9)

Adamant Batholith

The western tail of the Adamant batholith north of Stitt Creek extends westward from Rogers Pass map-area as far as Norman Wood Creek. The main rock type is a dark speckled hornblende granodiorite. Some biotite occurs near the outer edge of the body. Rocks transitional between hornblende granodiorite and augite - hypersthene monzonite occur around Mount Remillard and at the eastern edge of the map-area. The granodiorite north of Stitt Creek is abundantly laced with pegmatite dykes. The batholith has been emplaced into rocks belonging mainly to the Horsethief Creek Group. Some marble and white quartzite on the north side of the batholith and continuing eastward into Rogers Pass area may belong to the Badshot Formation and Hamill Group respectively.

Potassium-argon (K-Ar) age determinations from the outer granodiorite in Rogers Pass map-area give apparent ages of 281 m.y. and 200 m.y. on biotite, 116 m.y. on hornblende, and 92 m.y. on potash feldspar. K-Ar dates from the same region on mica from a crosscutting quartz-rich vein and pegmatite give ages of 90 m.y. and 130 m.y. respectively. It is clear that the Adamant batholith has a complex history, and P.E. Fox considers that this

possibly involves early intrusion of hypersthene monzonite, with later deformation and reintrusion and associated metamorphism of the early monzonite to a mafic granodiorite (Leech et al., 1963, p. 19).

Granitic Stocks in the Selkirk Mountains

The Bigmouth Creek stock, those clustered between Goldstream River and Downie Creek, and the Belcher Creek stock are all characteristically porphyritic and in this way resemble the Fang Creek stock at the head of Downie Creek just east of the map-area. Specimens from the last yielded a K-Ar date of 168 m.y. on biotite. The stocks are generally quartz monzonites, composed of megacrysts of microcline up to 2 inches in length embedded in a matrix of potash feldspar, plagioclase, and varying amounts of quartz, biotite, and hornblende. The Bigmouth Creek pluton, however, varies from hornblende syenite to quartz monzonite.

Most of the stocks have relatively smooth, sharp, and discordant contacts with the country rock. Exceptions are the more or less concordant, north-dipping southern contact of the Bigmouth Creek body and the confused relations exhibited at the west end of the pluton south of Goldstream River. The western end of the latter body is poorly exposed in a timbered area. It appears to consist of westerly trending masses of schist and gneiss mixed with more or less conformable bodies of granitic rock regarded as tongues protruding westerly from the main stock.

Granitic Plutons Intrusive into the Shuswap Metamorphic Complex

The stock in the Clachnacudainn Salient varies from a quartz monzonite in its northern part to almost a syenite at the eastern edge of the map-area. The rock is composed of microcline, sodic plagioclase, biotite and varying amounts of quartz. A K-Ar date on biotite from the "syenitic" part gave an age of 110 m.y.

A northerly elongate pluton crossing Anstey River underlies a heavily timbered and burnt-over region. Its extent and character is not accurately known. The rock on Long Ridge is a foliated and lineated granite. Contact relations with the surrounding rocks have been observed only on the mountains west of Perry River. There the granite intertongues with the southwesterly dipping gneisses and schists and sends a few crosscutting, non-foliated porphyritic dykes into the latter.

Dykes

Leucogranite and felsite dykes are particularly numerous in the timbered hills between Hunakwa Lake and Seymour Arm and in the southwesternmost corner of the map-area.

Dark green speckled "dioritic" dykes cut the Chancellor Formation on Kinbasket Mountain. They superficially resemble the nepheline syenites in Rogers Pass map-area. These dykes have subsequently been deformed with the enclosing rocks and now appear as disconnected lenses.

By far the most common dykes are brown-weathering lamprophyres. In thin section the rock is porphyritic with phenocrysts of phlogopite, clinopyroxene, potash feldspar, and minor amphibole, chlorite, and clinozoisite. It is probably a minette. The lamprophyre dykes occur in north-trending steeply dipping swarms which cut the granitic gneisses of the Frenchman Cap gneiss dome and enveloping paragneisses. A K-Ar date on the phlogopite phenocrysts suggests that the rock crystallized 41 m.y. ago. This date is slightly younger than dates obtained from volcanic rocks in the southern interior of British Columbia (Mathews, 1963). There the ages range from 45 to 53 m.y. (Middle Eocene, Kulp, 1961). The lamprophyre dykes may thus represent a late phase of Middle Eocene volcanism.

STRUCTURAL GEOLOGY

SHUSWAP METAMORPHIC COMPLEX

Gneiss Dome

The dominant structural feature in that part of the Shuswap Metamorphic Complex exposed in Big Bend map-area is the gneiss dome having culminations near Frenchman Cap and upper Ratchford Creek. The shape of the dome cannot be accurately represented. Some idea of its form, however, is outlined by the foliation in the granitic gneisses and is emphasized by the paragneiss envelope, particularly by the quartzite and marble beds. The dome is elongated in a north-northwesterly direction. Its flanks dip smoothly away from the central part except in its southwestern part around upper Perry River where there is a southwest-plunging mushroom-like bulge (Section IJ) and on its east side where the margin of the dome steps downward to the east in a series of folds with increasingly flatter west-dipping axial planes (Section DE). In longitudinal section the upper surface of the granitic gneisses rises northward to a

culmination a few miles southwest of Frenchman Cap. This surface then slopes gently northward into a shallow depression between Ratchford and Seymour Creeks. It then rises gently to a second culmination between Ratchford and Fissure Creeks and finally slopes northward at a moderate angle. The two culminations appear to be crudely en échelon.

The only large folds (those with amplitudes up to a mile or so) that can be readily seen are those exposed on cliffs on the eastern side of the dome, particularly on Frenchman Cap. Elsewhere folds have been recognized only as a result of mapping. Some folds have developed along westerly or west-southwesterly trending axes, and others along north-northwesterly trending axes. Field evidence suggests that some westerly trending folds developed before those trending north-northwest. At present, however, no break has been recognized between the development of folds in a westerly direction and those deformed in a north-northwesterly direction. In fact both sets of folds appear to have evolved under the same metamorphic conditions and hence may be broadly contemporaneous. More work needs to be done before the time relations between the two fold trends can be established with certainty.

Westerly Trending Structures

Both west-southwest- and west-trending structures are included in this group. Folds whose axes trend westerly are accompanied by a mineral lineation that is almost invariably parallel with the fold axes. The mineral lineation is generally expressed by streaks of biotite but is also commonly shown by aligned crystals of hornblende, kyanite, and sillimanite. Mullion structure is prominent in the hinge zones of folds in quartzite. Westerly trending structures are most commonly noted on the western flank of the dome where the foliation strikes at a high angle to the fold axes. The folds are usually highly attenuated with axial planes essentially parallel with the foliation. The common limb of adjacent folds is frequently missing. In one instance near the head of Kirbyville Creek an attenuated fold has been refolded about a parallel axis into a more open fold.

Most of the westerly trending folds seen are from a few inches to several tens of feet in amplitude. Large folds and piles of large folds, however, have been mapped between Sibley and Kirbyville Creeks (Section KL) and west of Myoff Creek, and probably exist south of Copeland and Bews Creeks where the quartzite is unusually thick. Stratum contours on the quartzite bed east of the

head of Myoff Creek indicate that the re-entrant in the dome there is caused by a westerly plunging synform. The largest westerly trending folds or piles of folds in the paragneiss envelope occur on the northern and southern flanks of the dome and above the depression east of Myoff Creek (Section IJ). By contrast the quartzite west of the mushroom-shaped bulge west of Perry River appears to be in disconnected, thin lenses or blocks.

In some places westerly trending folds appear to have developed before those trending north-northwest. For example, southwest of Frenchman Cap the limbs of westerly trending folds have been redeformed by north-northwesterly folds and in numerous places mineral lineations apparently related to the westerly trending folds can be traced around north-northwesterly trending folds. Since folds trending in these two main directions were apparently developed under the same metamorphic conditions they may also have been developed more or less contemporaneously.

North-northwesterly Trending Structures

Structures in this category are characterized by folds with curved axes and hence of variable plunge. They include folds whose axes range in plunge from northwest to southerly.

In cross-section the style of north-northwesterly trending folds in the granitic gneisses is generally disharmonic. The folds range from more or less regular asymmetrical or tight overturned folds, through clusters of chevron-like folds, and chevron-shaped antiforms separated by broad, flat, slightly rippled synforms, to flow folds of ptygmatic type characterized by bulbous forms with antiforms in one layer lying directly below synforms in an overlying layer. Mafic minerals and feldspar augen lie in the foliation planes that outline the folds. The attitude of the axial planes of the folds is variable. In some folds the dip of the axial plane changes. For the dome as a whole, axial planes are generally steeply west-dipping in its central part but become flatter eastward, particularly below the glacier at the head of Big Eddy Creek (Section DE). The axes of these folds are also commonly curved. Consequently in flat outcrops the gneissic layers form concentrically layered "eyed" patterns. These "eyed" folds are arranged in a crude en échelon fashion. The fold upon which the River Jordan property is located was described by Riley (1961) as a southeasterly plunging syncline. Although the fold has a synformal shape its limbs converge in the direction of the apparent southeasterly plunge. The fold may therefore be a conical fold or part of the northwesterly trending en échelon system.

Unusual folds of special interest were noted in the granitic gneisses west of uppermost Perry River and at the head of Frisby Glacier. The folds in the former area plunge moderately northwest. Their axial planes dip westerly rather more gently than the predominant attitude of the westerly dipping foliation. Thus the folds closing to the west are asymmetrical with long west-dipping upper limbs and short east-dipping lower limbs. Hence they have the form of "fir-tree" folds (Carey, 1962). In common with such folds those on the western flank of the dome may have originated in response to the upward diapiric movement of the central part of the dome. This interpretation is favoured since no evidence was seen on the western flank of the dome for folds strongly overturned to the east for which the "fir-tree" folds might be drag-folds on the overturned limb. The folds at the head of Frisby Glacier cascade downward in such a fashion that quartzo-feldspathic material appears to have flowed downward to the west to form bulbous folds surrounded by a mafic-rich layer, leaving behind it thinner necks or tails connecting the cores of the folds with the parent quartzo-feldspathic layer.

Other structural features of note in the granitic gneisses are boudinage structures where amphibolitic and pegmatitic layers have been stretched and pulled apart, plastic shears, and locally small, healed slides where some layers of gneisses cut off more steeply dipping layers beneath.

Whereas similar folds with axial-plane cleavage were not noted in the granitic gneisses such folds occur in the paragneiss envelope together with concentric and disharmonic types. The similar folds commonly have micas oriented parallel with the axial-plane cleavage and are characterized by pronounced crenulations where the cleavage intersects the foliation surface outlining the fold.

The paragneisses on the north flank of the dome are much less strongly folded than the upper part of the granitic gneisses. This decrease in the intensity of folding continues upward through the paragneisses such that on the largest scale the gneisses exposed near the top of the cliffs north of Fissure Creek form a broad, relatively smooth, north-plunging arch.

The structural pattern in the Shuswap rocks in the northwest corner of the map-area is not understood because of the abundance of masking pegmatite and the lack of good horizon markers and recognizable stratigraphy. Most of the folds plunge moderately westward and appear to have gently south-southwest-dipping axial planes. Some attenuated, south-plunging folds were noted on the

limbs of the west-plunging folds. It is not clear whether the west-trending folds are related to those of the same trend farther south around Kirbyville Creek or whether they are a more westerly trending continuation of Selkirk structures sweeping around the northern end of the gneiss dome.

Structures in the Clachnacudainn Salient

The dominant structural element in the southwestern part of the salient is a westerly or west-southwesterly plunging lineation. Most commonly this is a mineral lineation exhibited not only by mafic minerals but by quartz grains as well. Folds axes were rarely seen but those observed parallel the mineral lineation. The westerly plunging lineation was apparently impressed on the rocks after the folding and faulting of some of the granodioritic gneisses and their subsequent intrusion by leucogranite as described earlier.

At least one large southwest-plunging fold, several hundred feet in amplitude, could be vaguely seen west of the head of Clachnacudainn Creek. In this region folds and mineral lineations are common in the paragneisses, mixed with granoblastic quartzo-feldspathic layers laced with pegmatite.

Near the northeastern margin of the salient, axes of attenuated folds and mineral lineations plunge most commonly gently northwest or southeast in marked contrast to the rest of the salient. It appears then that only the outer or northeastern margin of the salient was deformed into northwesterly trending structures common to the unmetamorphosed rocks to the northeast in the Selkirk Mountains.

Late Structures

Mylonitic rocks occur at several points along the Big Bend highway. This, and the fact that the metamorphic grade increases rapidly from greenschist facies on the east to upper almandine-amphibolite facies to the west, suggest that a fault zone may underlie much of Columbia River valley at least from Ruddock Creek to La Forme Creek. Highly sheared rocks and a fault zone near Albert Canyon in Rogers Pass area suggest that a similar if not the same zone may separate the Clachnacudainn Salient from the low-grade rocks to the northeast. The mylonites are developed in the crystalline rocks of the Shuswap Metamorphic Complex and hence movement between the Selkirk rocks and the Shuswap

crystalline rocks took place after metamorphism in at least the marginal part of the latter had ceased and the rocks had become relatively rigid.

Aerial photographs reveal many prominent north-trending lineaments. Valleys such as those of Seymour River, Ratchford Creek-Myoff Creek-Perry River, and the lower parts of Jordan River and Frisby Creek all appear to have developed along such lineaments. These lineaments follow a steeply dipping joint set. Some of the joints are marked by a zone of shearing and others reveal some stratigraphic displacement but, in general, there is little or no displacement. For example, in places where there is good stratigraphic control, such as at the head of Ratchford Creek, marble beds can be traced without displacement across the lineament. The apparent offset of quartzite across the same lineament at Perry River may be accounted for by faulting but, if so, then the fault must die out at the head of Ratchford Creek for the reason given above. Alternatively the quartzite may be only apparently displaced across the head of Perry River by a mushroom-shaped bulge in the gneiss dome in which the "overhanging" part is covered by drift.

Most commonly, however, the lineaments are emphasized by lamprophyre dykes following the joint set. The date of 41 m.y. on one of these lamprophyres indicates that the rocks of the Shuswap Metamorphic Complex had ceased to be deformed and metamorphosed and were fractured some time before. It supports the relationship east of Kelowna in Kettle River map-area where Tertiary beds containing volcanic rocks 47 $\pm$ 2 m.y. old overlie the Shuswap rocks unconformably (Little, 1961; Mathews, 1963).

SELKIRK MOUNTAINS

The predominant structural trends in this region are northwesterly as displayed by the strike of the foliation, the traces of the axial planes of folds where they can be mapped, the traces of faults, and the outcrop patterns of the formations. Northeast of a line from the head of Windy Creek northwest past Argonaut Mountain to near the mouth of Bigmouth Creek, the structures are overturned to the northeast with southwest-dipping foliation and axial planes. Southwest of this line the structures are overturned in the opposite direction, with predominant east- and northeast-dipping foliation and axial planes (Section ABC). This structural axis — here called the "Selkirk axis" — is the northwestward continuation of that described in Rogers Pass map-area (Wheeler,

1963). The northwestward-narrowing strip of the Hamill Group crosses the structural axis near the head of Norman Wood Creek. In so doing the Hamill beds change northwestward from predominantly northeast-dipping structures through those dipping steeply east and then across the axis over to southwest-dipping beds. It is noteworthy that in the Selkirks the area of southwesterly and westerly overturned structures lies opposite that in the Shuswap Metamorphic Complex embracing the gneiss dome, its paragneiss envelope, and the Clachnacudainn Salient (Sections DE and FGH).

A characteristic feature of the outcrop pattern, particularly of the limestone of the Horsethief Creek Group, and to a lesser degree the Hamill Group itself, is the way these units pinch out along strike. Few of these terminations have been thoroughly investigated but some investigations have indicated that the terminations occur around highly attenuated folds whose axis trend westerly or northeasterly. In fact it appears that the belt of Hamill Group rocks lying northeast of Downie Creek ends just east of the map-area north of Mount Moloch, not because of a sudden, steep southerly plunge (Wheeler, 1963), but about recumbent folds that plunge steeply northeast.

Structures belonging to the three main trends — westerly, northeasterly, and northwesterly — are described briefly below. Westerly and northeasterly trending folds probably belong to the same set and appear to be earlier than the development of northwesterly trending folds and faults.

Westerly Trending Structures

Westerly trending structures occur principally northeast of the Selkirk axis in highly metamorphosed rocks. There, westerly plunging folds are accompanied by linear structures parallel with the axes of the folds. Lineations are expressed by streaks of mica and aligned crystals of sillimanite and kyanite, and by crenulations developed where the axial-plane cleavage in similar folds intersects the folded foliation surface. In cross-section the folds are both of similar and disharmonic types. The former have a marked axial plane cleavage with which mica plates and intermediate axes of feldspar augen are parallel. The long axes of the augen are parallel with the fold axis. Such folds are particularly well displayed at the head of the west fork of Windy Creek. In this region the limbs of westerly plunging attenuated recumbent folds of an amplitude of a mile or more can be traced back and forth by means of marble beds in the metamorphosed Horsethief Creek Group. The axes of the westerly trending folds plunge more and more steeply west as the

Selkirk axis is approached from the northeast. At the head of Norman Wood Creek on the Selkirk axis these folds plunge almost vertically. There, marble and skarn correlated with the Badshot Formation occur in the core of a fold closing to the north and are surrounded by Hamill quartzite in turn surrounded by rocks traceable to the south into recognizable Horsethief Creek Group rocks. Hence folds closing to the north are probably synclines.

Steeply dipping, westerly striking beds just north of the Adamant batholith probably represent northwesterly striking beds which have been deflected into parallelism with the borders of the batholith possibly in response to reintrusion of the latter in Cretaceous time.

Some easterly trending wrinkle lineations occur in phyllonites and low-grade schists between French Creek and Columbia River and west of Standard Peak.

Northeasterly Trending Structures

Northeasterly trending structures are most prominent in the rocks of greenschist facies southwest of the Selkirk axis. The structures are characterized by northeast-plunging fold axes, wrinkle lineations from the intersection of an axial-plane cleavage with the bedding, and mineral lineations displayed by alignment of megacrysts of biotite, chlorite, and locally hornblende. Large folds developed around northeast-plunging axes occur in some places. For example, 4 miles northwest of Mount Holway a northeast-plunging fold closes to the northwest. The youngest beds, the Lardeau Group, are in the core of the fold so that once again a fold closing to the north is a syncline. Similarly, just east of the map-area, the northeast-plunging folds close to the southeast and terminate. The belt of Hamill Group northeast of Downie Creek should be anticlines. That they are, is confirmed by the stratigraphy, for the beds are progressively younger southeastward across the folds. Elsewhere terminations of thin beds around small attenuated northeast-plunging folds suggest by analogy that some of the large terminations may also be around northeasterly plunging folds.

Preliminary analysis by unfolding on the stereonet suggests that the westerly plunging folds northeast of the Selkirk axis belong to the same system as the northeasterly plunging folds southwest of the Selkirk axis. It appears that the former have been redeformed by the warp northwest of the Adamant batholith. There the belt of Hamill quartzite which dips northeasterly south of the Adamant batholith has been overturned to a southwest dip and carried northeastward.

The relationship of some southwest-plunging fold axes and mineral lineations northeast of the Selkirk axis remains uncertain. East of the head of Norman Wood Creek, westerly trending lineations could be traced around the hinge of a southwest-plunging fold but this fold's relationship to northwest-trending folds is not known.

Northwesterly Trending Structures

Northwesterly trending structures southwest of the Selkirk axis appear to have been directed southwestward, toward the gneiss dome. Axial planes of folds, and thrust faults, generally dip northeast. The folds and their axial traces can be most readily mapped in the competent Hamill quartzites and where limestone beds provide good horizon markers. The style of folding is variable. Concentric folds are most common in the thick-bedded parts of the Hamill Group but similar folds predominate in other rocks.

Thrust faults are most easily recognized in strata involving the Hamill Group and Badshot Formation. Those in the Hamill Group are developed either close to the hinge of a fold or across the steeper limb (Section FGH). Near the bend in Sorcerer Creek northeasterly dipping Hamill beds are cut off below by a flatter fault from the underlying Horsethief Creek Group. The Hamill Group apparently slid over the older Horsethief Creek rocks in the same manner as above the Argentine thrust fault in Rogers Pass area (Wheeler, 1963). South of the bend of Sorcerer Creek several faults trend northwest. The relationship of these faults to the fault separating Hamill Group from the Horsethief Creek Group has not yet been established.

Two thrust faults underlie the Carnes Peak massif. The lower or northerly one rises in steps to the northwest. The upper or southerly fault is recognized by the truncation below of more steeply dipping east-dipping beds by flattish south-dipping beds.

Several faults, not included on the map, lie along the sheared-out lower limbs of attenuated overturned anticlines outlined by the Badshot Formation near the head of Carnes Creek.

The intensity of deformation increases southwestward toward the gneiss dome and particularly toward the Clachnacudainn Salient. Folds become tighter and thrust faults more numerous until in some areas, particularly that around Downie Creek, they are so repetitive that the region is essentially an imbricate zone.

Other features indicative of intense deformation and characteristic of the imbricate zone are huge pods or lenses of quartzite probably belonging to the Hamill Group. These pods may be squeezed off parts of quartzitic cores of extremely attenuated anticlines.

Folds and faults are exceedingly difficult to recognize in the weak rocks of the Horsethief Creek Group and Lardeau Group north of Goldstream River and south of Downie Creek respectively. In these areas the rocks have, in general, a gently dipping to almost flat foliation. Thin sections from some of the pelitic rocks reveal extreme deformation featured by sheared-out grains of quartz and numerous anastomosing shears cutting across microfolds outlined by micas, all characteristic of phyllonites.

Northwesterly trending structures occur north of Goldstream River where the east-dipping part of the Hamill Group and associated rocks are warped into open southeast-plunging folds (Section ABC). The underlying marbles east of the mouth of French Creek are deformed into folds having a pronounced, steeply-northeast-dipping axial-plane cleavage. These northwesterly trending folds are tighter closer to the Selkirk axis as on Argonaut Mountain and at the head of French Creek. There the rocks are considerably metamorphosed and garnet porphyroblasts with lenticular envelopes of hornblende and plagioclase are aligned parallel with the steeply-northeast-dipping cleavage superimposed on the earlier foliation outlining the westerly trending structures. In this region some northwest-trending structures were apparently also developed after twisting of the belt of Hamill and associated rocks near the tail of the Adamant batholith. Furthermore, rocks near the Selkirk axis were still undergoing metamorphism during this late northwesterly trending open folding.

Some southeast-plunging warps on the southeast side of Carnes Peak massif may also belong to the same fold system as that around French Creek.

The relationships between certain groups of rocks are not yet understood in some places where insufficient mapping has been done and in others where exposures are poor. An example of the former is the area southeast of the mouth of Sorcerer Creek where a northeast-plunging synclinal fold closing to the northwest lies opposite a southeastward narrowing belt of Horsethief Creek Group rocks. Another example is the area between the mouth of Sorcerer Creek and Goldstream River where the virtual absence of Hamill rocks and the similarity of Lardeau and Horsethief Creek pelitic rocks make the distribution of the rocks of the two groups

uncertain*. The heavily timbered and drift-filled valleys of Columbia and Goldstream Rivers mask the relationships between the Horsethief Creek and Lardeau Groups along these valleys.

Northwesterly trending structures northeast of the Selkirk axis have been directed northeastwards towards the Rocky Mountain Trench. The structures are developed in medium-grade rocks and because of the lack of horizon markers few large folds have been recognized. Marble beds outline some synforms overturned to the northeast, and the nepheline syenite gneiss in the core of an overturned and recumbent antiform outlines an undulating nappe (Section ABC). The folds plunge moderately to the northwest but displacement of the nepheline syenite across the valley next northeast from Trident Creek suggests that at least some of the folds are cut by northeast-trending faults which reduce the net plunge. Another northeast-trending fault may also follow the valley of Trident Creek.

Minor folds vary from disharmonious flow folds to folds of similar type. In places these folds split locally and form en échelon arrangements. Westerly trending lineations wrap around northwesterly trending folds. Locally, in the hinge zones of these folds a new mineral lineation is developed parallel with the northwesterly fold axis.

ROCKY MOUNTAIN STRUCTURES

Structures in the Rocky Mountains in Big Bend map-area are characterized by folds with southwest-dipping axial planes and southwest-dipping faults. This style is characteristic of the southwesternmost fringe of the Rocky Mountains as far south as Big Foster Creek in Rogers Pass map-area about opposite the Adamant batholith (Wheeler, 1963). The same region in the Rockies is the site of regional metamorphism up to kyanite-almandine subfacies.

Noteworthy features in the Rocky Mountains within the map-area are the existence of southwest-plunging, minor, similar folds in the phlogopite marbles of the Chancellor Formation and the mass of breccia up to 1,000 feet wide between the two faults on the southern slopes of Kinbasket Mountain. The breccia, which weathers yellowish buff, is composed of fragments of limestone and marble up to 20 feet across. Most fragments are angular but some are somewhat rounded. They lie in a finer-textured matrix cemented by travertine. Mica crystals occur in the fragments and in the

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* In 1964 the belt of Hamill Group rocks east of Downie Creek was traced northwestward into the belt east of French Creek.

matrix. Although Fyles (1960a) considered the crystals to have been a product of metamorphism subsequent to the formation of the breccia, the writer considers the crystals in the matrix to be detrital and to have been freed from the blocks of phlogopite marble. This is suggested by the irregular distribution of mica crystals which appear to occur only in the matrix near mica-bearing marble fragments but which are absent in the matrix when the surrounding fragments lack mica. Thus the breccia is considered post-metamorphic. Its origin is uncertain but superficially appears to be related to the southwest-dipping faults.

The master fault which brings the Horsethief Creek Group against limy rocks of the Rocky Mountain province probably passes along the southwest side of Kinbasket Lake. The Columbia River valley there represents one of the narrowest parts of the Rocky Mountain Trench.

ECONOMIC GEOLOGY

The following is a brief summary of the mineral deposits in the map-area. As only a few properties have been examined so far, this information is mainly from annual reports of the British Columbia Minister of Mines and particularly from Gunning (1929).

Lead-zinc deposits, generally low in silver, are the predominant type in the map-area.

Kinbasket (1)* property lies 300 to 400 feet above the southwestern shore of Kinbasket Lake between Trident and Windy Creeks. The showings consist of sphalerite and galena replacements of limestone mapped with the Horsethief Creek Group. Replacements occur at intervals over a distance of about 1,000 feet. The sulphides occur in layers up to 3 to 4 inches wide and where they are concentrated in drag-folds such layers aggregate several feet in width. The Consolidated Mining and Smelting Company of Canada, Limited had the property under option in 1951 when some geological mapping and exploration was undertaken. Since then the claims have reverted to the Crown.

Ruddock Creek (2) property, discovered in 1960, is being explored by Falconbridge Nickel Mines, Limited. Mineralized zones in calcareous layers in gneisses and schists of map-unit E have been traced intermittently for several thousand feet from an

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*Numbers refer to properties shown on the accompanying map.

elevation of about 7,500 feet at the head of Ruddock Creek northwesterly around the summit mass of the peak, 6 miles west of Gordon Horne Peak, and thence westerly down into Oliver Creek valley. The mineralized zones consist of relatively continuous layers, a few feet to a few tens of feet thick, containing dark brown sphalerite, pyrrhotite, and galena, closely associated with dark grey, fetid marble. Sphalerite occurs in three ways: commonly as a medium-grained granular aggregate with quartz; as a matrix to a breccia composed of rounded and streaked-out fragments of quartz and siliceous rocks; and locally as very fine grained masses with pyrrhotite and quartz forming a dense, thinly banded rock containing eye-shaped cherty fragments. The cherty material resembles mylonite (Fyles, 1962). Fluorite, barite, epidote, and amphibole occur here and there in the mineralized zones.

Around the peak 6 miles west of Gordon Horne Peak the schist and gneiss dip gently southwest and are characterized by small folds that plunge gently west-northwest. Numerous sheets and irregular masses of pegmatite on the property obscure the geology and add to the difficulty of exploring the mineralized zones.

Detailed mapping, drilling, and sampling is currently being undertaken. The entire operation is serviced by helicopter.

Cottonbelt (3) property lies between elevations of 5,000 feet and 6,000 feet on the hills south of Blais Creek. The property, which has remained relatively unexplored since the 1920's, is accessible by 18 miles of road and trail from the head of Seymour Arm. The mineralized zone consists of galena, sphalerite, pyrrhotite, and magnetite. Some grey copper and molybdenite has also been reported. It lies about 100 feet east of the southwesternmost of two prominent beds of marble which can be traced intermittently from Blais Creek to Ratchford Creek. The mineralized zone dips about 35°SW, parallel with the bedding in the host schists and gneisses, and has been traced for a distance of more than 2,000 feet on the surface, with widths up to 12 feet. Underground the zone was followed by a tunnel for 800 feet, the width averaging between 18 and 24 inches.

A second zone, the Complex, lies 3,000 feet to the northeast of the Cottonbelt vein. The Complex has been traced for about 1,000 feet by open-cuts. A tunnel driven on the vein revealed 7 feet of mineralized rock, largely of magnetite but containing values in lead, zinc, and copper.

River Jordan (4) property (Riley, 1961) lies 12 miles northwest of Revelstoke between elevations of 5,800 feet and 7,900 feet on the northern slopes of Mount Copeland. The property can be reached by 10 miles of road and trail up Jordan River and Copeland Creek. The last part rises 2,800 feet in 1 1/2 miles of switchbacks. The property lay dormant since the 1890's until 1955 when it was restaked and optioned to American Standard Mines Limited. The following year some mapping and sampling were undertaken. In 1963 Bralorne Pioneer Mines, Limited, spent 2 months on a drilling program.

The mineralized zones are bedded lodes within a succession of gneisses, schists, quartzites, and marble deformed into a synform overturned to the northeast. This synform is considered to be a conical fold or part of the northwesterly trending en échelon system. The two lodes, one on each limb of the fold, are considered to be the same bed inasmuch as each lode lies about the same distance above the marble bed.

The sulphides in the lodes are galena, sphalerite, minor chalcopyrite, pyrite, and pyrrhotite. Gangue minerals are quartz, calcite, and locally barite. All these minerals replace an incompetent, impure limestone which has been drag-folded and brecciated. Sphalerite is dominant in the higher parts of the southern limb and at its western end where it is accompanied by barite. Galena prevails in the lower parts of the southern limb and at the eastern end of the fold.

The No. 1 lode, averaging about 5 feet in width, is exposed intermittently for about 3,500 feet, about half the total length of the southwest limb of the fold. Large sections of the lode are covered by glacier and moraine. The No. 2 lode, averaging a little less than 2 feet in width, has been traced discontinuously for 2,100 feet. Riley estimated the deposit held 2,872,700 tons (allowing for dilution) containing 1.1 ounces per ton of silver, 5.1 per cent lead, and 5.6 per cent zinc.

The following lead-zinc deposits occur in the Badshot Formation or in the Lardeau Group close to the Badshot Formation.

Mastodon Mine (5) is at an elevation of 5,000 feet on the ridge between La Forme and Carnes Creeks. It is developed on four levels and is serviced by an incline from the main camp. The latter, the site of a 200-ton mill, is at an elevation of 3,400 feet on the north side of La Forme Creek, 4 1/2 miles from the Big Bend highway. The mine has operated periodically, the last time during the latter part of 1960 by Mastodon Zinc Mines, Limited, when 15,532 tons of

ore was milled. The ore averaged 0.2 ounce per ton of silver, 0.5 per cent lead, and 9.5 per cent zinc.

The orebodies, principally replacements of calcareous rock by sphalerite, lie on the west side of a lenticular mass of carbonate extending from the east fork of La Forme Creek northwest to Carnes Creek. The adjoining phyllites as well as the limestone are isoclinally folded and highly sheared. The rocks are cut by several strike faults more or less parallel with the foliation and are characterized by minor folds which are Z-shaped when looking down the plunge. The minor folds plunge northeast mainly down the dip of the foliation and less commonly gently to the north and northwest. The orebodies consist principally of light yellowish brown to dark brown sphalerite and minor galena and grey copper in a gangue of unreplaced remnants of host rock. The orebodies are in or close to the strike faults and form northeast-dipping tabular or lenticular bodies that rake to the north, apparently controlled by the plunge of the minor folds. Fyles (1960b) considered that the structural conditions of rocks adjacent to the strike faults were more important than the chemical character of the rocks.

Lead King (6) showings lie about 2 miles east of the Mastodon mill. They are at the southeastern end of the same northeast-dipping carbonate body, at the side of which lies the Mastodon Mine. The mineralized zone consists of a 200-foot zone of sphalerite and galena in dolomite.

Little Slide (7) showings are northeast of the east fork of La Forme Creek about 3 miles east of the Mastodon Mill. The northwesterly showings consist of five or six white quartz veins containing galena, sphalerite, and minor chalcopyrite. The veins strike between N 25 °E and N 45 °E and dip very steeply northwest, thus transecting the northeast-dipping sequence of grey limestone, dolomite, and grey and green phyllite. The showings 1/2 mile to the southeast are discontinuous lenticular replacements by galena and sphalerite, of limestone and dolomite, in a northeast-dipping assemblage of calcareous rocks and grey and green phyllites. In one place sphalerite occurs in small lenses at the crest of a tight fold at the phyllite-limestone contact.

J and L group (8) is on the shoulder between the east and south forks of Carnes Creek about 8 miles by trail from the Big Bend highway. Some work was done on the property in the 1920's but none since.

The lode lies along a well-defined shear zone at or near the contact between quartz-sericite schist and limestone. The contact, which strikes northwest and dips into the hill at 30 to 55°NE, has been traced at intervals by open-cuts and trenches for more than 5,000 feet. The mineralized zone is not continuous although locally it is 6 to 8 feet wide. It has formed partly by filling of the shear zone and partly by replacement of the foot-wall limestone. Sulphides occur as lenses and bunches, here and there 3 feet wide but rarely more than 12 to 16 inches. They include a fine-grained mixture of sphalerite, galena, arsenopyrite, pyrite, chalcopyrite, and minute amounts of grey copper. Gunning (1929, p. 170) stated that polished sections reveal that the pyrite and arsenopyrite generally occur as crushed and rounded grains. Gangue minerals are quartz and calcite. Much of the lode is extremely altered and decomposed by oxidation.

Short adits have been driven at the northwest end of the mineralized zone at an elevation of 3,475 feet and about 2,500 feet southeast at an elevation of 4,075 feet. A short inclined shaft was sunk at an elevation of 3,825 feet about 1,000 feet southeast of the lower adit.

A and E (9) showings lie between the elevations of 6,000 feet and 7,200 feet on the northeastern slopes of the hill south of Burke Creek. They are reached by a trail up Burke Creek past a cabin (in good condition) near timber-line at 5,700 feet. The showings consist of two principal zones of mineralization. The southwestern one occurs at the contact of northeast-dipping Badshot marble lying structurally on black slate of the Lardeau Group. The lode is exposed on the side of a steep bluff rising for several hundred feet to the summit to the southeast. The rugged terrain hampers detailed examination of the lode but Gunning observed 2 to 3 feet of pyrite, sphalerite, and galena. The sulphides appear to have replaced the limestone near the contact and are along the zone as lenticular bodies. Some smaller veins, a few containing almost pure galena, intersect the main zone at small angles. Some of the lower exposures contain arsenopyrite with the lead-zinc minerals.

A second zone lies about 200 feet stratigraphically above and northeast of the first. It occurs in limestone which contains a thin bed of grey sericite schist. This zone, which lies parallel with the first, has been traced for 150 feet and varies in width from 6 inches to 2 1/2 feet. Sulphides comprising pyrrhotite, sphalerite, and galena are finely intergrown. Grey copper occurs in small amounts in galena.

Some quartz veins east of the Roseberry group and south of the A and E group are heavily mineralized with grey copper, and two minerals resembling bournonite (lead-copper-antimony sulphide) and boulangerite (lead-antimony sulphide). Some pyrite and chalcopyrite are also present. This mineral suite is typical of the quartz-tetrahedrite assemblage (Gunning, 1929) of which the George Group in Rogers Pass map-area is the outstanding example.

Keystone (10) claim at the head of Keystone Creek is accessible by logging road and trail from the Big Bend highway. The claim is staked amid an assemblage of limestone, carbonaceous slate, mica schist, and greenstone. Workings consist of two short adits and a winze from the lower one. Very gently dipping limestone has been replaced along the bedding for about 45 feet by quartz, pyrite, pyrrhotite, sphalerite, and galena and a little chalcopyrite. Some pyrite, quartz, and calcite occupy a fissure striking N 30°E and dipping steeply southeast.

Small amounts of sulphides like those on the Keystone claim are found in quartz veins and as small replacements on adjoining claims to the southeast.

Two copper showings, only, are known in the map-area. Montgomery group (11) lies on the southwest ridge of Downie Peak, principally on slopes southeast of the ridge. A trail leads from Downie Creek bridge to the workings at an elevation of 5,200 feet. The deposits occur within a contact metamorphic assemblage of northeast-dipping marble and metasediments of the Lardeau Group which have been intruded by a cluster of quartz monzonite stocks. The mineralized zone lies not far beneath marble beds and above mica, chlorite, and andalusite schists, quartzites, and calc-silicate rocks. Many fine-grained granitic dykes cut the metasediments near the workings. The deposits consist of lenticular, bedded replacements of rocks that were originally calcareous sandstone, by pyrrhotite, some pyrite and chalcopyrite, and a little sphalerite. Gangue minerals are quartz and silicified wall-rocks, with some garnet, epidote, and actinolite. No sulphides occur in pure marble.

One mineralized zone has been followed by open-cuts along strike for several thousand feet and over a vertical range of over 1,000 feet. Sulphides are present in zones 1 foot to 15 feet in width. Chalcopyrite is most abundant in the siliceous country rocks on the hanging-wall side of the main mineralized zone and locally in siliceous rocks within the mineralized zone. A second bedded, mineralized zone occurs a few hundred feet higher in the succession to the northeast.

Standard group (12) is at the head of Standard Creek between elevations of 6,600 and 7,200 feet. It can be reached by logging road and trail. Workings in 1928 consisted of 2,000 feet of tunnels and raises on five principal levels and numerous open-cuts.

On the property, two large sill-like bodies of greenstone are separated by a broad zone of interbedded limestone, pyritic graphitic schist, sericitic schist, and chloritic schist, which all dip 20 to 40°E. Sulphides, which comprise a fine-grained mixture of pyrite, pyrrhotite, chalcopyrite, and a little sphalerite and here and there clots of chalcopyrite, occur only in the greenstones along shear zones as replacement bodies that parallel the bedding. Gangue minerals are watery-looking quartz and a little calcite. Along parts of the mineralized zone and in some other places the greenstone has been altered to talc and various carbonates.

Gold-quartz deposits occur principally around the headwaters of Old Camp, McCulloch, and Graham Creeks. The best known claims are those of the Ole Bull, Orphan Boy, and adjoining claims staked in the years following the gold rush in 1865. Most of the work done on these claims was done before 1900. In 1959 Stanmack Mines, Limited (13) did some work on the veins. The deposits consist of several quartz veins mineralized with pyrite, free gold, and some pyrrhotite. The veins strike N 10-20°E and dip steeply east, thus crosscutting at a high angle the gently northeast-dipping impure quartzites and mica and chlorite schists of the Horsethief Creek Group. The veins range from 6 inches to 3 feet or so in width. The sediments near the vein are in some places extensively carbonated. Gold occurs free or in pyrite. Gunning (1929) considered that the gold is primarily associated with the sulphides but upon oxidization of the latter the gold is set free and hence free gold should be found only in the oxidized part of the vein. Gunning recovered free gold when such oxidized zones were panned.

Roseberry group (14), including the Salisbury claim, occurs at an elevation of about 5,500 feet on the ridge east of the mouth of Kelly Creek. Arsenopyrite and pyrite carrying gold occur in quartz veins up to 5 feet in width. Veins on the Salisbury claim lie in altered diorite. Near the veins the rocks are silicified and carbonated.

Carbonate Chief property is on the west side of the basin at the head of Mars Creek but its exact location is not known. Reports state that numerous quartz veins carrying pyrite contain appreciable gold. The veins occur in black to grey, siliceous slate.

Molybdenite is an important mineral on two properties in Columbia River valley a few miles north of Mars Creek. Sterling (15) property staked in 1938 and 1939 lies just east of the Big Bend highway, 700 feet south of the 34-mile post. The workings consist of three short adits and open-cuts in a heavily timbered area. The deposit consists of molybdenite, pyrrhotite, and pyrite disseminated in bodies of massive, siliceous rock enclosed in quartz-muscovite schist and phyllite. Stevenson (1940) considered the deposits to be a high-temperature replacement of schist by feldspar and quartz. The replacement zones trend north and northeasterly. The largest replacement body is 40 feet wide but its length is not known. The next largest body, about 300 feet south-southwest of the largest, is 35 feet wide. It may be part of the largest body. The smallest body, about 75 feet northeast of the largest one, is 1 foot to 2 feet wide and its possible length is 175 feet.

Hard Pan (16) occurrence lying a short distance north along the highway from the Sterling showings is developed on an 18-inch quartz vein carrying pyrite, pyrrhotite, and molybdenite, with, in parts, some silver, lead, and zinc.

Monarch group (17) lies on Goldstream River a short distance above its mouth. There some serpentine layers occur in talc and graphitic schists a short distance west of the limestone at the falls. Some of the serpentine contains stringers and veinlets of asbestos of actinolitic variety. Three short tunnels constitute the workings.

Placer gold has been sought at intervals over many years from McCulloch Creek, Graham Creek, Old Camp Creek, the lower part of French Creek, and from bars on Columbia River. In recent years work has been done on Graham Creek, McCulloch Creek, and on Columbia River at the mouth of Kirbyville Creek. Large boulders provide a problem to mining on both McCulloch and Graham Creeks.

EXPLORATION NOTES

The map-area seems to be most favourable for the discovery of lead-zinc deposits. In the Selkirks, sulphides of these metals are most commonly associated with limestones of the Badshot Formation and with the lower part of the Lardeau Group. Only the Kinbasket deposit occurs in the Horsethief Creek Group but even there the stratigraphic position of the marbles southwest of Kinbasket Lake is far from certain. Mineral zones in some of the

occurrences are traceable for more than 1,000 feet. Observers have noted that in the Mastodon, Little Slide, and Kinbasket occurrences, sulphide concentrations are to a considerable degree related to drag-folds. It has been emphasized how significantly the outcrop pattern and distribution of rock types has been influenced by westerly and northeasterly trending folds. It is suggested therefore that concentrations of sulphide related to such folds should have a reasonable hope of producing ore shoots down the plunge of the folds. Hence particular attention should be paid to the attitude of folds related to sulphide concentration.

In all three occurrences in the Shuswap Metamorphic Complex, mineralization is continuous over thousands of feet. All are related to impure marbles not far removed stratigraphically from pure marbles and quartzites. Consequently such impure marbles in the quartzite, marble, paragneiss envelope offer a promising zone for prospecting for lead and zinc.

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