CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

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CANAL FLATS, BRITISH COLUMBIA

(Map and Preliminary Account)

By

Geoffrey B. Leech

OTTAWA
1954

Price, 50 cents

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PRELIMINARY ACCOUNT
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Illustration

Preliminary map - Canal Flats, British Columbia .... In pocket

CANAL FLATS, BRITISH COLUMBIA

INTRODUCTION

Canal Flats map-area, between latitudes 50°00' and 50°15' and longitudes 115°30' and 116°00', straddles the Rocky Mountain Trench at the Columbia-Kootenay watershed. The eastern part is in the Rocky Mountains and the western part in Purcell Mountains. Strata in the Rocky Mountains, with which this report deals, are of Late Precambrian and Palaeozoic ages, chiefly the latter. The Purcell Mountain part consists of Late Precambrian rocks intruded by a Mesozoic (?) batholith.

Various geologists have visited the Rocky Mountain Trench near Canal Flats in the 90 years since the first, James Hector, traversed the route in 1859, but they attempted no systematic mapping. G. M. Dawson followed the trench in 1883 and 1884; he noted the physiography and found Cambrian fossils at Columbia Lake. S. J. Schofield visited Mounts Sabine and Grainger in 1914 and 1921 and measured a section in the Hughes Range just south of the map-area (Schofield, 1922)[1]. C. D. Walcott studied sections on Mounts Sabine and Grainger in 1923 (Walcott, 1924). J. F. Walker continued Schofield's work in 1922-24, extending the reconnaissance along the west flank of the trench. He published a geological sketch map on a scale of 20 miles to the inch (Walker, 1926). In 1950-52 G. G. L. Henderson, then of the British Columbia Department of Mines, mapped the Stanford Range, whose southern tip is in Canal Flats map-area. In 1953 the writer mapped the eastern third of the map-area and reconnoitred the remainder of the east half. He is indebted to G. G. L. Henderson, who made available the results of work in the Stanford Range and discussed them in the field.

The central or Rocky Mountain Trench part of the map-area is served by a hard-topped highway and the Kootenay Central Railway of the Canadian Pacific system. Branch roads follow the valleys of Kootenay River and Findlay Creek. The lower ground adjacent to the trench contains a network of logging roads, some of which remain more or less permanently passable but most of which are short-lived. In 1953 private logging roads were under construction up Ram and Nine Mile Creeks. The eastern part of the map-area, in the Rockies, is a well-known big game area and is served by pack-horse trails. A well-travelled trail, reached from a logging road near the south bend of Lussier River, leads via Lussier Canyon and Alces (Moose) Lake to, and beyond, White Swan Lake. A branch along the upper Lussier was open to horses as far as Roam Creek in 1953. Horses

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[1] Names and dates are those of references given in the Bibliography at the end of this report.

can be taken to timber-line on the headwaters of Mutton (Lamb) Creek. The northeast corner of the map-area can be reached from a trail on the east bank of White River, east of the map-area, but the river can only be forded during relatively low water. The writer took horses half a mile into the map-area up Moscow Creek from White River and an old trapping trail could be reopened farther.

The main physiographic units east of the Rocky Mountain Trench and south of Kootenay River trend north and northwesterly. From the trench eastward these are: a mountain range that extends northward from latitude 50 degrees to the Kootenay at Mount Grainger; a broad valley that contains lower Lussier River and extends north to the Kootenay; the Hughes Range, transected by Lussier Canyon; a broad valley containing upper Lussier River, and continued to the north by the linear narrow valleys of south-flowing Mutton Creek and north-flowing Nine Mile Creek; and mountains in the northeast part of the map-area, which are linked with the Hughes Range at the heads of Mutton and Nine Mile Creeks.

Glaciers were active in the area and left their imprint on many topographic details. Ice probably buried the area completely, as glacial erratics occur at an altitude of 7,750 feet in the northern headwaters of Ram Creek in the Hughes Range, and at 7,200 feet east of Nine Mile Creek. At Ram Creek the erratics include "syenite", amygdular lava of Siyeh type, and dioritic rock of Moyie (Purcell) Intrusions type. Syenitic erratics are present also east of Nine Mile Creek and in the 5,100-foot pass south of Mount Glenn. These igneous rocks, all foreign to the Rockies part of the map-area, occur in place in the Hughes Range south of the map-area and in the Purcell Mountains. Syenitic and dioritic rocks occur also on Ice and Cross Rivers respectively, well north of the map-area, but the lava occurs only to the south.

The drainage pattern in which Lussier River transects the Hughes Range appears to be post-glacial. The topography indicates that Mutton Creek and the upper part of Lussier River once flowed eastward through the valley of White Swan Lake. These may have been captured by headward erosion of a stream on the west flank of Hughes Range at the site of the present Lussier Canyon when eastward escape of the present upper Lussier was blocked by ice in the White Swan route. Thick deposits of glacial silt occur in upper Lussier Valley and may reflect temporary ponding. The present lower Lussier may occupy part of a former course of Kootenay River through the broad low pass east of Mount Grainger. The altitude of this drift-laden pass is about 3,350 feet, roughly the same altitude as the top of the post-glacial gorge at Gibraltar Rock farther north on the Kootenay. The pass is 600 feet above the present discharge of the Kootenay to the Rocky Mountain Trench through the steep-walled and relatively narrow valley between Mounts Grainger and DeSmet.

GENERAL GEOLOGY

TABLE OF FORMATIONS

Period or epoch	Group or formation	Lithology
Pleistocene and Recent		Glacial till; gravel, sand, silt, alluvium
Unconformable contact		
Mississippian		Limestone, shale; chert
Relationship unknown		
Silurian and (or) Devonian		Gypsum, limestone
Relationship unknown		
Silurian?		Dolomite; limestone; shale
Relationship unknown		
Silurian	Brisco formation	Dolomite, limestone, shale, quartzite
Conformable contact		
Upper Ordovician	Beaverfoot formation	Dolomite, limestone; quartzite
Conformable contact		
Middle or Upper Ordovician	Wonah formation	Quartzite, sandstone

Disconformable contact

Lower and Middle Ordovician	Glenogle formation	Shale, limestone; siltstone

Conformable contact

Upper Cambrian and Lower Ordovician	McKay group	Limestone, shale

Conformable contact

Middle and (or) Upper Cambrian	Jubilee formation	Dolomite

Conformable (?) contact

Lower Cambrian		Shale, sandstone, limestone, quartzite
	Conformable contact	
	Cranbrook formation	Siliceous quartzite, grit, and pebble conglomerate; sandstone

Disconformable contact (possible angular discordance)

Windermere	Horsethief Creek series	Argillite, grit, pebble conglomerate
	Conformable (?) contact	
	Toby formation	Conglomerate, argillite

Disconformable (?) contact

Upper Purcell		Argillite, argillaceous dolomite; quartzite

UPPER PURCELL

Upper Purcell strata occur on the west flank of the Hughes Range south of Ram Creek. They are chiefly or entirely a continuation of strata Schofield (1922, p. 13) classed as Rooseville formation about 1 1/2 miles south of the Canal Flats map-area.

Argillaceous rocks predominate. Argillites, which include silty and dolomitic varieties, are accompanied by dolomites and minor amounts of fine-grained quartzite. Most of the rocks are distinctly bedded in thicknesses of from 4 to 18 inches and are laminated. The laminae, which are generally between 1/32 of an inch and 1 inch thick, are due partly to compositional layering and partly to colour gradations in rock of apparently uniform composition. The rocks weather to shades of grey, greenish grey, and buff. Fresh surfaces are mostly shades of grey or green, except for some of the argillite, which is always red. Mud-cracks, ripple-marks, and cross-laminations are present.

Upper Purcell strata are overlain with apparent disconformity by the Toby formation of the Windermere system.

WINDERMERE

Toby Formation

The Toby formation, the basal unit of the Windermere system, overlies Upper Purcell strata in the Hughes Range. The Windermere is reported to overlie the Purcell with regional unconformity (Walker, 1926; Rice, 1941, p. 14). No angular unconformity was recognized in Hughes Range outcrops, but bedding is not everywhere distinct in the basal Toby strata. The Toby appears, however, to rest on slightly different facies of Upper Purcell strata in different outcrops.

The Toby formation in the Hughes Range consists chiefly of argillaceous conglomerate. The ratio of fragments to matrix differs from place to place. Some conglomerate is composed largely of closely spaced fragments and some has only occasional fragments. The matrix ranges from argillite to siltstone. Weathered surfaces are rusty brown or yellowish grey and fresh surfaces grey, brown, red, purple, or, less commonly, green.

The embedded fragments range from grit particles to boulders 2 feet or more across. They are characteristically unsorted and their shapes are mostly subangular to subrounded. Fragments of argillite, laminated or massive, predominate, but quartzite fragments, mostly grey and green, occasionally pink, are common, and locally compose 50 per cent of the total. Pebbles, cobbles, and boulders of buff weathering grey dolomite are also locally abundant. Depositional lamination is apparent in some outcrops containing few fragments but many rocks of this type have a secondary platy structure that obscures bedding and may be confused with it. Outcrops of secondarily foliated rock disintegrate into lenticular and chip-like fragments. Toby formation nearly everywhere contains intercalations of argillite, siltstone, and quartzite, and the following sequence, observed half a mile north of the south boundary of the area, illustrates the variation that may occur.

Cranbrook quartzite

Disconformity	Feet
Gap in section	25
Hematitic brown conglomerate	10
Gap in section	60
Conglomerate with about 5 per cent of interbedded argillite	230
Argillite, laminated grey and green, with 6-inch beds of brownish quartzite	15
Conglomerate with boulders up to 2 feet across	25
Quartzite, limonitic, in beds 4 to 18 inches thick	40
Gap in section	100
Pebble conglomerate	10
Siltstone with laminae of argillite	5
Gap in section	25
Pebble conglomerate with intercalations of argillite and siltstone	75
Gap in section	300
Conglomerate, mostly pebble conglomerate	75
	995

Disconformity (?)

Upper Purcell siltstone and quartzite

The Toby formation is overlain disconformably, and perhaps with angular unconformity, by quartzite of the Lower Cambrian Cranbrook formation. Individual outcrops have revealed no clear-cut angular unconformity but the Toby formation appears to be bevelled by the Cranbrook formation. The Toby is not more than 45 feet thick 3/4 mile south of the area but is 1,000 feet thick 1 1/2 miles farther north along its trace, on a spur 1/2 mile within the area. This change in thickness may be in part a feature of original deposition.

Horsethief Creek Series

The Horsethief Creek series (Rice, 1941, p. 17), originally called Horsethief formation (Walker, 1926, p. 14), is reported to overlie the Toby formation conformably in the Purcell Mountains. The contact was not seen in the present map-area.

The Horsethief Creek series is absent in the Hughes Range but it underlies the Cranbrook formation at and south of Mount Grainger and at Mount DeSmet. The base of the series was not seen, and the following description is of beds near the Cranbrook formation. These consist of dark green and brown argillite, grit, and pebble conglomerate, the latter composed of rounded quartz pebbles and fragments of argillite in an argillaceous matrix.

CAMBRIAN

Cranbrook Formation

The Cranbrook formation overlies both Toby formation and Horsethief Creek series disconformably, and possibly with angular unconformity. It consists of siliceous quartzite, grit, and pebble conglomerate, with some yellow weathering, yellowish sandstone beds near the top of the formation. Weathered surfaces are smooth, and are white, yellowish, or, less commonly, pinkish in colour. Most fresh exposures are grey, white, or cream coloured, but some are greenish or pinkish. The quartzite and grit consist of quartz grains in a hard siliceous matrix, and the pebble conglomerates of rounded quartz pebbles in a matrix of siliceous quartzite or grit. Beds and lenses of conglomerate occur throughout the formation. The Cranbrook formation is distinctly bedded, chiefly in thicknesses of 1 foot to 6 feet. Many beds are massive, but some display repetitive colour gradations that are in part also grain-size gradations. Some show cross-lamination, preliminary study of which suggests that the sediments had a southeastern or southern source. The formation is about 800 feet thick in the Hughes Range and Mount Grainger belts but is only about 250 feet thick at Mount DeSmet, 2 miles north across Kootenay River from Mount Grainger.

Lower Cambrian fossils, including the trilobites Callavia and possibly Nevadia, were collected at a point on the crest of the Hughes Range half a mile south of latitude 50 degrees, and were identified by R. V. Best of Princeton University. They occur in a 20-foot zone of yellow sandstone about 100 feet from the top of the Cranbrook formation.

The Cranbrook formation rests on different thicknesses of the Toby formation in the Hughes Range, and on the younger Horsethief Creek series farther northwest. The observed relationship may be due to angular unconformity, or disconformity, or to limited deposition of Windermere strata, but no evidence proving any one of these was seen. Elsewhere, however, the Lower Cambrian rests disconformably on the Proterozoic in the Purcell Mountains (Evans, 1933, p. 118; Rice, 1941, p. 29), but the contact is conformable in the Salmo area (Little, 1950, p. 10).

Post-Cranbrook Lower Cambrian Strata

Three belts of a post-Cranbrook Lower Cambrian formation were investigated in 1953 but only the Hughes Range belt extending from lower Ram Creek southward along the west flank and summit of the range has been mapped. The Mount Grainger belt runs southward from Kootenay River at Mount Grainger and passes east of Mud Creek. A third series of occurrences in the vicinity of Mount DeSmet, on the north side of Kootenay River opposite Mount Grainger, was visited briefly. All are underlain by Cranbrook formation and overlain by Jubilee formation.

The formation succeeds the Cranbrook formation conformably. Its lower and middle parts are chiefly sandstones and shales, the former grading locally to grit and small-pebble conglomerate. The sandstones are rather characteristically limonitic but range from white siliceous types to red and purple, richly hematitic varieties. The shales, some of which are arenaceous, are chiefly red and green. Limy beds, principally limy sandstones, occur throughout the section but are more abundant in the higher parts where some true limestone occurs. Most of the limestone is brown weathering, crystalline, and grey, but fine-grained black limestones and oolitic limestone occur. The formation displays cross-lamination, ripple-mark, scour and fill structures, and mud-cracks.

Preliminary measurements indicate that the thickness of the formation in the Hughes Range and Mount Grainger belts ranges from about 770 feet to about 1,500 feet. It is only 345 feet thick at Mount DeSmet (Henderson, in press). Part of the variation may be a primary depositional feature and part due to a possible erosional disconformity at the base of the overlying Jubilee formation.

Eleven collections of fossils from the upper half of the formation in both the Hughes Range and Mount Grainger belts all contain Lower Cambrian faunas. The following genera, identified by T. E. Bolton of the Geological Survey, are present: *Kutorgina*(?), *Lingulella*, *Bonnia*, *Olenellus*, *Paedeumias*, and *Wanneria*. The formation is approximately chronologically equivalent to the fossiliferous part of the Eager formation of Cranbrook district (Schofield, 1922, p. 12) and to Lower Cambrian strata formerly referred to the base of the Mount Whyte formation (Rasetti, 1951, p. 86).

Schofield (1922, p. 15 and p. 13) assigned the strata of the Hughes Range belt to the Burton formation, his Ram Creek section being measured 1 3/4 miles south of latitude 50 degrees, on the ridge separating the extreme headwaters of Ram Creek from Diorite Creek.

As the type Burton strata near Elko, B. C. are chiefly or entirely Middle Cambrian the writer cannot agree with this correlation. The Mount Grainger locality was visited by Schofield (1922, p. 14). Walcott (1924, p. 29), and Walker (1926, p. 17). Walcott correlated the Lower Cambrian beds there with the lower part of the Mount Whyte formation. The Mount Whyte formation has since been redefined as Middle Cambrian, and the beds with which Walcott correlated the Mount Grainger strata assigned to the Lower Cambrian St. Piran formation (Rasetti, 1951, p. 86).

Jubilee Formation

The Jubilee formation overlies Lower Cambrian strata and is succeeded by Upper Cambrian beds of the McKay group. It has yielded no identifiable fossils.

The Jubilee formation is a cliff-forming dolomite unit that contains two fairly distinct divisions. The Lower Division is well bedded and the beds themselves are rather characteristically laminated. Bed thicknesses are generally 1 foot to 3 feet and laminations are measurable in fractions of an inch. The laminae are to some extent colour phenomena, visible on both weathered and fresh surfaces, but some are compositional, as witnessed by relative relief on weathered surfaces. Some are disrupted by small-scale sedimentary brecciation. The dolomite ranges from a fine-grained, dense-looking rock to one that is visibly crystalline. Most of it is cream coloured to dark blue-grey on its rough textured, weathered surfaces, and white to dark grey on fresh surfaces. Segregation of dolomite of different shades and of silica gives much of the rock a mottled look, the most common being light-coloured patches in a generally darker rock. Chert, ranging in colour from white to black, occurs in lenses and laminae oriented parallel to bedding planes and in irregular lacy networks, some of which simulate chain corals. In the Hughes Range the upper part of the Lower Division is distinct from the rest in that it weathers more uniformly cream coloured, is light coloured on fresh surfaces, and has laminations that are distinct on weathered surfaces only.

The Upper Division is more massive than the Lower, although thick bedding is fairly distinct in the Hughes Range. Surfaces weather mainly grey, but creamy, buff, and pink hues can also be seen, especially from a distance of a few yards. Fresh surfaces range in colour from white to dark grey, with light shades predominant. The Upper Division is, on the whole, more coarsely crystalline than the Lower, although the grain size may vary erratically from coarse to fine in a single bed. The larger grain size manifests itself in sandy-textured weathered surfaces. Near the base of the Upper Division are numerous small vugs, lined with white, medium-grained dolomite, that yield pitted weathered surfaces. The pits are 1/8 inch to 1 inch long, oriented parallel to bedding planes, and occur in conjunction with buff and pinkish surface hues.

The Jubilee formation is approximately 3,875 feet thick in the Hughes Range. In a section measured near Ram Creek the Lower Division is 2,320 feet thick, the upper 600 feet of which can be recognized as a sub-unit. The Upper Division is 1,554 feet thick.

The succession of strata called Jubilee formation in Canal Flats map-area was named Elko by Schofield (1915, p. 47; 1922, pp. 13 and 14). Walcott (1924, p. 29) followed Schofield's usage at Mount Grainger but tentatively assigned the upper part of the formation as exposed on Mount Sabine (overlooking the settlement of Canal Flats) to the Lyell formation (Walcott, 1924, p. 28; 1928, p. 228). The writer abandons the name Elko because it involves correlation along 50 miles of unmapped territory with a formation of unknown age. Walker (1926, pp. 16 and 22) correlated the formation at Ram Creek and Mount Grainger, and its continuation north along the Rocky Mountain Trench, with the Ottertail formation of the Field district. Evans (1933, pp. 125-126) introduced the name Jubilee to apply to the formation along the trench previously correlated with the Ottertail by Walker. Henderson (in press) traced the Jubilee formation from Evans' map-area to Canal Flats. The writer follows the usage of Evans and Henderson, preferring a term initiated for strata along the Rocky Mountain Trench to an uncertain correlation with strata of the Field district.

The age of the Jubilee formation is somewhere between latest Lower Cambrian and medial Upper Cambrian. In Canal Flats area the Jubilee overlies *Olenellus*-bearing Lower Cambrian strata and underlies medial Upper Cambrian beds of the McKay group. If correlation with the Elko formation is correct the Jubilee is younger than the Burton formation, whose upper part contains a *Bathyuriscus* fauna indicative of medial Middle Cambrian age.

CAMBRIAN AND ORDOVICIAN

McKay Group

The McKay group of limestones and shales overlies the Jubilee formation conformably but with an abrupt lithological change. The group is an important component of the Hughes Range structural division and of the White Swan and Moscow Creek structural divisions, which lie successively eastward (*See* section on Structural Geology).

In the Hughes Range structural division the McKay group is about 2,880 feet thick. It contains four mappable lithological units. The lowest, unit I, about 1,180 feet thick, consists of shale and shaly limestone with nodular and bedded intercalations of purer limestone. It is soft and forms rounded slopes. Below timber-line the shales disintegrate into a distinctive grey soil studded with lenticular pieces of limestone. The shales are buff, green, or grey on weathered surfaces and green or grey on fresh surfaces, the limestones grey to buff on weathered surfaces and light to dark grey on fresh ones. Limy shales are abundant. Beds of limestone conglomerate and limestone breccia are distinctive components. The fragments in these beds are mostly pebble-size but some are 4 inches long. Unit I contains numerous Upper Cambrian fossils. Unit II, which overlies it, is a cliff-former. It consists of about 435 feet of thin-bedded, dark weathering, dark limestone and some limestone conglomerate, with shale partings. Lenses of dark chert are present. Unit III, about 175 feet thick, is a softer, grey weathering assemblage of fissile green shale and nodular shaly limestone. Mud-cracks are conspicuous. Some beds are crowded with fragments of Lower Ordovician fossils. Unit IV, the uppermost, is about 1,090 feet thick and is another cliff-former. It consists chiefly of limestone, mostly argillaceous and moderately thin bedded, of massive, laminated, and fragmental types. Shale occurs throughout in partings and interbeds and is the dominant rock in a 200-foot zone situated about two-thirds of the way up the unit. Irregularly selective dolomitization is important in the top 200 feet of the unit and results in a buff weathering rock.

In the White Swan structural division McKay strata occupy the crest of the main anticline. At White Swan Lake 2,500 feet of strata, chiefly impure limestone, are exposed, but the total thickness of the McKay group in this division is unknown because the base is concealed. It is probably greater than that in the Hughes Range. The lithological units distinguished in the Hughes Range are not apparent here. Instead of the thin-bedded alternation of limestone and shale that characterizes the Hughes Range section the beds are thick and the argillaceous components form irregular laminae and networks whose buff-coloured weathered surfaces stand in relief above the grey weathering more limy matrix. The rocks range from grey weathering dark limestones with the surface pattern described above to buff weathering argillaceous rocks with pits where lenses of purer limestone have weathered out.

In the easternmost, Moscow Creek, structural division about 4,500 feet of McKay strata are exposed. The basal beds are concealed but the lithology of the rest of the section differs again from that of the White Swan division. The section consists of thin-bedded alternations of fairly pure blue-grey limestone, nodular shaly limestone, intraformational limestone breccia and conglomerate, and limy and non-limy shale. The intraformational conglomerate and breccia occurs characteristically in predominantly shaly parts of the section, which exhibit also mud-cracks and ripple-marks. A 30-foot zone of siltstone is present near the top of the group. The transition to the overlying Glenogle formation is marked by a decrease in the proportion of limestone to shale and by the shale becoming darker. The Moscow Creek section resembles that in the Hughes Range more nearly than that in the intervening White Swan structural division by reason of its thin bedding, discrete shaly beds, and the presence of intraformational conglomerates and breccias. The upper part is, however, more nodular and shaly than the upper part of the Hughes Range section.

The age of the McKay group is Upper Cambrian and Lower Ordovician. The strata yielded numerous fossils, which were identified by T. E. Bolton of the Geological Survey.

In the Hughes Range the Cambrian and Ordovician components can be separated fairly accurately because their boundary lies in the relatively thin unit II. Unit I contains a Briscoia fauna of the Franconian stage of the Upper Cambrian. Collections from this division contain:

Eoorthis (?) sp.
Lingulella (?) sp.
Obolus concentricus Ulrich and Cooper
Briscoia sinclairensis Walcott
Briscoia sp. aff. B. coloradoensis (Walcott)
Blountiella sp. cf. B. albertella Resser
Pterocephalina (?) sp.
Taenicephalus (?) sp.

Collections from unit II contain the following Cambrian and Ordovician fossils:

Eoorthis (?) sp.
Lingulella sp.
Lingulepis cf. tenuilineata Poulsen
Nanorthis cf. putilla (Walcott)
Obolus sp.
Blountia sp. cf. B. plana Resser
Bynumia cf. venusta Resser
Illaenurus cf. albertensis Resser
Pseudoagnostus cf. canadensis (Billings)
Symphysurina spicata Ulrich

Units III and IV (highest) of the Hughes Range section of the McKay group are Lower Ordovician.

Unit III contains:

Eoorthis (?) sp.
Lingulepis sp. aff. L. tenuilineata Poulsen
Bellefontia nonius Walcott
Symphysurina spicata Ulrich
Trigonocerea sp.
Xenostegium sp.

Unit IV contains:

Clarkella nona (Walcott)
Eoorthis (?) sp.
Lingulella sp.
Hormotoma sp.

Lecanospira sp.
Ophileta leo (Walcott)
Raphistoma (?) sp.
Raphistomina sp.
Hystricurus sp.
Kainella billingsi (Walcott)
Leiostegium formosa Hintze

McKay strata in the White Swan structural division yielded no diagnostic fossils, but the presence of *Ecculiomphalus* in a collection made near the top shows that the upper part is post-Cambrian.

Fossils collected from McKay strata in the Moscow Creek structural division, all from the upper 960 feet, are Lower Ordovician. They are:

Archaeorthis cf. *occidens* Ulrich and Cooper
Nanorthis cf. *putilla laeviuscula* (Walcott)
Syntrophina sp.
Raphistomina sp. indet.
Ophileta cf. *leo* (Walcott)
Hystricurus (?) sp.
Leiostegium manitouense Walcott
Protopliomerops cf. *superciliosa* Ross
Symphysurina spicata Ulrich

T. E. Bolton, who examined all the McKay collections, commented that this fauna is approximately the same age as that in unit IV of the Hughes Range, which represents Evans' faunal zones 3 and 4 (*See* below).

In the Hughes Range Lower Ordovician McKay strata are overlain by the Upper Ordovician Beaverfoot formation, but farther east, in the White Swan and Moscow Creek structural divisions, the Glenogle and Wonah formations intervene. The same conditions occur to the north, where Evans (1933) found that western occurrences of the McKay group are overlain by the Beaverfoot formation, whereas eastern ones are part of the sequence McKay-Glenogle-Wonah-Beaverfoot. He was able to show, moreover, that in the Brisco and Van Horne Ranges the upper part of the western McKay is the same age as the Glenogle formation. He divided the McKay group into eight faunal zones, only the lower four of which are older than the Glenogle formation. In Canal Flats map-area unit IV of the Hughes Range is correlative with Evans' faunal zones 3 and 4, and is older than the Glenogle formation of the White Swan and Moscow Creek structural divisions that probably corresponds to Evans' McKay faunal zone 6. Thus the uppermost strata of the McKay group in both western and eastern parts of the area are of the same age and are older than the Glenogle formation.

In the Hughes Range the McKay group and the succeeding Beaverfoot formation appear concordant in strike and dip but the contact represents a considerable time interval during which sediments may have been deposited and subsequently eroded. The character of the McKay strata immediately beneath the Beaverfoot changes from place to place along the strike, which may indicate that the Beaverfoot rests on different horizons of the McKay but could also result merely from vagaries in deposition and dolomitization. Westward across the strike, however, the Beaverfoot formation evidently rests on successively older beds, because on Mount Sabine it overlies Upper Cambrian strata equivalent to unit I of the Hughes Range McKay group.

ORDOVICIAN

Glenogle Formation

The Glenogle formation overlies the McKay group conformably. It occurs only in the White Swan and Moscow Creek structural divisions. In the White Swan division it appears along the perimeter of the main domal anticline and in the smaller anticline at Ptarmigan Lake. In the Moscow Creek division it is part of an inverted succession on the underlimb of an overturned anticline. The formation is 450 feet thick on the west flank of White Knight Mountain, in the White Swan division, but is 1,000 to 1,100 feet thick on the northern watershed of Moscow Creek. This difference in thickness in adjoining structural divisions results partly from regional depositional thinning towards the south and west, and perhaps partly from an overlying disconformity that is increasingly effective in the same directions. Juxtaposition of originally different parts of the basin of sedimentation during mountain building has made the contrast more pronounced.

The Glenogle formation consists principally of shale and limy shale, accompanied by shaly limestone, limestone, and a little siltstone and fine-grained quartzite. The shaly rocks are black, and weather black, brown, and tan, whereas the purer limestones are dark grey to black and weather grey. The latter form lenses and beds up to 18 inches in thickness in the shales. Unweathered Glenogle strata look fairly massive and the limestone beds are inconspicuous, but on weathering the fissile character of the shale is readily apparent and the more massive limestone stands out in relief. Silty laminae, commonly 1/20 to 1/10 inch thick, occur throughout. Thin beds of siltstone and fine-grained quartzite occur in the upper half of the formation.

The contact with underlying McKay strata is distinct in the White Swan structural division but broadly gradational in the Moscow Creek division. There the basal Glenogle is thinly bedded limestone and shale and the topmost McKay is thinly bedded nodular limestone and shaly limestone. An arbitrary boundary was chosen between a series of grey weathering, dark grey, nodular limestones below and a zone of black impure limestone and limy shale that weathers to a distinctly and evenly laminated light and dark pattern above. The laminated rock contains lenses of grey weathering, grey limestone. About 100 feet of strata above this arbitrary boundary could almost equally well be assigned to the McKay group on a compositional basis, but is placed in the Glenogle chiefly because of its physical appearance. The upper contact of the Glenogle formation against quartzite of the Wonah formation is abrupt. It seems concordant but, as noted in the next section, probably represents an hiatus.

Fossils, chiefly graptolites, are abundant in the Glenogle formation. The fauna from two measured sections as identified by T. E. Bolton of the Geological Survey are listed below.

Section on west face of White Knight Mountain, White Swan structural division; distances in feet above the base:

Feet

454 Base of Wonah formation

447 G.S.C. Loc. Cat. 23924

Climacograptus sp. indet.
Didymograptus spp.
D. cf. *spinosus* Ruedemann
Glossograptus spp.
Lasiograptus sp.
L. inutilis (Hall)
Loganograptus logani pertenuis Ruedemann
Phyllograptus cf. *ilicifolius* Hall

359 G.S.C. Loc. Cat. 23926

Climacograptus sp.
Lasiograptus echinatus Ruedemann
L. echinatus major Ruedemann
Tetragraptus sp.
T. pendens Elles

273 G.S.C. Loc. Cat. 23934

Diplograptus sp.
Glossograptus cf. *ciliatus* Emmons
Leptograptus flaccidus (Hall)
Loganograptus logani (Hall)
L. cf. *logani pertenuis* Ruedemann
Phyllograptus sp.
P. cf. *angustifolius* Hall

Feet

191-220 G.S.C. Loc. Cat. 23922 and 23936

Diplograptus sp.
Glossograptus horridus Ruedemann
Isograptus walcottorum Ruedemann
Phyllograptus cf. angustifolius Hall
Trigonograptus ensiformis Hall

153 G.S.C. Loc. Cat. 23925

Cardiograptus angustifolius Ruedemann
Isograptus walcottorum Ruedemann

118 G.S.C. Loc. Cat. 23927

Cardiograptus cf. folium Ruedemann
Isograptus walcottorum Ruedemann
cf. Leptograptus flaccidus (Hall)
Phyllograptus sp.
P. ilicifolius Hall

105 1/2 G.S.C. Loc. Cat. 23935

Isograptus walcottorum Ruedemann

97 G.S.C. Loc. Cat. 23929

Didymograptus nicholsoni planus Elles and Wood
Phyllograptus (?) sp.

57 G.S.C. Loc. Cat. 23937

Didymograptus cf. nitidus (Hall)
Isograptus walcottorum Ruedemann
Lingula spp. (in limestone, wider form than those at 43-53 feet)

43-53 G.S.C. Loc. Cat. 23930

Lingula spp.

Section on north boundary of Moscow Creek watershed, Moscow Creek structural division; distances in feet stratigraphically above the arbitrary base of the Glenogle.

Feet

1,103 Base of Wonah formation

1,102-1,103 G.S.C. Loc. Cat. 23918

Climacograptus sp.
C. antiquus Lapworth
Didymograptus sp.
Diplograptus gladius Ruedemann
Glossograptus horridus Ruedemann
Lasiograptus echinatus major Ruedemann
Thamnograptus sp.

1,044 G.S.C. Loc. Cat. 23918A

Climacograptus sp.
Didymograptus sp.
Glossograptus horridus Ruedemann
Lasiograptus cf. inutilis (Hall)

941 G.S.C. Loc. Cat. 23920

Climacograptus sp.
Isograptus cadaceus armatus Ruedemann
Lasiograptus cf. echinatus major Ruedemann

899 G.S.C. Loc. Cat. 23919

Climacograptus cf. antiquus Lapworth
Didymograptus sp.
D. cf. nicholsoni Lapworth
Diplograptus sp.
Glossograptus horridus Ruedemann
Lasiograptus echinatus Ruedemann
L. echinatus major Ruedemann
Trigonograptus ensiformis (Hall)

860-861 G.S.C. Loc. Cat. 23933

Climacograptus sp.
Clonograptus sp. cf. C. flexilis Hall
Glossograptus horridus Ruedemann

576 G.S.C. Loc. Cat. 23932

Cardiograptus folium Ruedemann
Isograptus cf. cadaceus (Salter)
I. walcottorum Ruedemann

Feet

484 G. S. C. Loc. Cat. 23928

Didymograptus cf. euodus Lapworth
Isograptus walcottorum Ruedemann

433 G. S. C. Loc. Cat. 23931

Didymograptus cf. nicholsoni planus Elles and Wood
Isograptus walcottorum Ruedemann
Phyllograptus cf. angustifolius Hall

Mr. Bolton commented as follows:

"From the above graptolite assemblages a late Lower Ordovician (Canadian) to early Middle Ordovician (Chazyan) Deepkill age can be assigned to these shales; no truly definite Normanskill fauna appears to be present. The graptolites collected on White Knight Mountain, in particular, best indicate Raymond's C-D horizons of the Levis shale and the upper zone of the Deepkill series (zone of Diplograptus dentatus). The faunas may be correlated with similar zones in the Windermere Glenogle section and the quarry at Glenogle".

Wonah Formation

The Wonah formation overlies the Glenogle formation, and like that formation is restricted to the White Swan and Moscow Creek structural divisions. The formation is only 35 feet thick on the headwaters of Nine Mile and Mutton Creeks in the western part of the White Swan division, but to the northeast, in the Moscow Creek division, it reaches a thickness of 300 feet in the overturned succession north of Moscow Creek.

The Wonah formation consists of white and yellowish, siliceous and limy quartzite and sandstone. The sandstone gives a rough texture to weathered surfaces, especially where it occurs as lenses and nodules in quartzite. Cross-lamination is common. The top of the formation is dolomitic and grades into the sandy dolomite of the base of the Beaverfoot formation. The only fossils seen in the Wonah formation are fragments of crinoid stems and trail-like markings in the dolomitic upper beds.

The Wonah formation overlies upper Deepkill (upper Lower and lower Middle Ordovician) beds of the Glenogle formation with apparent conformity. Farther north, however, it overlies Normanskill (mid-Middle Ordovician) strata (Evans, 1933, p. 135). The contact at Canal Flats should thus represent an hiatus. The alternative, that the Wonah was distinctly time-transgressive, and progressively younger to the north, is unlikely as the Wonah grades upward into the Beaverfoot formation, of Richmond (Upper Ordovician) age, at both localities. The surface of disconformity between the Glenogle and Wonah formations is probably the eastern equivalent of that between the McKay group and the Beaverfoot formations in the Hughes Range and between Upper Cambrian strata and the Beaverfoot formation on Mount Sabine.

ORDOVICIAN AND (?) SILURIAN

Beaverfoot and (?) Brisco Formations

The Beaverfoot formation overlies the McKay group disconformably in and west of the Hughes Range structural division and overlies the Wonah formation conformably in the White Swan and Moscow Creek divisions.

The name Beaverfoot was introduced by Burling (1922) for a thick succession of strata, to only part of which the term is now applied. Walcott (1924) separated the basal quartzites of Burling's Beaverfoot in a new formation, the Wonah, and called the upper beds, which are Silurian in age, the Brisco formation. The Beaverfoot formation, as thus restricted, is Upper Ordovician. Walcott (1928, p. 213) stated that he had no difficulty in seeing the contact between the restricted Beaverfoot formation and his new Brisco formation, but later workers have been less fortunate. Walker (1926), Evans (1933), and Henderson (in press) found it necessary to treat Beaverfoot and Brisco formations as a single field unit.

In Canal Flats area the writer followed the same procedure, but all fossils collected from the unit are Upper Ordovician and the unit, as mapped, may be entirely Beaverfoot formation. The presence of Brisco strata in it is possible, however, because the collections do not represent all the highest beds and because of the lithologic similarity of the upper part of the Beaverfoot formation to the lower part of the Brisco formation. Beds on the east edge of the fault system at the Mutton Creek-Nine Mile Creek divide and on Mutton Creek half a mile northwest of Alces Lake may thus be Brisco. A group of lithologically distinctive strata at Alces Lake that are certainly Brisco are mapped separately.

The Beaverfoot formation consists of dolomite and limestone, with a little quartzite and sandstone near the top. Dolomite, which predominates, weathers chiefly bluish grey and buffish grey, but phases as dark as chocolate-brown occur. Colours of fresh surfaces range from light grey to black. Mottled patterns are general on both weathered and fresh surfaces. Blebs and lenses of chert are fairly common. The limestones are mostly grey weathering dark types, with mottled patterns where selectively dolomitized. Vagaries of dolomitization cause rapid and erratic changes in gross appearance along strike of the formation, especially near the base. Where the Beaverfoot rests on the McKay group the base consists typically of thick-bedded, blue-grey weathering, dark limestone or its dolomitized equivalent, the latter weathering buffish grey. The contact with McKay rocks is distinct except where, as on Mount Glenn, the basal Beaverfoot is thinner bedded than usual and the uppermost McKay thick bedded. Where the Beaverfoot formation succeeds the Wonah formation its base contains some 10 feet of thin-bedded sandy dolomite or sandy dolomitic limestone, which is overlain by thick-bedded limestone or dolomite. Sandstone and quartzite occur in the higher parts of the Beaverfoot formation and (?) in the base of the Brisco formation in the White Swan and Moscow Creek structural divisions. They range from resistant, white, siliceous types to easily weathered, yellowish, dolomitic varieties. Pieces of float and isolated outcrops are difficult to distinguish from Wonah formation.

In fault blocks and isolated outcrops Beaverfoot-Brisco dolomite may be confused with Jubilee dolomite, but the chief differences are the generally more distinct bedding of the Beaverfoot-Brisco, the presence in it of fossils, and the virtual absence of the laminations that characterize the lower division of the Jubilee formation.

Fossils are abundant in the basal beds of the Beaverfoot formation, especially in limestone. They are fewer and less well preserved in succeeding strata and seem to have been partly destroyed during dolomitization. Those in limestone consist either of carbonate or silica but those in dolomite are almost invariably silicified. The more important collections, all of Richmond (Upper Ordovician) age, are listed below, the fossils having been identified by T. E. Bolton of the Geological Survey.

Fossils from the Hughes Range structural division

1. 2,650 feet on bearing 238 degrees from Mount Glenn
   Basal beds — G.S.C. Loc. Cat. 23860

   Calapoecia canadensis Billings
   Halysites sp.
   Lichenaria sp. aff. *L. major* Bassler
   Streptelasma sp.
   Pachydictya sp.
   Rhombotrypa sp. and other branching bryozoans
   Platystrophia sp. (of *P. globosa* McEwan type)
   Strophomena sp.
   Hormotoma sp.
   Bumastus sp.

2. 11,400 feet on bearing 146 degrees from Mount Glenn
Basal beds G.S.C. Loc. Cat. 23846

Streptelasma prolongatum Wilson
Crinoid columnals
Dinorthis cf. rockymontana Wilson
Rhynchotrema sp. indet.

3. 4,000 feet on bearing 182 degrees from Lussier River Hot Springs
Basal beds G.S.C. Loc. Cat. 23863

Favistella sp.
Halysites delicatulus Wilson
Streptelasma trilobatum Whiteaves
Crinoid columnals
Dinorthis sp.
D. cf. columbia Wilson
Rafinesquina sp.

4. 4,000 feet on bearing 103 degrees from The Shark Tooth
Basal beds G.S.C. Loc. Cat. 23852

Favistella alveolata (Goldfuss)
Halysites delicatulus Wilson
Streptelasma distinctum Wilson
S. trilobatum Whiteaves
Dinorthis columbia Wilson
D. rockymontana Wilson
Rhynchotrema cf. kananaskia Wilson

About 150 feet above base G.S.C. Loc. Cat. 23848

Halysites cf. pulchellus Wilson

5. 500 feet on bearing 225 degrees from 7,675-foot peak on north side of Ram Creek - Roam Creek pass
Basal beds G.S.C. Loc. Cat. 23853

Crinoid columnals
Favistella alveolata stellaris (Wilson)
Streptelasma prolongatum Wilson
Rhynchotrema cf. increbescens occidens Wilson

Fossils from the White Swan structural division

1. Section on west face of White Knight Mountain
194-330 feet above base of formation G.S.C. Loc. Cat. 23865

Diplophyllum halysitoides (Wilson)
D. primum (Wilson)

Halysites robustus Wilson
Streptelasma sp.

83-86 feet above base G.S.C. Loc. Cat. 23866

Helopora sp. cf. H. harrisi James
Pachydictya sp.
Microtrypa (?) sp.
Rhynchotrema increbescens occidens Wilson
Skenidiodes sp.
Strophomena sp.
Strophomena sp. cf. S. billingsi (W. and S.)
Vogdesia sp. cf. V. vigilans (Meek and Worthen)
Leperditia sp.

39 feet above base G.S.C. Loc. Cat. 23868

Calapoecia n. sp.

Basal 24 feet of Beaverfoot G.S.C. Loc. Cat. 23908

Receptaculites sp. (R. occidentalis Salter type)
Diplophyllum primum (Wilson)
Favistella alveolata (Goldfuss)
F. alveolata stellaris (Wilson)
Halysites robustus (Wilson)
Lyopora n. sp.
Streptelasma sp.
S. prolongatum Wilson
S. trilobatum Whiteaves
Crinoid columnals
Hallopora sp.
Helopora sp.
Monotrypella (?) sp.
Pachydictya sp.
Dinorthis rockymontana Wilson
Rafinesquina sp.
Rhynchotrema kananaskia Wilson
R. pisina Wilson
Sowerbyella sp.
Fusispira sp.
Liospira sp.
Raphistoma sp.
Endoceras sp.

Wonah-Beaverfoot transition beds G.S.C. Loc. Cat. 23844

Branching bryozoans indet.
Helopora sp.

2. White Swan Lake
   Basal beds 3,700 feet on bearing 102 degrees from west end of White Swan Lake — G.S.C. Loc. Cat. 23843

   Receptaculites sp.
   Lichenaria sp.
   Halysites robustus Wilson
   Streptelasma prolongatum Wilson
   S. trilobatum Whiteaves
   Crinoid columnals
   Platystrophia sp. indet.
   Rafinesquina sp.
   Opikina sp.
   Sowerbyella (?) sp.
   Hormotoma sp. and other indet. Gastropoda
   Armenoceras sp.

   Approx. 300 feet above base — G.S.C. Loc. Cat. 23845

   Favistella alveolata stellaris (Wilson)
   Halysites delicatulus Wilson
   Streptelasma sp.

3. East of Nine Mile Creek - 10,000 feet on bearing 83 degrees from Mount Glenn
   About 1,000 feet above base of Beaverfoot — G.S.C. Loc. Cat. 23862

   Cup corals indet.
   Lichenaria (?) sp.
   Crinoid columnals
   Pachydictya sp.
   Helopora sp.
   Rafinesquina sp.
   Opikina sp.
   Rhynchotrema sp.
   Hormotoma sp.
   Cornulites sp.
   Bathyurus sp.
   Ceraurus sp.
   Encrinurus cf. *cybeleformis* Raymond

Fossils from Moscow Creek Structural Division

8,000-foot peak at northwest headwaters of Moscow Creek
About 900 feet above base of Beaverfoot — G.S.C. Loc. Cat. 23859

Favositidae indet.
Streptelasma sp. indet.
Hesperorthis sp.

Platystrophia (?) sp.
Rhynchotrema sp.
Hormotoma gracilis (Hall)
H. salteria canadensis (Ulrich and Schofield)
Loxonema sp.

Mr. T. E. Bolton commented as follows:

"The Upper Ordovician Richmond age assigned to the Beaverfoot by past workers, although disputed by a few, is confirmed by the present collection. In particular, the abundant fauna at the base of the Beaverfoot contains Calapoecia canadensis, Favistella alveolata, Streptelasma trilobatum, and Vogdesia vigilans, all principally Richmond forms. Nine corals and five brachiopods common in the Beaverfoot farther north are also abundant in the Canal Flats collections.

"The occurrence of Streptelasma trilobatum Whiteaves is particularly noteworthy. This species is confined to the upper member of the Bighorn formation of Wyoming; Stony Mountain formation of southern Manitoba and its equivalent in the Fort Churchill area; Richmond of Silliman's Fossil Mount, Frobisher Bay, Baffin Land; and the Cape Calhoun beds (synonymous with S. foerstei Troedsson) at Cape Calhoun, northern Greenland.

"The highest beds represented by collections are also of Ordovician age as indicated by the gastropods Hormotoma gracilis, H. salteria canadensis, the trilobites Bathyurus and Ceraurus, and the brachiopods Rafinesquina and Opikina."

SILURIAN

Brisco Formation

Brisco strata occur in an incompletely exposed fault block at the east end of Alces (Moose) Lake. They dip east and the succession, from west to east, is: dolomite; 32 feet of limy sandstone and quartzite; 4 feet of silty dolomite; 110 feet of black shale and black limestone; and, on the east, grey limestone. The black shale, which resembles that of the Glenogle formation, contains a Middle Silurian fauna, identified by T. E. Bolton and R. Thorsteinsson.

Monograptus cf. clintonensis (Hall)
M. columbianus Ruedemann
M. cf. vomerinus (Nicholson)
M. walcottorum Ruedemann
Stomatograptus grandis Suess
Parmorthis (?) sp.
Tryblidium (?) sp.
Michelinoceras (?) sp.

According to Thorsteinsson this is the first record of Stomatograptus grandis Suess on the North American continent proper, the nearest previous discovery being on Cornwallis Island, in the Canadian Arctic.

The shale is correlative with shale that occurs about 300 feet above the base of the Brisco formation near Radium Hot Springs (Walcott, 1924, p. 12).

As noted previously, Brisco strata may also be present in the map-unit designated "Beaverfoot and (?) Brisco formations".

SILURIAN AND (OR) DEVONIAN

Isolated outcrops of Silurian and (or) Devonian rocks occur in a graben-like structure in the valleys of upper Lussier River and Coyote Creek. Two lithologic units are present, one of which consists of dolomite and limestone and the other of gypsum and limestone. They were not seen in contact.

The dolomite-limestone unit outcrops on Lussier River above Coyote Creek. About 80 per cent of the exposed rock is dolomite and limy dolomite that weathers grey and greenish grey, and is dark grey on fresh surfaces. It forms massive beds 12 to 18 inches thick. The accompanying limestone, some of which is argillaceous, weathers grey and is dark on fresh surfaces. These rocks strike northeast and northwest and dip fairly steeply southeast and northeast. Their stratigraphic relations are unknown but the rocks resemble part of the Silurian Brisco formation north of the map-area.

The gypsum-limestone unit is exposed in at least five places in the upper Lussier Valley and occurs also east and south of the map-area. All outcrops are surrounded by drift that effectively conceals the extent and stratigraphic relations of the unit.

The largest outcrop, on the east bank of Lussier River a mile above Roam Creek, is 1/3 mile long and up to 300 feet high. It consists of laminated white and grey, more or less pure gypsum rock in which the chief impurities are carbonates and anhydrite. The rock is described more fully in the section entitled "Gypsum". The beds are contorted but may strike northeasterly and dip steeply southeasterly. The stratigraphic boundaries and thickness are unknown.

Limestone occurs above gypsum on the west side of Coyote Creek at a point 4 miles above its mouth and 1 1/2 miles east of the map-area. The dominant type is a rather distinctive, dense, cherty-looking, black limestone, with a sharply angular fracture. Much of it is brecciated. Fine-grained, grey limestone is also present. Similar black limestone occurs in a sink-hole 1/2 mile to the west, and in a sink-hole in Lussier Valley a mile above Coyote Creek.

The most northerly observed outcrops of the gypsum-limestone unit are on the edge of a fault zone on the east bank of Lussier River a mile south of Mutton Creek. The exposures consist chiefly of thinly bedded, laminated, black limestone and thinly laminated black and grey limestone but impure gypsum and gypsiferous carbonate rock occur at the south end of the series of brecciated outcrops. Small amounts of native sulphur occur in the gypsum.

The only fossils seen in the gypsum-limestone lithologic unit are small unidentifiable gastropods in black limestone on Coyote Creek. The unit is, however, post-Ordovician and occurs on both sides at the base of a ridge whose upper part is Mississippian. It is, therefore, probably Silurian or Devonian. The gypsum in the large outcrops above Roam Creek resembles the gypsum on Kootenay River and at Windermere, which Henderson (in press) found to be somewhere between Middle Silurian and Middle Devonian in age.

MISSISSIPPIAN

Relatively flat-lying Mississippian strata form the upper part of the small mountain range between Lussier River and Coyote Creek, in the southeast corner of the map-area. Drift conceals their relation to the gypsiferous formation that occurs on both sides at the base of the range.

The lowest observed member of the Mississippian sequence is limy and non-limy black shale, with interbedded black limestone near the top. This member is at least 150 feet thick. It is succeeded by about 200 feet of grey weathering, fine-grained, dark grey limestone and cherty limestone, the siliceous parts of which weather light grey and stand out in relief. The rock is fairly thin bedded and some beds are laminated. A 25-foot zone of crystalline crinoidal limestone occurs near the base of the member. The third member consists of about 1,000 feet of impure limestone, mostly cherty and silty, limy siltstone, and chert. Except near the top the member is mostly thin bedded. Grey-buffs, tans, and browns predominate on weathered surfaces and fresh surfaces are grey to black. Laminated rocks that resemble siltstones but which are essentially limestones are distinctive components of the lower half of the member. They contain an alternation of light and dark layers of minute to 1/2 inch thickness. Cross-lamination is fairly common. Abundance of chert is another characteristic of this member. Chert pervades the crystalline fabric of the limestone and also forms discrete lenses and layers that give weathered surfaces a patchy aspect. Replacement of limestone by chert is complete locally across stratigraphic sections of 10 feet or so. The chert is black and weathers black or brownish, except near the top of the member where light-coloured chert is present. Another distinctive component of this member is brown silty limestone and limy siltstone with black worm-like markings. It is less abundant than the cherty and laminated limestones and occurs chiefly in the lower half. The black markings curve at random in planes parallel with the bedding, and their widths, usually 1/30 to 1/20 of an inch, are uniform from end to end. The upper part of the member contains alternate zones of brownish weathering, thin-bedded, impure limestones and thicker bedded, grey weathering, purer grey limestone, and, by increase in the latter, grades into the overlying member.

The highest observed member, which is at least 300 feet thick, consists of thick-bedded, grey weathering, grey limestone, chiefly crystalline and crinoidal. A collection from the highest observed part of the section contains:

Spirifer centronatus Winchell
Spirifer sp. cf. *S. centronatus* Winchell
Spirifer ex. gp. *S. striatiformis* Meek
Spirifer ex. gp. *S. rowleyi* Weller
Dictyoclostus sp.
Dielasma sp.
Cleiothyridina sp.
Schellwienella cf. *S. inequalis* Hall
Streptorhynchus ? sp.
Small solitary rugose corals indet.
Pleurodictyum placenta Girty

Dr. P. Harker, who examined the collection, commented that the fauna has Kinderhook/Osage affinities that indicate correlation with the late Banff or early Rundle strata of the eastern Rockies.

STRUCTURAL GEOLOGY

The part of Canal Flats map-area east of the Rocky Mountain Trench and Kootenay River may be divided into structural divisions that trend northerly and northwesterly and are separated by faults. The divisions will be described in order from west to east.

The western or Mount Grainger structural division composes the low mountains bordering the trench southward from Kootenay River at Mount Grainger. It consists of an easterly dipping succession of Windermere and Cambrian strata (not geologically patterned on the accompanying map). The division is bounded on the east by faults in the valley that contains lower Lussier River and the broad pass north to Kootenay River. The general pattern in this valley is graben-like, in that fault-bounded younger strata occupy the bottom and older strata form the walls, but movement along the faults, which dip steeply and are loci of intense brecciation, may be essentially horizontal.

The Hughes Range structural division lies east of this fault zone. It is the eastern limb of a faulted anticline whose crest lay near the western fault zone and which plunges gently north. It contains a succession of strata from Windermere to Ordovician in age, which dip progressively more steeply eastward. The precipitous western side of the Hughes Range thus exposes stratigraphic sections whereas the eastern exposes dip-slopes of Beaverfoot (Upper Ordovician) strata. Two steep-dipping right-hand transverse faults cut the division. One crosses the Range a mile north of the Ram Creek-Roam Creek pass and the other is north of Lussier Canyon. The Ram Creek fault has an apparent horizontal offset of 1 1/2 miles. Drag-folds suggest that the north block moved relatively eastward and upward. The fault appears to offset a longitudinal fault on the west flank of Hughes Range that is roughly parallel with those in the bottom of lower Lussier Valley. The transverse fault turns southward as it approaches the major longitudinal fault in upper Lussier Valley that is the east boundary of the Hughes Range structural division, but their junction is concealed. That part of the longitudinal fault north of the junction is east of the projection of the southern part, and thus either the longitudinal fault bends near the junction or its north part is displaced relatively eastward by the Ram Creek transverse fault. The offset pattern of the transverse fault near Lussier Canyon is similar to that at Ram Creek. This fault also swings southward as it approaches the fault system in upper Lussier Valley and may offset it.

A major fault system, mentioned above, limits the Hughes Range structural division on the east. The observed faults are marked by wide zones of brown breccia. The boundary faults of the system are widely separated south of Alces Lake, converge northward to the Mutton Creek-Nine Mile Creek divide, and diverge again farther north on Nine Mile Creek. The pattern is graben-like south of Alces Lake, in that strata as young as the Mississippian occur between the boundary faults whereas the strata outside are Cambrian and Ordovician. The western boundary fault dips east in this southern section, but the dip of the eastern fault is unknown. To the north, where the faults diverge on Nine Mile Creek, the pattern again appears graben-like because the drift-covered area between the faults contains sink-holes that suggest the presence of Silurian or Devonian gypsum whereas the rocks outside the faults are chiefly or entirely Cambrian and Ordovician. The dip of the eastern boundary fault here is steeply west to vertical, and that of the western one is probably nearly vertical. The degree to which the graben-like pattern was produced by net movements along the strike of the faults rather than across it is not definitely known. Two formations, the Glenogle and Wonah, are limited to the area east of the fault system although the formations that immediately underlie and overlie them are present on both sides of it. The Glenogle and Wonah formations thin westward and southward and thus the present distribution may have resulted from foreshortening of the original basin of deposition by thrusting across the fault system or by horizontal movement in which the west side was displaced relatively northward along the system.

The White Swan structural division, characterized by upright folds, lies east of the fault system just described, between it and a fault that dips east and is probably a thrust. The main fold, on the west side of the division, is an elongate dome whose crest is bowed slightly westward. The dome plunges gently north opposite Nine Mile Creek and plunges south at angles of 15 to 30 degrees south of White Swan Lake. The west flank dips 55 to 65 degrees west but is locally overturned westward. The east flank dips in general 30 to 45 degrees eastward but is complicated by subsidiary folds and a steep west dipping reverse fault, adjacent to which the strata are locally overturned to the east.

The Moscow Creek structural division occupies the north-eastern part of the map-area. This division is the underlimb of a major anticline overturned to the west. The axial plane of this fold, together with the eastern limb, has been removed by erosion but appears to have dipped 55 to 60 degrees northeast. Strata in the western part of the underlimb are more completely overturned than those to the east, the resulting dips being, consequently, more gentle, and contain cross folds that strike northwest. The rocks in the extreme northeast corner of the map-area have a pronounced secondary foliation that strikes northwesterly. They are on the western edge of a major fault zone along White River just east of the map-area (Henderson, in press).

ECONOMIC GEOLOGY

GYPSUM

Gypsum occurs in a graben-like structure in the valleys of upper Lussier River and Coyote Creek. It outcrops in four localities and almost certainly underlies parts of the intervening drift-covered ground.

The largest gypsum exposure is on the east bank of Lussier River 1 mile above Roam Creek. It forms a series of steep slopes and bluffs 1/3 mile long and up to 300 feet high. The whole outcrop is gypsum rock but the purity varies. The strata are contorted but the general strike appears to be northeasterly, with a steep south-easterly dip. The gypsum is fine-grained, bedded, and characteristically in fine laminae whose thicknesses range down to a small fraction of an inch. Its colour ranges from white to dark grey, but the colour is not a guide to purity. The fabric consists or irregularly alternating lighter and darker laminae, with, in places, minute black laminae. The laminae are almost certainly sedimentary features. Stringers and lenses of coarser white gypsum are common, expecially in fractures, some of which contain blebs and disseminated particles of native sulphur. The chief impurities in the gypsum are calcium and magnesian carbonates and anhydrite, which form discrete layers and laminae and also occur intergrown with gypsum grains. The anhydrite is generally medium grey in colour and is somewhat more coarsely crystalline than much of the gypsum. Most of the out-crop seems free of layers of carbonate and anhydrite but some other-wise pure gypsum contains disseminated small rhombic crystals of dolomite. Estimation of the grade of the deposit would require detailed examination of the stratigraphy and structure and extensive sampling.

Another type of gypsum deposit occurs on the west bank of Lussier River 800 feet below Roam Creek, and east of the map-area on the west side of Coyote Creek Valley 4 miles above the mouth of that creek and 2 1/2 miles east of the Lussier locality. The Lussier exposure is about 40 feet long and 15 feet high. It occurs in a drift-covered area and may have been affected by extensive land creep. The Coyote Creek exposure is about 150 feet long and 30 feet wide, and limestone and limestone breccia occur above it. Both exposures contain white, medium-grained, pure gypsum; white and grey fine-grained gypsum; grey limy gypsum; breccia consisting of fragments of limestone and limy gypsum in a matrix of white and grey gypsum; and earthy gypsite containing gypsum (selenite) crystals. The deposits have a fissile or platy structure, due partly to the lenticular and laminar arrangement of the various components, but they lack small-scale sedimentary lamination and their general appearance suggests that they have been recrystallized and possibly dissolved and redeposited.

A small outcrop of gypsum and gypsiferous carbonate rock occurs on the edge of a fault zone on the east bank of Lussier River 1 1/4 miles south of Mutton Creek. Native sulphur is present in veinlets of white crystalline gypsum that cut fine-grained impure gypsum. The deposit is of interest only in so far as it indicates gypsum may be present beneath sink-holes in nearby drift-covered ground on the west and south.

Sink-holes caused by solution of underlying gypsum occur in the overburden around three of the four gypsum outcrops and they pock the bedrock on the large exposure south of Roam Creek. Besides being present near gypsum outcrops sink-holes occur sporadically all along Lussier Valley from the gypsum outcrop near Mutton Creek to and beyond the south boundary of the map-area. They are particularly numerous east of the river midway between Coyote Creek and White Swan Lake and large ones occur in Coyote Creek Valley east of the map-area. Sink-holes whose sides have not slumped are typically conical with acute vertices. The largest are 100 feet or more deep but most are 10 to 40 feet deep. Solution is still going on beneath some of them, as is indicated by up-ended logs in their vertices. In Coyote Creek Valley a creek disappears down a sink-hole and reappears at the gypsum outcrop half a mile away.

Bedrock is exposed in only two of the numerous sink-holes visited, aside from those at actual gypsum outcrops. One of these is on the east flank and the other on the west flank of the mountain between Lussier River and Coyote Creek. The eastern one, which is east of the map-area, is half a mile from a gypsum outcrop. The western, a mile south of the mouth of Coyote Creek, is 2 miles north of the nearest known gypsum outcrop. At both sink-holes is exposed the distinctive black limestone breccia that is associated with gypsum on Coyote Creek.

Most sink-holes in the drift-covered Lussier and Coyote Creek Valleys are probably underlain by gypsum, and for this reason the positions of representative ones are shown on the accompanying map. It should be noted, however, that although sink-holes are important indicators of gypsum they are not infallible guides. They can develop entirely in glacial silts, and they occur above fault breccia north of White Swan Lake. They are probably most reliable as guides when they are closely spaced, as they are near the east edge of the map-area between Coyote Creek and White Swan Lake.

Large gypsum deposits occur in Kootenay Valley at and near Nine Mile Creek, outside the area mapped in 1953. Columbia Gypsum Products, Incorporated, of Spokane, Washington, and Western Gypsum Products Limited, of Winnipeg, Manitoba, hold claims there.

MINERAL SPRINGS

Warm mineral springs occur on Lussier River and Ram Creek. The Lussier springs issue from Beaverfoot strata beside the trail on the north bank of the river, at the elbow where it cuts the Hughes Range. They are sulphurous, and on August 30, 1953, they issued at 108 degrees. Curiously enough, a cool orifice, only 18 inches from a warm one, yielded water at 62 degrees F. A cabin and two small log-walled pools, one of which is enclosed, have been built at these springs. The Ram Creek warm springs issue from numerous closely spaced orifices in the Jubilee formation at an altitude of 4,750 feet on a northern tributary 2 1/2 miles from the mouth of the creek. They are non-sulphurous, taste alkaline, and deposit calcareous sinter. Both the Lussier and Ram Creek springs issue down-slope from the traces of steep transverse faults.

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